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## ABSTRACT

This module is the third in a series of three wiring publications, includes additional technical knowledge and applications required for job entry in the commercial and industrial wiring trade. The module contains 15 instructional units that cover the following topics: blueprint reading and load calculations; tools and equipment; service; transformers; rough-in; lighting; motors and controllers; electrical diagrams and symbols; two and three wire controls; separate control circuits; sequence control circuits; jogging controls; reversing starters; special control circuits; and programmable controls. A special supplement of practice situations is also provided. Each instructional unit follows a standard format that includes some or all of these eight basic components: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to tests and assignment sheets. All of the unit components focus on measurable and observable learning outcomes and are designed for use for more than one lesson or class period. Instructional task analyses; a glossary; a list of tools, equipment, and materials; and 19 references are provided. (KC)

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# **COMMERCIAL AND INDUSTRIAL WIRING**

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# COMMERCIAL AND INDUSTRIAL WIRING

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## FOREWORD

*Commercial and Industrial Wiring* is the third in a series of three wiring publications and includes the additional technical knowledge and applications required for job entry in the commercial and industrial wiring trade.

*Basic Wiring*, the first publication in the series, serves as the foundation for students enrolled in a wiring program. It is a prerequisite to either *Commercial and Industrial Wiring* or *Residential Wiring*. This series should provide the flexibility that instructors need to meet the individual needs of their students and the community.

*Residential Wiring*, the second publication in the series, is a revision of MAVCC's 1983 wiring publication of the same name. This manual picks up where *Basic Wiring* ends and prepares the student for entry-level employment in the residential wiring trade.

These publications were developed with the assistance of many individuals who have expertise in various areas of the wiring trade. Some of these individuals represent professional associations and industry. Their assistance and devotion to this project is greatly appreciated. It should be emphasized that the student needs to be aware of professional trade associations and take an active part in them as much as possible. The professional trade associations, as well as vocational education, are an excellent avenue for continuing education within the electrical trade.

Every effort has been made to make these publications basic, readable, and by all means, usable. Three vital parts of instruction have been intentionally omitted from these publications: motivation, personalization, and localization. Those areas are left to the individual instructors and the instructors should capitalize on them. As these publications are used, it is hoped that students performance will improve and that students will be better able to assume a role in electrical wiring.

Harley Schlichting, Chairman  
Board of Directors  
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## USE OF THIS PUBLICATION

### Instructional Units

*Commercial and Industrial Wiring* contains fifteen units of instruction. Each instructional unit includes some or all of the basic components of a unit of instruction; performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

- A. The amount of material that can be covered in each class period
- B. The skills which must be demonstrated
  - 1. Supplies needed
  - 2. Equipment needed
  - 3. Amount of practice needed
  - 4. Amount of class time needed for demonstrations
- C. Supplementary materials such as pamphlets or filmstrips that must be ordered
- D. Resource people who must be contacted

### Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

## **Suggested Activities for the Instructor**

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

### **Information Sheets**

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

### **Transparency Masters**

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

### **Assignment Sheets**

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

### **Job Sheets**

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

## **Test and Evaluation**

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

## **Test Answers**

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

# COMMERCIAL AND INDUSTRIAL WIRING

## INSTRUCTIONAL TASK ANALYSIS

JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)

RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)

### UNIT I: BLUEPRINT READING AND LOAD CALCULATIONS

1. Terms and definitions
2. Mechanical symbols
3. Plumbing symbols
4. Structural symbols
5. Architectural symbols
6. Electrical symbols
7. Panel, circuit, and other electrical symbols
8. Types of blueprint lines
9. Typical electrical specifications
10. Minimum requirements for electrical devices
11. Determining motor-circuit wire sizes
12. Load calculations
13. Demand factor
14. Voltage drop
15. Types of blueprints
16. Construct an electrical blueprint
17. Perform load calculations
18. Compute lighting loads
19. Derate neutral loads
20. Determine maximum numbers of conductors in conduit
21. Compute voltage drop



**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

## **UNIT II: TOOLS AND EQUIPMENT**

1. Terms and definitions
2. Types of conduit benders
3. Wire termination tools
4. Wire and cable pulling equipment
5. Conduit cutting and threading tools
6. Knockout cutters
7. Power actuated tools
8. Types of excavation equipment
9. Bend, cut, ream and thread 1/2-inch rigid metal conduit
10. Bend EMT stub-ups
11. Make back-to-back bends on 1/2-inch EMT
12. Make offset bends on 1/2-inch EMT
13. Bend and install 1/2-inch EMT
14. Bend a three-point saddle on 1/2-inch EMT
15. Bend a four-point saddle on 1/2-inch EMT
16. Cut, ream, offset, and install connectors on 1/2-inch PVC

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

### **UNIT III: SERVICE**

1. Terms and definitions
  2. NEC requirements for drop clearance and laterals
  3. Switch gears and disconnects
  4. NEC exceptions for overcurrent protection devices
  5. Methods of determining short circuit current protection
  6. Grounding electrodes and ground fault
  7. Service entrance devices
  8. Emergency and standby systems
  9. Procedure for balancing loads
- 
10. Install an overhead raceway with service entrance conductors to a meter base
  11. Connect meter base assembly to load center or panel

### **UNIT IV: TRANSFORMERS**

1. Terms and definitions
2. Basic types of transformers
3. Diagrams of the two most commonly used voltage systems
4. NEC requirements for dry type transformers
5. NEC requirements for oil-filled transformers

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

6. NEC requirements for askarel-filled transformers
7. Function of a buck and boost transformer
8. Transformer locations
9. Installation and termination of transformers
10. Locate and list two exceptions on transformer room construction for dry type transformers
11. Locate and list two exceptions concerning oil-insulated transformers
12. Draw a three-wire wye-delta transformer
13. Convert amperes to KVA on a three-phase system
14. Test transformer turn ratios
15. Test transformer insulation resistance
16. Connect three transformers in a delta-delta configuration
17. Connect transformer primary and secondary windings in a delta-wye configuration

**UNIT V: ROUGH-IN**

1. Terms and definitions
2. Branch circuit and feeder installation
3. Devices used in special circuit installations

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

7. Determine the number of conductors allowed to be added to an existing conduit
8. Rough-in a wood framed wall
9. Install outlet boxes on steel rods
10. Install outlet boxes on steel studs using caddy metal stud clips for switch
11. Install masonry boxes in a block wall

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

4. Steps for determining the number of conductors allowed in a conduit, based on cross-sectional area
5. Exceptions to the NEC requirements for support of flexible metal conduit
6. Optional calculations for additional loads to existing installations

**UNIT VI: LIGHTING**

1. Terms and definitions
2. Basic types of lighting
3. Characteristics of incandescent lighting
4. Characteristics of fluorescent lighting
5. Characteristics of high intensity discharge lamps
6. Methods of calculating light
7. Calculating branch circuits and voltage
8. Switching systems

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

9. Locate articles in the NEC concerning lighting requirements
10. Change a two lamp ballast in a fluorescent fixture
11. Change sockets in a fluorescent fixture
12. Change an HID ballast
13. Change a quartz lamp

**UNIT VII: MOTORS AND CONTROLLERS**

1. Terms and definitions
2. Direct current motor theory of operation
3. Types of DC motors
4. Single-phase motor theory of operation
5. Types of single-phase motors
6. Three-phase motor theory of operation
7. Types of three-phase motors
8. Reversing a three-phase motor
9. Typical supply voltage for three-phase motors
10. Dual voltage schematics and terminal connections
11. Motor problems and their typical symptoms
12. Remedies for motor problems

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

13. Safety rules to observe when working around motors
14. Types of contactors
15. Parts of a manual contactor
16. Electrical devices or circuits controlled by contactors
17. Types of motor starters
18. Types of magnetic motor starters
19. Uses of magnetic motor starters
20. Comparison of parts in magnetic contactors with parts in magnetic motor starters
21. Reasons a contactor cannot be used to control a motor
22. Purposes of a coil assembly
23. Parts of a coil assembly
24. Interpret nameplate information
25. Describe remedies for common motor problems
26. Use the NEC to answer questions about motor control circuits
27. Distinguish between motor starters and contactors
28. Answer questions about uses of contactors and motor starters
29. Disassemble, inspect, and clean a motor

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

30. Identify run, common, and start terminals on a hermetically sealed motor
31. Test capacitors with an ohmmeter
32. Wire a three-phase motor for dual voltages
33. Perform maintenance on a magnetic motor starter or contactor

**UNIT VIII: ELECTRICAL DIAGRAMS AND SYMBOLS**

1. Terms and definitions
2. Characteristics of wiring diagrams
3. Characteristics of ladder diagrams
4. Characteristics of one-line diagrams
5. Wiring and ladder diagram symbols
6. Major steps in constructing a ladder diagram
7. Construct a basic ladder diagram
8. Identify electrical symbols in a wiring diagram

**UNIT IX: TWO AND THREE WIRE CONTROLS**

1. Terms and definitions
2. Typical two-wire pilot devices
3. Advantages of two-wire controls
4. Basic rule for three-wire controls

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

5. Advantages of three-wire controls
6. Operation of a two-wire control system
7. Operation of a three-wire control system
8. Complete a ladder and a wiring diagram of a two-wire control using a thermal switch
9. Draw a ladder diagram of a three-wire control with an "on" indicating pilot light
10. Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light
11. Determine the number and size of conductors needed to operate a two-wire control system
12. Determine the number and size of conductors needed to operate a three-wire control system
13. Wire a two-wire control
14. Wire two float switches to operate a starter (series connection)
15. Wire two float switches to operate a starter (parallel connections)
16. Wire a pressure switch to operate a starter with "on" and "off" pilot lights
17. Wire a three-wire control system
18. Wire a multiple station three-wire control
19. Wire a multiple station three-wire control with "on" and "off" pilot lights



**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

### **UNIT X: SEPARATE CONTROL CIRCUITS**

1. Terms and definitions
2. Reasons for separate control circuits
3. Applications for separate control circuits
4. Sources of separate control circuits
5. Typical control transformer schematics and their voltage ratings
6. Necessary changes that must be made to a starter when using a separate control circuit
7. Read and interpret ladder diagrams using separate control circuits
8. Answer questions dealing with control circuits
9. Determine the size and number of conductors needed to operate a separate control circuit
10. Wire a relay and a load with a separate control circuit
11. Wire a three-phase starter to operate by a separate control circuit

### **UNIT XI: SEQUENCE CONTROL**

1. Terms and definitions
2. Purpose of sequence control
3. Advantages of sequence control
4. Uses of sequence control

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

5. Purpose of auxiliary contact interlocking
6. Advantages of auxiliary contact interlocking
7. Uses of auxiliary contact interlocking
8. Answer questions related to a sequence control diagram
9. Answer questions related to an auxiliary contact interlocking diagram
10. Wire two starters in sequence
11. Wire two starters with auxiliary contact interlocking

**UNIT XII: JOGGING CONTROLS**

1. Jogging
2. Methods of jogging control
3. Advantages of jogging control
4. Sequence of operation of three ladder diagrams
5. Convert three ladder diagrams to wiring diagrams
6. Determine the number of conductors needed to operate jogging controls
7. Wire a jog through a lock-stop push button
8. Wire a jog through a two-position selector switch
9. Wire a jog through a two-circuit push button
10. Wire a jog through a control relay

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

### **UNIT XIII: REVERSING STARTERS**

1. Terms and definitions
2. Types of reversing starter construction
3. Types of interlocking methods for reversing starters
4. Types of drum controls
5. Drum switch diagram
6. Describe the sequence of operation of ladder diagrams
7. Determine the number of conductors needed to operate a reversing control
8. Wire a reversing starter with a three-position selector switch
9. Wire a reversing starter with one control station using auxiliary contact and mechanical interlock
10. Wire a reversing starter with one control station using push button interlock and auxiliary contact interlock
11. Wire a reversing starter with two control stations
12. Wire a drum switch
13. Wire a reversing starter with jog in both directions

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

#### **UNIT XIV: SPECIAL CONTROL CIRCUITS**

1. Terms and definitions
2. Parts of a control relay
3. Uses for control relays
4. Parts of a latching relay
5. Uses for latching relays
6. Types of timing relays
7. Applications for timing relays
8. How a ground fault indicator works
9. How an alarm silencing circuit is used
10. Build a relay control circuit
11. Wire a latching relay or contactor
12. Wire a timed *on* circuit
13. Wire a timed *off* circuit
14. Energize three starters in a timed sequential order
15. De-energize three starters in a timed sequential order
16. Build a ground fault indicator circuit

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

### **UNIT XV: PROGRAMMABLE CONTROLS**

1. Terms and definitions
2. Programmable controller functions
3. Three stages necessary to control a process
4. Input devices
5. Output devices
6. Components of a programmable controller
7. States of contacts
8. Types of I/O modules
9. Parts of an optical coupler
10. Basic PC ladder logic symbols
11. Why a stop button is wired normally closed
12. Basic numbering systems used in programmable controls
13. Match I/O devices with their functions
14. Convert between numbering systems

## COMMERCIAL AND INDUSTRIAL WIRING

### GLOSSARY

#### A

**Accelerating contactors** — Contactors or relays used in starting motors at low speed then increasing to maximum speed in preset timed steps

**Across-the-line** — Method of starting an electric motor by connecting it directly to supply line

**Ambient temperature** — The temperature in the area where the transformer is to be located. High temperatures will raise the insulation temperatures and shorten the life of the transformer. The KVA rating should be derated .4% for each 1°C over 30°C average ambient temperature for 150°C insulation

**Ampacity** — The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating

**Analog signal** — A signal which varies proportionally with some aspect of the environment; the signal from a pressure transducer which varies with the amount of pressure being applied

**Arc chute** — Partition between contacts to reduce electrical arcing

**Armature** — Portion of coil assembly moved by magnetism

**Automatic starting** — Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

**Auxiliary contacts** — Set of normally open auxiliary contacts on a starter, contactor, or relay that close when main contacts close, providing a means of sealing or holding the circuit in the energized state

#### B

**B** — Blue lamp

**Backhoe** — Machine used for digging ditches on construction sites

**Ballast** — Transformer used in lighting circuits

**Bender** — Used for bending pipe used in electrical trades

**Bimetal** — Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

**Blueprint** — Copy of the original detailed drawings of a structure

**Blueprint lines** — Set of conventional symbols to depict an object

**Branch circuit** — The circuit that extends from the last overcurrent protection device to the outlets

**Buck and boost transformer** — A transformer that increases or decreases voltage

## C

**Cable benders** — Mechanical or hydraulic devices used to bend heavy conductors in panels and junction boxes

**Cable cutters** — Used in cutting conductors

**Cathode** — Coiled coil or triple coil tungsten wire at each end of lamp which is coated with materials which emits electrons

**Coefficient** — The square root of the ratio of the power reflected from a surface to the power incident of the same surface

**Contactor** — Device without overload protection; repeatedly establishes and interrupts an electric power circuit

**Control transformer** — Small transformer used to step supply voltage down to appropriate control voltage

**Copper-clad aluminum** — Aluminum conductor with an outer coating of copper metallurgically bonded to the aluminum core

**Color coding** — Assigning colors to conductors based on their uses

**Counter** — A logic element in a PC user program which is used to simulate the operation of electro-mechanical counters

**Covered** — Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation

**Cross phasing** — Unintentional contact of two or more electrical phases; results in a short circuit

**Cross-sectional area** — Area in square inches allowed in a conduit or tubing; area required for conductors in a conduit or tubing

**CT** — Current transformer

**Cutting tools** — Saws used in cutting conduit for electrical insulations

**CW** — Cool white lamp

## D

**D** — Daylight lamp

**Delta** — Three-phase circuit in which the windings are connected in series (form a closed loop)

**Disconnects** — Devices used for breaking a circuit which may be fused or unfused

**Discrete** — A two-state reference in the user program which can be either on or off

**Down stream** — Coming after, following other devices or events

**Drop chain** — Short length of small chain used to pull cable or flexible conduit through an enclosed space or wall cavity

**Drum switch** — A switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or surfaces of a rotating cylinder

**Dual voltage motor** — Motor capable of being wired to run at two different voltages

## **E**

**Equipment grounding conductor** — Conductor used to connect non-current-carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor

## **F**

**FC** — Foot candles

**Feeder circuit** — All circuit conductors between the service equipment or the source of a separately derived system and final branch circuit overcurrent device

**Fiber optics** — Transfer of discrete signals through glass fibers with light

**Fish** — Establishing a connection between two points so a cable or length of flexible conduit can be installed

**Fish tape** — Metal tape used to run through a conduit for the pulling of conductors

**Fish wire** — Length of wire with a hook formed in one end to catch material to be installed in a space

**Flourescent lighting** — Electric discharge lighting

**Full voltage control** — Function of magnetic control that connects equipment directly to supply line on starting

## **G**

**G** — Green lamp

**Ground** — To connect electrical equipment either intentionally or accidentally to the earth or to some conducting body that serves as the earth

**Grounded** — Connected to earth or to some conducting body that serves in place of the earth

**Grounded conductor** — System or circuit conductor that is intentionally grounded

**Grounding-electrode conductor** — Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source of separately derived system



## H

**Hammer drills** — Used to bore through concrete

**HID** — High Intensity discharge

## I

**Incandescent lighting** — Consists of a filament which is a highly refractory conductor mounted in a transparent or translucent glass bulb

**Indicating pilot light** — Small light that indicates status of controls or machinery

**Input** — A signal which provides the controller information about the system; can be discrete, numeric, or analog

**Insulated** — Conductor encased within material of composition and thickness recognized by the *National Electric Code* as electrical insulation

**Interlocking** — To interrelate with other controllers; a device is connected in such a way that the operation of one part controls the operation of another

**Isolating transformer** — Insulates the primary circuit from the secondary circuit as with an insulating transformer, but frequently with no voltage change

## J

**Jet line** — Line sucked through a conduit by vacuum so a rope or tape can be pulled through a conduit

**Jogging (Inching)** — Momentarily operating; moving driven machine a small distance

## K

**Knockout cutter** — Used to cut holes, slots, and cuts in electrical boxes and studs

## L

**Ladder diagram (line diagram)** — Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit

**Lightning arrester** — Device connected to the supply side of a system, designed to absorb transient surges

**Logic** — A system which contains digital switching functions, circuits, or devices

**Low voltage protection** — Magnetic control only; nonautomatic restarting; two-wire control; power failure disconnects service; when power is restored the controller automatically restarts motor

**Lumens** — A unit of light emitted from a point light source of one candle through a unit solid angle

## M

**Magnetic contactor** — Contactor operated electromechanically

**Mechanical interlocking** — Means of locking out contactors through the use of mechanical devices such as cams or blocks

**Motor control center** — Large panel used in industrial applications to centrally locate motor starters, motor branch circuit short circuit and ground-fault protective devices and motor branch circuit disconnecting means

**Motor driven timing relay** — Relay whose timed contacts are operated through the action of a variable speed, extremely small motor

**Multispeed starter** — Starter designed to start motor at a reduced speed and built to full speed in preset steps

## N

**Networking** — Tie in of multiple PCs to communicate with each other in the performance of a process

## O

**One-line diagram** — Schematic consisting of single-phase and three-phase power lines, indicates power distribution and fuse and interrupter coordination

**Output** — A signal coming from the controller to field devices; can be discrete, numeric, or analog

**Overload relay** — Device for protecting motor from overload current or voltage

## P

**Phosphor** — Coating inside a fluorescent bulb to determine the color of light

**Photocell** — Light activated switch

**Photometer** — Instrument used in determining lumens

**Pilot device** — Directs operation of another device; alters the electrical circuit

**Pipe chase** — Usually a vertical space between two floors, dedicated for the running of pipes and conduits between floors

**PK** — Pink lamp

**Pneumatic timing relay** — Relay whose timed contacts are operated through the action of an air bellows and needle valve

**Power factor** — Ratio of active power to apparent power

**Power fish-tape system** — Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls

**Programmer** — A device designed to allow inserting, monitoring, and editing a user program in the PC

**Programmable controller (PC) (PLC)** — A solid state control system which contains a user programmable memory for the storage of instructions to perform specific functions in an operation

**PT** — Potential transformer

**Pulling equipment** — Used for pulling multiple and large conductors through a conduit. These may be manual or electrically operated

**Pulling lube** — Wax based product that allows the conductors to pass through the conduit causing less friction

**Pulling sleeve** — Attaches around the end of conductors so they may be pulled through a conduit

**Pull rope** — Strong rope of nylon or other substance used to pull heavy conductors into raceways

**Push button** — Switch, manually operable plunger, button, or actuating device

**Push-button interlocking** — Means of interlocking reversing starters through the use of two-circuit push buttons with normally open and normally closed contacts

**Push-to-test pilot light** — Used to indicate "on" and "off" status of a motor and to verify condition by means of indicating a burned out lamp

## **R**

**Raceway** — An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the *National Electrical Code*

**Racing** — Condition that occurs when both forward and reversing push buttons are operated simultaneously; coils "race" to close

**Ram-set gun** — Uses charges that shoot studs and tie downs in concrete, metal, and wood

**Relay** — Operated by a change in one electrical circuit to control a device in the same circuit or another circuit; used in control circuits

**Remote control** — Device that controls electrical apparatus from some distance

**Reversing starter** — Starter consisting of two identical contactors and one overload relay assembly; used in reversal of polyphase motors

## S

**Selector switch** — Manually operated multiposition switch

**Service** — Where power is metered or is first attached to the structure

**Service drop** — Power conductors coming into building from power company

**Service panel** — Main control panel where voltage and current are distributed to different locations

**Shading coil** — Single turn of conducting material mounted on the magnetic assembly face to produce out-of-phase magnetic force

**Single phasing** — Loss of one phase of a three-phase system

**Solid state timing relay** — Relay whose timed contacts are operated by an electronic timer (microchip)

**Specifications** — A detailed set of written instructions which explains the drawing

**Starter** — Control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting

**Strippers** — Used for removing insulation from conductors

**Switch gear** — Devices used for disconnecting power on electrical circuits

**Symbol** — An arbitrary sign that has been standardized and is used to represent an object, quantity, or method

## T

**Thermal overloads (heater)** — Device used to sense current draw in a circuit and open a control circuit when its rating is exceeded

**Threading tools** — Used to thread pipe so electrical fittings may be attached to conduit

**Three-wire control** — Uses momentary contact; start/stop stations and a memory circuit interlock connected in parallel with the start button to maintain the circuit

**Time clock** — An electromechanical or electronic switch designed to control electrical circuits and equipment based on preset times of day

**Timer** — Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric

**Torque** — Force that produces a rotating or twisting action

**Transformer vault** — Area in which transformers are installed for safety protection. This area is usually constructed with concrete and fire-retardant doors

**Trencher** — Machine used for digging trenches

**Trim out** — Final stage in a wiring project; involves devices and plates, connecting and securing equipment, hanging fixtures, and testing the system

**Troubleshooting** — The systematic diagnosis of a malfunction

**Two-wire control** — Any type of switch having a definite "on" and "off" position that is used to control a magnetic starter or contactor

## **U**

**Under voltage relay** — Relays whose coils are connected between the line terminals of a motor branch circuit; opens a set of N/O contacts if one or more phases is lost

## **V**

**Voltage drop** — A reduction in available voltage at the end of a circuit

**Voltage rating** — Maximum voltage at which a device is designed to operate

## **W**

**W** — White lamp

**Winch** — Manual or motor-powered mechanical device used to pull conductors into a raceway

**Wire dispenser** — Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway

**Wire-pulling compound** — Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway

**Wiring diagram** — Schematic consisting of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring

**WW** — Warm white lamp

**Wye** — Three-phase circuit in which the windings are connected in parallel (form the shape of a "Y")

# COMMERCIAL AND INDUSTRIAL WIRING

## TOOLS, EQUIPMENT, AND MATERIALS LIST

Awl	Normally closed push button
Ball peen hammer	Normally open push button
Beam, 2"x4"	Octagon box
Bleeder resistor	Ohmmeter
Box clips	One-hole straps, 1/2"
Boxes, 1900	Outlet boxes
Center punch	Paper
Clean rags	Pencil
Combination wrench set	Pilot light
Compressed air	Pipe straps, 2"
Compressor units	Plaster ring
Conduit pipe die	Polishing cloth
Construction blueprint	Pouch tools
Control transformer	Power supply
Copper, #2 & #4	Pressure switch
Cutting oil	PVC cement
Drum switch	PVC connectors
Dual voltage motor	Quartz lamp
EMT bender	Reaming tool
EMT couplings and connectors	Relay, 4-pole
Float switch	Republic bender
Folding rule with sliding scale	Reversing starter
Framed wall with 2"x4" studs	Rigid metal conduit
Fuses	Rod hanger clamps
Fuse block	Rule
Fuse holders	Safety glasses
Hacksaw	Service entrance cap
Hammer	Sheet metal screws
Hanger box	Small socket wrench set
Hickey's pipe vise	Soft faced hammer
HID ballast	Split-phase motor
Knife	Square outlet boxes
Lamp	Start/stop station
Latching relay, 4-pole	Stove bolt
Level	Test jumpers
Lock-stop device	Thermometer
Machine oil	Three-element control station
Magnetic coils	Three-phase open starter
Marking pencil	Time clock
Measuring tape	Two-element control station
Megger tester	Voltmeter
Meter base, 3φ	Wire
Mock up wall	Wire brush
Motor cleaning fluid	Wire markers
Mounting board	Wire nuts
Mounting nails	

## COMMERCIAL AND INDUSTRIAL WIRING

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# **BLUEPRINT READING AND LOAD CALCULATIONS**

## **UNIT I**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to identify blueprint symbols and compute load calculations and voltage drop. Competencies will be demonstrated by completing the assignment sheets and the unit test with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to blueprint reading and load calculations with their correct definitions.
2. Identify mechanical symbols.
3. Identify plumbing symbols.
4. Identify structural symbols.
5. Identify architectural symbols.
6. Identify electrical symbols.
7. Identify panel, circuit, and other electrical symbols.
8. Match types of blueprint lines with their pictures and descriptions.
9. List four typical electrical specifications.
10. Complete statements concerning minimum requirements for electrical devices.
11. Determine motor-circuit wire sizes by using the NEC.



**OBJECTIVE SHEET**

12. Select true statements concerning load calculations.
13. Define demand factor.
14. Select true statements concerning voltage drop.
15. Match types of blueprints with their correct descriptions.
16. Construct an electrical blueprint. (Assignment Sheet #1)
17. Perform load calculations. (Assignment Sheet #2)
18. Compute lighting loads. (Assignment Sheet #3)
19. Derate neutral loads. (Assignment Sheet #4)
20. Determine maximum numbers of conductors in conduit. (Assignment Sheet #5)
21. Compute voltage drop. (Assignment Sheet #6)

## BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Make transparencies from the transparency masters included in this unit.
- C. Provide students with objective sheet.
- D. Discuss unit and specific objectives.
- E. Provide students with information and assignment sheets.
- F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

- G. Integrate the following activities throughout the teaching of this unit:

1. Take students on a field trip to a construction site.
2. Have a representative from a local engineering firm talk to class about the importance of reading various types of blueprints.
3. Invite a local inspector to class to discuss pertinent codes and requirements.
4. Show students examples of various types of blueprints.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

- H. Give test.
- I. Evaluate test.
- J. Reteach if necessary.

### REFERENCES USED IN WRITING THIS UNIT

- A. Mullin/Smith. *Electrical Wiring*. Albany, NY: Delmar Publishers, 1985.
- B. *National Electrical Code, 1987*. Quincy, MA: National Fire Protection Association, 1986.
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# Alphabet of Lines

**Object Line**



**Dimension Line**



**Extension Line**



**Hidden Line**



**Center Line**



**Cutting Plane**



**Break Line-Long**



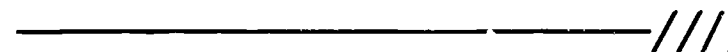
**Break Line-Short**



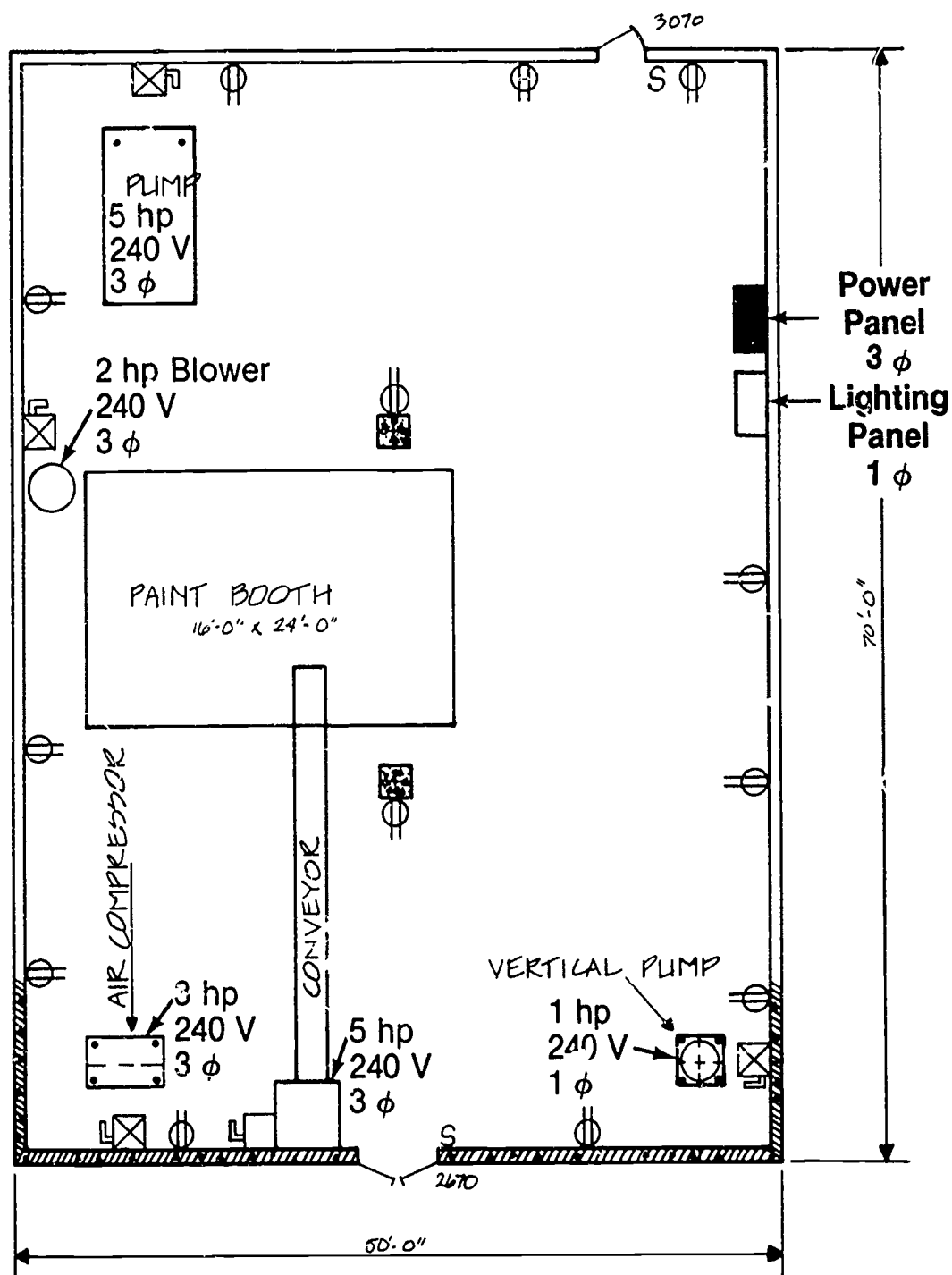
**Leader**



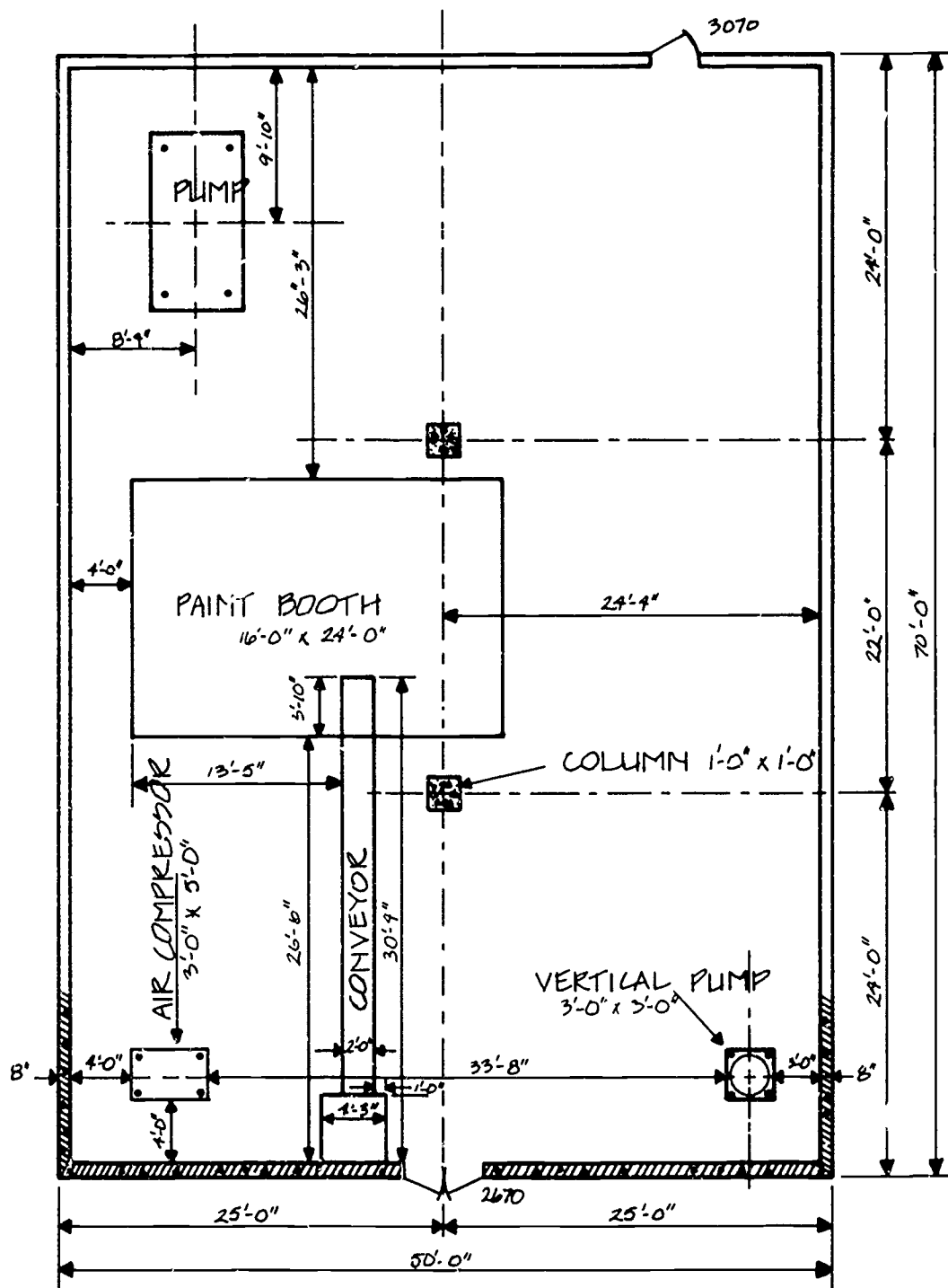
**Section Lining**



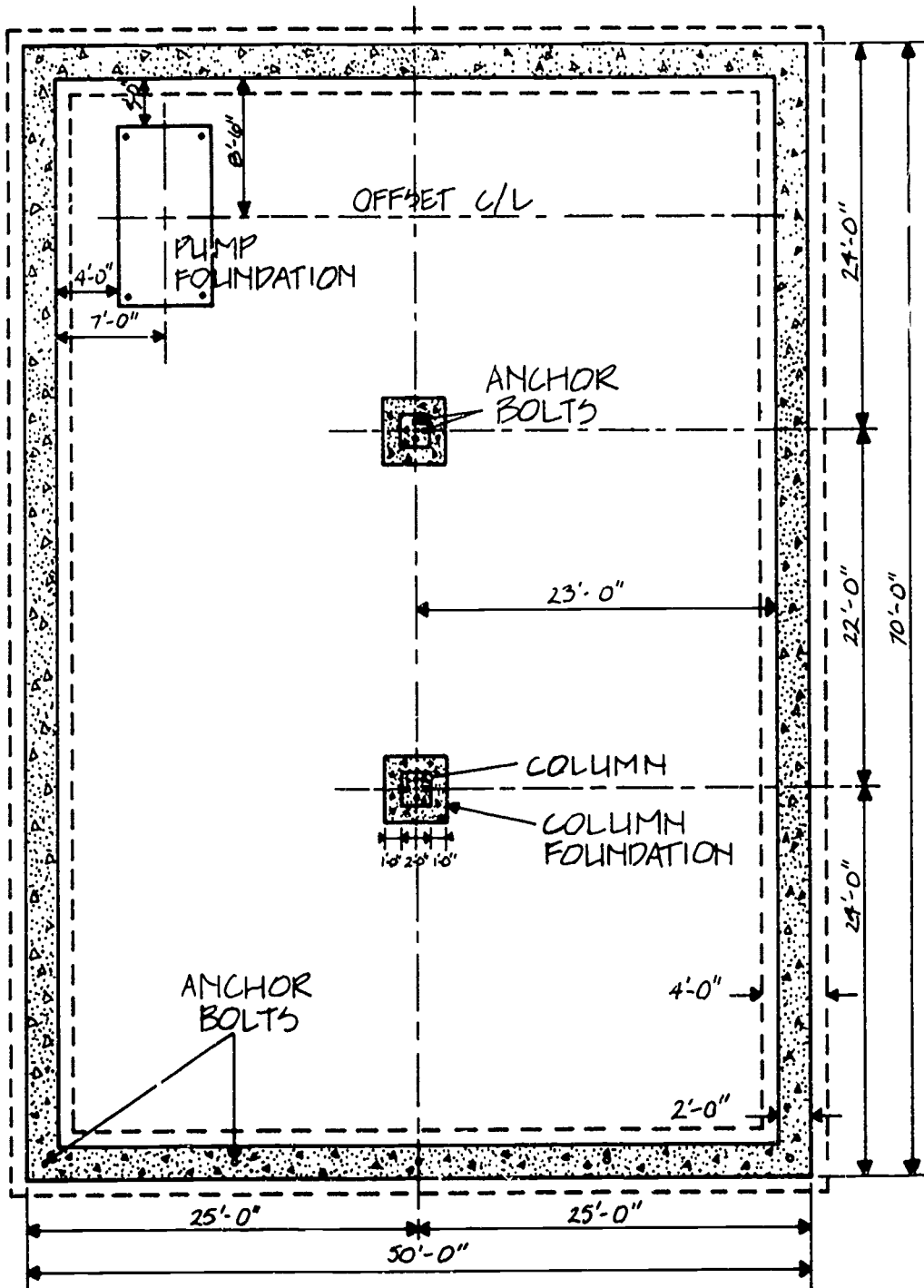
# Electrical Floor Plan



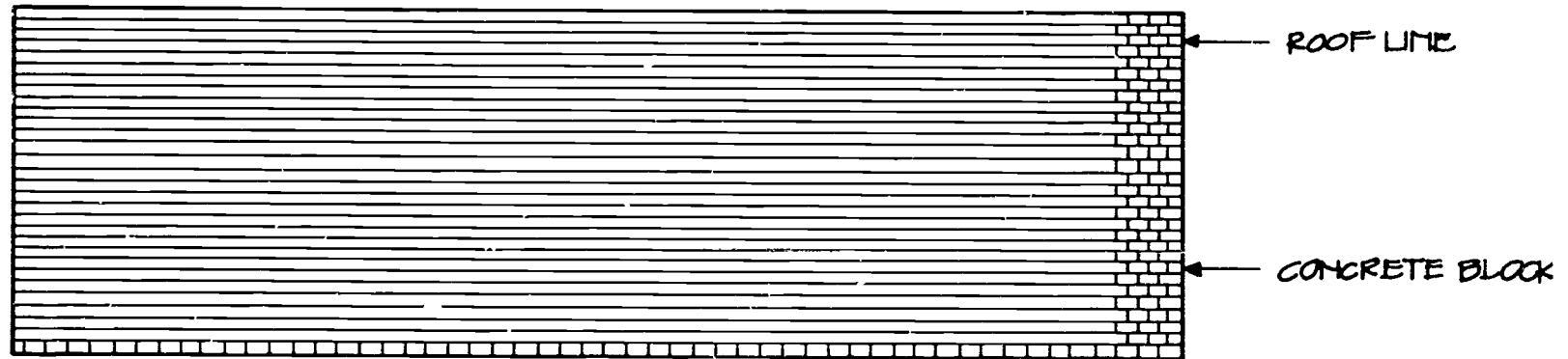
# Floor Plan



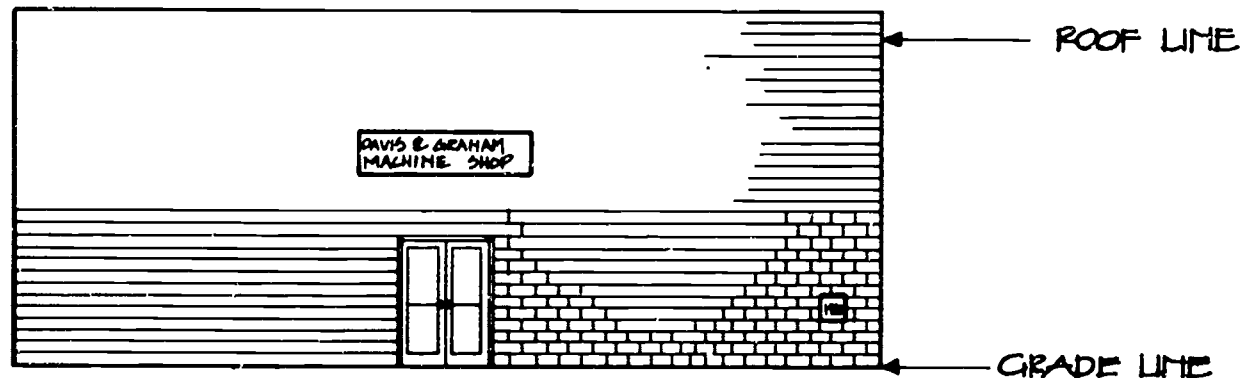
# Foundation Plan



# Elevations

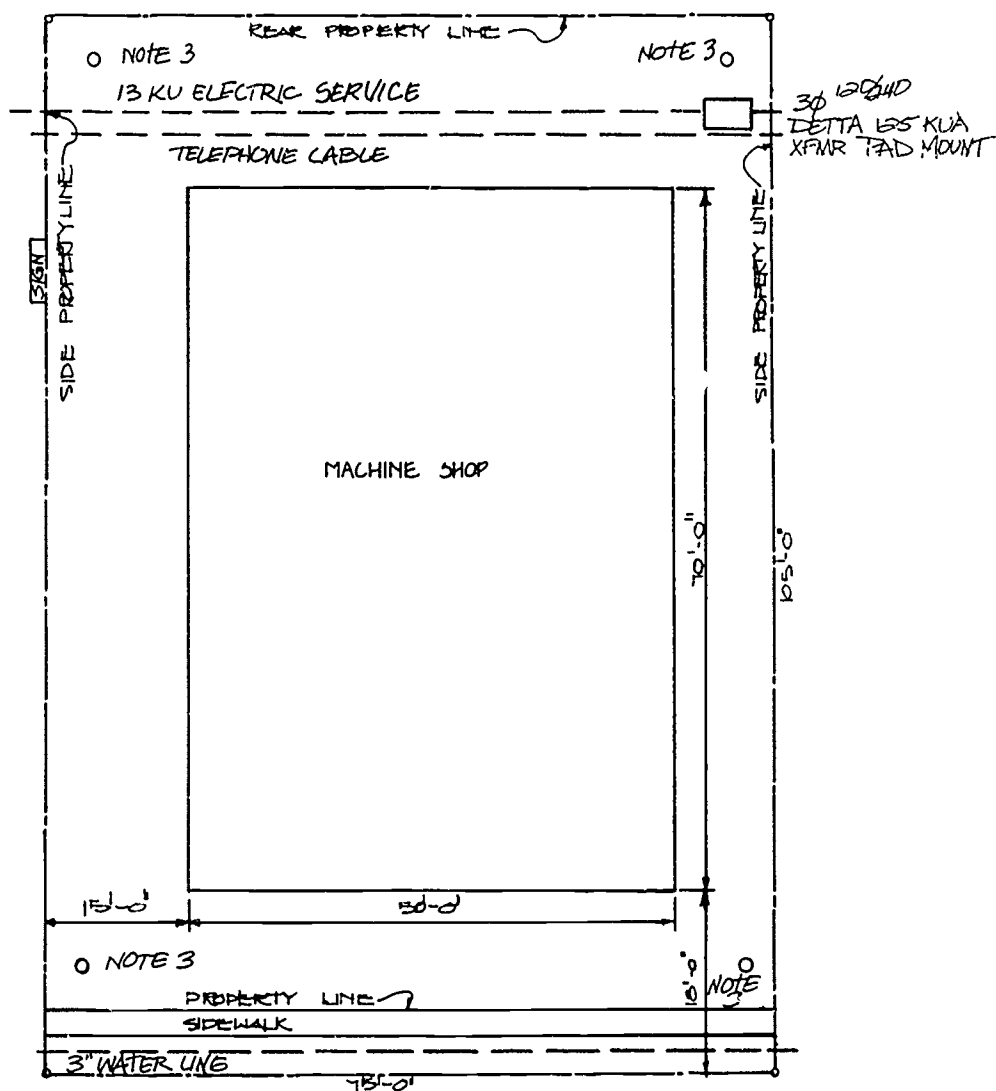


WEST ELEVATION



SOUTH ELEVATION

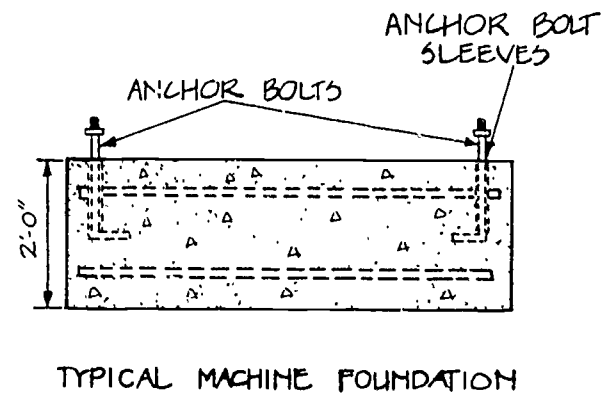
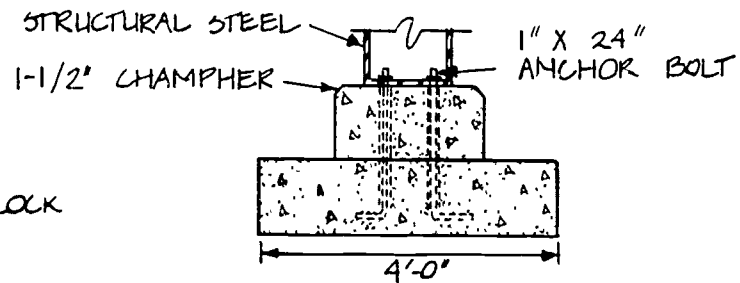
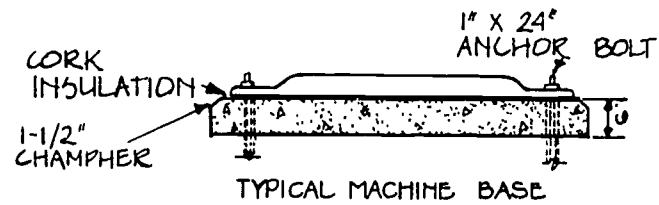
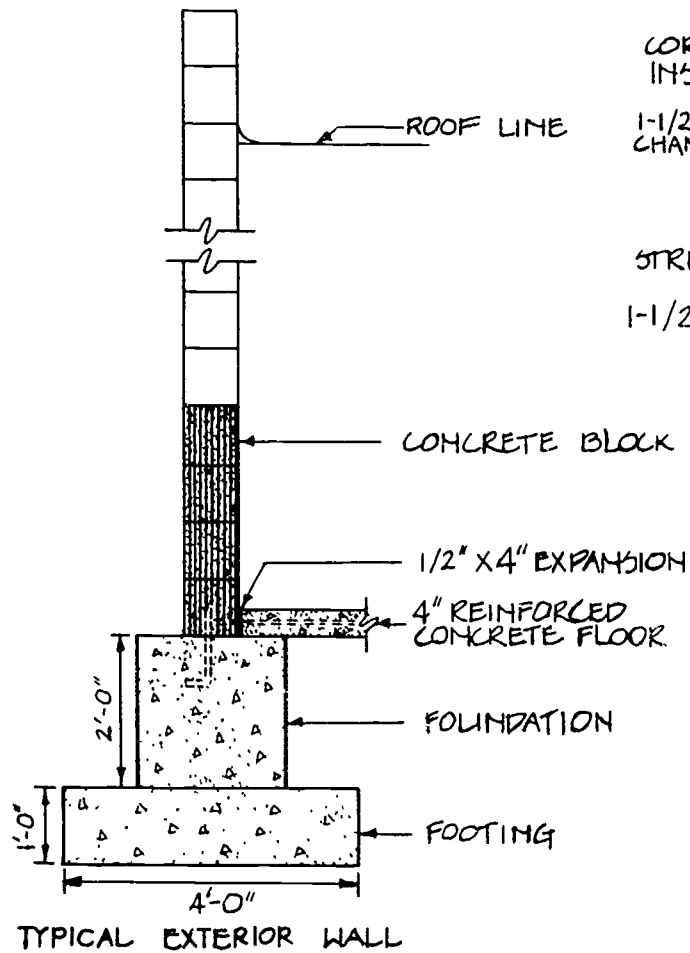
## Plot Plan



**NOTE 3: 30' steel pole with one 250W HPS flood.**



# Details



# BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

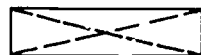
## INFORMATION SHEET

### I. Terms and definitions

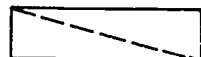
- A. Blueprint — Copy of the original detailed drawings of a structure
- B. Blueprint lines — Set of conventional symbols to depict an object
- C. Branch circuit — The circuit that extends from the last overcurrent protection device to the outlets
- D. Feeder circuit — All circuit conductors between the service equipment or the source of a separately derived system and final branch circuit overcurrent device
- E. Specifications — A detailed set of written instructions which explains the drawing
- F. Symbol — An arbitrary sign that has been standardized and is used to represent an object, quantity, or method
- G. Voltage drop — A reduction in available voltage at the end of a circuit

### II. Mechanical symbols

- A. Duct section exhaust, return

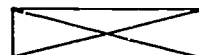


riser to 2nd floor

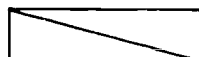


riser to 1st floor

- B. Duct section supply

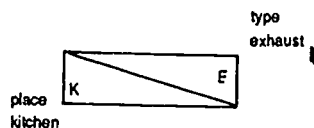


riser to 1st floor

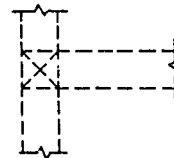


riser to 2nd floor

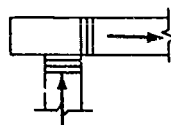
- C. Duct section notation



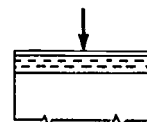
- D. Duct connection below joist



- E. Fan flexible connection

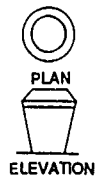


- F. Louver 8 screen air intake

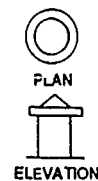


## INFORMATION SHEET

### G. Rainproof ventilator

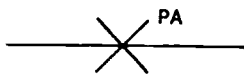


### H. Standard ventilator

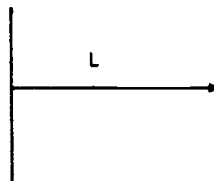


(NOTE: The following symbols are single line representation.)

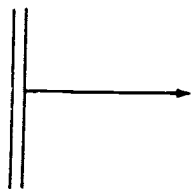
### I. Anchor



### J. Louver opening



### K. Register or grille



## III. Plumbing symbols

### A. Corner bath —



### B. Recessed bath —



### C. Roll rim bath —



### D. Sitz bath —



### E. Foot bath —



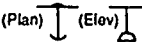
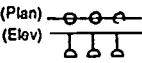















### F. Bidet —




















### G. Shower stall —









## INFORMATION SHEET

H.	Shower head —	
I.	Overhead gang shower —	
J.	Pedestal lavatory —	
K.	Wall lavatory —	
L.	Corner lavatory —	
M.	Manicure/Medical lavatory —	
N.	Dental lavatory —	
O.	Plain kitchen sink —	
P.	Kitchen sink, R & L drain board —	
Q.	Kitchen sink, LH drain board —	
R.	Combination sink & dishwasher —	
S.	Combination sink & laundry tray —	
T.	Service sink —	
U.	Wash sink (Wall type) —	
V.	Wash sink —	
W.	Laundry tray —	
X.	Water closet (Low tank) —	

# INFORMATION SHEET

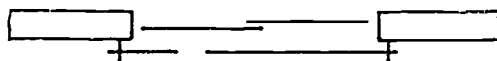
Y.	Water closet (No tank) —	
Z.	Urinal (Pedestal type) —	
AA.	Urinal (Wall type) —	
BB.	Urinal (Corner type) —	
CC.	Urinal (Stall type) —	
DD.	Urinal (Trough type) —	
EE.	Drinking fountain (Pedestal type) —	
FF.	Drinking fountain (Wall type) —	
GG.	Drinking fountain (Trough type) —	
HH.	Hot water tank —	
II.	Water heater —	
JJ.	Meter —	
KK.	Hose rack —	
LL.	Hose bibb —	
MM.	Gas outlet —	
NN.	Vacuum outlet —	
OO.	Drain —	

# INFORMATION SHEET

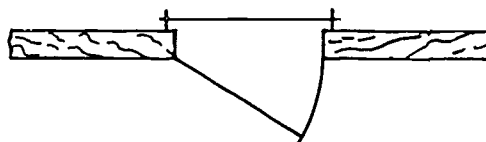
PP.	Grease separator —	
QQ.	Oil separator —	
RR.	Cleanout —	
SS.	Garage drain —	
TT.	Floor drain with backwater valve —	
UU.	Roof sump —	

## IV. Structural symbols

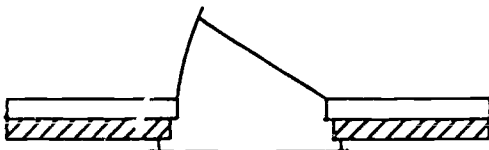
A. Plan view of exterior door in wood frame wall



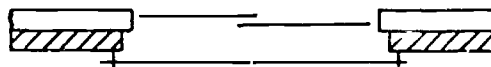
B. Plan view of exterior sliding door in wood frame wall



C. Plan view of exterior door in masonry veneer wall



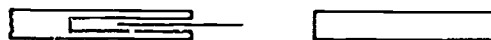
D. Plan view of exterior sliding door in masonry veneer wall



E. Plan view of interior hinged door



F. Plan view of interior pocket door



# INFORMATION SHEET

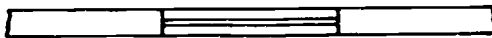
G. Folding door



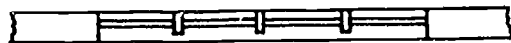
H. Plastered arch doorway



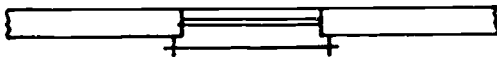
I. Single window in frame wall



J. Multiple windows in frame wall





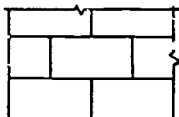


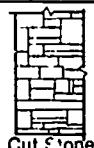



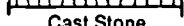



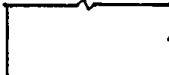
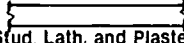
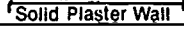







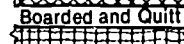
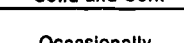







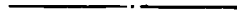
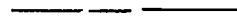




K. Plan view of double hung window in frame wall



# INFORMATION SHEET

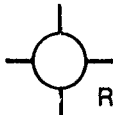

## V. Architectural symbols

ELEVATION	PLAN	SECTION
Brick  (Common, face, etc.)	 Common  Face  Firebrick	Same as plan view
Concrete Block 	 or 	
Stone  Cut Stone  Rubble	 Cut Stone  Rubble  Cast Stone (Concrete)	
Glass  or 		
Plaster 	 Stud, Lath, and Plaster  Solid Plaster Wall	
Wood  Siding  Panel	Floor areas are left blank, note indicates kind of wood used	 Rough Member  Trim
Insulation 	 Loose Fill or Batts  Boarded and Quilt  Solid and Cork	Same as plan view
Sheet Metal Flashing 	Occasionally indicated by note	
Metals Other than Flashing Indicated by note or drawn to scale	Same as elevation	Small Scale  Steel  Aluminum Large Scale  Cast Iron  Bronze or Brass
Structural Steel Indicated by note or drawn to scale	 or  or 	Reinforcing Bars  L-angles Small Scale  I-beams Large Scale








## INFORMATION SHEET



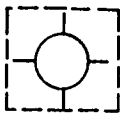
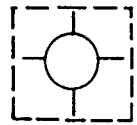


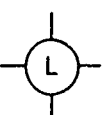
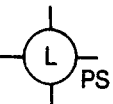
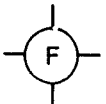
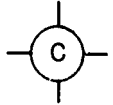


### VI. Electrical symbols

- |    |                                  |   |
|----|----------------------------------|---|
| A. | Single pole switch —             | S   |
| B. | Three way switch —               | $S_3$   |
| C. | Four way switch —                | $S_4$   |
| D. | Automatic door switch —          | $S_D$   |
| E. | Key operated switch —            | $S_K$   |
| F. | Switch with pilot light —        | $S_p$   |
| G. | Weatherproof switch —            | $S_{wp}$  |
| H. | Fused switch —                   | $S_f$   |
| I. | Double pole switch —             | $S_2$   |
| J. | Switch for low voltage system —  | <u>S</u>  |
| K. | Circuit breaker —                | $S_{cb}$  |
| L. | Remote control switch —          | $S_{rc}$  |
| M. | Low voltage wire —               | — — — — —   |
| N. | Low voltage master switch —      | $M_s$   |
| O. | Relay equipped lighting outlet — |  |
| P. | Single receptacle outlet —       |  |









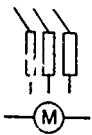


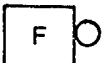






# INFORMATION SHEET

- Q. Duplex receptacle outlet — 
- R. Split wired receptacle outlet — 
- S. Floor receptacle outlet — 
- T. Weatherproof duplex outlet — 
- U. Special circuit — 

(NOTE: This must be explained in the symbol key.)







- V. Junction box — 
- W. Lighting outlet — 
- X. Square recessed light (size varies) — 
- Y. Rectangular recessed light (size varies) — 
- Z. Round recessed light (size varies) — 
- AA. Flourescent light — 
- BB. Lampholder -- 
- CC. Lampholder with pull switch — 
- DD. Fan outlet — 
- EE. Clock outlet — 
- FF. Chime — 
- GG. Bell — 

# INFORMATION SHEET


HH.	Buzzer —	
II.	Push button —	
JJ.	Electric door opener —	
KK.	Interconnecting telephone —	
LL.	Telephone switchboard —	
MM.	Outside telephone —	
NN.	T.V. outlet —	
OO.	Computer —	
PP.	Combination starter —	
QQ.	Switch leg indicator —	
RR.	Baseboard heat —	
SS.	Fire alarm bell —	
TT.	Fire alarm station —	
UU.	Automatic fire alarm device —	
VV.	Horn —	
WW.	Interconnection box —	
XX.	Battery —	
YY.	Auxiliary system circuits	

## INFORMATION SHEET


### VII. Panel, circuit, and other electrical symbols

- A. Lighting panel — 
- B. Power panel — 
- C. Branch circuit, concealed in ceiling or wall — 
- D. Branch circuit, concealed in floor — 
- E. Branch circuit, exposed — 
- F. Home run to panelboard — 







(NOTE: Indicate number of circuits by number of arrows.)

- G. Feeders — 

(NOTE: Use heavy lines and designate by number corresponding to listing in Feeder Schedule.)

- H. Underfloor duct and junction box. Triple system. — 

(NOTE: For double or single systems eliminate one or two lines.)

- i. Generator — 
- J. Motor — 
- K. Instrument — 
- L. Power transformer — 
- M. Controller — 
- N. Isolating switch — 






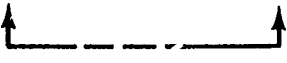
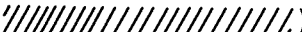


## INFORMATION SHEET

O. Overcurrent device, (fuse, breaker, thermal overload) — 

P. Switch and fuse —



### VIII. Types of blueprint lines

- A. Object lines — (  ) — Show the main outline of the building including exterior walls, interior partitions, porches, patios, drive-ways, and interior walls; these lines should be the outstanding lines on a drawing
- B. Dimension lines — (  ) — Thin unbroken lines which building dimensions are placed upon
- C. Extension lines — (  ) — Extend, but do not touch, the object lines and permit dimension lines to be drawn between them
- D. Hidden lines — (  ) — Short dashes used to show lines that are not visible from that view
- E. Center lines — (  ) — A series of short and long dashes used to designate the center of doors, windows, and circles and to provide a reference point for dimensioning
- F. Cutting-plane lines — (  ) — Heavy lines consisting of a series of one long and two short dashes with arrows at each end pointing away from the area that is cut away for the purpose of sectioning
- G. Section lines — (  ) — A series of lines of various shapes or symbols used to depict an area that is a cross section of the whole object and also depicts the type of material to be used in construction
- H. Break lines — (  ) — Used when an area cannot or should not be drawn entirely
- I. Leaders — (  ) — Used to connect a note or dimension to a part of the building

### IX. Typical electrical specifications

#### A. Minimum standards

**EXAMPLE:** The contractor shall install the complete electrical system according to national and local electrical codes, as per plans and specifications.

## INFORMATION SHEET

### B. Type of equipment

**EXAMPLE:** All switches, duplex receptacles, and other outlets shall be in conduit (EMT will be acceptable). Electrical contractor shall furnish all lighting fixtures as per specifications or approved substitutes.

### C. Type of installation

**EXAMPLE:** Electrical service equipment shall be of units specified on plans or shall be approved substitutes or like quality. All work shall be done in coordination with other crafts.

### D. Special instructions

**EXAMPLE:** Receptacle circuits shall include an equipment grounding conductor of proper size.

## X. Minimum requirements for electrical devices

### A. Receptacles

(NOTE: Refer to NEC Article 210, Part C.)

1. Rooftop heating, air conditioning, and refrigeration equipment must have a 125 volt receptacle within 75 feet of equipment.

(NOTE: Refer to NEC Article 210-63.)

2. Show windows must have one receptacle for each 12 linear feet.

(NOTE: Refer to NEC Article 210-62.)

- B. Lighting — A unit load of not less than that specified in NEC Table 220-3(b) for occupancies therein shall constitute the minimum lighting load for each square foot (0.093 sqm) of floor area

(NOTE: Refer to NEC Article 220-3[b].)

- C. Disconnects — Are required by code for motors and appliances and each service, feeder, or branch circuit at the point where it originates and shall be legibly marked

(NOTE: Refer to NEC Article 110-22.)

## INFORMATION SHEET

### XI. Steps for determining motor-circuit wire sizes

(NOTE: NEC Article 430-148 gives normal amperages for single-phase motors, and Article 430-150 gives similar information for three-phase motors.)

- A. Determine motor size, voltage, and phase from print.
- B. Determine full-load amperes from NEC Articles 430-148 and 430-150.
- C. Determine circuit ampacity from NEC Article 430-22 (continuous-duty motors).
- D. Determine wire insulation type, using NEC Table 310-13.

**EXAMPLE:** THW would be the type of heat-resistant insulation needed for a dry location in a machine shop where the temperature of the conductor does not exceed 40°C at any time.

- E. Determine wire size from NEC Table 310-16.

(NOTE: According to NEC 210-19, conductors shall be rated to prevent a voltage drop exceeding 3 percent. Number 12 wire is normally required on motor circuits rated 1 to 16 amperes.)

**EXAMPLE:**

**TABLE 1**

<b>Motors</b>	<b>Full-Load Amps Per NEC 430-148 NEC 430-150</b>	<b>Calculated Circuit Ampacity Per NEC 430-22</b>	<b>THW Wire size NEC 310-16</b>
1 hp 240 Volts 1 $\phi$	8.0	10.0	#12
2 hp 240 Volts 3 $\phi$	6.8	8.5	#12
3 hp 240 Volts 3 $\phi$	9.6	12.0	#12
7.5 hp 240 Volts 3 $\phi$	22.0	27.5	#10
15 hp 240 Volts 3 $\phi$	42.0	52.5	# 6

## INFORMATION SHEET

### XII. Load calculations

(NOTE: The NEC allows only a specified number of conductors in a raceway. See Table 3-A and 3-B in Chapter Nine. Also see Note 8, Table 310-16.)

#### A. Feeder calculations

1. Feeder size is determined by branch circuit loads to be supplied. It is accepted practice to allow a growth factor of 25%.

(NOTE: Refer to NEC Article 220-22.)

2. For 3-wire DC or single phase AC, 4-wire, 3 phase and 5-wire, 2 phase systems, a further demand factor of 70% shall be permitted for that portion of the unbalanced load in excess of 200 amperes. No reduction is permitted on the neutral conductor concerning electric discharge lighting. This is referred to as derating neutral.

(NOTE: Refer to NEC Article 220-22.)

#### B. Branch circuit calculations

1. The loads are classified in four separate groups:
  - a. General lighting — Table 220-3(b) and 220-10(b)
  - b. General purpose receptacle loads — 220-3(c)(5) and Table 220-13
  - c. Special appliance loads — 220-3(c)(5), Exception #1
  - d. Motor loads — Table 220-14, 430-22(a), 430-24 and 430-25
2. Concerning temperature calculations, no conductor shall be used in such a manner that its operating temperature will exceed that designated for the type of insulated conductor involved.

(NOTE: See Tables 310-13 and 310-61 for maximum temperature. Tables 310-16 through 310-19 and 310-69 through 310-80, provide conductor sizes, types, ampacities, ambient temperatures, and number of associated conductors.)

### XIII. Demand factor — The ratio of the maximum demand of a system, or part of a system, to the total connected load of a system or the part of the system under consideration

(NOTE: Refer to NEC Table 220-20, 220-32, and 220-4.)



## INFORMATION SHEET

### XIV. Voltage drop

(NOTE: Refer to NEC Article 215-2.)

- A. If voltage drop is too great, electrical equipment can overheat.
- B. Voltage drop must be considered when feeder and branch circuit conductors are selected.
- C. The formula for voltage drop is:

$$VD = \frac{2 \times K \times L \times I}{1000}$$

- D. The values that may be used when determining voltage drop are:

VD — Voltage drop

K — Resistor of conductor material (Chapter 9, Table 8, NEC)

L — One-way length of circuit in feet

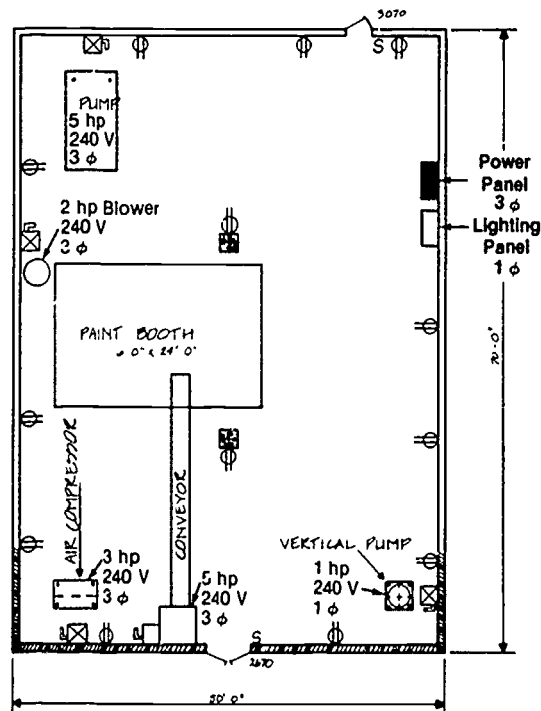
I — Current in conductor in amperage

CM — Conductor area in circular mils (Chapter 9, Table 8, NEC)

1000 — Length of conductors (Chapter 9, Table 8, NEC)

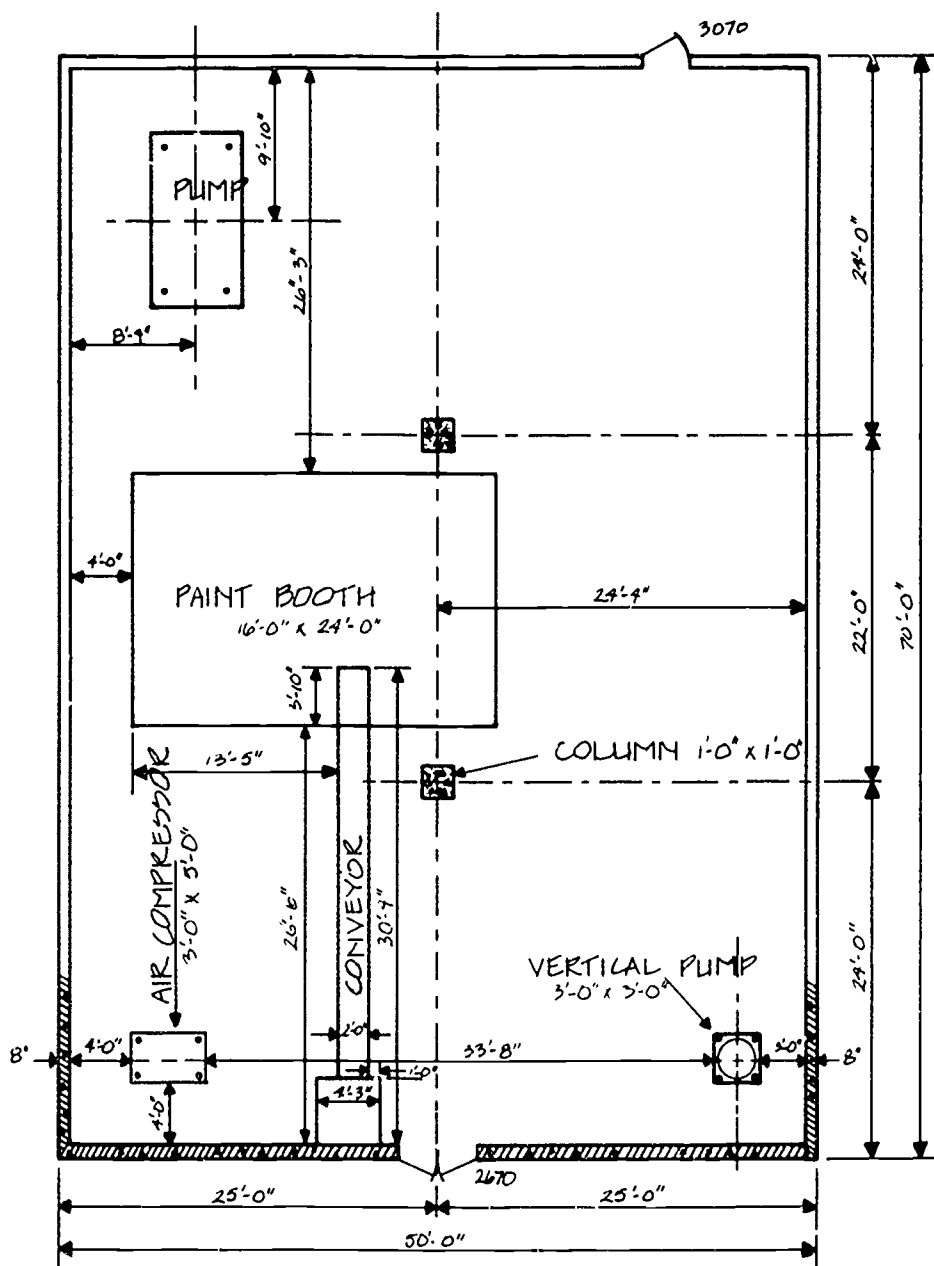
### XV. Types of blueprints

- A. Electrical floor plan — Shows locations of switches, outlets, lighting, and special equipment



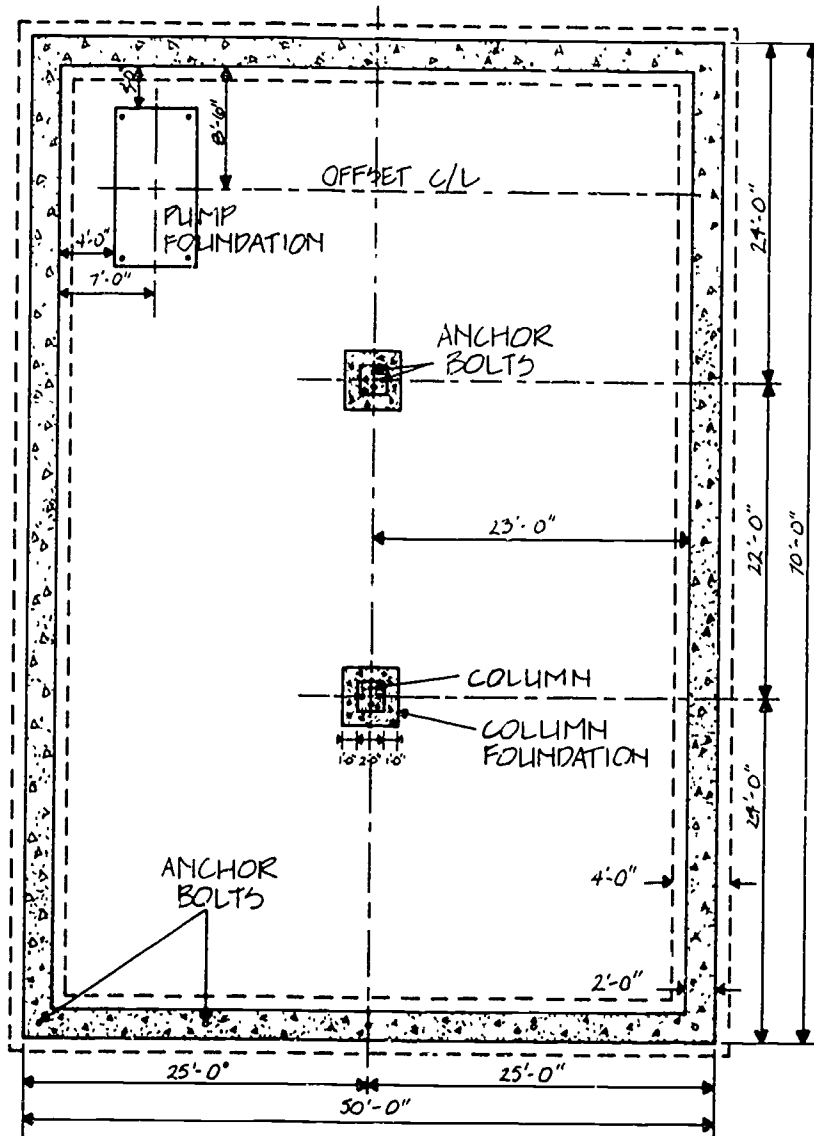
# INFORMATION SHEET

- B. Floor plan — Similar to electrical but shows equipment, wall, and structural support locations



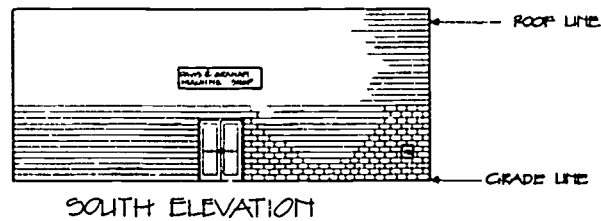
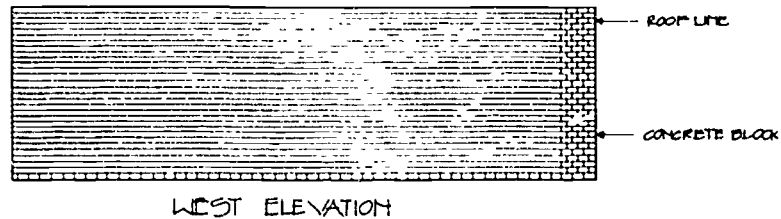
# INFORMATION SHEET

- C. Foundation plan — Shows structural support characteristics of building which is pertinent when planning conduit runs

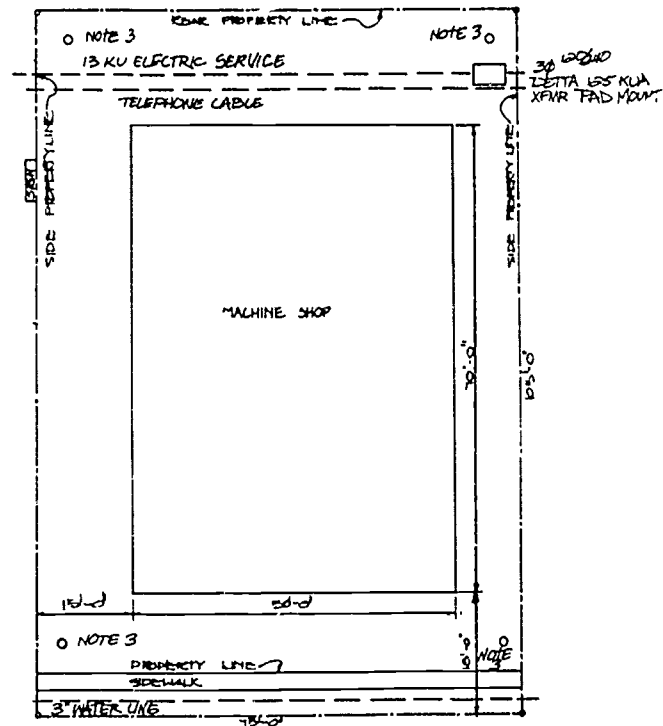


## INFORMATION SHEET

- D. Elevations — Clarify placement of exterior lighting and power outlets

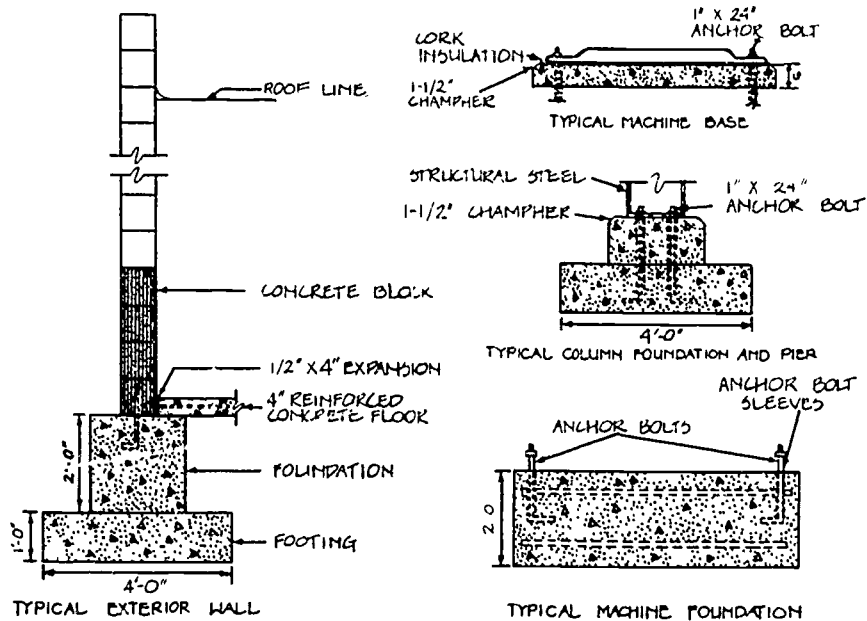


- E. Plot plan — Shows location of building in relationships to layout of land and location of utilities and site lighting



## INFORMATION SHEET

- F. Details — Clarify specific installation requirements such as j-bolts for site lighting or special equipment mounting devices



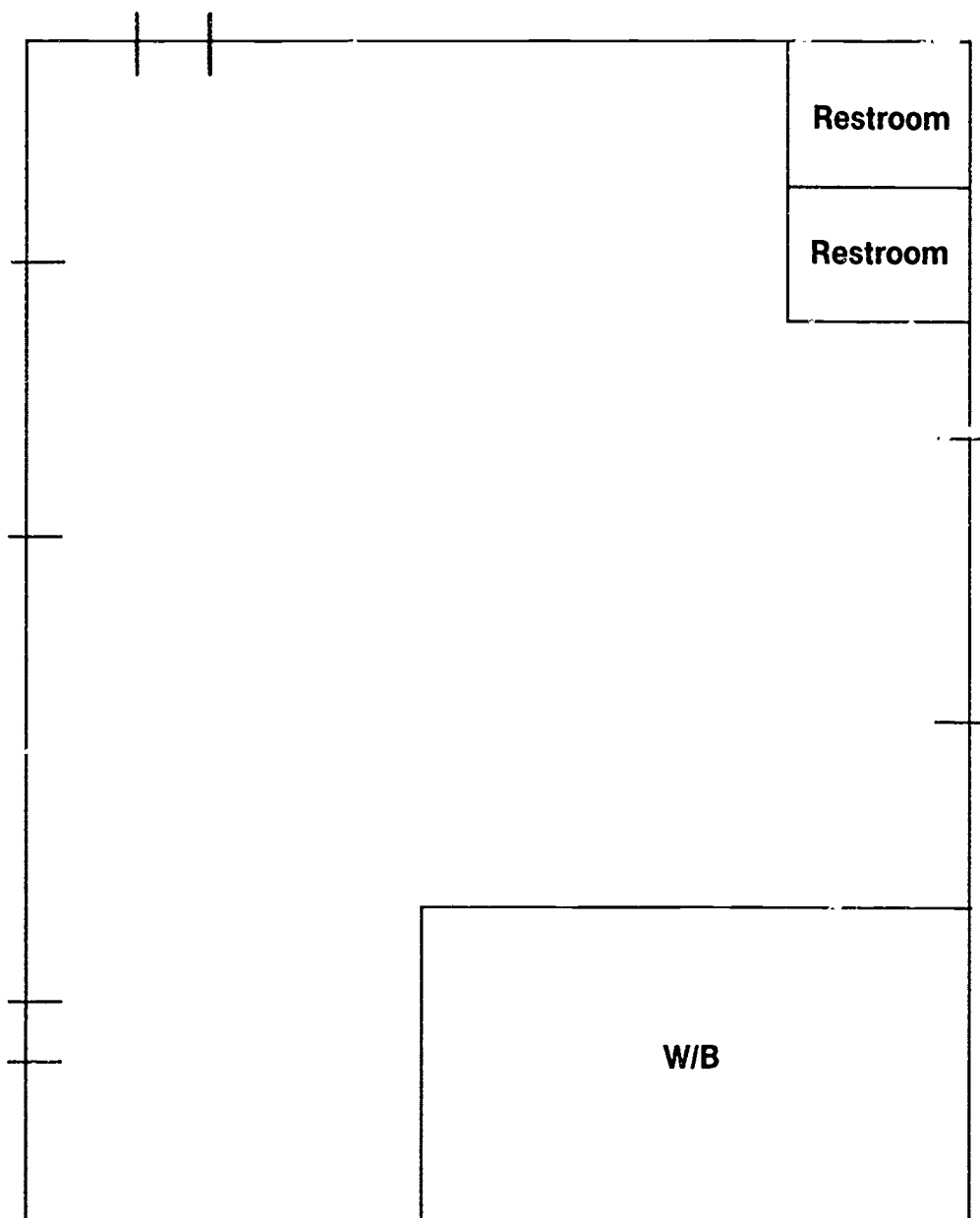
## BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

### ASSIGNMENT SHEET #1 — CONSTRUCT AN ELECTRICAL BLUEPRINT

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions: Using the electrical symbols found in the Information Sheet, construct an electrical drawing of a garage with two restrooms, office, shop area, and wash bay.



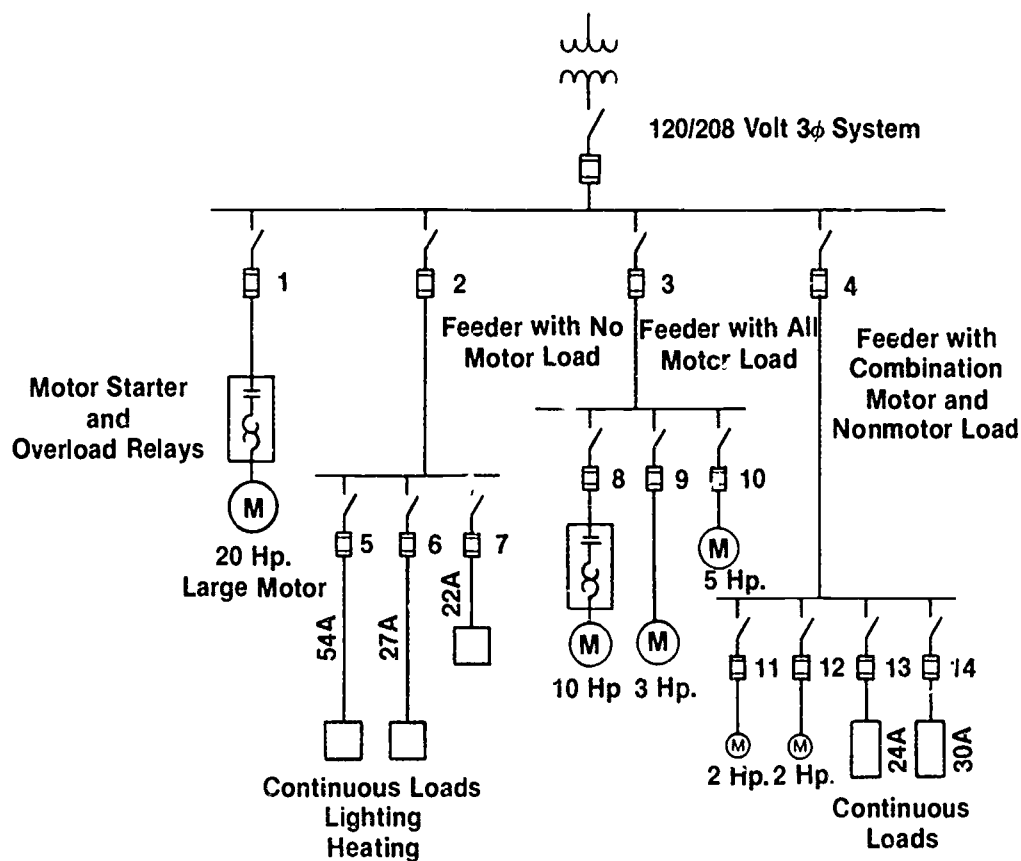
# BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

## ASSIGNMENT SHEET #2 — PERFORM LOAD CALCULATIONS

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions: Using the NEC, calculate the total connected load as well as branch circuit loads on line diagram shown below.



## ASSIGNMENT SHEET #2

- A. Total connected load \_\_\_\_\_ A
- B. Service fuse size \_\_\_\_\_ A
- C. Service entrance conductor size using THW \_\_\_\_\_
- D. Branch circuit conductor size and fuse size

Circuit	Fuse Size	Conductor Size (THHN)
1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____
5	_____	_____
6	_____	_____
7	_____	_____
8	_____	_____
9	_____	_____
10	_____	_____
11	_____	_____
12	_____	_____
13	_____	_____
14	_____	_____



## BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

### ASSIGNMENT SHEET #3 — COMPUTE LIGHTING LOADS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Using the NEC code, compute the following lighting loads.

- A. Bank building with 4500 sq. ft. 120v/230, 1 $\phi$ .

\_\_\_\_\_

- B. Restaurant with dining area 736 sq. ft. 277v/480, 3 $\phi$ .

\_\_\_\_\_

- C. School with a classroom of 860 sq. ft. 120v/240, 3 $\phi$ .

\_\_\_\_\_

- D. Auditorium in a school having 7430 sq. ft. 277v/480, 3 $\phi$ .

\_\_\_\_\_

- E. Barber shop having 450 sq. ft. of floor for cutting hair at 120v/230, 1 $\phi$ .

\_\_\_\_\_

## BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

### ASSIGNMENT SHEET #4 — DERATE NEUTRAL LOADS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Derate the following amperes for the neutral loads for incandescent lighting. Refer to NEC Article 220-22.

EXAMPLE:  $250 \text{ amps} \times .70 = 175 \text{ amps}$

- A. \_\_\_\_\_ 500 amps
- B. \_\_\_\_\_ 400 amps
- C. \_\_\_\_\_ 640 amps
- D. \_\_\_\_\_ 750 amps
- E. \_\_\_\_\_ 385 amps
- F. \_\_\_\_\_ 274 amps
- G. \_\_\_\_\_ 482 amps
- H. \_\_\_\_\_ 550 amps
- I. \_\_\_\_\_ 270 amps
- J. \_\_\_\_\_ 700 amps

## BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

### ASSIGNMENT SHEET #5 — DETERMINE MAXIMUM NUMBERS OF CONDUCTORS IN CONDUIT

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Determine the maximum number of conductors in conduit for the problems below.

- A. Conduit fill for #12 THW wires in a  $\frac{1}{2}$ " conduit

\_\_\_\_\_

- B. Conduit fill for #8 RHW wires in a  $1 \frac{1}{4}$ " conduit

\_\_\_\_\_

- C. Conduit fill for #14 TW wires in a  $2 \frac{1}{2}$ " conduit

\_\_\_\_\_

- D. Conduit fill for #3/0 THW wires in a 3" conduit

\_\_\_\_\_

- E. Conduit fill for #10 THWN wires in a 1" conduit

\_\_\_\_\_

## BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

### ASSIGNMENT SHEET #6 — COMPUTE VOLTAGE DROP

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions: Compute voltage drop for the following problems.

- A. What size AWG THW copper conductors are required for a 240 volt, two-wire lighting feeder with an 80-amp load? The feeder conductor is 115' in one-way length.
- \_\_\_\_\_
- B. What is the voltage drop if a motor draws 22 amperes at 230 volts and the feeder circuit is 150 feet in length?
- \_\_\_\_\_
- C. What is the voltage drop on a 240 volt, single-phase feeder supplying a 125 amp continuous load located 100 feet away?
- \_\_\_\_\_

# BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

## ANSWERS TO ASSIGNMENT SHEETS

**Assignment Sheet #1** — Evaluated to the satisfaction of the instructor

**Assignment Sheet #2**

- A. 338.04 amps
- B. 350 amps
- C. 500 MCM THWcu

D.	Circuit	Fuse Size (Dual Element)	Conductor Size (THHN)
	1	80A	#6
	2	125A	#2
	3	70A	#6
	4	90A	#4
	5	70A	#6
	6	35A	#8
	7	30A	#10
	8	40A	#8
	9	15A	#14
	10	25A	#10
	11	15A	#14
	12	15A	#14
	13	40A	#8
	14	40A	#8

**Assignment Sheet #3**

- A. 168.75 amps
- B. 5.31 amps
- C. 21.5 amps
- D. 26.82 amps
- E. 11.25 amps

**ANSWERS TO ASSIGNMENT SHEETS****Assignment Sheet #4**

- |    |             |    |            |
|----|-------------|----|------------|
| A. | 350 amps    | F. | 176.3 amps |
| B. | 280 amps    | G. | 278.2 amps |
| C. | 355.6 amps  | H. | 311.5 amps |
| D. | 409.5 amps  | I. | 174.9 amps |
| E. | 230.65 amps | J. | 385 amps   |

**Assignment Sheet #5**

- A. 4
- B. 10
- C. 142
- D. 9
- E. 18

**Assignment Sheet #6**

- A. #4
- B. 7.63 volts
- C. 7.2 volts

# BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

## TEST

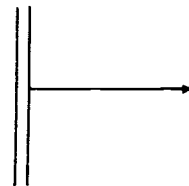
NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

- |         |  |                    |
|---------|--|--------------------|
| _____a. | Set of conventional symbols to depict an object  | 1. Blueprint       |
| _____b. | A reduction in available voltage at the end of a circuit   | 2. Blueprint lines |
| _____c. | The circuit that extends from the last over-current protection device to the outlets   | 3. Branch circuit  |
| _____d. | Copy of the original detailed drawings of a structure  | 4. Feeder circuit  |
| _____e. | All circuit conductors between the service equipment or the source of a separately derived system and final branch circuit over-current device | 5. Specifications  |
| _____f. | A detailed set of written instructions which explains the drawing  | 6. Symbols         |
| _____g. | An arbitrary sign that has been standardized and is used to represent an object, quantity, or method   | 7. Voltage drop    |

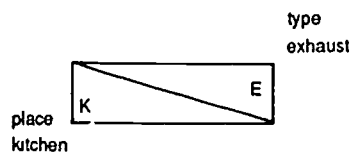
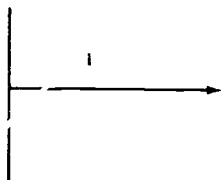
2. Identify the following mechanical symbols.



a. \_\_\_\_\_

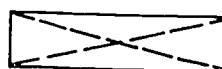
b. \_\_\_\_\_

## TEST



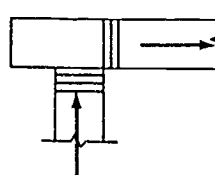
c. \_\_\_\_\_

d. \_\_\_\_\_



e. \_\_\_\_\_

f. \_\_\_\_\_

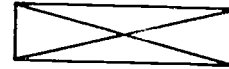
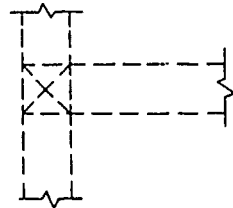


g. \_\_\_\_\_

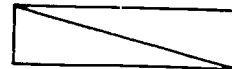
h. \_\_\_\_\_



# TEST



riser to 1st floor



riser to 2nd floor

i. \_\_\_\_\_ j. \_\_\_\_\_

3. Identify the following plumbing symbols.



\_\_\_\_\_



\_\_\_\_\_



\_\_\_\_\_



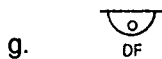
\_\_\_\_\_



\_\_\_\_\_



\_\_\_\_\_



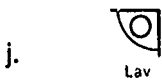
\_\_\_\_\_



\_\_\_\_\_










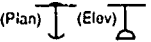



\_\_\_\_\_

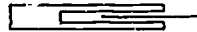
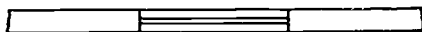


\_\_\_\_\_

## TEST

- k.  \_\_\_\_\_
- l.  \_\_\_\_\_
- m.  \_\_\_\_\_
- n.  \_\_\_\_\_
- o.  \_\_\_\_\_
- p.  \_\_\_\_\_
- q.  \_\_\_\_\_
- r.  \_\_\_\_\_
- s.  \_\_\_\_\_
- t.  \_\_\_\_\_
- u.  \_\_\_\_\_

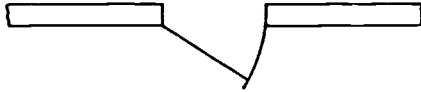
4. Identify the following structural symbols.



a. \_\_\_\_\_

b. \_\_\_\_\_

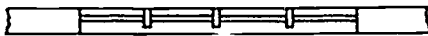
TEST



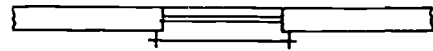
c. \_\_\_\_\_



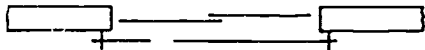
d. \_\_\_\_\_



e. \_\_\_\_\_



f. \_\_\_\_\_



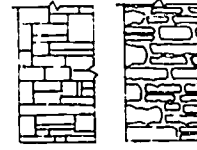
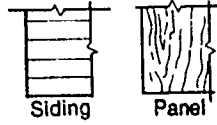
g. \_\_\_\_\_



h. \_\_\_\_\_

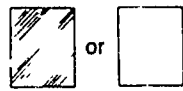
## TEST

5. Identify the following architectural symbols.



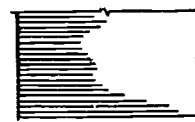
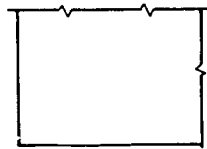
a. \_\_\_\_\_

b. \_\_\_\_\_



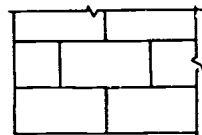
c. \_\_\_\_\_

d. \_\_\_\_\_



e. \_\_\_\_\_

f. \_\_\_\_\_



g. \_\_\_\_\_

h. \_\_\_\_\_


## TEST

6. Identify the electrical symbols below.


a.  $S_3$  \_\_\_\_\_

b.  $S_2$  \_\_\_\_\_

c. \_\_\_\_\_

d.  \_\_\_\_\_

e.  $S_f$  \_\_\_\_\_

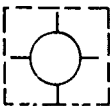
f.  \_\_\_\_\_

g.  $S$  \_\_\_\_\_

h.  $S_p$  \_\_\_\_\_

i.  \_\_\_\_\_

j.  \_\_\_\_\_

k.  \_\_\_\_\_

l.  \_\_\_\_\_







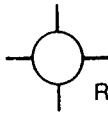



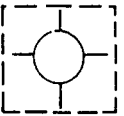


m.  \_\_\_\_\_

n.  $S$  \_\_\_\_\_



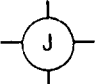
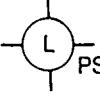





o.  $S_{cb}$  \_\_\_\_\_

p.  $M_s$  \_\_\_\_\_

## TEST











q.		<hr/>
r.		<hr/>
s.		<hr/>
t.		<hr/>
u.	$S_D$	<hr/>
v.	$S_{wp}$	<hr/>
w.		<hr/>
x.		<hr/>
y.		<hr/>
z.		<hr/>
aa.		<hr/>
bb.		<hr/>
cc.		<hr/>
dd.		<hr/>
ee.		<hr/>
ff.	$S_A$	<hr/>

## TEST

gg.		<hr/>
hh.		<hr/>
ii.		<hr/>
jj.		<hr/>
kk.		<hr/>
ll.		<hr/>
mm.		<hr/>
nn.		<hr/>
oo.		<hr/>

## TEST

7. Identify the panel, circuit, and other electrical symbols below.

- a.  \_\_\_\_\_
- b.  \_\_\_\_\_
- c.  \_\_\_\_\_
- d.  \_\_\_\_\_
- e.  \_\_\_\_\_
- f.  \_\_\_\_\_
- g.  \_\_\_\_\_
- h.  \_\_\_\_\_
- i.  \_\_\_\_\_
- j.  \_\_\_\_\_



## TEST

8. Match the names of types of lines on the right with their pictures and descriptions.

- |         |   |                        |
|---------|---|------------------------|
| _____a. | Used to connect a note or dimension to a part of the building   | 1. Object lines        |
| _____b. | Short dashes used to show lines that are not visible from that view   | 2. Center lines        |
| _____c. | Heavy lines consisting of a series of one long and two short dashes with arrows at each end pointing away from the area that is cut away for the purpose of sectioning                        | 3. Leaders             |
| _____d. | Thin unbroken lines which building dimensions are placed upon   | 4. Extension lines     |
| _____e. | Used when an area cannot or should not be drawn entirely  | 5. Section lines       |
| _____f. | A series of lines of various shapes or symbols used to depict an area that is a cross section of the whole object and also depicts the type of material to be used in construction            | 6. Cutting-plane lines |
| _____g. | Extend, but do not touch, the object lines and permit dimension lines to be drawn between them  | 7. Hidden lines        |
| _____h. | A series of short and long dashes used to designate the center of doors, windows, and circles and to provide a reference point for dimensioning   | 8. Dimension lines     |
| _____i. | Show the main outline of the building including exterior walls, interior partitions, porches, patios, driveways, and interior walls; these lines should be the outstanding lines on a drawing | 9. Break lines         |

## TEST

9. List four typical electrical specifications.
- \_\_\_\_\_
  - \_\_\_\_\_
  - \_\_\_\_\_
  - \_\_\_\_\_
10. Complete the following statements concerning minimum requirements for electrical devices by inserting the word(s) or numbers which best complete each statement.
- Rooftop heating, air conditioning, and refrigeration equipment must have a \_\_\_\_\_ volt receptacle within 75 feet of equipment.
  - Show windows must have one receptacle for each \_\_\_\_\_ linear feet.
  - A unit of not less than that specified in NEC Table 220-3(b) for occupancies listed therein shall constitute the minimum lighting load for each \_\_\_\_\_ of floor area.
  - Disconnects are required by code for \_\_\_\_\_ and \_\_\_\_\_.
11. Determine motor-circuit wire sizes by using the NEC.
- 1hp 240 volts 1 $\phi$  \_\_\_\_\_
  - 2hp 240 volts 3 $\phi$  \_\_\_\_\_
  - 3hp 240 volts 3 $\phi$  \_\_\_\_\_
  - 7.5hp 240 volts 3 $\phi$  \_\_\_\_\_
  - 15hp 240 volts 3 $\phi$  \_\_\_\_\_

## TEST

12. Select true statements concerning load calculations by placing an "X" in the blanks preceding the true statements.

- \_\_\_\_a. Feeder size is determined by branch circuit loads to be supplied. It is accepted practice to allow a growth factor of 35%.
- \_\_\_\_b. For 3-wire DC or single phase AC, 4-wire, 3 phase and 5-wire, 2 phase systems, a further demand factor of 70% shall be permitted for that portion of the unbalanced load in excess of 200 amperes. No reduction is permitted on the neutral conductor concerning electric discharge lighting.
- \_\_\_\_c. Loads for branch circuit calculations are classified in two separate groups: general purpose receptacle loads and motor loads.
- \_\_\_\_d. Concerning temperature calculations, no conductor shall be used in such a manner that its operating temperature will exceed that designated for the type of insulated conductor involved.

13. Define demand factor.

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14. Select true statements concerning voltage drop by placing an "X" in the blanks preceding the true statements.

- \_\_\_\_a. If voltage drop is too great, electrical equipment can overheat.
- \_\_\_\_b. Voltage drop must be considered when feeder and branch circuit conductors are selected.
- \_\_\_\_c. The formula for calculating voltage drop is

$$\frac{VD = 2 \times K \times L \times I}{1000}$$

- \_\_\_\_d. The values that may be used when determining voltage drop are:

VD = Voltage drop  
 K = Resistivity of conductor material  
 L = One way length of circuit in feet  
 I = Current in conductor in amperage  
 CM = Conductor area in circular mils  
 1000 = Length of conductors

## TEST

15. Match types of blueprints on the right with their correct descriptions.

- |  |   |
|--|---|
| <p>_____a. Shows location of building in relationship to layout of land and location of utilities and site lighting</p> <p>_____b. Clarify placement of exterior lighting and power outlets</p> <p>_____c. Similar to electrical but shows equipment, wall, and structural support locations</p> <p>_____d. Shows exact locations of switches, outlets, lighting, and special equipment</p> <p>_____e. Clarify specific installation requirements such as j-bolts for site lighting or special equipment mounting devices</p> <p>_____f. Shows structural support characteristics of building which is pertinent when planning</p> | <p>1. Electrical floor plan</p> <p>2. Floor plan</p> <p>3. Foundation plan</p> <p>4. Elevations</p> <p>5. Plot plan</p> <p>6. Details</p> |
|--|---|

16. Construct an electrical blueprint. (Assignment Sheet #1)

17. Perform load calculations. (Assignment Sheet #2)

18. Compute lighting loads. (Assignment Sheet #3)

19. Derate neutral loads. (Assignment Sheet #4)

20. Determine maximum numbers of conductors in conduit. (Assignment Sheet #5)

21. Compute voltage drop. (Assignment Sheet #6)

# BLUEPRINT READING AND LOAD CALCULATIONS UNIT I

## ANSWERS TO TEST

1.
 

a.	2	e.	4
b.	7	f.	5
c.	3	g.	6
d.	1		
  
2.
 

a.	Anchor	f.	Duct section supply
b.	Register	g.	Rainproof ventilator
c.	Louver opening	h.	Fan flexible connection
d.	Duct section notation	i.	Duct connection below joist
e.	Standard ventilator	j.	Duct section exhaust, return
  
3.
 

a.	Shower stall	l.	Hose rack
b.	Water closet	m.	Vacuum outlet
c.	Plain kitchen sink	n.	Cleanout
d.	Meter	o.	Roof sump
e.	Drain	p.	Gas outlet
f.	Water heater	q.	Drinking fountain (pedestal type)
g.	Drinking fountain (wall type)	r.	Urinal (stall type)
h.	Corner bath	s.	Wash sink
i.	Laundry tray	t.	Shower head
j.	Corner lavatory	u.	Garage drain
k.	Hot water tank		
  
4.
 

a.	Single window in frame wall
b.	Plan view of interior pocket door
c.	Plan view of interior hinged door
d.	Plan view of exterior sliding door in wood frame wall
e.	Multiple windows in frame wall
f.	Plan view of double hung window in frame wall
g.	Plan view of exterior door in wood frame wall
h.	Folding door
  
5.
 

a.	Wood
b.	Stone
c.	Glass
d.	Sheet metal flashing
e.	Insulation
f.	Brick
g.	Concrete block
h.	Plaster

## ANSWERS TO TEST

6. a. Three way switch  
 b. Double pole switch  
 c. Low voltage wire  
 d. Horn  
 e. Fused switch  
 f. Fluorescent light  
 g. Single pole switch  
 h. Switch with pilot light  
 i. Bell  
 j. Push button  
 k. Square recessed light (size varies)  
 l. Chime  
 m. Buzzer  
 n. Switch for low voltage system  
 o. Circuit breaker  
 p. Low voltage master switch  
 q. Duplex receptacle outlet  
 r. Round recessed light (size varies)  
 s. Lampholder  
 t. Clock outlet  
 u. Automatic door switch  
 v. Weatherproof switch  
 w. Electric door opener  
 x. Switch leg indicator  
 y. Relay equipped lighting outlet  
 z. Split wired receptacle outlet  
 aa. Weatherproof duplex outlet  
 bb. Special circuit—Must be explained in the key to the symbols  
 cc. Rectangular recessed light (size varies)  
 dd. Fan outlet  
 ee. Lighting outlet  
 ff. Four way switch  
 gg. Single receptacle outlet  
 hh. Computer  
 ii. Junction box  
 jj. Lampholder with pull switch  
 kk. Lighting distribution panel  
 ll. T.V. outlet  
 mm. Master power service panel
7. a. Lighting panel  
 b. Generator  
 c. Controller  
 d. Power transformer  
 e. Feeders  
 f. Switch and fuse  
 g. Motor  
 h. Power panel  
 i. Overcurrent device  
 j. Instrument

## ANSWERS TO TEST

8.    a.    3                    f.    5  
      b.    7                    g.    4  
      c.    6                    h.    2  
      d.    8                    i.    1  
      e.    9
9.    a.    Minimum standards  
      b.    Type of equipment  
      c.    Type of installation  
      d.    Special instructions
10.   a.    125  
      b.    12  
      c.    Square foot  
      d.    Motors, appliances
11.   a.    #12  
      b.    #12  
      c.    #12  
      d.    #10  
      e.    #6
12.   b, d
13.   The ratio of the maximum demand of a system, or part of a system, to the total connected load of a system or the part of the system under consideration
14.   All are correct
15.   a.    5                    d.    1  
      b.    4                    e.    6  
      c.    2                    f.    3
- 16.-21.   Evaluated to the satisfaction of the instructor

## **TOOLS AND EQUIPMENT UNIT II**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to identify and use tools and equipment found in electrical trades. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to tools and equipment with their correct definitions.
2. Identify types of conduit benders.
3. Identify wire termination tools.
4. Identify wire and cable pulling equipment.
5. Identify conduit cutting and threading tools.
6. Identify knockout cutters.
7. List two power actuated tools used in the electrical trade.
8. List two types of excavation equipment.
9. Demonstrate the ability to:
  - a. Bend, cut, ream, and thread 1/2-inch rigid metal conduit. (Job Sheet #1)
  - b. Bend EMT stub-ups. (Job Sheet #2)
  - c. Make back-to-back bends on 1/2-inch EMT. (Job Sheet #3)



## OBJECTIVE SHEET

- d. Make offset bends on 1/2-inch EMT. (Job Sheet #4)
- e. Bend and install 1/2-inch EMT. (Job Sheet #5)
- f. Bend a three-point saddle on 1/2-inch EMT. (Job Sheet #6)
- g. Bend a four-point saddle on 1/2-inch EMT. (Job Sheet #7)
- h. Cut, ream, offset, and install connectors on 1/2-inch PVC. (Job Sheet #8)

## TOOLS AND EQUIPMENT UNIT II

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE. This activity should be completed prior to the teaching of this unit.)

- B. Provide students with objective sheet.
- C. Discuss unit and specific objectives.
- D. Provide students with information sheet.
- E. Discuss information sheet.
- F. Provide students with job sheets.
- G. Discuss and demonstrate the procedures outlined in the job sheets.
- H. Integrate the following activities throughout the teaching of this unit:
1. Have local equipment company demonstrate excavation equipment.
  2. Take tour of factory to look at bends on piping.
  3. Have supply house bring different kinds of tools and equipment to demonstrate.
  4. Review safety rules relating to proper use of equipment.
  5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.
- I. Give test.
- J. Evaluate test.
- K. Reteach if necessary.

## REFERENCES USED IN WRITING THIS UNIT

- A. Greenlee Tool Catalog. Rockford, IL: Greenlee Tool Company, 1985.
- B. Taylor, Mark. *Residential Wiring*. Revised. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1983.
- C. Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

## TOOLS AND EQUIPMENT UNIT II

### INFORMATION SHEET

#### I. Terms and definitions

- A. Backhoe — Machine used for digging ditches on construction sites
- B. Bender — Used for bending pipe used in electrical trades
- C. Cable bender — Used for bending large conductors
- D. Cable cutters — Used in cutting conductors
- E. Cutting tools — Saws used in cutting conduit for electrical insulations
- F. Fish tape — Metal tape used to run through a conduit for the pulling of conductors
- G. Hammer drills — Used to bore through concrete
- H. Jet line — Line sucked through a conduit by vacuum so a rope or tape can be pulled through a conduit
- I. Knockout cutter — Used to cut holes, slots, and cuts in electrical boxes and studs
- J. Pulling equipment — Used for pulling multiple and large conductors through a conduit. These may be manual or electrically operated.
- K. Pulling lube — Wax based product that allows the conductors to pass through the conduit causing less friction
- L. Pulling sleeve — Attaches around the end of conductors so they may be pulled through a conduit
- M. Ram-set gun — Uses charges that shoot studs and tie downs in concrete, metal, and wood
- N. Strippers — Used for removing insulation from conductors
- O. Threading tools — Used to thread pipe so electrical fittings may be attached to conduit
- P. Trencher — Machine used for digging trenches

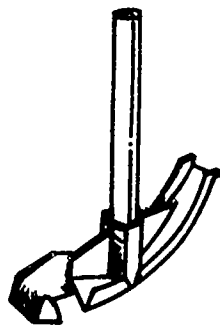
## INFORMATION SHEET

### II. Types of conduit benders

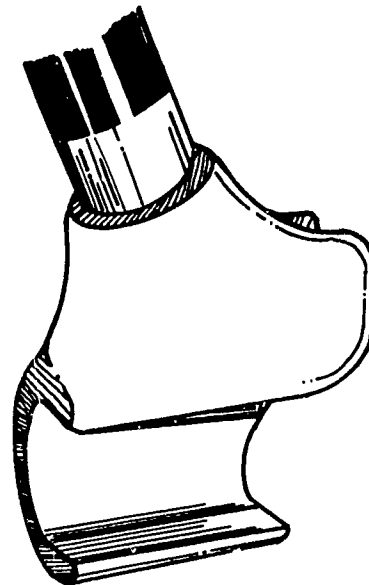
(NOTE: There are four basic types of benders used in the electrical field: manual, hydraulic, mechanical, and PVC.)

#### A. Manual conduit benders

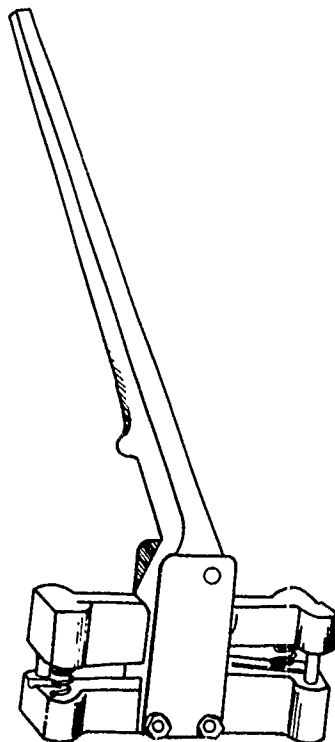
##### 1. Rigid bender



##### 2. Hickey bender



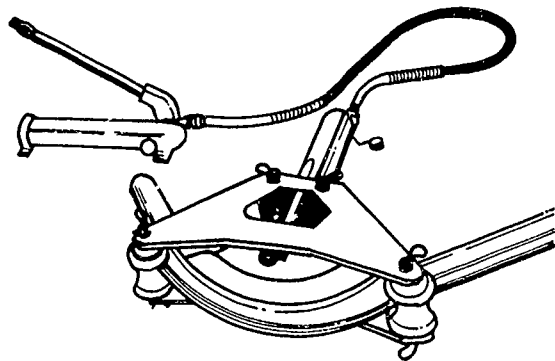
##### 3. One shot offset



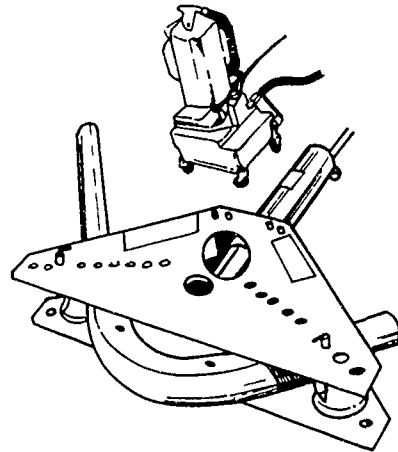
## INFORMATION SHEET

### B. Hydraulic conduit benders

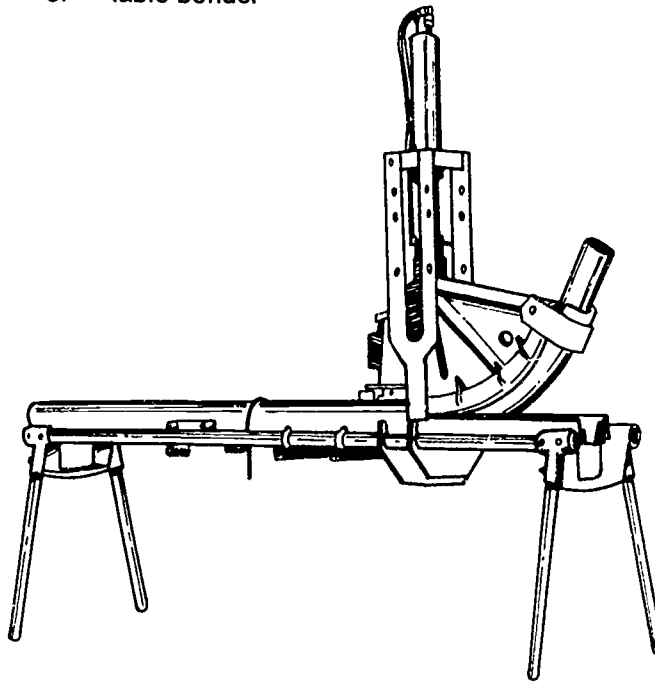
#### 1. Manual hydraulic bender



#### 2. Rigid bender



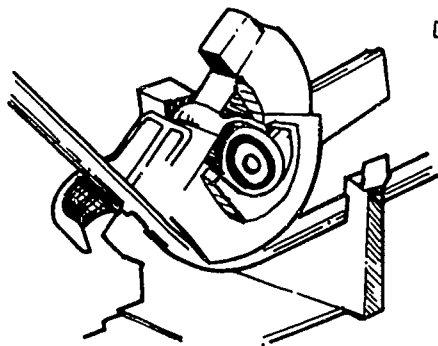
#### 3. Table bender



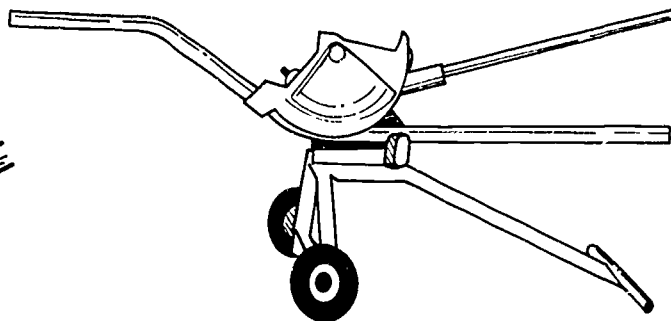
## INFORMATION SHEET

### C. Mechanical conduit benders

#### 1. Rigid bender

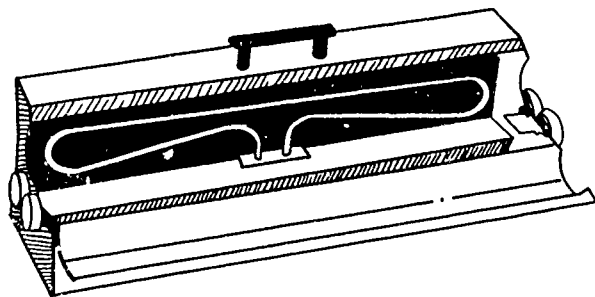


#### 2. EMT bender



### D. PVC bender

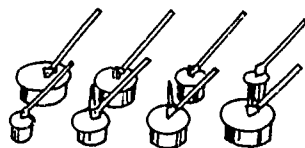
#### 1. Electric PVC heater



#### 2. PVC blanket



#### 3. PVC pipe plugs



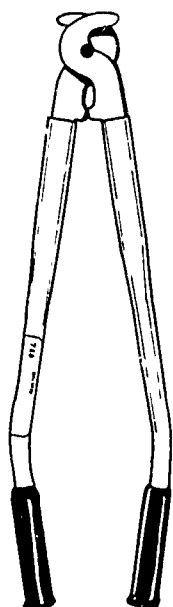
## INFORMATION SHEET

### III. Wire termination tools

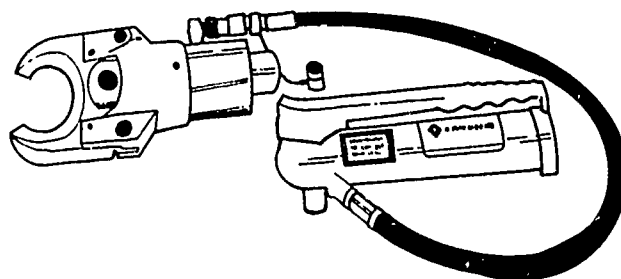
(NOTE: When terminating copper always use copper or copper clad lugs. When using aluminum always use aluminum lugs.)

#### A. Cable cutters

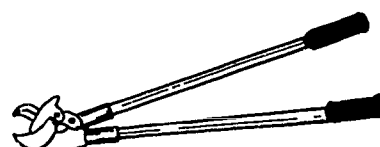
##### 1. Manual cutters



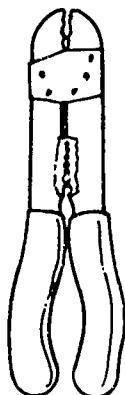
##### 2. Hydraulic cutters



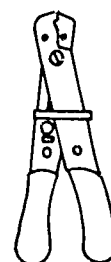
##### 3. Ratchet cutters



#### B. Wire strippers and crimpers



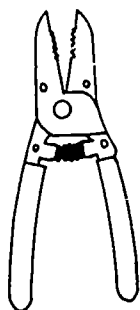
##### 1. Combination tool



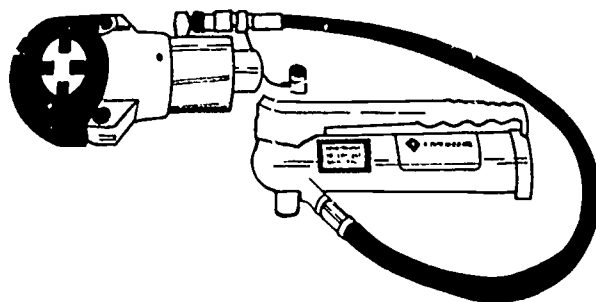
##### 2. Adjustable wire strippers



## INFORMATION SHEET

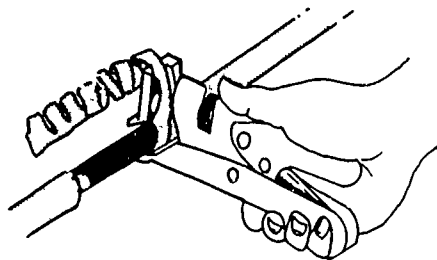


3. Stripper/cutter

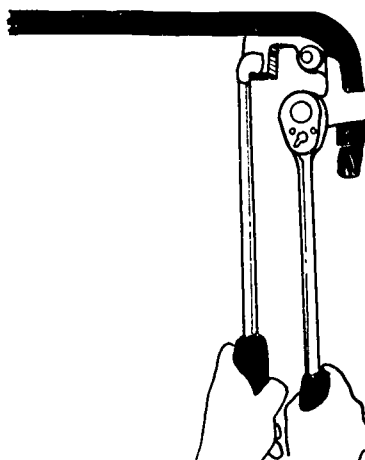


4. Hydraulic crimper

## C. Cable stripper and bender



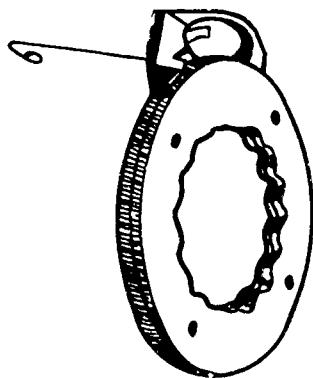
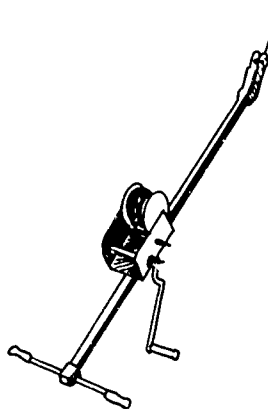
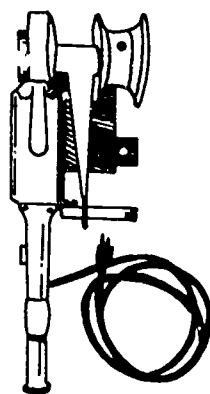
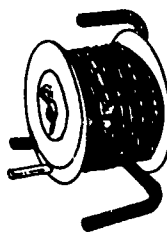
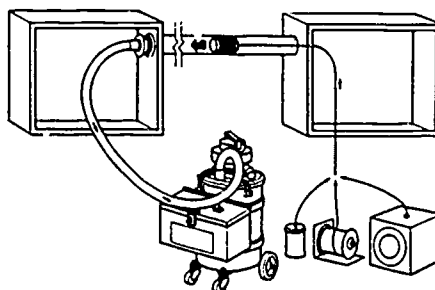
1. Cable stripper



2. Cable bender

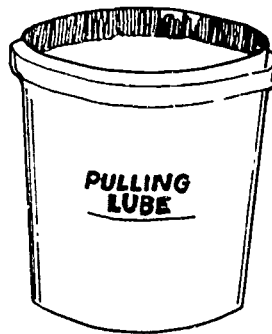
**INFORMATION SHEET****IV. Wire and cable pulling equipment**

(NOTE: Pulling wire and cable through a conduit requires special tools. Tool use will vary depending on the conductor distance, size, and length.)

**A. Fish tape****B. Manual puller****C. Electric puller****D. Pulling rope****E. Pulling sleeve****F. Jet line**

## INFORMATION SHEET

### G. Pulling lube

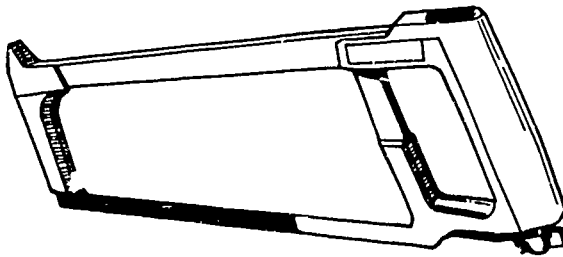


### V. Conduit cutting and threading tools

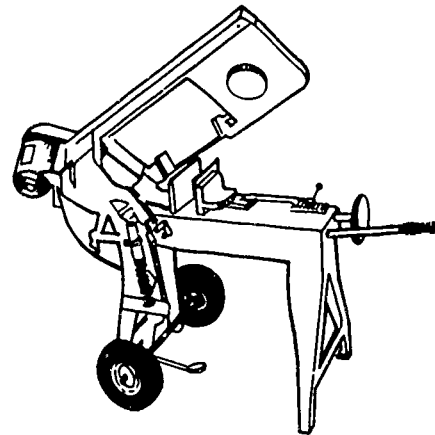
(NOTE: Equipment used in cutting and threading can be dangerous. Use caution when operating.)

#### A. Cutting tools

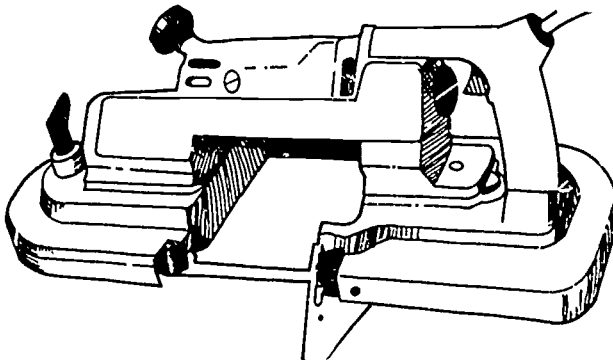
##### 1. Hacksaw



##### 2. Band saw



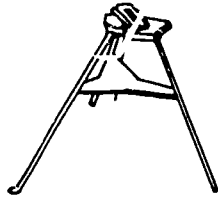
##### 3. Portable band saw



## INFORMATION SHEET

## B. Threading tools

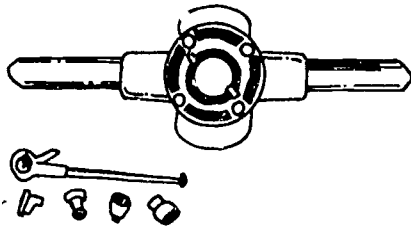
## 1. Pipe stand



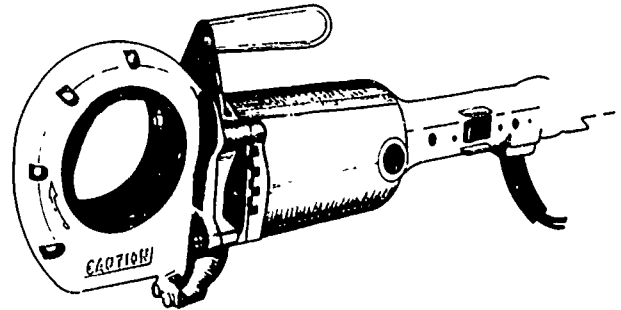
## 2. Electric die set



## 3. Manual die set



## 4. Electric portable threader

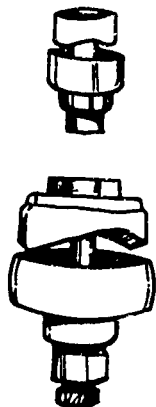


## INFORMATION SHEET

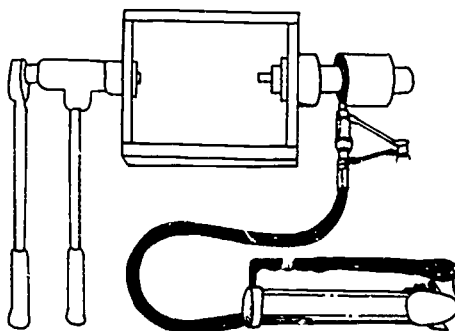
## VI. Knockout cutters

(NOTE: Knockout cutters are used for making holes, slots, and cuts for electrical devices to be installed.)

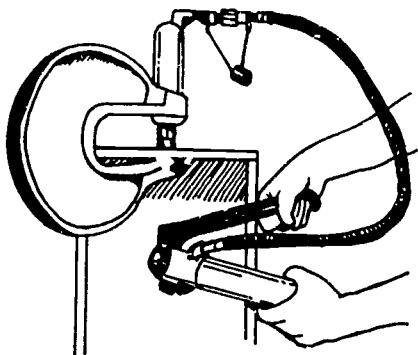
## A. Manual K.O.



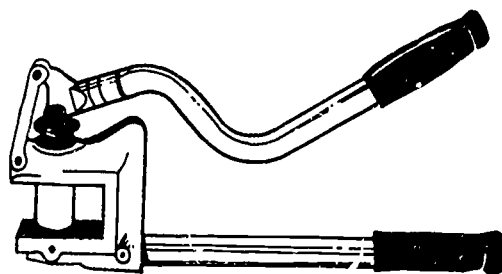
## B. Ratchet K.O. and hydraulic K.O.



## C. C-punch K.O.



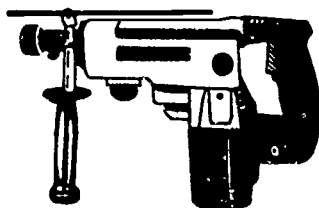
## D. Stud punch



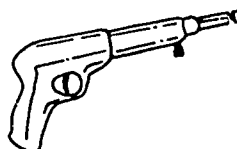
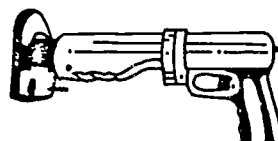
**INFORMATION SHEET****VII. Power actuated tools**

(NOTE: Never use these tools without first taking a safety test and getting approval from the instructor. These tools can be extremely dangerous.)

A. Hammer drill

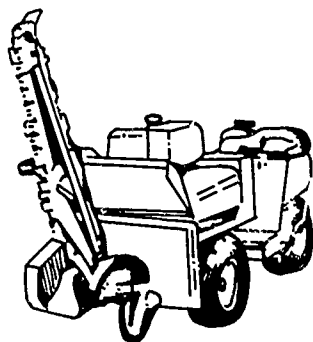


B. Ram-set gun

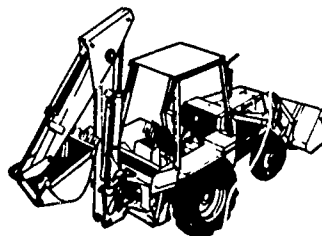
**VIII. Excavation equipment**

(NOTE: Special training must be taken before operating excavation equipment. Always have a locator on site before digging. This prevents cutting of gas, electrical, and telephone lines.)

A. Trencher



B. Backhoe



## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #1 — BEND, CUT, REAM, AND THREAD 1/2-INCH RIGID METAL CONDUIT

#### A. Equipment and materials needed

1. Eye protection
2. Hacksaw
3. 10-foot piece of 1/2-inch rigid metal conduit
4. 3/4-inch EMT bender with handle
5. Reaming tool
6. 1/2-inch conduit pipe die
7. Cutting oil
8. Hickey's pipe vise
9. Measuring tape and marking pencil

#### B. Procedure

1. Put on eye protection.
2. Measure and mark conduit for 18-inch stub-up.  
(NOTE: Check 3/4-inch EMT bender for take up.)
3. Place bender on conduit with "B" on bend mark.
4. Bend conduit, holding *heavy* foot pressure on bender.
5. Use hacksaw to cut off stub-up and 90-degree bend.
6. Place cut off piece of conduit in vice for threading.
7. Ream inside ends of conduit.
8. Thread end of stub, using 1/2-inch conduit pipe die and plenty of cutting oil.
9. Remove die and examine threads.

(NOTE: If die was good and an adequate amount of cutting oil was used, the threads should be smooth with sharp ridges.)

**JOB SHEET #1**

10. If threads are ragged, cut them off and repeat steps 8 and 9.

(NOTE: Show work to instructor for evaluation and commmer.(s.)

11. Clean work area; return equipment and materials to proper storage.



## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #2 — BEND EMT STUB-UPS

#### A. Equipment and materials needed

1. Measuring tape and marking pencil
2. 1/2-inch EMT bender with handle
3. 10-foot piece of 1/2-inch EMT
4. Hacksaw
5. Eye protection

#### B. Procedure

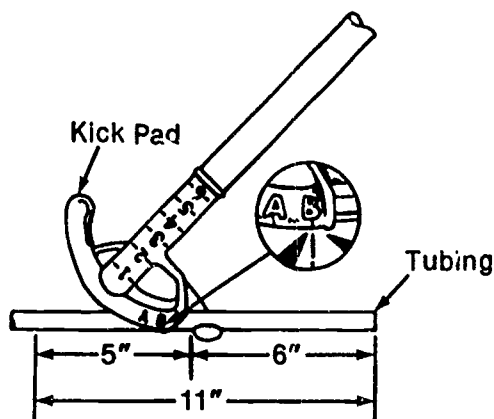
(NOTE: All benders are not marked alike. Check your bender, and use measurements given for it.)

1. Measure and mark tubing 11 inches from end to be bent.
2. Subtract 5 inches from mark made in step 1; mark this measurement.

(NOTE: This measurement varies for each size tubing.)

3. Put on eye protection.
4. Place conduit bender on tubing in position to bend toward end of tubing opposite marked end. (Figure 1)

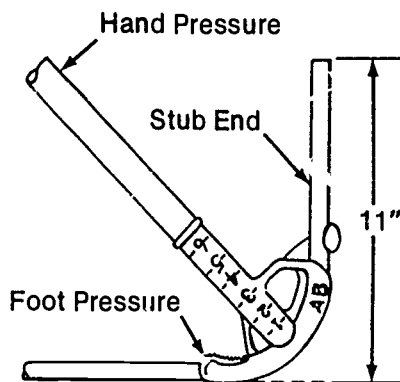
FIGURE 1



## JOB SHEET #2

5. Place bender mark "B" on mark made in step 2. (See Figure 1)
  6. Position tubing and bender on floor with one foot on the bender heel, keeping bender mark "B" on conduit mark.
  7. Place heavy foot pressure on bender kick pad.
  8. Make one sweeping movement of bender handle until tubing is perpendicular to floor.
  9. Before removing bender, measure height of tubing end above floor. (Figure 2)
- (NOTE: If bend is an exact 90 degrees, the end will be 11 inches above the floor.)

FIGURE 2



10. Remove bender.
- (NOTE: Show your work to the instructor for evaluation and comment.)
11. Use hacksaw to cut off bent end of tubing.
  12. Practice procedure by repeating steps 1 through 11 as many times as possible, using up the 10 feet of tubing.
  13. Clean work area; return equipment and materials to proper storage.

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #3 — MAKE BACK-TO-BACK BENDS ON 1/2-INCH EMT

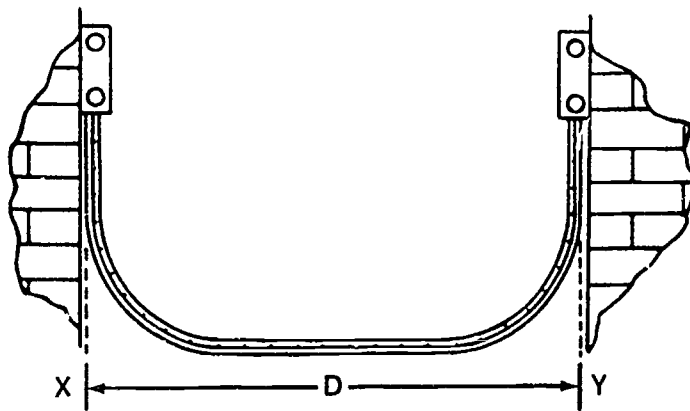
A. Equipment and materials needed

1. 10 feet of 1/2-inch EMT
2. Republic bender, Catalog #1472 or similar
3. Hacksaw
4. Measuring tape and marking pencil
5. Eye protection

B. Procedure

1. Measure 30 inches for distance D shown in Figure 1

FIGURE 1



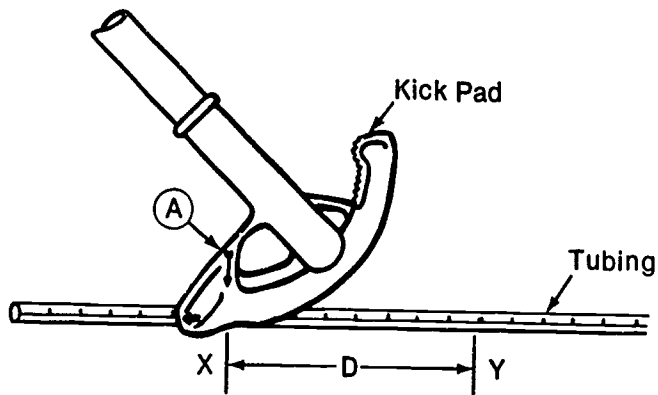
Used with permission of Republic Steel Corporation.

2. Mark tubing at points X and Y (D distance) shown in Figure 1.
3. Put on eye protection.

## JOB SHEET #3

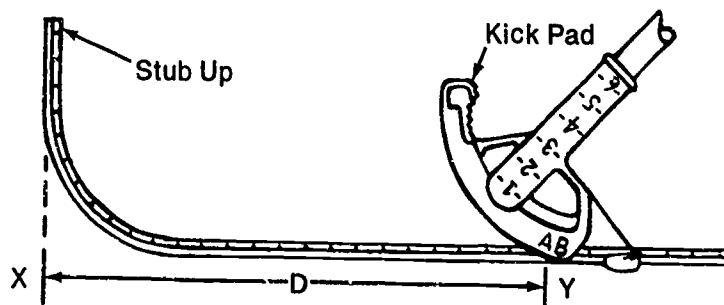
4. Place bender point "A" on tubing at point X as shown in Figure 2.

FIGURE 2



5. Place heavy foot pressure on bender kick pad.
6. Make one sweeping movement with bender handle until tubing is perpendicular to floor.
7. Remove bender.
8. Place bender mark "A" on tubing at point Y in position to bend *toward* point X; make sure that stub-up (made in step 5) points straight up. (Figure 3)

FIGURE 3



Used with permission of Republic Steel Corporation.

**JOB SHEET #3**

9. Repeat steps 5 and 6.
10. Remove bender.
11. Check distance from back to back.

(NOTE: If bender point "A" did not slip and bends are truly 90 degrees, the measurement will be 30 inches, the distance of D.)

(NOTE: Show your work to the instructor for evaluation and comment.)

12. Use hacksaw to cut off bent end of tubing.
13. Practice procedure by repeating steps 1 through 12 as many times as possible, using up the 10 feet of tubing.
14. Clean work area; return equipment and materials to proper storage.

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #4 — MAKE OFFSET BENDS ON 1/2-INCH EMT

#### A. Equipment and materials needed

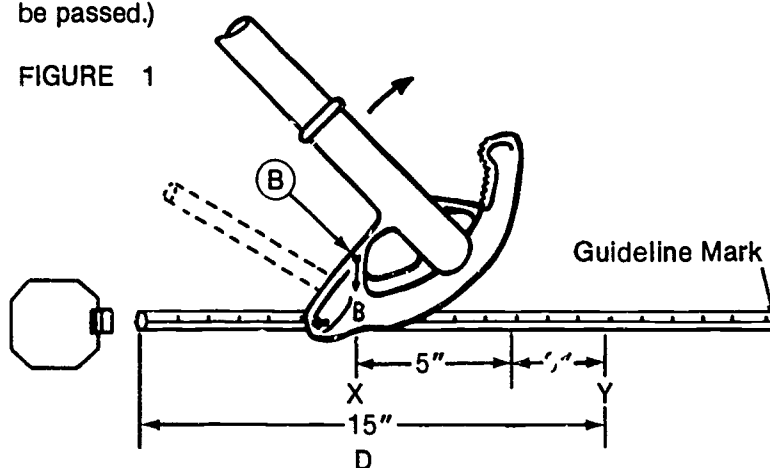
1. 1/2-inch EMT bender
2. 10 feet of 1/2-inch EMT
3. Measuring tape and marking pencil
4. Hacksaw
5. Eye protection

#### B. Procedure

1. Measure 15 inches from end of tubing for distance D shown in Figure 1.

(NOTE: This measurement represents the distance from outlet box to object to be passed.)

FIGURE 1



Used with permission of Republic Steel Corporation.

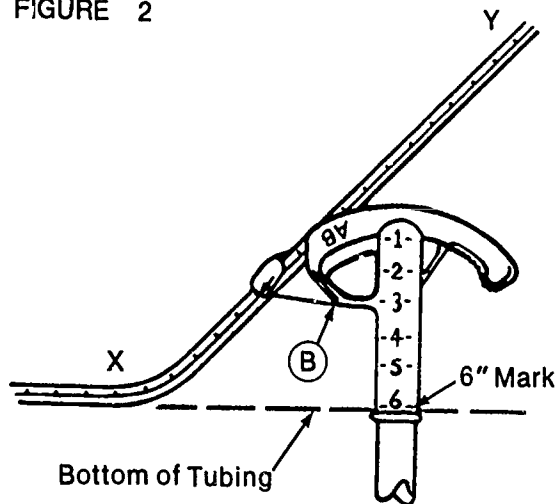
2. Mark the tubing at point Y shown in Figure 1.
3. Measure back 8 inches from point Y, and mark tubing at this measurement to establish point X.

(NOTE: The 8-inch number is determined by taking half the height of the offset and adding 5 inches.)

## JOB SHEET #4

4. Put on eye protection.
5. Place bender point "B" on tubing at point X, with bender in position to bend toward object to be passed.
6. Make 45-degree bend.
7. Remove bender.
8. Reverse the tubing and slip the end of it through holding hook on bender so that the lower part of the 45-degree bend is in line with the 6-inch depth measurement on side of bender as shown in Figure 2; mark tubing at point B.

FIGURE 2



Used with permission of Republic Steel Corporation.

9. Remove bender, and place on tubing with bender point "B" at 6-inch mark.
  10. Make 45-degree bend.
  11. Remove bender.
- (NOTE: This step completes the offset. Show work to instructor for evaluation and comments.)
12. Use hacksaw to cut off offset.
  13. Practice procedure at least five times, making 1-inch, 2-inch, 3-inch, 4-inch, and 5-inch offsets.
  14. Clean work area; return equipment and materials to proper storage.

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #5 — BEND AND INSTALL 1/2-INCH EMT

#### A. Equipment and materials needed

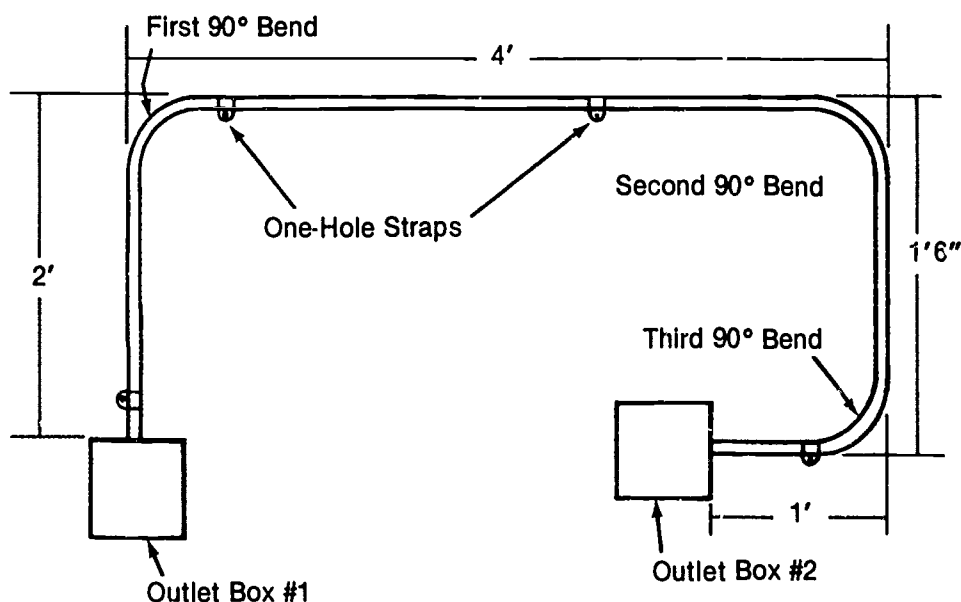
(NOTE: Refer to *NEC*, Articles 300 and 110.)

1. Pouch tools
2. Eye protection
3. Hacksaw
4. 1/2-Inch conduit bender
5. 20 feet of 1/2-Inch EMT
6. Two 4-inch square outlet boxes with mounting screws
7. Space to install 20 feet of tubing with three 90-degree bends and a 4-inch square box at each end
8. Four 1/2-inch one-hole straps, or other supports
9. EMT couplings and connectors, setscrew or raintight

#### B. Procedure

1. Mount the two outlet boxes as shown in Figure 1.

FIGURE 1





**JOB SHEET #5**

2. Open knockout holes only where needed for tubing connectors.
3. Install one EMT connector in each outlet box.
4. Measure distance and tubing for first 90-degree bend shown in Figure 1.
5. Make bend.
6. Measure tubing for second 90-degree bend.
7. Make bend.
8. Install and fasten tubing as shown in Figure 1.  
(NOTE: Refer to NEC Article 348-12 regarding straps.)
9. Measure distance and tubing for third 90-degree bend.
10. Bend tubing and install.  
(NOTE: If necessary, cut tubing to fit spacing. Be sure to wear eye protection when using hacksaw. Show work to instructor for evaluation and comments.)
11. Clean work area; return equipment and materials to proper storage.

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #6 — BEND A THREE-POINT SADDLE ON 1/2-INCH EMT

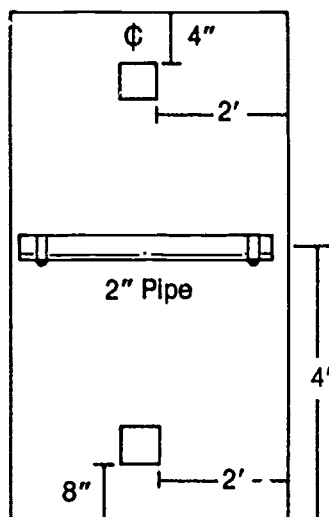
#### A. Equipment and materials needed

1. 1/2" EMT bender
2. 10' — 1/2" EMT
3. Pouch tools
4. 2" O.D. pipe
5. 2" pipe straps
6. 2 — 1900 boxes
7. 2 — 1/2 connectors
8. 2 — 1/2 one hole straps
9. 8 — #10 x 1" SMS
10. Eye protection

#### B. Procedure

1. Put on eye protection.
2. Mount the 2" pipe in the center of a 4' x 8' sheet of plywood, then mount the 2 1900 boxes. (Figure 1)

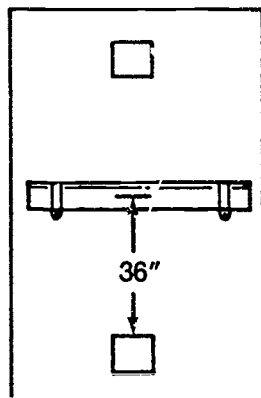
FIGURE 1



## JOB SHEET #6

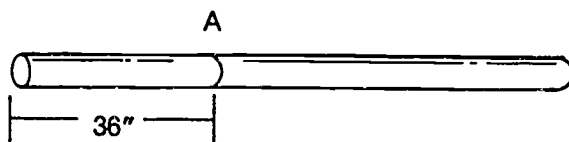
3. Measure from the bottom 1900 box to the center of the obstruction. (Figure 2)

FIGURE 2



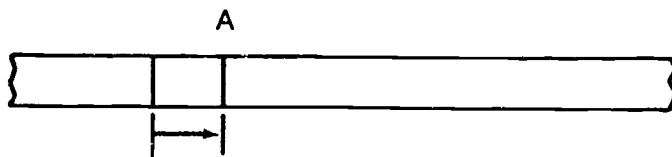
4. Mark this measurement on the 1/2" EMT. (Figure 3)

FIGURE 3



5. Measure the height of the obstruction. Move mark "A" ahead  $\frac{3}{16}$  of an inch for each inch of obstruction height. This becomes the center of the saddle (Figure 4)

FIGURE 4

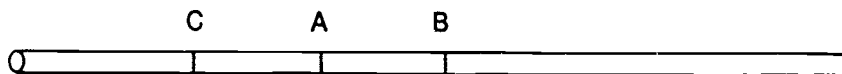


$$\frac{3}{16} \times \frac{2}{1} = \frac{6}{16} = \frac{3}{8}$$

## JOB SHEET #6

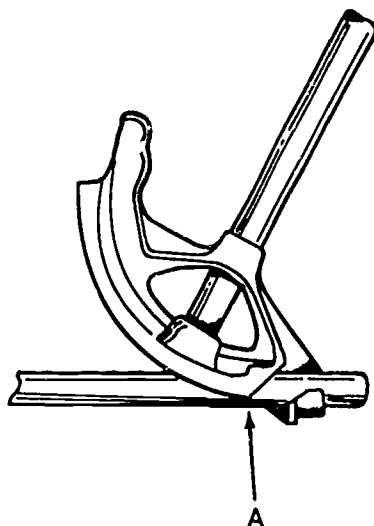
6. For each inch of obstruction height multiply that amount by  $2\frac{1}{2}$ . This will give you distance "L" between mark "A" and "B" and between mark "A" and "C". (NOTE:  $2\frac{1}{2}$  is a constant.) (Figure 5)

FIGURE 5



7. Place the bender rim notch or teardrop on mark "A" and pull to  $45^\circ$ . (Figure 6)

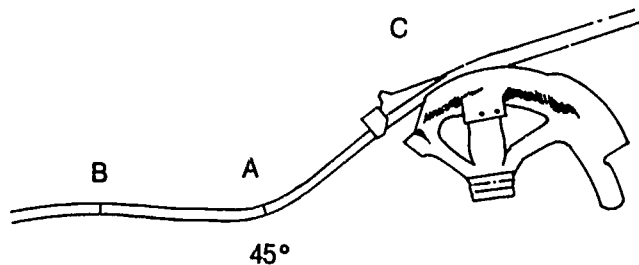
FIGURE 6



## JOB SHEET #6

8. Align mark "B" with the arrow on the bender and pull to  $22\frac{1}{2}^{\circ}$ . Repeat this by marking a  $22\frac{1}{2}^{\circ}$  bend at mark "C" also at the arrow. (Figure 7)

FIGURE 7



9. Install the conduit between the 1900 boxes.
10. Show work to instructor for evaluation and comments.
11. Clean work area and return equipment and materials to proper storage.

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #7 — BEND A FOUR-POINT SADDLE ON 1/2-INCH EMT

**A. Equipment and materials needed**

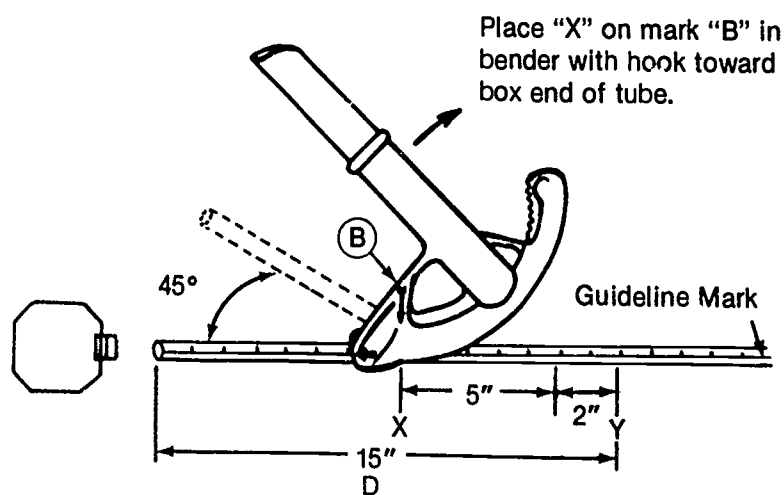
1. 1/2-inch EMT bender
2. 10-foot piece of 1/2-inch EMT
3. Measuring tape
4. 2-by-4 beam to be saddled
5. Eye protection

**B. Procedure**

1. Put on eye protection.
2. Make a 4-inch offset bend. (Figure 1)

(NOTE: Half the height of offset [2 inches] plus 5 inches for 1/2-inch conduit equals 7-inch total.)

FIGURE 1



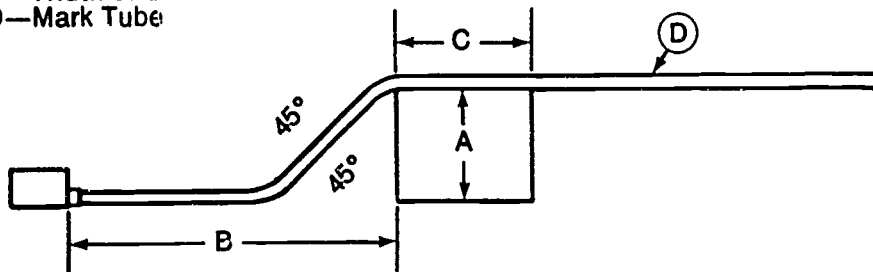
Used with permission of Republic Steel Corporation.

## JOB SHEET #7

3. Lay offset across beam to be saddled, and mark tubing at point D shown in Figure 2

FIGURE 2

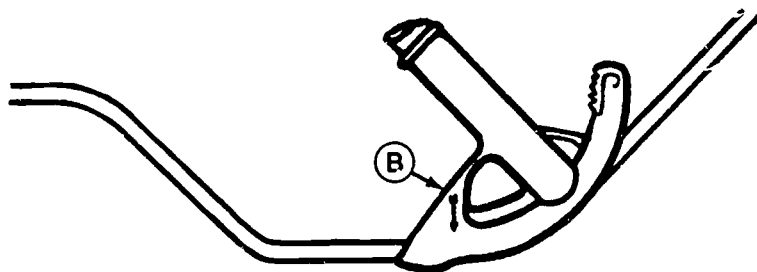
A—Height of Offset  
 B—Distance from Box to Offset  
 C—Width of Beam  
 D—Mark Tube



Used with permission of Republic Steel Corporation.

4. Place tubing in bender, with bender point "B" at mark D, and bender hook toward finished part of offset (Figure 3)

FIGURE 3



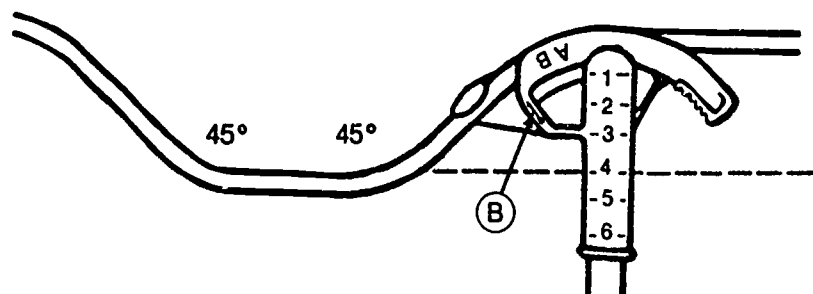
Used with permission of Republic Steel Corporation.

5. Make a 45-degree bend, and remove bender.

## JOB SHEET #7

6. Complete this leg of saddle by sighting along edge of tubing to the 4-inch mark on bender as shown in Figure 4; mark tubing at 4-inch mark.

FIGURE 4



Used with permission of Republic Steel Corporation.

7. Remove bender, and place on tubing with bender point B at 4-inch mark.
8. Make a 45-degree bend, and remove bender.
9. Place saddle over beam.
- (NOTE: Show work to instructor for evaluation and comments.)
10. Clean work area; return equipment and materials to proper storage.



## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #8 — CUT, REAM, OFFSET, AND INSTALL CONNECTORS ON 1/2-INCH PVC

#### A. Equipment and materials needed

1. 10 feet of 1/2-inch PVC
2. Hacksaw
3. Skinning knife or other reaming tool
4. 2 1/2-inch PVC connectors
5. PVC cement
6. Eye protection
7. Measuring tape and marking pencil

#### B. Procedure

1. Put on eye protection.
2. Measure and mark a 24-inch segment of PVC.
3. Cut off 24-inch piece, using hacksaw.  
(NOTE: PVC is soft enough to cut with a wood handsaw without damaging the saw.)
4. Using knife or reaming tool, remove burrs from inside and outside of cut conduit.  
(NOTE: Cleaner must be used if conduit has dirt or oil on it.)
5. Using PVC bender, bend two box offsets and install 1/2" PVC connectors.
6. Install PVC coupling on cleaned piece of PVC.

- a. Apply PVC cement to conduit *only*.

(NOTE: Close PVC cement container immediately after use. When PVC cement is applied to the female end of a splice, the cement is forced back into the conduit interior. When hard, it can damage insulation on wire and make pulling much more difficult.)

- b. Quickly insert conduit into connectors; twist the coupling one-quarter to one-half turn; let set for sixty seconds.

(NOTE: Show work to instructor for evaluation and comments.)

7. Clean work area; return equipment and materials to proper storage.

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #1 PRACTICAL TEST — BEND, CUT, REAM, AND THREAD 1/2-INCH RIGID METAL CONDUIT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Marked conduit 18 inches.  | _____ | _____ |
| 3. Set bender on B mark.  | _____ | _____ |
| 4. Cut off 90° bend.  | _____ | _____ |
| 5. Reamed conduit.  | _____ | _____ |
| 6. Used cutting oil on pipe.  | _____ | _____ |
| 7. Checked for condition of threads.                                | _____ | _____ |
| 8. Threaded both ends of pipe.                                      | _____ | _____ |
| 9. Checked in/put away tools and materials.                         | _____ | _____ |
| 10. Cleaned the work area.  | _____ | _____ |
| 11. Used proper tools correctly.                                    | _____ | _____ |
| 12. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 13. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 14. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Proper cut				
90° bend on pipe				
Thread depth				
Thread length				
Conduit reamed				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: if an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #2 PRACTICAL TEST — BEND EMT STUB-UPS

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Measured 11 inches to bent end.                                  | _____ | _____ |
| 3. Subtracted 5 inches from step 1.                                 | _____ | _____ |
| 4. Placed bender on proper mark and end.                            | _____ | _____ |
| 5. Placed bender on mark B.   | _____ | _____ |
| 6. Put proper foot pressure on bender.                              | _____ | _____ |
| 7. Stub is 11" from floor.  | _____ | _____ |
| 8. Cut pipe square with saw.  | _____ | _____ |
| 9. Reamed pipe outside and inside.                                  | _____ | _____ |
| 10. Checked in/put away tools and materials.                        | _____ | _____ |
| 11. Cleaned the work area.  | _____ | _____ |
| 12. Used proper tools correctly.                                    | _____ | _____ |
| 13. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 14. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 15. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Stub is 11" from floor				
EMT cut square				
Reamed properly				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #3 PRACTICAL TEST — MAKE BACK-TO-BACK BENDS ON 1/2-INCH EMT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Measured pipe 30'.   | _____ | _____ |
| 3. Placed bender at correct points.                                 | _____ | _____ |
| 4. Used proper foot pressure.                                       | _____ | _____ |
| 5. Cut pipe straight.   | _____ | _____ |
| 6. Reamed pipe inside and outside.                                  | _____ | _____ |
| 7. Checked in/put away tools and materials.                         | _____ | _____ |
| 8. Cleaned the work area.   | _____ | _____ |
| 9. Used proper tools correctly.                                     | _____ | _____ |
| 10. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 11. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 12. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Bent to proper dimensions				
Straight cut				
EMT reamed properly				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #4 PRACTICAL TEST — MAKE OFFSET BENDS ON 1/2-INCH EMT

STUDENT'S NAME \_\_\_\_\_ DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_ ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Measured 15 inches from end.	_____	_____
3. Placed bender on correct marks.	_____	_____
4. Made 45° bend.	_____	_____
5. Placed bender on correct mark.	_____	_____
6. Made 45° bend.	_____	_____
7. Checked in/put away tools and materials.	_____	_____
8. Cleaned the work area.	_____	_____
9. Used proper tools correctly.	_____	_____
10. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
11. Practiced safety rules throughout procedure.	_____	_____
12. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_



## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Cut EMT straight				
Reamed EMT				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #5 PRACTICAL TEST — BEND AND INSTALL 1/2-INCH EMT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Mounted boxes properly.  | _____ | _____ |
| 3. Measured pipe.   | _____ | _____ |
| 4. Made 90° bends in pipe.  | _____ | _____ |
| 5. Strapped pipe.   | _____ | _____ |
| 6. Cut pipe square.   | _____ | _____ |
| 7. Reamed outside and inside of pipe.                               | _____ | _____ |
| 8. Installed connectors in bores.                                   | _____ | _____ |
| 9. Tightened connector to pipe.                                     | _____ | _____ |
| 10. Checked in/put away tools and materials.                        | _____ | _____ |
| 11. Cleaned the work area.  | _____ | _____ |
| 12. Used proper tools correctly.                                    | _____ | _____ |
| 13. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 14. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 15. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #5 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Pipe measurement correct				
EMT measurements correct	4	3	2	1
90° bends accurate	4	3	2	1
Tubing fastened securely	4	3	2	1
Workmanship	4	3	2	1
Compliance to NEC	4	3	2	1

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #6 PRACTICAL TEST — BEND A THREE-POINT SADDLE ON 1/2-INCH EMT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

1. Checked out proper tools and materials.
2. Mounted equipment properly.
3. Obtained proper measurements.
4. Marked conduit carefully.
5. Placed bender on correct mark.
6. Checked in/put away tools and materials.
7. Cleaned the work area.
8. Used proper tools correctly.
9. Performed steps in a timely manner (\_\_\_\_hrs. \_\_\_\_min. \_\_\_\_sec.)
10. Practiced safety rules throughout procedure.
11. Provided satisfactory responses to questions asked.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #6 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Conduit saddle proper height				
Center of saddle directly over obstruction				
Bends accurate				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #7 PRACTICAL TEST — BEND A FOUR-POINT SADDLE ON 1/2-INCH EMT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Measured conduit.  | _____ | _____ |
| 3. Placed bender on correct mark.                                   | _____ | _____ |
| 4. Laid across beam and marked tubing.                              | _____ | _____ |
| 5. Placed bender on correct mark.                                   | _____ | _____ |
| 6. Measured conduit.  | _____ | _____ |
| 7. Used correct foot pressure.                                      | _____ | _____ |
| 8. Cut conduit straight.  | _____ | _____ |
| 9. Reamed outside and inside of conduit.                            | _____ | _____ |
| 10. Checked in/put away tools and materials.                        | _____ | _____ |
| 11. Cleaned the work area.  | _____ | _____ |
| 12. Used proper tools correctly.                                    | _____ | _____ |
| 13. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 14. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 15. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #7 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Pipe measurements correct				
	4	3	2	1
Bends match				
Workmanship	4	3	2	1
	4	3	2	1
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TOOLS AND EQUIPMENT UNIT II

### JOB SHEET #8 PRACTICAL TEST — CUT, REAM, OFFSET, AND INSTALL CONNECTORS ON 1/2-INCH PVC

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Cut conduit straight.  | _____ | _____ |
| 3. Reamed conduit.  | _____ | _____ |
| 4. Applied cleaner to pipe.   | _____ | _____ |
| 5. Applied cement to conduit.                                       | _____ | _____ |
| 6. Turned coupling 1/4 turn.  | _____ | _____ |
| 7. Checked in/put away tools and materials.                         | _____ | _____ |
| 8. Cleaned the work area.   | _____ | _____ |
| 9. Used proper tools correctly.                                     | _____ | _____ |
| 10. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 11. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 12. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_



## JOB SHEET #8 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Measured pipe correctly				
Placed bends at correct points				
45° bend				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TOOLS AND EQUIPMENT UNIT II

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

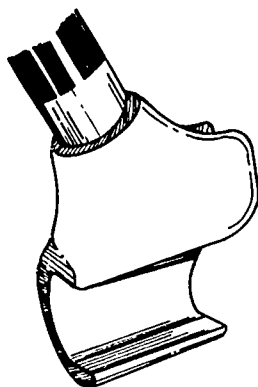
1. Match the terms on the right with their correct definitions.

- |  |                       |
|--|-----------------------|
| _____a. Machine used for digging trenches  | 1. Backhoe            |
| _____b. Machine used for digging ditches on construction sites   | 2. Bender             |
| _____c. Used to bore through concrete  | 3. Cable bender       |
| _____d. Saws used in cutting conduit for electrical insulation   | 4. Cable cutter       |
| _____e. Used for bending large conductors  | 5. Cutting tools      |
| _____f. Used to thread pipe so electrical fittings may be attached to conduit                          | 6. Fish tape          |
| _____g. Used for removing insulation from conductors   | 7. Hammer drill       |
| _____h. Used to cut holes, slots, and cuts in electrical boxes and studs                               | 8. Jet line           |
| _____i. Used for bending pipe used in electrical trades  | 9. Knockout cutter    |
| _____j. Used for pulling multiple and large conductors through a conduit                               | 10. Pulling equipment |
| _____k. Attaches around the end of conductors so they may be pulled through a conduit                  | 11. Pulling lube      |
| _____l. Uses charges that shoot studs and tie downs in concrete, metal, and wood                       | 12. Pulling sleeve    |
| _____m. Wax based product that allows the conductors to pass through the conduit causing less friction | 13. Ram-set gun       |
| _____n. Used in cutting conductors   | 14. Strippers         |
| _____o. Metal tape used to run through a conduit for the pulling of conductors                         | 15. Threading tools   |
| _____p. Line sucked through a conduit by vacuum so a rope or tape can be pulled through a conduit      | 16. Trencher          |

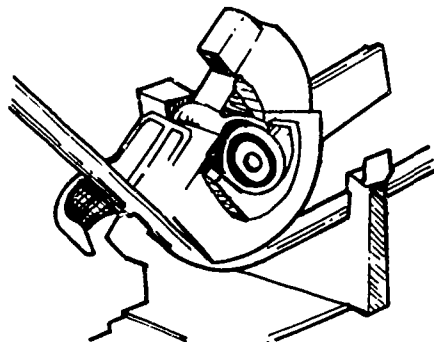
**TEST**

2. Identify the following types of conduit benders.

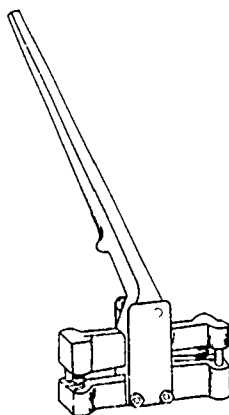
a. Manual conduit benders



1) \_\_\_\_\_



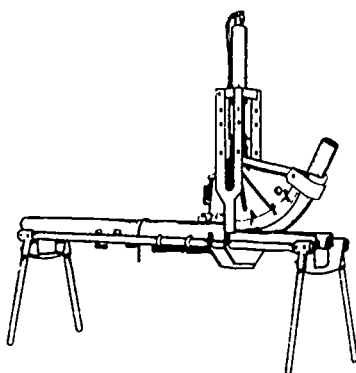
2) \_\_\_\_\_



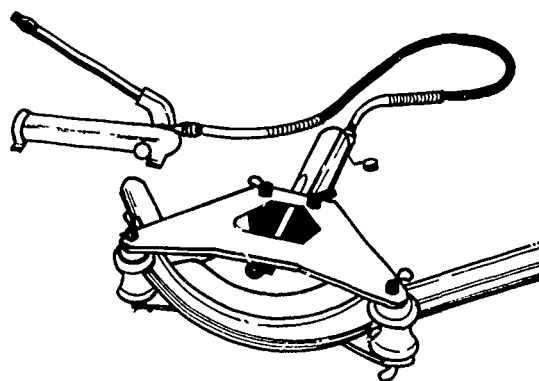
3) \_\_\_\_\_

## TEST

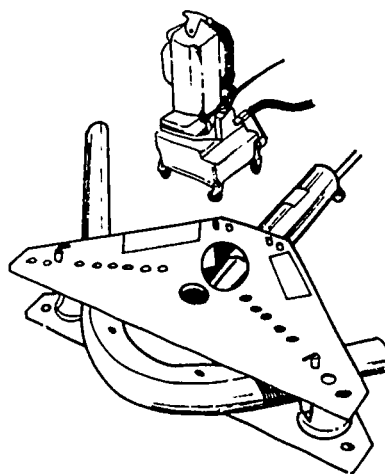
## b. Hydraulic conduit benders



1) \_\_\_\_\_



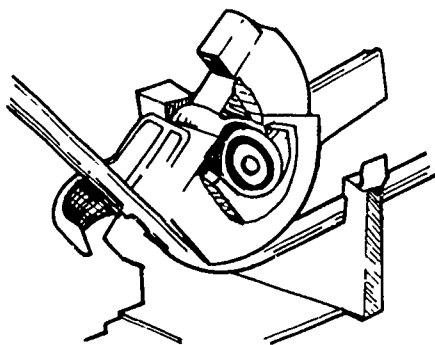
2) \_\_\_\_\_



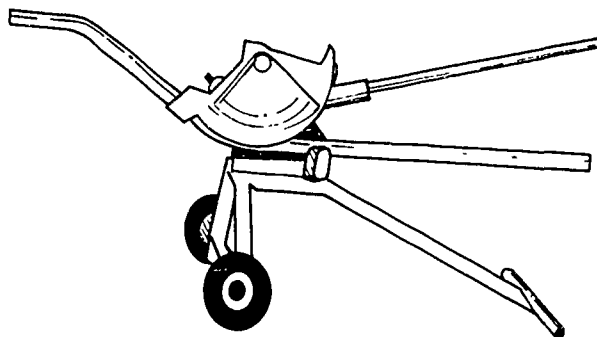
3) \_\_\_\_\_

## TEST

## c. Mechanical conduit benders

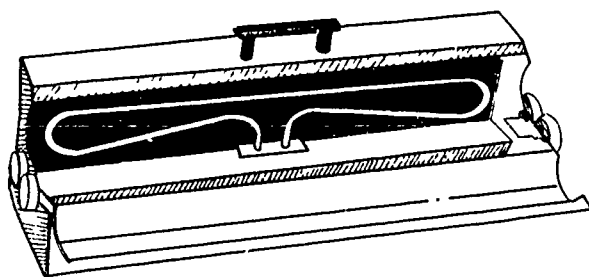


1) \_\_\_\_\_

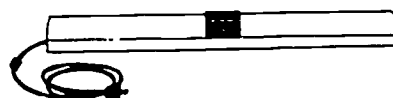


2) \_\_\_\_\_

## d. PVC bender

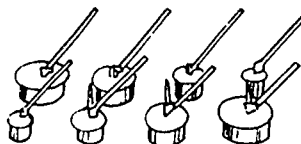


1) \_\_\_\_\_



2) \_\_\_\_\_

## TEST



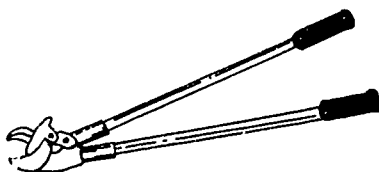
3) \_\_\_\_\_

3. Identify the wire termination tools shown below.

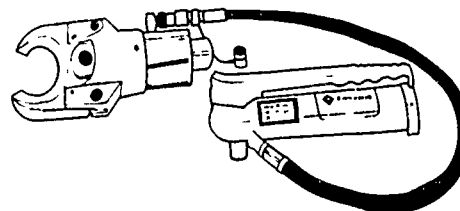
a. Cable cutters



2) \_\_\_\_\_



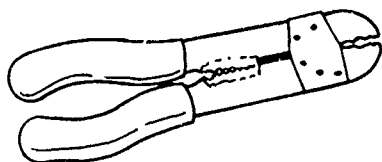
1) \_\_\_\_\_



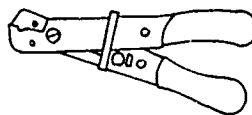
3) \_\_\_\_\_

## TEST

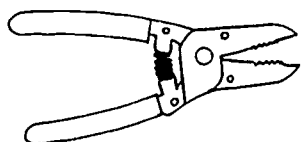
## b. Wire strippers and crimpers



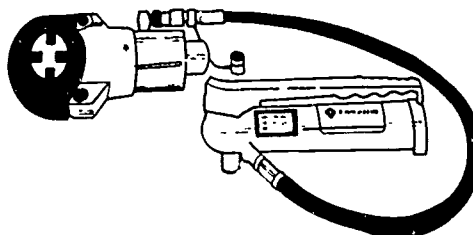
1) \_\_\_\_\_



2) \_\_\_\_\_

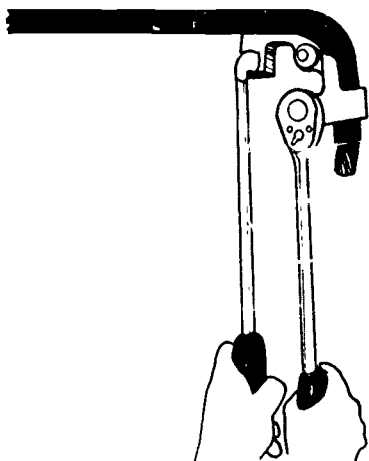


3) \_\_\_\_\_

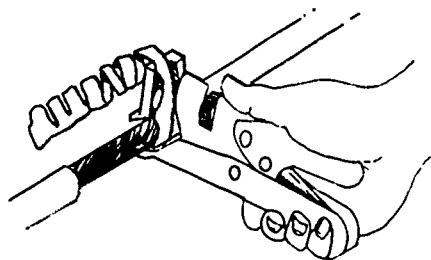


4) \_\_\_\_\_

## c. Cable strippers and benders



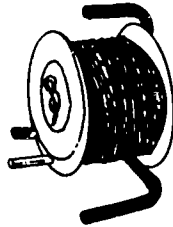
1) \_\_\_\_\_



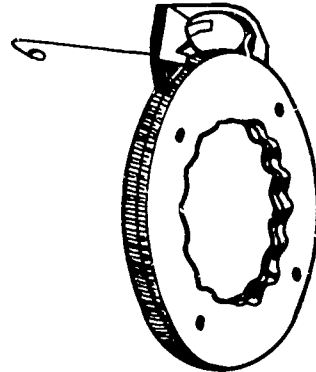
2) \_\_\_\_\_

# TEST

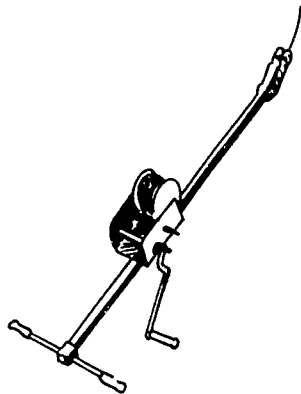
4. Identify the wire and cable pulling equipment shown below.



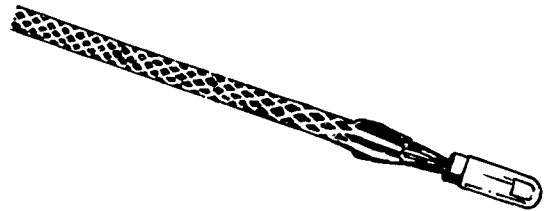
a. \_\_\_\_\_



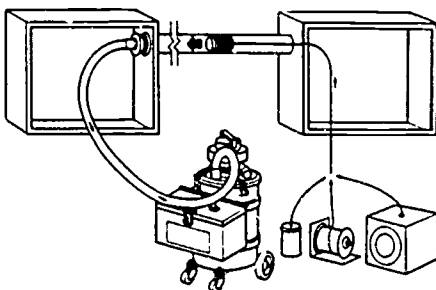
b. \_\_\_\_\_



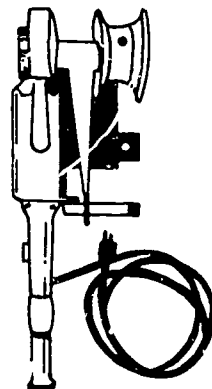
c. \_\_\_\_\_



d. \_\_\_\_\_



e. \_\_\_\_\_



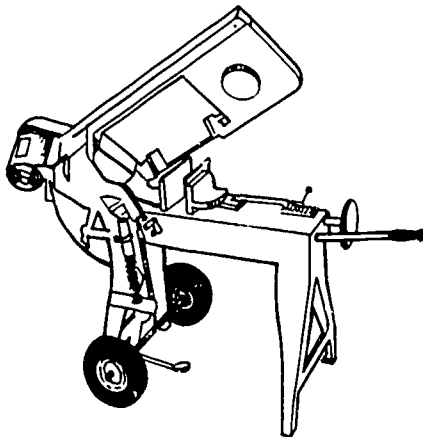
f. \_\_\_\_\_



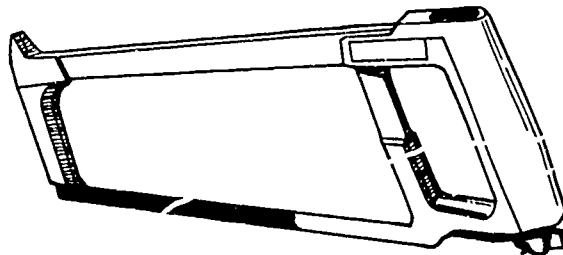
## TEST

5. Identify conduit cutting and threading tools shown below.

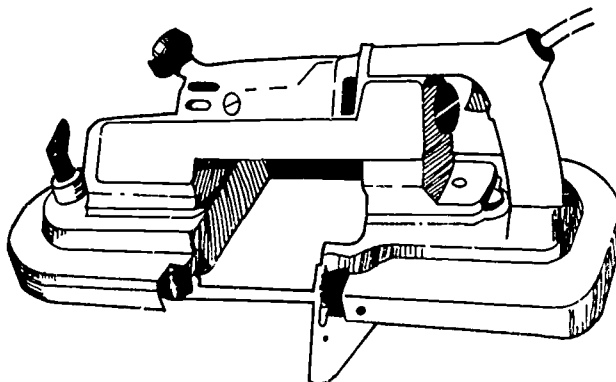
a. Cutting tools



1) \_\_\_\_\_



2) \_\_\_\_\_



3) \_\_\_\_\_

## TEST

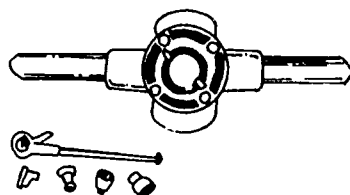
## b. Threading tools



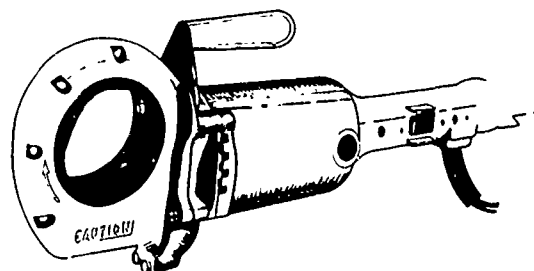
1) \_\_\_\_\_



2) \_\_\_\_\_



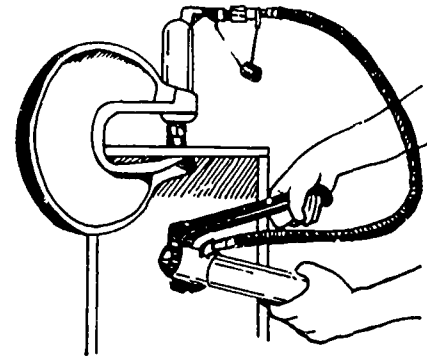
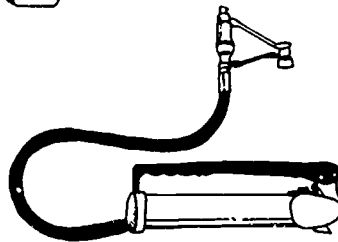
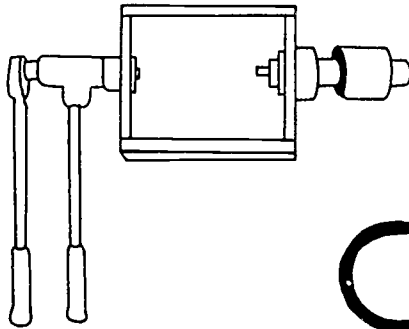
3) \_\_\_\_\_



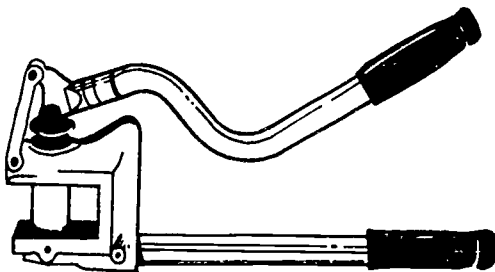
4) \_\_\_\_\_

## TEST

6. Identify the following knockout cutters.



a. \_\_\_\_\_ b. \_\_\_\_\_ c. \_\_\_\_\_



d. \_\_\_\_\_ e. \_\_\_\_\_

**TEST**

7. List two power actuated tools used in the electrical trade.

- a. \_\_\_\_\_
- b. \_\_\_\_\_

8. List two types of excavation equipment.

- a. \_\_\_\_\_
- b. \_\_\_\_\_

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

9. Demonstrate the ability to:

- a. Bend, cut, ream, and thread 1/2-inch rigid metal conduit. (Job Sheet #1)
- b. Bend EMT stub-ups. (Job Sheet #2)
- c. Make back-to-back bends on 1/2-inch EMT. (Job Sheet #3)
- d. Make offset bends on 1/2-inch EMT. (Job Sheet #4)
- e. Bend and install 1/2-inch EMT. (Job Sheet #5)
- f. Bend a three-point saddle on 1/2-inch EMT. (Job Sheet #6)
- g. Bend a four-point saddle on 1/2-inch EMT. (Job Sheet #7)
- h. Cut, ream, offset, and install connectors on 1/2-inch PVC. (Job Sheet #8)

## TOOLS AND EQUIPMENT UNIT II

### ANSWERS TO TEST

1.   a.   16                   e.   3                   i.   2                   m.   11  
     b.   1                   f.   15                  j.   10                  n.   4  
     c.   7                   g.   14               k.   12                  o.   6  
     d.   5                   h.   9                  l.   13                  p.   8
  
2.   a.   1) Hickey bender  
       2) Rigid bender  
       3) One shot offset  
  
     c.   1) Rigid bender  
       2) EMT bender  
  
     b.   1) Table bender  
       2) Manual hydraulic bender  
       3) Rigid bender  
  
     d.   1) Electric PVC heater  
       2) PVC blanket  
       3) PVC pipe plugs
  
3.   a.   1) Ratchet cutters  
       2) Manual cutters  
       3) Hydraulic cutters  
  
     c.   1) Cable bender  
       2) Cable stripper  
  
     b.   1) Combination tool  
       2) Adjustable wire strippers  
       3) Stripper/cutter  
       4) Hydraulic crimper
  
4.   a.   Pulling rope  
     b.   Fish tape  
     c.   Manual puller  
     d.   Pulling sleeve  
  
     e.   Jet line  
     f.   Electric puller
  
5.   a.   1) Band saw  
       2) Hacksaw  
       3) Portable band saw  
  
     b.   1) Pipe stand  
       2) Electric die set  
       3) Manual die set  
       4) Electric portable threader
  
6.   a.   Ratchet K.O.  
     b.   Hydraulic K.O.  
     c.   C-punch K.O.  
  
     d.   Stud punch  
     e.   Manual K.O.
  
7.   a.   Hammer drill  
     b.   Ram-set gun
  
8.   a.   Trencher  
     b.   Backhoe
  
9.   Performance skills evaluated to the satisfaction of the instructor.

## **SERVICE UNIT III**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to install 100 amp service and determine switch gear, service entrance, drop clearances, laterals, and emergency standby systems. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to service with their correct definitions.
2. Complete statements concerning NEC requirements for drop clearance and laterals.
3. Select true statements concerning switch gears and disconnects.
4. Match NEC exceptions for overcurrent protection devices with their correct statements.
5. Complete statements concerning grounding electrodes and ground fault.
6. Select true statements concerning service entrance devices.
7. Complete statements concerning emergency and standby systems.
8. State the procedure for balancing loads.
9. Demonstrate the ability to:
  - a. Install an overhead raceway with service entrance conductors to a meter base. (Job Sheet #1)
  - b. Connect meter base assembly to load center or panel. (Job Sheet #2)

## SERVICE UNIT III

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Make transparencies from the transparency masters included in this unit.
- C. Provide students with objective sheet.
- D. Discuss unit and specific objectives.
- E. Provide students with information sheet.
- F. Discuss information sheet.

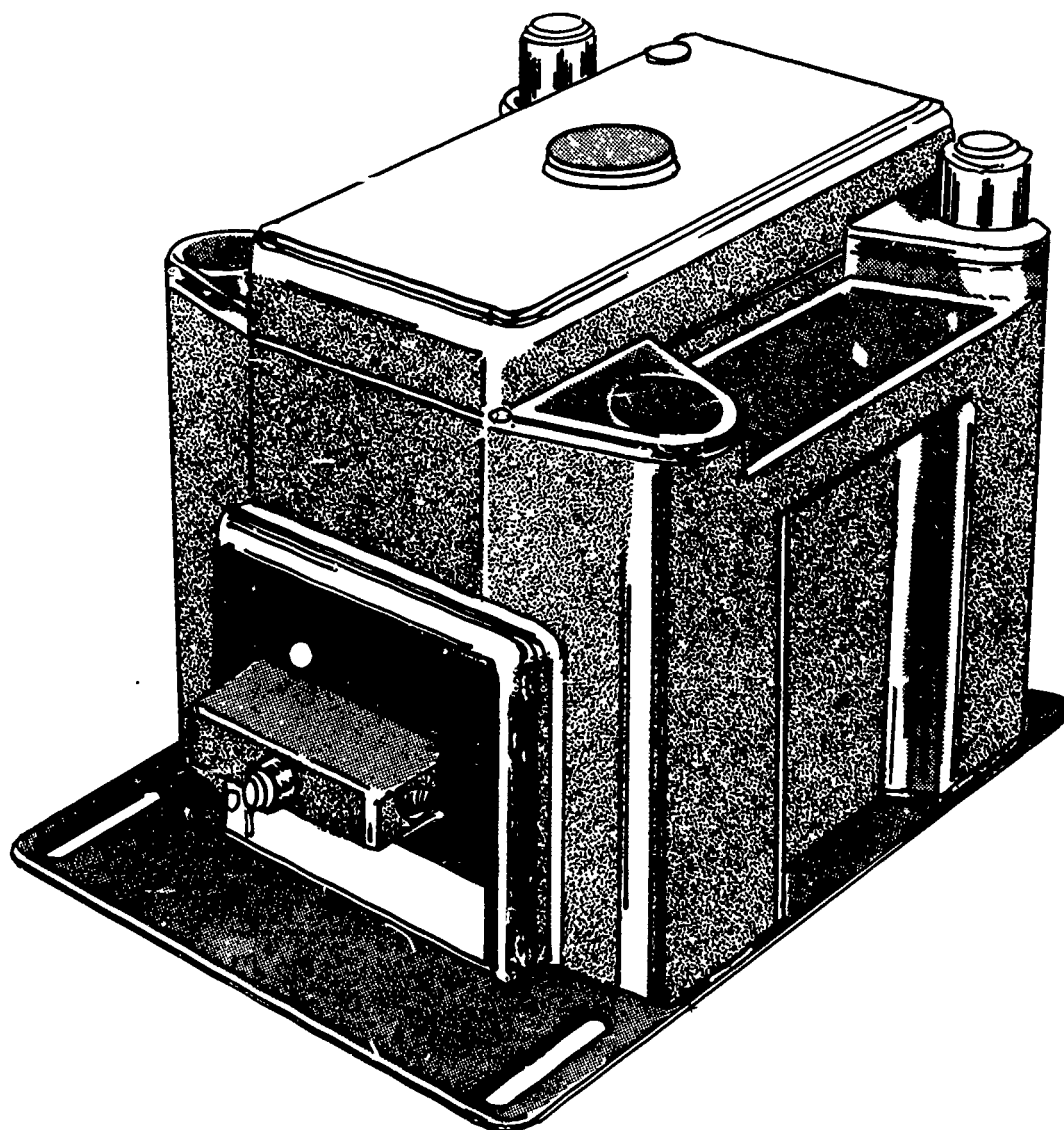
(NOTE: Use the transparencies to enhance the information as needed.)

- G. Provide students with job sheets.
- H. Discuss and demonstrate the procedures outlined in the job sheets.
- I. Integrate the following activities throughout the teaching of this unit:
1. Invite a local power company representative to discuss the uses of emergency and stand by equipment and NEC regulations dealing with services.
  2. Take students on a field trip to a power company.
  3. Have a supply house representative demonstrate the different devices for services.
  4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.
- J. Give test.
- K. Evaluate test.
- L. Reteach if necessary.

### REFERENCES USED IN WRITING THIS UNIT

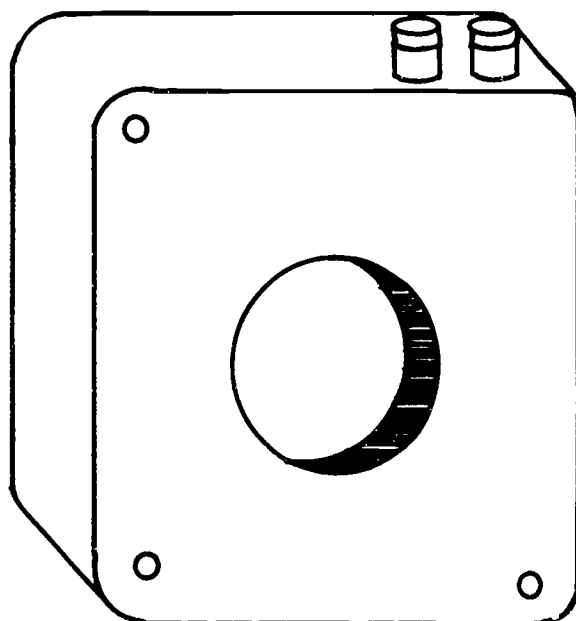
- A. *National Electrical Code, 1987*. Quincy, MA: National Fire Protection Association, 1986.
- B. Stallcup, James C. *Designing Electrical Systems*. Alsip, IL: American Technical Publishers, Inc., 1984.

# Potential Transformer

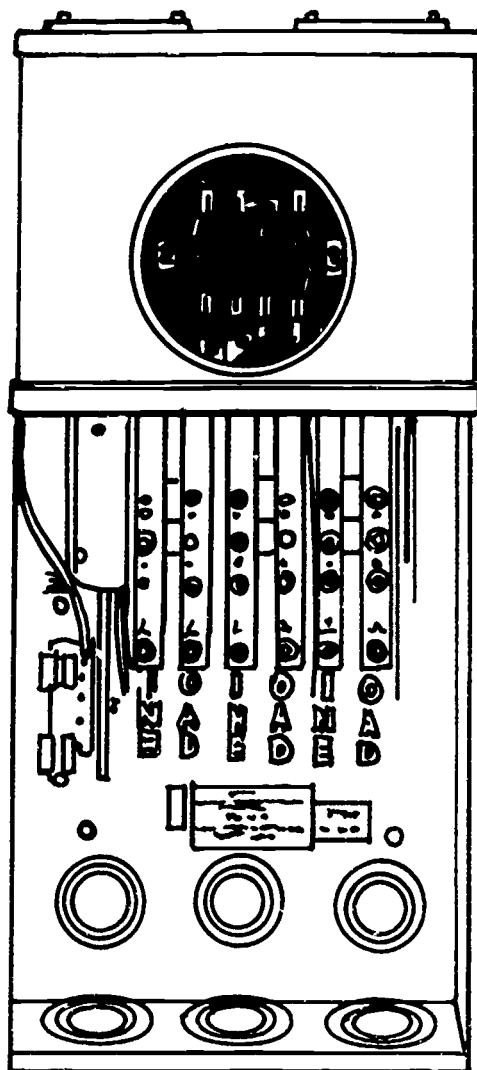




# Current Transformer



# Three-Phase Meter Base Assembly



16i

## SERVICE UNIT III

### INFORMATION SHEET

#### I. Terms and definitions

- A. CT — Current transformer
- B. Disconnects — Devices used for breaking a circuit which may be fused or unfused
- C. Equipment grounding conductor — Conductor used to connect non-current-carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor
- D. Ground — To connect electrical equipment either intentionally or accidentally to the earth or to some conducting body that serves as the earth
- E. Grounded — Connected to earth or to some conducting body that serves in place of the earth
- F. Grounded conductor — System or circuit conductor that is intentionally grounded
- G. Grounding-electrode conductor — Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source of separately derived system
- H. PT — Potential transformer
- I. Service — Where power is metered or is first attached to the structure
- J. Service drop — Power conductors coming into building from power company
- K. Service panel — Main control panel where voltage and current are distributed to different locations

(NOTE: This may also be referred to as a distribution panel or panelboard.)

- L. Switch gear — Devices used for disconnecting power on electrical circuits

#### II. NEC requirements for drop clearance and laterals

- A. There are two types of services used in the electrical trade: overhead and underground (lateral). Overhead services have different code requirements than underground.
- B. Overhead services must be of specific size and have a minimum clearance from finished grade.

## INFORMATION SHEET

- C. The smallest conductors that can be used on a service are #8 copper or #6 aluminum. In special cases #12 hard-drawn copper may be used on branch or small equipment.

(NOTE: Refer to NEC Article 230-23.)

- D. Clearances for service drops must comply with the NEC. Service drop conductors passing over a roof must be at least 8 feet above the roof.

(NOTE: Refer to NEC Article 230-24.)

- E. There are two NEC exceptions which pertain to service drops.

1. Exception #1 allows service drops to pass 3 feet above the roof when the roof has a slope of 4 inches in 12 inches and the voltage is not in excess of 300 volts. When voltage is in excess of 300 volts, an 8 feet clearance must be used.

(NOTE: Refer to NEC Article 230-24.)

2. Exception #2 allows the service drop to be attached to the service mast when the drop does not pass over 4 feet of roof and the mast is at least 18 inches above the roof line.

- F. Service drop conductors rated at 600v or less have minimum clearances.

(NOTE: Refer to NEC Article 230-24[b].)

- G. An underground service lateral must have a conductor size of at least #8 copper or #6 aluminum.

(NOTE: Refer to NEC Article 230-31.)

### III. Switch gears and disconnects

- A. A switch gear is used for breaking the current or voltage from the meter base to the means of disconnection before being allowed to enter branch circuits.

- B. Service disconnects are readily accessible for breaking the power entering a building. More than one disconnect may be used on a service.

(NOTE: Refer to NEC Articles 230-71 and 230-72.)

- C. All service disconnects have overload protection. The disconnect must be large enough to carry the computed load it supplies.

(NOTE: Refer to NEC Article 230-79.)

## INFORMATION SHEET

### IV. NEC exceptions for overcurrent protection devices

(NOTE: Overcurrent protection devices must not be greater than the load carrying capacity of the service entrance conductors. There are four exceptions to NEC Article 230-90 for overcurrent protection for services.)

- A. Exception 1 — An overcurrent protection device may be overfused to allow motors to attain running speed
- B. Exception 2 — If not a standard size, the next higher standard size overcurrent protection device is used
- C. Exception 3 — Two to six CBs or fuses may serve as overcurrent protection devices
- D. Exception 4 — An overcurrent protection device must be rated to carry locked-rotor current of fire pump motors

### V. Grounding electrodes and ground fault

- A. There are four types of electrode grounding systems used in electrical trades.

(NOTE: Refer to NEC Article 250-81.)

- 1. Metal water pipe
- 2. Building steel
- 3. Reinforcing rod (20 feet minimum length)
- 4. Ground ring

- B. A ground is required if the power company's transformer is grounded.

(NOTE: Refer to NEC Article 250-23[b].)

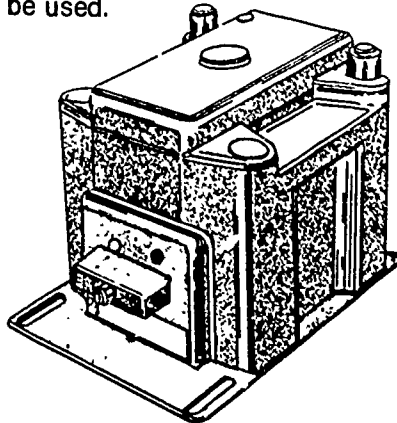
### VI. Service entrance devices

- A. Conductor sizes of 1/0 or larger comprising each phase to neutral will be permitted to be connected in parallel. This means two conductor are used as one.

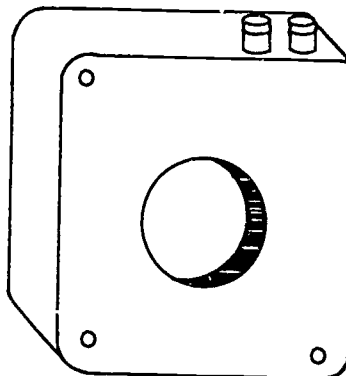
(NOTE: Refer to NEC Article 310-4.)

## INFORMATION SHEET

- B. A potential transformer steps the voltage down so voltage measuring devices may be used.



- C. A current transformer is a doughnut type device used in measuring current. An amprobe clamp-on ammeter is a current transformer. These are used in metering large services.



### VII. Emergency and standby systems

(NOTE: Refer to NEC Article 700.)

- A. Separate, derived systems such as a generator or battery backup are used when the incoming voltage from the power company is interrupted or cut off. These systems are used in hospitals, factories, and stores where electricity is a must.
- B. An automatic transfer switch senses a voltage loss and automatically switches a system to emergency power.

- viii. **Balancing loads** — When balancing loads on panels, transformers, and switching equipment, an amprobe should be used to determine amperage on each circuit. The sum of the loads on each phase should be close to equal value.

## SERVICE UNIT III

### JOB SHEET #1 — INSTALL AN OVERHEAD RACEWAY WITH SERVICE ENTRANCE CONDUCTORS TO A METER BASE

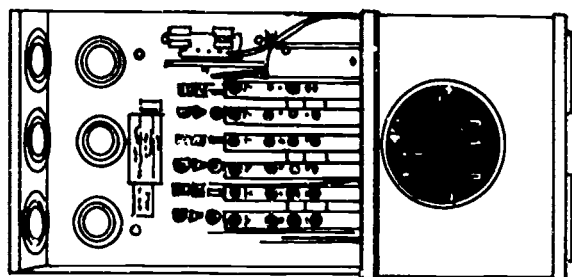
#### A. Equipment and materials needed

1. Flat blade screwdriver
2. Lineman's pliers
3. Hammer
4. Knife
5. Hacksaw
6. Folding rule with sliding scale
7. 3 $\phi$  meter base
8. Service entrance cap (1 1/2" clamp-on type)
9. 3' of 1 1/2" rigid metal conduit (threaded on one end,
10. 12' of #2 copper TW (two 6' pieces)
11. 6' of #4 copper
12. Safety glasses

#### B. Procedure

1. Gather equipment and materials.
2. Screw threaded end of raceway into hub. (Figure 1)

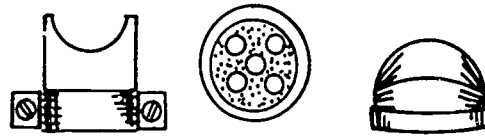
FIGURE 1



## JOB SHEET #1

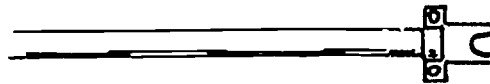
3. Remove cover and separator from weatherhead. (Figure 2)

FIGURE 2



4. Clamp weatherhead base onto the end of the service raceway. (Figure 3)

FIGURE 3



5. Install conductors in the raceway.

(NOTE: Start at weatherhead end.)

6. Connect grounded conductor to grounding lug.

(NOTE: When possible leave grounded conductor long enough to connect to disconnect equipment grounding bar.)

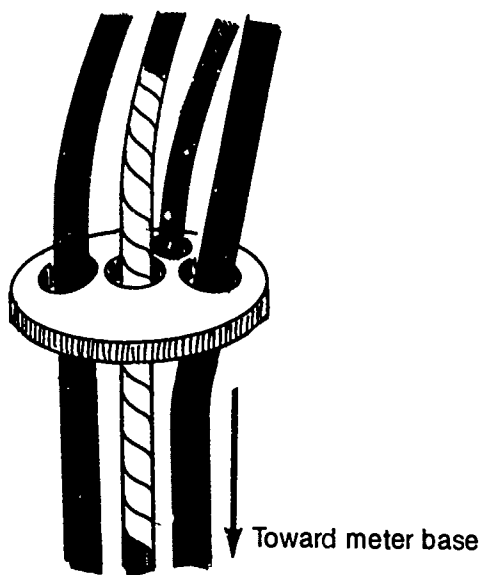
7. Remove 1" to 1 1/2" of insulation from ungrounded conductors and connect to line lugs.
8. Knock out four outlined holes in the entrance cap separator.
9. Put grounded conductor through center hole.



## JOB SHEET #1

10. Put ungrounded conductors through side holes. (Figure 4)

FIGURE 4



11. Gently start forming conductors so the separator will fit back in the base.

(NOTE: Care must be taken while you are bending the curvature in the conductors to prevent damage to the plastic conductor separator.)

12. Replace service entrance cap cover.

(NOTE: Show work to instructor for evaluation and comments.)

13. Clean work area and put away all equipment and materials.

## SERVICE UNIT III

### JOB SHEET #2 — CONNECT METER BASE ASSEMBLY TO LOAD CENTER OR PANEL

A. Equipment and materials needed

1. Screwdriver
2. Lineman's pliers
3. Hammer
4. Knife
5. Level
6. Rule
7. Awl
8. Meter base assembly from Job Sheet #1
9. Two 1 1/4" insulating bushings
10. Four 1 1/4" locknuts
11. One 1 1/4" reamed nipple long enough to connect meter base to distribution panel  
  
(NOTE: Nipple, bushings, and locknuts can be larger than 1 1/4" if conductor size or necessity mandates.)
12. #4 copper (1 piece)
13. #2 TW copper (3 pieces)
14. Eight 1" #12 metal tapping screws
15. One 100 amp 3 phase 3 wire SN. load center
16. One 1 1/2" rigid conduit strap
17. 2" x 4" mock up wall or roughed in residential dwelling
18. Safety glasses

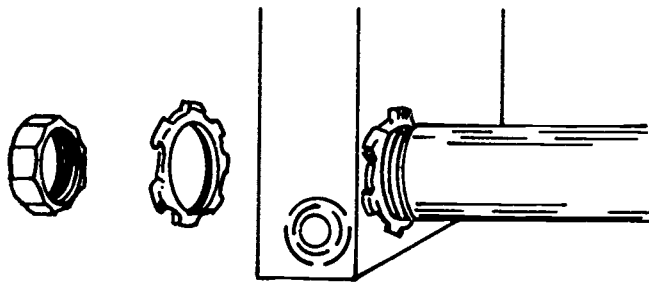
**JOB SHEET #2****B. Procedure**

1. Gather equipment and materials.
2. Mount load center between studs with metal tapping screws.

(NOTE: Panel height should be adjusted so that knockouts will line up with meter base between 5' and 6'. The utility company will give you their recommended height.)

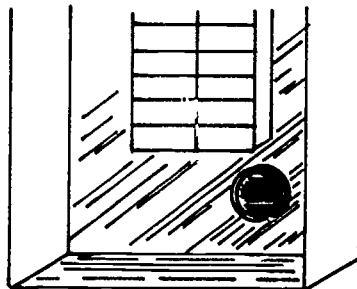
3. Remove load center knockout that will align with meter base at correct height.
4. Install nipple in opening with a locknut on the backside of load center and a locknut and bushing on the inside. (Figure 1)

(NOTE: Be sure that locknuts are installed tightly with teeth into the metal. Also be sure to check local codes on bonding.)

**FIGURE 1**

5. Remove appropriate knockout from meter base.
6. Put back up locknut for meter base on nipple.
7. Place nipple through meter base knockout and secure loosely with one screw. (Figure 2)

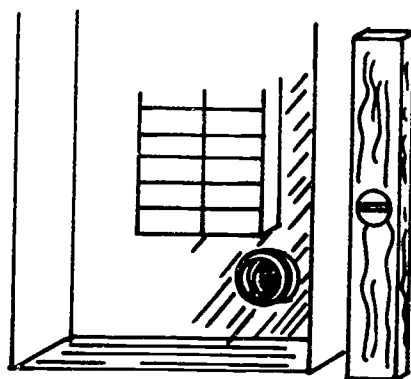
(NOTE: Cut off excess nipple; leave only what is needed for locknut and bushing.)

**FIGURE 2**

## JOB SHEET #2

8. Install internal locknut and bushing.
9. Place level on side of meter base and secure with mounting screws when leveled. (Figure 3)

FIGURE 3

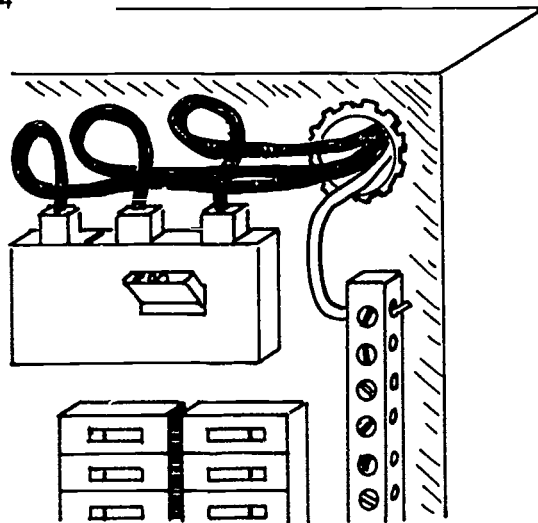


10. Put level on service raceway and secure with strap when leveled.
11. Install grounded conductor in nipple and connect to meter base and load center grounded lugs.  
  
(NOTE: Make all bends in conductors as square as possible while maintaining a radius equal to at least five times the diameter. Make sure you stay as far as possible from load and line lugs in your routing of the grounded conductors.)
12. Install ungrounded conductors in nipple.
13. Strip about 1 1/2" insulation from each of the ungrounded conductors, form them, and connect to meter load lugs.
14. Form ungrounded conductors in load center.

## JOB SHEET #2

15. Cut off excess and connect to load center line lugs. (Figure 4)

FIGURE 4



(NOTE: The service system is still without a grounding electrode conductor. This conductor can originate at the load center, or in the meter base. It can terminate at a cold water pipe or made electrode.)

16. Clean work area and put away all equipment and materials.

## SERVICE UNIT III

### JOB SHEET #1 PRACTICAL TEST — INSTALL AN OVERHEAD RACEWAY WITH SERVICE ENTRANCE CONDUCTORS TO A METER BASE

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Installed 1 1/2" conduit correct on meter base.                  | _____ | _____ |
| 3. Connected service head to 1 1/2" pipe.                           | _____ | _____ |
| 4. Installed conductors through pipe.                               | _____ | _____ |
| 5. Connected top half of service head.                              | _____ | _____ |
| 6. Marked neutral conductor with tape.                              | _____ | _____ |
| 7. Secured correctly with screws on wall.                           | _____ | _____ |
| 8. Checked in/put away tools and materials.                         | _____ | _____ |
| 9. Cleaned the work area.   | _____ | _____ |
| 10. Used proper tools correctly.                                    | _____ | _____ |
| 11. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 12. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 13. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Pipe installed correctly				
Service head properly connected				
Marked conductors properly				
Correct length on conductors				
Mounted correctly				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SERVICE UNIT III

### JOB SHEET #2 PRACTICAL TEST — CONNECT METER BASE ASSEMBLY TO LOAD CENTER OR PANEL

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

1. Checked out proper tools and materials.
2. Installed panel correct.
3. Connected 1 1/4" nipple from meter base to panel.
4. Installed conductors from panel to meter base.
5. Checked in/put away tools and materials.
6. Cleaned the work area.
7. Used proper tools correctly.
8. Performed steps in a timely manner (\_\_\_\_hrs. \_\_\_\_min. \_\_\_\_sec.)
9. Practiced safety rules throughout procedure.
10. Provided satisfactory responses to questions asked.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_



## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Panel mounted correctly				
Nipple installed correctly				
Conductor terminated				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# SERVICE UNIT III

## TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

- |         |   |                                  |
|---------|---|----------------------------------|
| _____a. | Potential transformer   | 1. CT                            |
| _____b. | System or circuit conductor that is intentionally grounded  | 2. Disconnects                   |
| _____c. | Devices used for breaking a circuit which may be fused or unfused   | 3. Equipment grounding conductor |
| _____d. | To connect electrical equipment either intentionally or accidentally to the earth or to some conducting body that serves as the earth   | 4. Ground                        |
| _____e. | Current transformer   | 5. Grounded                      |
| _____f. | Connected to earth or to some conducting body that serves in place of the earth   | 6. Grounded conductor            |
| _____g. | Where power is metered or is first attached to the structure  | 7. Grounding electrode conductor |
| _____h. | Main control panel where voltage and current are distributed to different locations   | 8. PT                            |
| _____i. | Power conductors coming into building from power company  | 9. Service                       |
| _____j. | Devices used for disconnecting power on electrical circuits   | 10. Service drop                 |
| _____k. | Conductor used to connect non-current carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor   | 11. Service panel                |
| _____l. | Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source separately derived system | 12. Switch gear                  |

## TEST

2. Complete the following statements concerning NEC requirements for drop clearance and laterals by inserting the words/numbers which best complete each statement.
- There are two basic types of services: \_\_\_\_\_ and \_\_\_\_\_.
  - Overhead services must be a specific size and have a minimum clearance from finished \_\_\_\_\_.
  - The smallest conductors that can be used on a service are \_\_\_\_\_ copper and \_\_\_\_\_ aluminum.
  - Service drop conductors passing over a roof must be at least \_\_\_\_\_ above the roof.
  - Exception #1 allows service drops to pass \_\_\_\_\_ feet above the roof when the roof has a slope of 4 inches in 12 inches and the voltage is not in excess of \_\_\_\_\_ volts.
  - Exception #2 allows the service drop to be attached to the service mast when the drop does not pass over 4 feet of roof and the mast is at least \_\_\_\_\_ inches above the roof line.
  - Service drop conductors rated at \_\_\_\_\_ or less have minimum clearances.
  - An underground service lateral must have a conductor size of at least \_\_\_\_\_ copper or \_\_\_\_\_ aluminum.
3. Select true statements concerning switch gears and disconnects by placing an "X" in the blank(s) preceding the true statement(s).
- \_\_\_\_\_ a. A switch gear is used for breaking the current or voltage from the meter base to the means of disconnection before being allowed to enter branch circuits.
  - \_\_\_\_\_ b. Service disconnects are readily accessible for breaking the power entering a building. Only one disconnect may be used on a service.
  - \_\_\_\_\_ c. Few service disconnects have overload protection. The disconnect must be large enough to carry the computed load it supplies.

## TEST

4. Match the NEC exceptions for overcurrent protection devices on the right with their correct statements.
- |         |  |                |
|---------|--|----------------|
| _____a. | Two to six CBs or fuses may serve as overcurrent protection devices                              | 1. Exception 1 |
| _____b. | If not a standard size, the next higher standard size overcurrent protection device is used      | 2. Exception 2 |
| _____c. | An overcurrent protection device may be overfused to allow motors to attain running speed        | 3. Exception 3 |
| _____d. | An overcurrent protection device must be rated to carry locked-rotor current of fire pump motors | 4. Exception 4 |
5. Complete the following statements concerning grounding electrodes and ground fault by circling the words/number which best completes each statement.
- a. There are four types of electrode grounding systems used in electrical trades. They include (**aluminum, metal**) waterpipe, building (**steel, iron**), reinforcing rod (**15 feet, 20 feet**) minimum length, ground (**rod, ring**).
- b. A ground (**is, is not**) required if the power company's transformer is grounded.
6. Select true statements concerning service entrance devices by placing an "X" in the blanks preceding the true statements.
- \_\_\_\_\_a. Conductor sizes of 1/0 or larger comprising each phase to neutral will be permitted to be connected in parallel. This means two conductors are used as one.
- \_\_\_\_\_b. A current transformer (CT) steps the voltage down so voltage measuring devices may be used.
- \_\_\_\_\_c. A potential transformer (PT) is a doughnut type device used in measuring current. These are used in metering large services.
7. Complete the following statements concerning emergency and standby systems by inserting the words which best complete each statement.
- a. Separate, derived systems such as a \_\_\_\_\_ or \_\_\_\_\_ are used when the incoming voltage from the power company is interrupted or cut off. These systems are used in \_\_\_\_\_, factories, and stores where electricity is a must.
- b. An \_\_\_\_\_ \_\_\_\_\_ senses a voltage loss and automatically switches a system to emergency power.

**TEST**

8. State the procedure for balancing loads.

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(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

9. Demonstrate the ability to:
- a. Install an overhead raceway with service entrance conductors to a meter base. (Job Sheet #1)
  - b. Connect meter base assembly to lead center or panel. (Job Sheet #2)

## SERVICE UNIT III

### ANSWERS TO TEST

1. 

a.	8	e.	1	i.	10
b.	6	f.	5	j.	12
c.	2	g.	9	k.	3
d.	4	h.	11	l.	7
2. 

a.	Overhead, underground	e.	3 feet
b.	Grade	f.	18
c.	#8, #6	g.	600v
d.	8 feet	h.	#8, #6
3. a
4. 

a.	3
b.	2
c.	1
d.	4
5. 

a.	Metal, steel, 20 feet, ring
b.	Is
6. a
7. 

a.	Generator, battery
b.	Automatic transfer switch
8. When balancing loads on panels, transformers, and switching equipment, an amprobe should be used to determine amperage on each circuit.
9. Performance skills evaluated to the satisfaction of the instructor

# **TRANSFORMERS**

## **UNIT IV**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to reference the NEC to determine transformer locations and to identify specific transformer requirements. Competencies will be demonstrated by completing the assignment sheets, job sheets, and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to transformers with their correct definitions.
2. List three basic types of transformers.
3. Draw diagrams of the two most commonly used voltage systems.
4. Select true statements concerning NEC requirements for dry type transformers.
5. Complete statements concerning NEC requirements for oil-filled transformers.
6. Select true statements concerning NEC requirements for askarel-filled transformers.
7. State the function of a buck and boost transformer.
8. Match NEC articles with their correct transformer locations.
9. Match NEC articles with the correct installation and termination of transformers.
10. Locate and list two exceptions on transformer room construction for dry type transformers. (Assignment Sheet #1)

## OBJECTIVE SHEET

11. Locate and list two exceptions concerning oil-insulated transformers. (Assignment Sheet #2)
12. Draw a three-phase wye-delta transformer. (Assignment Sheet #3)
13. Convert amperes to KVA on a three-phase system. (Assignment Sheet #4)
14. Demonstrate the ability to:
  - a. Test transformer turn ratios. (Job Sheet #1)
  - b. Test transformer insulation resistance. (Job Sheet #2)
  - c. Connect three transformers in a delta-delta configuration. (Job Sheet #3)
  - d. Connect transformer primary and secondary windings in a delta-wye configuration. (Job Sheet #4)



## TRANSFORMERS UNIT IV

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Make transparency from the transparency master included in this unit.
- C. Provide students with objective sheet.
- D. Discuss unit and specific objectives.
- E. Provide students with information and assignment sheets.
- F. Discuss information and assignment sheets.

(NOTE: Use the transparency to enhance the information as needed.)

- G. Provide students with job sheets.
- H. Discuss and demonstrate the procedures outlined in the job sheets.
- I. Integrate the following activities throughout the teaching of this unit:
1. Show a film on transformer maintenance.
  2. Invite a representative from a transformer winding shop to class to discuss transformer maintenance.
  3. Have students reference the NEC to locate specific NEC requirements pertaining to transformers.
  4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- J. Give test.
- K. Evaluate test.
- L. Reteach if necessary.

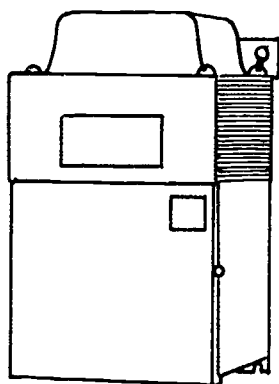
### REFERENCES USED IN WRITING THIS UNIT

- A. Stallcup, James G. *Designing Electrical Systems*. Alsip, IL: American Technical Publishers, Inc., 1983.
- B. Turner, J. Howard. *Understanding Electricity and Electrical Terms*. Athens, GA: American Association for Vocational Instructional Materials, 1974.

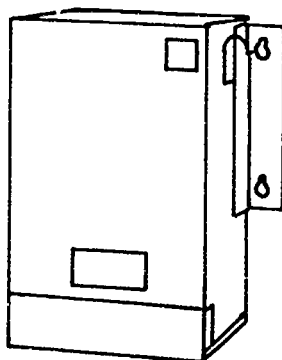
### SUGGESTED SUPPLEMENTAL MATERIAL

Film — *Transformer Maintenance*. NUS Training Corporation, 1350 Piccard Drive, Rockville, MD 20850.

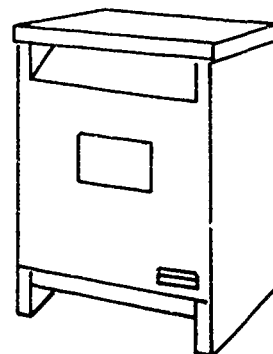
# Basic Types of Transformers



**indoor**

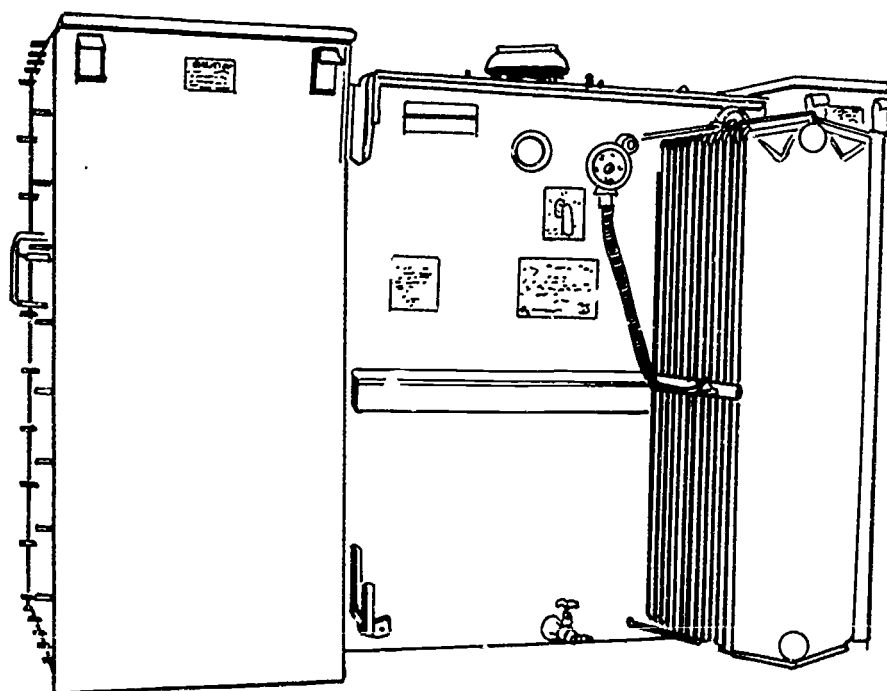


**Outdoor**



**Floor Mount**

## Dry Type



**Oil-filled or Askarel-filled**

## **TRANSFORMERS UNIT IV**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Ambient temperature — The temperature in the area where the transformer is to be located. High temperatures will raise the insulation temperatures and shorten the life of the transformer. The KVA rating should be derated .4% for each 1°C over 30°C average ambient temperature for 150°C insulation
- B. Buck and boost transformer — A transformer that increases or decreases voltage
- C. Isolating transformer — Insulates the primary circuit from the secondary circuit as with an insulating transformer, but frequently with no voltage change
- D. Transformer vault — Area in which transformers are installed for safety protection. This area is usually constructed with concrete and fire-retardant doors

#### **II. Basic types of transformers**

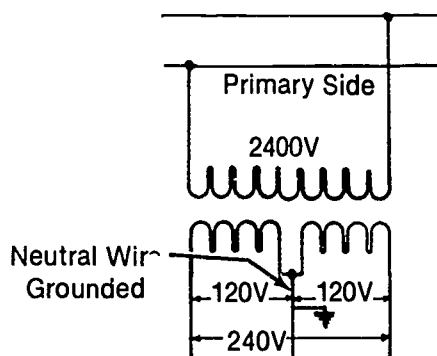
- A. Dry type — Do not have their core and coils submerged in oil
- B. Oil-filled — Must have their core and coils submerged in oil
- C. Askarel-filled — Filled with a liquid which produces gases from arcing

(NOTE: Askarel-filled transformers are slowly being eliminated due to the presence of PCBs.)

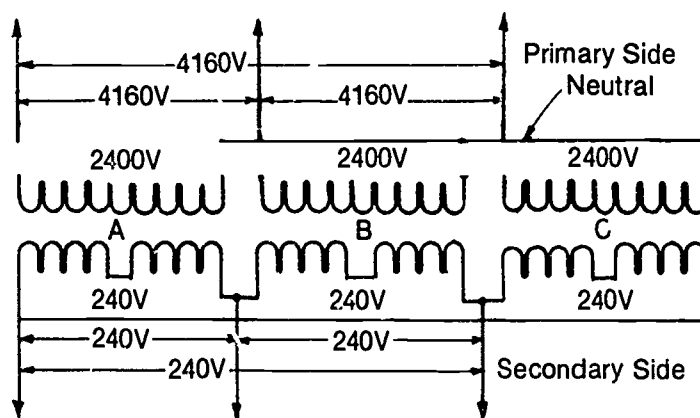
## INFORMATION SHEET

### III. Most commonly used voltage systems

#### A. Single phase transformers



#### B. Three phase transformers



## INFORMATION SHEET

### IV. NEC requirements for dry type transformers

(NOTE: Refer to NEC Article 450-21.)

- A. Dry type transformers installed indoors rated at 112.5 KVA must have a fire resistant, heat-insulating barrier between transformer and combustible materials. If a barrier is not used and voltage is over 600v, a 12" minimum from combustible material is used.
- B. Dry type transformers do not require a 12" separation of barrier if they are enclosed and are rated less than 112.5 KVA and will operate at 600v or less.
- C. Dry type transformers rated over 35,000 volts must be installed in a vault.

### V. NEC requirements for oil-filled transformers

- A. Oil-filled transformers can be installed indoors and outdoors. When mounted indoors oil-filled transformers must be mounted in a vault.
- B. NEC Article 450-26 pertains to oil insulated transformers which are installed indoors.

(NOTE: Read complete article and exceptions.)

- C. NEC Article 450-27 pertains to oil-insulated transformers which are installed outdoors.

(NOTE: Read complete article and exceptions.)

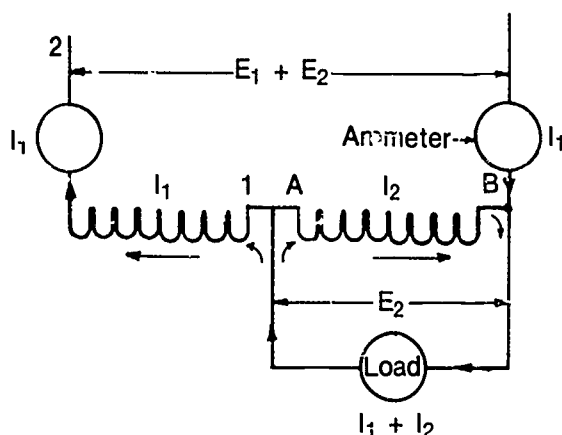
### VI. NEC requirements for askarel-filled transformers

- A. Askarel-filled transformers are filled with a liquid called askarel which will not burn and is nonexplosive. Gases are produced as a result of arcing. A vent is required if the transformer is over 25 KVA.
- B. NEC Article 450-25 pertains to askarel-insulated transformers installed indoors.

(NOTE: Read complete article on askarel transformers.)

## INFORMATION SHEET

- VII. Function of a buck and boost transformer** — It is used to increase or decrease voltage. The values used will depend on the line voltage and the amount of boost required.



(NOTE: A buck and boost transformer is wired like an autotransformer.)

**VIII. NEC articles concerning transformer locations**

(NOTE: Some dry, oil-filled, and askarel-filled transformers require vaults for their insulation. Read the following articles and exceptions.)

- A. NEC Article 450-41 pertains to the location of transformer vaults.
- B. NEC Article 450-42 pertains to walls, roofs, and floors.
- C. NEC Article 450-43 pertains to doorways.
- D. NEC Article 450-45 pertains to ventilation openings.
- E. NEC Article 450-47 pertains to water pipes and accessories.
- F. NEC Article 450-48 pertains to storage in vaults.

## INFORMATION SHEET

### IX. Installation and termination of transformers

- A. Mounting of transformers must comply with the NEC on location, storage, and uses. Refer to NEC Article 450-2.
- B. Grounding of transformers will comply with NEC 450-10.
- C. Overcurrent protection may be installed on primary and secondary windings of transformers. Refer to
  - 1. NEC Article 240-3, exception #5
  - 2. NEC Article 240-21, exception #s 2, 3, and 8
  - 3. NEC Article 384-16A



## TRANSFORMERS UNIT IV

### ASSIGNMENT SHEET #1 — LOCATE AND LIST TWO EXCEPTIONS ON TRANSFORMER ROOM CONSTRUCTION FOR DRY TYPE TRANSFORMERS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Using the NEC, locate and list two exceptions on transformer room construction for dry type transformers over 112.5 KVA.

A. Exception #1

B. Exception #2

## TRANSFORMERS UNIT IV

### ASSIGNMENT SHEET #2 — LOCATE AND LIST TWO EXCEPTIONS CONCERNING OIL-INSULATED TRANSFORMERS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Using the NEC, locate and list two exceptions concerning oil-insulated transformers installed outdoors where vaults are not required.

A. Exception #1

B. Exception #2

## TRANSFORMERS UNIT IV

### ASSIGNMENT SHEET #3 — DRAW A THREE-PHASE WYE-DELTA TRANSFORMER

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions: In the space provided below, draw a three-phase wye-delta transformer.

## TRANSFORMERS UNIT IV

### ASSIGNMENT SHEET #4 — CONVERT AMPERES TO KVA ON A THREE-PHASE SYSTEM

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Convert the following amperes to KVA on a 480v three-phase system.

EXAMPLE:  $\text{KVA} = \frac{\text{volts} \times \text{amps} \times 1.73}{1000}$

- A. 60.2 amps: \_\_\_\_\_ KVA
- B. 120 amps: \_\_\_\_\_ KVA
- C. 241 amps: \_\_\_\_\_ KVA
- D. 602 amps: \_\_\_\_\_ KVA

# TRANSFORMERS UNIT IV

## ANSWERS TO ASSIGNMENT SHEETS

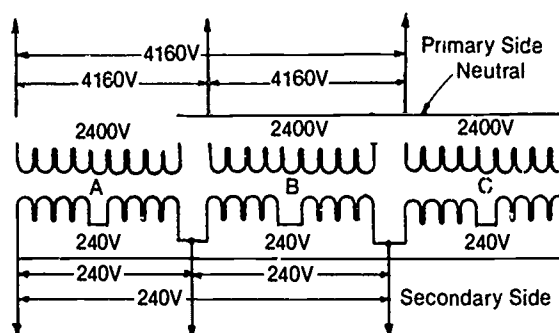
### Assignment Sheet #1

- A. NEC 450-21(b) Exception #1 to (b)
- B. NEC 450-21(b) Exception #2 to (b)

### Assignment Sheet #2

- A.-B. NEC 450-26 Exceptions #1 - #5 (any two)

### Assignment Sheet #3



### Assignment Sheet #4

- A. 50
- B. 100
- C. 200
- D. 500

## TRANSFORMERS UNIT IV

### JOB SHEET #1 — TEST TRANSFORMER TURN RATIOS

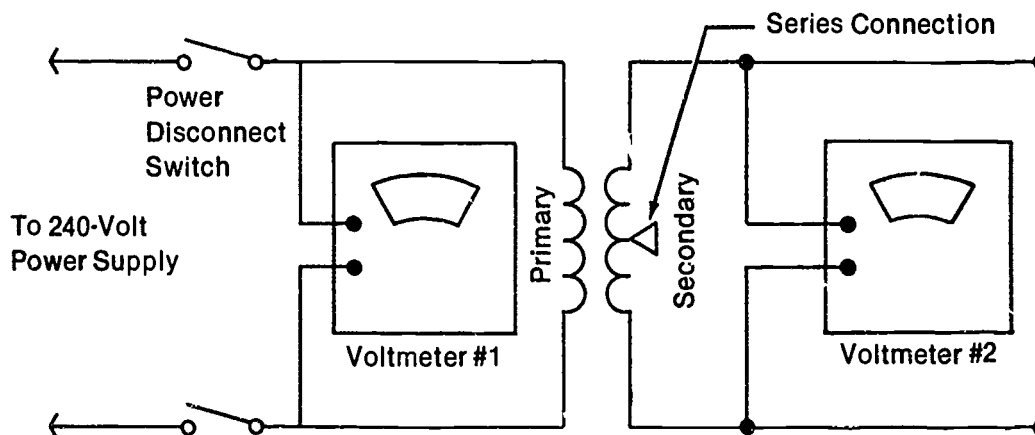
#### A. Equipment and materials needed

1. Transformer, rated 480 to 120/240 volts
2. Transformer, rated 240 to 24 volts
3. Transformer, rated 120 to 24 volts
4. Two voltmeters (one with 600-volt scale)
5. Wire or test jumpers to connect transformers to power supply
6. Single-phase power supply, 120/240-volt or 120/208-volt

#### B. Procedure

1. Connect both voltmeters to power supply, and adjust needles until both read the same at near midscale.
2. Connect transformer as shown in Figure 1.

FIGURE 1



3. Double-check connections for correctness.
4. Check to be sure that all leads are in the clear.

(NOTE: Show work to instructor before proceeding.)

## JOB SHEET #1

5. Energize power supply.
6. Read both voltmeters.
7. Record voltmeter readings for Transformer #1.

VM #1 = \_\_\_\_\_

VM #2 = \_\_\_\_\_

8. Open power switch.
9. Calculate actual transformer turn ratio.

(NOTE: Divide Voltmeter #2 reading by Voltmeter #1 reading to find the ratio. Show your work.)

T#1 turn ratio = \_\_\_\_\_

10. Compare calculated ratio with nameplate voltage ratio.

(NOTE: Calculated ratio should match nameplate within  $\pm 1$  percent.)

11. Test Transformer #2, using same procedure as that used to test Transformer #1.
12. Record voltmeter readings for Transformer #2, and calculate turn ratio.

(NOTE: Show your work.)

VM #1 = \_\_\_\_\_

VM #2 = \_\_\_\_\_

T#2 turn ratio = \_\_\_\_\_

13. Test Transformer #3, using the same procedure as that used to test Transformer #1.

**JOB SHEET #1**

14. Record voltmeter readings for Transformer #3, and calculate turn ratio.

(NOTE: Show your work.)

VM #1 = \_\_\_\_\_

VM #2 = \_\_\_\_\_

T#3 turn ratio = \_\_\_\_\_

(NOTE: Show results to instructor for evaluation and comments.)

15. Clean work area; put away all equipment and materials.



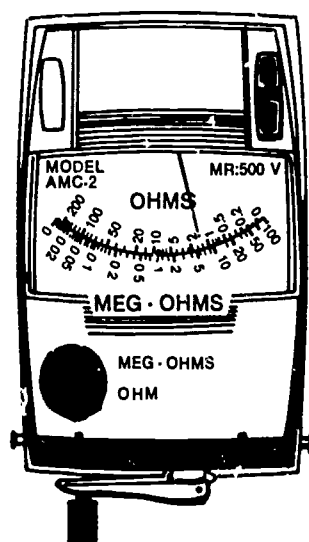
## TRANSFORMERS UNIT IV

### JOB SHEET #2 — TEST TRANSFORMER INSULATION RESISTANCE

A. Equipment needed

1. Three transformers (voltage not important; larger sizes if available)
2. Megger tester with leads (Figure 1)

FIGURE 1



3. Test jumpers or wire to short windings
4. Centigrade-scale thermometer

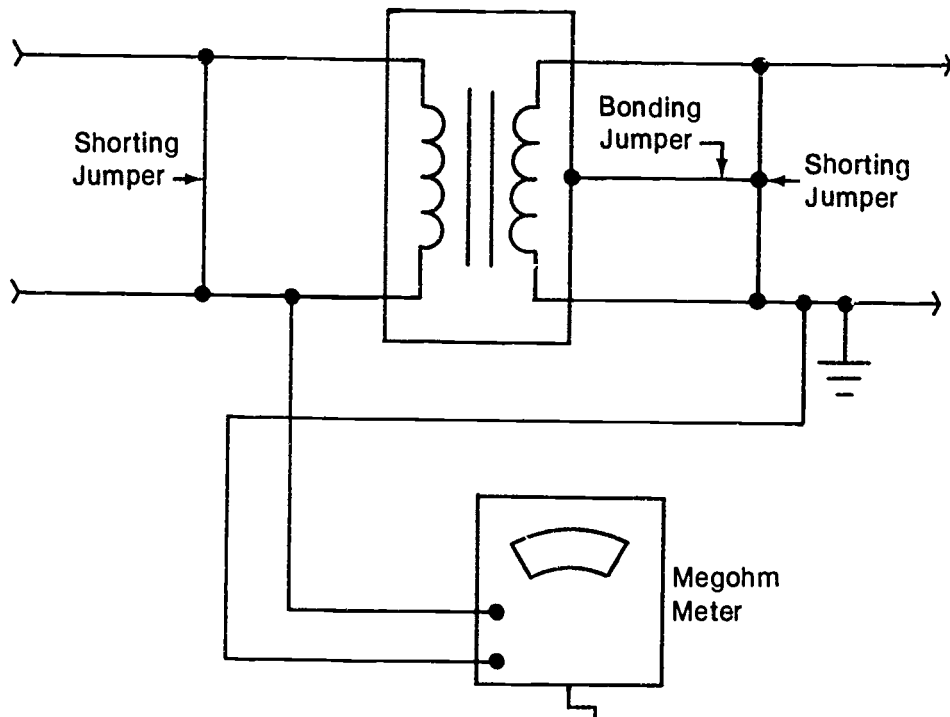
## JOB SHEET #2

## B. Procedure

1. Test primary winding to secondary and ground.

a. Construct circuit as shown in Figure 2.

FIGURE 2



- b. Short both windings.
- c. Ground the secondary winding to transformer case.
- d. As near as practical, place thermometer to get the temperature of the interior of the windings.
- e. Crank megger tester at about 120 rpm for sixty seconds or until needle settles down.
- f. Read Instrument while still cranking.
- g. Stop cranking.
- h. Record reading.

Megger reading = \_\_\_\_\_ Megohms

## JOB SHEET #2

- i. Check thermometer.

(NOTE: Insulation resistance will decrease by 50 percent for every 10-degree centigrade rise in temperature, or double for every 10-degree centigrade drop in temperature.)

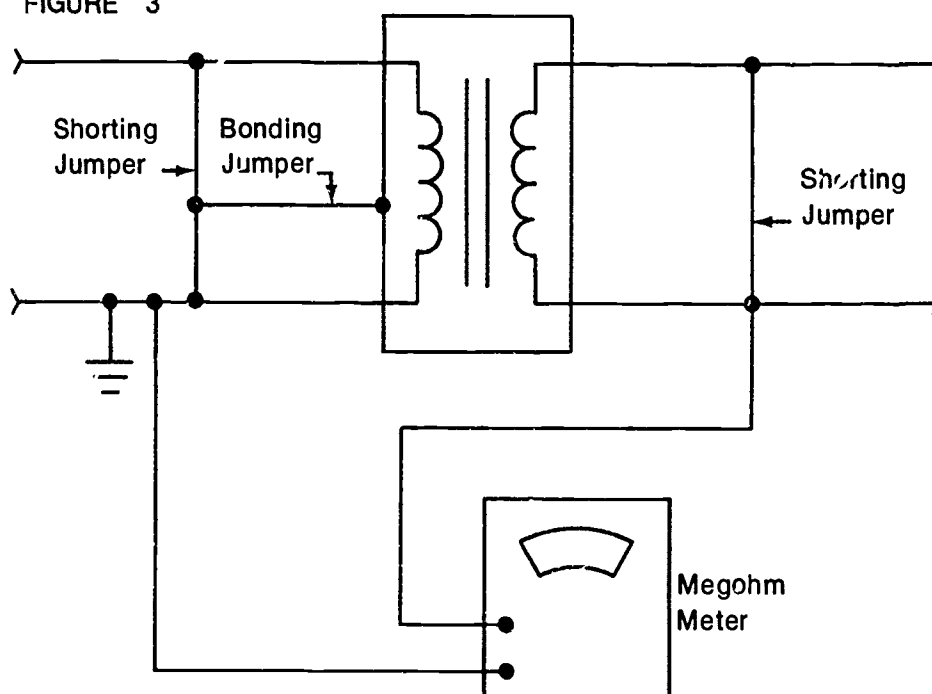
- j. Record temperature.

Temperature = \_\_\_\_\_ °C

(NOTE: Megohm readings become more meaningful when periodic tests are made on a piece of equipment, and then plotted on graph paper to make a curve.)

2. Test secondary to primary and ground (Figure 3).

FIGURE 3



- Short both windings.
- Ground the primary winding to transformer case.
- Make test as before (steps d. through j.) on primary insulation.

Megger reading = \_\_\_\_\_ Megohms

Temperature = \_\_\_\_\_ °C

(NOTE: Show results to instructor for evaluation.)

**JOB SHEET #2**

3. Repeat procedure on each remaining transformer.

a. Transformer #2

T2 megger reading = \_\_\_\_\_ Megohms

T2 temperature = \_\_\_\_\_ °C

b. Transformer #3

T3 megger reading = \_\_\_\_\_ Megohms

T3 temperature = \_\_\_\_\_ °C

(NOTE: Show results to instructor for evaluation and comments.)

4. Clean work area; put away equipment.

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## TRANSFORMERS UNIT IV

### JOB SHEET #3 — CONNECT THREE TRANSFORMERS IN A DELTA-DELTA CONFIGURATION

#### A. Equipment and materials needed

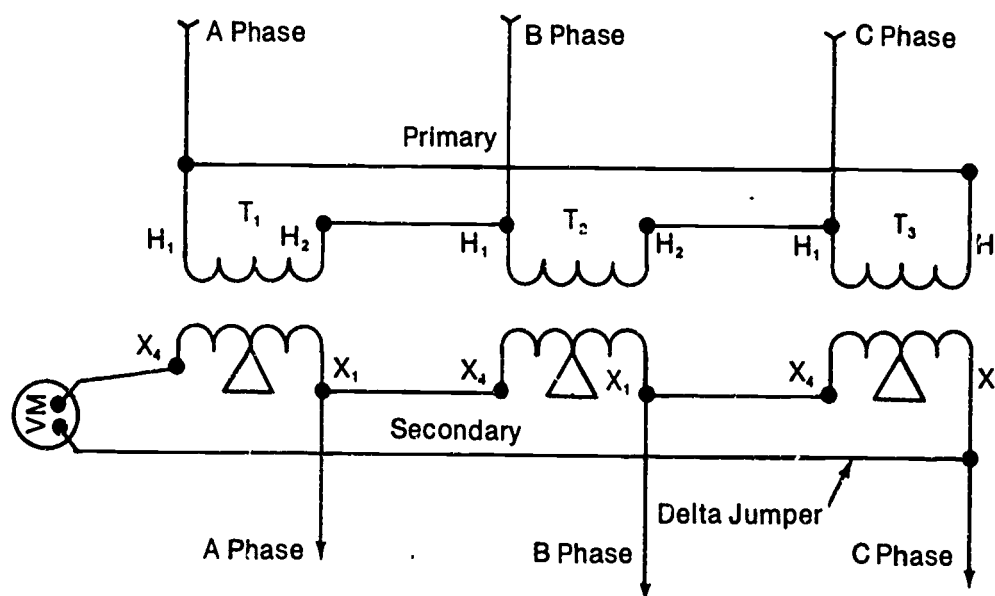
1. Three-phase power supply, 240-volt  
(NOTE: A three-phase 208-volt power supply will also serve satisfactorily.)
2. Three 5-ampere fuses in 240-volt circuit
3. #14 wire, approximately 20 feet
4. Wire nuts or bolts for connections
5. Three transformers rated 240 to 120/240 at 1 kilovolt-ampere
6. Voltmeter with 600-volt scale

#### B. Procedure

1. Connect transformers as shown in Figure 1

(NOTE: Leave X1 of T3 open for polarity test.)

FIGURE 1



### JOB SHEET #3

2. Check connections for correctness; make sure that all leads are clear and that voltmeter is set on 600-volt scale.
3. Connect primary leads A, B, and C to L1, L2, and L3 of 240-volt power supply.

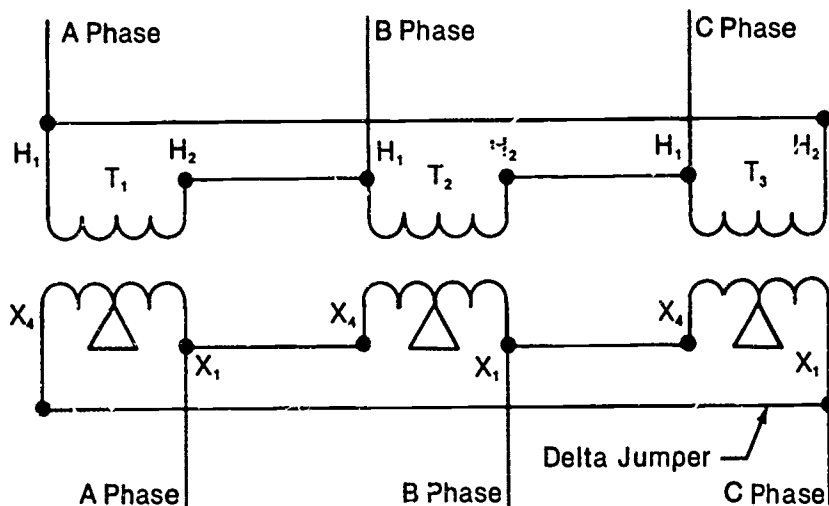
(NOTE: Show work to instructor before proceeding.)

4. Energize 240-volt circuit.
5. Read voltmeter.

(NOTE: Voltmeter should read zero or twice the secondary v.c.'s. If voltmeter reads zero, move voltmeter leads to primary leads A and B and read again. This procedure tests both the power supply and voltmeter. If tests show volts normal between primary phases A and B and zero at the open connection on the secondary, the delta-delta connections and polarity of transformers are correct.)

6. Deenergize transformer.
7. Close the connection between the delta jumper and X1 of T3. (Figure 2)

FIGURE 2



## JOB SHEET #3

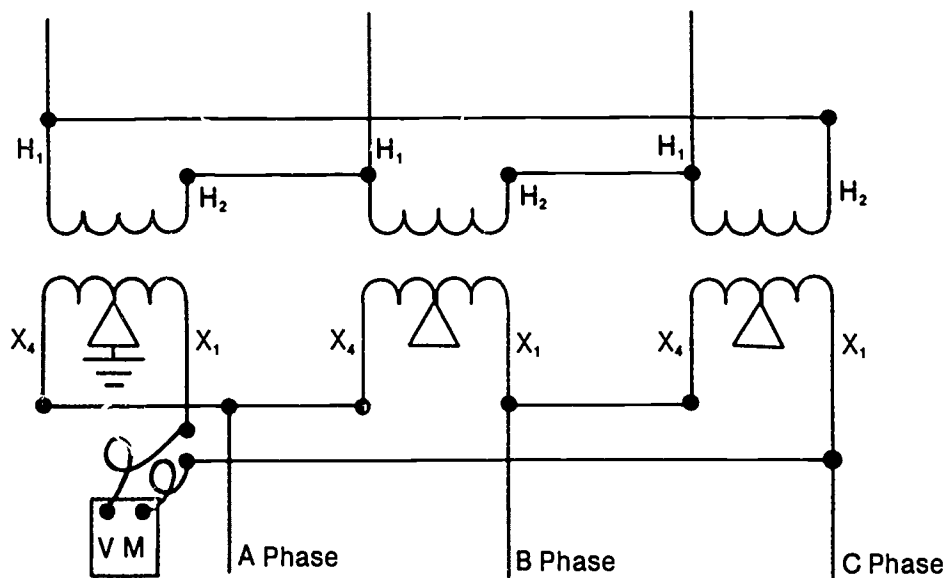
8. Energize the 240-volt circuit.
9. Using voltmeter, read and record primary voltage.  
Phases A to B \_\_\_\_\_  
Phases A to C \_\_\_\_\_  
Phases B to C \_\_\_\_\_
10. Using voltmeter, read and record secondary voltage.  
Phases A to B \_\_\_\_\_  
Phases A to C \_\_\_\_\_  
Phases B to C \_\_\_\_\_  
Phase A to ground \_\_\_\_\_  
Phase B to ground \_\_\_\_\_  
Phase C to ground \_\_\_\_\_
11. Deenergize 240-volt power supply.
12. Deenergize transformer bank, and connect midpoint of T1 secondary to ground.
13. Reenergize transformer bank.
14. Again check and record voltages between each secondary-phase lead and ground.  
Phase A to ground \_\_\_\_\_  
Phase B to ground \_\_\_\_\_  
Phase C to ground \_\_\_\_\_  
  
(NOTE: Voltages to ground are stable and high leg registers on voltmeter.)
15. Deenergize transformer bank.
16. Disconnect T1 leads X1 and X4.

## JOB SHEET #3

17. Connect T1 lead X4 to T2 lead X4. (Figure 3)

**(CAUTION: Tie or otherwise fasten T1 lead X1 clear of other leads and ground. Be cautious of higher voltages.)**

FIGURE 3



18. Reenergize transformer bank.
19. Set voltmeter on 600-volt scale.

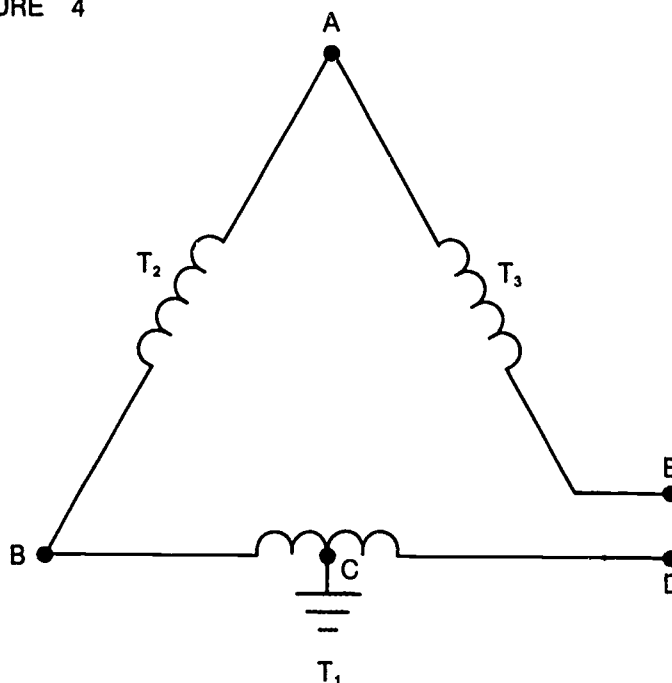


## JOB SHEET #3

20. Check and record voltages between various points on the secondary shown in Figure 4.

(NOTE: This experiment shows what can happen if transformer polarities are not taken into consideration when connecting transformers.)

FIGURE 4



Points A to C \_\_\_\_\_

Points B to C \_\_\_\_\_

Points C to D \_\_\_\_\_

Points B to E \_\_\_\_\_

Points B to E \_\_\_\_\_

Points D to E \_\_\_\_\_

Points A to E \_\_\_\_\_

Points B to D \_\_\_\_\_

**JOB SHEET #3**

21. Open and lock open 240-volt power supply switch.

**(CAUTION: When working with voltages of 4,160; 7,200; 12,500 or higher; the results are magnified accordingly.)**

**(NOTE: Show work to instructor for evaluation and comments; if approved by instructor, transformers may be held for Job Sheet #4; if not approved, rework to the instructor's satisfaction.)**

## TRANSFORMERS UNIT IV

### JOB SHEET #4 — CONNECT TRANSFORMER PRIMARY AND SECONDARY WINDINGS IN A DELTA-WYE CONFIGURATION

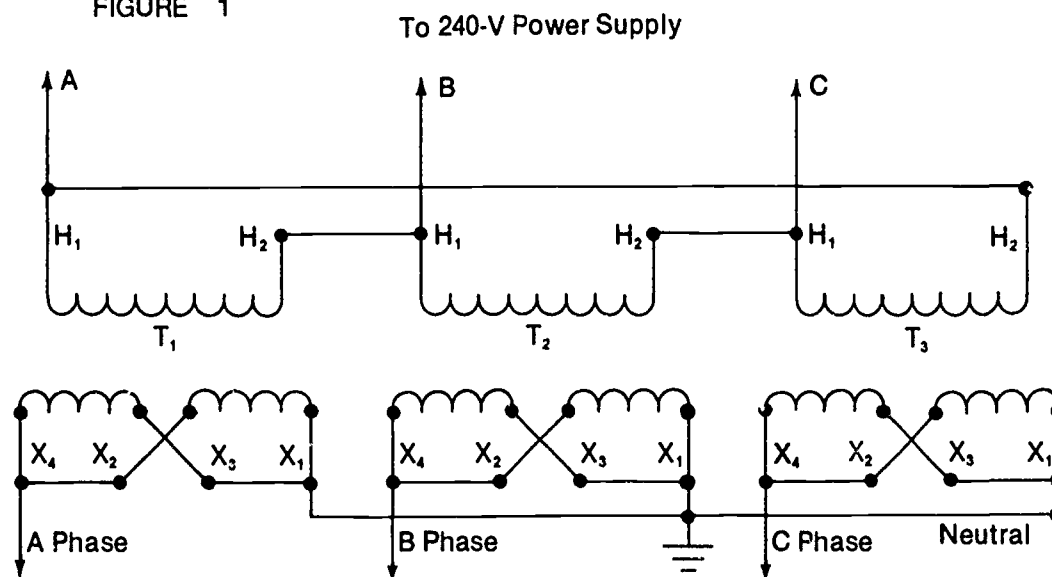
#### A. Equipment and materials needed

1. Three-phase power supply, 240-volt  
(NOTE: A three-phase 208-volt power supply will also serve satisfactorily.)
2. Three 5-ampere fuses in 240-volt circuit
3. #14 wire, approximately 20 feet
4. Wire nuts or bolts for connections
5. Three transformers rated 240 to 120/240 (200 volt-amperes to 1 kilovolt-ampere capacity)
6. Voltmeter with 600-volt scale
7. One lamp and socket, 100 watt, 120 volt

#### B. Procedure

1. Connect transformers in a delta primary to wye secondary configuration as shown in Figure 1.

FIGURE 1



**JOB SHEET #4**

2. Double-check all connections for correctness.

(NOTE: Show connections to instructor before proceeding.)

3. Energize 240-volt circuit.

4. Read and record low-side voltages.

Phases A to B \_\_\_\_\_

Phases A to C \_\_\_\_\_

Phases B to C \_\_\_\_\_

Phase A to neutral \_\_\_\_\_

Phase B to neutral \_\_\_\_\_

Phase C to neutral \_\_\_\_\_

5. Deenergize 240-volt circuit.

6. Connect 100-watt lamp to phase A and neutral.

7. Reenergize 240-volt circuit.

8. Read and record voltages.

Phase A to neutral \_\_\_\_\_

Phase B to neutral \_\_\_\_\_

Phase C to neutral \_\_\_\_\_

9. Deenergize 240-volt circuit.

10. Connect the neutral to ground.

(NOTE: An ungrounded neutral can shift when the load is unbalanced, causing low voltage at one point and high voltage at other points.)

11. Read and record low-side voltages again.

Phase A to neutral \_\_\_\_\_

Phase B to neutral \_\_\_\_\_

Phase C to neutral \_\_\_\_\_

Phases A to B \_\_\_\_\_

Phases A to C \_\_\_\_\_

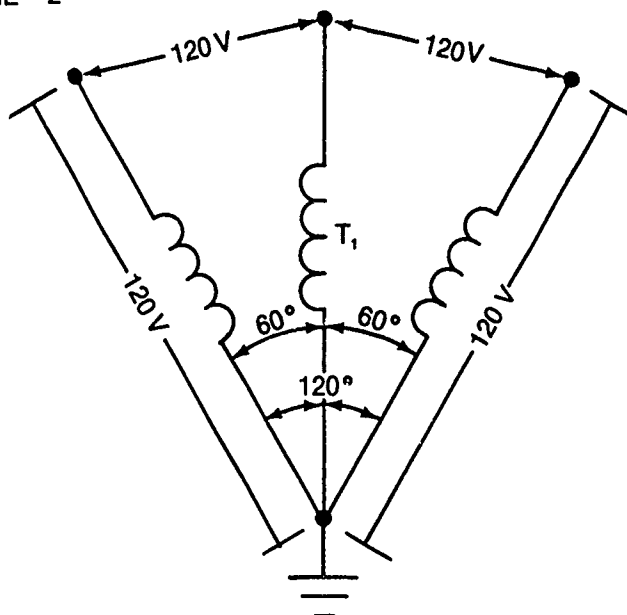
Phases B to C \_\_\_\_\_

## JOB SHEET #4

12. Deenergize 240-volt circuit.
13. Disconnect T1 secondary leads from T2 and T3.
14. Connect terminal X4 of T1 to the neutral point.
15. Reenergize the circuit.
16. Read and record secondary voltages.

(NOTE: Figure 2 represents shift of phases due to improper connections.)

FIGURE 2



Phases A to B \_\_\_\_\_

Phases A to C \_\_\_\_\_

Phases B to C \_\_\_\_\_

Phase A to neutral \_\_\_\_\_

Phase B to neutral \_\_\_\_\_

Phase C to neutral \_\_\_\_\_

(NOTE: Show work to instructor for evaluation and comments.)

17. Disassemble transformer.
18. Clean work area; put away all equipment and materials.

## TRANSFORMERS UNIT IV

### JOB SHEET #1 PRACTICAL TEST — TEST TRANSFORMER TURN RATIOS

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Connected voltmeters to power supply.                            | _____ | _____ |
| 3. Connected transformer.   | _____ | _____ |
| 4. Checked connections.   | _____ | _____ |
| 5. Energized power supply.  | _____ | _____ |
| 6. Read and recorded voltmeter readings.                            | _____ | _____ |
| 7. Calculated transformer turn ratio.                               | _____ | _____ |
| 8. Checked in/put away tools and materials.                         | _____ | _____ |
| 9. Cleaned the work area.   | _____ | _____ |
| 10. Used proper tools correctly.                                    | _____ | _____ |
| 11. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 12. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 13. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Voltmeters and transformer connected correctly				
Voltmeter readings accurately recorded				
Transformer turn ratios calculated correctly				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TRANSFORMERS UNIT IV

### JOB SHEET #2 PRACTICAL TEST — TEST TRANSFORMER INSULATION RESISTANCE

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Tested primary windings to secondary and ground.                | _____ | _____ |
| 3. Tested secondary to primary and ground.                         | _____ | _____ |
| 4. Recorded readings for each transformer.                         | _____ | _____ |
| 5. Checked in/put away tools and materials.                        | _____ | _____ |
| 6. Cleaned the work area.  | _____ | _____ |
| 7. Used proper tools correctly.                                    | _____ | _____ |
| 8. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 9. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 10. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_



## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Read instruments accurately and recorded readings				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TRANSFORMERS UNIT IV

### JOB SHEET #3 PRACTICAL TEST — CONNECT THREE TRANSFORMERS IN A DELTA-DELTA CONFIGURATION

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Connections correct.  | _____ | _____ |
| 3. Power applied.  | _____ | _____ |
| 4. Performed test satisfactorily.                                  | _____ | _____ |
| 5. Voltage correctly recorded.                                     | _____ | _____ |
| 6. Checked in/output way tools and materials.                      | _____ | _____ |
| 7. Cleaned the work area.  | _____ | _____ |
| 8. Used proper tools correctly.                                    | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                   | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Connected transformers in delta-delta				
Connections tight				
Obtained correct readings				
Workmanship				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TRANSFORMERS UNIT IV

### JOB SHEET #4 PRACTICAL TEST — CONNECT TRANSFORMER PRIMARY AND SECONDARY WINDINGS IN A DELTA-WYE CONFIGURATION

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Connections correct.  | _____ | _____ |
| 3. Power applied.  | _____ | _____ |
| 4. Performed test satisfactorily.                                  | _____ | _____ |
| 5. Voltage correctly recorded.                                     | _____ | _____ |
| 6. Checked in/put away tools and materials.                        | _____ | _____ |
| 7. Cleaned the work area.  | _____ | _____ |
| 8. Used proper tools correctly.                                    | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                   | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Connected transformers in delta-wye				
Connections tight				
Obtained correct readings				
Workmanship				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TRANSFORMERS UNIT IV

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

- |         |   |                               |
|---------|---|-------------------------------|
| _____a. | A transformer that increases or decreases voltage   | 1. Ambient temperature        |
| _____b. | Insulates the primary circuit from the secondary circuit as with an insulating transformer, but frequently with no voltage change       | 2. Buck and boost transformer |
| _____c. | Area in which transformers are installed for safety protection. This area is usually constructed with concrete and fire-retardant doors | 3. Isolating transformer      |
| _____d. | The temperature in the area where the transformer is to be located  | 4. Transformer vault          |

2. List three basic types of transformers.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

3. Draw diagrams of the two most commonly used voltage systems.

- a. Single phase transformer

## TEST

- b. Three phase transformer
4. Select true statements concerning NEC requirements for dry type transformers by placing an "X" in the blanks preceding the true statements.
- \_\_\_\_a. Dry type transformers installed indoors rated at 112.5 KVA must have a fire resistant, heat insulating barrier between transformer and combustible materials.
- \_\_\_\_b. Dry type transformers require a 12" separation or barrier if they are enclosed and are rated less than 112.5 KVA and will operate at 300v or less.
- \_\_\_\_c. Dry type transformers rated over 15,000 volts must be installed in a vault.
5. Complete the following statements concerning NEC requirements for oil-filled transformers by inserting the words which best complete each statement.
- a. Oil-filled transformers can be installed indoors and outdoors. When mounted indoors oil-filled transformers must be mounted in a \_\_\_\_\_.
- b. NEC Article 450-26 pertains to oil insulated transformers which are installed \_\_\_\_\_.
- c. NEC Article 450-27 pertains to oil-insulated transformers which are installed \_\_\_\_\_.

## TEST

6. Select true statements concerning NEC requirements for askarel-filled transformers by placing an "X" in the blanks preceding the true statements.

- \_\_\_\_a. Askarel-filled transformers are filled with a liquid called askarel which will not burn and is nonexplosive.
- \_\_\_\_b. Gases are produced as a result of arcing.
- \_\_\_\_c. A vent is not required if the transformer is under 115 KVA.
- \_\_\_\_d. NEC Article 450-25 pertains to askarel-insulated transformers installed indoors.

7. State the function of a buck and boost transformer.

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8. Match NEC articles on the right with their correct transformer locations.

- |                                    |                       |
|------------------------------------|-----------------------|
| ____a. Ventilation openings        | 1. NEC Article 450-41 |
| ____b. Transformer vaults          | 2. NEC Article 450-42 |
| ____c. Storage in vaults           | 3. NEC Article 450-43 |
| ____d. Doorways                    | 4. NEC Article 450-45 |
| ____e. Walls, roofs, and floors    | 5. NEC Article 450-47 |
| ____f. Water pipes and accessories | 6. NEC Article 450-48 |

9. Match NEC articles on the right with the correct installation and termination of transformers.

- |  |                       |
|--|-----------------------|
| ____a. Mounting of transformers must comply with code on locations, storage, and uses            | 1. NEC Article 450-2  |
| ____b. Overcurrent protection may be installed on primary and secondary windings of transformers | 2. NEC Article 450-10 |
| ____c. Grounding of transformers   | 3. NEC Article 240-3  |

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

10. Locate and list two exceptions on transformer room construction for dry type transformers. (Assignment Sheet #1)



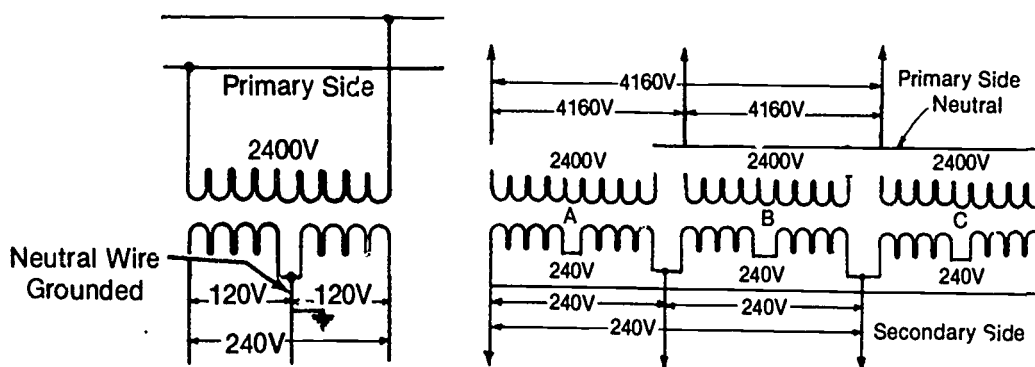
## TEST

11. Locate and list two exceptions concerning oil-insulated transformers. (Assignment Sheet #2)
12. Draw a three-phase wye-delta transformer. (Assignment Sheet #3)
13. Convert amperes to KVA on a three-phase system. (Assignment Sheet #4)
14. Demonstrate the ability to:
  - a. Test transformer turn ratios. (Job Sheet #1)
  - b. Test transformer insulation resistance. (Job Sheet #2)
  - c. Connect three transformers in a delta-delta configuration. (Job Sheet #3)
  - d. Connect transformer primary and secondary windings in a delta-wye configuration. (Job Sheet #4)

# TRANSFORMERS UNIT IV

## ANSWERS TO TEST

1.
  - a. 2
  - b. 3
  - c. 4
  - d. 1
2.
  - a. Dry type
  - b. Oil-filled
  - c. Askarel-filled
3.
  - a. Single phase transformer
  - b. Three phase transformer



4.
  - a, b
5.
  - a. Vault
  - b. Indoors
  - c. Outdoors
6.
  - a, b, d
7. It is used to increase or decrease voltage.

## ANSWERS TO TEST

- |    |    |   |    |   |
|----|----|---|----|---|
| 8. | a. | 4 | d. | 3 |
|    | b. | 1 | e. | 2 |
|    | c. | 6 | f. | 5 |

- |    |    |   |
|----|----|---|
| 9. | a. | 1 |
|    | b. | 3 |
|    | c. | 2 |

10.-13. Evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor

## **ROUGH-IN UNIT V**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to rough-in a commercial or industrial job. Competencies will be demonstrated by completing the assignment sheet, job sheets and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to rough-in with their correct definitions.
2. Select true statements concerning branch circuit and feeder installation.
3. Identify devices used in special circuit installations.
4. Arrange in order the steps for determining the number of conductors allowed in a conduit, based on cross-sectional area.
5. List exceptions to the NEC requirements for support of flexible metal conduit.
6. Complete statements concerning optional calculations for additional loads to existing installations.
7. Determine the number of conductors allowed to be added to an existing conduit. (Assignment Sheet #1)
8. Demonstrate the ability to:
  - a. Rough-in a wood framed wall. (Job Sheet #1)
  - b. Install outlet boxes on steel rods. (Job Sheet #2)

**OBJECTIVE SHEET**

- c. Install outlet boxes on steel studs using caddy metal stud clips for switch boxes. (Job Sheet #3)
- d. Install masonry boxes in a block wall. (Job Sheet #4)

## ROUGH-IN UNIT V

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Make transparencies from the transparency masters included with this unit.
- C. Provide students with objective sheet.
- D. Discuss unit and specific objectives.
- E. Provide students with information and assignment sheets.
- F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

- G. Provide students with job sheets.
- H. Discuss and demonstrate the procedures outlined in the job sheets.
- I. Integrate the following activities throughout the teaching of this unit:
1. Take students on a field trip to a commercial job in the area.
  2. Have representative from a local supply house give demonstration of trim out devices.
  3. Invite a local electrical contractor to class to talk about commercial jobs.
  4. Set up several live troubleshooting projects in lab, and demonstrate and discuss troubleshooting procedures. See Handout #1.

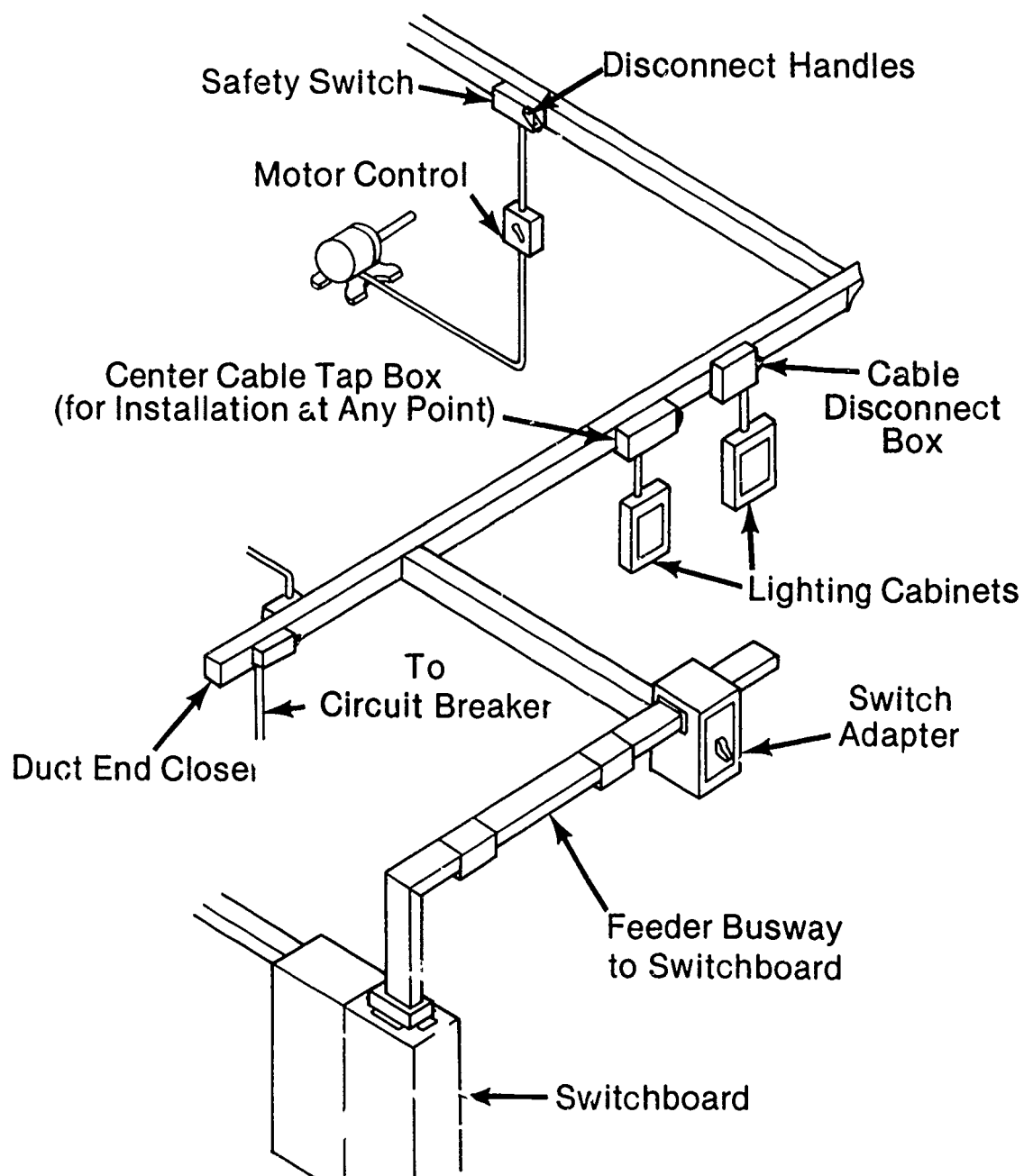
(NOTE: The teaching of troubleshooting skills should be integrated throughout this publication.)

5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- J. Give test.
- K. Evaluate test.
- L. Reteach if necessary.

## REFERENCES USED IN WRITING THIS UNIT

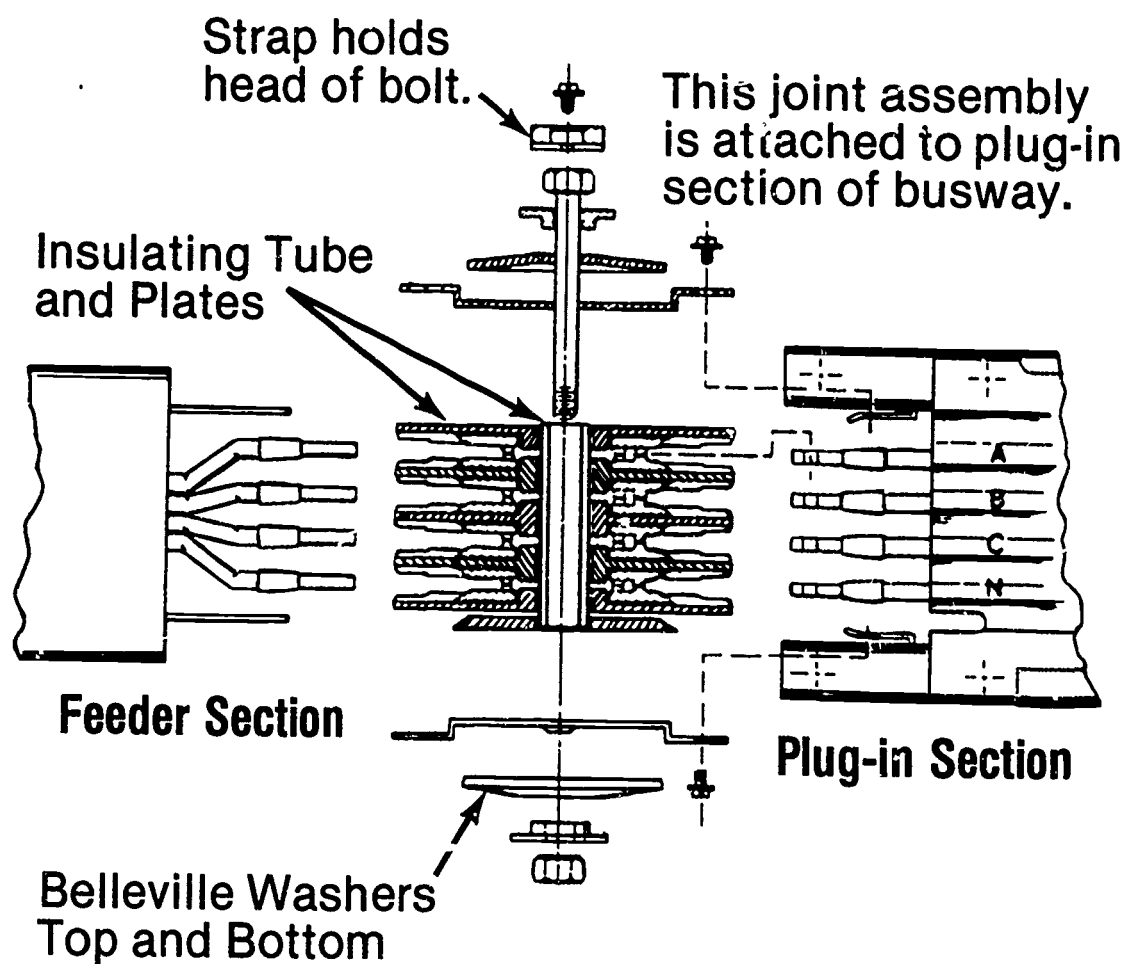
- A. Schram, Peter J. *The National Electrical Code Handbook*, 1987. Quincy, MA: National Fire Protection Association, 1986.
- B. Summers, Wilford. *American Electrician's Handbook*. New York: McGraw-Hill Book Company, 1981.
- C. Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

# Buss-Duct





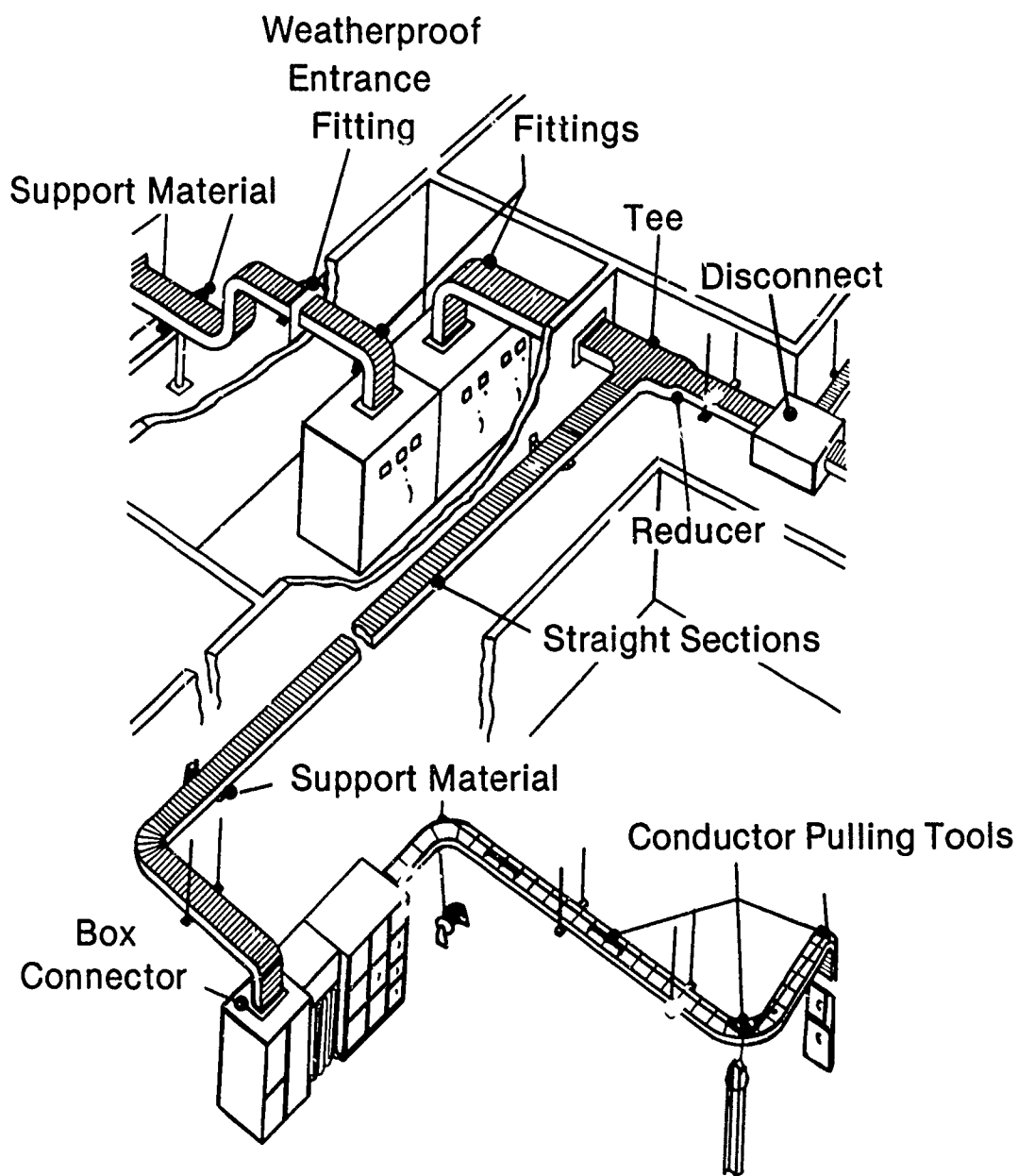
# Buss-Duct (Continued)



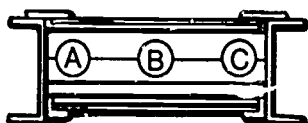
One Bolt Joint Assembly

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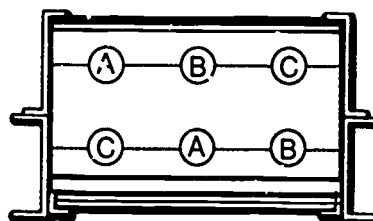
# Cable Tray



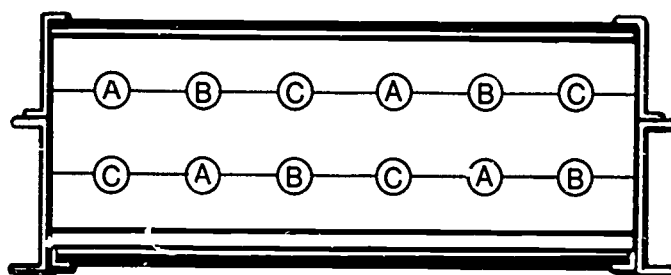
# Cable Spacing In Cable Tray



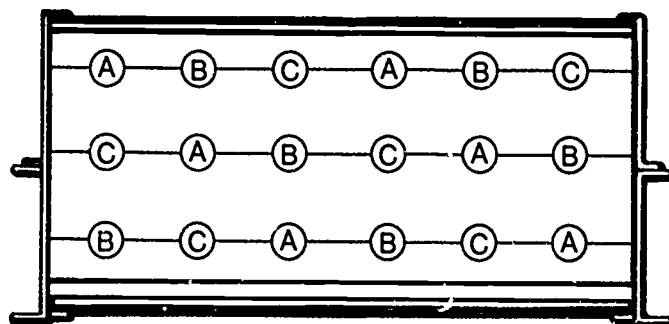
3 Conductor



6 Conductor



12 Conductor



18 Conductor

## ROUGH-IN UNIT V

### HANDOUT #1 — TROUBLESHOOTING PROCEDURES

- A. Determine symptoms of system malfunction. Consult owner about operation of system before, during, and after problem occurred.

(NOTE: A great deal of information can be gained in this questioning—Did it flicker, hum, or explode? Was anything unusual going on at the time of problem [lightning, unusual load, too many appliances plugged in]. Has it happened before?)

- B. Inspect the system.

(NOTE: The panel is the place to start since the overcurrent protection device will identify the problem circuit. Most national, state, and local codes require that panels be identified.)

1. Trace system from panel by

- a. Color of conductor
- b. Number of conductor
- c. Using an ohmmeter

**(CAUTION: Always disconnect supply power from circuit to be tested before using ohmmeter. Line voltages will damage meter.)**

2. Check conductor's condition.

- a. Conductor discolored from overheating
- b. Conductor insulation damaged or nicked
- c. Loose conductor connection at devices or splice points

3. Check devices or fixtures.

- a. Device worn or overheated
- b. Fixture worn or overheated
- c. Reversed outlet polarity which may cause neutral overload

(NOTE: Fixtures with bulbs larger than their rating may have internal damage.)

**HANDOUT #1**

- C. Locate problem causing area.
  - 1. Bad device or fixture
  - 2. Broken conductor
  - 3. Circuit overload
- D. Repair or replace cause of problem.
  - 1. Install new device or fixture
  - 2. Rewire circuit
  - 3. Install extra circuit to compensate for overload

## ROUGH-IN UNIT V

### INFORMATION SHEET

#### I. Terms and definitions

- A. Ampacity — The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating
- B. Cable benders — Mechanical or hydraulic devices used to bend heavy conductors in panels and junction boxes
- C. Copper-clad aluminum — Aluminum conductor with an outer coating of copper metallurgically bonded to the aluminum core
- D. Color coding — Assigning colors to conductors based on their uses
- E. Covered — Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation
- F. Cross-sectional area — Area in square inches allowed in a conduit or tubing; area required for conductors in a conduit or tubing
- G. Drop chain — Short length of small chain used to pull cable or flexible conduit through an enclosed space or wall cavity
- H. Fish — Establishing a connection between two points so a cable or length of flexible conduit can be installed
- I. Fish wire — Length of wire with a hook formed in one end to catch material to be installed in a space
- J. Insulated — Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation
- K. Pipe chase — Usually a vertical space between two floors, dedicated for the running of pipes and conduits between floors
- L. Power fish-tape system — Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls
- M. Pull rope — Strong rope of nylon or other substance used to pull heavy conductors into raceways
- N. Raceway — An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the *National Electrical Code*

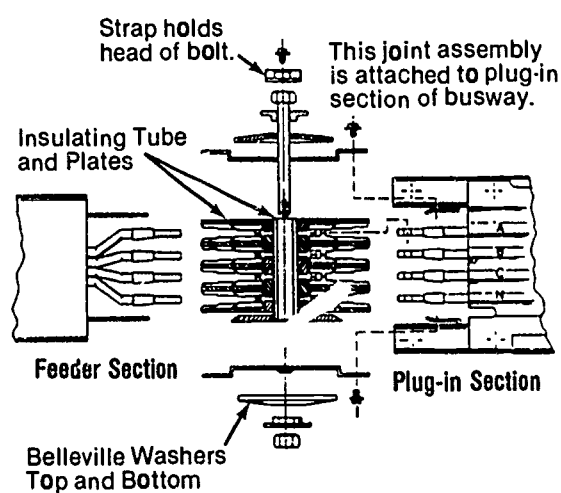
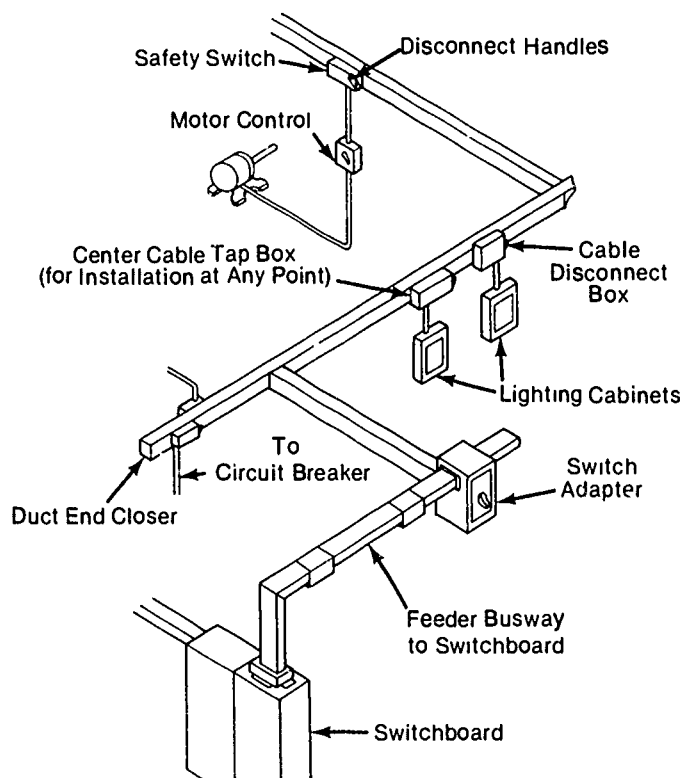
## INFORMATION SHEET

- O. Trim out — Final stage in a wiring project; involves devices and plates, connecting and securing equipment, hanging fixtures, and testing the system
  - P. Troubleshooting — The systematic diagnosis of a malfunction
  - Q. Voltage rating — Maximum voltage at which a device is designed to operate
  - R. Wire dispenser — Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway
  - S. Wire-pulling compound — Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway
  - T. Winch — Manual or motor-powered mechanical device used to pull conductors into a raceway
- II. Branch circuit and feeder installation**
- A. When using multi-phase circuitry, balancing must take place to regulate the even flow of current on each of the phases. This is done by connecting an ammeter to the incoming conductor. By using the reading, circuits may be moved to balance the load by switching conductors with different phases.
  - B. Color coding for a high leg delta 4-wire system must be marked with orange color (refer to NEC Art: 215-8) and must be located on center lug (refer to NEC Art: 384-3-F) when neutral is present.
  - C. When identifying neutrals, NEC Section 200-6 states that conductors not white must be marked with continuous white or natural gray tape, or white paint.
  - D. Temporary wiring and lighting must comply with NEC Article 305 which states that temporary power shall be equipped with GFI protection. Temporary lighting shall be protected from accidental contact or breakage by a suitable fixture or lampholder with a guard.

## INFORMATION SHEET

### III. Devices used in special circuit installations

#### A. Buss-duct



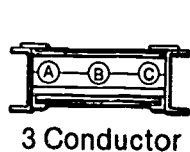
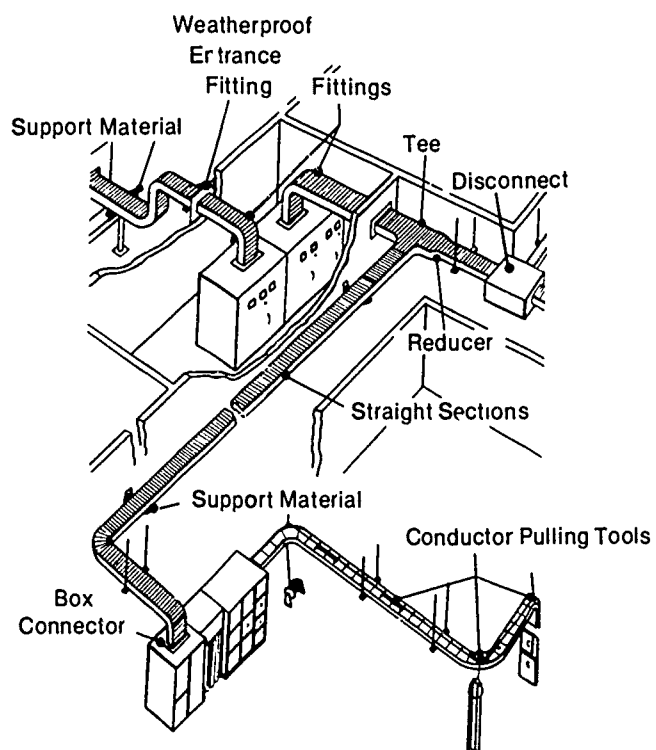
One Bolt Joint Assembly

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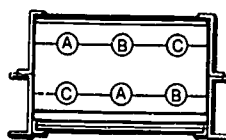


# **INFORMATION SHEET**

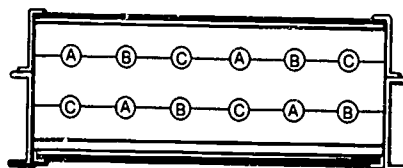
## **B. Cable tray**



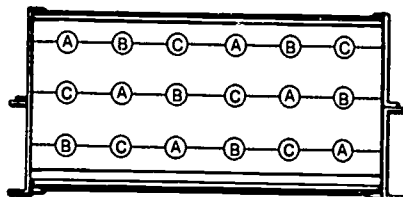
**3 Conductor**



**6 Conductor**



**12 Conductor**



**18 Conductor**

## INFORMATION SHEET

### IV. Steps for determining the number of conductors allowed in a conduit, based on cross-sectional area

- A. Determine size of existing conduit.
- B. Determine number and size of existing conductors.
- C. Find area of conduit or tubing using Table 4, Chapter 9 of the NEC.
- D. Compute total area occupied by existing conductors based on Table 5, Chapter 9 of the NEC.
- E. Determine number of conductors that may be added.

**EXAMPLE:** An existing 1 inch conduit contains three #8 THHN conductors. Four #12 THW conductors need to be added to feed a new circuit.

1 inch conduit with over two conductors not lead covered has an area of .34 square inches (Table 4, Chapter 9)

#8 THHN has an area of .0471 sq. in. (Table 5, Chapter 9)

$$\begin{array}{r} .0471 \text{ sq. in.} \\ \times \quad 3 \\ \hline .1413 \text{ sq. in.} \end{array}$$

#12 THW has an area of .0172 sq. in. (Table 5, Chapter 9)

$$\begin{array}{r} .0172 \text{ sq. in.} \\ \times \quad 4 \\ \hline .0688 \text{ sq. in.} \end{array}$$

Total area required for conductors is:

$$\begin{array}{r} .0471 \\ + .0688 \\ \hline .1159 \text{ sq. in.} \end{array}$$

.1159 is less than .34 therefore the four #12 THW conductors may be added.

## INFORMATION SHEET

### V. Exceptions to the NEC requirements for support of flexible metal conduit

(NOTE: Refer to NEC Art: 350-4.)

- A. Where flexible metal conduit is fished
- B. Lengths not exceeding 3 feet
- C. Lengths not exceeding 6 feet from a fixture terminal connection to lighting fixtures

### VI. Optional calculation for additional loads to existing installations

(NOTE: For the purpose of allowing additional loads to be connected to existing feeders and services, it shall be permitted to use the actual KVA demand figures to determine the existing load on a service or feeder when all the following conditions are met. Refer to NEC Art: 230-35[1][2][3].)

- A. The maximum demand data is available in KVA for a minimum of a one year period.
- B. The existing demand at 125 percent plus the new load does not exceed the ampacity of the feeders or rating of the service.
- C. The feeder or service has overcurrent protection in accordance with sections 230-90 and 240-3 of the NEC.

(NOTE: Article 230-90 requires overload protection in each ungrounded conductor. Article 240-3 requires that conductors other than flexible cords and fixture wires be protected against overcurrent in accordance with their ampacities as specified in Tables 310-16 through 310-31 and all applicable notes to these tables.)

# ROUGH-IN UNIT V

## ASSIGNMENT SHEET #1 — DETERMINE THE NUMBER OF CONDUCTORS ALLOWED TO BE ADDED TO AN EXISTING CONDUIT

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

**Directions:** Using the steps listed in Objective IV of the Information Sheet and the NEC, determine if additional conductors may be added to a conduit if a new conduit is necessary. Show your calculations.

1. An existing  $\frac{3}{4}$ " conduit contains three #10 THW conductors; you need to add three more #10 THW conductors.
2. A  $\frac{1}{2}$ " conduit contains three #12 THHN conductors. Will four more #12 THHN conductors be allowed?
3. A  $1\frac{1}{2}$ " conduit contains three 1/0 THW conductors. Will three #6 THHN conductors be allowed?

# ROUGH-IN UNIT V

## ANSWERS TO ASSIGNMENT SHEET #1

1. .21 sq. in. conduit area  
.0311 sq. in. #10 THW

.0311

x 6

.1866 sq. in.

.1866 is less than .21; therefore, the additional wires are allowed.

2. .12 sq. in. conduit area  
.0117 sq. in. #12 THHN

.0117

x 7

.0819 sq. in.

.0819 is less than .12; therefore, the additional wires are allowed.

3. .82 sq. in. conduit area  
.2367 sq. in. for I/O THW  
.0519 sq. in. for #6 THHN

.2367

x 3

.7101 sq. in.

.0519

x 3

.1557 sq. in.

.7101

+.1557

.8658 sq. in.

.8658 is greater than .82; therefore, a new conduit must be run.

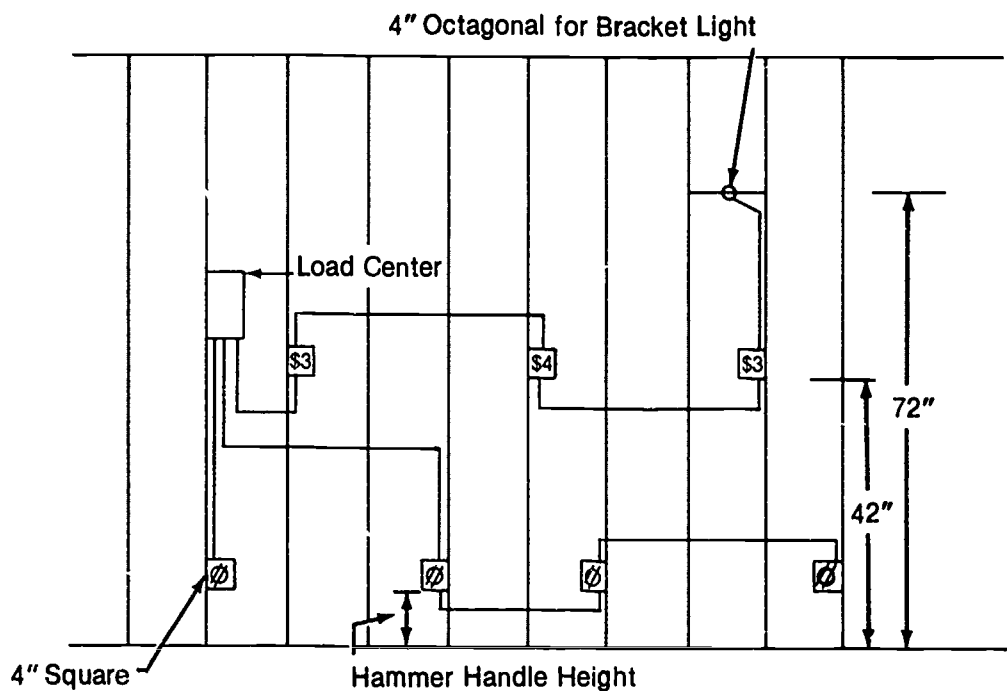
## ROUGH-IN UNIT V

### JOB SHEET #1 — ROUGH-IN A WOOD FRAMED WALL

#### A. Equipment and materials needed

1. Pouch tools, including hammer and tape
2. Construction blueprint showing locations and other necessary information for box installation (Figure 1)

FIGURE 1



3. 8-foot section of framed wall with 2" x 4" studs
4. Five outlet boxes, Raco #560 or equivalent
5. Two 4-inch square boxes, Raco #255 or equivalent
6. One plaster ring, Raco #772 or equivalent
7. One plaster ring, Raco #778 or equivalent
8. #8 mounting nails
9. 4-inch octagon box, Raco #125 or equivalent

**JOB SHEET #1**

10. One expandable hanger bar, Raco #924 or equivalent
11. One roll #12 THHN white
12. One roll #12 THHN black
13. One roll #12 THHN blue
14. One roll #12 THHN red
15. 40' — 1/2" EMT

**B. Procedure**

1. View blueprint for installation information to determine location of boxes.

(NOTE: Mount boxes to allow for 5/8-inch Sheetrock.)

2. Lay out job by marking studs where boxes are to be installed.
3. Place boxes on floor along wall where each is to be installed.
4. Measure heights, and mark studs for mounting boxes.

(NOTE: A quick accurate method for measuring for box installation is to cut a piece of conduit, lathe, or other similar material to proper length from floor or floor plate to bottom of box. Boxes can be held on top of the measuring device and fastened to stud. This will prevent reading a rule for locating each box. A method often used in industry for height location of receptacle boxes is to set a hammer on the floor and position the box on top of the handle. The receptacle box can be fastened to the stud at that height.)

5. Mount outlet boxes (Figure 2)

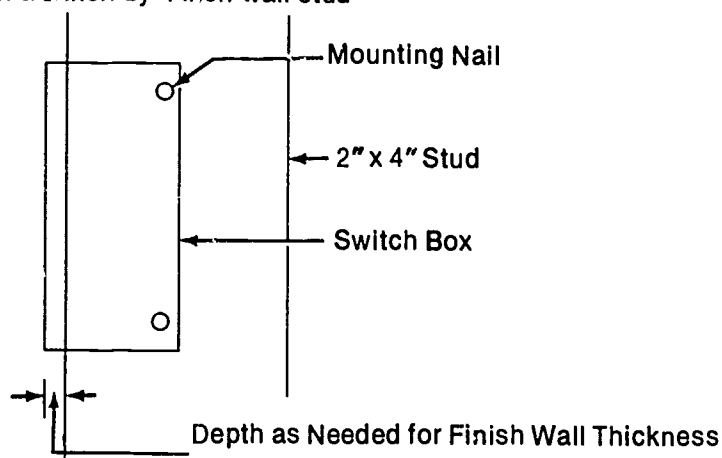
- a. Mount electrical boxes to studs at the locations and heights marked, with front edge of boxes parallel to face of stud and extended 1/2-inch to allow for 5/8-inch Sheetrock. (See Figure 1)

(NOTE: Four-inch square boxes are usually mounted with #8 or roofing nails, and switch boxes are usually mounted with #16 nails.)

## JOB SHEET #1

FIGURE 2

Switch box mounted on a 2-inch by 4-inch wall stud

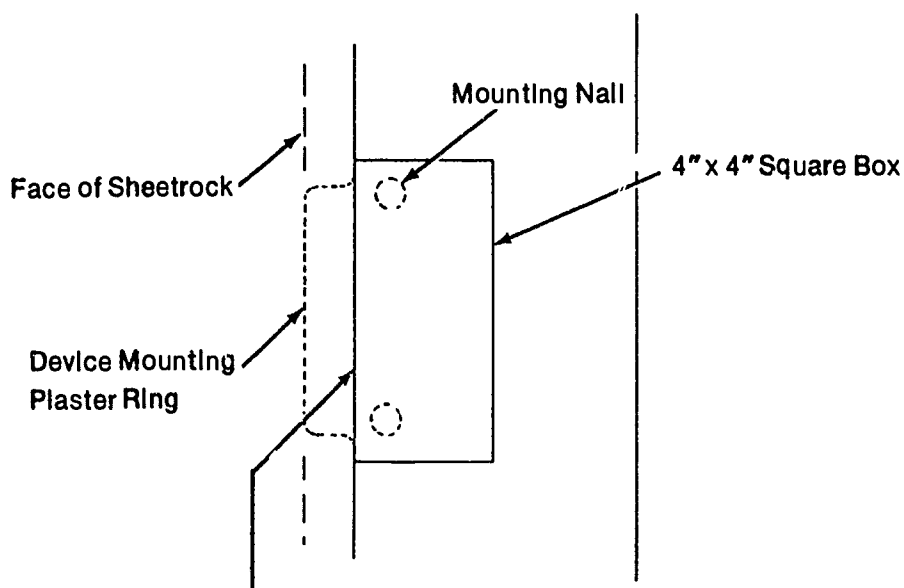


6. Mount 4-inch square boxes to studs at the height and location as marked with front edge of box flush with face of stud. (Figure 3)

(NOTE: Set four-inch square boxes  $\frac{1}{2}$  inch lower than switch boxes, device screws inside.)

FIGURE 3

4" x 4" Box Mounted on  
2" x 4" Stud



Front of box should be flush with 2" x 4" stud.



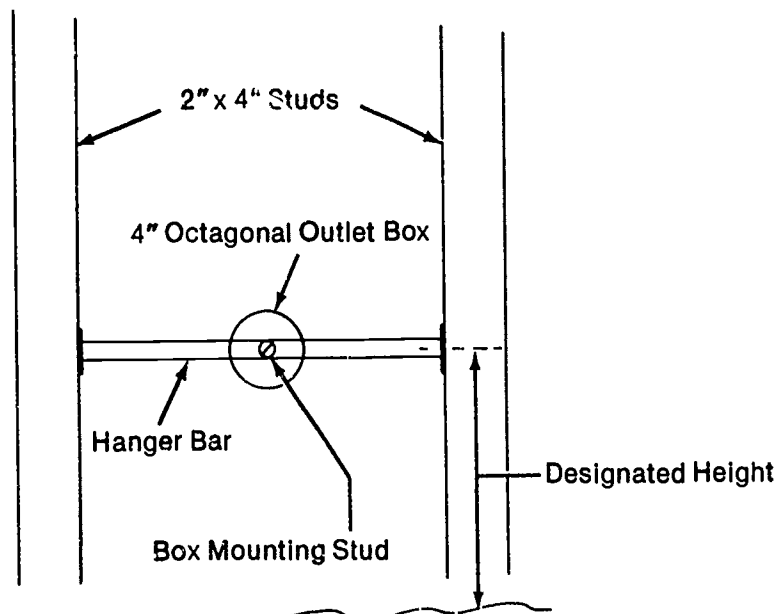
## JOB SHEET #1

7. Install octagonal outlet box for wall bracket light between two studs at location and height marked.
  - a. Spread expandable hanger bar to proper length to properly fit between studs.
  - b. Attach hanger bar to studs. (Figure 4)

(NOTE: Hanger bars are usually fastened to studs with #8 nails.)

FIGURE 4

4" Octagonal Outlet Box Mounted on Hanger Bar



- c. Attach octagonal box to hanger bar stud.
8. Rough-in EMT runs.
9. Pull conductors and make up.
10. Have Instructor evaluate project.
11. Clean work area; put away equipment and materials.

## ROUGH-IN UNIT V

### JOB SHEET #2 — INSTALL OUTLET BOXES ON STEEL RODS

A. Equipment and materials needed

1. Stove bolt,  $\frac{1}{4}$  inch by  $\frac{1}{2}$  inch
2. 3-foot piece of  $\frac{1}{2}$ -inch EMT
3. 4-inch square outlet box, Raco #255 or equivalent
4.  $\frac{1}{2}$ -inch EMT connector
5. Two 3-foot pieces of  $\frac{1}{4}$ -inch rod
6. Two rod-hanger clamps, Caddy Catalog #708-2-4 or equivalent
7. Two conduit box clips, Caddy Catalog #4-1-2-4 or equivalent
8. Pouch tools

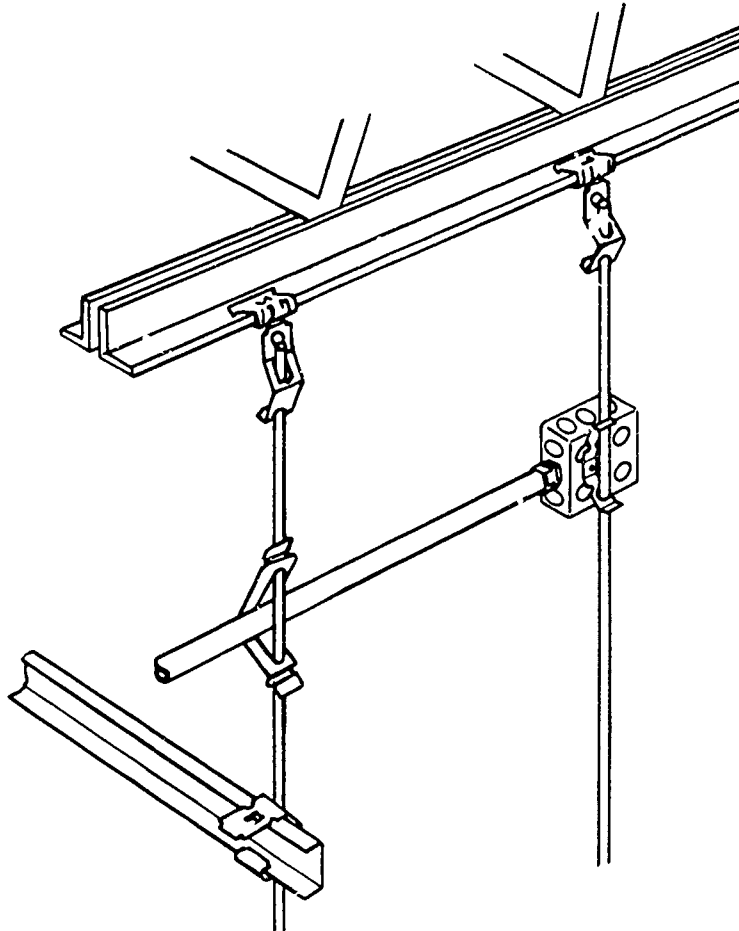
B. Procedure

1. Install two  $\frac{1}{4}$ -inch rods in rod-hanger clamps.
2. Mount two rod-hanger clamps on suspended angle iron approximately 24 inches apart.

**JOB SHEET #2**

3. Install 1/2-inch EMT in 4-inch square box. (Figure 1)

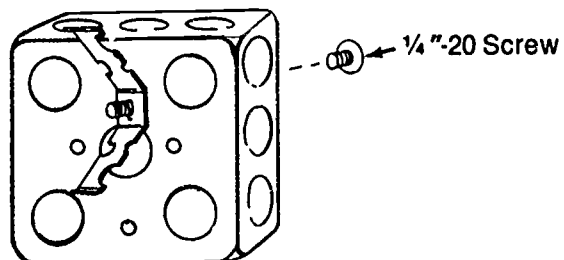
FIGURE 1



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4. Fasten rod-hanger clip to square box. (Figure 2)

FIGURE 2

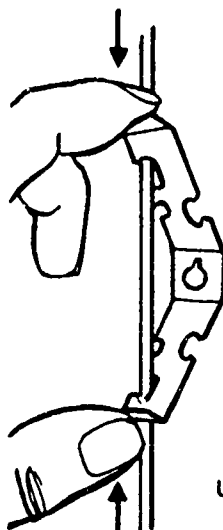


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**JOB SHEET #2**

5. Mount box and EMT to the two 1/2-inch rods. (See Figure 3)
6. Adjust to proper height (Figure 3)

FIGURE 3



Used with permission of ERICO Products, Inc.

7. Have instructor evaluate your project.
8. Clean work area; put away equipment and materials.

## ROUGH-IN UNIT V

### JOB SHEET #3 — INSTALL OUTLET BOXES ON STEEL STUDS USING CADDY METAL STUD CLIPS FOR SWITCH BOXES

#### A. Equipment and materials needed

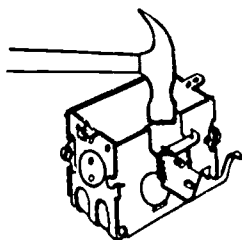
1. Hammer
2. 8-foot section of steel-stud wall
3. Three electrical boxes, Raco #560 or equivalent
4. 4-inch square electrical box, Raco #211 or equivalent
5. Handy box, Raco #660 or equivalent
6. Metal stud clip, Caddy #MSB-625 or equivalent
7. Four MF clips for switch boxes, Caddy #MF-625 or equivalent

#### B. Procedure

(NOTE: Boxes may be mounted at nondesignated places since intent of this job sheet is to acquaint students with box mounting methods when working with steel-stud walls.)

1. Mount metal stud clip to switch box. (Figure 1)

FIGURE 1

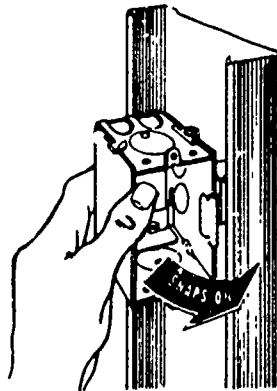


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**JOB SHEET #3**

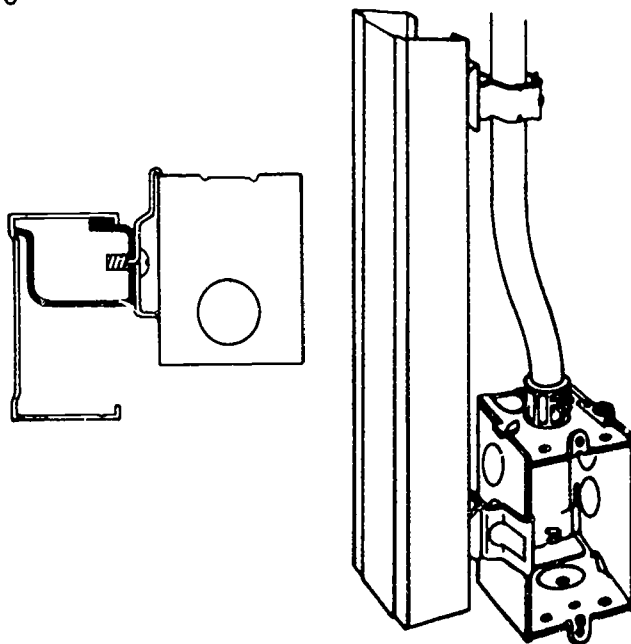
2. Mount box and clip to steel stud. (Figures 2 and 3)

FIGURE 2



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FIGURE 3

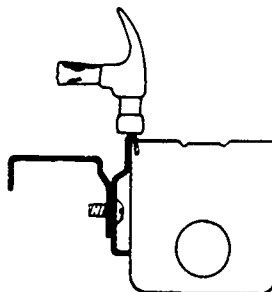


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**JOB SHEET #3**

3. Mount one MF clip on each of the other boxes. (Figure 4)

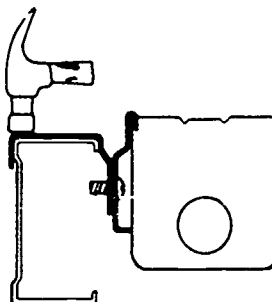
FIGURE 4



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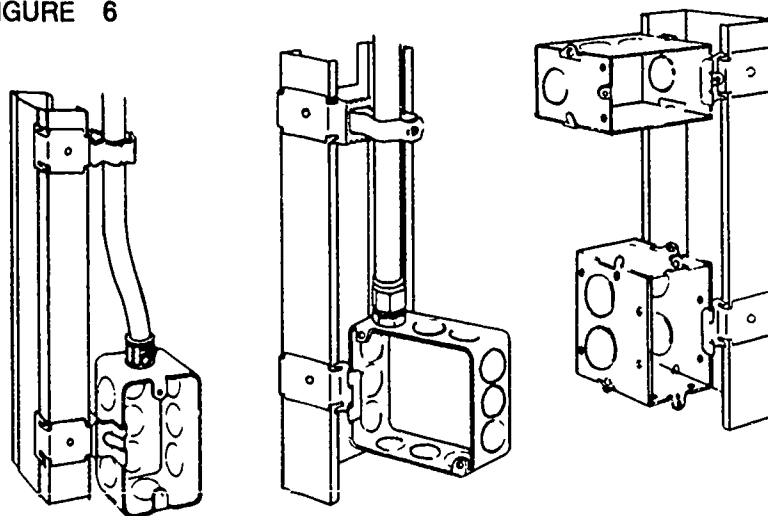
4. Mount clips and boxes to metal studs. (Figures 5 and 6)

FIGURE 5



Used with permission of ERICO Products, Inc.

FIGURE 6



Used with permission of ERICO Products, Inc.

5. Have instructor evaluate your work.  
6. Clean work area; put away equipment and materials.

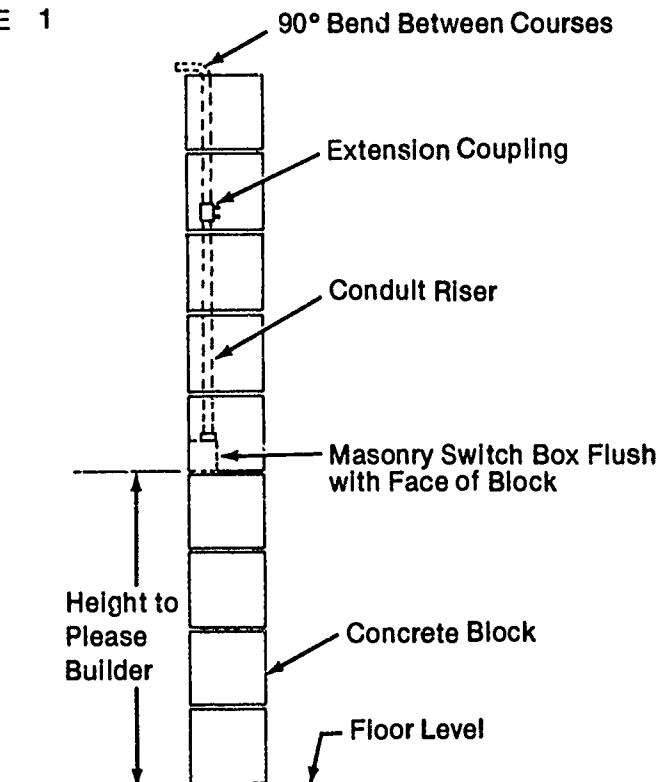
## ROUGH-IN UNIT V

### JOB SHEET #4 — INSTALL MASONRY BOXES IN A BLOCK WALL

#### A. Equipment and materials needed

1. Pouch tools
2. Hacksaw
3. Two masonry switch boxes, Raco #695 or equivalent
4. Two masonry two-gang boxes, Raco #696 or equivalent
5. 20 feet of 1/2-inch EMT
6. Four 1/2-inch EMT setscrew connectors
7. Four 1/2-inch EMT setscrew couplings
8. Conduit bender
9. Blueprint (Figure 1)

FIGURE 1





**JOB SHEET #4****B. Procedure**

(NOTE: This job must be done in cooperation with the masonry instructor because the electrical components are to be installed as the block wall is constructed.)

1. Open 1/2-inch knockout hole nearest to the back of box so that EMT will be in the hollow of the cement blocks.

(NOTE: Masonry boxes generally have concentric 1/2-inch and 3/4-inch knockout punchings; exercise care to break out only the 1/2-inch part.)

2. Cut eight pieces of 1/2-inch EMT, approximately 30 inches long.

(NOTE: Cut all eight pieces exactly the same length.)

3. Install 1/2-inch EMT connectors in each of the four masonry box knockout holes.

(NOTE: If during knockout removal, the 3/4-inch punching breaks out instead of the 1/2-inch punching, see your instructor. You will need two 3/4-inch by 1/2-inch reducing washers for each 3/4-inch hole to properly install 1/2-inch EMT.)

4. Install a 30-inch piece of EMT in each connector.

(NOTE: The person laying the blocks must install each block down over the vertical conduit.)

5. Deliver the made-up boxes to the block layer.

(NOTE: The electrician and the block layer must work together to be sure that the boxes are installed in the proper locations, and correctly installed with the EMT extending upward in the wall. See Figure 1.)

6. When the block wall reaches desired height, install the masonry boxes with conduit extending upward.

7. Supervise the installation of the next layers of blocks until only a short portion of the conduit is visible above the wall.

(NOTE: The block mason must raise the blocks above the height of the conduit, and then lower the next blocks over the conduit so that it extends upward through the hollow of the blocks.)

8. Install 30-inch pieces of conduit equipped with couplings to increase the height for next layers of blocks.

(NOTE: The conduit is extended upward 2 or 3 feet at a time as the height of the wall increases.)

**JOB SHEET #4**

9. Make a 90-degree bend in the conduit when the wall and conduit reach required height.  
  
(NOTE: A 90-degree bend will allow the conduit to stick out of the wall between courses. This will prevent having to cut into the blocks.)
10. Have the instructor evaluate your work.
11. Clean work area; put away equipment and materials.

## ROUGH-IN UNIT V

### PRACTICAL TEST JOB SHEET #1 — ROUGH-IN A WOOD FRAMED WALL

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Mounted box on stud for $\frac{5}{8}$ -inch Sheetrock.	_____	_____
3. Marked studs where boxes are located.	_____	_____
4. Placed boxes on floor where they are to be installed.	_____	_____
5. Measured boxes on studs.	_____	_____
6. Installed switch boxes.	_____	_____
7. Installed octagonal box outlet.	_____	_____
8. Installed 4" x 4" box.	_____	_____
9. Mounted plaster ring.	_____	_____
10. Checked in/put away tools and materials.	_____	_____
11. Cleaned the work area.	_____	_____
12. Used proper tools correctly.	_____	_____
13. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
14. Practiced safety rules throughout procedure.	_____	_____
15. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Allowed for $\frac{5}{8}$ -inch Sheet-rock				
Wall measurements correct				
Bar hanger correctly fastened to studs				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## ROUGH-IN UNIT V

### PRACTICAL TEST JOB SHEET #2 — INSTALL OUTLET BOXES ON STEEL RODS

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Installed 1/2-inch rods.   | _____ | _____ |
| 3. Mounted hangers, clamps.   | _____ | _____ |
| 4. Installed 1/2-inch EMT.  | _____ | _____ |
| 5. Fastened box.  | _____ | _____ |
| 6. Mounted EMT on rods.   | _____ | _____ |
| 7. Adjusted proper height.  | _____ | _____ |
| 8. Installed 1/2-inch EMT to box.                                   | _____ | _____ |
| 9. Checked in/put away tools and materials.                         | _____ | _____ |
| 10. Cleaned the work area.  | _____ | _____ |
| 11. Used proper tools correctly.                                    | _____ | _____ |
| 12. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 13. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 14. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Rods installed properly				
Hanger mounted correctly				
Box fastened properly				
EMT level				
Box connected to EMT				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_  
 \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## ROUGH-IN UNIT V

### PRACTICAL TEST JOB SHEET #3 — INSTALL OUTLET BOXES ON STEEL STUDS USING CADDY METAL CLIPS FOR SWITCH BOXES

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Mounted metal stud clip to switch box.	_____	_____
3. Mounted box to stud.	_____	_____
4. Mounted MF clip to box.	_____	_____
5. Mounted clips and box to studs.	_____	_____
6. Checked in/put away tools and materials.	_____	_____
7. Cleaned the work area.	_____	_____
8. Used proper tools correctly.	_____	_____
9. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
10. Practiced safety rules throughout procedure.	_____	_____
11. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Clip mounted to box				
Boxes mounted to stud correctly				
MF clip mounted to box				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)



## ROUGH-IN UNIT V

### PRACTICAL TEST JOB SHEET #4 — INSTALL MASONRY BOXES IN A BLOCK WALL

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Opened 1/2-inch knockout.  | _____ | _____ |
| 3. Cut EMT 30 inches long.  | _____ | _____ |
| 4. Installed EMT in boxes.  | _____ | _____ |
| 5. Installed couplings to extend EMT.                               | _____ | _____ |
| 6. Made 90 degree bend on EMT.                                      | _____ | _____ |
| 7. Checked in/put away tools and materials.                         | _____ | _____ |
| 8. Cleaned the work area.   | _____ | _____ |
| 9. Used proper tools correctly.                                     | _____ | _____ |
| 10. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 11. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 12. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
All pieces of EMT cut the same length approximately 30"				
Connector connected in box properly				
Coupling connected properly				
90 degree correct				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# ROUGH-IN UNIT V

## TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

- |         |  |                            |
|---------|--|----------------------------|
| _____a. | Assigning colors to conductors based on their uses.  | 1. Ampacity                |
| _____b. | The systematic diagnosis of a malfunction  | 2. Cable benders           |
| _____c. | An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the National Electrical Code | 3. Copper-clad aluminum    |
| _____d. | The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating                  | 4. Color coding            |
| _____e. | Strong rope of nylon or other substance used to pull heavy conductors into raceways  | 5. Covered                 |
| _____f. | Maximum voltage at which a device is designed to operate   | 6. Cross-sectional area    |
| _____g. | Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway   | 7. Drop chain              |
| _____h. | Establishing a connection between two points so a cable or length of flexible conduit can be installed   | 8. Fish                    |
| _____i. | Mechanical or hydraulic devices used to bend heavy conductors in panels and junction boxes   | 9. Fish wire               |
| _____j. | Conductor encased within material of composition and thickness not recognized by the <i>National Electrical Code</i> as electrical insulation        | 10. Insulated              |
|         |  | 11. Pipe chase             |
|         |  | 12. Power fish-tape system |
|         |  | 13. Pull rope              |
|         |  | 14. Raceway                |
|         |  | 15. Trim out               |
|         |  | 16. Troubleshooting        |
|         |  | 17. Voltage rating         |
|         |  | 18. Wire dispenser         |
|         |  | 19. Wire-pulling compound  |
|         |  | 20. Winch                  |

## TEST

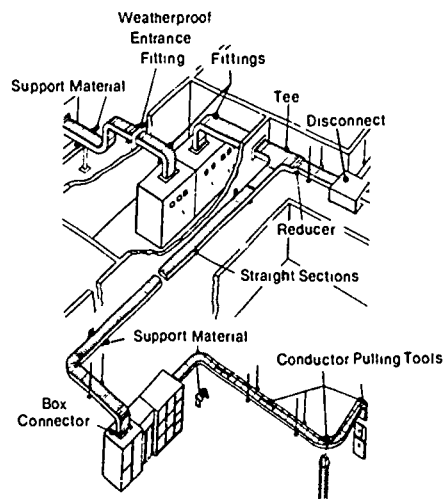
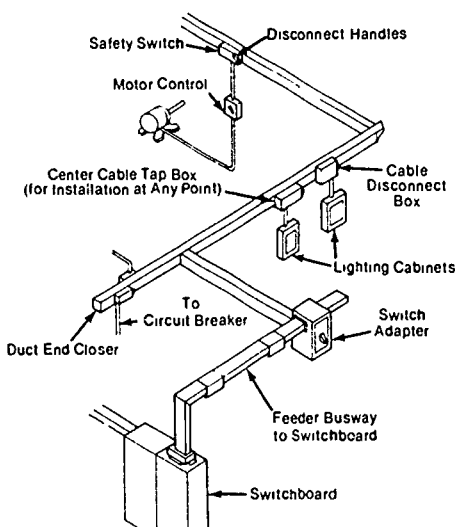
- \_\_\_\_\_k. Final stage in a wiring project; involves devices and plates, connecting and securing equipment, hanging fixtures, and testing the system
- \_\_\_\_\_l. Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway
- \_\_\_\_\_m. Aluminum conductor with an outer coating of copper metallurgically bonded to the aluminum core
- \_\_\_\_\_n. Area in square inches allowed in a conduit or tubing; area required for conductors in a conduit or tubing
- \_\_\_\_\_o. Usually a vertical space between two floors, dedicated for the running of pipes and conduits between floors
- \_\_\_\_\_p. Short length of small chain used to pull conductors or flexible conduit through an enclosed space or wall cavity
- \_\_\_\_\_q. Length of wire with a hook formed in one end to catch material to be installed in a space
- \_\_\_\_\_r. Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation
- \_\_\_\_\_s. Manual or motor-powered mechanical device used to pull conductors into a raceway
- \_\_\_\_\_t. Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls

## TEST

2. Select true statements concerning branch circuit and feeder installation by placing an "X" in the blanks preceding the true statements.

- \_\_\_\_\_a. When using multi-phase circuitry, balancing must take place to regulate the even flow of current on each of the phases.
- \_\_\_\_\_b. Color coding for a high leg delta 4-wire system must be marked with yellow color and must be located on center lug.
- \_\_\_\_\_c. When identifying neutrals, the NEC states that conductors not white must be marked with continuous white or gray tape, or white paint.
- \_\_\_\_\_d. Temporary lighting shall be protected from accidental contact or breakage by a suitable fixture or lampholder with a guard.

3. Identify devices used in special circuit installations.



a. \_\_\_\_\_

b. \_\_\_\_\_

## TEST

4. Arrange in order the steps for determining the number of conductors allowed in a conduit based on cross-sectional area by numbering from 1 to 5.
- \_\_\_\_\_a. Compute total area occupied by existing conductors based on Table 5, Chapter 9 of the NEC.
  - \_\_\_\_\_b. Determine size of existing conduit.
  - \_\_\_\_\_c. Determine number of conductors that may be added.
  - \_\_\_\_\_d. Find area of conduit or tubing using Table 4, Chapter 9 of the NEC.
  - \_\_\_\_\_e. Determine number and size of existing conductors.
5. List two exceptions to the NEC requirements for support of flexible metal conduit.
- a. \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
  - b. \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
6. Complete the following list of statements concerning conditions for using the optional calculations for additional loads to existing installations by inserting the word which best completes each statement.
- a. The maximum demand data is available in KVA for a minimum of a \_\_\_\_\_ period.
  - b. The existing demand at 125 percent plus the new load does not exceed the ampacity of the feeders or \_\_\_\_\_ of the service.
  - c. The feeder or service has \_\_\_\_\_ in accordance with sections 230-90 and 240-3 of the NEC.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

7. Determine the number of conductors allowed to be added to an existing conduit. (Assignment Sheet #1)

**TEST**

8. Demonstrate the ability to:
  - a. Rough-in a wood framed wall. (Job Sheet #1)
  - b. Install outlet boxes on steel rods. (Job Sheet #2)
  - c. Install outlet boxes on steel studs using caddy metal stud clips for switch boxes. (Job Sheet #3)
  - d. Install masonry boxes in a block wall. (Job Sheet #4)

**ROUGH-IN  
UNIT V****ANSWERS TO TEST**

1.   a.    4                   e.    12                   i.    11                   m.    7  
      b.    9                   f.    10                   j.    3  
      c.    1                   g.    2                   k.    6  
      d.    8                   h.    5                   l.    13
2.   a, c, d
3.   a.    Buss-duct  
      b.    Cable tray
4.   a.    4  
      b.    1  
      c.    5  
      d.    3  
      e.    2
5.   Any two of the following:
  - a.    Where flexible metal conduit is fished
  - b.    Lengths not exceeding three feet
  - c.    Lengths not exceeding six feet from a fixture terminal connection to lighting fixtures
6.   a.    One year  
      b.    Rating  
      c.    Overcurrent protection
7.   Evaluated to the satisfaction of the instructor
8.   Performance skills evaluated to the satisfaction of the instructor



## **LIGHTING UNIT VI**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to troubleshoot and repair lighting fixtures. Competencies will be demonstrated by completing the assignment sheet, job sheets, and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to lighting with their correct definitions.
2. List three basic types of lighting.
3. Select true statements concerning characteristics of incandescent lighting.
4. Complete statements concerning characteristics of fluorescent lighting.
5. Complete statements concerning characteristics of high intensity discharge lamps.
6. List three methods of calculating light.
7. Complete statements concerning calculating branch circuits and voltage.
8. Select true statements concerning switching systems.
9. Locate articles in the NEC concerning lighting requirements. (Assignment Sheet #1)

## OBJECTIVE SHEET

10. Demonstrate the ability to:
  - a. Change a two lamp ballast in a fluorescent fixture. (Job Sheet #1)
  - b. Change sockets in a fluorescent fixture. (Job Sheet #2)
  - c. Change an HID ballast. (Job Sheet #3)
  - d. Change a quartz lamp. (Job Sheet #4)

## LIGHTING UNIT VI

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Provide students with objective sheet.
- C. Discuss unit and specific objectives.
- D. Provide students with information and assignment sheets.
- E. Discuss information and assignment sheets.
- F. Provide students with job sheets.
- G. Discuss and demonstrate the procedures outlined in the job sheets.
- H. Integrate the following activities throughout the teaching of this unit:
1. Invite a representative from a ballast company to show and discuss the various types of ballasts and their functions.
  2. Show a film on advance ballast lighting.
  3. Set up a display of the various types of lighting and point out special features.
  4. Take students on a field trip to view different types of lighting used in commercial and industrial buildings.
  5. Provide students with a copy of Handout #1 — Troubleshooting Procedures. Discuss and demonstrate procedures.
  6. Provide students with troubleshooting problems to practice the procedures listed in Handout #1.
  7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- I. Give test.
- J. Evaluate test.
- K. Reteach if necessary.

## REFERENCES USED IN WRITING THIS UNIT

- A. Mullin/Smith. *Electrical Wiring (Commercial)*. Albany, NY: Delmar Publishers, 1984.
- B. *Pocket Guide to Flourescent Lamp Ballasts*. Carrollton, TX: Advance Transformer Company, 1986.
- C. *Pocket Guide to HID Lamp Ballasts*. Carrollton, TX: Advance Transformer Company, 1986.

(NOTE: Copies of the pocket guides listed in B and C may be obtained by writing to Advance Transformer Company, 1435 Bradley Lane, Suite 157, Carrollton, TX 75007.)

## SUGGESTED SUPPLEMENTAL MATERIAL

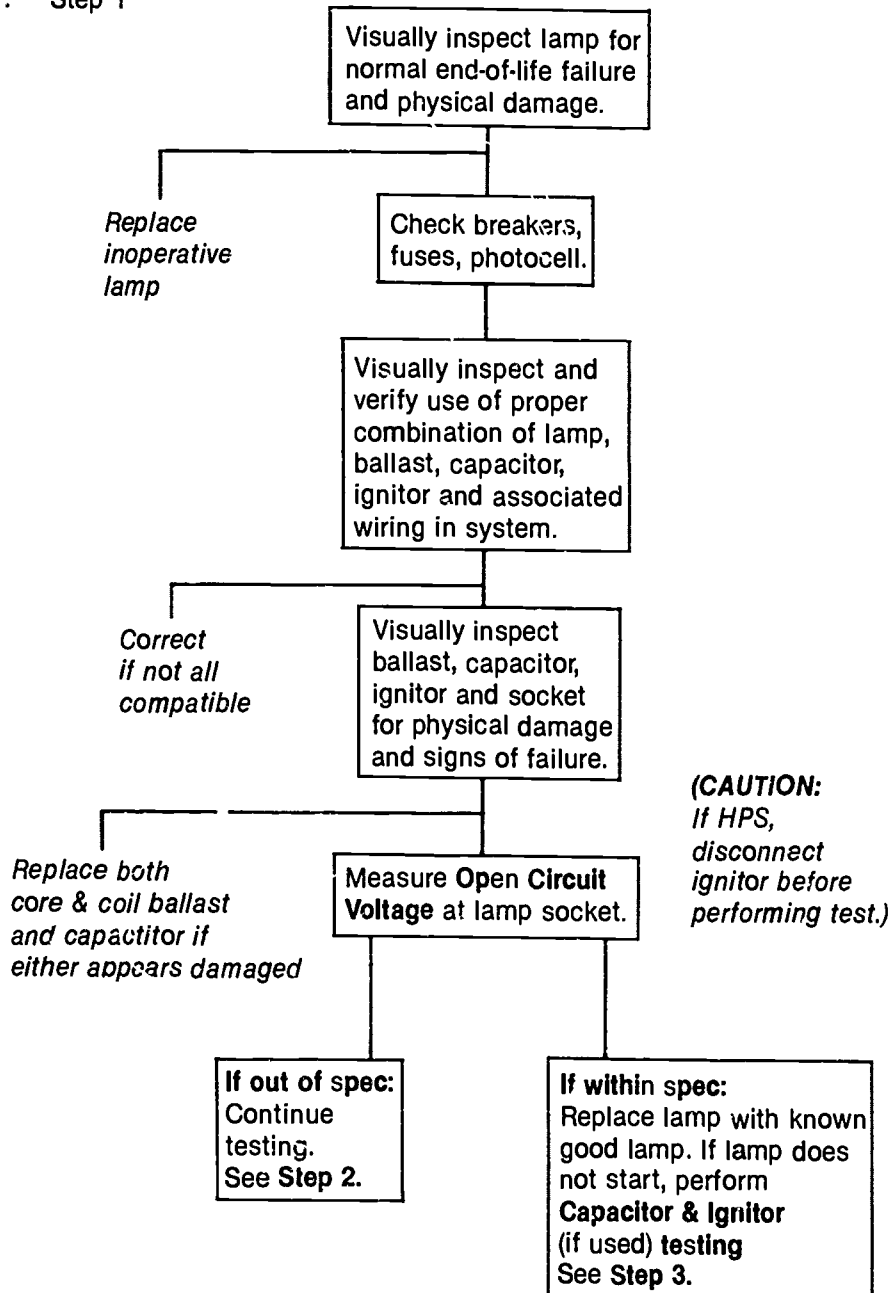
Film — *HID Lighting*. Advance Transformer Company, 1435 Bradley Lane, Suite 157, Carrollton, TX 75007.

# LIGHTING UNIT VI

## HANDOUT #1 — TROUBLESHOOTING PROCEDURES

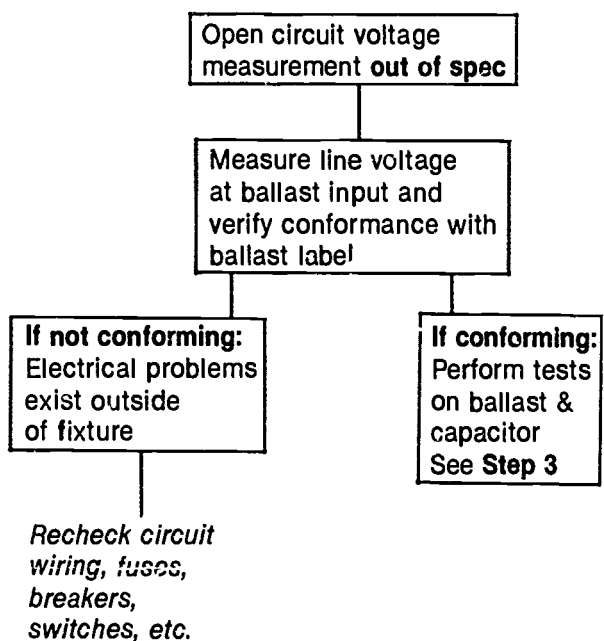
### A. Lamp will not start

#### 1. Step 1

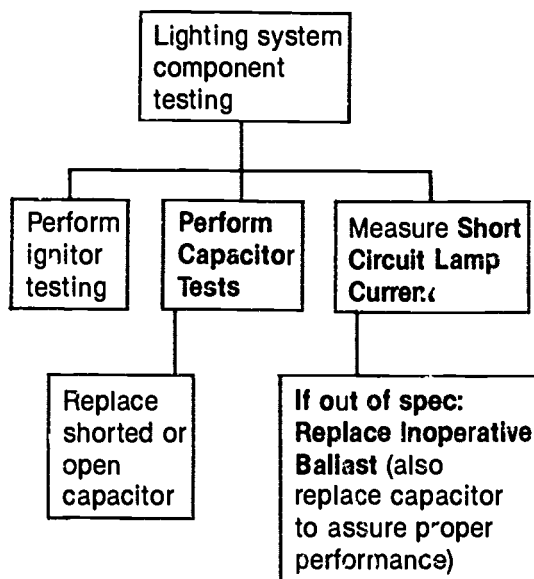


## HANDOUT #1

## 2. Step 2

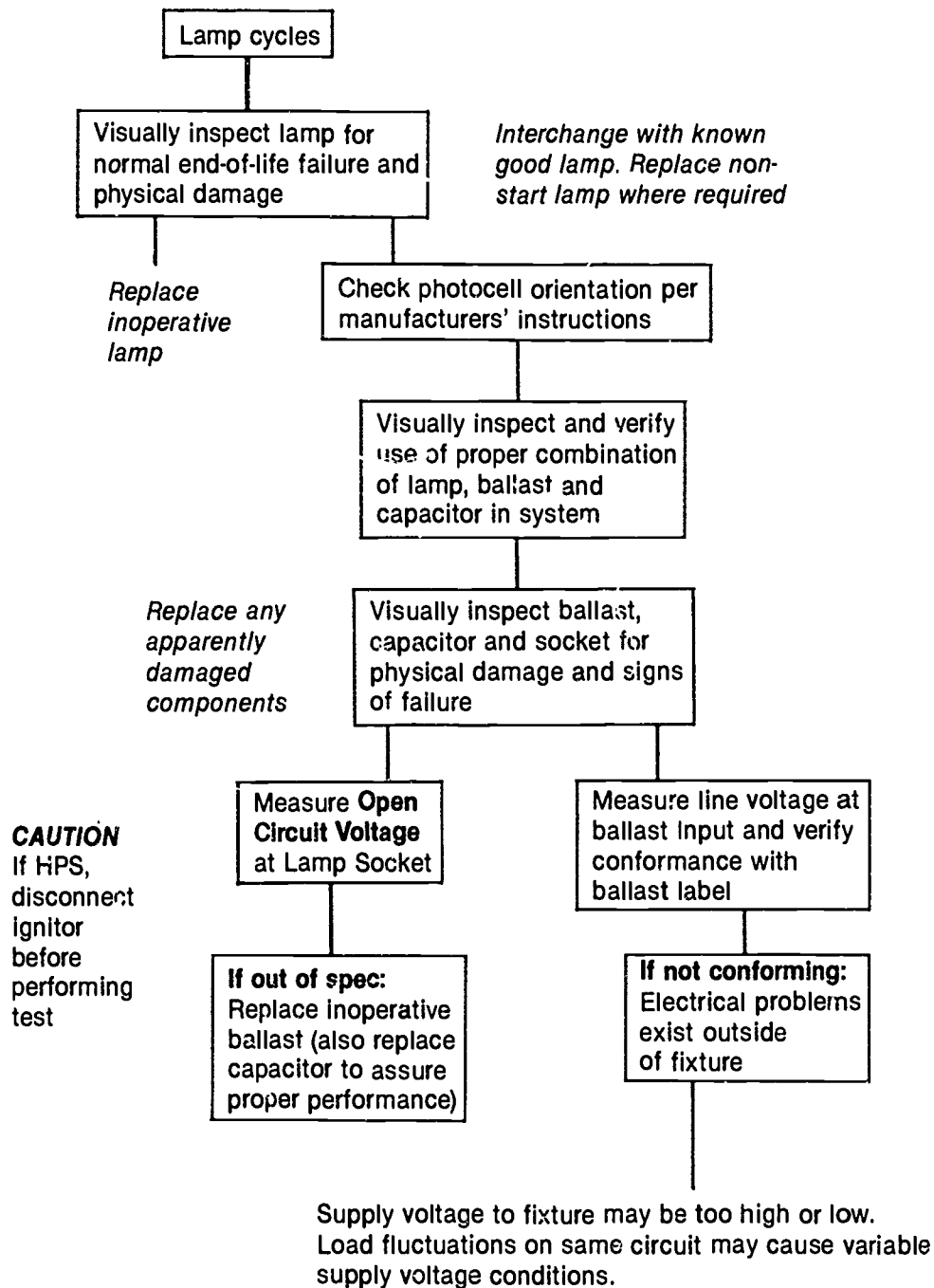


## 3. Step 3



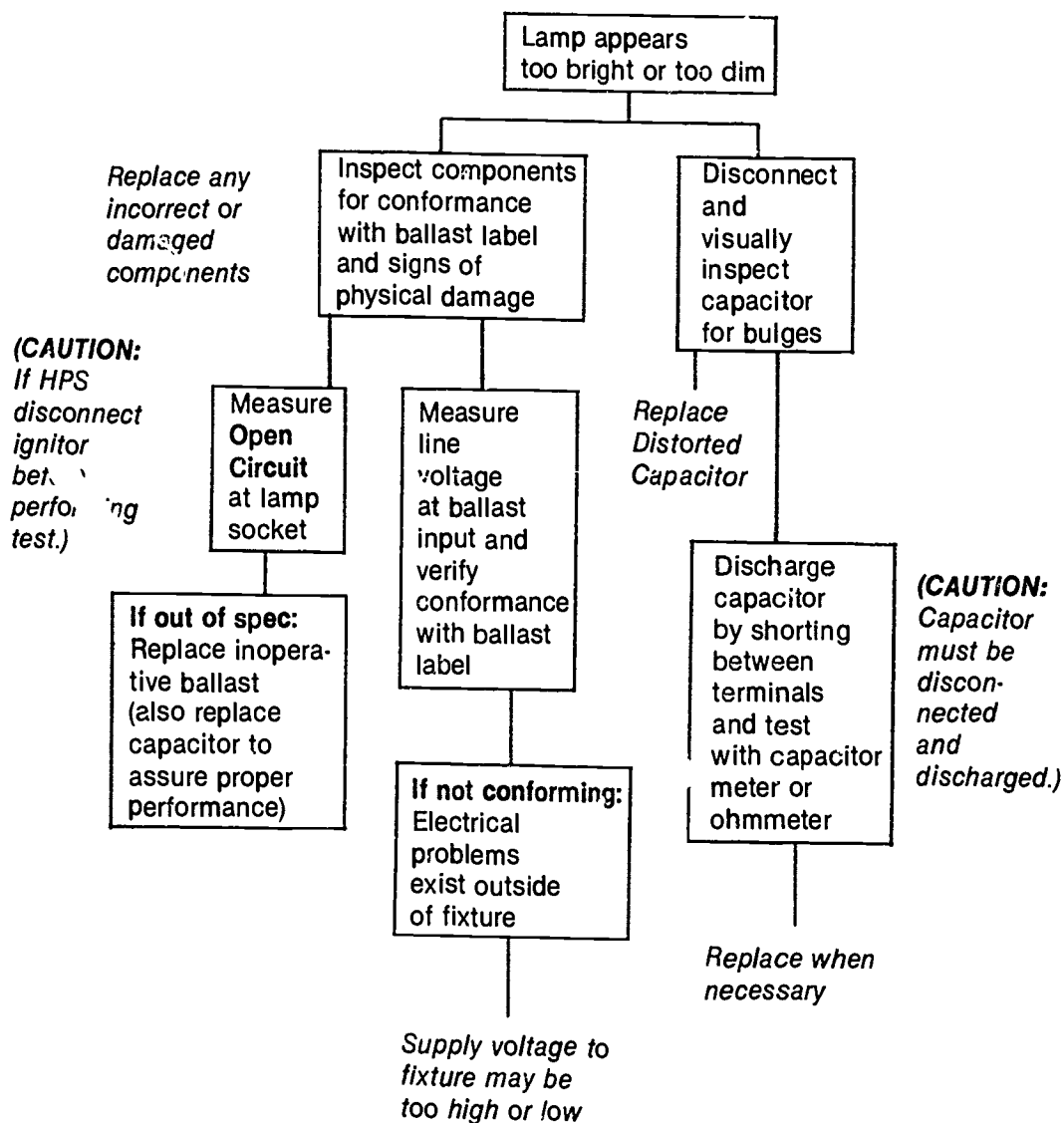
## HANDOUT #1

## B. Lamp cycles



## HANDOUT #1

## C. Lamp too bright or dim



Courtesy of Advance Transformer Company.



## LIGHTING UNIT VI

### INFORMATION SHEET

#### I. Terms and definitions

- A. B — Blue lamp
- B. Ballast — Transformer used in lighting circuits
- C. Cathode — Coiled coil or triple coil tungsten wire at each end of lamp which is coated with material which emits electrons
- D. Coefficient — The square root of the ratio of the power reflected from a surface to the power incident of the same surface
- E. CW — Cool white lamp
- F. D — Daylight lamp
- G. Fluorescent lighting — Electric discharge lighting
- H. FC — Foot-candles
- I. G — Green lamp
- J. HID — High intensity discharge
- K. Incandescent lighting — Consists of a filament which is a highly refractory conductor mounted in a transparent or translucent glass bulb
- L. Lumens — A unit of light emitted from a point light source of one candle through a unit solid angle
- M. PK — Pink lamp
- N. Photocell — Light activated switch
- O. Photometer — Instrument used in determining lumens
- P. Phosphor — Coating inside a fluorescent bulb to determine the color of light
- Q. W — White lamp
- R. WW — Warm white lamp

#### II. Basic types of lighting

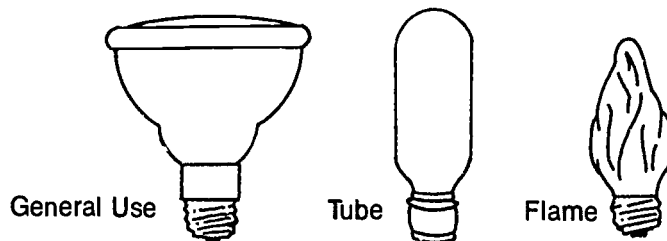
- A. Incandescent
- B. Fluorescent
- C. High intensity discharge (HID)

## INFORMATION SHEET

### III. Characteristics of incandescent lighting

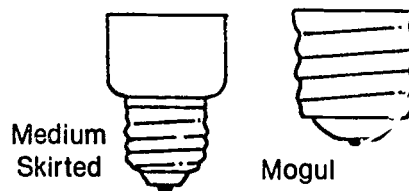
- A. It has the lowest efficiency rating of any lamp, but is the most popular type used because of the low cost.
- B. Incandescent lamps come in many different sizes and shapes.

EXAMPLES:



- C. Incandescent lamps have different bases.

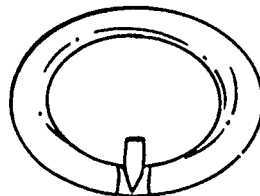
EXAMPLES:



### IV. Characteristics of fluorescent lighting

- A. Classification of fluorescent lamps are determined by the type, length or wattage, shape and color.

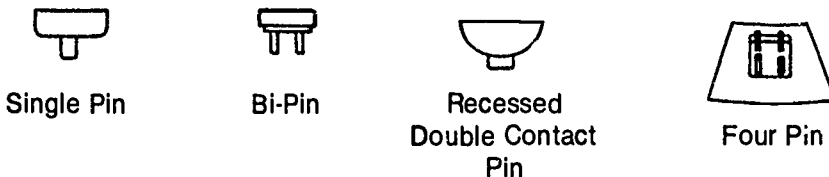
EXAMPLE:



- B. The color of a fluorescent lamp depends on the phosphor used inside the bulb. Different colors are usually marked on the lamp as WW—warm white, D—daylight, W—white, CW—cool white, WW—warm white, B—blue, PK—pink, and G—green.

## INFORMATION SHEET

- C. There are four types of contacts found in tube bases of fluorescent lamps.



- D. There are three types of fluorescent tubes: preheat, rapid-start, and instant-start.
- E. The ballast is necessary to start the tube and to stabilize the current flow. Without it the fluorescent light would quickly burn itself out.

### V. Characteristics of high intensity discharge (HID) lamps

- A. There are four basic types of HID lamps used in the lighting industry: mercury, metal halide, high pressure sodium, and low pressure sodium.
- B. Mercury and metal halide lamps have an additional electrode to assist lamp starting while high pressure sodium, low pressure sodium, and some newer metal halide lamps have no starting electrodes.
- C. There are disadvantages and advantages when using high intensity discharge lighting.
1. Disadvantages — HID lighting takes longer to reach full output. When power is lost, HID lighting goes through a cooling period before coming back on. Emergency back up lighting is generally used when an HID system is in operation.

Light Source	Warm-Up Time	Restrike Time
Mercury Vapor	5-7 minutes	3-6 minutes
Metal Halide	2-5 minutes	10-20 minutes
High Pressure Sodium	3-4 minutes	1/2-1 minutes
Low Pressure Sodium	7-10 minutes	3-12 minutes

2. Advantages — HID lighting provides a greater lumens-per-watt for the cost of operation. HID lighting is less expensive to operate than any other source of lighting. HID lighting also has fewer maintenance problems.

## INFORMATION SHEET

### VI. Methods of calculating light

- A. Foot-candles may be calculated when the lumens and square feet are known.

(NOTE: The intensity of light at a distance from the source is expressed in foot-candles or in lumens.)

$$\text{Footcandles} = \frac{\text{Lumens on a surface}}{\text{Area of surface in sq. ft.}}$$

- B. To obtain the output of a light source in lumens when spherical candle power is known, use

$$F = 12.57 \times I \text{ LM}$$

- C. A photometer is an instrument used in determining the luminous intensity, in candles, of a light source.

### VII. Calculating branch circuits and voltage

- A. When calculating branch circuits for lighting loads of not less than that specified in NEC Table 220-3(b), the minimum lighting load for each square foot is 0.093 square meters of floor area.
- B. If line voltage is higher or lower than that for which the ballast was designed, this condition can affect lamp life, ballast life, and lamp light output. Ballasts should operate within  $\pm 7 \frac{1}{2}\%$  of rated voltage.

### VIII. Switching systems

- A. Switches, photocells, and magnetic lighting contactors may be used to control lighting circuits.
- B. Switches may be used for controlling lighting circuits when the amperes are within the rating of the switch.
- C. A photocell is a switch activated by light or sunlight. It may be used for controlling lights within its ampacity or can control a lighting contactor.
- D. Lighting contactors are used when photocells and switches cannot control the lighting amperage. Photocells and switches may then be used as control circuits for a lighting contactor.
- E. Switches and dimmers may be used on fluorescent and HID lighting. The output of fluorescent or HID lamps can be adjusted by holding a constant voltage on the cathodes and controlling the current passing through the lamp. Thyristors, silicon-controlled rectifiers, and autotransformers can provide this type of control.

## LIGHTING UNIT VI

### ASSIGNMENT SHEET #1 — LOCATE ARTICLES IN THE NEC CONCERNING LIGHTING REQUIREMENTS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: List NEC article numbers for the following lighting conditions.

- A. Autotransformers \_\_\_\_\_
- B. Tapp conductors \_\_\_\_\_
- C. Emergency lighting switch requirements \_\_\_\_\_
- D. Wet and damp locations \_\_\_\_\_
- E. Transformer ratings \_\_\_\_\_
- F. Track lighting \_\_\_\_\_

# **LIGHTING UNIT VI**

## **ANSWERS TO ASSIGNMENT SHEET #1**

- A. 410-78
- B. 410-67(c)
- C. 700-20
- D. 410-4
- E. 410-83
- F. 410-103

## **LIGHTING UNIT VI**

### **JOB SHEET #1 — CHANGE A TWO LAMP BALLAST IN A FLOURESCENT FIXTURE**

#### **A. Equipment and materials needed**

1. Pouch tools
2. Eight wire nuts
3. Two lamp ballast
4. Safety glasses

#### **B. Procedure**

1. Put on safety glasses.
2. Disconnect power.
3. Remove ballast cover from fixture.
4. Cut wires 6" from ends of socket.

(NOTE: Do not cut wires less than 6" as this will void warranty.)

5. Remove c ballast.
6. Install new ballast.

(NOTE: Check warranty date on ballast. Most ballasts are under warranty for one year.)

7. Re-connect conductors back by color.
8. Re-connect power.
9. Install ballast cover plate.
10. Install lamps.
11. Apply power and check fixture operation.

(NOTE: Have instructor check project before power is applied.)

12. Clean work area; put away all equipment and materials.

## LIGHTING UNIT VI

### JOB SHEET #2 — CHANGE SOCKETS IN A FLOURESCENT FIXTURE

A. Equipment and materials needed

1. Pouch tools
2. Eight two-pin fixture sockets
3. Safety glasses

B. Procedure

1. Put on safety glasses.
2. Disconnect power.
3. Remove ballast cover from fixture.
4. Remove socket end plate.
5. Remove one socket at a time and replace with new.
6. Install socket end plate.
7. Re-connect power.
8. Install ballast cover plate.
9. Apply power and check fixture operation.

(NOTE: Have instructor check project before power is applied.)

10. Clean work area; put away all equipment and materials.



## LIGHTING UNIT VI

### JOB SHEET #3 — CHANGE AN HID BALLAST

A. Equipment and materials needed

1. Pouch tools
2. HID ballast
3. 12 yellow wire outs

B. Procedure

1. Disconnect power.
2. Remove cover from fixture.
3. Check old ballast voltage to new ballast.
4. Cut old ballast wiring.
5. Remove old ballast.
6. Install new ballast.
7. Connect new ballast.
8. Install cover plate.
9. Apply power and check fixture operation.  
(NOTE: Have instructor check project before power is applied.)
10. Clean work area; put away all equipment and materials.

## LIGHTING UNIT VI

### JOB SHEET #4 — CHANGE A QUARTZ LAMP

(NOTE: A quartz lamp must never be touched by hands because the oil on your skin will cause the lamp to burn out. Use a paper towel or rag that does not contain any oily products to change the lamp.)

A. Equipment and materials needed

1. Pouch tools
2. Paper towels or clean rags
3. Quartz lamp

B. Procedure

1. Disconnect power.
2. Open cover to fixture.
3. Remove old lamp.
4. Install new lamp with towel or rag.
5. Close cover to fixture.
6. Apply power and check fixture operation.

(NOTE: Have instructor check project before power is applied.)

7. Clean work area; put away all equipment and materials.

## LIGHTING UNIT VI

### JOB SHEET #1 PRACTICAL TEST — CHANGE A TWO LAMP BALLAST IN A FLOURESCENT FIXTURE

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Disconnected power.  | _____ | _____ |
| 3. Removed old ballast.   | _____ | _____ |
| 4. Installed new ballast.   | _____ | _____ |
| 5. Made connection to color code.                                   | _____ | _____ |
| 6. Installed lamps.   | _____ | _____ |
| 7. Reconnected power and tested.                                    | _____ | _____ |
| 8. Checked in/put away tools and materials.                         | _____ | _____ |
| 9. Cleaned the work area.   | _____ | _____ |
| 10. Used proper tools correctly.                                    | _____ | _____ |
| 11. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 12. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 13. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ballast installed properly				
Connections tight				
Lamps installed correctly				
Project works				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## LIGHTING UNIT VI

### JOB SHEET #2 PRACTICAL TEST — CHANGE SOCKETS IN A FLOURESCENT FIXTURE

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Disconnected power.  | _____ | _____ |
| 3. Removed ballast and socket end plate.                            | _____ | _____ |
| 4. Installed sockets one at a time.                                 | _____ | _____ |
| 5. Installed ballast cover and end plate.                           | _____ | _____ |
| 6. Installed lamps.   | _____ | _____ |
| 7. Reconnected power and checked.                                   | _____ | _____ |
| 8. Checked in/put away tools and materials.                         | _____ | _____ |
| 9. Cleaned the work area.   | _____ | _____ |
| 10. Used proper tools correctly.                                    | _____ | _____ |
| 11. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 12. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 13. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Sockets wired correctly				
Connections tight				
Lamps installed correctly				
Project works				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## LIGHTING UNIT VI

### JOB SHEET #3 PRACTICAL TEST — CHANGE AN HID BALLAST

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Power disconnected.  | _____ | _____ |
| 3. Removed old ballast.   | _____ | _____ |
| 4. Installed new ballast.   | _____ | _____ |
| 5. Reconnected new ballast.   | _____ | _____ |
| 6. Installed cover plate.   | _____ | _____ |
| 7. Connected power.   | _____ | _____ |
| 8. Checked in/put away tools and materials.                         | _____ | _____ |
| 9. Cleaned the work area.   | _____ | _____ |
| 10. Used proper tools correctly.                                    | _____ | _____ |
| 11. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 12. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 13. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Voltages match				
Ballast installed correctly				
Project works				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)



## LIGHTING UNIT VI

### JOB SHEET #4 PRACTICAL TEST — CHANGE A QUARTZ LAMP

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Power disconnected.  | _____ | _____ |
| 3. Opened cover to fixture.   | _____ | _____ |
| 4. Removed old lamp.  | _____ | _____ |
| 5. Installed new lamp with rag or towel.                            | _____ | _____ |
| 6. Applied power.   | _____ | _____ |
| 7. Checked in/put away tools and materials.                         | _____ | _____ |
| 8. Cleaned the work area.   | _____ | _____ |
| 9. Used proper tools correctly.                                     | _____ | _____ |
| 10. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 11. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 12. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
New lamp installed correctly				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# LIGHTING UNIT VI

## TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

- |  |                           |
|--|---------------------------|
| _____a. Green lamp   | 1. B                      |
| _____b. Light activated switch   | 2. Ballast                |
| _____c. White lamp   | 3. Cathode                |
| _____d. Foot-candles   | 4. Coefficient            |
| _____e. Transformer used in lighting circuits  | 5. CW                     |
| _____f. Electric discharge lighting  | 6. D                      |
| _____g. Instrument used in determining lumens  | 7. Fluorescent lighting   |
| _____h. Warm white lamp  | 8. FC                     |
| _____i. Coating inside a fluorescent bulb to determine the color of light  | 9. G                      |
| _____j. A unit of light emitted from a point light source of one candle through a unit solid angle                       | 10. HID                   |
| _____k. High intensity discharge   | 11. Incandescent lighting |
| _____l. Daylight lamp  | 12. Lumens                |
| _____m. Consists of a filament which is a highly refractory conductor mounted in a transparent or translucent glass bulb | 13. PK                    |
| _____n. Cool white lamp  | 14. Photocell             |
| _____o. Blue lamp  | 15. Photometer            |
| _____p. Coiled coil or triple coil tungsten wire at each end of lamp which is coated with material which emits electrons | 16. Phosphor              |
| _____q. Pink lamp  | 17. W                     |
| _____r. The square root of the ratio of the power reflected from a surface to the power incident of the same surface     | 18. WW                    |

## TEST

2. List the three basic types of lighting.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
  
3. Select true statements concerning characteristics of incandescent lighting by placing an "X" in the blanks preceding the true statements.
  - \_\_\_\_\_a. It has the highest efficiency rating of any lamp and is the most popular type because of the low cost.
  - \_\_\_\_\_b. Incandescent lamps come in many different sizes and shapes.
  - \_\_\_\_\_c. Incandescent lamps have different bases.
  
4. Complete the following statements concerning characteristics of fluorescent lighting by inserting the word(s) which best complete each statement.
  - a. Classifications of fluorescent lamps are determined by the type, length or wattage, shape and \_\_\_\_\_.
  - b. The color of a fluorescent bulb depends on the \_\_\_\_\_ used inside the bulb.
  - c. There are four types of contacts found on tube bases of fluorescent lamps: single pin, bipin, four pin and \_\_\_\_\_.
  - d. There are three types of fluorescent tubes: \_\_\_\_\_, rapid-start, and instant-start.
  - e. The ballast is necessary to start the tube and to \_\_\_\_\_ the current flow.
  
5. Complete the following statements concerning characteristics of high intensity discharge lamps by inserting the words which best complete each statement.
  - a. There are four basic types of HID lamps used in the lighting industry: \_\_\_\_\_, metal halide, high pressure sodium, and low pressure sodium.
  - b. \_\_\_\_\_ and \_\_\_\_\_ lamps have an additional electrode to assist lamp starting while others have no starting electrodes.
  - c. When power is lost, HID lighting goes through a \_\_\_\_\_ period before coming back on.
  - d. HID lighting provides a greater \_\_\_\_\_ for the cost of operation.

## TEST

6. List three methods of calculating light.

(HINT: Two methods use formulas to calculate light.)

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

7. Complete the following statements concerning calculating branch circuits and voltage by circling the numbers which best complete each statement.

- a. When calculating branch circuits for lighting loads of not less than that specified in NEC Table 220-3(b), the minimum lighting load for each square foot is (**0.039**, **0.093**) square meter of floor area.
- b. Ballasts should operate within (**+7 1/2%**, **+5 1/2%**) of rated voltage.

8. Select true statements concerning switching systems by placing an "X" in the blanks preceding the true statements.

- \_\_\_\_a. Switches, photocells, and magnetic lighting contactors may be used to control lighting circuits.
- \_\_\_\_b. A photocell is a switch activated by light or motion.
- \_\_\_\_c. Lighting contactors are used when photocells and switches control the lighting amperage.
- \_\_\_\_d. Switches and dimmers may be used on fluorescent and HID lighting.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

- 9. Locate articles in the NEC concerning lighting requirements. (Assignment Sheet #1)
- 10. Demonstrate the ability to:
  - a. Change a two lamp ballast in a fluorescent fixture. (Job Sheet #1)
  - b. Change sockets in a fluorescent fixture. (Job Sheet #2)
  - c. Change an HID ballast. (Job Sheet #3)
  - d. Change a quartz lamp. (Job Sheet #4)

# LIGHTING UNIT VI

## ANSWERS TO TEST

1.   a.    9                   e.    2                   i.    16                   m.   11                   q.   13  
      b.   14                  f.    7                   j.    12                   n.    5                   r.    4  
      c.   17                  g.   15                   k.   10                   o.    1  
      d.   8                   h.   18                   l.    6                   p.    3
  
2.   a.    Incandescent  
      b.    Flourescent  
      c.    High intensity discharge (HID)
  
3.   d, c
  
4.   a.    Color  
      b.    Phosphor  
      c.    Recessed double contact  
      d.    Preheat  
      e.    Stabilize
  
5.   a.    Mercury  
      b.    Mercury, metal halide  
      c.    Cooling  
      d.    Lumens-per-watt
  
6.   a.    Footcandles =  $\frac{\text{Lumens on a surface}}{\text{Area of surface in sq. ft.}}$   
      b.     $F = 12.57 \times I \text{ LM}$   
      c.    Photometer
  
7.   a.    0.093  
      b.    +7 1/2%
  
8.   a, d
  
9.   Evaluated to the satisfaction of the instructor
  
10.   Performance skills evaluated to the satisfaction of the instructor

## **MOTORS AND CONTROLLERS UNIT VII**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to identify common contactors and starters as well as typical motors. Competencies will be demonstrated by completing the assignment sheets, job sheets, and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to motors and controllers with their correct definitions.
2. Discuss direct current motor theory of operation.
3. List three types of DC motors.
4. Discuss single-phase motor theory of operation.
5. List five types of single phase motors.
6. Discuss three-phase motor theory of operation.
7. List three types of three-phase motors.
8. State the procedure for reversing a three-phase motor.
9. Select from a list typical supply voltage for three-phase motors.
10. Identify schematic and terminal connections for delta and wye wound three-phase motors.
11. Match motor problems with their typical symptoms.
12. Match remedies with the correct symptoms of motor problems.

## OBJECTIVE SHEET

13. Complete a list of safety rules to observe when working around motors.
14. List two types of contactors.
15. Identify parts of a manual contactor.
16. Select from a list electrical devices or circuits controlled by contactors.
17. Name two types of motor starters.
18. Identify two types of magnetic motor starters.
19. List three uses of magnetic motor starters.
20. Compare parts in magnetic contactors with parts in magnetic motor starters.
21. List three reasons a contactor cannot be used to control a motor.
22. State two purposes of a coil assembly.
23. Identify parts of a coil assembly.
24. Interpret nameplate information. (Assignment Sheet #1)
25. Describe remedies for common motor problems. (Assignment Sheet #2)
26. Use the National Electrical Code to answer questions about motor control circuits. (Assignment Sheet #3)
27. Distinguish between motor starters and contactors. (Assignment Sheet #4)
28. Answer questions about uses of contactors and motor starters. (Assignment Sheet #5)
29. Demonstrate the ability to:
  - a. Disassemble, inspect, and clean a motor. (Job Sheet #1)
  - b. Identify run, common, and start terminals on a hermetically sealed motor. (Job Sheet #2)
  - c. Test capacitors with an ohmmeter. (Job Sheet #3)
  - d. Wire a three-phase motor for dual voltages. (Job Sheet #4)
  - e. Perform maintenance on a magnetic motor starter or contactor. (Job Sheet #5)



## MOTORS AND CONTROLLERS UNIT VII

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Make transparencies from the transparency masters included with this unit.
- C. Provide students with objective sheet.
- D. Discuss unit and specific objectives.
- E. Provide students with information and assignment sheets.
- F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

- G. Provide students with job sheets.
- H. Discuss and demonstrate the procedures outlined in the job sheets.
- I. Integrate the following activities throughout the teaching of this unit:
1. Visit a motor winding shop.
  2. Visit a local industry and view types of motors and controllers used.
  3. Invite a local maintenance or industrial electrician to speak on the importance of controls and motors.
  4. Teach and test this unit in two parts: Objectives 1-13 and Objectives 14-23.
  5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- J. Give test.
- K. Evaluate test.
- L. Reteach if necessary.

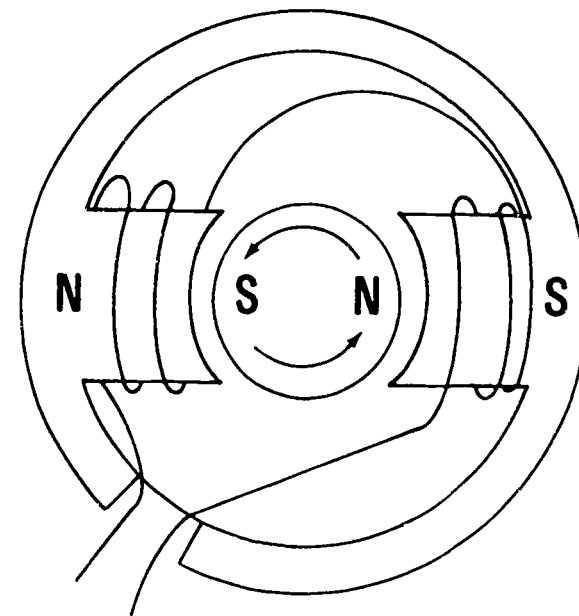
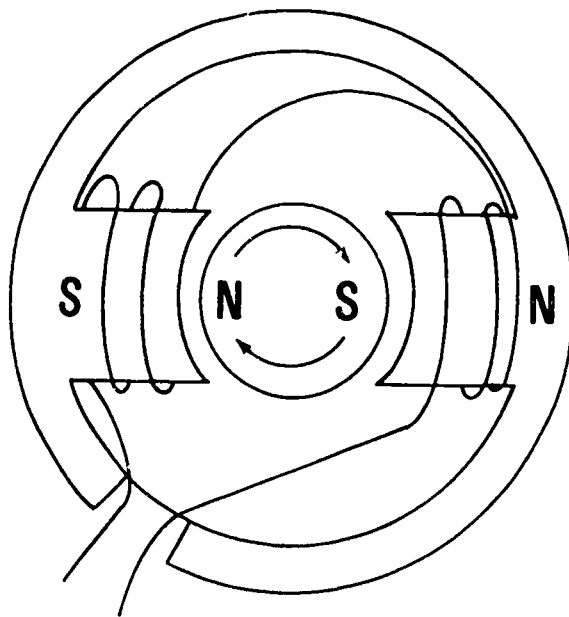
### REFERENCES USED IN WRITING THIS UNIT

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- B. *National Electrical Code, 1987*. Quincy, MA: National Fire Protection Association, 1986.
- C. Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

### SUGGESTED SUPPLEMENTAL MATERIAL

Slide tape series — *Rotating Machinery Explained*. Bergwall.

## Magnetic Poles in an Electric Motor

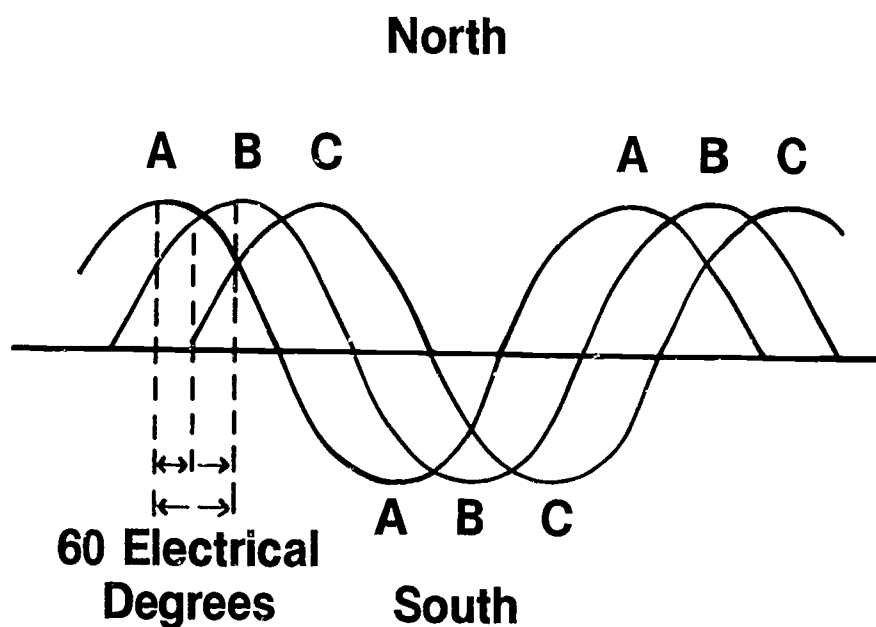


**Reversing Direction of Current Flow Reverses Magnetic Polarity of Poles**

306

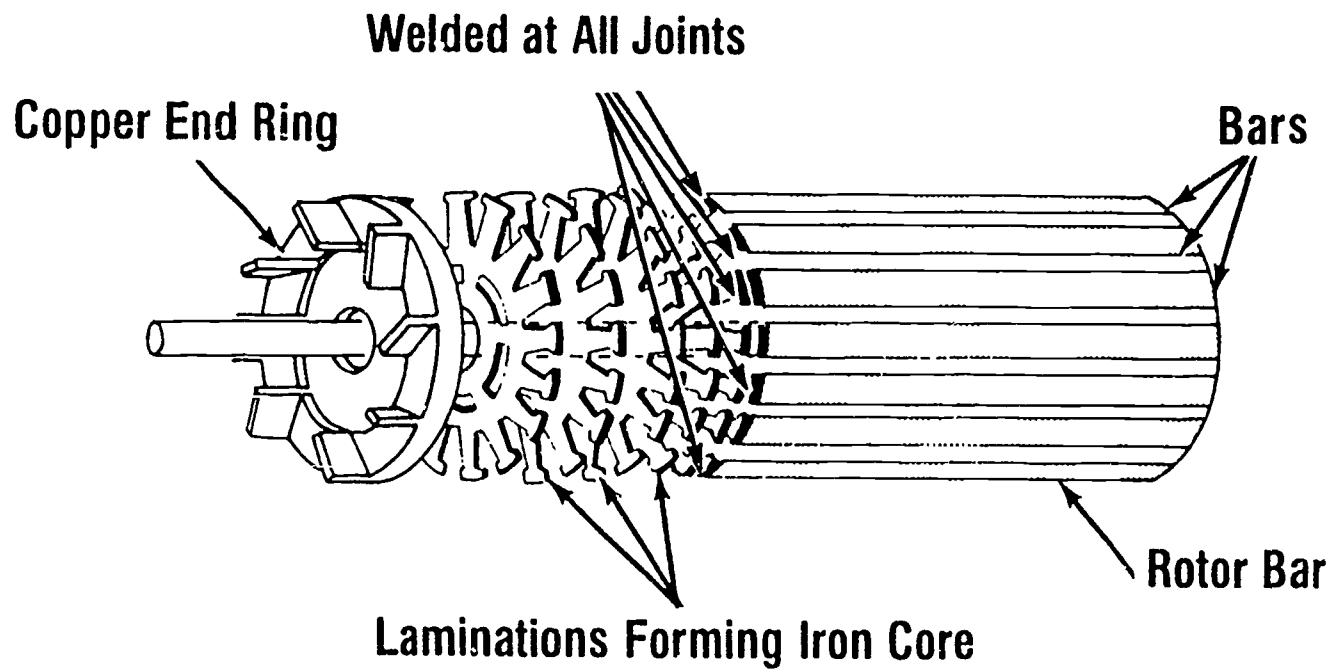
307

# Polyphase Magnetism



As the magnitude of each phase sine wave increases . . . so does the strength of the magnetic field it induces

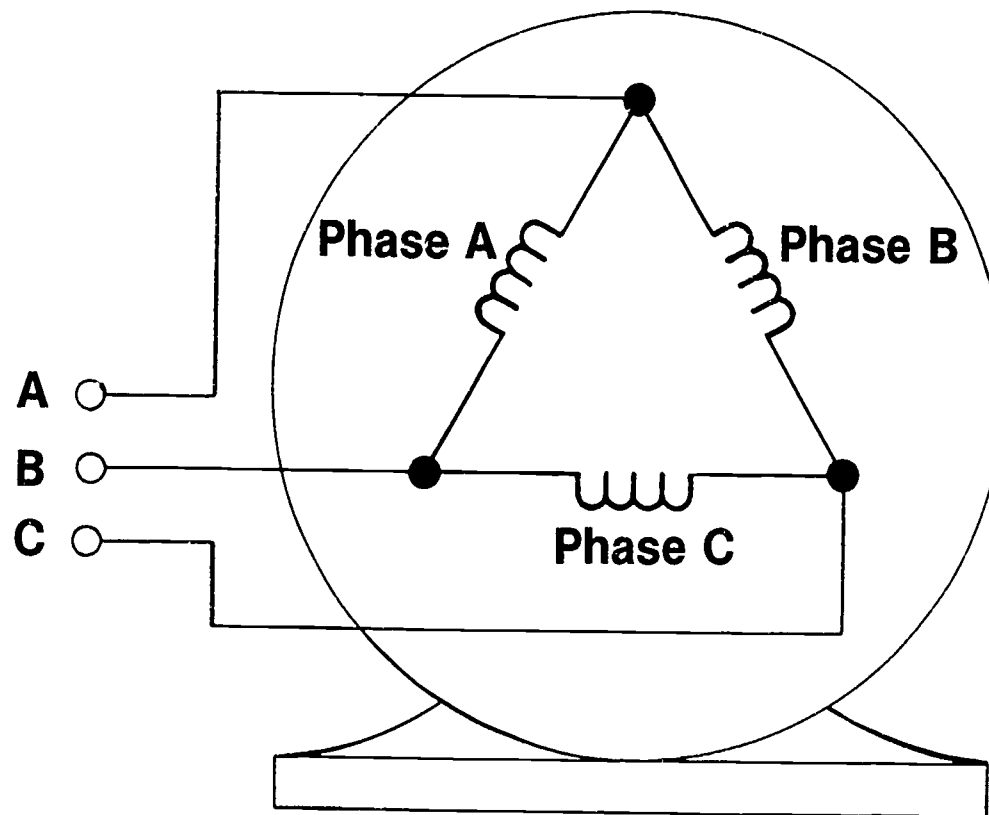
# Squirrel-Cage Rotor



309

310

# Delta-Wound Motor

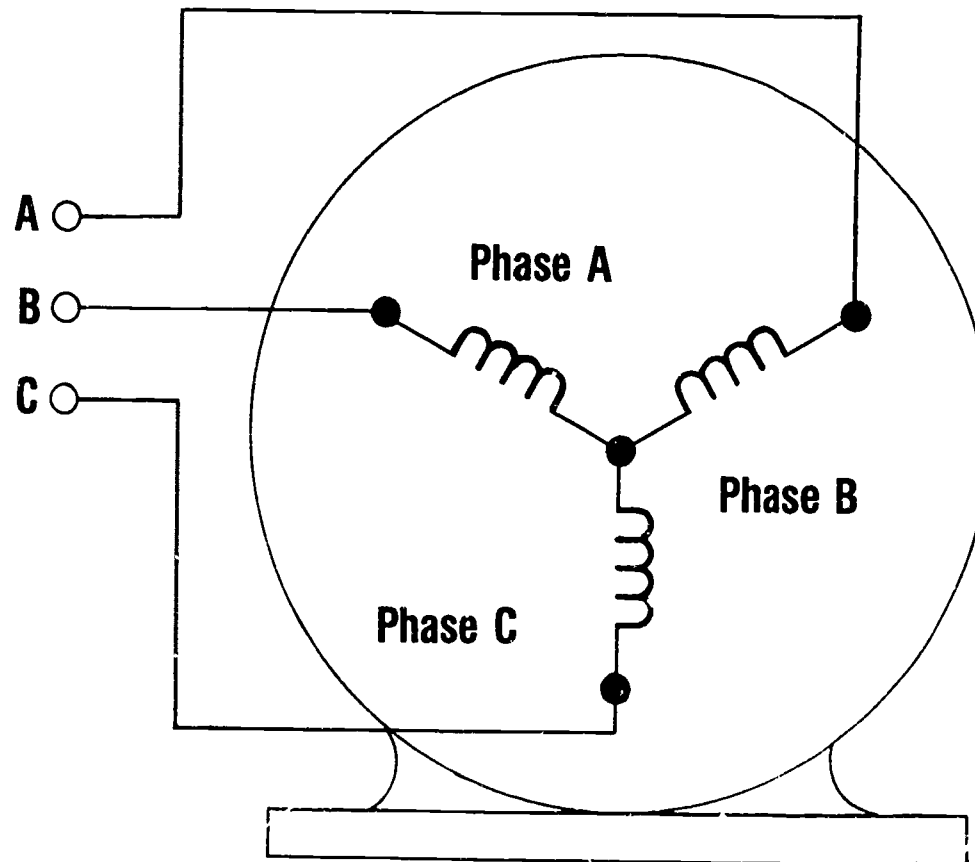


311

312

CIW-329

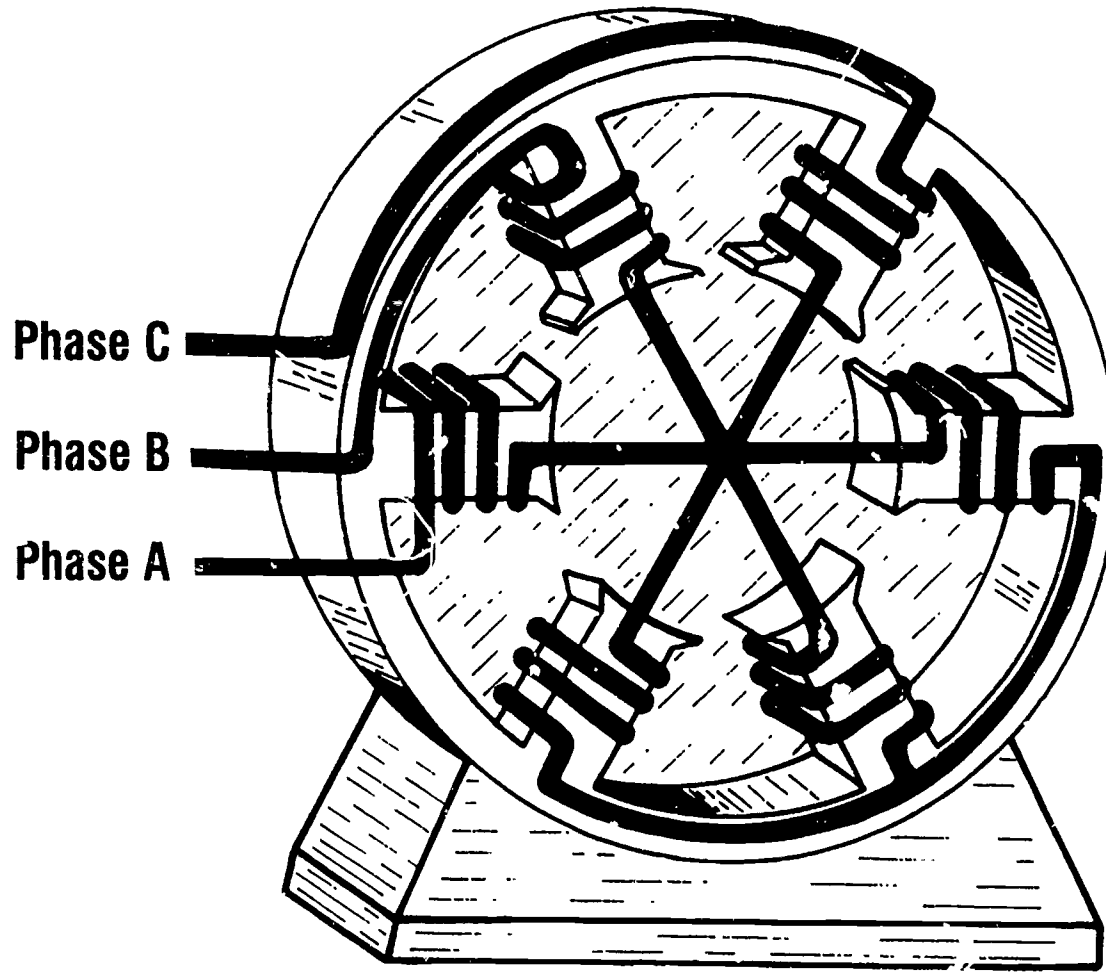
# Wye-Wound Motor (Single Speed)



313

314

# Three-Phase Motor Windings



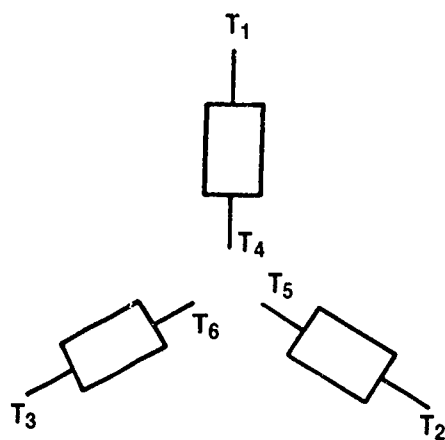
315

316

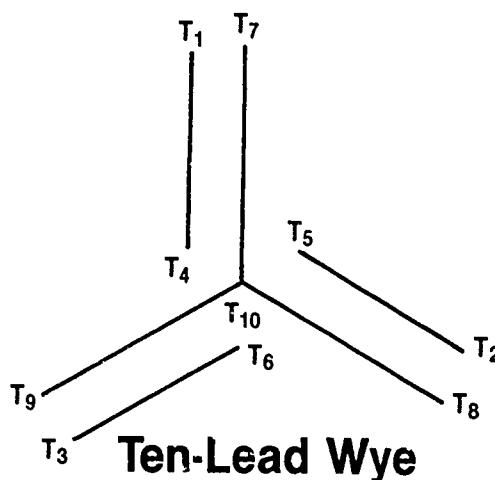
CIW-333



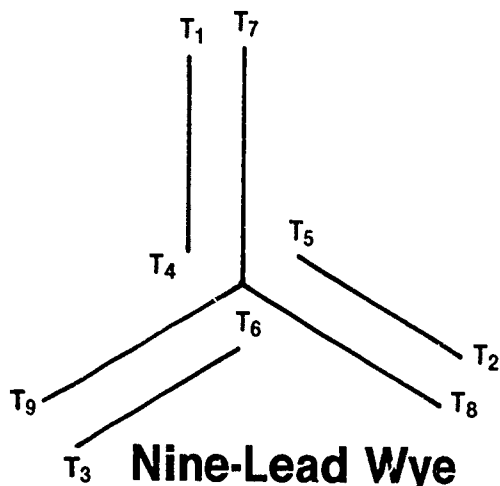
# Dual-Voltage Three-Phase Motor Showing Possible Six, Nine, and Ten Leads



**Six-Lead Wye**

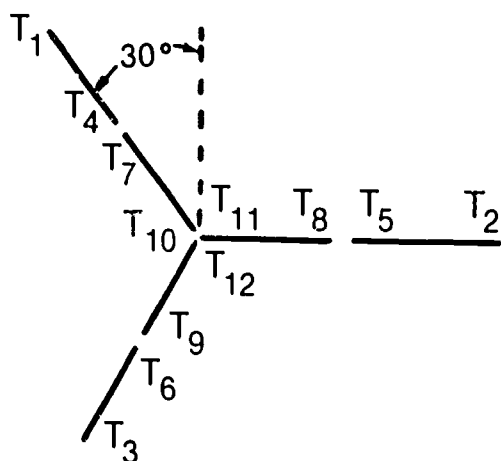


**Ten-Lead Wye**

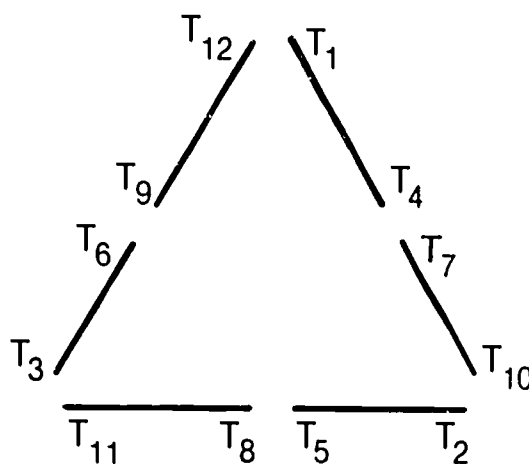


**Nine-Lead Wye**

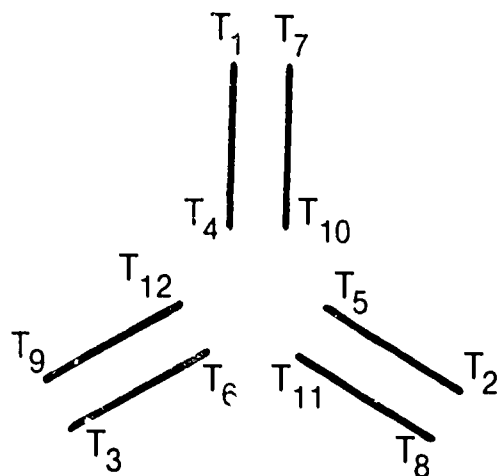
# Dual-Voltage Three-Phase Motor Showing Possible Twelve Leads



**Twelve-Lead Wye  
(High Voltage)**

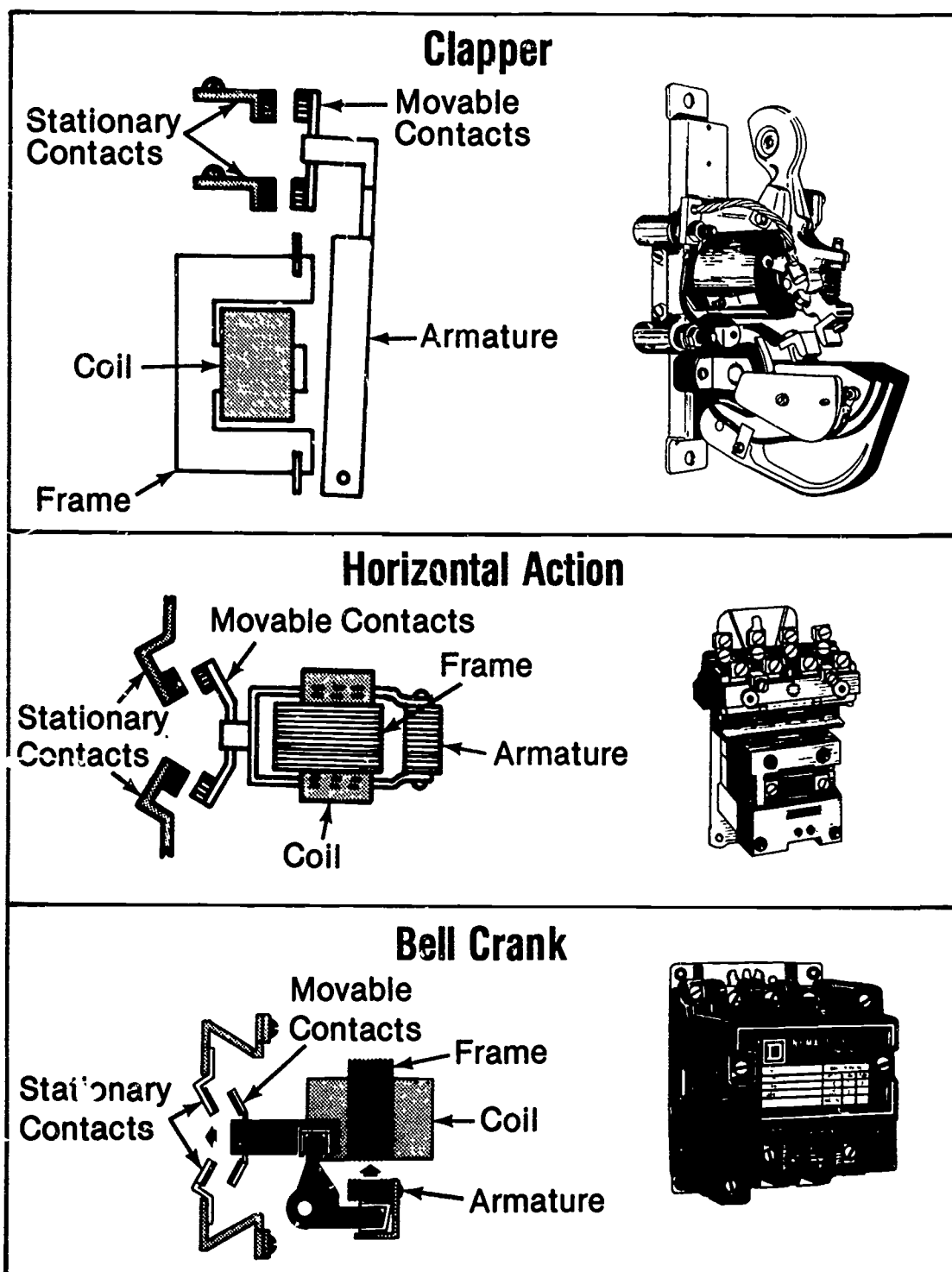


**Twelve-Lead Delta  
(High Voltage)**



**Twelve-Lead Wye  
(Low Voltage)**

# Types of Magnetic-Contactor Assemblies



Adapted with permission of Cutler-Hammer Products/Eaton Corp; Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin; and courtesy of Square D Company.

TM 9  
Objective XV

# MOTORS AND CONTROLLERS

## UNIT VII

### INFORMATION SHEET

#### I. Terms and definitions

- A. Arc chute — Partition between contacts to reduce electrical arcing
- B. Armature — Portion of coil assembly moved by magnetism
- C. Contactor — Device used to make and break electrical power circuit
- D. Delta — Three-phase circuit in which the windings are connected in series (form a closed loop)
- E. Dual voltage motor — Motor capable of being wired to run at two different voltages
- F. Power factor — Ratio of active power to apparent power
- G. Relay — Operated by a change in one electrical circuit to control a device in the same circuit or another circuit; used in control circuits
- H. Shading coil — Single turn of conducting material mounted on the magnetic assembly face to produce out-of-phase magnetic force
- I. Single phasing — Loss of one phase of a three-phase system
- J. Starter — Device used to make or break a motor's power circuit
- K. Thermal overloads (heater) — Device used to sense current draw in a circuit and open a control circuit when it's rating is exceeded
- L. Torque — Force that produces a rotating or twisting action  
(NOTE: Amount of torque is expressed in foot-pounds.)
- M. Wye — Three-phase circuit in which the windings are connected in parallel (form the shape of a 'Y')

#### II. Direct-current motor theory of operation (DC motors)

(NOTE: Direct-current motors rotate through the interaction of two magnetic fields.)

- A. Magnetic field produced at face of stationary poles
- B. Magnetic field produced by current flowing in **armature** winding
- C. Fields repel each other causing the **armature** to rotate

## INFORMATION SHEET

### III. Types of DC motors

#### A. Shunt motor

(NOTE: A shunt motor has the field connected in parallel with its armature.)

#### B. Series motor

(NOTE: A series motor has the fields connected in series with the armature.)

#### C. Compound motors

(NOTE: A compound motor has combination series and shunt windings. The series windings are connected in series with the armature and the shunt windings are connected in parallel.)

### IV. Single phase motor theory of operation

#### A. Operates on a single wave form from a 2-wire A/C system

#### B. A/C single phase current produces a varying magnetic field

(NOTE: The varying field, when applied directly to the field windings of most single phase motors cannot produce starting torque. Series motors contain an armature winding in series with the main winding and develops sufficient starting torque.)

### V. Types of single phase motors

(NOTE: Average starting torques of single-phase motors is expressed as a percentage of the running torque of each motor.)

#### A. Shaded pole (100% starting torque)

(NOTE: Used in small sizes only for timers, small fans, light duty kitchen appliances, etc.)

#### B. Split phase (200% starting torque)

#### C. Capacitor (300% starting torque)

#### D. Induction repulsion (400% starting torque)

#### E. Series (500% starting torque)

## INFORMATION SHEET

### VI. Three-phase motor theory of operation

(NOTE: The three-phase motor is the workhorse of industry. They are rugged and reliable and the most dependable type of motor.)

- A. Current in the stator produces a rotating magnetic field.
- B. Currents induced in the rotor create a magnetic field.
- C. The rotor turns, seeking an opposite pole

### VII. Types of three-phase motors

(NOTE: An unloaded or lightly loaded three-phase motor will continue to run but will not start under single phase conditions.)

- A. Squirrel-cage induction

(NOTE: This is the most commonly used motor in industrial applications.)

- B. Wound-rotor

(NOTE: This is commonly called a slip-ring motor.)

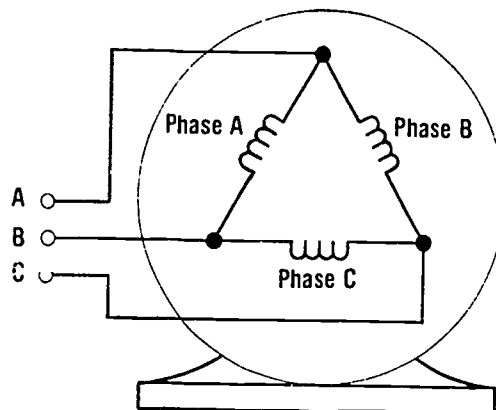
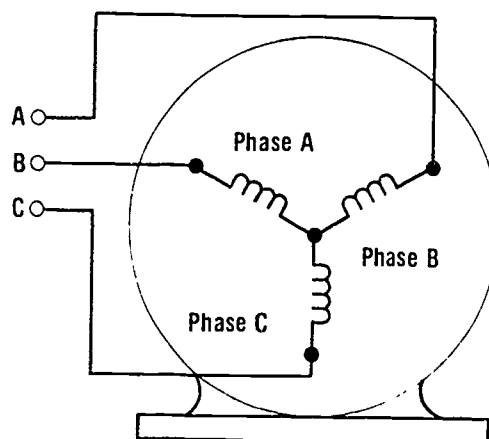
- C. Synchronous

(NOTE: Synchronous motors are frequently used for power-factor correction. When used for this purpose they are known as synchronous condensers.)

## INFORMATION SHEET

- VIII. **Reversing rotation of three-phase motors** — A three-phase motor is reversed by interchanging any two of the three supply lines anywhere between the motor and the source of supply.

## Delta-Wound Motor

Wye-Wound Motor  
(Single Speed)

## INFORMATION SHEET

### IX. Typical supply voltages for three-phase motors

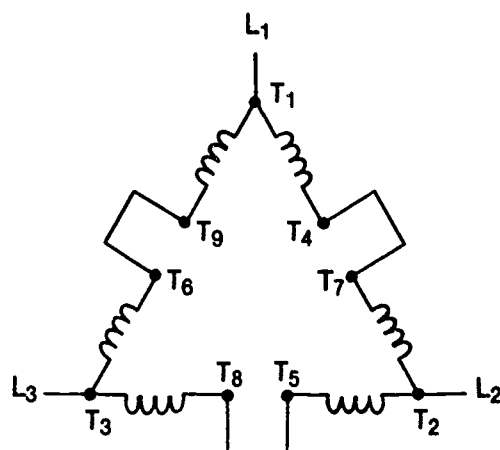
- A. 240-volt three-phase delta
- B. 480-volt three-phase delta
- C. 208-volt three-phase wye
- D. 480-volt three-phase wye

### X. Dual voltage schematics and terminal connections

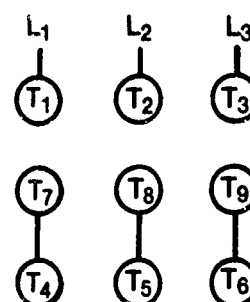
#### A. Delta-wound nine-lead motor (high voltage)

(NOTE: On a typical 240/480-volt dual-voltage motor the 240-volt windings would wire in parallel and the 480-volt windings would wire in series, as shown.)

Schematic Connection

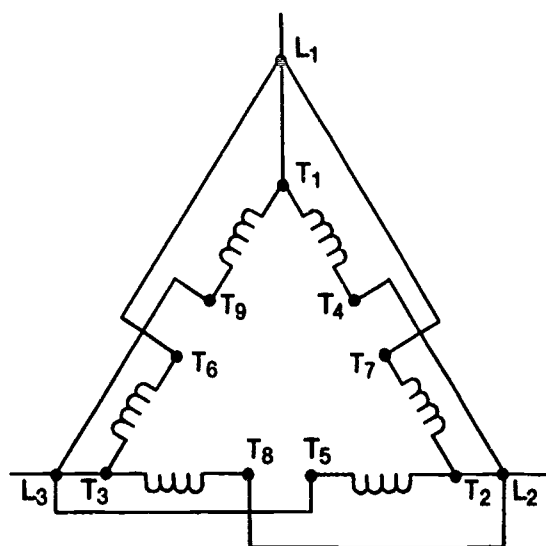


Terminal Connection

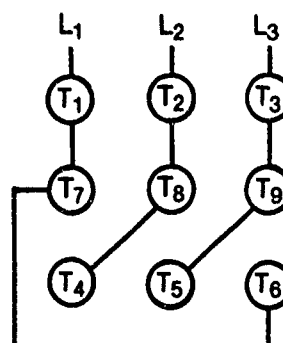


#### B. Delta-wound nine-lead motor (low voltage)

Schematic Connection



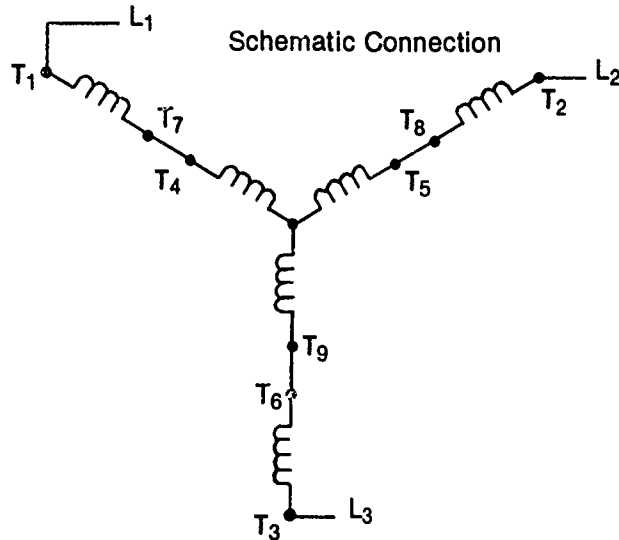
Terminal Connection



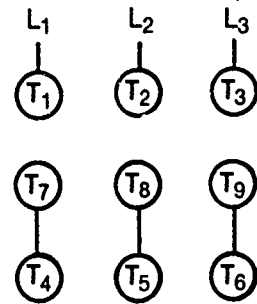


# **INFORMATION SHEET**

## **C. Wye-wound nine-lead motor (high voltage)**

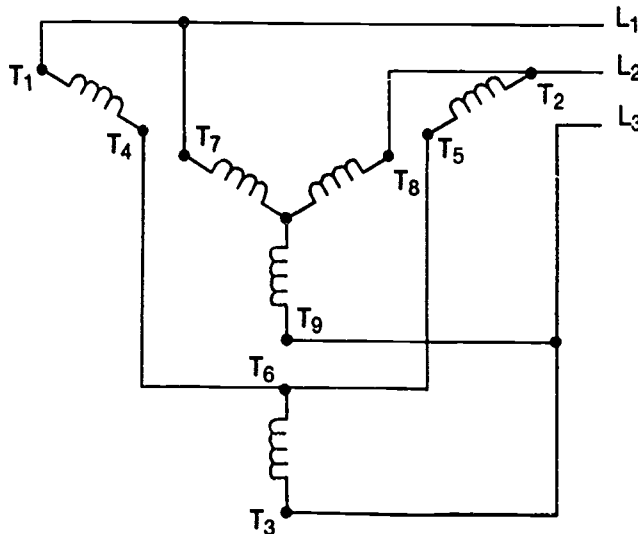


### Terminal Connection

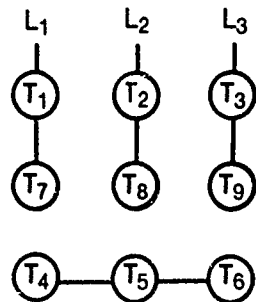


## **D. Wye-wound nine-lead motor (low voltage)**

### Schematic Connection



### Terminal Connection



## INFORMATION SHEET

### XI. Motor problems and their typical symptoms

#### A. Failure to start

1. Blown fuse or open circuit breaker
2. Low voltage or no voltage
3. Open wiring circuit
4. Incorrect power line connection
5. Excessive load
6. Excessive end play
7. Seized or worn bearings
8. Open overload

#### B. Excessive noise

1. Unbalanced parts  
EXAMPLES: Bearings, pulley, rotor
2. Bent shaft
3. Loose parts
4. Faulty alignment
5. Worn bearings
6. Dirt in air gap between rotor and stator
7. Uneven air gap
8. Shorted silicon-controlled rectifier (SCR) drive unit

#### C. Overheated bearings

1. Lack of oil
2. Dirty oil
3. Oil not reaching shaft
4. Excessive grease or oil

## INFORMATION SHEET

5. Excessive belt tension
6. Rough bearing surface
7. Bent shaft
8. Misalignment of shaft and bearing
9. Excessive end thrust
10. Excessive side pull
11. Belt slippage

**D. Overheated motor**

1. Obstruction of ventilating system
2. Overloading
3. Rotor dragging on stator
4. Incorrect voltage
5. High ambient temperature

## **XII. Remedies for motor problems**

**A. Failure to start**

1. Check supply voltage.

(NOTE: Supply voltage should be within 10 percent of motor name-plate voltage. If no voltage, reset breaker or check fuses.)

2. Check motor wiring with ohmmeter.
3. Remove load from motor and try to start.
4. Move motor shaft by hand to check for end play, side play, and bearing tightness.

**B. Excessive noise**

1. Replace out-of-balance pulley.
2. Remove pulley and check straightness of shaft.
3. Tighten motor accessories and mounting.

**INFORMATION SHEET**

4. Align drive pulley with driven pulley.
5. Replace bearings.
6. Clean motor.
7. Check for out-of-round motor.

**C. Overheated bearings**

1. Use recommended nondetergent motor-bearing oil.
2. Put clean oil in reservoir.

(NOTE: This will be possible only on large motors with bearing oil reservoirs.)

3. Clean excessive grease buildup from ball bearings.
4. Adjust belt to proper tension.
5. Move motor shaft by hand to check for end play, side play, and bearing tightness.
6. Replace rough or worn bearings.
7. Remove pulley and check for bent shaft.
8. Align drive pulley with driven pulley.

**D. Overheated motor**

1. Clean motor.
2. Adjust belt tension.
3. Check full load amperage.
4. Check for correct voltage.

(NOTE: A voltage check should be made at the motor terminals with the motor under load.)

5. Check for loose bearings.
6. Check for tight bearings.
7. Check pulley alignment.
8. Remove pulley and check for bent shaft.

## INFORMATION SHEET

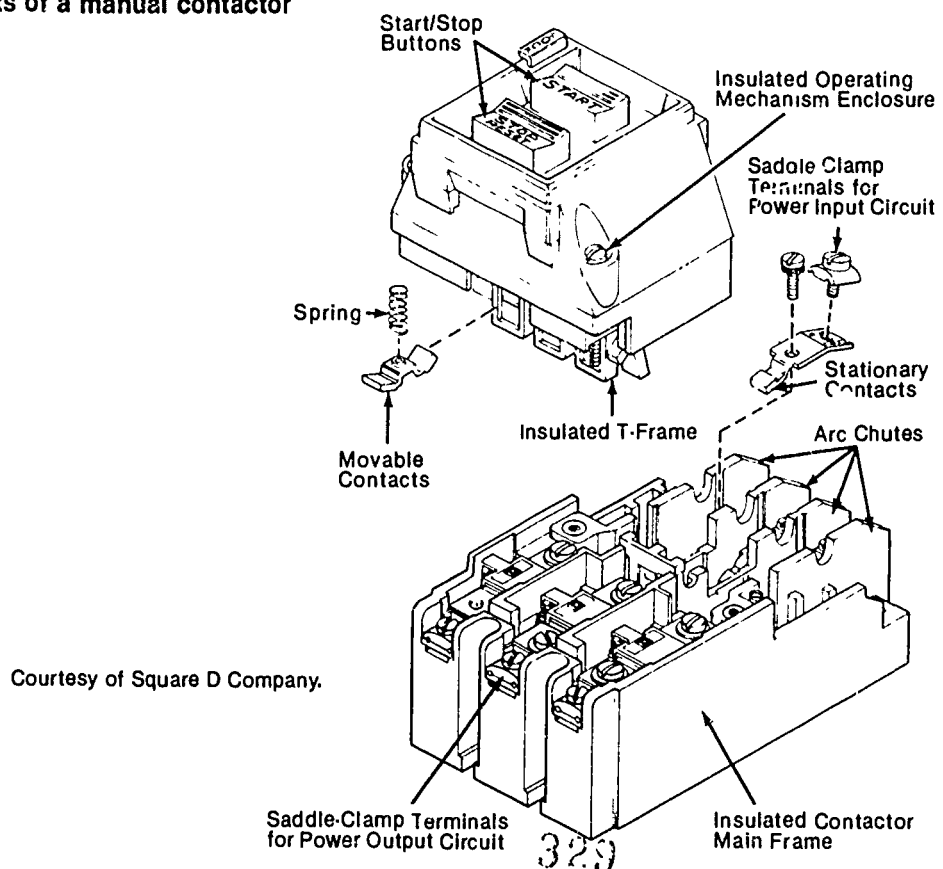
### XIII. Safety rules to observe when working around motors

- A. Do not underestimate the danger of the circuit.
- B. Use caution around electric arcs.
- C. Never install equipment that will overload the circuit.
- D. Never bypass protective devices.
- E. Protect all wires from physical and thermal hazards.
- F. Tag and lock electrical disconnects when working on motors or motor circuits.
- G. Wear eye protection.
- H. Do not touch moving parts.
- I. Ground all electric motor frames.

### XIV. Types of contactors

- A. Manual
- B. Magnetic

### XV. Parts of a manual contactor



## INFORMATION SHEET

### XVI. Electrical devices and circuits controlled by magnetic contactors

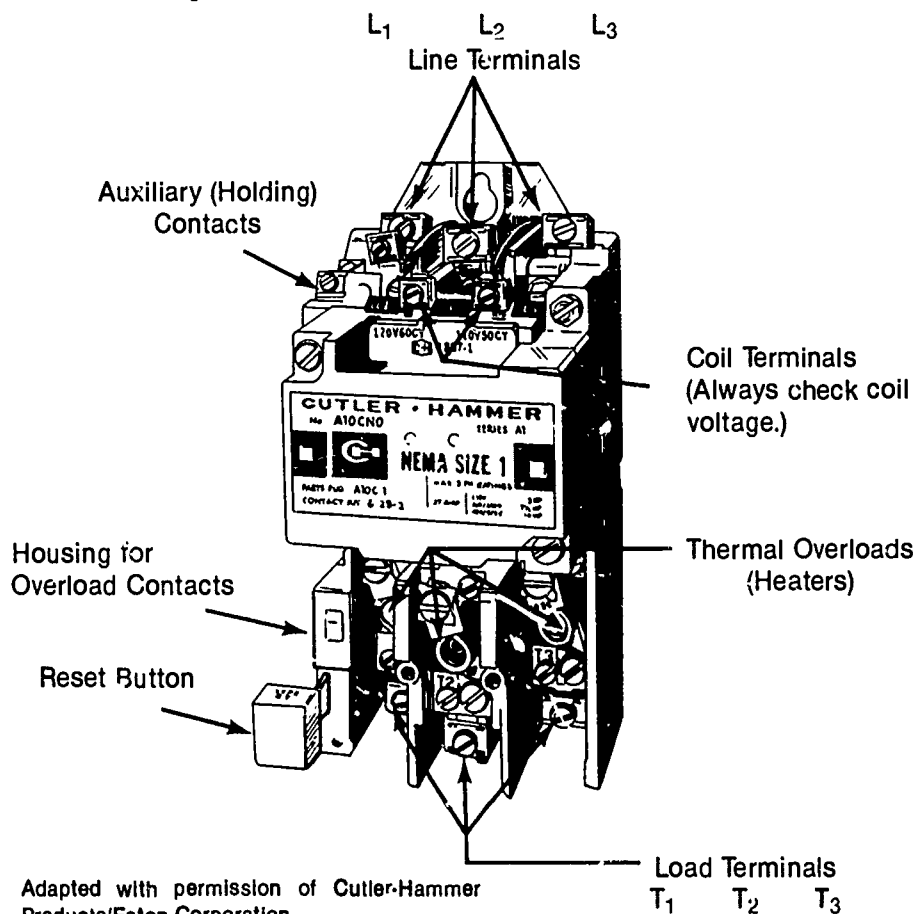
- A. Lighting loads
- B. Heaters
- C. Transformers
- D. Capacitors
- E. Power circuits

### XVII. Types of motor starters

- A. Manual
- B. Magnetic

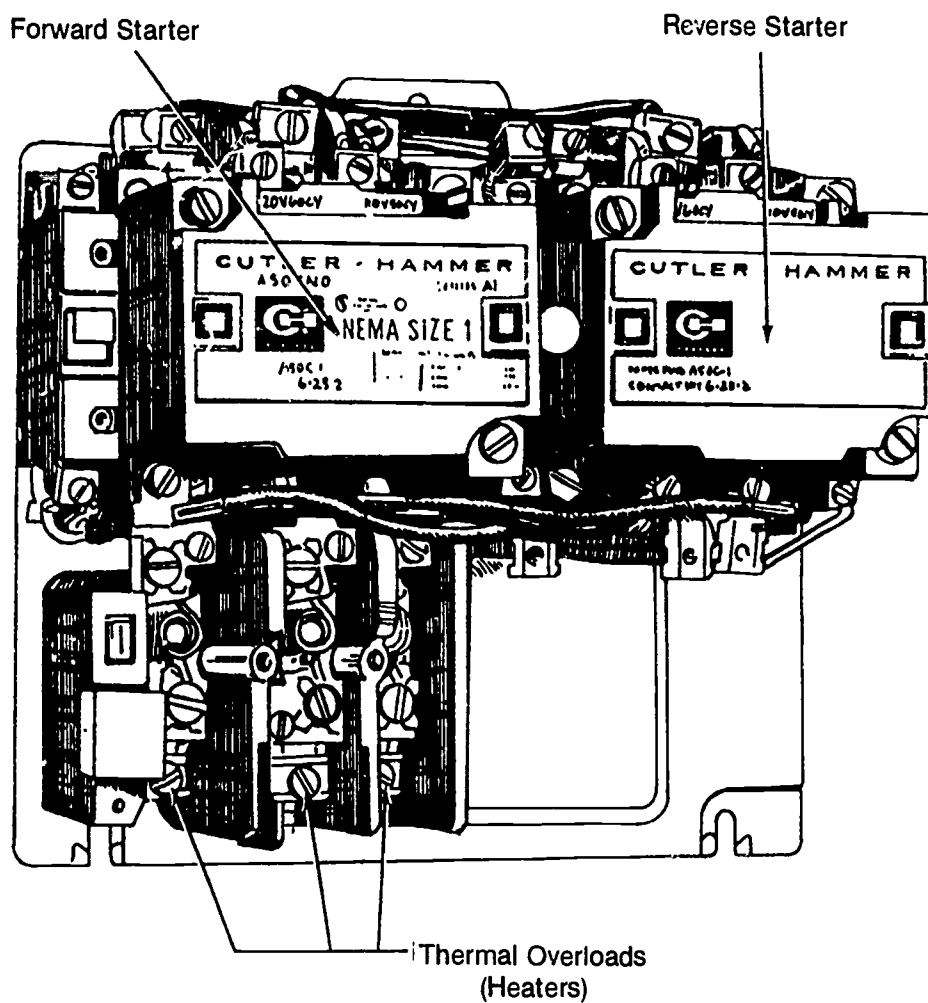
### XVIII. Types of magnetic motor starters and their parts

- A. Starting



## INFORMATION SHEET

## B. Reversing



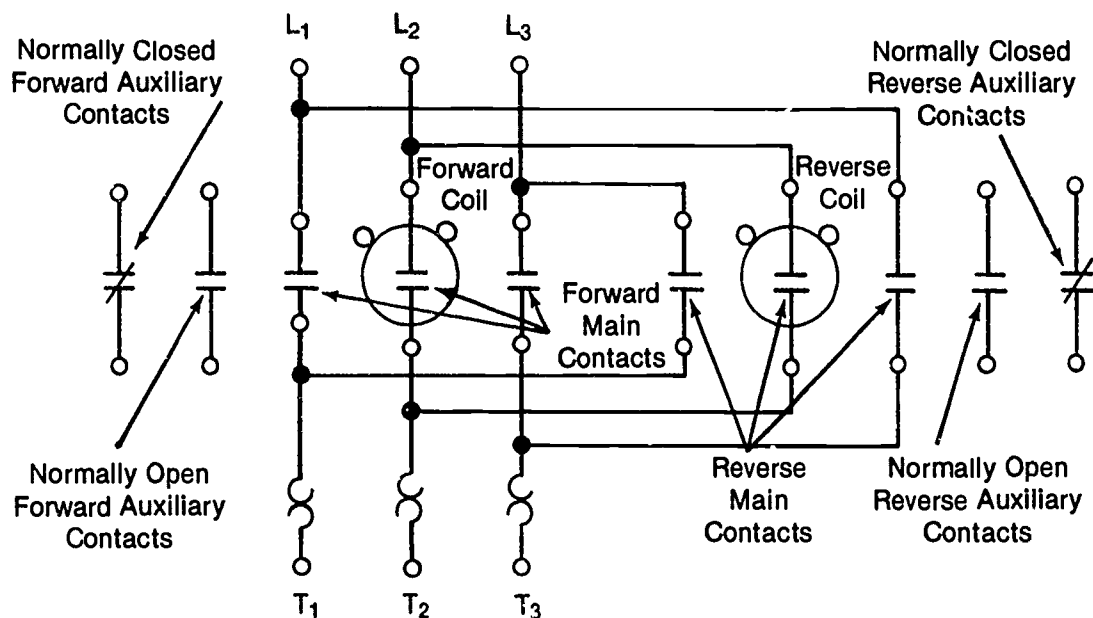
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## INFORMATION SHEET

(NOTE: Reversing any two phases will change rotation of motor.  $L_1$  and  $L_3$  are reversed.)

EXAMPLE:



### XIX. Uses of magnetic motor starters

- A. Starting motors
- B. Reversing motors
- C. Braking motors to stop
- D. Controlling speed of motors



## INFORMATION SHEET

### XX Comparison of parts in magnetic contactors and parts in magnetic motor starters

(NOTE: Motor starters are contactors with overload protection for the motor.)

TABLE 1

Parts	Contactors	Motor Starters
Line terminals	Yes	Yes
Power contacts	Yes	Yes
Load terminals	Yes	Yes
Holding contacts	Yes	Yes
Coil	Yes	Yes
Thermal overloads (heaters)	No	Yes
Reset button	No	Yes
Overload contact	No	Yes

### XXI. Reasons a contactor cannot be used to control a motor

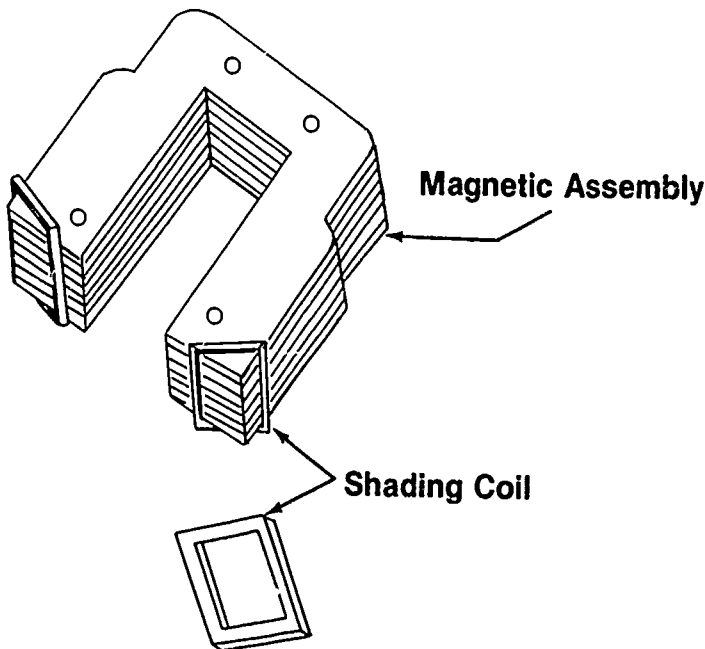
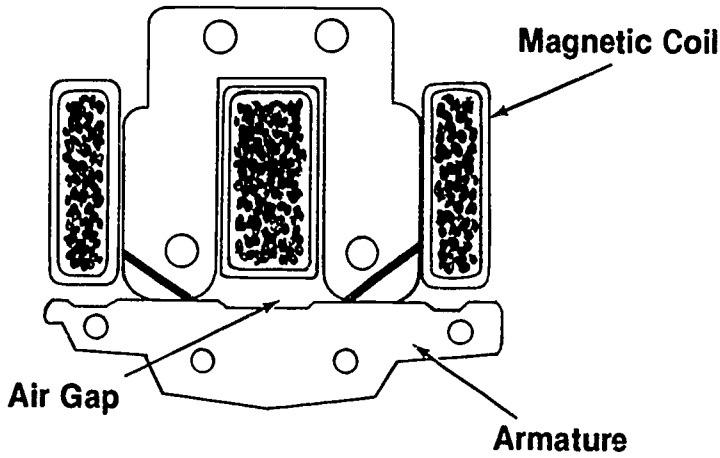
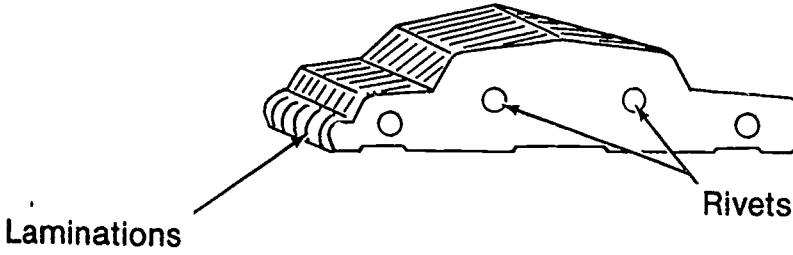
- A. Contactor does not provide running overload protection for motor
- B. Contactor is not designed for high inrush current for motor starting
- C. Contactor does not contain a set of overload contacts

### XXII. Purposes of a coil assembly

- A. Changes electrical signal to magnetic signal
- B. Activates mechanical portion of motor starter

# INFORMATION SHEET

## XXIII. Parts of a coil assembly



## MOTORS AND CONTROLLERS UNIT VII

### ASSIGNMENT SHEET #1 — INTERPRET NAMEPLATE INFORMATION

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

The industrial electrician must be able to interpret motor nameplate information in order to be able to service and repair a motor.

Directions: Select an electric motor as specified by your instructor. Use the information on the nameplate to complete the following questions.

- A. What is the horsepower of the motor? \_\_\_\_\_
- B. Is this a single-phase or three-phase motor? \_\_\_\_\_
- C. At how many revolutions per minute does the motor operate? \_\_\_\_\_
- D. What is the recommended voltage to which this motor should be connected? \_\_\_\_\_
- E. What type of overload protection does the motor have? \_\_\_\_\_
- F. How long is the motor designed to operate? \_\_\_\_\_
- G. Under what temperature will the motor operate? \_\_\_\_\_
- H. What is the identification number? \_\_\_\_\_
- I. At how many cycles per second does the motor operate? \_\_\_\_\_
- J. What is the motor type? \_\_\_\_\_
- K. What type of current does the motor use? \_\_\_\_\_
- L. What is the service factor of the motor? \_\_\_\_\_
- M. What type of mounting is used? \_\_\_\_\_

## MOTORS AND CONTROLLERS UNIT VII

### ASSIGNMENT SHEET #2 — DESCRIBE REMEDIES FOR COMMON MOTOR PROBLEMS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

An industrial electrician must be able to determine causes and remedy common motor problems.

Directions: In the following situations, the problems are stated. Write solutions for each problem.

A. Motor fails to start — \_\_\_\_\_

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B. Motor is overheating — \_\_\_\_\_

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**ASSIGNMENT SHEET #2**

C. Motor is excessively noisy — \_\_\_\_\_

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D. Motor bearings are overheating — \_\_\_\_\_

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## MOTORS AND CONTROLLERS UNIT VII

### ASSIGNMENT SHEET #3 — USE NATIONAL ELECTRICAL CODE TO ANSWER QUESTIONS ABOUT MOTOR CONTROL CIRCUITS

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

The industrial electrician must be able to interpret and apply the *National Electrical Code* by properly wiring all motor control circuits according to information found in Article 430.

Directions: Use the *National Electrical Code* to answer the following questions.

- A. State the section of the *National Electrical Code* that deals with overcurrent protection.

\_\_\_\_\_

- B. List two exceptions for conductor protection in motor control circuits.

1. \_\_\_\_\_

2. \_\_\_\_\_

- C. Is a transformer used to step down voltage for motor control circuits exempt from Article 430? Write an "X" in the appropriate blank.

Yes \_\_\_\_\_ No \_\_\_\_\_

- D. Describe the *National Electrical Code* requirements for protecting control conductors.

\_\_\_\_\_

- E. State time when motor control circuits must be disconnected.

\_\_\_\_\_

- F. Define a motor control circuit.

\_\_\_\_\_

\_\_\_\_\_

- G. State procedures for protecting conductors in control circuits.

\_\_\_\_\_

- H. Define "insight" as it applies to motors and controllers.

\_\_\_\_\_

\_\_\_\_\_

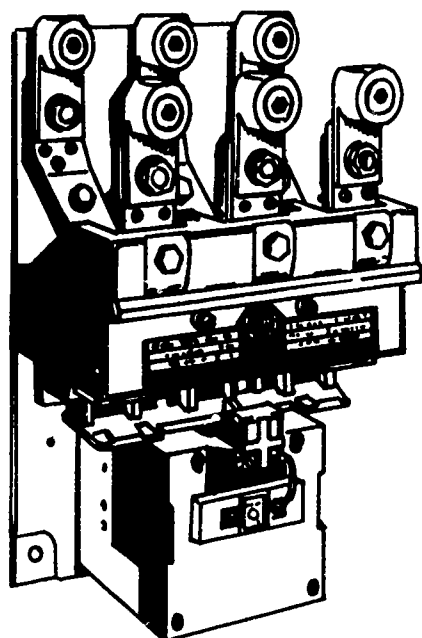
# **MOTORS AND CONTROLLERS** **UNIT VII**

## **ASSIGNMENT SHEET #4 — DISTINGUISH BETWEEN MOTOR STARTERS AND CONTACTORS**

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

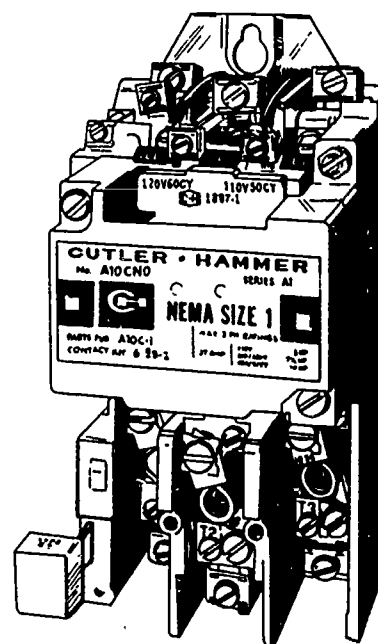
When servicing existing equipment, an electrician must be able to identify at a glance a motor starter or a contactor. Contactors never have thermal overloads (heaters), reset buttons, or overload contacts.

Directions: Look at each of the following pictures. Label each "contactor" or "motor starter."



A. \_\_\_\_\_

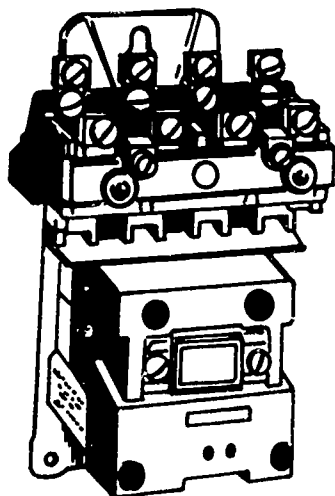
Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.



B. \_\_\_\_\_

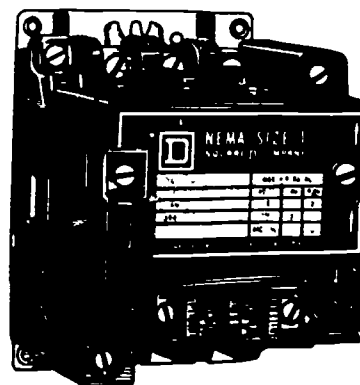
Adapted with permission of Cutler-Hammer Products/Eaton Corporation.

# ASSIGNMENT SHEET #4



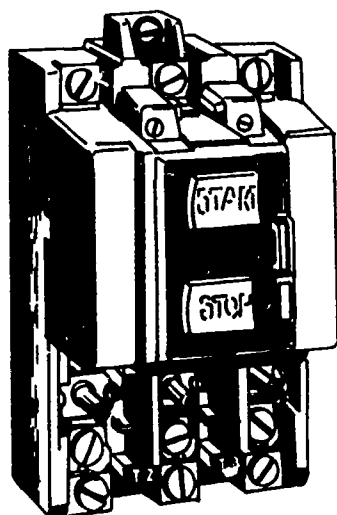
C.

Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.



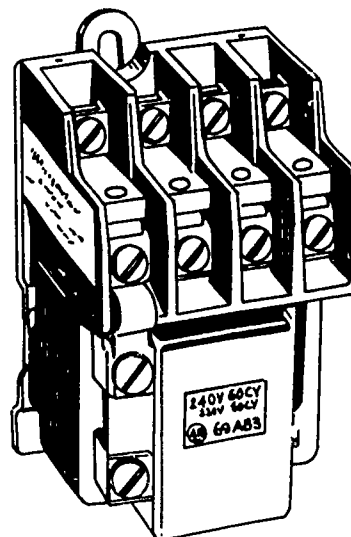
D.

Courtesy of Square D Company.



E.

Adapted with permission of Cutler-Hammer Products/Eaton Corporation.

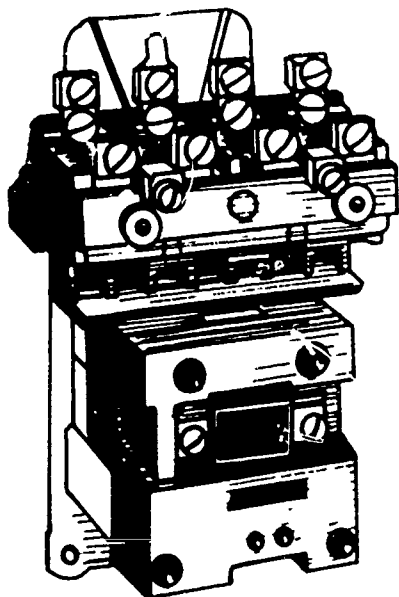


F.

Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.



## ASSIGNMENT SHEET #4



G. \_\_\_\_\_

Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.

H. Which items did you recognize as being contactors? \_\_\_\_\_

Explain why you selected these items as contactors.

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I. Which items did you select as being motor starters? \_\_\_\_\_

Explain why you selected these items as motor starters.

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## MOTORS AND CONTROLLERS UNIT VII

### ASSIGNMENT SHEET #5 — ANSWER QUESTIONS ABOUT USES OF CONTACTORS AND MOTOR STARTERS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

An industrial electrician must be able to select a motor starter or contactor according to its correct use. Contactors are used to make and break an electrical power circuit. Motor starters are used to make and break a motor's power circuit.

Directions: Complete each of the following questions about motor starters and contactors and their uses.

- A. Which of the following lists contains contactor parts and which contains motor starter parts? Write "contactor" or "motor starter" in the blank above the correct column.

1. \_\_\_\_\_ 2. \_\_\_\_\_

Line terminals  
Load terminals  
Power contacts  
Coil  
Holding contacts  
Overload contact  
Reset button  
Thermal overloads (heaters)

Line terminals  
Load terminals  
Coil  
Holding contacts  
Power contacts

- B. Name five uses of magnetic contactors.

1. \_\_\_\_\_  
2. \_\_\_\_\_  
3. \_\_\_\_\_  
4. \_\_\_\_\_  
5. \_\_\_\_\_

- C. List four uses of magnetic motor starters.

1. \_\_\_\_\_  
2. \_\_\_\_\_  
3. \_\_\_\_\_  
4. \_\_\_\_\_

## ASSIGNMENT SHEET #5

D. State three reasons why a contactor cannot be used to control a motor.

1. \_\_\_\_\_  
\_\_\_\_\_
2. \_\_\_\_\_  
\_\_\_\_\_
3. \_\_\_\_\_  
\_\_\_\_\_

## MOTORS AND CONTROLLERS UNIT VII

### ANSWERS TO ASSIGNMENT SHEETS

**ASSIGNMENT SHEET #1** — Evaluated to the satisfaction of the instructor

#### ASSIGNMENT SHEET #2

- A.
  - 1. Check supply voltage.
  - 2. Check motor wiring with ohmmeter.
  - 3. Remove load from motor and try to start.
  - 4. Move motor shaft by hand to check for end play and bearing tightness.
- B.
  - 1. Clean motor.
  - 2. Adjust belt tension.
  - 3. Check full load amperage.
  - 4. Check for correct voltage.
  - 5. Check for loose bearings.
  - 6. Check for tight bearings.
  - 7. Check pulley alignment.
  - 8. Check for bent shaft.
- C.
  - 1. Replace out of balance pulley.
  - 2. Remove pulley and check straightness of shaft.
  - 3. Tighten motor accessories and mounting.
  - 4. Align drive pulley and driven pulley.
  - 5. Replace bearings.
  - 6. Clean motor.
  - 7. Check for out-of-round motor.
- D.
  - 1. Use recommended motor bearing oil
  - 2. Put clean oil in reservoir.
  - 3. Clean excessive grease build up.
  - 4. Adjust belt.
  - 5. Move shaft by hand to check end and side play.
  - 6. Replace rough or worn bearing.
  - 7. Remove pulley and check for bent shaft.
  - 8. Align drive pulley with driven pulley.

#### ASSIGNMENT SHEET #3

- A. 430-72
- B.
  - 1. Conductors that do not leave enclosure
  - 2. Conductors supplied by transformer
- C. No
- D. Must be protected by raceway or enclosure
- E. At time motor circuit is disconnected

## ANSWERS TO ASSIGNMENT SHEETS

- F. A circuit designed for signaling and control of a motor starter
- G. Conduit or raceway
- H. A disconnecting means shall be located in sight from the controller location

### ASSIGNMENT SHEET #4

- A. Contactor
- B. Motor starter
- C. Contactor
- D. Contactor
- E. Motor starter
- F. Contactor
- G. Contactor
- H. A, C, D, F, G; contactors do not have thermal overloads (heaters), reset button, or overload contacts
- I. B, E; motor starters do have thermal overloads (heaters), reset button, or overload contacts

### ASSIGNMENT SHEET #5

- A.
  - 1. Motor starter
  - 2. Contactor
- B.
  - 1. Lighting loads
  - 2. Heaters
  - 3. Transformers
  - 4. Capacitors
  - 5. Power circuits
- C.
  - 1. Starting motors
  - 2. Reversing motors
  - 3. Braking motors to stop
  - 4. Controlling speed of motors
- D.
  - 1. Contactor does not provide running overload protection for motor
  - 2. Contactor is not designed for high inrush current for motor starting
  - 3. Contactor does not contain a set of overload contacts

## **MOTORS AND CONTROLLERS UNIT VII**

### **JOB SHEET #1 — DISASSEMBLE, INSPECT, AND CLEAN A MOTOR**

#### **A. Equipment and materials needed**

1. Split-phase motor
2. Screwdriver set
3. Combination wrench set
4. Center punch
5. Ball peen hammer
6. Soft-faced hammer
7. Small socket wrench set
8. Motor cleaning fluid
9. Clean shop towel
10. Compressed air
11. Eye protection
12. Lead marking material
13. Polishing cloth
14. Gear puller
15. Machine oil

#### **B. Procedure**

1. Put on eye protection.
2. Check to be sure that electrical power is disconnected and locked open.
3. Remove motor from equipment, if necessary, and mark leads.
4. Clean outer surface of motor.

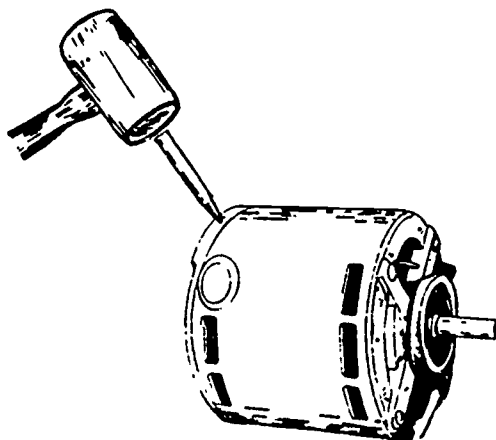
**JOB SHEET #1**

5. Disconnect wires at motor terminals.

(NOTE: Label wire positions by number or color on motor terminals, or draw a diagram.)

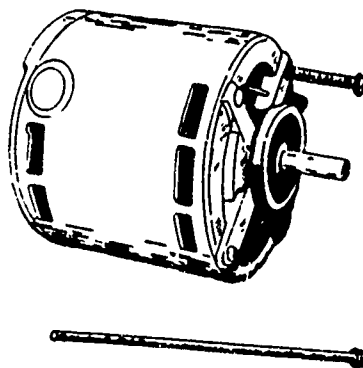
6. Remove motor pulley.
7. Mark end bells to keep them in their proper places (Figure 1).
- Using center punch, place one mark on pulley end bell and two marks on opposite end bell.
  - Mark housing in the same way.

FIGURE 1



8. Check motor for end play.
9. Remove bolts holding end bells. (Figure 2)

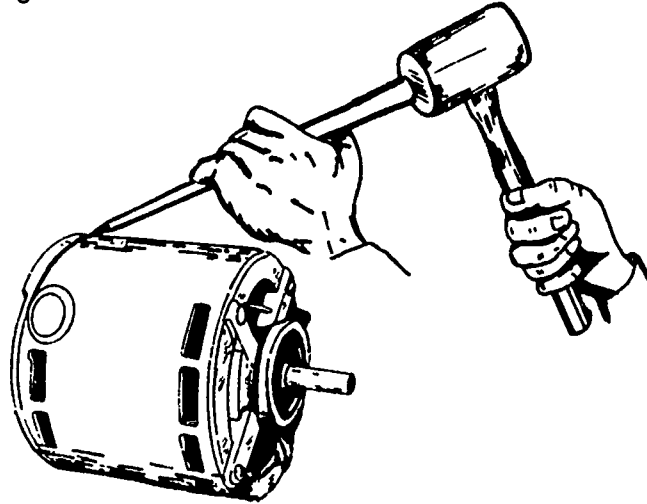
FIGURE 2



## JOB SHEET #1

10. Polish shaft ends for easy removal.
11. Use soft-faced hammer and punch to tap end bells loose (Figure 3).

FIGURE 3



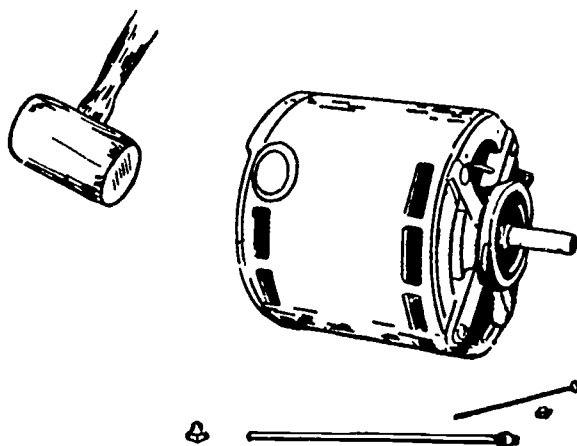
12. Remove end bell that does not contain starting switch.
13. Remove rotor.  
(NOTE: Observe position and number of thrust washers as you remove the rotor.)
14. Remove end bell containing starting switch.  
(CAUTION: Do not attempt to remove stator.)
15. Clean motor with compressed air.
16. Check centrifugal mechanism and starting switch.
17. Clean outside of motor with special cleaning fluid.
18. Check stator coils, insulation, and coil supports.
19. Clean bearings, and make sure that wicking is in place and oiled.  
(CAUTION: Do not clean ball bearings with compressed air.)
20. Reinstall end bell containing starting switch.
21. Insert rotor, making sure that thrust washers are in place.  
(NOTE: Place a drop of oil on bearing part of the shaft.)



## JOB SHEET #1

22. Reinstall second end bell.
23. Visually inspect rotor and stator alignment.
24. Check position of end bells to center punch marks.
25. Use soft-faced hammer to tap end bells into place. (Figure 4)

FIGURE 4



26. Insert end-bell bolts; tighten.
27. Turn shaft by hand, and check for end play.  
(NOTE: If shaft is tight, end bells may not be in proper alignment, or the wicking may be between bearing and shaft.)
28. Connect temporary leads; test motor.  
(NOTE: Show work to instructor for evaluation and comments.)
29. Clean work area; put equipment and materials in proper storage.

## MOTORS AND CONTROLLERS UNIT VII

### JOB SHEET #2 — IDENTIFY RUN, COMMON, AND START TERMINALS ON A HERMETICALLY SEALED MOTOR

**A. Equipment and materials needed**

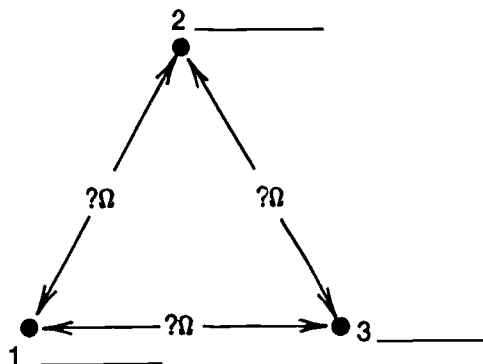
1. Ohmmeter with leads and test clips
2. Three hermetically sealed compressor units
3. Paper to sketch terminals and record ohm readings
4. Pen or pencil

**B. Procedure**

(NOTE: The terminals on most units are *not* identified.)

1. Clean terminals to ensure good connections.
2. Draw sketch of compressor unit electrical terminals as shown in Figure 1.

FIGURE 1



3. Test and record ohms between terminals 1 and 2.

1 to 2 = \_\_\_\_\_ ohms

4. Test and record ohms between terminals 2 and 3.

2 to 3 = \_\_\_\_\_ ohms

5. Test and record ohms between terminals 1 and 3.

1 to 3 = \_\_\_\_\_ ohms

## JOB SHEET #2

5. Analyze readings and label sketch as in Figures 2-4.

FIGURE 2

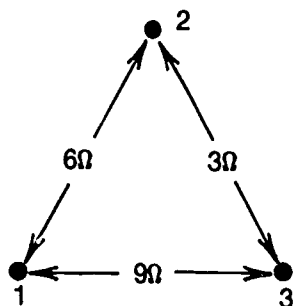


FIGURE 3

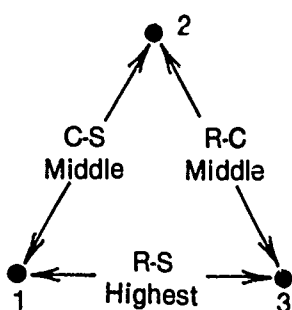
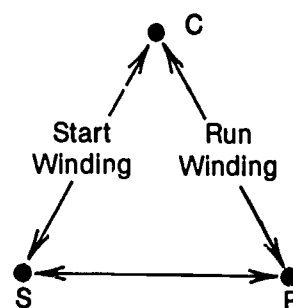


FIGURE 4



(NOTE: The run winding has larger wire, so it has the lowest resistance [R is common to highest and lowest readings]. The start winding has smaller wire and more terminals, so it has a higher reading [S is common to highest and middle readings]. The combined resistance of run and start windings is measured between R and S, so it gives the highest reading [C is common to middle and lowest readings].)

7. Repeat steps 1 through 6 on at least two more compressor units.

(NOTE: Show your results to the instructor.)

8. Clean work area; return equipment and materials to their proper places.

## MOTORS AND CONTROLLERS UNIT VII

### JOB SHEET #3 — TEST CAPACITORS WITH AN OHMMETER

#### A. Equipment and materials needed

1. 1,000-ohm ohmmeter with leads
2. Six start or run capacitors with clean terminals
3. Bleeder resistor with attached leads, approximately 75 ohms

(NOTE: The TIF-CT-660 capacitor tester has proven to be a good, inexpensive tool for these tests; however, ohmmeters may also be used.)

4. Eye protection

#### B. Procedure

1. Put on eye protection.
2. Apply bleeder resistor across capacitor terminals long enough to be sure that capacitor is discharged.
3. Set ohmmeter on  $R \times 1,000$  range.
4. Set ohmmeter leads and zero instrument.
5. Test for ground on run capacitors.
  - a. Connect one ohmmeter lead to case.
  - b. Touch other lead to capacitor terminal.

(NOTE: If indicator moves toward zero, capacitor is probably bad and should be discarded. No movement of indicator indicates that unit is not grounded.)

6. Test for open and charging ability.
  - a. Discharge capacitor completely.
  - b. Connect one lead to one capacitor terminal.

(NOTE: Make a good connection.)

**JOB SHEET #3**

- c. While watching ohmmeter, firmly contact other capacitor terminal with second lead.

(NOTE: If the capacitor is good, the ohmmeter indicator will make a sudden move toward zero ohms, then stop and move less rapidly to the high resistance end of scale as the capacitor takes a charge from the voltage applied by the ohmmeter.)

- d. Discharge capacitor and repeat test several times.

(NOTE: If capacitor is open, the ohmmeter indicator will not move. If capacitor is shorted, the instrument will indicate zero or low resistance. If this occurs, discard the unit.)

7. Repeat test procedure on each capacitor.

(NOTE: Destroy bad units to prevent their reinstallation. Show your work to the instructor for evaluation and comments.)

8. Clean work area; return equipment and materials to their proper places.

## MOTORS AND CONTROLLERS UNIT VII

### JOB SHEET #4 — WIRE A THREE-PHASE MOTOR FOR DUAL VOLTAGES

#### A. Equipment and materials needed

1. Dual-voltage motor
2. Pouch tools
3. Wire nuts
4. Wire markers

#### B. Procedure

1. Open motor lead connection box.
2. Separate leads.
3. Check motor name plate for low-voltage connections.
4. Hook up leads as shown on motor plate.
5. Label leads that would go to L1, L2, and L3.
6. Tell instructor the voltage you wired the motor for; have instructor inspect your work.
7. Disconnect all leads.
8. Check motor name plate for high-voltage connections.
9. Hook up leads as shown on motor name plate.
10. Mark leads that would go to L1, L2, and L3.  
  
(NOTE: Tell the instructor what voltage you set the motor up for; have instructor inspect your work.)
11. Reverse the motor's rotation.
12. Have instructor evaluate your work.
13. Clean work area; return equipment and materials to their proper places.

## MOTORS AND CONTROLLERS UNIT VII

### JOB SHEET #5 — PERFORM MAINTENANCE ON A MAGNETIC MOTOR STARTER OR CONTACTOR

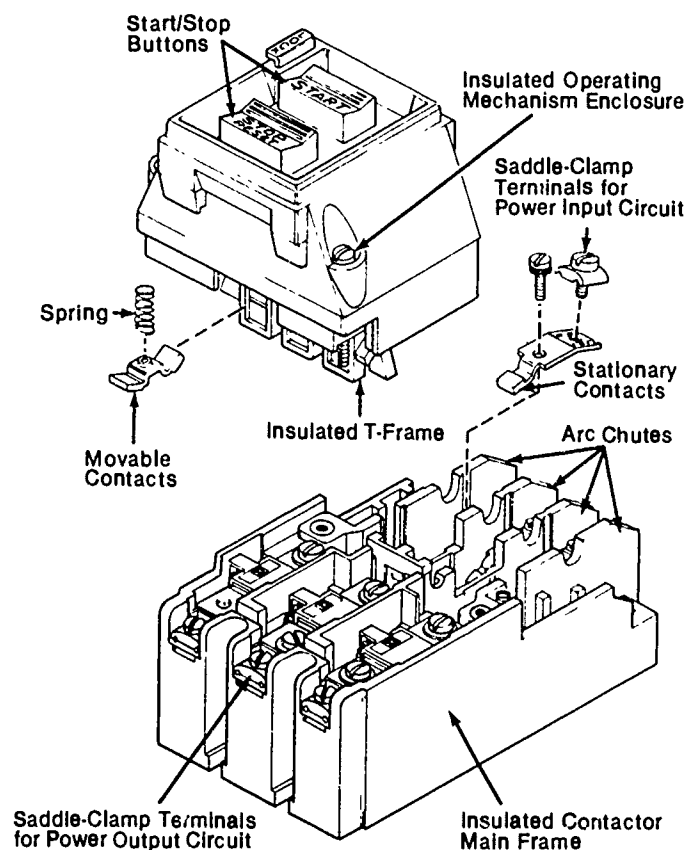
A. Equipment and materials needed

1. Contactor or motor starter
2. Screwdriver
3. Needle-nosed pliers
4. New magnetic coil
5. Wire brush

B. Procedure (Figure 1)

(NOTE: Figure 1 illustrates a manual contactor; however, contacts are the same on manual and magnetic contactors and motor starters.)

FIGURE 1



Courtesy of Square D Company.

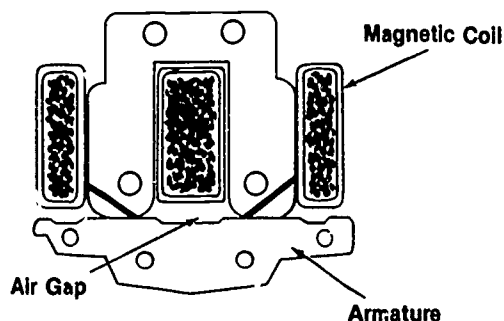
# JOB SHEET #5

1. Remove screws holding insulated operating mechanism enclosure to insulated contactor main frame.
2. Gently pull operating mechanism enclosure from main frame.
3. Locate moveable contacts; remove them from holder.

(NOTE: Take care not to allow the small spring on top of the contact to jump out and become lost.)

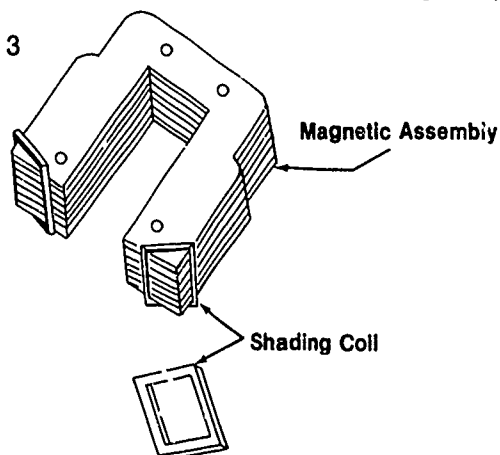
4. Replace movable contacts and springs. (Figure 2)

FIGURE 2



5. Disassemble armature and coil assembly. (Figure 3)

FIGURE 3



6. Clean armature with wire brush.
7. Check shading coil to see that it is secure.
8. Reassemble coil assembly.

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**JOB SHEET #5**

9. Replace coil assembly in contactor or motor starter.
10. Replace coil cover.
11. Tighten coil cover screws.
12. Hook coil wires to coil terminals.

(NOTE: Have instructor inspect contactor or motor starter.)

13. Clean work area; put away equipment and materials.

## MOTORS AND CONTROLLERS UNIT VII

### JOB SHEET #1 PRACTICAL TEST — DISASSEMBLE, INSPECT, AND CLEAN A MOTOR

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Locked out power.  | _____ | _____ |
| 3. Marked loads.  | _____ | _____ |
| 4. Cleaned motor.   | _____ | _____ |
| 5. Marked end bells.  | _____ | _____ |
| 6. Checked for end play.  | _____ | _____ |
| 7. Polished shaft ends.   | _____ | _____ |
| 8. Cleaned with air.  | _____ | _____ |
| 9. Replaced thrust washers.   | _____ | _____ |
| 10. Replaced end bell.  | _____ | _____ |
| 11. Tightened bolts.  | _____ | _____ |
| 12. Turned shaft by hand.   | _____ | _____ |
| 13. Checked motor.  | _____ | _____ |
| 14. Checked in/put away tools and materials.                        | _____ | _____ |
| 15. Cleaned the work area.  | _____ | _____ |
| 16. Used proper tools correctly.                                    | _____ | _____ |
| 17. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 18. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 19. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Cleaned motor				
Reassembled correctly				
Motor runs				
Workmanship				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

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## MOTORS AND CONTROLLERS UNIT VII

### JOB SHEET #2 PRACTICAL TEST — IDENTIFY RUN, COMMON, AND START TERMINALS ON A HERMETICALLY SEALED MOTOR

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Cleaned terminals.  | _____ | _____ |
| 3. Drew sketch of terminals.                                       | _____ | _____ |
| 4. Adjusted ohmmeter.  | _____ | _____ |
| 5. Ran test.   | _____ | _____ |
| 6. Checked in/put away tools and materials.                        | _____ | _____ |
| 7. Cleaned the work area.  | _____ | _____ |
| 8. Used proper tools correctly.                                    | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                   | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Motor 1 correct I.D.				
	4	3	2	1
Motor 2 correct I.D.				
	4	3	2	1
Motor 3 correct I.D.				
	4	3	2	1
Workmanship				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## MOTORS AND CONTROLLERS UNIT VII

### JOB SHEET #3 PRACTICAL TEST — TEST CAPACITORS WITH AN OHMMETER

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Put on eye protection.   | _____ | _____ |
| 3. Applied bleeder resistor.  | _____ | _____ |
| 4. Set meter correctly.   | _____ | _____ |
| 5. Zeroed meter.  | _____ | _____ |
| 6. Checked for ground.  | _____ | _____ |
| 7. Performed test.  | _____ | _____ |
| 8. Checked in/put away tools and materials.                         | _____ | _____ |
| 9. Cleaned the work area.   | _____ | _____ |
| 10. Used proper tools correctly.                                    | _____ | _____ |
| 11. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 12. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 13. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "4" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria: (NOTE: Student must rate 4.)

	4	3	2	1
Capacitor 1				
Capacitor 2				
Capacitor 3				
Capacitor 4				
Capacitor 5				
Capacitor 6				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# MOTORS AND CONTROLLERS

## UNIT VII

### JOB SHEET #4 PRACTICAL TEST — WIRE A THREE-PHASE MOTOR FOR DUAL VOLTAGES

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Checked nameplate.	_____	_____
3. Connected leads.	_____	_____
4. Reversed motor.	_____	_____
5. Checked in/put away tools and materials.	_____	_____
6. Cleaned the work area.	_____	_____
7. Used proper tools correctly.	_____	_____
8. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
9. Practiced safety rules throughout procedure.	_____	_____
10. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_



## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Proper high voltage connection				
Proper low voltage connection				
Workmanship				

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## MOTORS AND CONTROLLERS UNIT VII

### JOB SHEET #5 PRACTICAL TEST — PERFORM MAINTENANCE ON A MAGNETIC MOTOR STARTER OR CONTACTOR

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Laid out parts in an orderly manner.                             | _____ | _____ |
| 3. Removed contacts.  | _____ | _____ |
| 4. Replaced contacts properly.                                      | _____ | _____ |
| 5. Cleaned armature.  | _____ | _____ |
| 6. Checked shaded coil.   | _____ | _____ |
| 7. Reassembled unit.  | _____ | _____ |
| 8. Checked in/put away tools and materials.                         | _____ | _____ |
| 9. Cleaned the work area.   | _____ | _____ |
| 10. Used proper tools correctly.                                    | _____ | _____ |
| 11. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 12. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 13. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #5 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Contacts operable				
Armature clean				
Unit operates				
Workmanship				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# MOTORS AND CONTROLLERS

## UNIT VII

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

- |   |                       |
|---|-----------------------|
| _____a. Three-phase circuit in which the windings are connected in parallel (form the shape of a Y)                                       | 1. Arc chute          |
| _____b. Ratio of active power to apparent power   | 2. Armature           |
| _____c. Device used to make or break a motor's power circuit  | 3. Contactor          |
| _____d. Partition between contacts to reduce electrical arcing  | 4. Delta              |
| _____e. Single turn of conducting material mounted on the magnetic assembly face to produce out-of-phase magnetic force                   | 5. Dual voltage motor |
| _____f. Force that produces a rotating or twisting action   | 6. Power factor       |
| _____g. Portion of coil assembly moved by magnetism   | 7. Relay              |
| _____h. Operated by a change in one electrical circuit to control advice in the same circuit or another circuit; used in control circuits | 8. Shading coil       |
| _____i. Device used to sense current draw in a circuit and open a control circuit when its rating is exceeded                             | 9. Single phasing     |
| _____j. Three-phase circuit in which the windings are connected in series (form a closed loop)  | 10. Starter           |
| _____k. Motor capable of being wired to run at two different voltages   | 11. Thermal overloads |
| _____l. Device used to make and break electrical power circuit  | 12. Torque            |
| _____m. Loss of one phase of a three-phase system   | 13. Wye               |

**TEST**

2. Discuss the direct current motor theory of operation.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

3. List three types of DC motors.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

4. Discuss the single-phase motor theory of operation.

- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

5. List five types of single-phase motors.

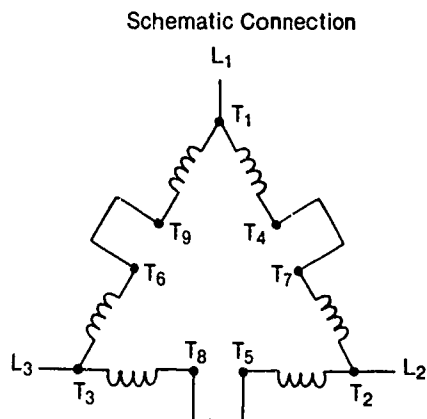
- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

6. Discuss three-phase motor theory of operation.

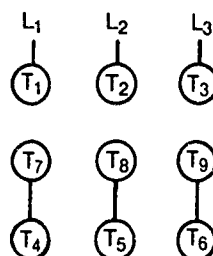
- a. \_\_\_\_\_  
\_\_\_\_\_
- b. \_\_\_\_\_  
\_\_\_\_\_
- c. \_\_\_\_\_  
\_\_\_\_\_

## TEST

7. List three types of three-phase motors.
- \_\_\_\_\_
  - \_\_\_\_\_
  - \_\_\_\_\_
8. State the procedure for reversing a three-phase motor.
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
9. Select from the following list typical supply voltages for three-phase motors by placing an "X" in the blanks preceding the correct answers.
- \_\_\_\_\_ 360-volt three-phase delta
  - \_\_\_\_\_ 240-volt three-phase delta
  - \_\_\_\_\_ 208-volt three-phase wye
  - \_\_\_\_\_ 240-volt three-phase wye
  - \_\_\_\_\_ 480-volt three-phase wye
10. Identify schematic and terminal connections for delta and wye wound three-phase motors.
- \_\_\_\_\_

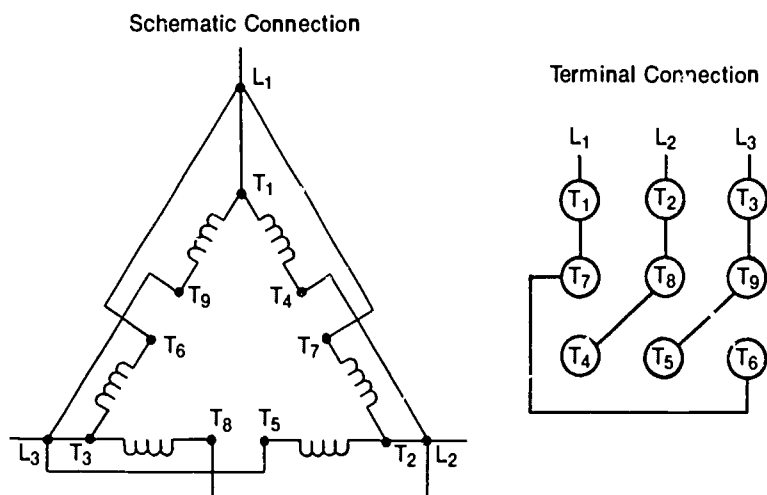


Terminal Connection

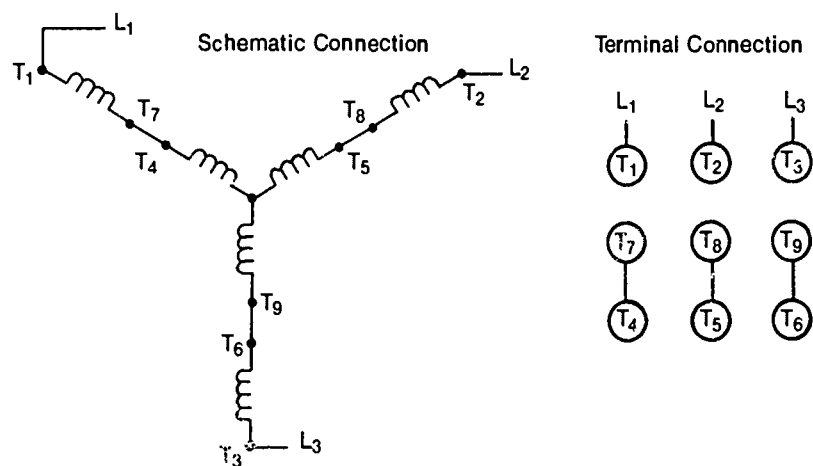


## TEST

b.

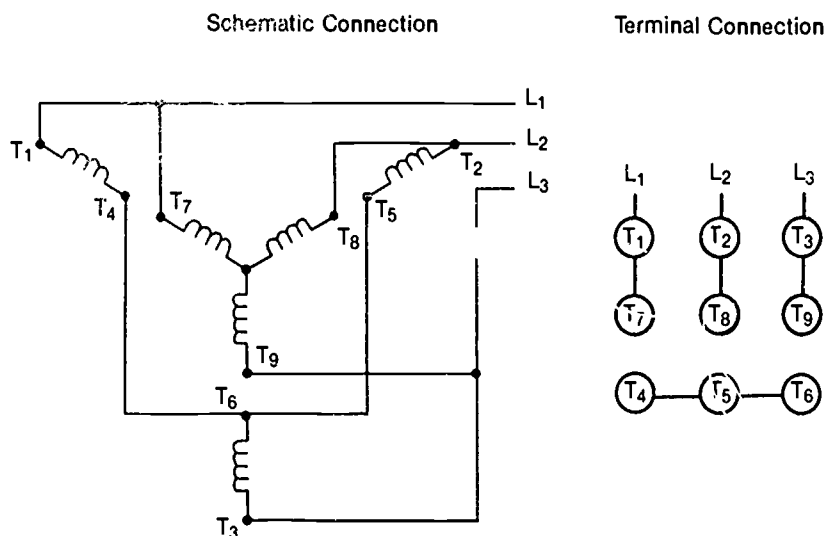


c.



## TEST

d.



11. Match motor problems on the right with their typical symptoms.

(NOTE: Blanks should contain more than one answer.)

- |                              |                                      |
|------------------------------|--------------------------------------|
| a. _____ Failure to start    | 1. Obstruction of ventilating system |
| b. _____ Excessive noise     | 2. Lack of oil                       |
| c. _____ Overheated bearings | 3. Unbalanced parts                  |
| d. _____ Overheated motor    | 4. Overloading                       |
|                              | 5. Dirty oil                         |
|                              | 6. Bent shaft                        |
|                              | 7. Incorrect voltage                 |
|                              | 8. Excessive end thrust              |
|                              | 9. Faulty alignment                  |
|                              | 10. High ambient temperature         |
|                              | 11. Excessive greaser oil            |
|                              | 12. Worn bearings                    |
|                              | 13. Blown fuse                       |
|                              | 14. Open overload                    |
|                              | 15. Excessive load                   |



## TEST

12. Match remedies on the right with the correct symptoms of motor problems.

- |                              |                                     |
|------------------------------|-------------------------------------|
| a. _____ Failure to start    | 1. Clean motor                      |
| b. _____ Excessive noise     | 2. Put clean oil in reservoir       |
| c. _____ Overheated bearings | 3. Replace bearings                 |
| d. _____ Overheated motor    | 4. Adjust bolt tension              |
|                              | 5. Check for correct voltage        |
|                              | 6. Check supply voltage             |
|                              | 7. Check full load amps             |
|                              | 8. Check motor wiring with ohmmeter |

13. Complete the following list of safety rules to observe when working around motors by inserting the word which best completes each rule.

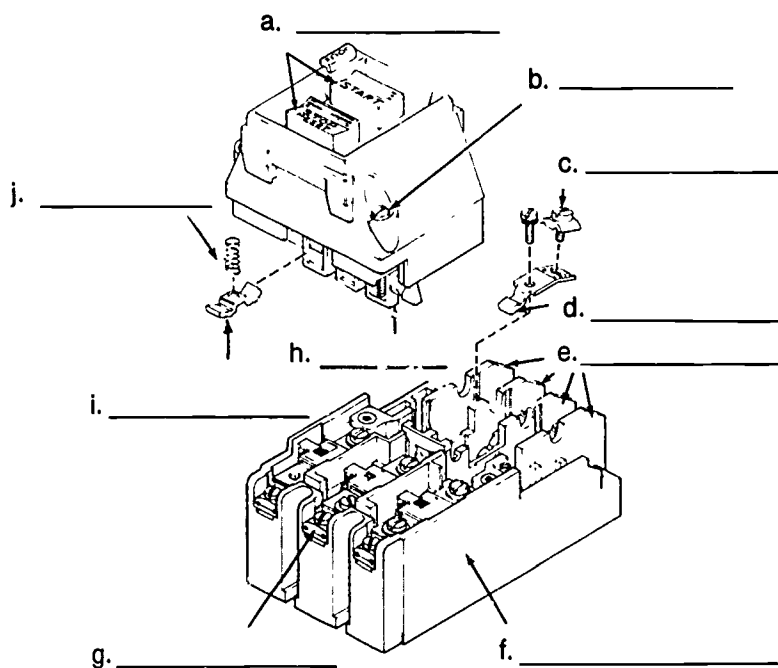
- a. Do not underestimate the \_\_\_\_\_ of the circuit.
- b. Never install equipment that will \_\_\_\_\_ the circuit.
- c. Never bypass \_\_\_\_\_ devices.
- d. Protect all \_\_\_\_\_ from physical and thermal hazards.
- e. \_\_\_\_\_ and \_\_\_\_\_ electrical disconnects when working on motors or motor circuits.
- f. \_\_\_\_\_ all electric motor frames.

14. Name two types of contactors.

- a. \_\_\_\_\_
- b. \_\_\_\_\_

## TEST

15. Identify the parts of the manual contactor illustrated below.



16. Select from the following list electrical devices or circuits controlled by contactors by placing an "X" in the blanks preceding the correct answers.

- \_\_\_\_ a. Starting buttons
- \_\_\_\_ b. Lighting loads
- \_\_\_\_ c. Heaters
- \_\_\_\_ d. Transformers
- \_\_\_\_ e. Overload contacts
- \_\_\_\_ f. Capacitors
- \_\_\_\_ g. Power circuits

## TEST

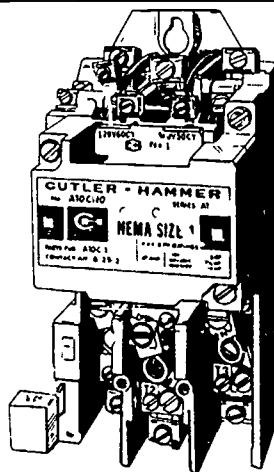
17. Name two types of motor starters.

a. \_\_\_\_\_

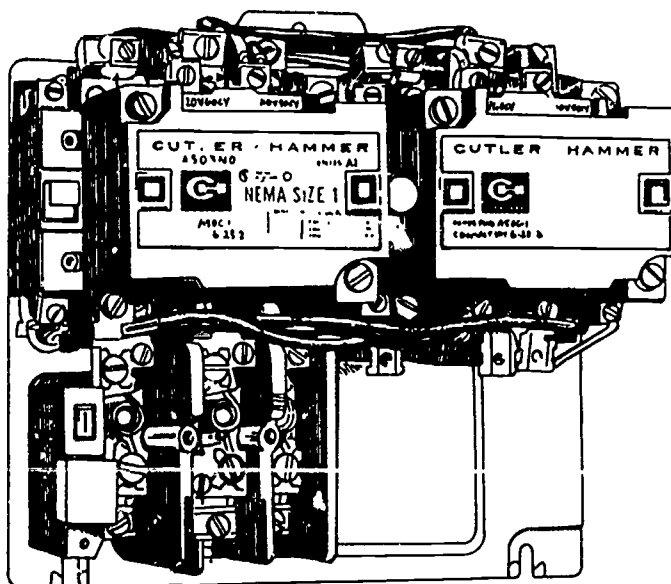
b. \_\_\_\_\_

18. Identify two types of magnetic motor starters.

a. \_\_\_\_\_



b. \_\_\_\_\_



## TEST

19. List three uses of magnetic motor starters.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

20. Compare parts in magnetic contactors with parts in magnetic motor starters.

Parts	Contactors	Motor Starters
Overload contact		
Line terminals		
Reset button		
Power contacts		
Thermal overload (heater)		
Load terminals		
Coil		
Holding contacts		

21. Complete the following statements concerning reasons a contactor cannot be used to control a motor by inserting the word that best completes each statement.

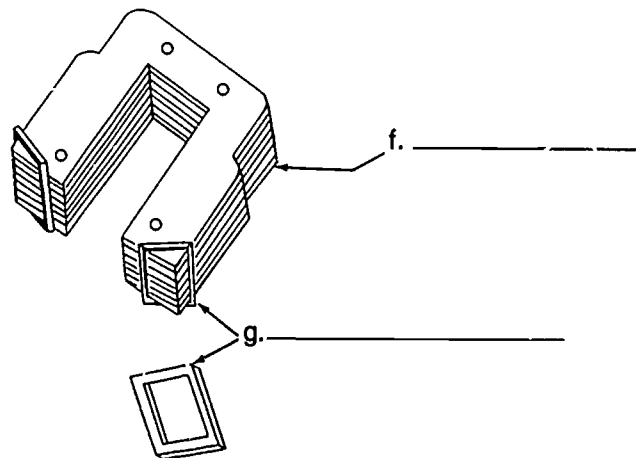
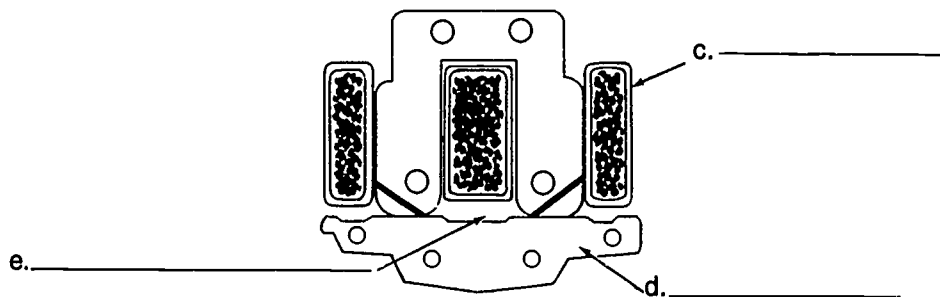
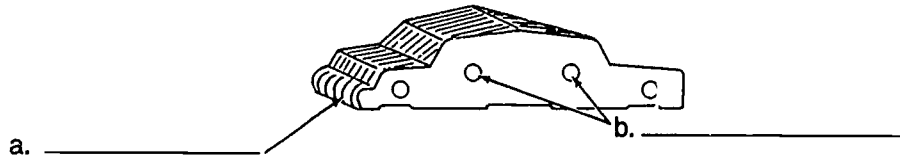
- a. Contactor does not provide running \_\_\_\_\_ for motor.
- b. Contactor is not designed for \_\_\_\_\_ for motor starting.
- c. Contactor does not contain a set of \_\_\_\_\_.

22. State the purposes of a coil assembly.

- a. \_\_\_\_\_
- b. \_\_\_\_\_

## TEST

23. Identify parts of the coil assembly illustrated below.



(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

24. Interpret nameplate information. (Assignment Sheet #1)
25. Describe remedies for common motor problems. (Assignment Sheet #2)
26. Use the National Electrical Code to answer questions about motor control circuits. (Assignment Sheet #3)
27. Distinguish between motor starters and contactors. (Assignment Sheet #4)

**TEST**

28. Answer questions about uses of contactors and motor starters. (Assignment Sheet #5)
29. Demonstrate the ability to:
  - a. Disassemble, inspect, and clean a motor. (Job Sheet #1)
  - b. Identify run, common, and start terminals on a hermetically sealed motor. (Job Sheet #2)
  - c. Test capacitors with an ohmmeter. (Job Sheet #3)
  - d. Wire a three-phase motor for dual voltages. (Job Sheet #4)
  - e. Perform maintenance on a magnetic motor starter or contactor. (Job Sheet #5)

## MOTORS AND CONTROLLERS UNIT VII

### ANSWERS TO TEST

1.   a.   13                   e.   8                   i.   11                   m.   9  
      b.   6                   f.   12                  j.   4  
      c.   10                  g.   2                  k.   5  
      d.   1                  h.   7                  l.   3
  
2.   a.   Magnetic field is produced at face of stationary poles  
      b.   Magnetic field produced in armature windings  
      c.   Fields repel each other
  
3.   a.   Shunt  
      b.   Series  
      c.   Compound
  
4.   a.   Operates on single wave form  
      b.   A/C current produces a varying magnetic field
  
5.   a.   Shaded pole  
      b.   Split phase  
      c.   Capacitor  
      d.   Induction repulsion  
      e.   Series
  
6.   a.   Current in stator produces a rotating magnetic field  
      b.   Currents in rotor create a magnetic field  
      c.   The rotor turns, seeking an opposite pole
  
7.   a.   Squirrel cage  
      b.   Wound rotor  
      c.   Synchronous
  
8.   Reverse any two leads
  
9.   c, e

**ANSWERS TO TEST**

- 10.
  - a. Delta-wound 9-lead high voltage
  - b. Delta-wound 9-lead low voltage
  - c. Wye-wound 9-lead high voltage
  - d. Wye-wound 9-lead low voltage
  
- 11.
  - a. 13, 14, 15
  - b. 3, 12, 9, 12
  - c. 2, 5, 8, 11
  - d. 1, 4, 7, 10
  
- 12.
  - a. 6, 8
  - b. 3, 1
  - c. 2, 4
  - d. 1, 5, 4, 7
  
- 13.
  - a. Danger
  - b. Overload
  - c. Protective
  - d. Wires
  - e. Tag, look
  
- 14.
  - a. Manual
  - b. Magnetic
  
- 15.
  - a. Start/stop button
  - b. Insulated operating mechanism enclosure
  - c. Saddle clamp terminal for power input
  - d. Insulated T-frame assembly
  - e. Moveable contacts
  - f. Spring
  - g. Stationary contact
  - h. Arch chutes
  - i. Insulated contactor main frame
  - j. Saddle clamp terminals for power output
  
- 16. b, c, d, f, g
  
- 17.
  - a. Manual
  - b. Magnetic



## ANSWERS TO TEST

18. a. Reversing  
b. Starting
19. Any three of the following:
- a. Starting motors
  - b. Reversing motors
  - c. Braking motors to stop
  - d. Controlling speed of motors
- 20.
- | Contactors | Starters |
|------------|----------|
| No         | Yes      |
| Yes        | Yes      |
| No         | Yes      |
| Yes        | Yes      |
| No         | Yes      |
| Yes        | Yes      |
| Yes        | Yes      |
| Yes        | Yes      |
21. a. Overload protection  
b. High inrush current  
c. Overload contacts
22. a. Changes electrical signal to magnetic signal  
b. Activates mechanical portion of motor starter
23. a. Laminations  
b. Rivets  
c. Magnetic coil  
d. Armature  
e. Air gap  
f. Magnetic assembly  
g. Shading coil
- 24.-28. Evaluated to the satisfaction of the instructor
29. Performance skills evaluated to the satisfaction of the instructor

## **ELECTRICAL DIAGRAMS AND SYMBOLS UNIT VIII**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to draw and interpret electrical control diagrams. Competencies will be demonstrated by completing the assignment sheets and the unit test with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to electrical diagrams with their correct definitions.
2. Complete a list of characteristics of wiring diagrams.
3. Select true statements concerning characteristics of ladder diagrams.
4. State the characteristics of one-line diagrams.
5. Identify wiring and ladder diagram symbols.
6. Arrange in order major steps in constructing a ladder diagram.
7. Construct a basic ladder diagram. (Assignment Sheet #1)
8. Identify electrical symbols in a wiring diagram. (Assignment Sheet #2)

## **ELECTRICAL DIAGRAMS AND SYMBOLS UNIT VIII**

### **SUGGESTED ACTIVITIES**

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Provide students with objective sheet.
- C. Discuss unit and specific objectives.
- D. Provide students with information and assignment sheets.
- E. Discuss information and assignment sheets.
- F. Integrate the following activities throughout the teaching of this unit:
1. Provide students with examples of wiring and ladder diagrams.
  2. Have students evaluate sequence of operation of various ladder diagrams.
  3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- G. Give test.
- H. Evaluate test.
- I. Reteach if necessary.

### **REFERENCES USED IN WRITING THIS UNIT**

- A. Rockis, Gary and Glen Mazur. *Electrical Motor Controls*. Alsip, IL: American Technical Publishers, 1982.
- B. Teagus, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

# ELECTRICAL DIAGRAMS AND SYMBOLS

## UNIT VIII

### INFORMATION SHEET

#### I. Terms and definitions

- A. Across-the-line — Method of starting an electric motor by connecting it directly to supply line
- B. Automatic starting — Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device
- C. Auxiliary contact — Contact provided in addition to the main circuit contacts but operated with the main contacts

(NOTE: Auxiliary contacts are mechanically operated by the coil of the starter or contactor.)

- D. Bimetal — Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

(NOTE: Bimetals are frequently used in thermal overload relays.)

- E. Contactor — Device without overload protection; repeatedly establishes and interrupts an electric power circuit
- F. Full voltage control — Function of magnetic control that connects equipment directly to supply line on starting
- G. Jogging (inching) — Momentarily operating; moving driven machine a small distance
- H. Ladder diagram (line diagram) — Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit

(NOTE: Ladder diagrams depict control logic.)

- I. Magnetic contactor — Contactor operated electromechanically
- J. Multispeed starter — Starter designed to start motor at a reduced speed and built to full speed in preset steps
- K. One-line diagram — Schematic consisting of single-phase and three-phase power lines; indicates power distribution and fuse and interrupter coordination

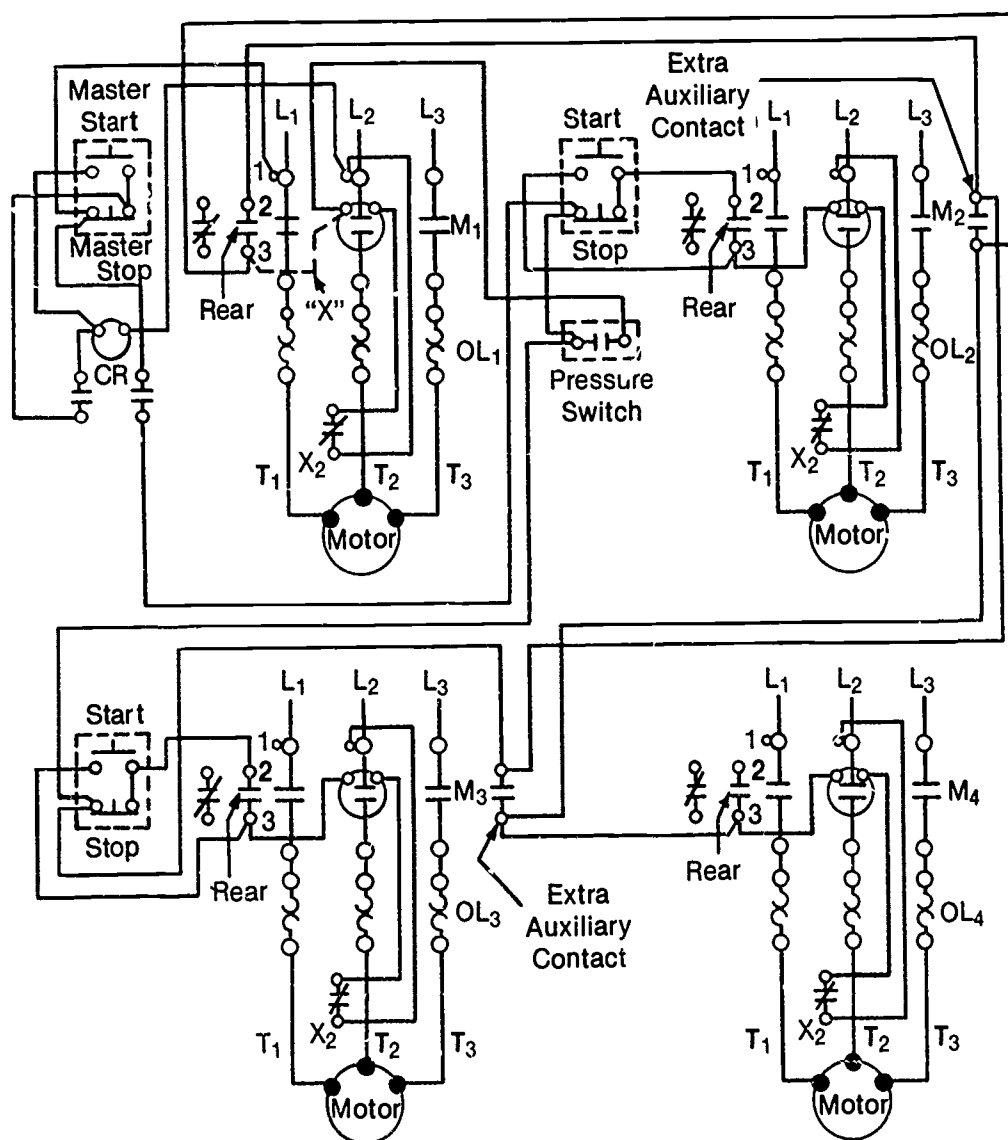
## INFORMATION SHEET

- L. Overload relay — Device for protecting motor from overload current or voltage  
  
(NOTE: An overload relay does not necessarily protect against short circuit, but does cause and maintain interruption from power supply until reset.)
- M. Push button — Switch, manually operable plunger, button, or actuating device
- N. Relay — Electromechanical device operated by a coil; uses contacts to make or break circuits
- O. Remote control — Device that controls electrical apparatus from some distance
- P. Selector switch — Manually operated multiposition switch  
  
(NOTE: The selector switch is also called a *multiple-contact switch*.)
- Q. Starter — Control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting
- R. Timer — Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric
- S. Wiring diagram — Schematic consisting of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring

## INFORMATION SHEET

### II. Characteristics of wiring diagrams

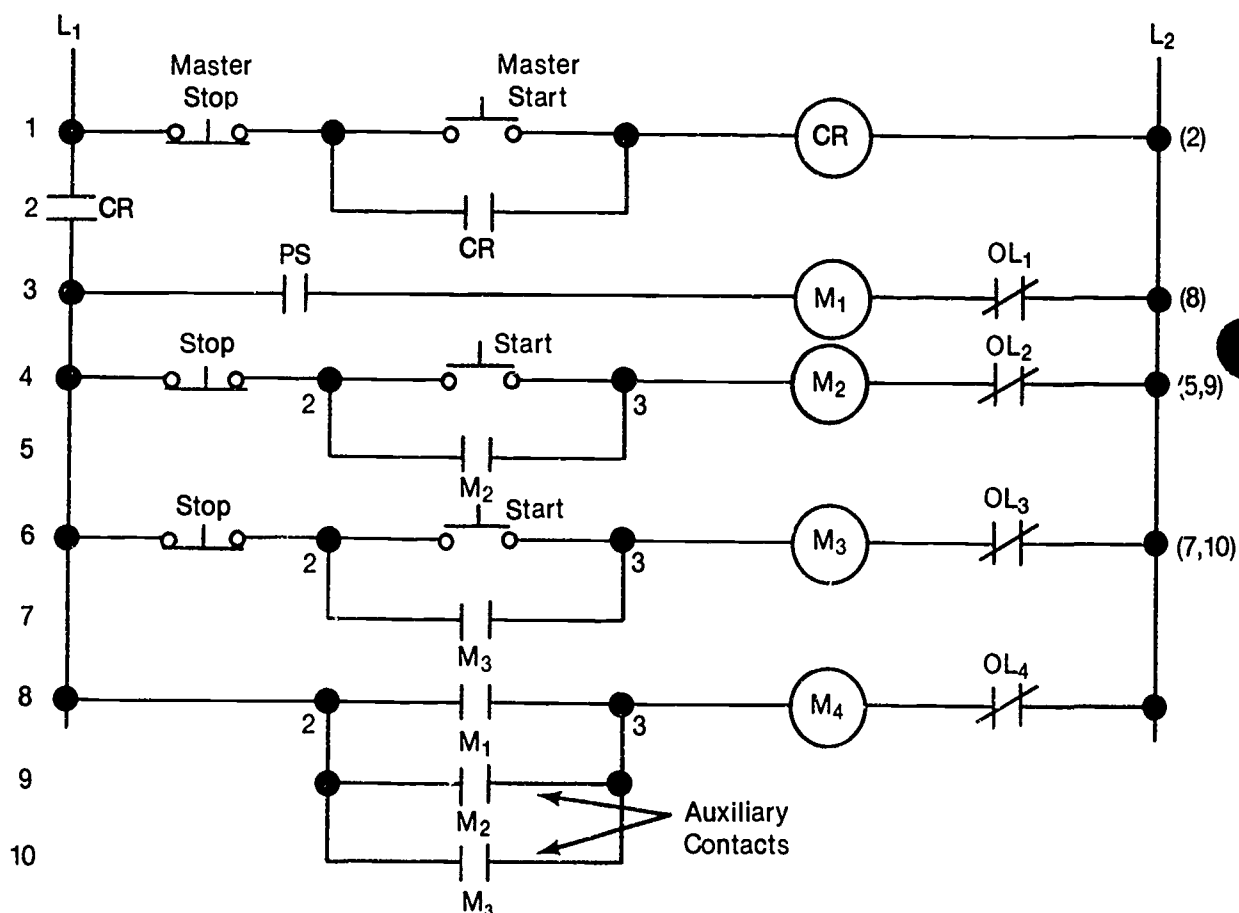
- A. Show components in their approximate locations
- B. Provide guide for field wiring
- C. Use standard symbology
- D. Show power and control lines together
- E. Make circuits difficult to trace



## INFORMATION SHEET

### III. Characteristics of ladder diagrams

- A. Resemble a ladder
- B. Show individual circuits as ladder rungs
- C. Use standard electrical symbols
- D. Separate power and control lines
- E. Simplify circuit troubleshooting

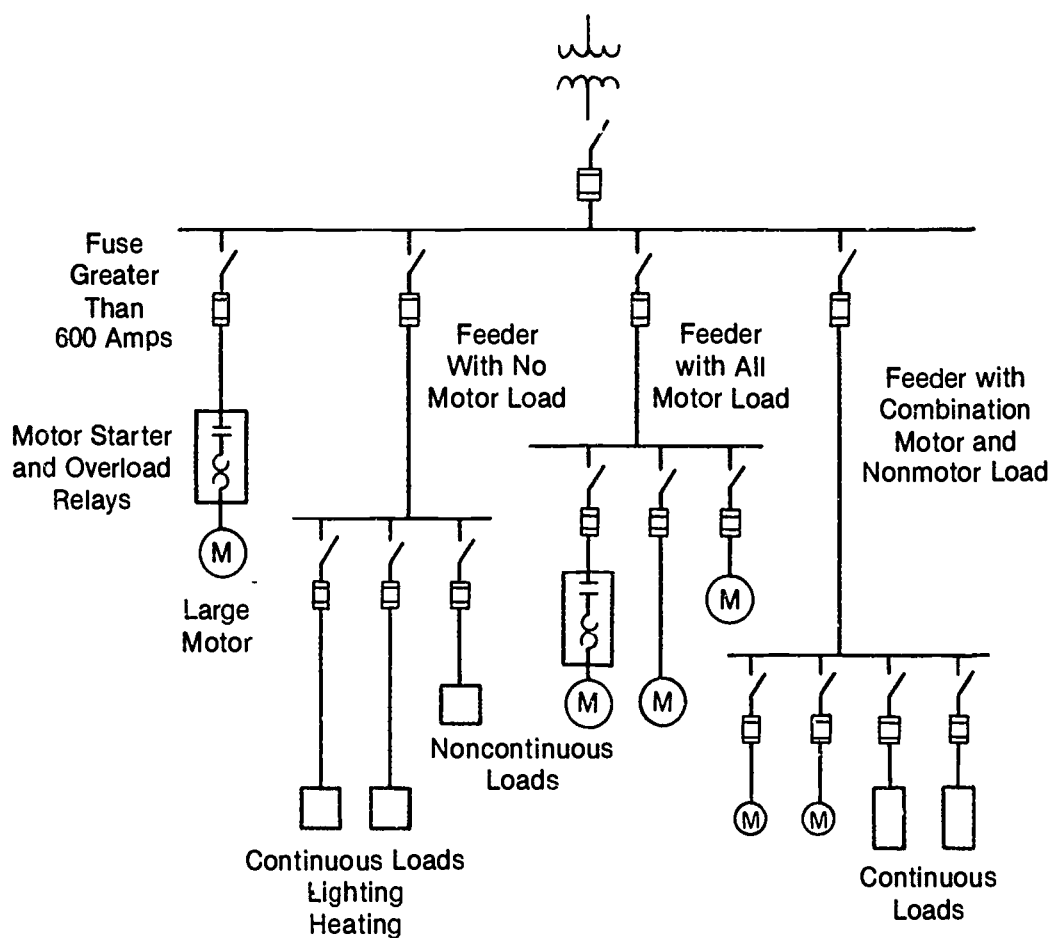


(NOTE: The electrical industry is rapidly changing over to ladder diagrams; however it is important that the electrical technician is able to read and interpret all types of diagrams.)

## INFORMATION SHEET

### IV. Characteristics of one-line diagrams

- A. Show location of transformers
- B. Show location of overcurrent devices
- C. Indicate overcurrent device sizes
- D. Indicate sizes of loads
- E. Indicate characteristics of loads

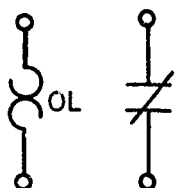




# INFORMATION SHEET

## V. Wiring and ladder diagram symbols

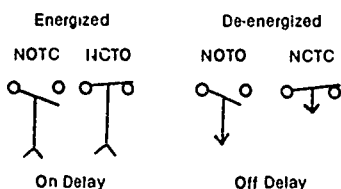
A. Thermal overload relay



B. Time delay relay coil



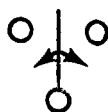
C. Timed contacts



D. Standard resistor



E. Plugging switch



F. Limit switch (normally open)



G. Limit switch (normally closed)



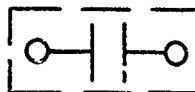
H. Limit switch (held open)



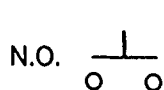
I. Limit switch (held closed)



J. Two wire pilot device



K. Momentary contact



Single Circuit



N.O. and N.C.



Double Circuit



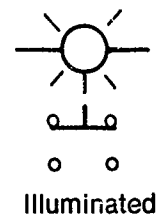
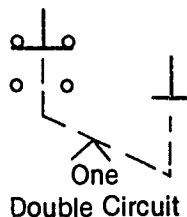
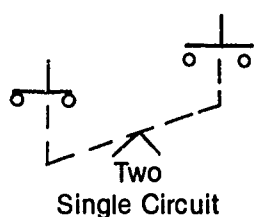
Mushroom Head



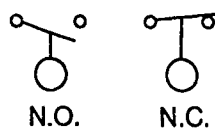
Wobble Stick

# INFORMATION SHEET

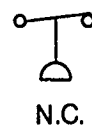
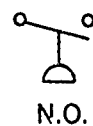
## L. Maintained contact



## M. Liquid level switch



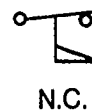
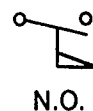
## N. Pressure and vacuum switches



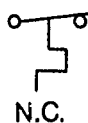
## O. Foot switches



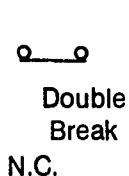
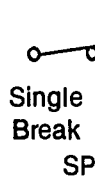
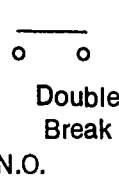
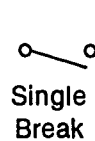
## P. Flow switch



## Q. Temperature actuated switch



## R. Switches

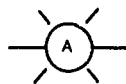


SPST N.O.

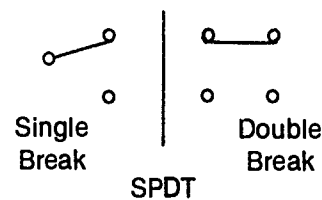
SPST N.C.

## S. Pilot lights

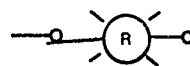
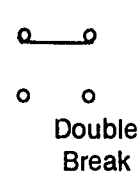
(NOTE: Indicate color by letter.)



Non Push-to-test



SPDT



Push-to-test

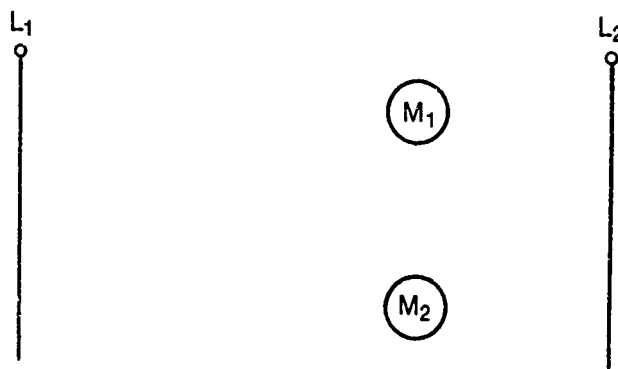
## INFORMATION SHEET

### VI. Major steps in constructing ladder diagrams

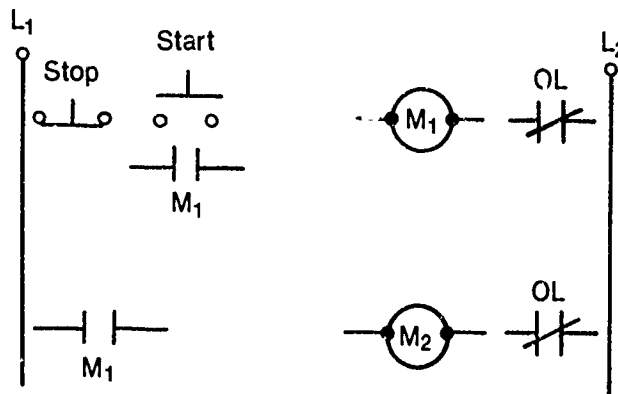
#### A. Establish and label power lines



#### B. Identify and label loads

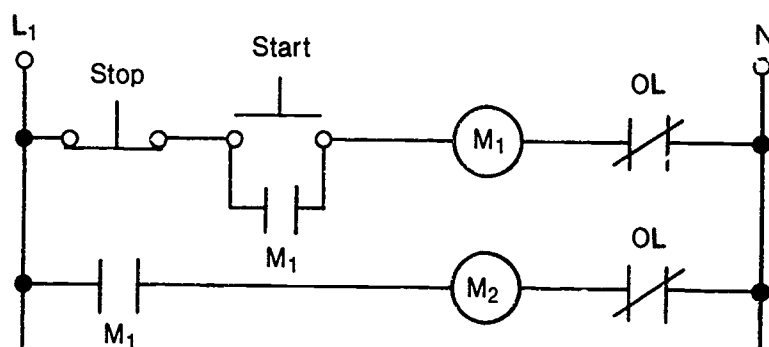


#### C. Identify and label control devices and contacts for each circuit (rung)



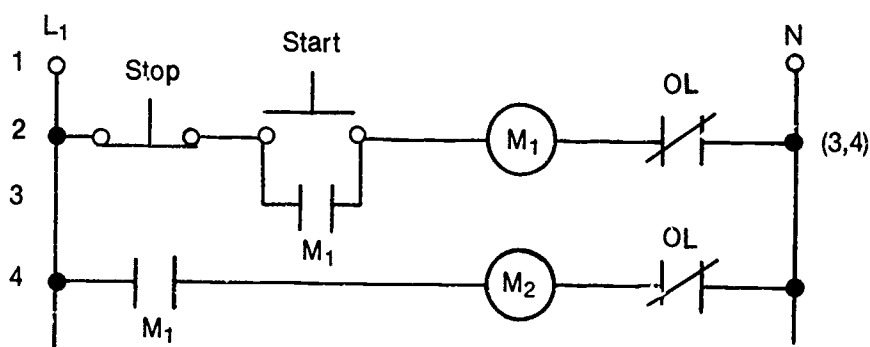
# INFORMATION SHEET

- D. Connect circuit wires, keeping ladder rungs equidistant for ease of reading



- E. Number rungs, and cross reference

(NOTE: This step is extremely important especially in more complex diagrams containing many rungs.)



## ELECTRICAL DIAGRAMS AND SYMBOLS UNIT VIII

### ASSIGNMENT SHEET #1 — CONSTRUCT A BASIC LADDER DIAGRAM

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

The electrical technician must be able to draw and read ladder diagrams to facilitate troubleshooting procedures.

Directions: In the space provided below, draw, label, and reference a ladder diagram with the following components: 120 VAC fused power supply, three loads, two single-pole single-throw (SPST) switches, and one control relay with a line voltage coil. Each load is to be a parallel circuit. Control two loads with the relay, one load with an SPST switch, and the relay coil with an SPST switch.

## ELECTRICAL DIAGRAMS AND SYMBOLS UNIT VIII

### ASSIGNMENT SHEET #2 — IDENTIFY ELECTRICAL SYMBOLS IN A WIRING DIAGRAM

NAME \_\_\_\_\_

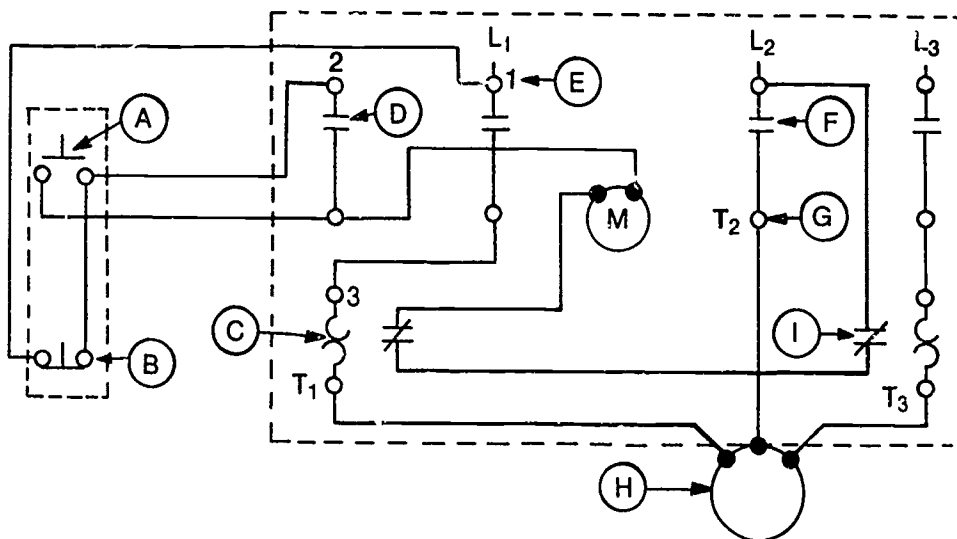
SCORE \_\_\_\_\_

The electrical technician must be able to identify electrical symbols in a wiring diagram in order to recognize all component parts in a device or circuit.

Directions: Identify the electrical symbols used in the wiring diagram illustrated below. Write the answers in the blanks.

Line and control wiring terminal  
Normally closed push button (stop)  
Three-phase motor  
Overload device switch  
Normally open push button (start)

T2 motor lead terminal  
Auxiliary contact  
Thermal overload relay  
Main contact



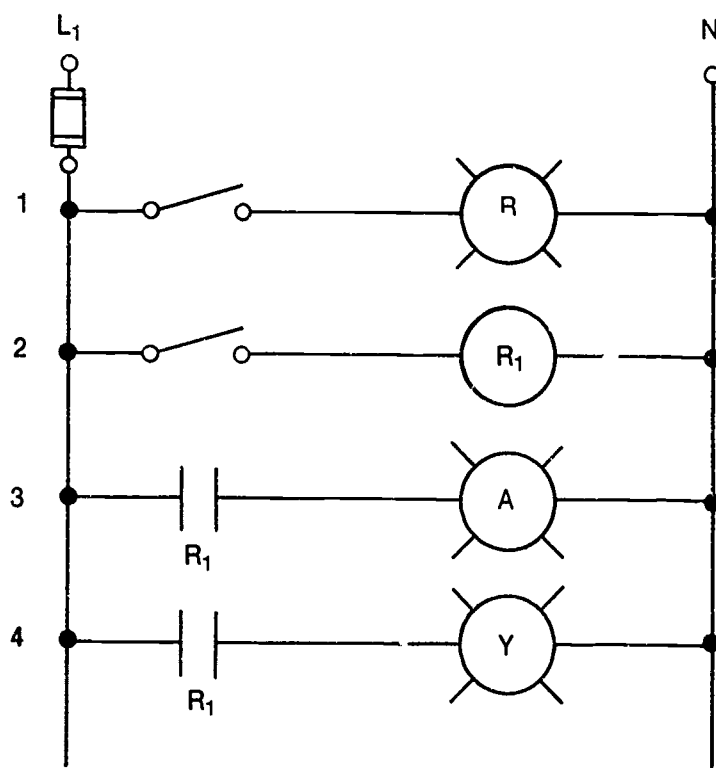
A. \_\_\_\_\_  
B. \_\_\_\_\_  
C. \_\_\_\_\_  
D. \_\_\_\_\_  
E. \_\_\_\_\_

F. \_\_\_\_\_  
G. \_\_\_\_\_  
H. \_\_\_\_\_  
I. \_\_\_\_\_

# ELECTRICAL DIAGRAMS AND SYMBOLS UNIT VIII

## ANSWERS TO ASSIGNMENT SHEETS

### Assignment Sheet #1



### Assignment Sheet #2

- A. Normally open push button (start)
- B. Normally closed push button (stop)
- C. Thermal overload relay
- D. Auxiliary contact
- E. Line and control wiring terminal
- F. Main contact
- G. T2 motor lead terminal
- H. Three-phase motor
- I. Overload device switch

# ELECTRICAL DIAGRAMS AND SYMBOLS

## UNIT VIII

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions. Definitions are continued on the next page.

- |   |                         |
|---|-------------------------|
| _____a. Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric | 1. Across-the-line      |
| _____b. Control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting     | 2. Automatic starting   |
| _____c. Manually operated multiposition switch  | 3. Auxiliary contact    |
| _____d. Contactor operated electromechanically  | 4. Bimetal              |
| _____e. Momentary operating; moving driven machine a small distance   | 5. Contactor            |
| _____f. Device that controls electrical apparatus from some distance  | 6. Full voltage control |
| _____g. Switch, manually operable plunger, button, or actuating device  | 7. Jogging              |
| _____h. Function of magnetic control that connects equipment directly to line supply on starting  | 8. Ladder diagram       |
| _____i. Electromechanical device operated by a coil; uses contacts to make or break circuits  | 9. Magnetic contactor   |
| _____j. Device for protecting motor from overload current or voltage  | 10. Multispeed starter  |
| _____k. Starter designed to start motor at a reduced speed and built to full speed in preset steps  | 11. One-line diagram    |
| _____l. Device without overload protection; repeatedly establishes and interrupts an electric power circuit                               | 12. Overload relay      |
| _____m. Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection                               | 13. Push button         |
|   | 14. Relay               |
|   | 15. Remote control      |
|   | 16. Selector switch     |
|   | 17. Starter             |
|   | 18. Timer               |
|   | 19. Wiring diagram      |



## TEST

- \_\_\_\_\_ n. Schematic consisting of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring
- \_\_\_\_\_ o. Schematic consisting of single-phase and three-phase power lines; indicates power distribution and fuse and interrupter coordination
- \_\_\_\_\_ p. Contact provided in addition to the main circuit contacts but operated with the main contacts
- \_\_\_\_\_ q. Method of starting an electric motor by connecting it directly to supply line
- \_\_\_\_\_ r. Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device
- \_\_\_\_\_ s. Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit
2. Complete the following list of characteristics of wiring diagrams by inserting the word which best completes each statement.
- Show components in their \_\_\_\_\_ locations.
  - Provide \_\_\_\_\_ for field wiring.
  - Use electrical \_\_\_\_\_.
  - Show \_\_\_\_\_ and \_\_\_\_\_ lines together.
  - Make circuits difficult to \_\_\_\_\_.
3. Select true statements concerning characteristics of ladder diagrams by placing an "X" in the blanks preceding the true statements.
- \_\_\_\_\_ a. Resemble a ladder
  - \_\_\_\_\_ b. Depict individual circuits as ladder rungs
  - \_\_\_\_\_ c. Use mechanical symbols
  - \_\_\_\_\_ d. Show power control voltages together
  - \_\_\_\_\_ e. Simplify circuit troubleshooting

## TEST

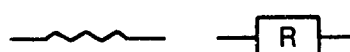
4. State the characteristics of one line diagrams.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

5. Identify wiring and ladder diagram symbols shown below.



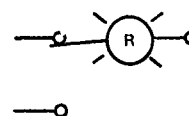
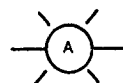
a. \_\_\_\_\_



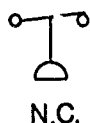
b. \_\_\_\_\_



c. \_\_\_\_\_



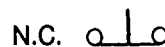
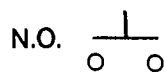
d. \_\_\_\_\_



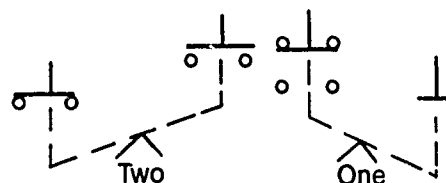
e. \_\_\_\_\_



f. \_\_\_\_\_

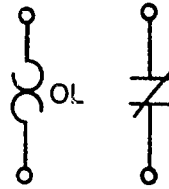
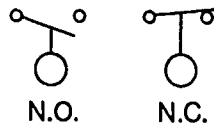


g. \_\_\_\_\_



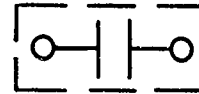
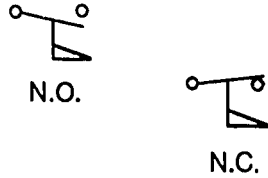
h. \_\_\_\_\_

## TEST



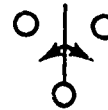
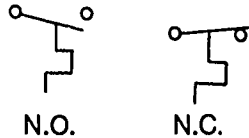
i. \_\_\_\_\_

j. \_\_\_\_\_



k. \_\_\_\_\_

l. \_\_\_\_\_



m. \_\_\_\_\_

n. \_\_\_\_\_

6. Arrange in order the major steps in constructing a ladder diagram. Number the blanks in the appropriate sequence.

- \_\_\_\_\_a. Identify and label loads.
- \_\_\_\_\_b. Connect circuit wires, keeping ladder rungs equidistant for ease of reading.
- \_\_\_\_\_c. Establish and label power lines.
- \_\_\_\_\_d. Identify and label control devices and contacts for each circuit (rung).
- \_\_\_\_\_e. Number rungs, and cross reference.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

- 7. Construct a basic ladder diagram. (Assignment Sheet #1)
- 8. Identify electrical symbols in a wiring diagram. (Assignment Sheet #2)

## ELECTRICAL DIAGRAMS AND SYMBOLS UNIT VIII

### ANSWERS TO TEST

1.   a.   18           f.   15           k.   10           p.   3  
     b.   17           g.   13           l.   5           q.   1  
     c.   16           h.   6           m.   4           r.   2  
     d.    .           i.   14          n.   19          s.   8  
     e.   7           j.   12
  
2.   a.   Approximate  
     b.   Guide  
     c.   Symbols  
     d.   Power, control  
     e.   Trace
  
3.   a, b, e
  
4.   a.   Show location of transformers  
     b.   Show location of overcurrent devices  
     c.   Indicate overcurrent device sizes  
     d.   Indicate sizes of loads  
     e.   Indicate characteristics of loads
  
5.   a.   Limit switch (normally open)           h.   Maintained contact  
     b.   Standard resistor                   i.   Liquid level switch  
     c.   Foot switch                           j.   Thermal overload relay  
     d.   Pilot lights                           k.   Flow switch  
     e.   Pressure and vacuum switch           l.   Two wire pilot device  
     f.   Time delay relay coil               m.   Temperature actuated switch  
     g.   Momentary contact                   n.   Plugging switch
  
6.   a.   2  
     b.   4  
     c.   1  
     d.   3  
     e.   5
  
- 7.-8.   Evaluated to the satisfaction of the instructor

## **TWO AND THREE WIRE CONTROLS UNIT IX**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to interpret wiring and ladder diagrams related to two-wire and three-wire controls as well as wire these systems. Competencies will be demonstrated by completing the assignment sheets, job sheets, and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to two and three wire controls with their correct definitions.
2. Identify typical two-wire pilot devices.
3. List two advantages of two-wire controls.
4. State the basic rule for three-wire controls.
5. List two advantages of three-wire controls.
6. Describe the operation of a two-wire control system.
7. Describe the operation of a three-wire control system.
8. Complete a ladder and a wiring diagram of a two-wire control using a thermal switch. (Assignment Sheet #1)
9. Draw a ladder diagram of a three-wire control with an "on" indicating pilot light. (Assignment Sheet #2)
10. Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light. (Assignment Sheet #3)

**OBJECTIVE SHEET**

11. Determine the number and size of conductors needed to operate a two-wire control system. (Assignment Sheet #4)
12. Determine the number and size of conductors needed to operate a three-wire control system. (Assignment Sheet #5)
13. Demonstrate the ability to:
  - a. Wire a two-wire control. (Job Sheet #1)
  - b. Wire two float switches to operate a starter (series connection). (Job Sheet #2)
  - c. Wire two float switches to operate a starter (parallel connections). (Job Sheet #3)
  - d. Wire a pressure switch to operate a starter with "on" and "off" pilot lights. (Job Sheet #4)
  - e. Wire a three-wire control system. (Job Sheet #5)
  - f. Wire a multiple station three-wire control. (Job Sheet #6)
  - g. Wire a multiple station three-wire control with "on" and "off" pilot lights. (Job Sheet #7)

## TWO AND THREE WIRE CONTROLS UNIT IX

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Provide students with objective sheet.
- C. Discuss unit and specific objectives.
- D. Provide students with information and assignment sheets.
- E. Discuss information and assignment sheets.
- F. Provide students with job sheets.
- G. Discuss and demonstrate the procedures outlined in the job sheets.
- H. Integrate the following activities throughout the teaching of this unit:
1. Tour an industrial facility utilizing two-wire and three-wire controls.
  2. Show students various two-wire pilot devices.
  3. Invite an industrial maintenance technician to speak to the class.
  4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- I. Give test.
- J. Evaluate test.
- K. Reteach if necessary.

## REFERENCES USED IN WRITING THIS UNIT

- A. Alerich, Walter M.. *Electric Motor Control*. Third Edition. Albany, NY: Delmar Publishers, Inc., 1983.
- B. *National Electrical Code, 1987*. Quincy, MA: National Fire Protection Association, 1986.
- C. *Overcurrent Protection and the 1987 NEC*. St. Louis, MO: Bussmann, Cooper Industries, Inc. Bulletin NE-87.

## SUGGESTED SUPPLEMENTAL MATERIAL

Texts —

- A. Square D Digest, 1987.
- B. Industrial Control Catalog. Cutler Hammer, Milwaukee, WI, 1987.



## **TWO AND THREE WIRE CONTROLS UNIT IX**

### **HANDOUT #1 — MOTOR CONTROLS**

(NOTE: Please retain this handout. It will be used in all units dealing with motor controls.)

Table 430-148 — Full-Load Currents In Amperes Single-Phase Alternating-Current Motors

Table 430-150 — Full-Load Current Three-Phase Alternating-Current Motors

Article 430-22 — Single Motor (Motor Circuit Conductors)

Article 430-32 — Continuous-Duty Motors (Motor Overload Protection)

(NOTE: With starters and overload relays, the proper heater element is selected from the manufacturer's tables based on the motor full-load current rating. The NEMA size of the starter must be known in order to select the proper part number.)

Article 430-52 — Rating or Setting of Individual Motor Circuits (Motor Branch Circuit Protection)

Table 310-16 — Ampacities of Not More Than Three Single Insulated Conductors, In Raceway In Free Air

Table 3A&3B Chapter 9 — Maximum Number of Conductors In Trade Sizes of Conduit or Tubing

Table 4 Chapter 9 — Dimensions and Percent Area of Conduit and of Tubing

Table 5 Chapter 9 — Dimensions of Rubber-Covered and Thermoplastic-Covered Conductors

## 430-32. Motor Overload Protection

### 430-32. Continuous-Duty Motors.

(a) **More than 1 Horsepower.** Each continuous-duty motor rated more than 1 horsepower shall be protected against overload by one of the following means.

(1) A separate overload device that is responsive to motor current. This device shall be selected to trip or rated at no more than the following percent of the motor nameplate full-load current rating:

Motors with a marked service factor not less than 1.15	125%
Motors with a marked temperature rise not over 40°C	125%
All other motors	115%

Modification of this value shall be permitted as provided in Section 430-34.

For a multispeed motor, each winding connection shall be considered separately.

Where a separate motor overload device is so connected that it does not carry the total current designated on the motor nameplate, such as for wye-delta starting, the proper percentage of nameplate current applying to the selection or setting of the overload device shall be clearly designated on the equipment, or the manufacturer's selection table shall take this into account.

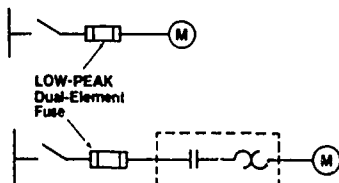
(2) A thermal protector integral with the motor, approved for use with the motor, it protects on the basis that it will prevent dangerous overheating of the motor due to overload and failure to start. The ultimate trip current of a thermally protected motor shall not exceed the following percentage of motor full-load current given in Tables 430-148, 430-149, and 430-150.

Motor full-load current not exceeding 9 amperes	170%
Motor full-load current 9.1 to and including 20 amperes	156%
Motor full-load current greater than 20 amperes	140%

If the motor current interrupting device is separate from the motor and its control circuit is operated by a protective device integral with the motor, it shall be so arranged that the opening of the control circuit will result in interruption of current to the motor.

### 155 What are the typical ways of providing motor running protection external to the motor?

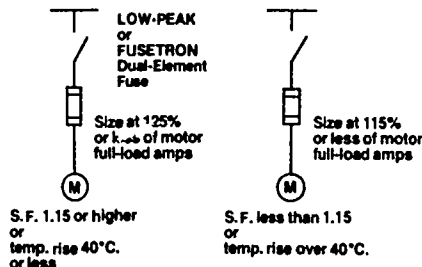
Generally, motor starters with overload relays and/or dual-element fuses are used to provide motor running protection.



### 156 Typically, how are the devices selected for protection of motors?

With starters and overload relays, the proper heater element is selected from manufacturers' tables based on the motor full-load current rating. The level of protection by this selection process complies with Article 430.

When employing dual-element fuses for motor-running, overload protection, the rating of the fuse should be as follows:



### 157 Do fuses sized as above also provide branch-circuit protection requirements?

Yes, they do. Sizing FUSETRON and LOW-PEAK Dual Element fuses for motor-running, overload protection also provides the necessary short-circuit protection per 430-52. The use of these dual-element fuses permits close sizing. Thus, fuse case sizes often can be smaller, thereby permitting the use of smaller switches.

### 158 Can circuit breakers and fuses other than dual-element fuses be used to give motor overload protection?

Not generally. The conventional circuit breakers usually must be sized at 250% of the motor full-load amperes to avoid tripping on motor starting current, and thus cannot provide overload protection. Instantaneous only circuit breakers or motor short-circuit protectors are only equipped with a short-circuit tripping element and therefore are incapable of providing overload protection. For motor applications, the non-time delay fuses such as the LIMITRON KTS-R fuses normally have to be sized at 300% of a motor full-load current rating to avoid opening on motor start up and therefore, do not provide overload protection.

**Footnote—Abnormal Motor Operation.** The application of motors under certain abnormal operating conditions often requires the use of larger size fuses than would normally be required. The use of oversize fuses limits protection to short-circuit or branch circuit protection only. The types of abnormal motor installations that may be encountered include the following: (a) Fuse in high ambient temperature locations. (b) Motors having a high code letter (or possibly no code letter) with full-voltage start. (c) Motors driving high inertial loads or motors which must be frequently cycled off-and-on. Typical high inertial loads are machines such as punch presses having large mass flywheels or machines such as centrifugal extractors and pulverizers or large fans which cannot be brought up to speed quickly. (d) High efficiency motors with high inrush currents.

Note—Fusetron, Limitron, Low-Peak, Hi-CAP, and T-Tron are registered trademarks of Busmann, Cooper Industries, Inc.

## 430-52. Motor Branch Circuit Protection

**430-52. Rating or Setting for Individual Motor Circuit.** The motor branch-circuit short-circuit and ground-fault protective device shall be capable of carrying the starting current of the motor. A protective device having a rating or setting not exceeding the value calculated according to the values given in Table 430-152 shall be used.

(FPN): See Section 240.6 for standard ratings of fuses and circuit breakers.

An instantaneous trip circuit breaker shall be used only if adjustable, and if part of a combination controller having motor overload and also short circuit and ground-fault protection in each conductor. A motor short-circuit protector shall be permitted in lieu of devices listed in Table 430-152 if the motor short-circuit protector is part of a combination controller having both motor overload protection and short-circuit and ground-fault protection in each conductor and if it will operate at not more than 1300 percent of full load motor current. An instantaneous trip circuit breaker or motor short circuit protector shall be used only as part of a combination motor controller which provides coordinated motor branch-circuit overload and short-circuit and ground-fault protection.

Where maximum branch-circuit short-circuit and ground fault protective device ratings are shown in the manufacturer's overload relay table for use with a motor controller or are otherwise marked on the equipment, they shall not be exceeded even if higher values are allowed as shown above.

Suitable fuses shall be permitted in lieu of devices listed in Table 430-152 for an adjustable speed drive system provided that the marking for replacement fuses is provided adjacent to the fuses.

### 150 What is the basic content of this Section?

This Section deals with the protection of motor branch circuits against short-circuit damage. It established the maximum permissible settings for overcurrent protective devices (Branch circuits include all of the circuit components—wire, switches, motor starters, etc.). As is apparent in Code Table 430-152, maximum settings vary with different types of motors, each type having unique starting characteristics. Motors to which the maximum permissible settings or ratings apply (shown in the condensed Table below) include all types of single phase, three-phase squirrel cage and three phase synchronous motors with full-voltage starting.

These maximum values do not preclude the application of lower sizes. Also, compliance with Sections 110-10 must be analyzed. Motor starters have relatively low short-circuit current withstands. Refer to Buss Bulletins SPD & MPB for specific fuse recommendations.

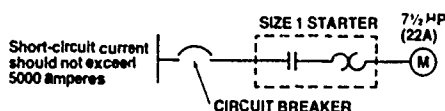
**Maximum Rating or Setting of Protective Devices†**

Fuse	Circuit Breaker*	
	Instantaneous	Inverse
Non-Time-Delay	Dual-Element Time-Delay	Type Only
300%	175%	700%
		250%

†See Article 430, Section 430-52, Exceptions 1 thru 3.

\*For latest information, check manufacturer's data and/or Underwriters Laboratories' U.L. Standard #508 for damage and warning label requirements.

### 160 What about starter withstandability and Section 110-10 on component protection?

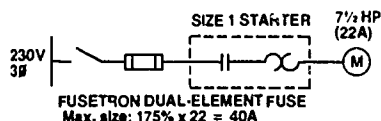


Under short-circuit conditions the branch circuit protective device must protect the circuit components from extensive damage. Therefore, the following factors should be analyzed: available short circuit current let-thru characteristics of the overcurrent protective device, and starter withstandability.

As an Example, a Size 1 Starter has been tested by U.L. with 5000 ampere minimum available short circuit current per U.L. Standard 508. Thus, in the example above, the available short-circuit currents

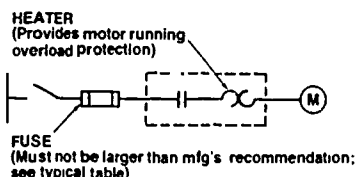
should not exceed 5000 amperes since the circuit breaker is not current limiting.

### 161 In the circuit below using a Buss FUSETRON dual-element, time-delay fuse, can available short-circuit current exceed 5000 amperes?



Yes, because the FUSETRON fuse is "current limiting," good short-circuit protection is provided even though available short-circuit current greatly exceeds 5000 amperes. (Specifically, the FUSETRON fuse would give protection against fault currents in excess of 70,000 amperes.) It is also significant to note that because the FUSETRON fuse is a time-delay fuse, it actually could be sized at 125% of full-load current (or 25 amperes) with the advantage of permitting the use of a smaller disconnect switch and providing backup overload protection and even better short-circuit protection. Note—the Buss RK1 Low-Peak fuse will provide short-circuit protection superior to that of the FUSETRON fuse.

### 162 The second to last paragraph of Code Section 430-52 states "Where maximum branch-circuit short-circuit and ground-fault protective device ratings are shown in the manufacturer's overload relay table for use with a motor controller or are otherwise marked on the equipment, they shall not be exceeded even if higher values are allowed as shown above." Why is this requirement necessary?



**TYPICAL EXAMPLE:** The chart shown below is typical for starter manufacturers and may be found on the inside of the door of the starter enclosure. (See starter manufacturer for specific recommendations.)

Heater Code marking	Full Load Current of Motor (Amperes) (40°C Ambient)	Max. Fuse
XX03	25- 27	1
XX04	28- 31	3
XX05	32- 34	3
XX06	35- 38	3
XX14	76- 83	6
XX15	84- 91	6
XX16	92-100	6
XX17	101-111	6
XX18	112-122	6

Above Heaters for use on Size 0

The overload relay heater elements of a motor controller often have a relatively low short-circuit current withstand rating. The maximum ratings of protective devices given in Table 430-152 thus do not necessarily apply being too large to provide adequate protection. Consequently the starter manufacturer includes an overload relay table within the starter enclosure. This table states the maximum fuse size ratings to be used which will adequately protect the overload relay heaters as determined by U.L., Inc. The protective device used in such cases must be a fuse.

Note—Fusetron, Limitron, Low-Peak, HI-CAP, and T-Tron are registered trademarks of Bussmann, Cooper Industries, Inc.

## 430-52. Motor Branch Circuit Protection

**163** When protective devices of low ampere ratings (1 amp, 3 amp, ...) are used to protect the overload relays in controllers for very small motors, what type device must be used?

Section 240-6 has an exception listing additional standard fuse ampere ratings of 1, 3, 6, and 10 amperes. These additional fuse ratings apply only to fuses. The lower ratings were added to provide more effective protection for circuits with small motors in accordance with Sections 430-52 and 430-40 and UL requirements for protecting the overload relays in controllers for very small motors. Fuse manufacturers have available other intermediate fuse ampere ratings to provide closer circuit protection (such as sizing dual-element fuses at 125% of motor current) or to comply with "Maximum Fuse" sizes specified in controller manufacturer's overload relay tables.

**164** The last paragraph of Section 430-52 reads, "Suitable fuses shall be permitted in lieu of devices listed in Table 430-152 for an adjustable speed drive system provided that the marking for replacement fuses is provided adjacent to the fuses." Why is this Code provision necessary?

Some "solid-state" motor starters require fuses specifically designed to protect semi-conductor components. The code provision was necessary in order to give branch-circuit short-circuit and ground-fault "recognition" to these fuses.

## 430-53. Several Motors or Loads on One Branch Circuit

**430-53. Several Motors or Loads on One Branch Circuit.** Two or more motors or one or more motors and other loads shall be permitted to be connected to the same branch circuit under the conditions specified in (a), (b), or (c) below.

**(c) Other Group Installations.** Two or more motors of any rating or one or more motors and other load(s), with each motor having individual overload protection, shall be permitted to be connected to one branch circuit where the motor controller(s) and overload device(s) are (1) installed as a listed factory assembly and the motor branch-circuit short-circuit and ground-fault protective device is either provided as part of the assembly or is specified by a marking on the assembly, or (2) the motor branch-circuit short-circuit and ground-fault protective device, the motor controller(s) and overload device(s) are field-installed as separate assemblies listed for such use and provided with manufacturers' instructions for use with each other, and (3) all of the following conditions are complied with:

(1) Each motor overload device is listed for group installation with a specified maximum rating of fuse and/or inverse time circuit breaker.

(2) Each motor controller is listed for group installation with a specified maximum rating of fuse and/or circuit breaker.

(3) Each circuit breaker is one of the inverse time type and listed for group installation.

(4) The branch circuit shall be protected by fuses or inverse time circuit breakers having a rating not exceeding that specified in Section 430-52 for the largest motor connected to the branch circuit plus an amount equal to the sum of the full-load current ratings of all other motors and the ratings of other loads connected to the circuit. Where this calculation results in a rating less than the ampacity of the supply conductors, it shall be permitted to increase the maximum rating of the fuses or circuit breaker to a value not exceeding that permitted by Section 240-3, Exception No. 1.

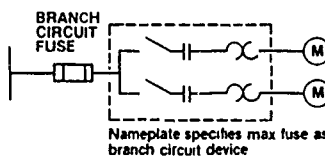
(5) The branch-circuit fuses or inverse time circuit breakers are not larger than allowed by Section 430-40 for the thermal cutout or overload relay protecting the smallest motor of the group.

(FPN) See Section 110-10.

**165** What does this Section mean?

Simply stated, branch circuit protection for group motor installations must be UL and factory listed for such installations. This listing can be accomplished as a factory installed assembly with specified marking, or field installed as separate assemblies listed for use with each other with instructions provided by the manufacturer. For the best protection of group motor installations, the branch circuit protective device should be current limiting. The Fine Print Note reference to Section 110-10 emphasizes the necessity to comply with the component short circuit withstand ratings.

**166** If the equipment nameplate specifies "max" fuse for a multimotor circuit, what must the branch circuit device be?



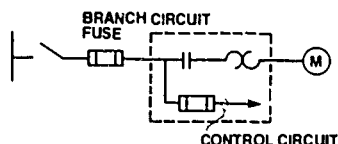
It must be a fuse, rated at not more than what is specified on the nameplate. The best type of fuse to use is a current limiting fuse.

## 430-71&72. Motor Control-Circuit Protection

**430-71. General.** Part F contains modifications of the general requirements and applies to the particular conditions of motor control circuits.

**Definition of Motor Control Circuit:** The circuit of a control apparatus or system that carries the electric signals directing the performance of the controller, but does not carry the main power current.

**167 What does this Section mean?**

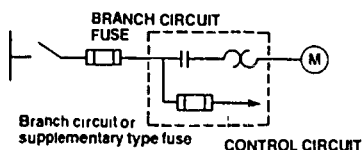


Section 430-71 defines the control circuit of a motor controller (control apparatus). The relationship of a control circuit to the circuit carrying the main power current is illustrated in the above circuit diagram.

**430-72. Overcurrent Protection.**

**(a) General.** A motor control circuit tapped from the load side of a motor branch circuit short circuit and ground-fault protective device(s) and functioning to control the motor(s) connected to that branch circuit shall be protected against overcurrent in accordance with Section 430-72. Such a tapped control circuit shall not be considered to be a branch circuit and shall be permitted to be protected by either a supplementary or branch circuit overcurrent protective device(s). A motor control circuit other than such a tapped control circuit shall be protected against overcurrent in accordance with Section 725-12 or 725-35 as applicable.

**168 What does this Section mean?**

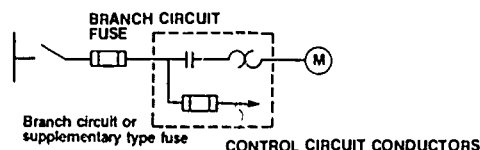


As shown in the above circuit, the motor control circuit tapped on the load side of the motor branch circuit protective device can be protected by either a branch or supplementary type protective device (such a control circuit is not to be considered a branch circuit).

**New U.L. requirement—**For motor controllers listed for available fault currents greater than 10,000 amperes, the control circuit fuse must be a branch circuit fuse with a sufficient interrupting rating. (The use of Buss FNO-R, KTK-R, JJS, or JJN fuses is recommended; these fuses have branch-circuit listing status, high interrupting rating, current limitation, and small size.)

**(b) Conductor Protection.** The overcurrent protection for conductors shall not exceed the values specified in Column A of Table 430-72(b).

**165 What does this Section mean?**



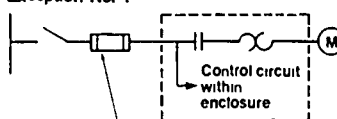
Control circuit conductors must be protected by a fuse rated at not more than those values shown in Column "A" of Table 430-72(b).

**Exception No. 1** Conductors which do not extend beyond the motor control equipment enclosure shall require only short-circuit and ground fault protection and shall be permitted to be protected by the motor branch circuit short circuit and ground-fault protective device(s) where the rating of the protective device(s) is not over the value specified in Column B of Table 430-72(b).

**170 What does this Exception mean?**

If the control conductors do not leave the enclosure, they can be considered to be protected by the branch circuit fuse, if that fuse does not exceed the values of Table 430-72(b) Column B.

**Exception No. 1**



The motor branch protective device is considered to also protect the control conductors if the conductors do not extend beyond the enclosure and the maximum rating of the protective device is not greater than Table 430-72(b) Column B.

**Exception No. 2** Conductors which extend beyond the motor control equipment enclosure shall require only short circuit and ground fault protection and shall be permitted to be protected by the motor branch circuit short circuit and ground fault protective device(s) where the rating of the protective device(s) is not over the value specified in Column C of Table 430-72(b).

**Table 430-72(b). Maximum Rating of Overcurrent Protective Device-Amperes**

Control Circuit Conductor Size, AWG	Column A Basic Rule		Column B Exception No. 1		Column C Exception No. 2	
	Copper	Alum. or Copper-Clad	Copper	Alum. or Copper-Clad	Copper	Alum. or Copper-Clad
18	7	—	25	—	7	—
16	10	—	40	—	10	—
14	Note 1	—	100	—	45	—
12	Note 1	Note 1	120	100	60	45
10	Note 1	Note 1	160	140	90	75
larger than 10	Note 1	Note 1	Note 2	Note 2	Note 3	Note 3

Note 1 Value specified in Tables 310-16 through 310-31, as applicable.

Note 2 400 percent of value specified in Table 310-17 for 60°C conductors.

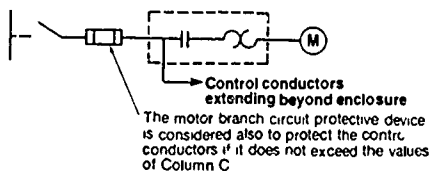
Note 3 300 percent of value specified in Table 310-16 for 60°C conductors.

## 430-71&72. Motor Control-Circuit Protection

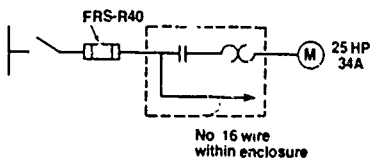
### 171 What does this Exception mean?

If the control conductors leave the enclosure, they can be considered to be protected by the branch circuit fuse, if that fuse does not exceed the values of Table 430-72(b) Column C

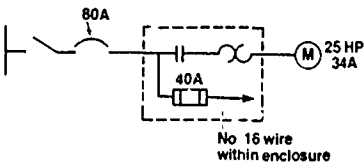
#### (Exception No. 2)



### 172 Do the two circuits shown below require individual control-circuit protection?



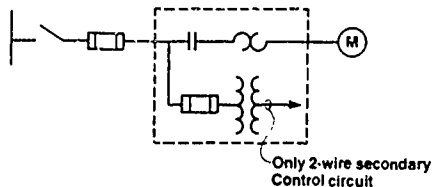
No. The FRS-R 40 ampere fuses are sized within the 40 ampere requirement for #16 conductor within enclosure (See Table 430-72(b))



Yes. Individual control circuit fuses are required since the 80 ampere circuit breaker has a rating in excess of the 40 ampere requirement for #16 conductor within enclosure (See Table 430-72(b))

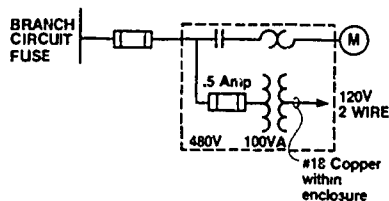
Note: Section 110.10 and 240.1 require that component withstand not be exceeded. Not all overcurrent devices set at 400% can protect #16 and #18 conductors.

**Exception No. 3** Conductors supplied by the secondary side of a single phase transformer having only a two-wire (single-voltage) secondary shall be permitted to be protected by overcurrent protection provided on the primary (supply) side of the transformer provided this protection does not exceed the value determined by multiplying the appropriate maximum rating of the overcurrent device for the secondary conductor from Table 430-72(b) by the secondary-to-primary voltage ratio. Transformer secondary conductors (other than two-wire) are not considered to be protected by the primary overcurrent protection.



### 173 What does this Exception mean?

Primary fusing of a control transformer can be considered to protect the 2-wire, secondary conductors if the fuse rating does not exceed the value of multiplying the appropriate rating from Table 430-72(b) with the secondary to primary voltage ratio.



From Table 430-72(b)

Wire Size	Max. Protection
#18 Copper	7 Amp Fuse

Maximum primary fuse shall not exceed 1.75A as determined by —

$$\frac{120V}{480V} \times 7A = 1.75A$$

Comparison By Largest H.P. Motor (480V) Circuit Where Branch Circuit Protective Device is Considered To Protect The Control Conductors Per 430-72(b) (2), Exc. 1 and 2.

Protective Device	Approx. Size As Percent Motor F.L.A.	Level Of Protection	Control Circuit Within Enclosure			Control Circuit Extending Beyond Enclosure		
			#18	#16	#14	#18	#16	#14
FUSETRON or LOW-PEAK Fuse	125%	Overload and Branch Circuit	15hp	25hp	60hp	3hp	5hp	25hp
	175%		10hp	15hp	40hp	2hp	3hp	15hp
Non-Time Delay Fuse	300%	Branch Circuit Only	5hp	7 1/2hp	20hp	1hp	1 1/2hp	10hp
Thermal Magnetic Circuit Breaker	250%		5hp	10hp	30hp	1 1/2hp	2hp	10hp
Instantaneous Only Circuit Breaker	1000%*		1hp	2hp	5hp	1/4hp	1/2hp	2hp

\*Instantaneous only circuit breakers cannot provide any overload protection. Typically to hold starting currents, instantaneous trip is set at 1000% to 1300% of motor full load amperes.

Note—Fusetron, Limitron, Low-Peak, HI-CAP, and T-Tron are registered trademarks of Busmann, Cooper Industries, Inc.



## 430-71&amp;72. Motor Control-Circuit Protection

## 174 Even though a fuse or circuit breaker can be sized at 300% or 400% of the conductor ampacity, what level of control conductor protection can be expected?

The protective device would respond only to high level conductor overcurrents, the control conductors would not be protected against lower overcurrent levels. This lack of protection could result in a prolonged 200% control circuit overcurrent and eventual insulation breakdown and melting of the conductors. For example, if the control circuit run were of considerable length, the conductor impedance might be sufficiently high to limit fault currents to 200% to 400% of the conductor ampacity. Thus, oversized overcurrent devices would provide inadequate protection. In contrast, fuses sized to the conductors ampacity would provide full-range overcurrent protection, their use is to be recommended.

(c) **Control Circuit Transformer.** Where a motor control circuit transformer is provided, the transformer shall be protected in accordance with Article 450.

**Exception No. 1** Control circuit transformers rated less than 50 VA and an integral part of the motor controller and located within the motor controller enclosure.

**Exception No. 2** Where the control circuit transformer rated primary current is less than 2 amperes, an overcurrent device rated or set at not more than 500 percent of the rated primary current shall be permitted in the primary circuit.

## 175 What are the provisions of this Section?

Control transformers must adhere to the rules governing other transformers (600 volts or less), as below.

## Primary Fuse Protection Only

Transformer Primary Current	Primary Fuse Ampacity Must Not Exceed
Less than 2 amps	500%* (Exception No. 2)*
2 to 9 amps	167%
9 amps or more	125%

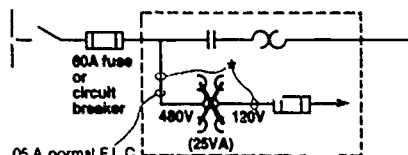
\*Primary protection using time delay fuses sized not in excess of 250% is recommended.

## Primary and Secondary Fuse Protection

Primary Fuse Does Not Exceed	Secondary Current	Secondary Fuse
250%	9 amps or more	125%
250%	Less than 9 amps	167%

## Application Guideline to 430-72(C) Exception No. 1

The conditions of 430-72(C) Exception No. 1 permits the use of a control transformer rated less than 50 VA\* without the inclusion of individual protection on the primary side of the transformer in the control circuit proper, thus protection of the transformer primary against short circuit currents is dependent upon the device used for branch circuit protection. However, consideration should be given to protecting the control transformer on the primary side with individual fuses specifically sized for control transformer protection.



05 A normal F.L.C. (breakdown of transformer windings could cause current to increase many times over normal level but less than 60A). \*Conductor protection still required per Section 430-72(b).

\*Control Transformers rated less than 50 VA are usually impedance protected or have other types of protection, such as inherent protection.

Take the case, for instance, in which a short occurs in a control transformer (such as would result from insulation deterioration and breakdown) (See diagram above in which a 60 ampere branch-circuit fuse is shown). Now, if the resultant overcurrent drawn by the control circuit as a result of shorted control transformer is relatively low (actually could be less than 60 amperes) compared to the response time of the 60 ampere branch circuit fuse or circuit breaker the transformer could become so hot that extensive damage could be done to the insulation of the control conductors the transformer itself could burst into flames.

However, inclusion of fuse protection in the primary of the control transformer would eliminate this type of hazard. Buss type FNO or FNO-R Time-Delay fuses could be sized as low as 125% of the transformer full-load amperes. The Buss type KTK or KTK-R fast-acting fuses could be typically sized at 300% of the primary full-load amperes. When applying fuses, the time-current characteristics should be checked to determine if the fuse can hold the inrush magnetizing current of the transformer.

## Fuses Commonly Used in Control Circuits

There are several fuse types which have small dimensions that are ideally suited for control circuit protection. The KTK-R or FNO-R fuses are U.L. Listed as Class CC fuses and JJK (JJS) fuses as U.L. Class T fuses. The other fuses shown are U.L. Listed as supplementary protection. When used for control transformer, coil, or solenoid protection, the fuse should be selected to withstand the inrush current for the required time.

Symbol	Voltage Rating	Ampere Rating	U.L. Class	Interrupting Rating	Comment
<b>Branch Circuit Rejection Fuses</b>					
FNO-R	600V	1/4 thru 7 1/2	CC*	200KA	Time delay in overload region
SC	300V**	6 thru 60	G*	100KA	
KTK-R	600V	1/4 thru 30	CC*	200KA	No intentional time delay in the overload region
JJK	300V**	1 thru 1200	T*	200KA	
JJS	600V	1 thru 1200	T*	200KA	
SC	300V**	1 thru 5	G*	100KA	
<b>Supplementary Fuses</b>					
FNO	500V	1/4 thru 30	SUP*	10KA	
FNW	250V	12 thru 30	SUP*	10KA	
FNM	250V	0 thru 1	SUP*	35A	
FNM	250V	1 thru 3 1/2	SUP*	100A	
FNM	250V	3 1/2 thru 10	SUP*	200A	
FNM	125V	10 1 thru 15	SUP*	10KA	Time delay in the overload region
FNM	32V	15 1 thru 30	SUP*	1KA	
FNA	250V	1/4 thru 1/2	SUP*	35A	
FNA	125V	1 thru 15	SUP*	10KA	
FNA	32V	15 1 thru 30	SUP*	1KA	
KTK	600V	1/4 thru 30	SUP*	100KA	
BAF	250V	1/2 thru 1	SUP*	35A	
BAF	250V	1 thru 3 1/2	SUP*	100A	
BAF	250V	3 1/2 thru 10	SUP*	200A	
BAF	250V	10 1 thru 15	SUP*	750A	No intentional time delay in the overload region
BAF	125V	15 1 thru 30	SUP*	10KA	
BAN	250V	1/4 thru 1	SUP*	35A	
BAN	250V	1 thru 3 1/2	SUP*	100A	
BAN	250V	3 1/2 thru 10	SUP*	200A	
BAN	250V	10 1 thru 15	SUP*	750A	
BAN	250V	15 1 thru 30	SUP*	1500A	

\*U.L. Listed

\*\*300 volts L.G. (Can be used on 277/480 volt solidly grounded systems)

# Buss Fuse Selection Chart

(600 Volts or Less)

AIC	Circuit	Load	Ampere Rating	Fuse Type	Symbol	Voltage Rating (a-c)	UL Class	Remarks	
200,000A Interrupting Rating (rms symmetrical) Current Limiting	Main, Feeder and Branch	Conventional Dimensions—Class RK1, RK5 (0-600A), L (601-6000A)							
		All type loads (optimum overcurrent protection).	1/10-600A	LOW-PEAK <sub>1</sub> (dual-element, time-delay)	LPN-RK LPS-RK	250V 600V	RK1††	All-purpose fuses Unequaled for combined short-circuit and overload protection	
			601 to 6000A	HI-CAP <sub>1</sub> (time-delay)	KRP-C	600V	L		
		Motors, welders, transformers, capacitor banks (circuits with heavy inrush currents)	1/10 to 600A	FUSETRON <sub>1</sub> (dual-element, time-delay)	FRN-R FRS-R	250V 600V	FK5††	Moderate degree of current limitation	
			601 to 4000A	LIMITRON <sub>1</sub> (time-delay)	KLU	600V	L	All-purpose fuse Time-delay passes surge-currents	
		Non-motor loads (circuits with no heavy inrush currents) LIMITRON fuses particular suited for circuit breaker protection.	1/10 to 600A	LIMITRON <sub>1</sub> (fast-acting)	KTN-R KTS-R	250V 600V	RK1	Same short-circuit protection as LOW-PEAK fuses but must be sized larger for circuits with surge-currents; i.e., up to 300%. A fast-acting, high performance fuse	
			601 to 6000A		KTU	600V			
			Reduced Dimensions For Installation In Restricted Space						
		Branch	Motors, welders, etc. (circuits with no heavy inrush currents)	1 to 600A	HI-CAP <sub>1</sub> (time-delay)	JHC	600V		Can be sized as low as 150% motor F.L.A.
			Non-motor loads (circuits with no heavy inrush currents)	1 to 600A	LIMITRON <sub>1</sub> (quick-acting)	JKS	600V	J	Very similar to KTS-R LIMITRON.
	1 to 1200A			T-TRON <sub>TM</sub>	JJH JJS	300V 600V	T	The space saver (1/2 the size of KTN-R/KTS-R).	
Control transformer circuits and lighting ballasts, etc.	1/10 to 30A		LIMITRON <sub>1</sub> (fast acting) TRON <sub>1</sub> (time-delay)	KTU-R FNQ-R	600V	CC	Very compact. (1 1/2" x 1 1/2"), rejection feature		
	1/4 to 7 1/2A								
100,000AIC	General purpose, i.e., lighting panel boards	1 to 60A	SC	SC	300V	G	Current limiting; 1/2" dia x varying lengths per amp rating.		
10,000AIC	General Purpose (non-current limiting fuses)	Miscellaneous (available short-circuit current must not exceed 10,000A rms sym.)	1/10 to 600A	O <sup>1</sup> TIME	NON NOS	250V 600V	H or K5†	Forerunners of the modern cartridge fuse.	
				SUPER-LAG <sub>1</sub> RENEWABLE	REN RES	250V 600V	H		
		Plug fuses can be used for branch circuits and small component protection).	1/10 to 30A	FUSTAT <sub>1</sub> (dual-element, time-delay)	S	125V	S	Base threads of Type S differ with amp ratings. T and W have Edison base. T & S fuses recommended for motor circuits. W not recommended for circuits with motor loads	
				FUSETRON <sub>1</sub> (dual-element, time-delay)	T	125V	**		
			Buss Type W	W	125V	**			

JHC 1-10 is U.L. listed and CSA certified. JHC 15-600 is CSA certified. \*\*UL Listed as Edison Base Plug Fuse. † Some ampere ratings are available as UL Class K5 with a 50,000A interrupting rating. ††RK1 and RK5 fuses fit standard switches, fuseblocks and holders; however, the rejection feature of class R switches and fuseblocks designed specifically for rejection type fuses (RK1 and RK5) prevent the insertion of the non-rejection fuses (K1, K5, and H)

Bussmann, P.O. Box 14460, St. Louis, MO 63178 (314) 394-2877 Telex 44-841

(314) 527-3877 (Central Customer Service)


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## TWO AND THREE WIRE CONTROLS UNIT IX

### INFORMATION SHEET

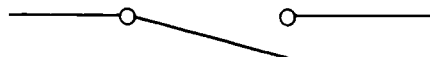
#### I. Terms and definitions

- A. Auxiliary contacts -- Set of normally open auxiliary contacts on a starter, contactor, or relay that close when main contacts close, providing a means of sealing or holding the circuit in the energized state
- B. Indicating pilot light -- Small light that indicates status of controls or machinery
- C. Low voltage protection -- Magnetic control only; nonautomatic restarting; three-wired control; power failure disconnects service; power restored by manual restart
- D. Low-voltage release -- Manual and magnetic control; automatic restarting; two-wire control; power failure disconnects service; when power is restored the controller automatically restarts motor
- E. Pilot device -- Directs operation of another device; alters the electrical circuit
- F. Three-wire control -- Uses momentary contact; start/stop stations and a memory circuit interlock connected in parallel with the start button to maintain the circuit
- G. Two-wire control -- Any type of switch having a definite "on" and "off" position that is used to control a magnetic starter or contactor

#### II. Typical two-wire pilot devices

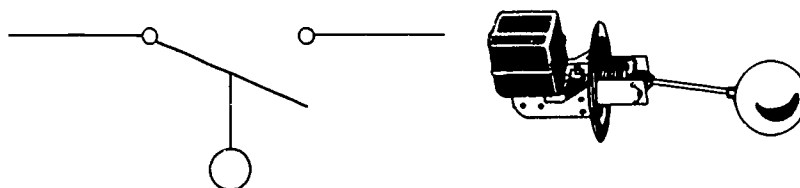
(NOTE: There are many different pilot devices. These are the most common.)

- A. Toggle switch

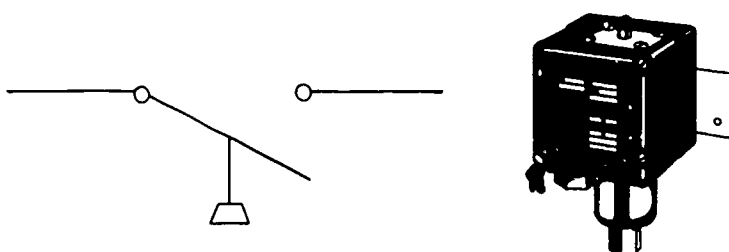


## INFORMATION SHEET

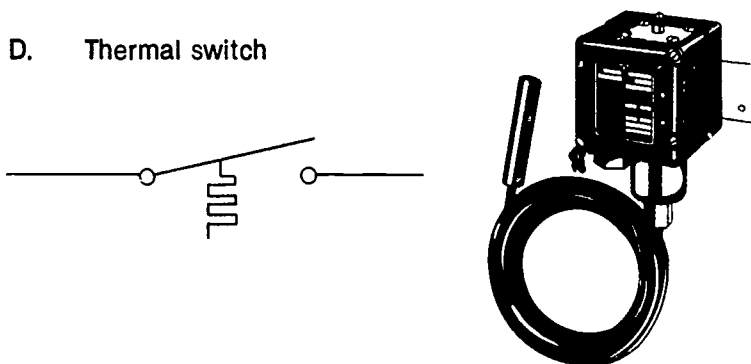
## B. Float switch



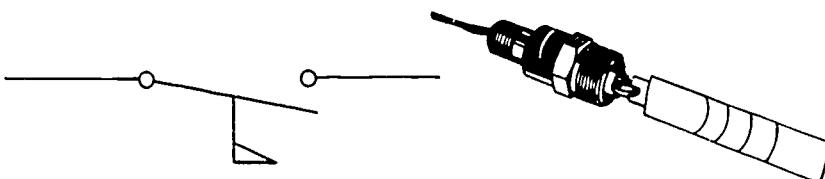
## C. Pressure switch



## D. Thermal switch

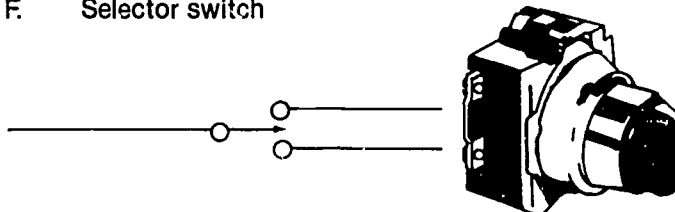


## E. Flow switch

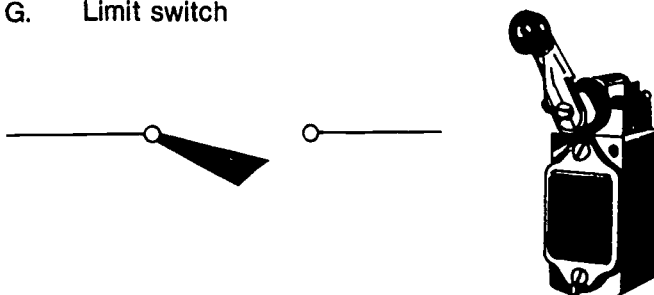


## INFORMATION SHEET

### F. Selector switch



### G. Limit switch

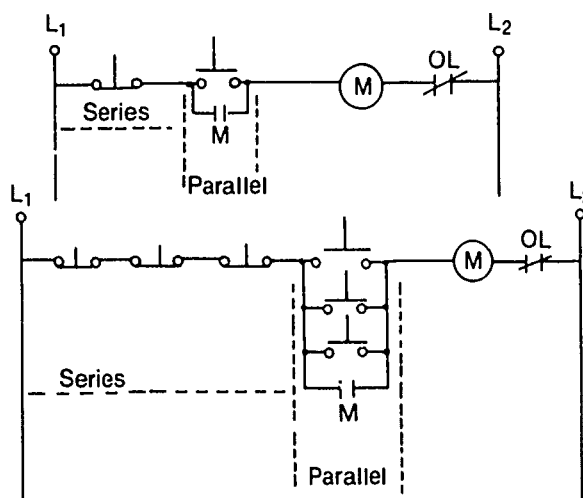


## III. Advantages of two-wire controls

- A. Provide low voltage release
- B. Do not require a human operator

## IV. Basic rule for three-wire controls — Stop buttons are in series with the “auxiliary contacts” and the start buttons are in parallel with the “auxiliary contacts”

(NOTE: This rule will apply no matter how many start/stop stations are used.)



## INFORMATION SHEET

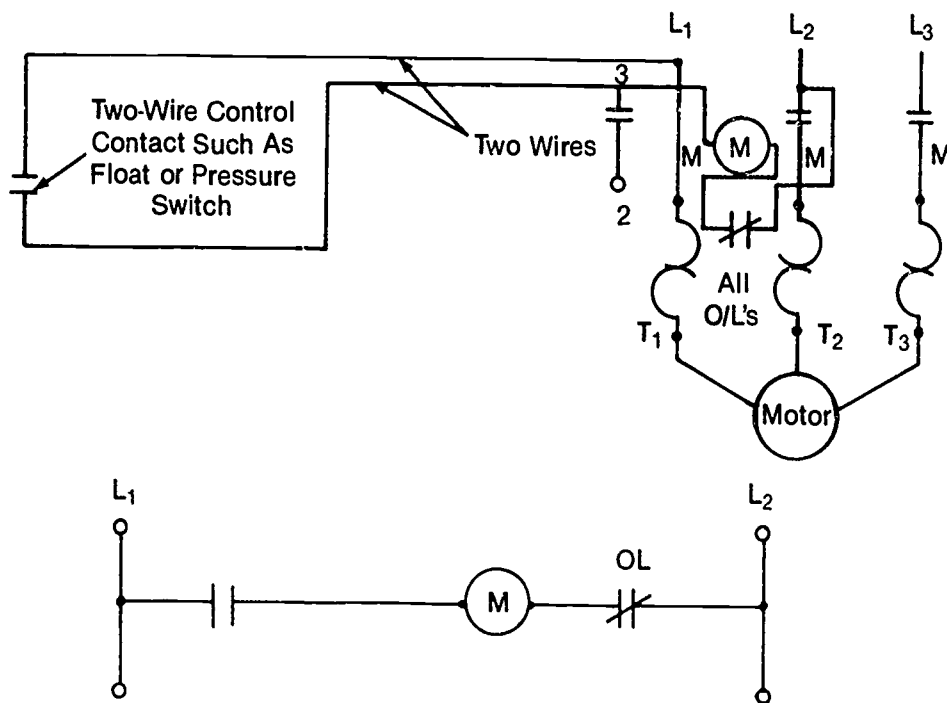
### V. Advantages of three-wire controls

#### A. Provide low-voltage protection

(NOTE: This protects both the operator and the equipment.)

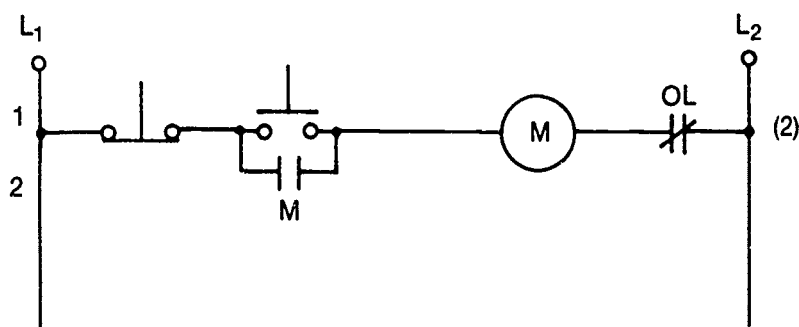
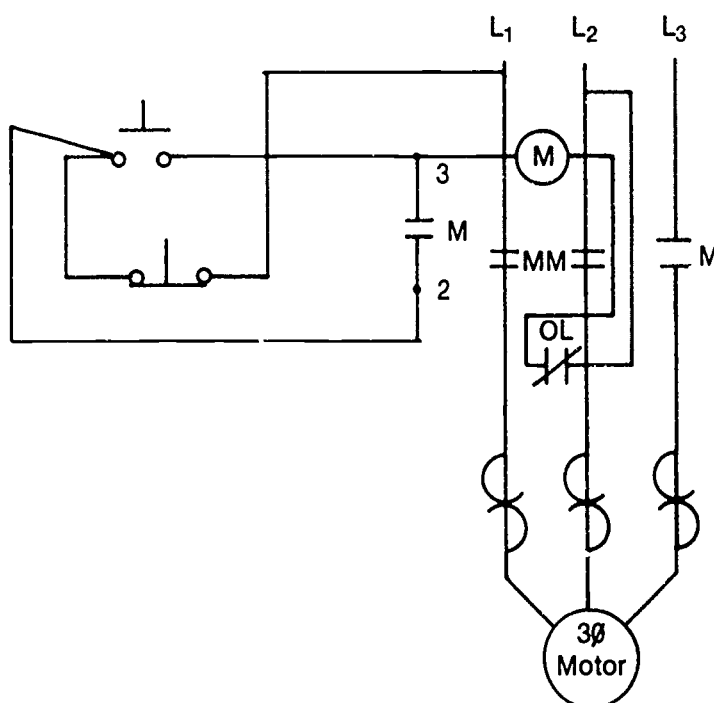
#### B. Allow for easy installation of indicating pilot lights

### VI. Operation of a two-wire control system — When the two-wire device is closed through some type of mechanical action, it allows current to flow to the starter's coil, energizing the coil and causing the starter to close.



## INFORMATION SHEET

- VII. Operation of a three-wire control system** — When the start button is depressed current is allowed to flow to the magnetic coil, energizing the coil. When the coil energizes the magnetic field, it pulls the armature toward it closing the main contacts. As the armature closes it also mechanically closes the auxiliary contacts (memory contacts) giving the current a path around the start button and keeping the coil energized. When the stop button is depressed, the flow of current is interrupted, allowing the magnetic field to dissipate.

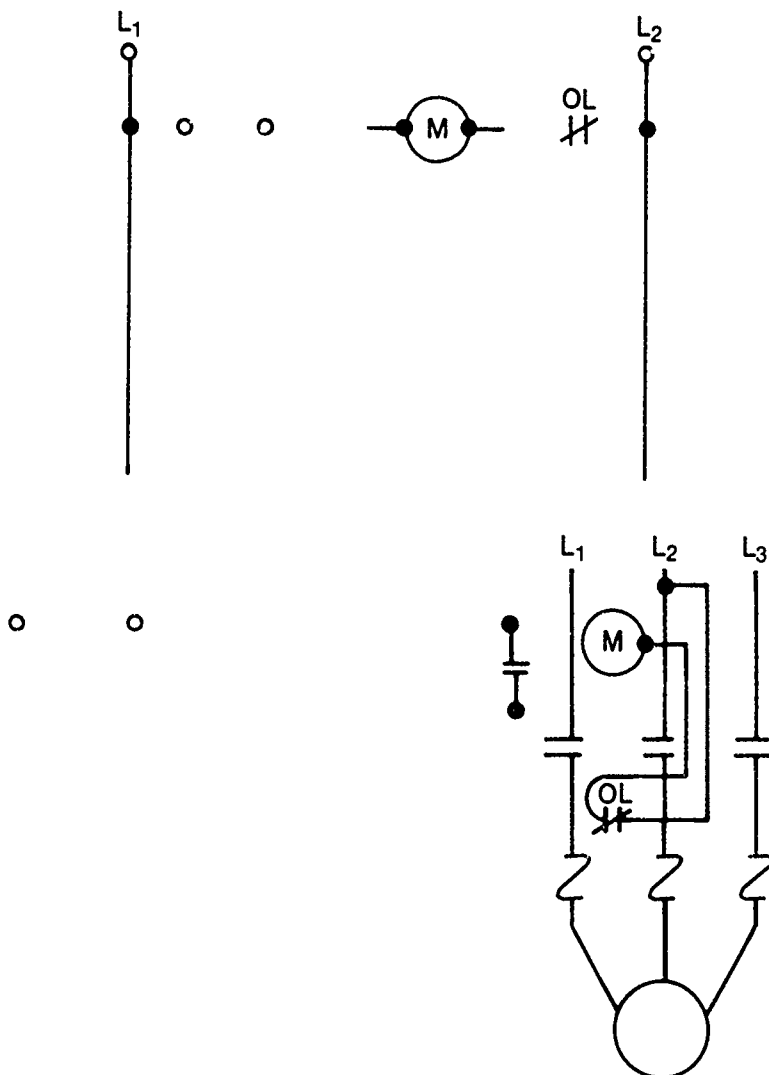


## TWO AND THREE WIRE CONTROLS UNIT IX

### ASSIGNMENT SHEET #1 — COMPLETE A LADDER AND A WIRING DIAGRAM OF A TWO-WIRE CONTROL USING A THERMAL SWITCH

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Complete the ladder and wiring diagram below, using a thermal switch.



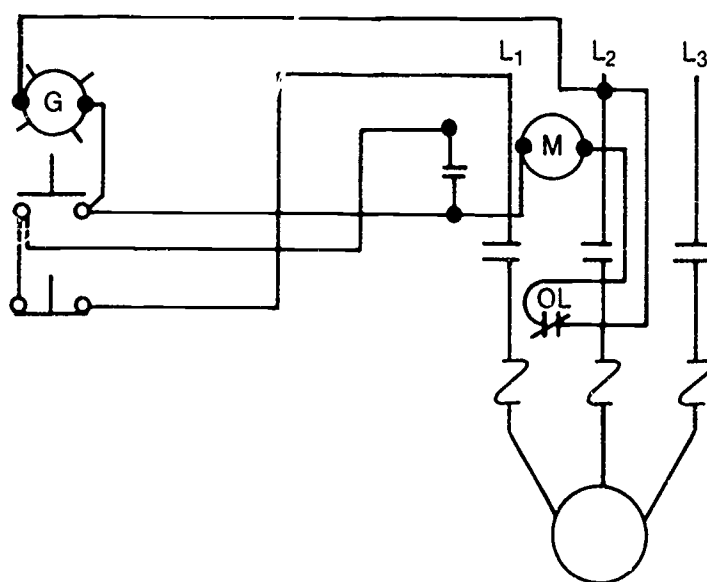
## TWO AND THREE WIRE CONTROLS UNIT IX

### ASSIGNMENT SHEET #2 -- DRAW A LADDER DIAGRAM OF A THREE-WIRE CONTROL WITH AN "ON" INDICATING PILOT LIGHT

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions: Convert the following wiring diagram to a ladder diagram.



## TWO AND THREE WIRE CONTROLS UNIT IX

### ASSIGNMENT SHEET #3 — DRAW A LADDER AND A WIRING DIAGRAM OF A THREE-WIRE CONTROL WITH AN "OFF" INDICATING PILOT LIGHT

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light in the space provided below.

(NOTE: In order to operate the pilot light correctly an additional set of normally closed auxiliary contacts must be added.)



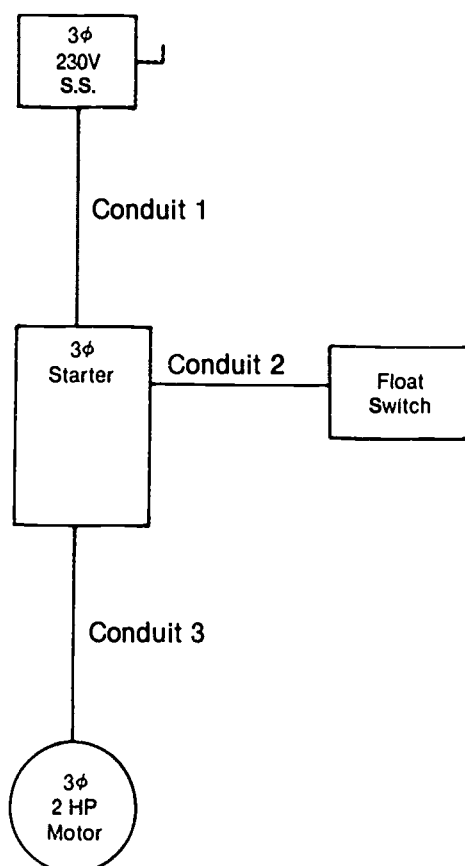
## TWO AND THREE WIRE CONTROLS UNIT IX

### ASSIGNMENT SHEET #4 -- DETERMINE THE NUMBER AND SIZE OF CONDUCTORS NEEDED TO OPERATE A TWO-WIRE CONTROL SYSTEM

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Using the drawing and the NEC determine the number of power and control conductors needed to operate the system. You must also determine the proper size conduit and the proper fuse size (dual element, time delay).

(NOTE: It may simplify the conductor count to draw a wiring diagram of this system.)



- A. Conduit 1 \_\_\_\_\_ inch EMT \_\_\_\_\_ conductors \_\_\_\_\_ Awg THWN
- B. Conduit 2 \_\_\_\_\_ inch EMT \_\_\_\_\_ conductors \_\_\_\_\_ Awg THWN
- C. Conduit 3 \_\_\_\_\_ inch EMT \_\_\_\_\_ conductors \_\_\_\_\_ Awg THWN
- D. Dual element time delay fuse size \_\_\_\_\_ amperes

## TWO AND THREE WIRE CONTROLS

### UNIT IX

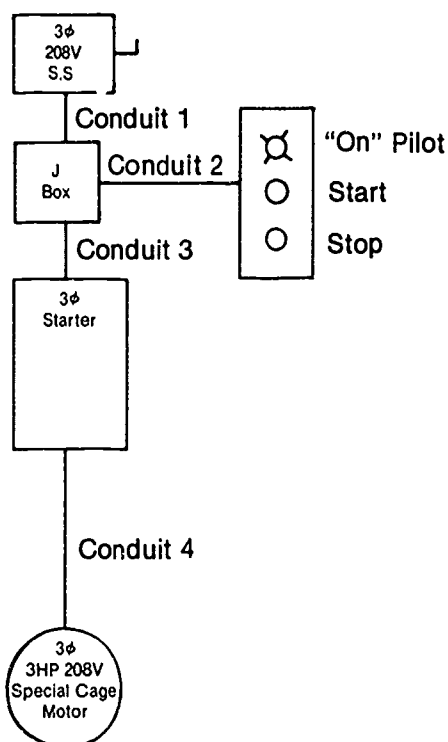
## ASSIGNMENT SHEET #5 — DETERMINE THE NUMBER AND SIZE OF CONDUCTORS NEEDED TO OPERATE A THREE-WIRE CONTROL SYSTEM

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

**Directions: Using the drawing and the NEC determine the number of power and control conductors needed to operate the system. You must also determine the proper size conduit and the proper fuse size (dual element, time delay).**

(NOTE: This starter has a line voltage coil.)



- A. Conduit 1 \_\_\_\_\_ inch EMT \_\_\_\_\_ conductors \_\_\_\_\_ Awg TW
- B. Conduit 2 \_\_\_\_\_ inch EMT \_\_\_\_\_ conductors \_\_\_\_\_ Awg THWN
- C. Conduit 3 \_\_\_\_\_ inch EMT \_\_\_\_\_ conductors \_\_\_\_\_ Awg TW  
\_\_\_\_\_ conductors \_\_\_\_\_ Awg THWN
- D. Conduit 4 \_\_\_\_\_ inch EMT \_\_\_\_\_ conductors \_\_\_\_\_ Awg TW
- E. Dual element time delay fuse size \_\_\_\_\_ amperes

## TWO AND THREE WIRE CONTROLS UNIT IX

### ANSWERS TO ASSIGNMENT SHEETS

**Assignment Sheet #1** — Evaluated to the satisfaction of the instructor

**Assignment Sheet #2** — Evaluated to the satisfaction of the instructor

**Assignment Sheet #3** — Evaluated to the satisfaction of the instructor

#### **Assignment Sheet #4**

- A. 1/2 inch EMT 3 conductors 12 or 14 Awg
- B. 1/2 inch EMT 2 conductors 12 or 14 Awg
- C. 1/2 inch EMT 3 conductors 12 or 14 Awg
- D. 10 amperes

#### **Assignment Sheet #5**

- A. 1/2 inch EMT 3 conductors 12 Awg
- B. 1/2 inch EMT 4 conductors 12 Awg
- C. 1/2 inch EMT 7 conductors 12 Awg
- D. 1/2 inch EMT 3 conductors 12 Awg
- E. 20 amperes

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**JOB SHEET #1**

3. In complete sentences, describe the sequence of operation of the system.

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4. Mount equipment.
5. Wire the system.
6. Have instructor evaluate the job.
7. Disassemble; store equipment and materials.

## **TWO AND THREE WIRE CONTROLS UNIT IX**

### **JOB SHEET #2 — WIRE TWO FLOAT SWITCHES TO OPERATE A STARTER (SERIES CONNECTION)**

(NOTE: Both switches must be activated in order for the starter to energize.)

**A. Equipment and materials needed**

1. Pouch tools
2. Three-phase open starter
3. Five feet #14 THHN
4. Mounting board
5. Four #10 x 1" sheet metal screws
6. Two float switches (momentary n/o push buttons, to simulate action of float switch)

**B. Procedure**

1. Draw a ladder and wiring diagram of your system in the space provided below.

2. Have your instructor approve your drawings.

**JOB SHEET #2**

3. In complete sentences, describe the sequence of operation of the system.

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4. Mount equipment.
5. Wire the system.
6. Have instructor evaluate the job.
7. Disassemble; store equipment and materials.

## TWO AND THREE WIRE CONTROLS UNIT IX

### JOB SHEET #3 — WIRE TWO FLOAT SWITCHES TO OPERATE A STARTER (PARALLEL CONNECTIONS)

(NOTE: Either switch will energize the starter.)

A. Equipment and materials needed

1. Pouch tools
2. Three-phase open starter
3. Six feet #14 THHN
4. Mounting board
5. Four #10 × 1" sheet metal screws
6. Two float switches (momentary n/o push buttons, to simulate action of float switches)

B. Procedure

1. Draw a ladder and wiring diagram of your system in the space provided below.
2. Have your instructor approve your drawings.



**JOB SHEET #3**

3. In complete sentences, describe the sequence of operation of the system.

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4. Mount equipment.
5. Wire the system.
6. Have instructor evaluate the job.
7. Disassemble; store equipment and materials.

## TWO AND THREE WIRE CONTROLS

### UNIT IX

## JOB SHEET #4 — WIRE A PRESSURE SWITCH TO OPERATE A STARTER WITH “ON” AND “OFF” PILOT LIGHTS

### A. Equipment and materials needed

1. Pouch tools
2. Three-phase open starter (with additional N/C auxiliary contacts)
3. Six feet #14 THHN
4. Ten #10 x 1" sheet metal screws
5. Pressure switch (momentary n/o push button, to simulate action of pressure switch)
6. Two 120 volt pilot lights

## B. Procedure

1. Draw a ladder and wiring diagram of your system in the space provided below.

- 2. Have your instructor approve your drawings.**

**JOB SHEET #4**

3. In complete sentences, describe the sequence of operation of the system.

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4. Mount equipment.
5. Wire the system.
6. Have instructor evaluate the job.
7. Disassemble; store equipment and materials.

## TWO AND THREE WIRE CONTROLS

### UNIT IX

## JOB SHEET #5 — WIRE A THREE-WIRE CONTROL SYSTEM

### A. Equipment and materials needed

1. Pouch tools
2. Three-phase open starter
3. Six feet #14 THHN
4. Mounting board
5. Six #10 × 1" sheet metal screws
6. Start stop station (1-n/o push button, 1-n/c push button)

## B. Procedure

1. Draw a ladder and wiring diagram of your system in the space provided below.

**JOB SHEET #5**

3. In complete sentences, describe the sequence of operation of the system.

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4. Mount equipment.
5. Wire the system.
6. Have instructor evaluate the job.
7. Disassemble; store equipment and materials.

## TWO AND THREE WIRE CONTROLS

### UNIT IX

## JOB SHEET #6 — WIRE A MULTIPLE STATION THREE-WIRE CONTROL

(NOTE: Stops are wired in series and starts are wired in parallel with the auxiliary contacts.)

### A. Equipment and materials needed

1. Pouch tools
2. Three-phase open starter
3. Two start stop stations
4. Eight #10 x 1" sheet metal screws
5. Mounting board
6. Ten feet #14 THHN

## B. Procedure

1. Draw a ladder and wiring diagram of your system in the space provided below.

- 2. Have your instructor approve your drawings.**

**JOB SHEET #6**

3. In complete sentences, describe the sequence of operation of the system.

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4. Mount equipment.
5. Wire the system.
6. Have instructor evaluate the job.
7. Disassemble; store equipment and materials.

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## TWO AND THREE WIRE CONTROLS

### UNIT IX

## JOB SHEET #7 — WIRE A MULTIPLE STATION THREE-WIRE CONTROL WITH “ON” AND “OFF” PILOT LIGHTS

### A. Equipment and materials needed

1. Pouch tools
2. Three-phase open starter (extra n/c contacts)
3. Two start stop stations
4. Two 120 volt pilot lights
5. Ten feet #14 THHN
6. Twelve #10 x 1" sheet metal screws

## B. Procedure

1. Draw a ladder and wiring diagram of your system in the space provided below.

- 2. Have your instructor approve your drawings.**



**JOB SHEET #7**

3. In complete sentences, describe the sequence of operation of the system.

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4. Mount equipment.
5. Wire the system.
6. Have instructor evaluate the job.
7. Disassemble; store equipment and materials.

## TWO AND THREE WIRE CONTROLS UNIT IX

### JOB SHEET #1 PRACTICAL TEST — WIRE A TWO-WIRE CONTROL

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Completed ladder diagram accurately and neatly.                 | _____ | _____ |
| 3. Completed wiring diagram accurately and neatly.                 | _____ | _____ |
| 4. Mounted equipment properly.                                     | _____ | _____ |
| 5. Made proper wiring terminations.                                | _____ | _____ |
| 6. Checked in/put away tools and materials.                        | _____ | _____ |
| 7. Cleaned the work area.  | _____ | _____ |
| 8. Used proper tools correctly.                                    | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                   | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Wiring diagram correct				
Sequence of operation correct				
Equipment mounted properly				
System operates				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TWO AND THREE WIRE CONTROLS UNIT IX

### JOB SHEET #2 PRACTICAL TEST — WIRE TWO FLOAT SWITCHES TO OPERATE A STARTER (SERIES CONNECTION)

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Completed ladder diagram accurately and neatly.	_____	_____
3. Completed wiring diagram accurately and neatly.	_____	_____
4. Mounted equipment properly.	_____	_____
5. Made proper wiring terminations.	_____	_____
6. Checked in/put away tools and materials.	_____	_____
7. Cleaned the work area.	_____	_____
8. Used proper tools correctly.	_____	_____
9. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
10. Practiced safety rules throughout procedure.	_____	_____
11. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
	4	3	2	1
Wiring diagram correct				
	4	3	2	1
Sequence of operation correct				
	4	3	2	1
Equipment mounted properly				
	4	3	2	1
System operates				
	4	3	2	1
Workmanship				
	4	3	2	1
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_  
 \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TWO AND THREE WIRE CONTROLS UNIT IX

### JOB SHEET #3 PRACTICAL TEST — WIRE TWO FLOAT SWITCHES TO OPERATE A STARTER (PARALLEL CONNECTIONS)

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Completed ladder diagram accurately and neatly.                 | _____ | _____ |
| 3. Completed wiring diagram accurately and neatly.                 | _____ | _____ |
| 4. Mounted equipment properly.                                     | _____ | _____ |
| 5. Made proper wiring terminations.                                | _____ | _____ |
| 6. Checked in/put away tools and materials.                        | _____ | _____ |
| 7. Cleaned the work area.  | _____ | _____ |
| 8. Used proper tools correctly.                                    | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                   | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Wiring diagram correct				
Sequence of operation correct				
Equipment mounted properly				
System operates				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TWO AND THREE WIRE CONTROLS UNIT IX

### JOB SHEET #4 PRACTICAL TEST — WIRE A PRESSURE SWITCH TO OPERATE A STARTER WITH "ON" AND "OFF" PILOT LIGHTS

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Completed ladder diagram accurately and neatly.                 | _____ | _____ |
| 3. Completed wiring diagram accurately and neatly.                 | _____ | _____ |
| 4. Mounted equipment properly.                                     | _____ | _____ |
| 5. Made proper wiring terminations.                                | _____ | _____ |
| 6. Checked in/put away tools and materials.                        | _____ | _____ |
| 7. Cleaned the work area.  | _____ | _____ |
| 8. Used proper tools correctly.                                    | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                   | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_



## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Wiring diagram correct				
Sequence of operation correct				
Equipment mounted properly				
System operates				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TWO AND THREE WIRE CONTROLS UNIT IX

### JOB SHEET #5 PRACTICAL TEST — WIRE A THREE-WIRE CONTROL SYSTEM

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Completed ladder diagram accurately and neatly.                 | _____ | _____ |
| 3. Completed wiring diagram accurately and neatly.                 | _____ | _____ |
| 4. Mounted equipment properly.                                     | _____ | _____ |
| 5. Made proper wiring terminations.                                | _____ | _____ |
| 6. Checked in/put away tools and materials.                        | _____ | _____ |
| 7. Cleaned the work area.  | _____ | _____ |
| 8. Used proper tools correctly.                                    | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                   | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #5 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Wiring diagram correct				
Sequence of operation correct				
Equipment mounted properly				
System operates				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TWO AND THREE WIRE CONTROLS UNIT IX

### JOB SHEET #6 PRACTICAL TEST — WIRE A MULTIPLE STATION THREE-WIRE CONTROL

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Completed ladder diagram accurately and neatly.                 | _____ | _____ |
| 3. Completed wiring diagram accurately and neatly.                 | _____ | _____ |
| 4. Mounted equipment properly.                                     | _____ | _____ |
| 5. Made proper wiring terminations.                                | _____ | _____ |
| 6. Checked in/put away tools and materials.                        | _____ | _____ |
| 7. Cleaned the work area.  | _____ | _____ |
| 8. Used proper tools correctly.                                    | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                   | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #6 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
	4	3	2	1
Wiring diagram correct				
	4	3	2	1
Sequence of operation correct				
	4	3	2	1
Equipment mounted properly				
	4	3	2	1
System operates				
	4	3	2	1
Workmanship				
	4	3	2	1
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TWO AND THREE WIRE CONTROLS UNIT IX

### JOB SHEET #7 PRACTICAL TEST — WIRE A MULTIPLE STATION THREE-WIRE CONTROL WITH "ON" AND "OFF" PILOT LIGHTS

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Completed ladder diagram accurately and neatly.	_____	_____
3. Completed wiring diagram accurately and neatly.	_____	_____
4. Mounted equipment properly.	_____	_____
5. Made proper wiring terminations.	_____	_____
6. Checked in/put away tools and materials.	_____	_____
7. Cleaned the work area.	_____	_____
8. Used proper tools correctly.	_____	_____
9. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
10. Practiced safety rules throughout procedure.	_____	_____
11. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #7 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Wiring diagram correct				
Sequence of operation correct				
Equipment mounted properly				
System operates				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## TWO AND THREE WIRE CONTROLS UNIT IX

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

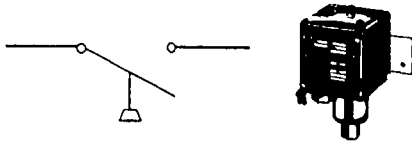
1. Match the terms on the right with their correct definitions.

- |   |                                  |
|---|----------------------------------|
| <p>_____a. Any type of switch having a definite "on" and "off" position that is used to control a magnetic starter or contactor</p>   | <p>1. Auxiliary contacts</p>     |
| <p>_____b. Set of normally open auxiliary contacts on a starter, contactor or relay that close when main contacts close, providing a means of sealing or holding the circuit in the energized state</p> | <p>2. Indicating pilot light</p> |
| <p>_____c. Small light that indicates status of controls or machinery</p>   | <p>3. Low voltage protection</p> |
| <p>_____d. Uses momentary contact; start/stop stations and a memory circuit interlock, connected in parallel with the start button to maintain the circuit</p>  | <p>4. Low voltage release</p>    |
| <p>_____e. Magnetic control only; nonautomatic restarting; three-wire control; power failure disconnects service; power restored by manual restart</p>  | <p>5. Pilot device</p>           |
| <p>_____f. Directs operation of another device; alters the electrical circuit</p>   | <p>6. Three-wire control</p>     |
| <p>_____g. Manual and magnetic control; automatic restarting; two-wire control; power failure disconnects service; when power is restored, the controller automatically restarts motor</p>              | <p>7. Two-wire control</p>       |

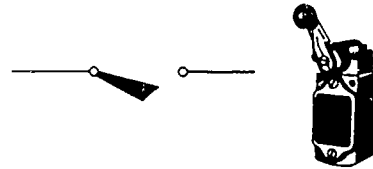


## TEST

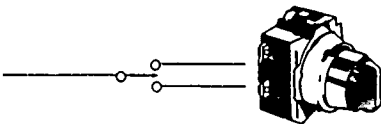
2. Identify typical two-wire pilot devices shown below.



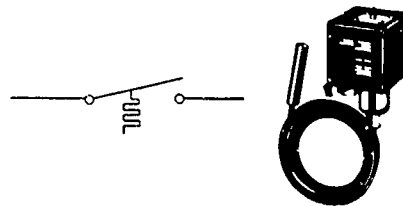
a. \_\_\_\_\_



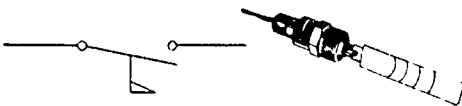
b. \_\_\_\_\_



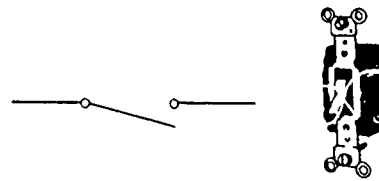
c. \_\_\_\_\_



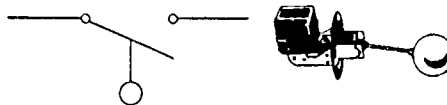
d. \_\_\_\_\_



e. \_\_\_\_\_



f. \_\_\_\_\_



g. \_\_\_\_\_

**TEST**

3. List two advantages of two-wire controls.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
4. State the basic rule for three-wire controls.  
\_\_\_\_\_  
\_\_\_\_\_
5. List two advantages of three-wire controls.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
6. Describe the operation of a two-wire control system.  
\_\_\_\_\_  
\_\_\_\_\_
7. Describe the operation of a three-wire control system.  
\_\_\_\_\_  
\_\_\_\_\_
8. Complete a ladder and a wiring diagram of a two-wire control using a thermal switch. (Assignment Sheet #1)
9. Draw a ladder diagram of a three-wire control with an "on" indicating pilot light. (Assignment Sheet #2)
10. Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light. (Assignment Sheet #3)
11. Determine the number and size of conductors needed to operate a two-wire control system. (Assignment Sheet #4)
12. Determine the number and size of conductors needed to operate a three-wire control system. (Assignment Sheet #5)

**TEST**

13. Demonstrate the ability to:
- a. Wire a two-wire control. (Job Sheet #1)
  - b. Wire two float switches to operate a starter (series connection). (Job Sheet #2)
  - c. Wire two float switches to operate a starter (parallel connections). (Job Sheet #3)
  - d. Wire a pressure switch to operate a starter with "on" and "off" pilot lights. (Job Sheet #4)
  - e. Wire a three-wire control system. (Job Sheet #5)
  - f. Wire a multiple station three-wire control. (Job Sheet #6)
  - g. Wire a multiple station three-wire control with "on" and "off" pilot lights. (Job Sheet #7)

## TWO AND THREE WIRE CONTROLS UNIT IX

### ANSWERS TO TEST

1.   a.    7                   e.    3  
     b.    1                   f.    5  
     c.    2                   g.    4  
     d.    6
  
2.   a.    Pressure switch                   e.    Flow switch  
     b.    Limit switch                    f.    Toggle switch  
     c.    Selector switch                 g.    Float switch  
     d.    Thermal switch
  
3.   a.    Provide low voltage release  
     b.    Do not require a human operator
  
4.   Stops in series — starts in parallel with the memory contacts
  
5.   a.    Provide low voltage protection  
     b.    Allow for easy installation of indicating pilot light
  
6.   When thermal switch closes, current flows to coil
  
7.   When start button is depressed current flows to coil where armature pulls in, closes auxiliary contacts, and seals around start button
  
- 8-12. Evaluated to the satisfaction of the instructor
  
13.   Performance skills evaluated to the satisfaction of the instructor

## **SEPARATE CONTROL CIRCUITS UNIT X**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to read and interpret diagrams and wire separate control circuits. Competencies will be demonstrated by completing the assignment sheets, job sheets, and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to separate control circuits with their correct definitions.
2. List two reasons for separate control circuits.
3. List three applications for separate control circuits.
4. List two sources of separate control circuits.
5. Match voltage ratings with their typical control transformer schematics.
6. Describe the necessary changes that must be made to a starter when using a separate control circuit.
7. Read and interpret ladder diagrams using separate control circuits. (Assignment Sheet #1)
8. Answer questions dealing with control circuits. (Assignment Sheet #2)
9. Determine the size and number of conductors needed to operate a separate control circuit. (Assignment Sheet #3)

**OBJECTIVE SHEET**

10. Demonstrate the ability to:
  - a. Wire a relay and a load with a separate control circuit. (Job Sheet #1)
  - b. Wire a three-phase starter to operate by a separate control circuit. (Job Sheet #2)

## SEPARATE CONTROL CIRCUITS UNIT X

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Provide students with objective sheet.
- C. Discuss unit and specific objectives.
- D. Provide students with information and assignment sheets.
- E. Discuss information and assignment sheets.
- F. Provide students with job sheets.
- G. Discuss and demonstrate the procedures outlined in the job sheets.
- H. Integrate the following activities throughout the teaching of this unit:
1. Visit the machine tool lab to view separate control circuits in use on machines.
  2. Visit a local industry that has a motor control center.
  3. Show students control transformers, time clocks, push-to-test lights, etc.
  4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- I. Give test.
- J. Evaluate test.
- K. Reteach if necessary.

**REFERENCES USED IN WRITING THIS UNIT**

- A. Alerich, Walter. *Electric Motor Controls*. Third Edition. Albany, NY: Delmar Publishers, Inc., 1983.
- B. *Digest*. Palatine, IL: Square D Company, 1987.
- C. Industrial Control Catalog, 1986-87. Milwaukee, WI: Cutler-Hammer, Eaton Corp., 1986.
- D. *National Electrical Code, 1987*. Quincy, MA: National Fire Protection Association, 1986.

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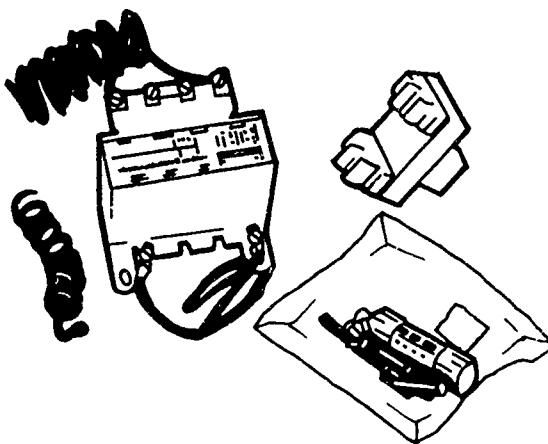


## SEPARATE CONTROL CIRCUITS UNIT X

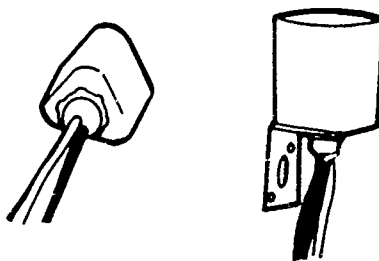
### INFORMATION SHEET

#### I. Terms and definitions

- A. Control transformer — Small transformer used to step supply voltage down to appropriate control voltage

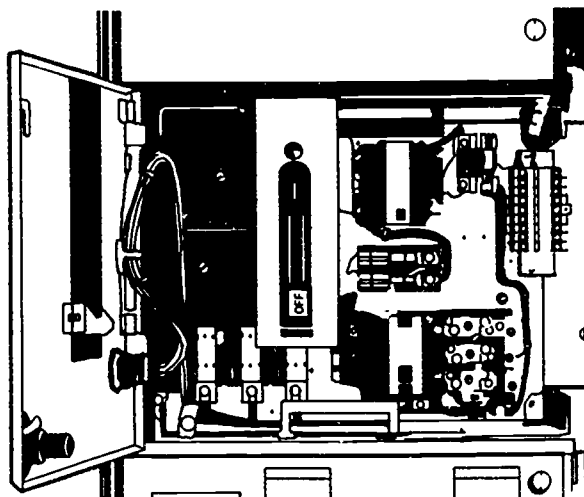


- B. Lightning arrestor — Device connected to the supply side of a system, designed to absorb transient surges

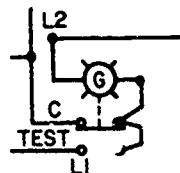
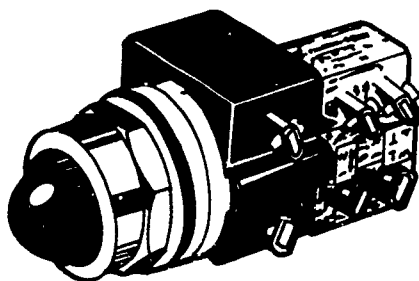


## INFORMATION SHEET

- C. Motor control center — Large panel used in industrial applications to centrally locate motor starters, motor branch circuit short circuit and ground-fault protective devices and motor branch circuit disconnecting means



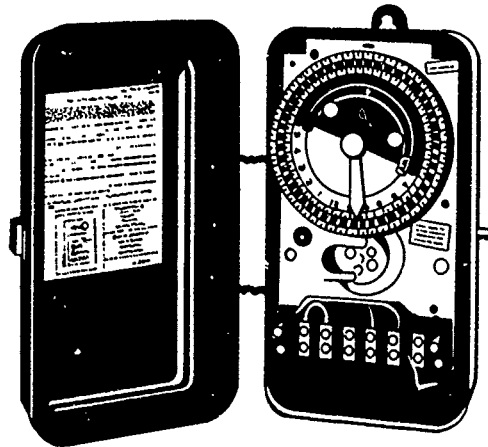
- D. Push-to-test pilot light — Used to indicate "on" and "off" status of a motor and to verify condition by means of indicating a burned out lamp



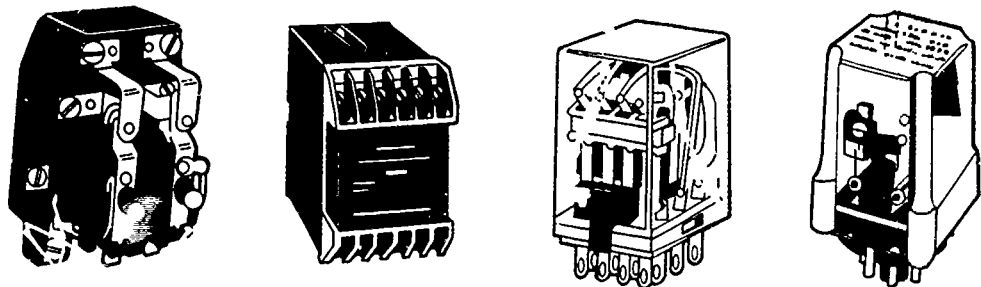
## INFORMATION SHEET

- E. Time clock — An electromechanical or electronic switch designed to control electrical circuits and equipment based on preset times of day

(NOTE: There are many different types of time clocks. It is necessary to obtain the manufacturers' schematics to wire each type.)



- F. Under voltage relay — Relays whose coils are connected between the line terminals of a motor branch circuit; opens a set of N/O contacts if one or more phases is lost



## II. Reasons for separate control circuits

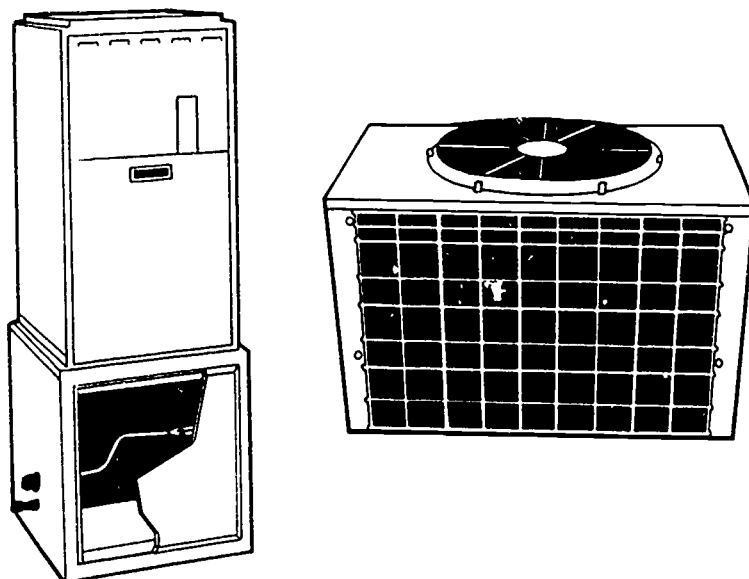
(NOTE: At times it may become necessary to operate pilot devices or push buttons at a lower voltage than the motor voltage. In such a case, a separate source, such as an isolating transformer or an independent voltage source may be used.)

- A. To step control voltage down to safe levels
- B. To match control voltage with control components operating voltage

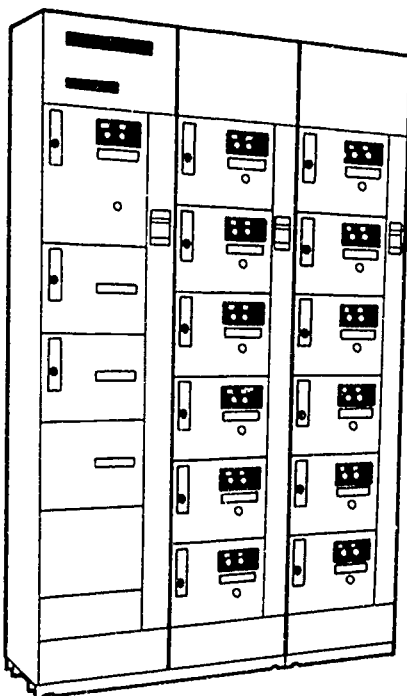
## INFORMATION SHEET

### III. Applications for separate control circuits

#### A. Air conditioning and heating equipment



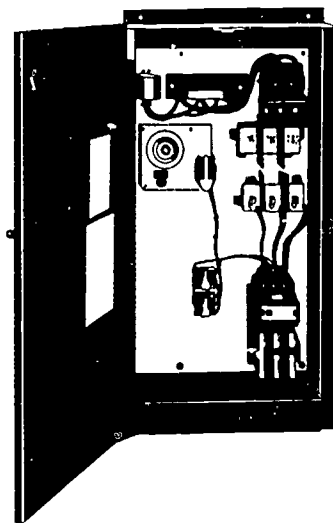
#### B. Motor control centers



## INFORMATION SHEET

### C. Pump control panels

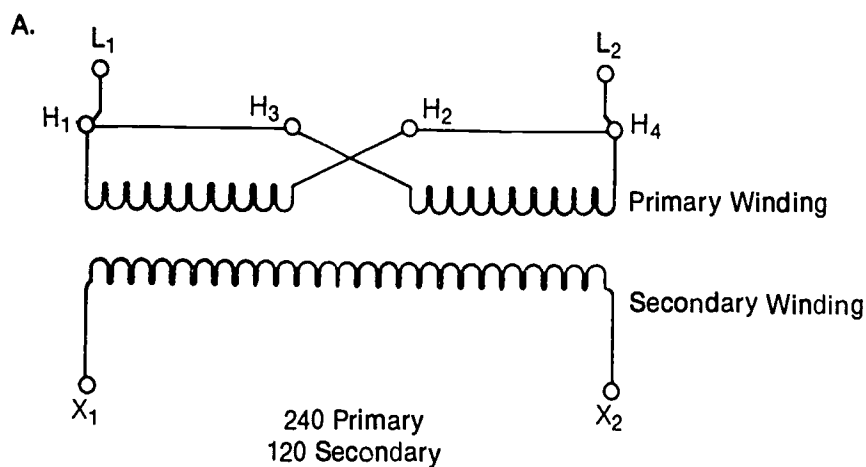
(NOTE: These units are extensively used in irrigation systems and oil field applications.)



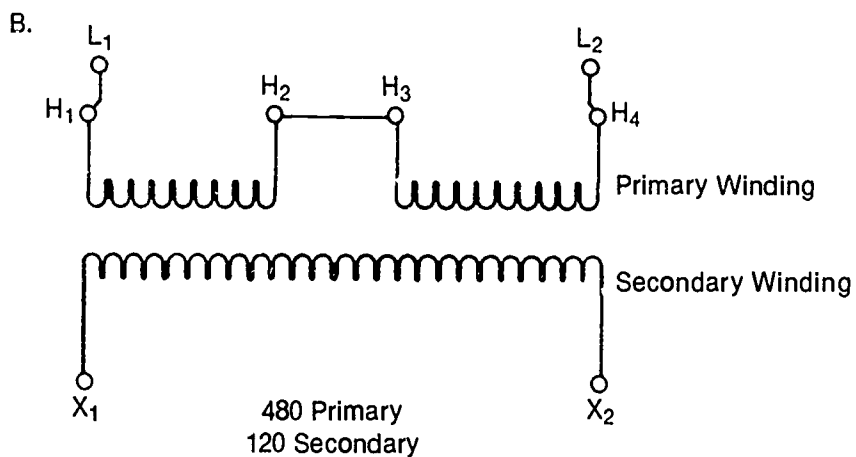
### IV. Sources of separate control circuits

- A. Control transformer
- B. Separate 120 volt control with circuit disconnect

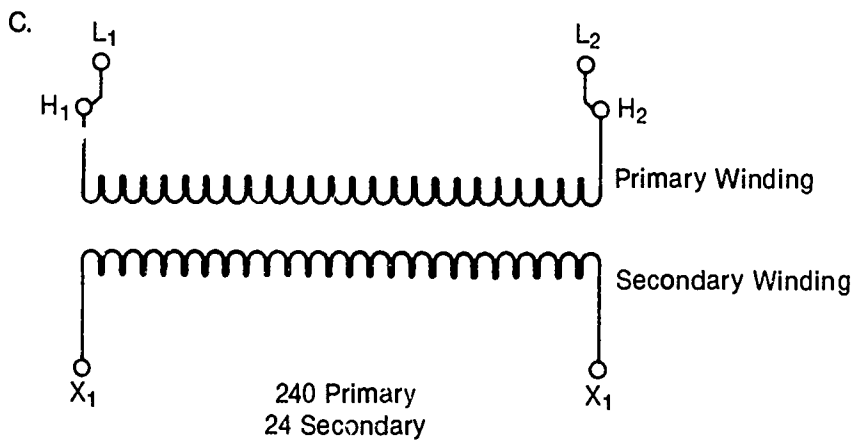
### V. Typical control transformer schematics and their voltage ratings



# INFORMATION SHEET

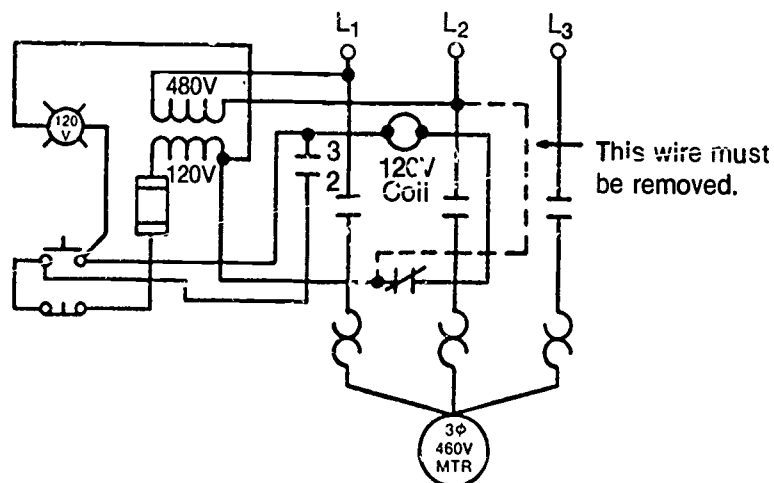


(NOTE: It is important to connect the primary taps correctly to match the input voltage.)



## INFORMATION SHEET

- VI. Necessary changes that must be made to a starter when using a separate control circuit —** When operating three-phase starters on a separate control source it is necessary to remove any and all wires that connect from the line terminals to any portion of the control circuitry. Specifically the wire that is connected from L2 to the coil must be removed.



## SEPARATE CONTROL CIRCUITS UNIT X

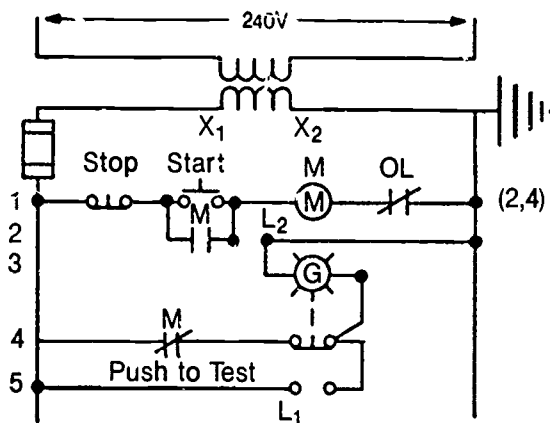
### ASSIGNMENT SHEET #1 — READ AND INTERPRET LADDER DIAGRAMS USING SEPARATE CONTROL CIRCUITS

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions: Evaluate the following ladder diagrams and describe the sequence of operation in the space provided.

A.




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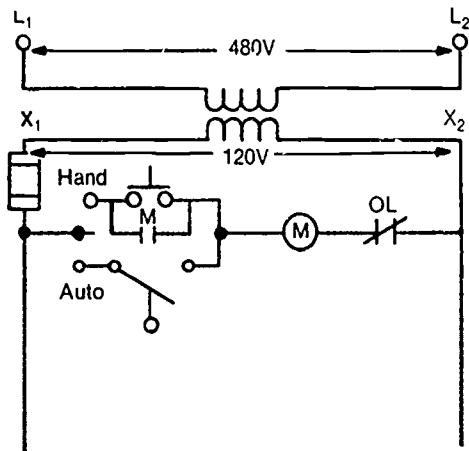
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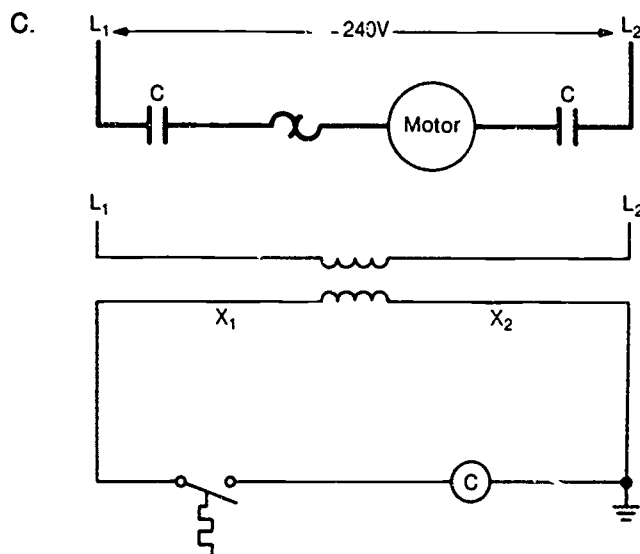


## ASSIGNMENT SHEET #1

B.



## ASSIGNMENT SHEET #1



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## SEPARATE CONTROL CIRCUITS UNIT X

### ASSIGNMENT SHEET #2 — ANSWER QUESTIONS DEALING WITH CONTROL CIRCUITS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Using the NEC, answer the following questions which deal with control circuits. Specify the appropriate Article number in the space provided.

- A. If the 16 Awg control circuit conductors extend beyond the control equipment enclosure, and are tapped from the motor branch circuit, is supplementary fuse protection required if the motor branch circuit is fused at 60 amperes?

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Article \_\_\_\_\_

- B. May a control transformer located within a motor controller enclosure be tapped from the line side of the disconnecting means?

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Article \_\_\_\_\_

- C. May the motor control circuit disconnecting means be located in a separate room from the motor circuit disconnecting means?

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Article \_\_\_\_\_

- D. What is the maximum percentage of rated primary current that an overcurrent device may be rated or set if the control circuit transformer rated primary current is less than 2 amperes?

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Article \_\_\_\_\_

## SEPARATE CONTROL CIRCUITS UNIT X

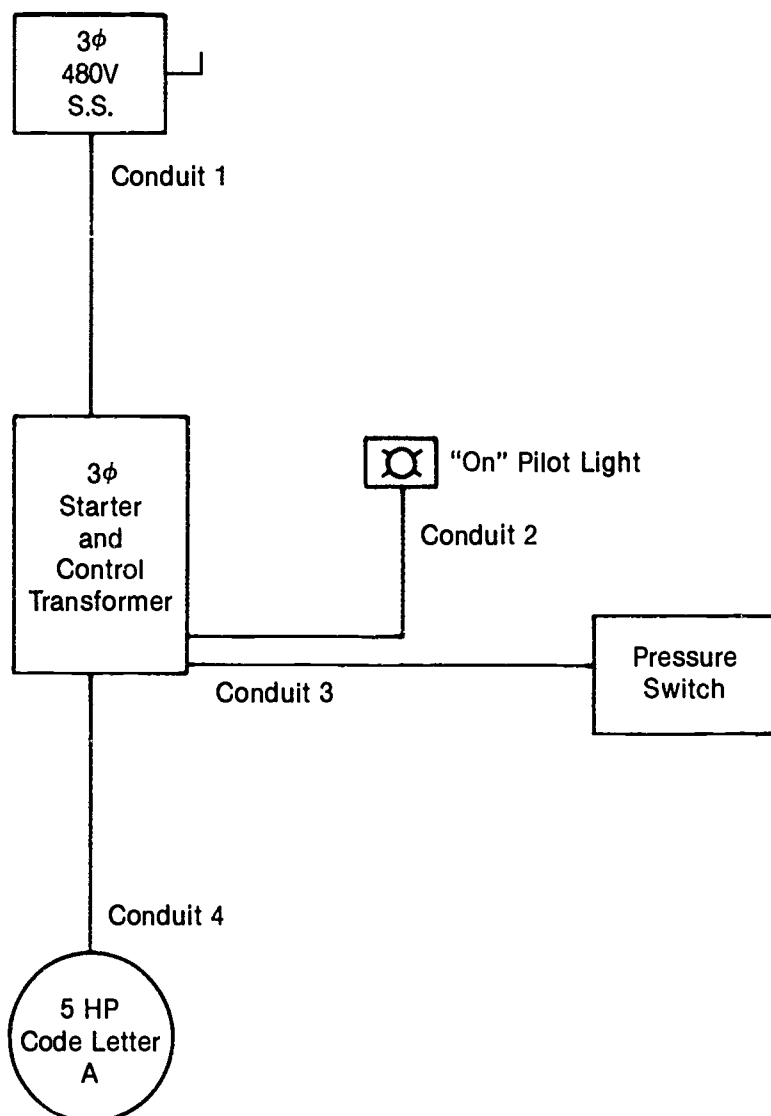
### ASSIGNMENT SHEET #3 — DETERMINE THE SIZE AND NUMBER OF CONDUCTORS NEEDED TO OPERATE A SEPARATE CONTROL CIRCUIT

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions: Using the NEC and the handout supplied to you in Unit XI, answer the questions following the diagram shown below.

(NOTE: Coil voltage is 1200.)



**ASSIGNMENT SHEET #3**

- A. Conduit 1 \_\_\_\_\_ conductors \_\_\_\_\_ AWG
- B. Conduit 2 \_\_\_\_\_ conductors \_\_\_\_\_ AWG
- C. Conduit 3 \_\_\_\_\_ conductors \_\_\_\_\_ AWG
- D. Conduit 4 \_\_\_\_\_ conductors \_\_\_\_\_ AWG
- E. Fuse size \_\_\_\_\_ (Dual element time delay)
- F. Heater amperes \_\_\_\_\_ part number \_\_\_\_\_

## SEPARATE CONTROL CIRCUITS UNIT X

### ANSWERS TO ASSIGNMENT SHEETS

**Assignment Sheet #1** — Evaluated to the satisfaction of the instructor

**Assignment Sheet #2**

- A. Yes — 430-72 Table 430-72(b) Column C
- B. No — 430-74(b)
- C. No — 430-74(a)
- D. 500% — 430-72(c) Exception 2

**Assignment Sheet #3**

- A. 3# 12 Awg
- B. 2# 14 Awg
- C. 2# 14 Awg
- D. 3# 12 Awg
- E. 15 amps
- F. Correct answer dependent on selection charts used

## SEPARATE CONTROL CIRCUITS UNIT X

### JOB SHEET #1 — WIRE A RELAY AND A LOAD WITH A SEPARATE CONTROL CIRCUIT

#### A. Equipment and materials needed

1. Pouch tools
2. Four pole relay with 24 volt coil (4 N/O)
3. 120/24 volt transformer
4. Start/stop station
5. Mounting board
6. Eight #10 × 1" sheet metal screws
7. Ten feet # 16 TFF
8. Pilot light

#### B. Procedure

1. Draw a ladder and a wiring diagram of a control system using one start/stop station to control a 4-pole relay. The relay will operate a 120 volt pilot light and will be actuated by 24 volts.

**JOB SHEET #1**

2. Have your instructor approve your drawings.
3. In complete sentences, describe the sequences of operation of your control system.

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4. Have your instructor approve your description.
5. Wire the system.
6. Have your instructor evaluate your work.
7. Disassemble and store equipment and materials.



## SEPARATE CONTROL CIRCUITS UNIT X

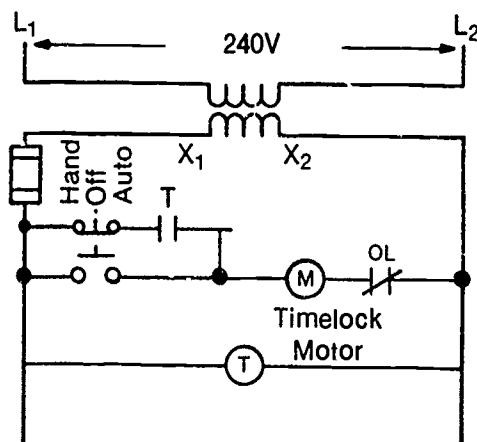
### JOB SHEET #2 — WIRE A THREE—PHASE STARTER TO OPERATE BY A SEPARATE CONTROL CIRCUIT

#### A. Equipment and materials needed

1. Pouch tools
2. 3 $\phi$  starter with 120 volt coil
3. 240 volt (live) 3 $\phi$  power source
4. 480-240/120 control transformer
5. Fuse block
6. 6/10 amp fuse
7. Mounting board
8. Three-position selector switch and enclosure
9. Twelve #10  $\times$  1" sheet metal screws
10. 24 hour time clock with 120 volt timer motor
11. 15' #14 THHN

#### B. Procedure

1. Using the following ladder diagram, write a complete sequence of operation of the system.



## JOB SHEET #2

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2. Have your instructor approve your sequence description.
3. Wire the system.
4. Have your instructor evaluate the job.
5. Disassemble and store equipment and materials.

## SEPARATE CONTROL CIRCUITS UNIT X

### JOB SHEET #1 PRACTICAL TEST — WIRE A RELAY AND A LOAD WITH A SEPARATE CONTROL CIRCUIT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                        | _____ | _____ |
| 2. Drew ladder diagram.   | _____ | _____ |
| 3. Drew wiring diagram.   | _____ | _____ |
| 4. Completed sequence description.                                | _____ | _____ |
| 5. Constructed system.  | _____ | _____ |
| 6. Checked in/put away tools and materials.                       | _____ | _____ |
| 7. Cleaned the work area.   | _____ | _____ |
| 8. Used proper tools correctly.                                   | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                  | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.           | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Wiring diagram correct				
System operates				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SEPARATE CONTROL CIRCUITS UNIT X

### JOB SHEET #2 PRACTICAL TEST — WIRE A THREE-PHASE STARTER TO OPERATE BY A SEPARATE CONTROL CIRCUIT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Completed sequence description.                                 | _____ | _____ |
| 3. Checked time clock schematic.                                   | _____ | _____ |
| 4. Constructed system.   | _____ | _____ |
| 5. Checked in/put away tools and materials.                        | _____ | _____ |
| 6. Cleaned the work area.  | _____ | _____ |
| 7. Used proper tools correctly.                                    | _____ | _____ |
| 8. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 9. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 10. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Proper sequence description				
System operates				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# SEPARATE CONTROL CIRCUITS UNIT X

## TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

- |         |   |                             |
|---------|---|-----------------------------|
| _____a. | Large panel used in industrial applications to centrally locate motor starter, motor branch circuit short circuit, and ground fault protective devices and motor branch circuit disconnecting means | 1. Control transformer      |
| _____b. | An electromechanical or electronic switch designed to control electrical circuits and equipment based on preset times of day  | 2. Lightning arrestor       |
| _____c. | Small transformer used to step supply voltage down to appropriate control voltage   | 3. Motor control center     |
| _____d. | Used to indicate "on" and "off" status of a motor and to verify condition by means of indicating a burned out lamp  | 4. Push-to-test pilot light |
| _____e. | Relays whose coils are connected between the line terminals of a motor branch circuit; opens a set of N/O contacts if one or more phases is lost  | 5. Time clock               |
| _____f. | Device connected to the supply side of a system, designed to absorb transient surges  | 6. Under voltage relay      |

2. List two reasons for separate control circuits.

- a. \_\_\_\_\_
- b. \_\_\_\_\_

3. List three applications for separate control circuits.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

## TEST

4. List two sources of separate control circuits.

a. \_\_\_\_\_

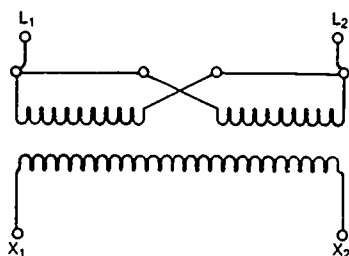
b. \_\_\_\_\_

5. Match the voltage ratings on the right with their typical control transformer schematics.

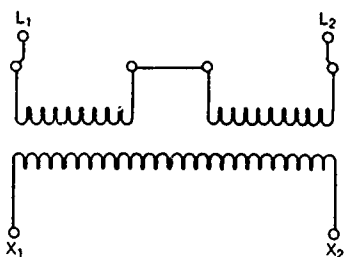
1. 240/120

2. 480/120

3. 240/24



a. \_\_\_\_\_



b. \_\_\_\_\_



c. \_\_\_\_\_



**TEST**

6. Describe the necessary changes that must be made to a starter when using a separate control circuit.

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(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

7. Read and interpret ladder diagrams using separate control circuits. (Assignment Sheet #1)
8. Answer questions dealing with control circuits. (Assignment Sheet #2)
9. Determine the size and number of conductors needed to operate a separate control circuit. (Assignment Sheet #3)
10. Demonstrate the ability to:
- a. Wire a relay and a load with a separate control circuit. (Job Sheet #1)
  - b. Wire a three-phase starter to operate by a separate control circuit. (Job Sheet #2)

## SEPARATE CONTROL CIRCUITS UNIT X

### ANSWERS TO TEST

1.   a.   3                   d.   4  
     b.   5                   e.   6  
     c.   1                   f.   2
2.   a.   To step control voltage down to safe levels  
     b.   To match control voltage with control components operating voltage
3.   a.   Air conditioning and heating equipment  
     b.   Motor control centers  
     c.   Pump control panels
4.   a.   Control transformer  
     b.   Separate 120 volt control with circuit disconnect
5.   a.   2  
     b.   1  
     c.   3
6.   Remove wire between L2 and the overloads
- 7.-9.   Evaluated to the satisfaction of the instructor
10.   Performance skills evaluated to the satisfaction of the instructor

## **SEQUENCE CONTROL UNIT XI**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to read and interpret ladder diagrams dealing with sequence control and auxiliary contact interlocking. The student should also be able to wire these types of applications. Competencies will be demonstrated by completing the assignment sheets, job sheets, and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to sequence control.
2. State the purpose of sequence control.
3. List two advantages of sequence control.
4. List two uses of sequence control.
5. State the purpose of auxiliary contact interlocking.
6. List two advantages of auxiliary contact interlocking.
7. List two uses of auxiliary contact interlocking.
8. Answer questions related to a sequence control diagram. (Assignment Sheet #1)
9. Answer questions related to an auxiliary contact interlocking diagram. (Assignment Sheet #2)
10. Demonstrate the ability to:
  - a. Wire two starters in sequence. (Job Sheet #1)
  - b. Wire two starters with auxiliary contact interlocking. (Job Sheet #2)

## SEQUENCE CONTROL UNIT XI

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Provide students with objective sheet.
- C. Discuss unit and specific objectives.
- D. Provide students with information and assignment sheets.
- E. Discuss information and assignment sheets.
- F. Provide students with job sheets.
- G. Discuss and demonstrate the procedures outlined in the job sheets.
- H. Integrate the following activities throughout the teaching of this unit:
1. Invite a local maintenance electrician to speak on the importance of sequencing and interlocking.
  2. Visit a supply house to view the various types of interlocking devices.
  3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- I. Give test.
- J. Evaluate test.
- K. Reteach if necessary.

### REFERENCE USED IN WRITING THIS MATERIAL

Alerich, Walter M. *Electric Motor Controls*. Third Edition. Albany, NY: Delmar Publishers, Inc., 1983.

### SUGGESTED SUPPLEMENTAL MATERIAL

Rexford, Kenneth B. *Electrical Controls For Machines*. Third Edition. Albany, NY: Delmar Publishers, 1987.

## INFORMATION SHEET

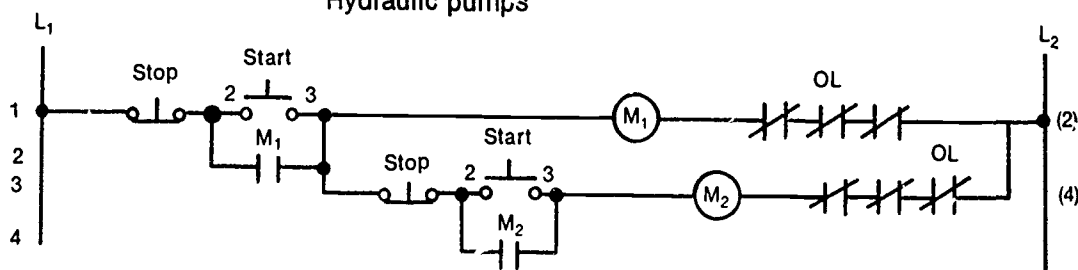
### III. Advantages of sequence control

- A. Assures proper order of start-up
- B. Shuts down all "down-stream" motors when a starter fails due to overload

### IV. Uses of sequence control

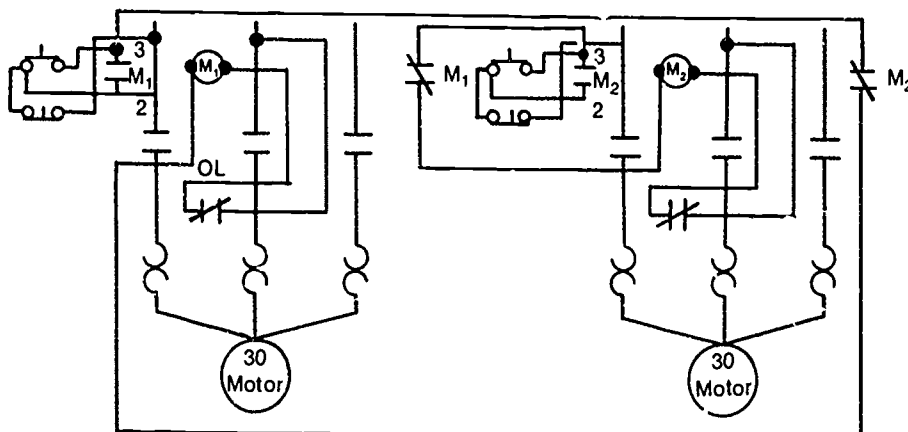
- A. Main or subassembly line conveyors
- B. Auxiliary equipment associated with machines

EXAMPLES: High pressure lubricating pumps  
Hydraulic pumps



(NOTE: Tracing out the ladder diagram you will note that the first starter is wired in the normal configuration of a three-wire control. Then on rung three you will see the second starter's control circuiting originates from terminal three on the first starter's auxiliary contacts. This allows for control current to flow to the second starter only after starter one seals in. If the OL of starter one opens both motors will stop.)

### V. Purpose of auxiliary contact interlocking — To prevent two machines or starters from conflicting with one another.



# SEQUENCE CONTROL UNIT XI

## INFORMATION SHEET

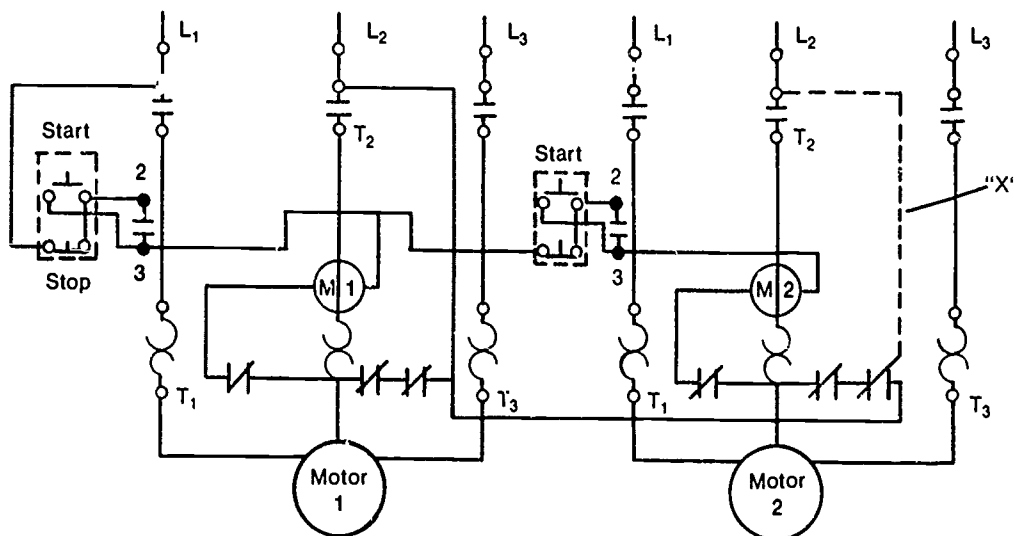
### I. Terms and definitions

- A. Auxiliary contacts — Contacts of a switching device in addition to the main circuit contacts; auxiliary contacts operate with the movement of the main contacts; can be N/O or N/C

(NOTE: In most cases, the addition of auxiliary contacts is a simple stack-on and screw-down procedure.)

- B. Cross phasing — Unintentional contact of two or more electrical phases; results in a short circuit
- C. Down stream — Coming after; following other devices or events
- D. Interlocking — To interrelate with other controllers; a device is connected in such a way that the operation of one part controls the operation of another

- II. Purpose of sequence control — To assure that one motor is running before any other can operate

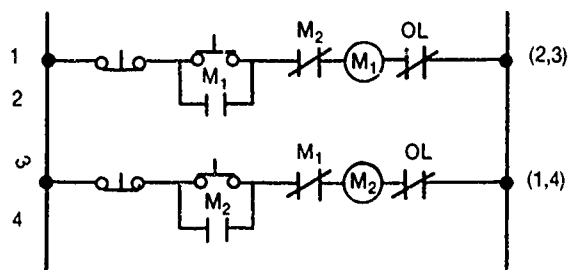


(NOTE: The wiring diagram indicates all control circuitry originating from starter one. Remember, starters are pre-wired from L2 through the overloads to the coil. Wire "X" must be removed in order to avoid the possibility of *cross phasing*. Refer to NEC Art: 430-113.)

## INFORMATION SHEET

### VI. Advantages of auxiliary contact interlocking

- A. Prevents motor starters from being energized when not desired
- B. Allows another method of sequencing motor starters



### VII. Uses of auxiliary contact interlocking

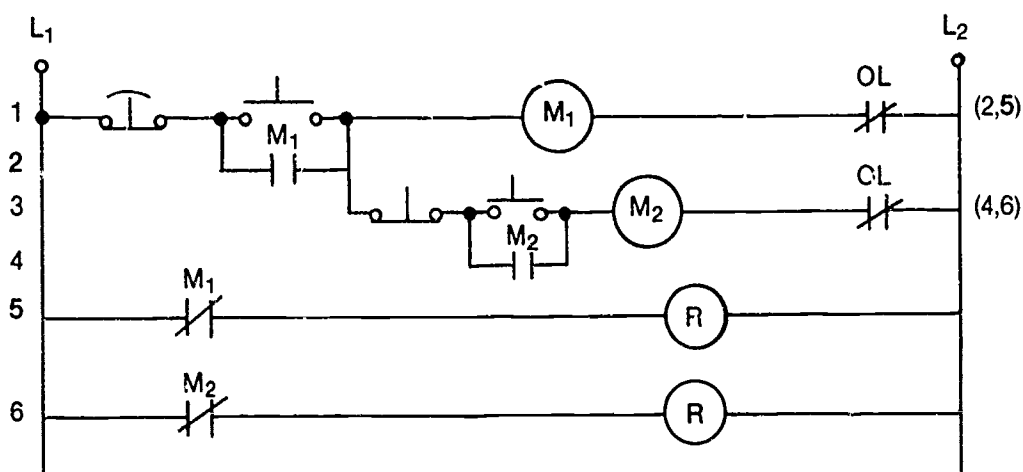
- A. Reversing starters
- B. Machine tools

## SEQUENCE CONTROL UNIT XI

### ASSIGNMENT SHEET #1 — ANSWER QUESTIONS RELATED TO A SEQUENCE CONTROL DIAGRAM

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Answer the following questions related to the sequence control diagram shown below.



- A. When the start button on Rung 1 is pressed, what is the sequence of events?

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- B. When the start button on Rung 3 is pressed, what is the sequence of events?

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## ASSIGNMENT SHEET #1

- C. If both coils M1 and M2 are energized, what is the sequence of events if the stop button on Rung 3 is pressed?

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- D. If both coils M1 and M2 are energized, what is the sequence of events if the stop button on Rung 1 is pressed?

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- E. Is it possible to energize coil M2, if coil M1 is not energized? Explain your answer.

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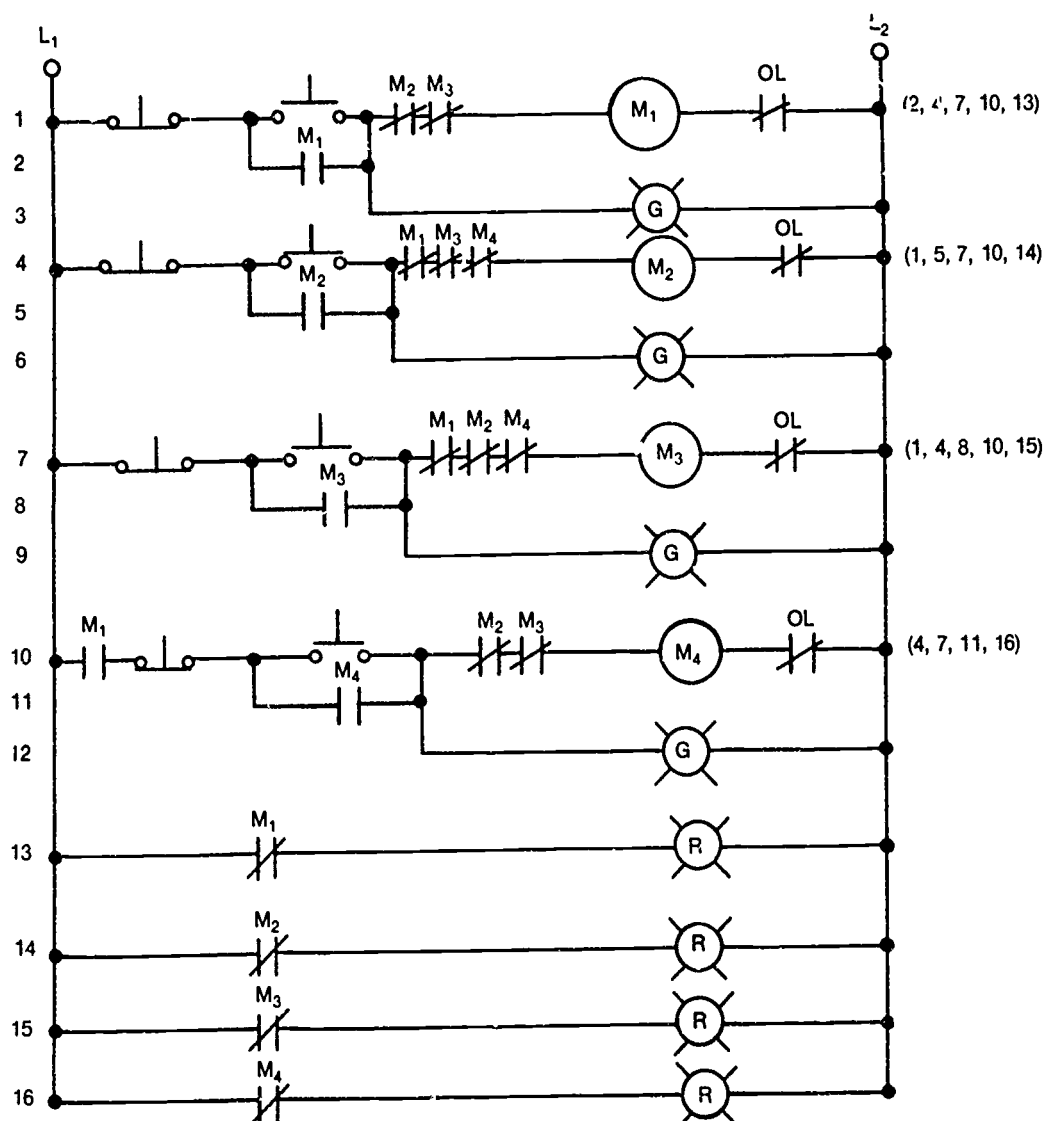
## SEQUENCE CONTROL UNIT XI

## ASSIGNMENT SHEET #2 — ANSWER QUESTIONS RELATED TO AN AUXILIARY CONTACT INTERLOCKING DIAGRAM

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

**Directions:** Answer the following questions related to the auxiliary contact interlocking diagram shown below.



**ASSIGNMENT SHEET #2**

- A. List in order, the sequence of events when the start button on Rung 10 is pressed.

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- B. If no coils are energized, what pilot lights are "on" and what is their purpose?

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- C. Is it possible to energize coil M4 and coil M1 at the same time? Explain your answer.

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## SEQUENCE CONTROL UNIT XI

### ANSWERS TO ASSIGNMENT SHEETS

#### Assignment Sheet #1

- A.
  - (1) Coil M1 energizes
  - (2) Contact M1, Rung 2 closes, sealing in coil M1 and energizing Rung 3
  - (3) Contact M1, Rung 5, opens, de-energizing red light
- B. Nothing—unless M1 is energized first
- C.
  - (1) Coil M2 de-energizes
  - (2) Contact M2, Rung 4 opens
  - (3) Contact M2, Rung 6 closes, energizing red light
- D.
  - (1) Rungs 1, 2, 3, and 4 de-energize
  - (2) Contact M1, Rung 2 and contact M2, Rung 4 open
  - (3) Contact M1, Rung 5 and contact M2, Rung 6 close and red lights energize
- E. No—power will not flow to Rung 3 unless coil M1 is energized

#### Assignment Sheet #2

- A. Nothing happens because N/O contact M1 is open
- B. Rungs 13, 14, 15, and 16. They are off indicators.
- C. Yes—because N/O interlocking on Rung 10 operated by M1 and there is not N/C interlocking

## SEQUENCE CONTROL UNIT XI

### JOB SHEET #1 — WIRE TWO STARTERS IN SEQUENCE

A. Equipment and materials needed

1. Two three-phase starters
2. Two start/stop stations
3. Twelve #10 x 1" sheet metal screws
4. 15' #16 TFFN
5. Mounting board

B. Procedure

1. Draw a ladder diagram of a system to operate two starters in sequence. Starter 1 must be energized before starter 2 is able to run.

**JOB SHEET #1**

2. Have your instructor approve your diagram.
3. In complete sentences, explain how your system operates.

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4. Have your instructor approve your explanation.
5. Wire the system.
6. Have your instructor evaluate the job.
7. Disassemble, clean work area, and return all equipment and materials to their proper storage area.

## SEQUENCE CONTROL UNIT XI

### JOB SHEET #2 — WIRE TWO STARTERS WITH AUXILIARY CONTACT INTERLOCKING

#### A. Equipment and materials needed

1. Two three-phase starters (with N/C auxiliary contacts)
2. Two start/stop stations
3. Twelve #10 x 1" sheet metal screws
4. 15' #16 THHN
5. Mounting board
6. Two pilot lights

#### B. Procedure

1. Draw a ladder diagram of a system designed to prevent two starters from being energized simultaneously. The starters must also indicate their energized status through the use of pilot lights.

**JOB SHEET #2**

2. Have your instructor approve your drawing.
3. In complete sentences, explain how your system operates.

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4. Have your instructor approve your explanation.
5. Wire the system.
6. Have your instructor evaluate the job.
7. Disassemble, clean work area, and return all equipment and materials to their proper storage area.



## SEQUENCE CONTROL UNIT XI

### JOB SHEET #1 PRACTICAL TEST — WIRE TWO STARTERS IN SEQUENCE

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Completed ladder diagram.  | _____ | _____ |
| 3. Instructor approved diagram.                                     | _____ | _____ |
| 4. Completed system explanation.                                    | _____ | _____ |
| 5. Instructor approved explanation.                                 | _____ | _____ |
| 6. Built system.  | _____ | _____ |
| 7. Checked in/put away tools and materials.                         | _____ | _____ |
| 8. Cleaned the work area.   | _____ | _____ |
| 9. Used proper tools correctly.                                     | _____ | _____ |
| 10. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 11. Practiced safety rules through _____ procedure.                 | _____ | _____ |
| 12. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Explanation correct				
System operating				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SEQUENCE CONTROL UNIT XI

### JOB SHEET #2 PRACTICAL TEST — WIRE TWO STARTERS WITH AUXILIARY CONTACT INTERLOCKING

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" or you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Completed ladder diagram.  | _____ | _____ |
| 3. Instructor approved diagram.                                     | _____ | _____ |
| 4. Completed system explanation.                                    | _____ | _____ |
| 5. Instructor approved explanation.                                 | _____ | _____ |
| 6. Built system.  | _____ | _____ |
| 7. Checked in/put away tools and materials.                         | _____ | _____ |
| 8. Cleaned the work area.   | _____ | _____ |
| 9. Used proper tools correctly.                                     | _____ | _____ |
| 10. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 11. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 12. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Explanation correct				
System operating				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SEQUENCE CONTROL UNIT XI

### TEST

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

1. Define the following terms related to sequence control.

a. Auxiliary contacts — \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

b. Cross phasing — \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

c. Down stream — \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

d. Interlocking — \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

2. State the purpose of sequence control.

\_\_\_\_\_  
\_\_\_\_\_

3. List two advantages of sequence control.

a. \_\_\_\_\_

b. \_\_\_\_\_

**TEST**

4. List two uses of sequence control.

a. \_\_\_\_\_  
b. \_\_\_\_\_

5. State the purpose of auxiliary contact interlocking.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

6. List two advantages of auxiliary contact interlocking.

a. \_\_\_\_\_  
b. \_\_\_\_\_

7. List two uses of auxiliary contact interlocking.

a. \_\_\_\_\_  
b. \_\_\_\_\_

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

8. Answer questions related to a sequence control diagram. (Assignment Sheet #1)
9. Answer questions related to an auxiliary contact interlocking diagram. (Assignment Sheet #2)
10. Demonstrate the ability to:
- a. Wire two starters in sequence. (Job Sheet #1)
- b. Wire two starters with auxiliary contact interlocking. (Job Sheet #2)

## SEQUENCE CONTROL UNIT XI

### ANSWERS TO TEST

1.
  - a. Contacts of a switching device in addition to the main circuit contacts; auxiliary contacts operate with the movement of the main contacts; can be N/O or N/C
  - b. Unintentional contact of two or more electrical phases; results in a short circuit
  - c. Coming after; following other devices or events
  - d. To interrelate with other controllers; a device is connected in such a way that the operation of one part controls the operation of another
2. To assure that one motor is running before any other can operate
3.
  - a. Assures proper order of start-up
  - b. Shuts down all "down-stream" motors when a starter fails due to overload
4.
  - a. Main or subassembly line conveyors
  - b. Auxiliary equipment associated with machines
5. To prevent two machines or starters from conflicting with one another.
6.
  - a. Prevents motor starters from being energized when not desired
  - b. Allows another method of sequencing
7.
  - a. Reversing starters
  - b. Machine tools
- 8-9. Evaluated to the satisfaction of the instructor
10. Performance skills evaluated to the satisfaction of the instructor

## **JOGGING CONTROLS UNIT XII**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to read and interpret ladder diagrams dealing with jogging controls as well as wire these types of circuits. Competencies will be demonstrated by completing the assignment sheets, job sheets, and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Define the term jogging.
2. Identify methods of jogging control.
3. Match methods of jogging control with their advantages.
4. Describe the sequence of operation of three ladder diagrams.
5. Convert three ladder diagrams to wiring diagrams. (Assignment Sheet #1)
6. Determine the number of conductors needed to operate jogging controls. (Assignment Sheet #2)
7. Demonstrate the ability to:
  - a. Wire a jog through a lock-stop push button. (Job Sheet #1)
  - b. Wire a jog through a two-position selector switch. (Job Sheet #2)
  - c. Wire a jog through a two-circuit push button. (Job Sheet #3)
  - d. Wire a jog through a control relay. (Job Sheet #4)



## **JOGGING CONTROLS UNIT XII**

### **SUGGESTED ACTIVITIES**

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Provide students with objective sheet.
- C. Discuss unit and specific objectives.
- D. Provide students with information and assignment sheets.
- E. Discuss information and assignment sheets.
- F. Provide students with job sheets.
- G. Discuss and demonstrate the procedures outlined in the job sheets.
- H. Integrate the following activities throughout the teaching of this unit:
1. Visit a local industry and view jogging controls in use.
  2. Visit a school machine shop and view jogging control on lathes.
  3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- I. Give test.
- J. Evaluate test.
- K. Reteach if necessary.

### **REFERENCE USED IN WRITING THIS MATERIAL**

Alerich, Walter M. *Electric Motor Controls*. Third Edition. Albany, NY: Delmar Publishers, Inc., 1983.

### **SUGGESTED SUPPLEMENTAL MATERIAL**

Publications —

- A. *Industrial Control Catalog*. Cutler Hammer Products, 4201 N. 27th Street, Milwaukee, WI.
- B. 1986 Digest. Square D Company, Falmouth, Indiana.

## JOGGING CONTROLS UNIT XII

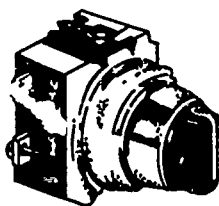
### INFORMATION SHEET

- I. **Jogging** — The quickly repeated closure of a circuit to start a motor from rest for the purpose of accomplishing small movements

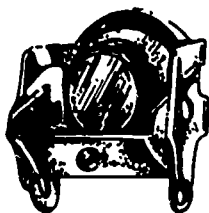
EXAMPLE: Short movement of a turret lathe in order to load material into the chuck

II. **Methods of jogging control**

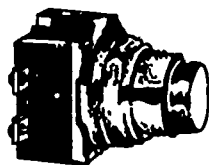
- A. Two-position selector switch



- B. Lock-stop push button



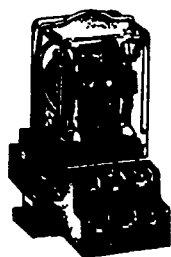
- C. Two-circuit push button



(NOTE: This is a momentary push button with a two-circuit NC/NO contact block.)

## INFORMATION SHEET

### D. Control relay



### III. Advantages of jogging control methods

#### A. Two-position selector switch

1. Inexpensive
2. Easy to install or retrofit
3. Reliable

#### B. Lock-stop push button

1. Inexpensive
2. Easy to install or retrofit
3. Reliable

#### C. Two-circuit push button

1. Ease of operation
2. Easy installation on initial wiring

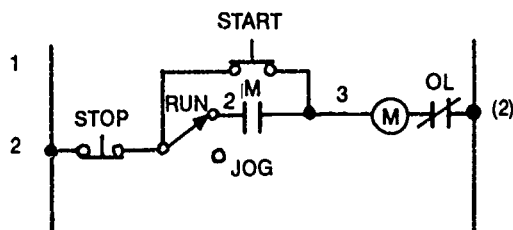
#### D. Control relay

1. Extremely reliable
2. May be used on multiple starters

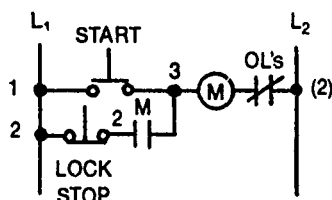
## INFORMATION SHEET

### IV. Sequence of operations

- A. Two-position selector switch — When the switch is in the run position the circuit operates as a normal three-wire control. When the switch is in the jog position the memory circuit will no longer operate, thus allowing the start button to "change" to a jog button.

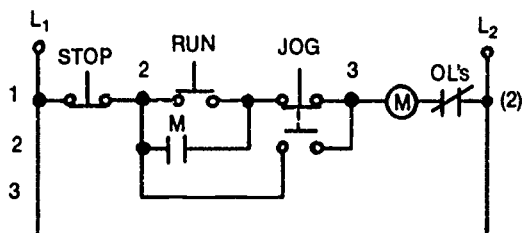


- B. Lock-stop push button — When the lock-stop is in the closed position, the circuit operates as a normal three-wire control. When the lock-stop is locked opening it allows the start button to function as a jog, due to the open memory circuit.



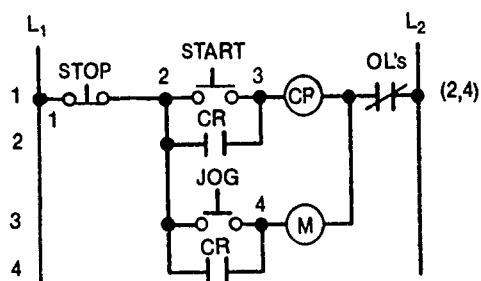
- C. Two-circuit push button — The normally closed contacts of the two-circuit push button is in series with the memory contacts. The normally open contacts are used to energize the coil. When the jog button is pressed the seal-in circuit is opened and the coil is energized. When the button is released the coil is de-energized before the seal-in portion of the circuit closes again.

**(CAUTION: A control station using this circuit, may maintain the circuit when the operator's finger is removed too quickly from the button. This could injure production workers, equipment, and machinery. Such a circuit is not recommended.)**



## INFORMATION SHEET

- D. Control relay — The control relay is used to seal in the circuit. When the start button is depressed the coil CR (control relay) is energized. When CR energizes N/O contacts CR on rung 2 and 4 close. CR rung 4 acts as seal-in for the starters coil.



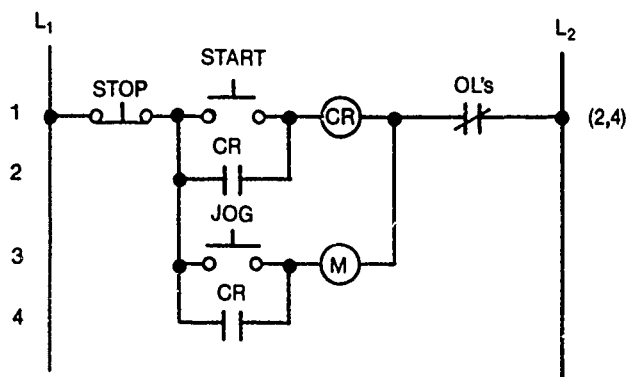
## JOGGING CONTROLS UNIT XII

### ASSIGNMENT SHEET #1 — CONVERT THREE LADDER DIAGRAMS TO WIRING DIAGRAMS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

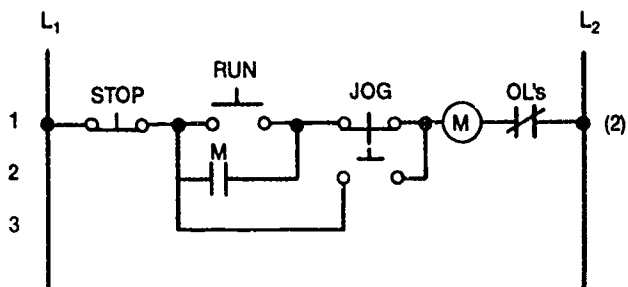
Directions: Convert the ladder diagrams shown below to wiring diagrams.

A.

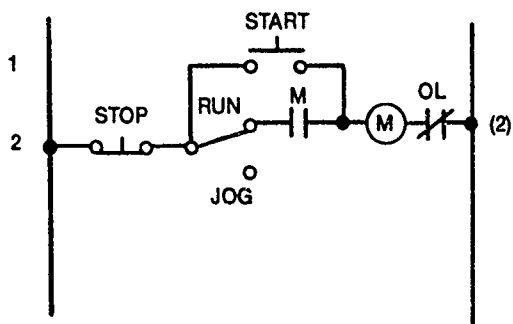


# ASSIGNMENT SHEET #1

B.



C.



## JOGGING CONTROLS UNIT XII

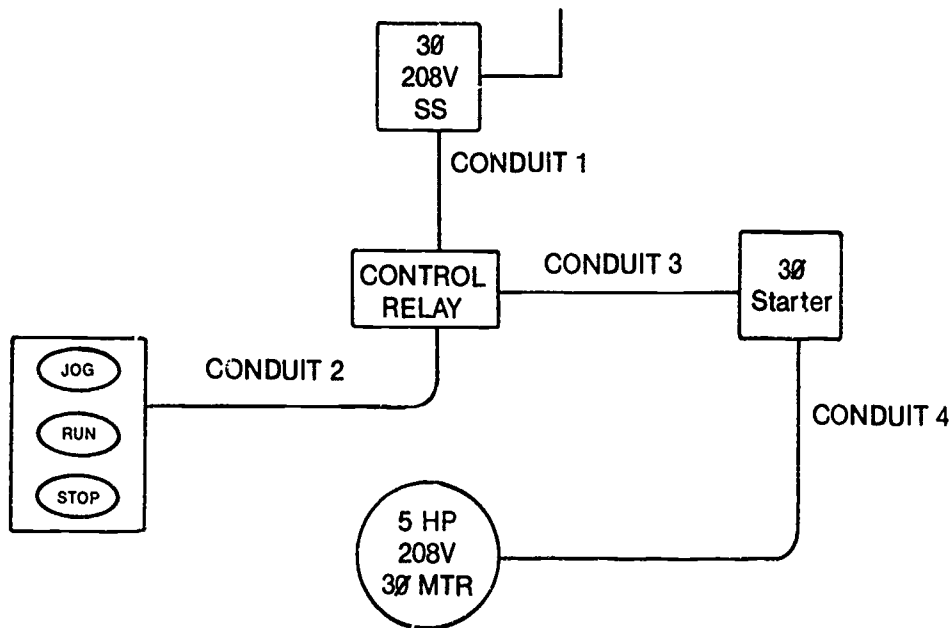
### ASSIGNMENT SHEET #2 — DETERMINE THE NUMBER OF CONDUCTORS NEEDED TO OPERATE JOGGING CONTROLS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

Directions: Using the NEC and the handout provided with Unit IX, determine the size and number of conductors needed to operate the following jogging control circuits. You must also determine the proper fuse size using a dual element time delay fuse, and the proper heater size.

(NOTE: This starter has a line voltage coil.)

A.



Conduit 1 \_\_\_\_\_ conductors \_\_\_\_\_ Awg

Conduit 2 \_\_\_\_\_ conductors \_\_\_\_\_ Awg

Conduit 3 \_\_\_\_\_ conductors \_\_\_\_\_ Awg

Conduit 4 \_\_\_\_\_ conductors \_\_\_\_\_ Awg

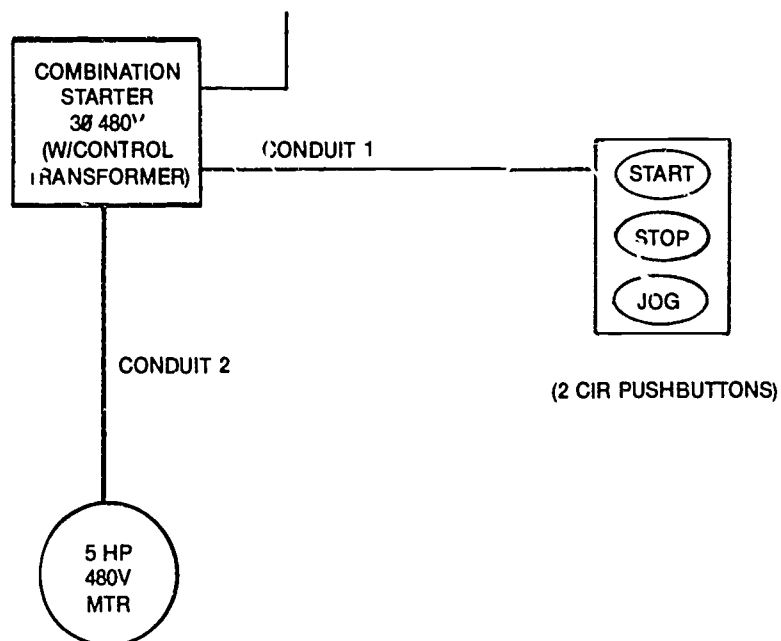
Dual element fuse \_\_\_\_\_ amps

Heater \_\_\_\_\_



# ASSIGNMENT SHEET #2

B.



Conduit 1 \_\_\_\_\_ conductors \_\_\_\_\_ Awg

Conduit 2 \_\_\_\_\_ conductors \_\_\_\_\_ Awg

Fuse size \_\_\_\_\_ (dual element time delay)

Heater amps \_\_\_\_\_ part number \_\_\_\_\_

## JOGGING CONTROLS UNIT XII

### ANSWERS TO ASSIGNMENT SHEETS

**Assignment Sheet #1** — Evaluated to the satisfaction of the instructor

**Assignment Sheet #2**

A. Conduit 1 3 conductors 10 Awg

Conduit 2 4 conductors 14 Awg

Conduit 3 3 conductors 14 Awg

Conduit 4 3 conductors 10 Awg

Dual element fuse 30 amp

Heater — Answer dependent upon selection charts used

B. Conduit 1 3 conductors 16 Awg

Conduit 2 3 conductors 12 Awg

Dual element fuse 15 amp

Heater — Answer dependent upon selection charts used

## JOGGING CONTROLS UNIT XII

### JOB SHEET #1 — WIRE A JOG THROUGH A LOCK-STOP PUSH BUTTON

- A. Equipment and materials needed
1. Pouch tools
  2. Three-phase starter
  3. Three-element control station
  4. Normally open push button
  5. Two normally closed push button
  6. Lock-stop device
  7. Eight #10 x 1" sheet metal screws
  8. 15' #14 THHN
- B. Procedure
1. Draw a ladder diagram of a jogging control using a lock-stop push button.

**JOB SHEET #1**

2. Have your instructor approve your diagram.
3. In complete sentences, describe the sequence of operation of your system.

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4. Have your instructor approve your system description.
5. Wire the system.
6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and return all equipment and materials to their proper storage area.

## JOGGING CONTROLS UNIT XII

### JOB SHEET #2 — WIRE A JOG THROUGH A TWO-POSITION SELECTOR

A. Equipment and materials needed

1. Pouch tools
2. Three-phase starter
3. Three-element control station
4. N/O push button
5. N/C push button
6. N/O two-position selector switch
7. Eight #10 x 1" sheet metal screws
8. 15' #14 THHN

B. Procedure

1. Draw a ladder diagram of a jogging control system using a two-position selector switch.

**JOB SHEET #2**

2. Have your instructor approve your diagram.
3. In complete sentences, describe the sequence of operation of your system.

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4. Have your instructor approve your system description.
5. Wire the system.
6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and return all equipment and materials to their proper storage area.

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## JOGGING CONTROLS UNIT XII

### JOB SHEET #3 — WIRE A JOG THROUGH A TWO-CIRCUIT PUSH BUTTON

A. Equipment and materials needed

1. Pouch tools
2. Three-phase starter
3. Three-element control station
4. N/O push button
5. N/C push button
6. N/O-N/C two-circuit pushbutton
7. Eight #10 x 1" sheet metal screws
8. 15' #14 THHN

B. Procedure

1. Draw a ladder diagram of a jogging control system using a two-circuit push button.

**JOB SHEET #3**

2. Have your instructor approve your diagram.
3. In complete sentences, describe the sequence of operation of your system.

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4. Have your instructor approve your system description.
5. Wire the system.
6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and return all equipment and materials to their proper storage area.



## JOGGING CONTROLS UNIT XII

### JOB SHEET #4 — WIRE A JOG THROUGH A CONTROL RELAY

A. Equipment and materials needed

1. Pouch tools
2. Three-phase starter
3. Three-element control station
4. Two N/O push buttons
5. N/C push button
6. Two pole control relay with compatible coil voltage
7. Eight #10 x 1" sheet metal screws
8. 15' #14 THHN

B. Procedure

1. Draw a ladder diagram of a jogging control system using a control relay.

**JOB SHEET #4**

2. Have your instructor approve your diagram.
3. In complete sentences, describe the sequence of operation of your system.

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4. Have your instructor approve your system description.
5. Wire the system.
6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and return all equipment and materials to their proper storage area.

## JOGGING CONTROLS UNIT XII

### JOB SHEET #1 PRACTICAL TEST — WIRE A JOG THROUGH A LOCK-STOP PUSH BUTTON

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES      NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Drew ladder diagram.   | _____ | _____ |
| 3. Had diagram approved.  | _____ | _____ |
| 4. Completed sequence explanation.                                  | _____ | _____ |
| 5. Had explanation approved.  | _____ | _____ |
| 6. Wired system.  | _____ | _____ |
| 7. Checked in/put away tools and materials.                         | _____ | _____ |
| 8. Cleaned the work area.   | _____ | _____ |
| 9. Used proper tools correctly.                                     | _____ | _____ |
| 10. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 11. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 12. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Sequence explanation correct				
Proper operation				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## JOGGING CONTROLS UNIT XII

### JOB SHEET #2 PRACTICAL TEST — WIRE A JOG THROUGH A TWO-POSITION SELECTOR

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Drew ladder diagram.   | _____ | _____ |
| 3. Had diagram approved.  | _____ | _____ |
| 4. Completed sequence description.                                  | _____ | _____ |
| 5. Had description approved.  | _____ | _____ |
| 6. Wired system.  | _____ | _____ |
| 7. Checked in/put away tools and materials.                         | _____ | _____ |
| 8. Cleaned the work area.   | _____ | _____ |
| 9. Used proper tools correctly.                                     | _____ | _____ |
| 10. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 11. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 12. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct	4	3	2	1
Sequence description correct	4	3	2	1
Proper operation	4	3	2	1
Workmanship	4	3	2	1
Compliance to NEC	4	3	2	1
EVALUATOR'S COMMENTS: _____				
_____				

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## JOGGING CONTROLS UNIT XII

### JOB SHEET #3 PRACTICAL TEST — WIRE A JOG THROUGH A TWO-CIRCUIT PUSH BUTTON

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Drew ladder diagram.	_____	_____
3. Had diagram approved.	_____	_____
4. Completed sequence description.	_____	_____
5. Had description approved.	_____	_____
6. Wired system.	_____	_____
7. Checked in/put away tools and materials.	_____	_____
8. Cleaned the work area.	_____	_____
9. Used proper tools correctly.	_____	_____
10. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
11. Practiced safety rules throughout procedure.	_____	_____
12. Provided satisfactory response to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Sequence description correct				
Proper operation				
Workmanship				
Compliance to NEC				
EVALUATOR'S COMMENTS: _____				
_____				

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)



## JOGGING CONTROLS UNIT XII

### JOB SHEET #4 PRACTICAL TEST — WIRE A JOG THROUGH A CONTROL RELAY

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES NO

- |   |       |       |
|---|-------|-------|
| 1. Checked out proper tools and materials.                          | _____ | _____ |
| 2. Drew ladder diagram.   | _____ | _____ |
| 3. Had diagram approved.  | _____ | _____ |
| 4. Completed sequence description.                                  | _____ | _____ |
| 5. Had description approved.  | _____ | _____ |
| 6. Wired system.  | _____ | _____ |
| 7. Checked in/put away tools and materials.                         | _____ | _____ |
| 8. Cleaned the work area.   | _____ | _____ |
| 9. Used proper tools correctly.                                     | _____ | _____ |
| 10. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 11. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 12. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct	4	3	2	1
Sequence description correct	4	3	2	1
Proper operation	4	3	2	1
Workmanship	4	3	2	1
Compliance to NEC	4	3	2	1
EVALUATOR'S COMMENTS: _____				
_____				

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## JOGGING CONTROLS UNIT XII

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Define the term jogging.

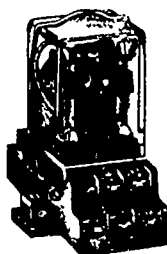
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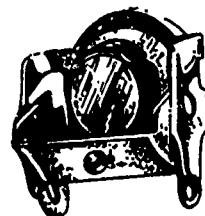
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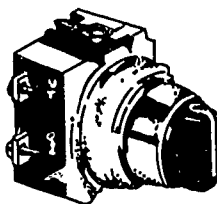
2. Identify methods of jogging control shown below.



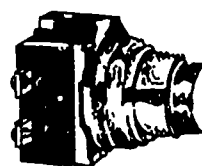
a. \_\_\_\_\_



b. \_\_\_\_\_



c. \_\_\_\_\_



d. \_\_\_\_\_

# TEST

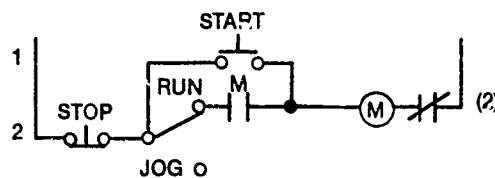
3. Match the methods of jogging control on the right with their correct advantages.

(NOTE: There may be more than one correct answer.)

- |         |   |                                 |
|---------|---|---------------------------------|
| _____a. | 1. Extremely reliable<br>2. May be used on multiple starters    | 1. Two position selector switch |
| _____b. | 1. Inexpensive<br>2. Easy to install or retrofit<br>3. Reliable | 2. Lock-stop push button        |
| _____c. | 1. Ease of operation<br>2. Easy installation on initial wiring  | 3. Two circuit push button      |
|         |   | 4. Control relay                |

4. Describe the sequence of operation of three ladder diagrams.

a.




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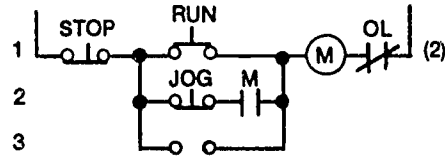
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# TEST

b.




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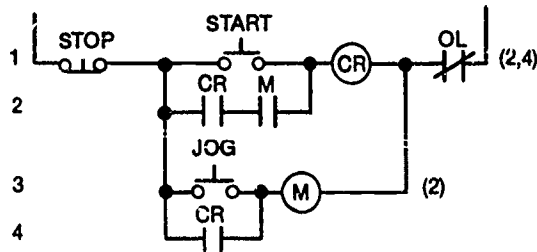
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c.




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## TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

5. Convert three ladder diagrams to wiring diagrams. (Assignment Sheet #1)
6. Determine the number of conductors needed to operate jogging controls. (Assignment Sheet #2)
7. Demonstrate the ability to:
  - a. Wire a jog through a lock-stop push button. (Job Sheet #1)
  - b. Wire a jog through a two-position selector switch. (Job Sheet #2)
  - c. Wire a jog through a two-circuit push button. (Job Sheet #3)
  - d. Wire a jog through a control relay. (Job Sheet #4)

## JOGGING CONTROLS UNIT XII

### ANSWERS TO TEST

1. The quickly repeated closure of a circuit to start a motor from rest for the purpose of accomplishing small movements
2.
  - a. Control relay
  - b. Lock-stop push button
  - c. Two-position selector switch
  - d. Two circuit push button
3.
  - a. 4
  - b. 1, 2
  - c. 3
4. Description should include:
  - a. When switch is closed it reacts as a normal 3-wire control. When switch is open seal in circuit is open.
  - b. When jog is pressed seal in circuit is opened and coil is energized through N/O portion of two-position push button.
  - c. When start button is pressed coil CR energizes, contact CR on Rung 2 closes, and contact CR on Rung 4 closes energizing coil M. When coil M energizes contact M, Rung 2 closes sealing in CR and M. When jog is pressed coil M energizes; when jog is released coil M de-energizes.
- 5-6. Evaluated to the satisfaction of the instructor
7. Performance skills evaluated to the satisfaction of the instructor

## **REVERSING STARTERS UNIT XIII**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to wire a reversing starter under various conditions. Competencies will be demonstrated by completing the assignment sheets, job sheets, and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to reversing starters with their correct definitions.
2. Identify two types of reversing starter construction.
3. List three types of interlocking methods for reversing starters.
4. Identify three types of drum controls.
5. Complete a drum switch diagram.
6. Describe the sequence of operation of ladder diagrams. (Assignment Sheet #1)
7. Determine the number of conductors needed to operate a reversing control. (Assignment Sheet #2)
8. Demonstrate the ability to:
  - a. Wire a reversing starter with a three-position selector switch. (Job Sheet #1)
  - b. Wire a reversing starter with one control station using auxiliary contact and mechanical interlock. (Job Sheet #2)
  - c. Wire a reversing starter with one control station using push button interlock and auxiliary contact interlock. (Job Sheet #3)



**OBJECTIVE SHEET**

- d. Wire a reversing starter with two control stations. (Job Sheet #4)
- e. Wire a drum switch. (Job Sheet #5)
- f. Wire a reversing starter with jog in both directions. (Job Sheet #6)

## REVERSING STARTERS UNIT XIII

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Provide students with objective sheet.
- C. Discuss unit and specific objectives.
- D. Provide students with information and assignment sheets.
- E. Discuss information and assignment sheets.
- F. Provide students with job sheets.
- G. Discuss and demonstrate the procedures outlined in the job sheets.
- H. Integrate the following activities throughout the teaching of this unit:
1. Disassemble several reversing starters and show how mechanical interlocking works.
  2. Arrange a tour of supply house to view different brands and sizes of reversing starters.
  3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- I. Give test.
- J. Evaluate test.
- K. Reteach if necessary.

### REFERENCE USED IN WRITING THIS MATERIAL

Alerich, Walter M. *Electric Motor Controls*. Third Edition. Albany, NY: Delmar Publishers, Inc., 1983.

### SUGGESTED SUPPLEMENTAL MATERIAL

*Rotating Machinery Explained*. Filmstrip #3, Reversing Starters, Bergwall.

## REVERSING STARTERS UNIT XIII

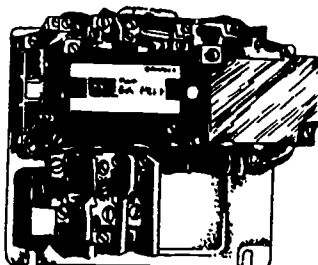
### INFORMATION SHEET

#### I. Terms and definitions

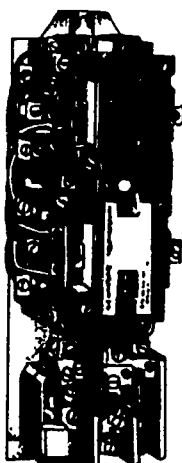
- A. Drum switch — A switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or surfaces of a rotating cylinder
- B. Mechanical interlocking — Means of locking out contactors through the use of mechanical devices such as cams or blocks
- C. Push-button interlocking — Means of interlocking reversing starters through the use of two-circuit push buttons with normally open and normally closed contacts
- D. Racing — Condition that occurs when both forward and reversing push buttons are operated simultaneously; coils "race" to close
- E. Reversing starter — Starter consisting of two identical contactors and one overload relay assembly; used in reversal of polyphase motors

#### II. Types of reversing starter construction

- A. Horizontal construction



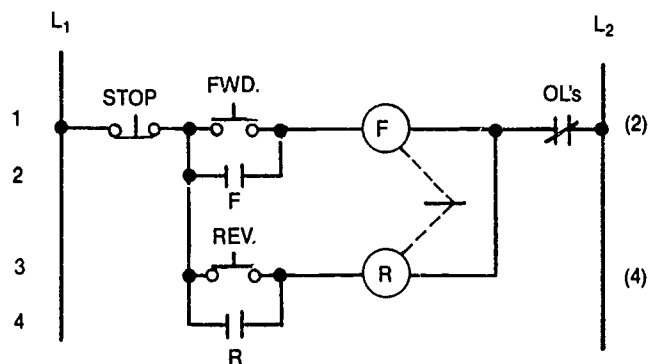
- B. Vertical construction



## INFORMATION SHEET

### III. Types of interlocking methods for reversing starters

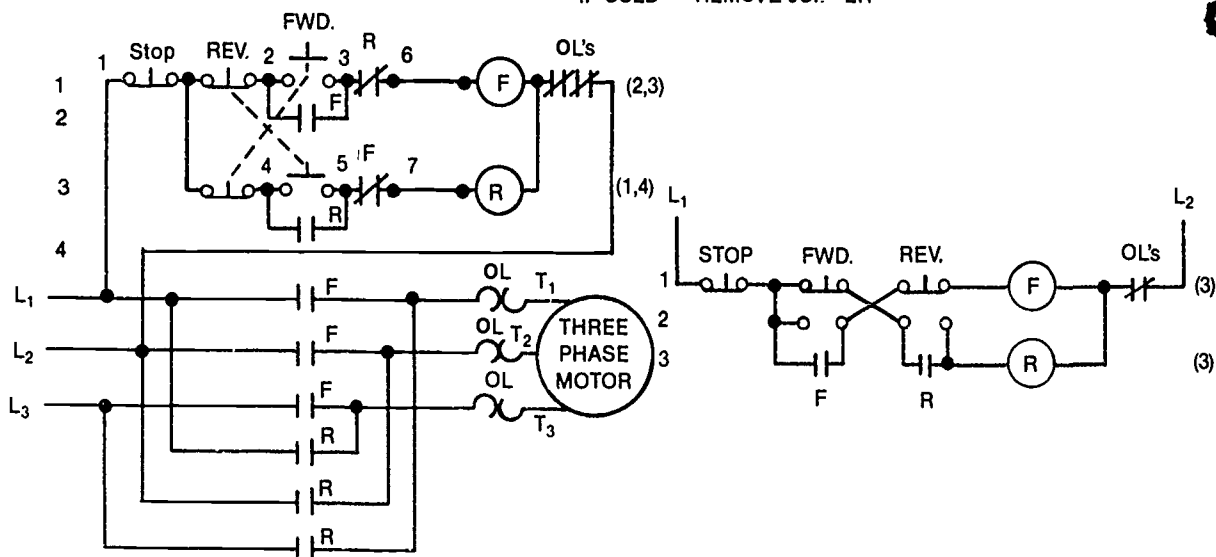
#### A. Mechanical interlocking



(NOTE: A mechanical interlock is either factory or field installed between the forward and reverse contactors. It locks out one contactor at the beginning of the stroke of either contactor. This will prevent short circuits and burnouts.)

#### B. Push button interlocking

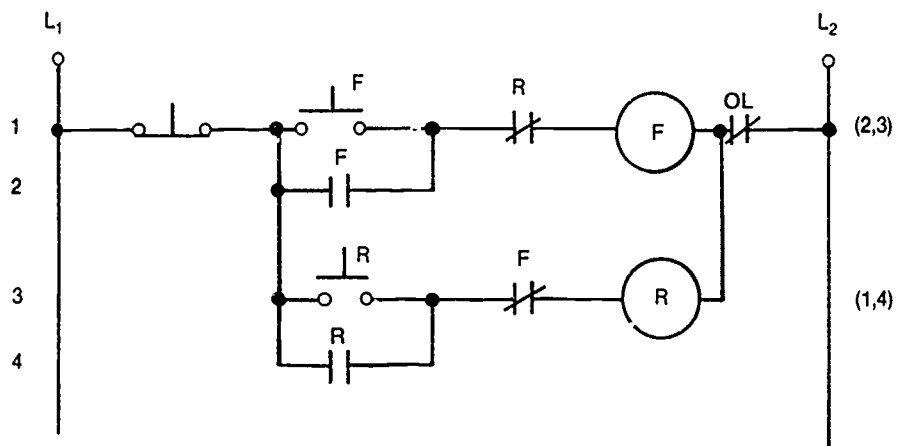
LIMIT SWITCHES  
IF USED — REMOVE JUMPER



(NOTE: This method will not allow the coils to race.)

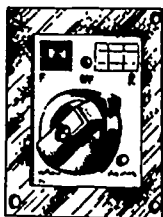
## INFORMATION SHEET

### C. Auxiliary contact interlocking

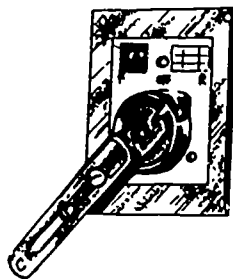


### IV. Three types of drum controls

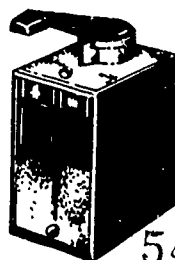
#### A. Flush mount knob operator



#### B. Flush mount adjustable operator



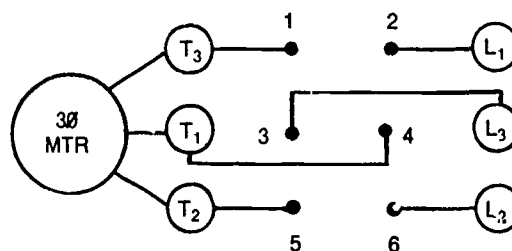
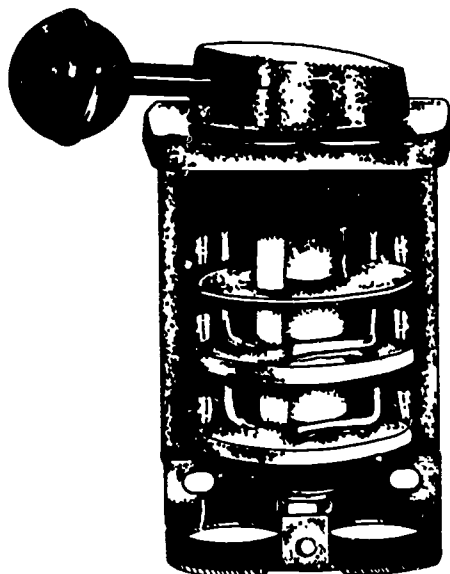
#### C. Surface mounting standard lever



## INFORMATION SHEET

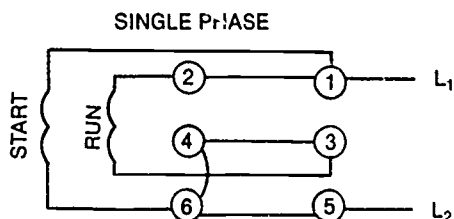
### V. Drum switch diagrams

(NOTE: Drum switches may be used as the only means of controlling a motor. However, if the starting inrush current is higher than the rating of the drum switch, a starter must be used.)



Connections for 3Ø

FORWARD	REVERSE
L <sub>1</sub> to T <sub>3</sub>	L <sub>1</sub> to T <sub>1</sub>
L <sub>2</sub> to T <sub>2</sub>	L <sub>2</sub> to T <sub>2</sub>
L <sub>3</sub> to T <sub>1</sub>	L <sub>3</sub> to T <sub>3</sub>



Connections for 1Ø

FORWARD	REVERSE
1 — 2	1 — 2
3 — 4	3 — 4
5 — 6	5 — 6

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# REVERSING STARTERS

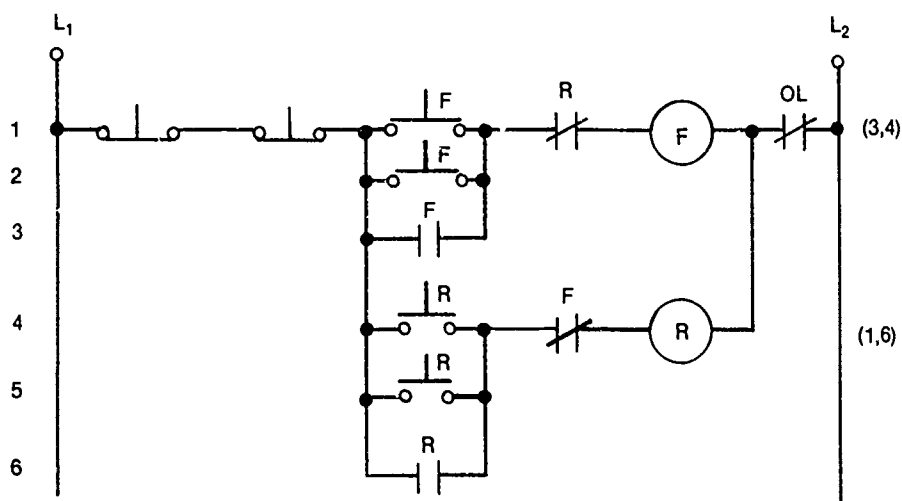
## UNIT XIII

## ASSIGNMENT SHEET #1 — DESCRIBE THE SEQUENCE OF OPERATION OF LADDER DIAGRAMS

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

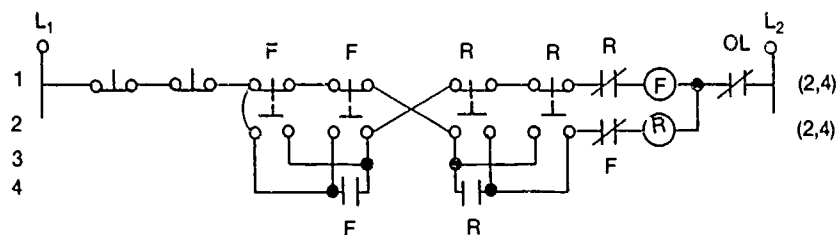
**Directions:** Describe the sequence of operation of the three ladder diagrams shown below.

**A.**

[illegible]

# ASSIGNMENT SHEET #1

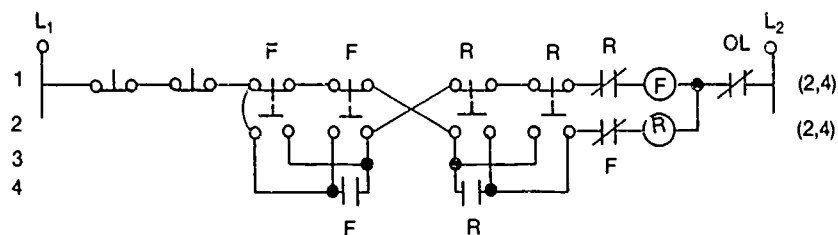
C.





# ASSIGNMENT SHEET #1

C.




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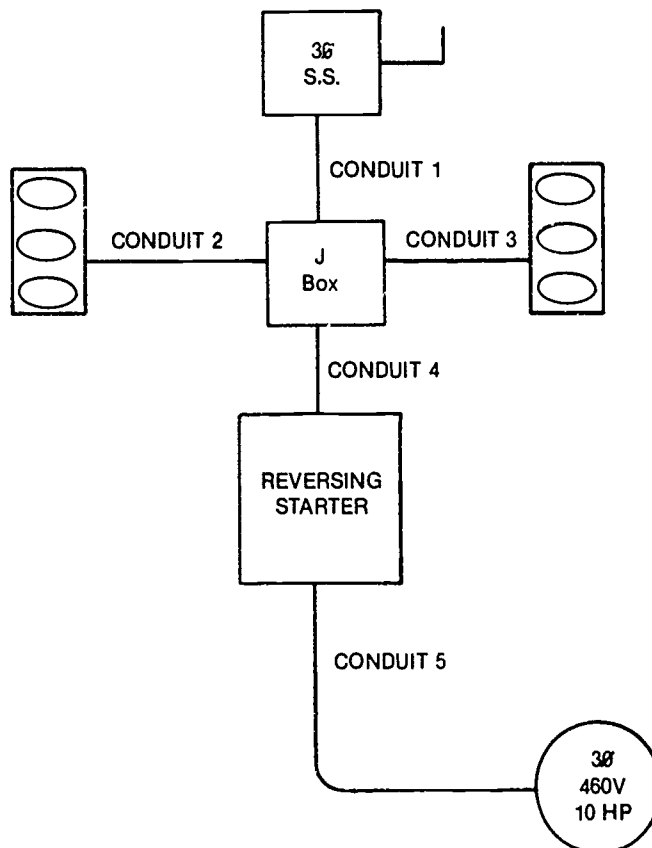
## REVERSING STARTERS UNIT XIII

### ASSIGNMENT SHEET #2 — DETERMINE THE NUMBER OF CONDUCTORS NEEDED TO OPERATE A REVERSING CONTROL

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions: Determine the number of 14 Awg control conductors needed to operate the control circuit of a system using two control stations with push button and auxiliary contact interlock. Also determine the number and size of motor branch circuit conductors as well as the size of conduit.



## ASSIGNMENT SHEET #2

Conduit 1 \_\_\_\_\_ inch \_\_\_\_\_ conductors \_\_\_\_\_ Awg THW  
Conduit 2 \_\_\_\_\_ inch \_\_\_\_\_ conductors \_\_\_\_\_ Awg THW  
Conduit 3 \_\_\_\_\_ inch \_\_\_\_\_ conductors \_\_\_\_\_ Awg THW  
Conduit 4 \_\_\_\_\_ inch \_\_\_\_\_ conductors \_\_\_\_\_ Awg THW  
Conduit 5 \_\_\_\_\_ inch \_\_\_\_\_ conductors \_\_\_\_\_ Awg THW

## REVERSING STARTERS UNIT XIII

### ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1 — Evaluated to the satisfaction of the instructor

#### Assignment Sheet #2

Conduit 1  $\frac{1}{2}$  inch 3 #12

Conduit 2  $\frac{3}{4}$  inch 8 #14

Conduit 3  $\frac{1}{2}$  inch 5 #14

Conduit 4  $\frac{3}{4}$  inch 3 #12 & 5 #14

Conduit 5  $\frac{1}{2}$  inch 3 #12

## **REVERSING STARTERS UNIT XIII**

### **JOB SHEET #1 — WIRE A REVERSING STARTER WITH A THREE-POSITION SELECTOR SWITCH**

**A. Equipment and materials needed**

1. Pouch tools
2. Three-position selector switch (N/O-N/O) and enclosure
3. Reversing starter with mechanical interlock
4. Eight #10 × 1" sheet metal screws
5. 15' #16 THWN
6. Mounting board

**B. Procedure**

1. Draw a ladder diagram of a control system using three-position selector switch to operate a reversing starter.

**JOB SHEET #1**

2. Have your instructor approve your diagram.
3. In complete sentences, explain the sequence of operations of your system.

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4. Have your instructor approve your explanation.
5. Wire the system.
6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and store all equipment and materials.

## REVERSING STARTERS UNIT XIII

### JOB SHEET #2 — WIRE A REVERSING STARTER WITH ONE CONTROL STATION USING AUXILIARY CONTACT AND MECHANICAL INTERLOCK

#### A. Equipment and materials needed

1. Pouch tools
2. Three-element control station
3. N/C push button
4. Two N/O push buttons
5. Reversing starter with mechanical interlock
6. Eight #10 × 1" sheet metal screws
7. Mounting board
8. 15' #16 THWN

#### B. Procedure

1. Draw a ladder diagram of a reversing control with one control station, using auxiliary contact and mechanical interlocking.

**JOB SHEET #2**

2. Have your instructor approve your diagram.
3. In complete sentences, explain the sequence of operations of your system.

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4. Have your instructor approve your explanation.
5. Wire the system.
6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and store all equipment and materials.

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## REVERSING STARTERS UNIT XIII

### JOB SHEET #3 -- WIRE A REVERSING STARTER WITH ONE CONTROL STATION USING PUSHBUTTON AND AUXILIARY CONTACT INTERLOCKING

#### A. Equipment and materials needed

1. Pouch tools
2. Three-element control station
3. N/C push button
4. Two N/O-N/C two circuit push buttons
5. Reversing starter
6. Eight #10 × 1" sheet metal screws
7. Mounting board
8. 15' #16 THWN

#### B. Procedure

1. Draw a ladder diagram of a system to operate a reversing starter using push button and auxiliary contact interlocking.

**JOB SHEET #3**

2. Have your instructor approve your diagram.
3. In complete sentences, explain the sequence of operations of your system.

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4. Have your instructor approve your explanation.
5. Wire the system.
6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and store all equipment and materials.

## REVERSING STARTERS UNIT XIII

### JOB SHEET #4 — WIRE A REVERSING STARTER WITH TWO CONTROL STATIONS

A. Equipment and materials needed

1. Pouch tools
2. Two forward/reverse/stop control stations
3. Reversing starter
4. Ten #10 x 1" sheet metal screws
5. Mounting board
6. 20' #16 THWN

B. Procedure

1. Draw a ladder diagram of a reversing control using two control stations.

**JOB SHEET #4**

2. Have your instructor approve your system drawing.
3. In complete sentences, explain the sequence of operations of your system.

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4. Have your instructor approve your explanation.
5. Wire your system.
6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and store all equipment and materials.

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## REVERSING STARTERS UNIT XIII

### JOB SHEET #5 — WIRE A DRUM SWITCH

#### Part I

##### A. Equipment and materials needed

1. Pouch tools
2. Drum switch for polyphase motors
3. 3 $\phi$  3/4hp. motor
4. 3 $\phi$  voltage source
5. Two #10 x 1" sheet metal screws
6. Mounting board

##### B. Procedure

1. Draw a wiring diagram of a drum switch.

(NOTE: Terminal connections for polyphase motors are located on the inside of the drum switch cover.)

2. Have your instructor approve your drawing.
3. Wire the drum switch.
4. Have your instructor evaluate your job.
5. Disassemble, clean work area, and store all equipment and materials.

## JOB SHEET #5

## Part II

## A. Equipment and materials needed

1. Pouch tools
2. Drum switch for 1 $\phi$  motor
3. 1 $\phi$   $\frac{3}{4}$ hp. motor
4. 1 $\phi$  240V voltage source
5. Two #10  $\times$  1" sheet metal screws
6. Mounting screws

## B. Procedure

1. Draw a wiring diagram of a drum switch.

(NOTE: Terminal connections for 1 $\phi$  motors are located on the inside cover of the drum switch cover.)

2. Have your instructor approve your drawing.
3. Wire the drum switch.
4. Have your instructor evaluate your job.
5. Disassemble, clean work area, and store all equipment and materials.

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# **REVERSING STARTERS** **UNIT XIII**

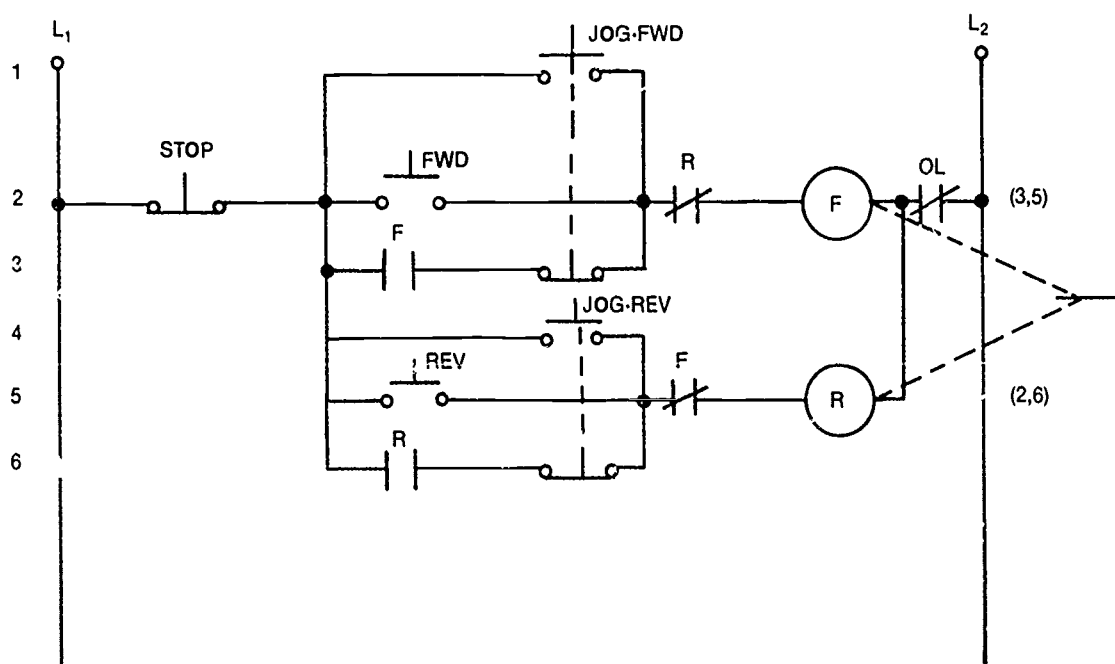
## **JOB SHEET #6 — WIRE A REVERSING STARTER WITH JOG IN BOTH DIRECTIONS**

### A. Equipment and materials needed

1. Pouch tools
2. N/C push button
3. Two-N/O push buttons
4. Two-N/O-N/C two-circuit push buttons
5. Three-element control station
6. Two-element control station
7. Reversing starter
8. Mounting board
9. Ten #10 x 1" sheet metal screws
10. 20' #16 THWN

### B. Procedure

1. Wire a reversing starter with jog in both directions, using the following diagram.



**JOB SHEET #6**

6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and store all equipment and materials.

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## REVERSING STARTERS UNIT XIII

### JOB SHEET #1 PRACTICAL TEST — WIRE A REVERSING STARTER WITH A THREE-POSITION SELECTOR SWITCH

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Completed diagram.	_____	_____
3. Completed explanation.	_____	_____
4. Built system.	_____	_____
5. Checked in/put away tools and materials.	_____	_____
6. Cleaned the work area.	_____	_____
7. Used proper tools correctly.	_____	_____
8. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
9. Practiced safety rules throughout procedure.	_____	_____
10. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Diagram correct				
Explanation correct				
System operating				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## REVERSING STARTERS UNIT XIII

### JOB SHEET #2 PRACTICAL TEST — WIRE A REVERSING STARTER WITH ONE CONTROL STATION USING AUXILIARY CONTACT AND MECHANICAL INTERLOCK

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES      NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Completed diagram.  | _____ | _____ |
| 3. Completed explanation.  | _____ | _____ |
| 4. Wired system.   | _____ | _____ |
| 5. Checked in/put away tools and materials.                        | _____ | _____ |
| 6. Cleaned the work area.  | _____ | _____ |
| 7. Used proper tools correctly.                                    | _____ | _____ |
| 8. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 9. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 10. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Diagram correct				
Explanation correct				
System operating				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## REVERSING STARTERS UNIT XIII

### JOB SHEET #3 PRACTICAL TEST — WIRE A REVERSING STARTER WITH ONE CONTROL STATION USING PUSHBUTTON AND AUXILIARY CONTACT INTERLOCKING

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Completed diagram.  | _____ | _____ |
| 3. Completed explanation.  | _____ | _____ |
| 4. Wired system.   | _____ | _____ |
| 5. Checked in/put away tools and materials.                        | _____ | _____ |
| 6. Cleaned the work area.  | _____ | _____ |
| 7. Used proper tools correctly.                                    | _____ | _____ |
| 8. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 9. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 10. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Explanation correct				
System operating				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

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## REVERSING STARTERS UNIT XIII

### JOB SHEET #4 PRACTICAL TEST — WIRE A REVERSING STARTER WITH TWO CONTROL STATIONS

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Completed diagram.	_____	_____
3. Completed explanation.	_____	_____
4. Wired system.	_____	_____
5. Checked in/put away tools and materials.	_____	_____
6. Cleaned the work area.	_____	_____
7. Used proper tools correctly.	_____	_____
8. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
9. Practiced safety rules throughout procedure.	_____	_____
10. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Explanation correct				
System operating				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)



## REVERSING STARTERS UNIT XIII

### JOB SHEET #5 PRACTICAL TEST — WIRE A DRUM SWITCH

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES      NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Drew diagram.   | _____ | _____ |
| 3. Wired drum switch.  | _____ | _____ |
| 4. Checked in/put away tools and materials.                        | _____ | _____ |
| 5. Cleaned the work area.  | _____ | _____ |
| 6. Used proper tools correctly.                                    | _____ | _____ |
| 7. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 8. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 9. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #5 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Diagrams correct				
Switch reversed motor rotation				
Workmanship				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## REVERSING STARTERS UNIT XIII

### JOB SHEET #6 PRACTICAL TEST — WIRE A REVERSING STARTER WITH JOG IN BOTH DIRECTIONS

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Evaluated diagram.  | _____ | _____ |
| 3. Determined correct wiring procedures.                           | _____ | _____ |
| 4. Wired job.  | _____ | _____ |
| 5. Checked in/put away tools and materials.                        | _____ | _____ |
| 6. Cleaned the work area.  | _____ | _____ |
| 7. Used proper tools correctly.                                    | _____ | _____ |
| 8. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 9. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 10. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #6 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Workmanship				
Starter operated correctly				
Jog operated correctly				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# REVERSING STARTERS UNIT XIII

## TEST

NAME \_\_\_\_\_

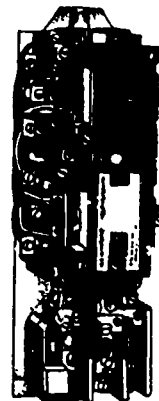
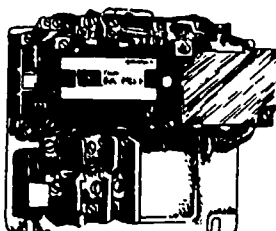
SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

- \_\_\_\_\_a. Means of locking out contactors through the use of mechanical devices such as cams or blocks
- \_\_\_\_\_b. A switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or surface of a rotating cylinder
- \_\_\_\_\_c. Means of interlocking reversing starters through the use of two-circuit push buttons with normally open and normally closed contacts
- \_\_\_\_\_d. Condition that occurs when both forward and reversing push buttons are operated simultaneously. Coils "race" to close
- \_\_\_\_\_e. Starter consisting of two identical contactors and one overload relay assembly; used in reversal of polyphase motors

1. Drum switch
2. Mechanical interlocking
3. Push button interlocking
4. Racing
5. Reversing starters

2. Identify two types of reversing starter constructions shown below.



a. \_\_\_\_\_

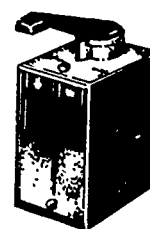
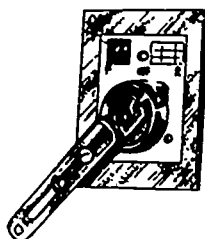
b. \_\_\_\_\_

# TEST

3. List three types of interlocking methods for reversing starters.

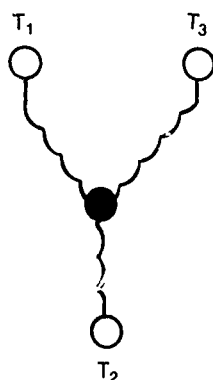
- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

4. Identify three types of drum switches shown below.



- a. \_\_\_\_\_ b. \_\_\_\_\_ c. \_\_\_\_\_

5. Complete the following drum switch diagram.



2

1

4

3

6

5

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

6. Describe the sequence of operation of ladder diagrams. (Assignment Sheet #1)
7. Determine the number of conductors needed to operate a reversing control. (Assignment Sheet #2)

**TEST**

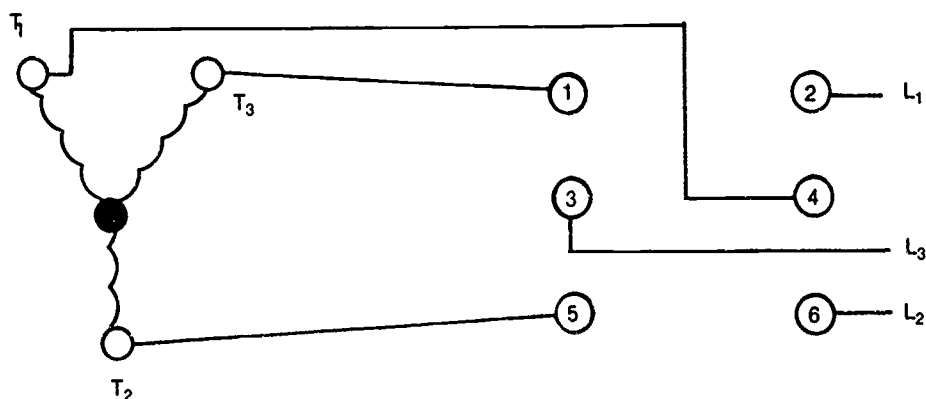
8. Demonstrate the ability to:
- a. Wire a reversing starter with a three-position selector switch. (Job Sheet #1)
  - b. Wire a reversing starter with one control station using auxiliary contact and mechanical interlock. (Job Sheet #2)
  - c. Wire a reversing starter with one control station using push button interlock and auxiliary contact interlock. (Job Sheet #3)
  - d. Wire a reversing starter with two control stations. (Job Sheet #4)
  - e. Wire a drum switch. (Job Sheet #5)
  - f. Wire a reversing starter with jog in both directions. (Job Sheet #6)

## REVERSING STARTERS UNIT XIII

### ANSWERS TO TEST

1.   a.   2                   d.   4  
     b.   1               e.   5  
     c.   3
  
2.   a.   Horizontal construction  
     b.   Vertical construction
  
3.   a.   Push button interlocking  
     b.   Auxiliary contact interlocking  
     c.   Mechanical interlocking
  
4.   a.   Flush mount knob operator  
     b.   Flush mount adjustable operator  
     c.   Surface mounting standard lever

5.



6-7. Evaluated to the satisfaction of the instructor

8. Performance skills evaluated to the satisfaction of the instructor



## **SPECIAL CONTROL CIRCUITS UNIT XIV**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to design and build special control circuits. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to special control circuits with their correct definitions.
2. Identify the parts of a control relay.
3. List two uses for control relays.
4. Identify the parts of a latching relay.
5. Describe the uses for latching relays.
6. List four types of timing relays.
7. Complete a list of applications for timing relays.
8. Describe how a ground fault indicator works.
9. Describe how an alarm silencing circuit is used.
10. Demonstrate the ability to:
  - a. Build a relay control circuit. (Job Sheet #1)
  - b. Wire a latching relay or contactor. (Job Sheet #2)

## OBJECTIVE SHEET

- c. Wire a timed *on* circuit. (Job Sheet #3)
- d. Wire a timed *off* circuit. (Job Sheet #4)
- e. Energize three starters in a timed sequential order. (Job Sheet #5)
- f. De-energize three starters in a timed sequential order. (Job Sheet #6)
- g. Build a ground fault indicator circuit. (Job Sheet #7)

## **SPECIAL CONTROL CIRCUITS UNIT XIV**

### **SUGGESTED ACTIVITIES**

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Make transparencies from the transparency masters included with this unit.
- C. Provide students with objective sheet.
- D. Discuss unit and specific objectives.
- E. Provide students with information sheet and handout.
- F. Discuss information sheet and handout.

(NOTE: Use the transparencies to enhance the information as needed.)

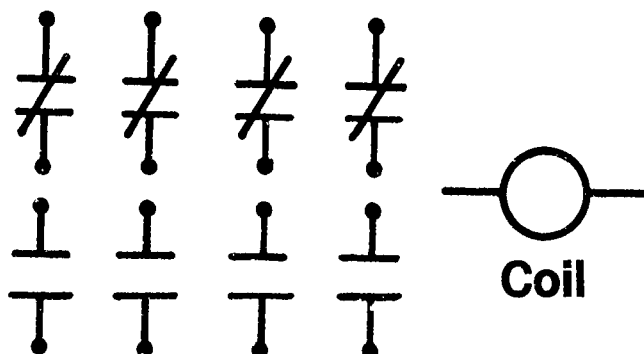
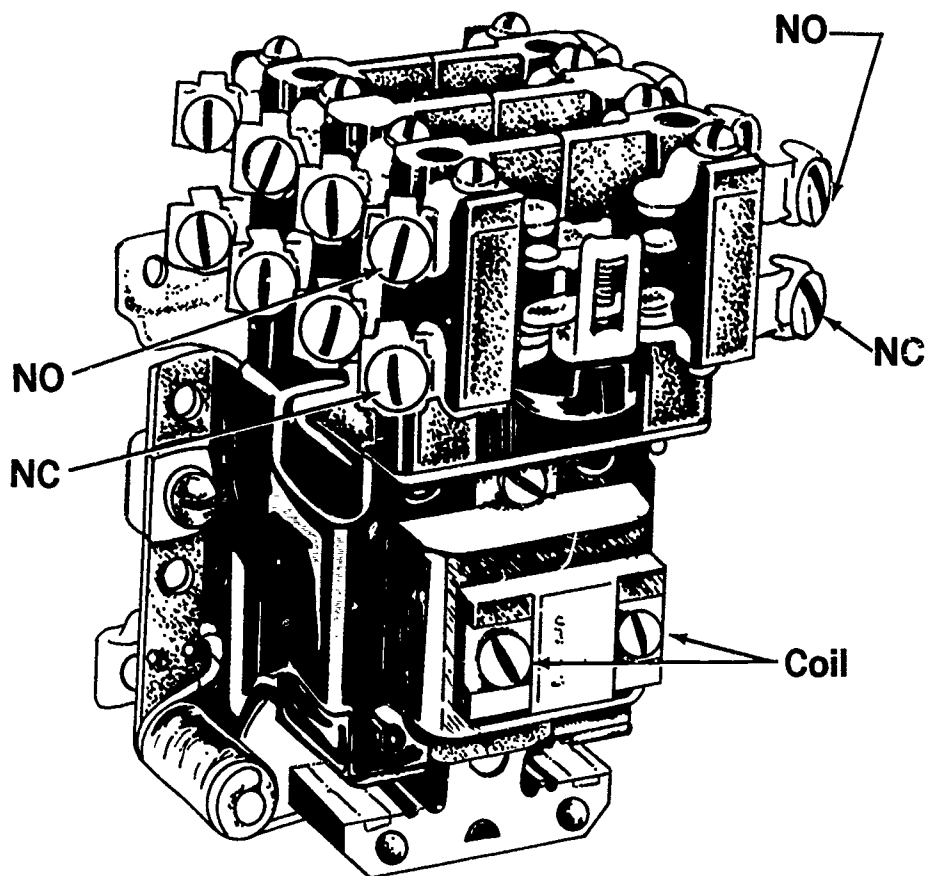
- G. Provide students with job sheets.
- H. Discuss and demonstrate the procedures outlined in the job sheets.
- I. Integrate the following activities throughout the teaching of this unit:
  - 1. Invite a maintenance electrician to speak to the class about special controls.
  - 2. Visit a local industry.
  - 3. Visit a supply house and view various relays.
  - 4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.
- J. Give test.
- K. Evaluate test.
- L. Reteach if necessary.

## REFERENCES USED IN WRITING THIS UNIT

- A. Alerich, Walter M. *Electric Motor Controls*. Third Edition. Albany, NY: Delmar Publishers, Inc., 1983.
- B. Rexford, Kenneth B. *Electrical Control for Machines*. Third Edition. Albany, NY: Delmar Publishers, 1987.

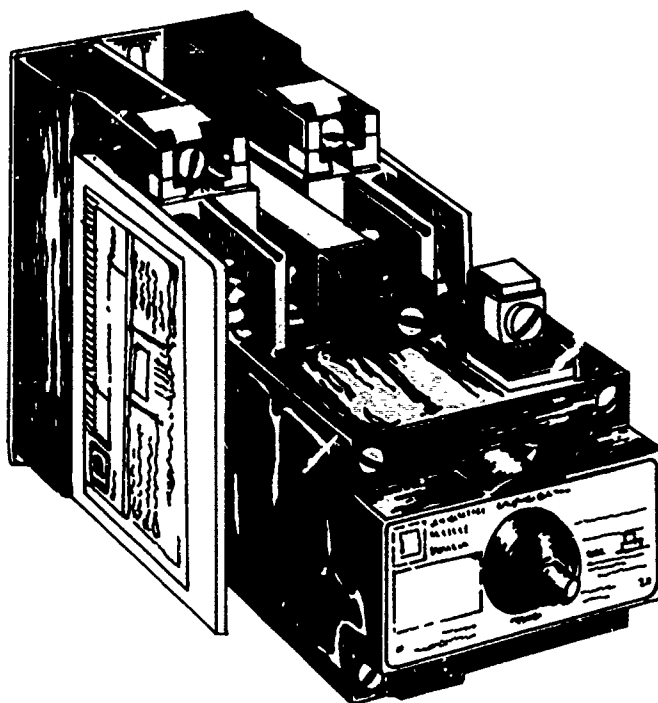
584

# Typical Control Relay

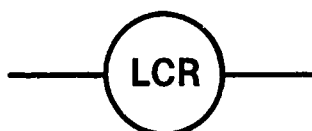


Courtesy of Square D Company.

# Latching Relay



Latch Coil



Normally Open Contact



Unlatch Coil



Normally Closed Contact

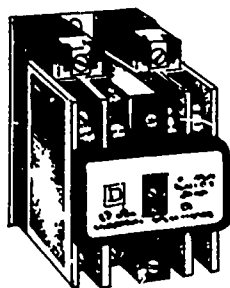


Courtesy of Square D Company.

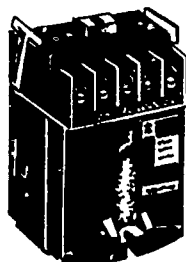
## SPECIAL CONTROL CIRCUITS UNIT XIV

### HANDOUT #1 — TYPES OF CONTROL RELAYS

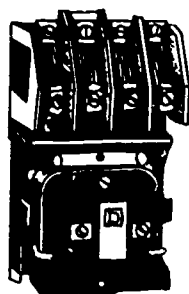
#### Industrial Control Relays



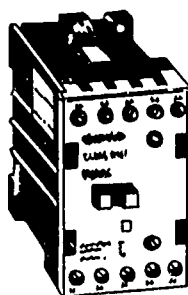
Type X



Type G

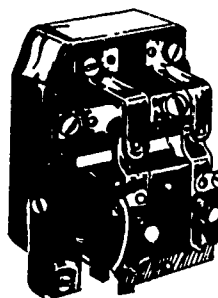


Type H

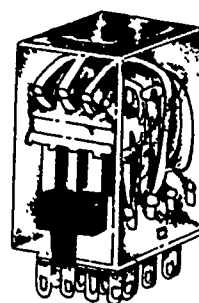


Type PH

#### General Purpose Control Relays



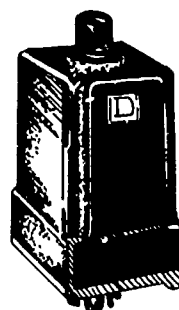
Type C



Type R

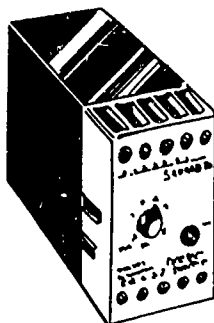


Type K



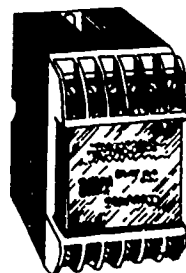
Type JCK

## Specialty Relays

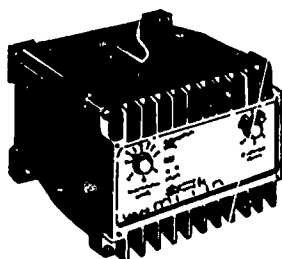


Type DSC/DCS  
Speed Control Relay

## Intrinsically Safe Relay



Barrier Relay



Type UBS  
Undervoltage  
Control Relay

Courtesy of Square D Company.



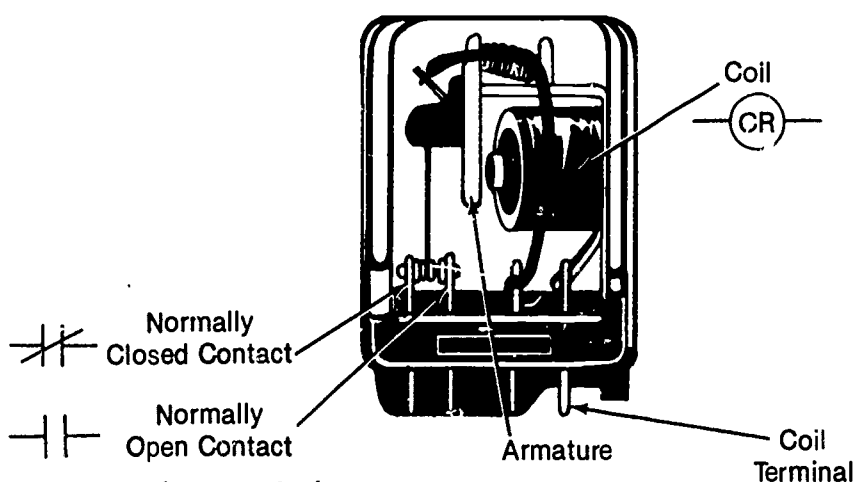
## SPECIAL CONTROL CIRCUITS UNIT XIV

### INFORMATION SHEET

#### I. Terms and definitions

- A. Accelerating contactors — Contactors or relays used in starting motors at low speed then increasing to maximum speed in preset timed steps
- B. Motor driven timing relay — Relay who's timed contacts are operated through the action of a variable speed, extremely small motor
- C. Pneumatic timing relay — Relay who's timed contacts are operated through the action of an air bellows and needle valve
- D. Solid state timing relay — Relay who's timed contacts are operated by an electronic timer (microchip)

#### II. Parts of a control relay

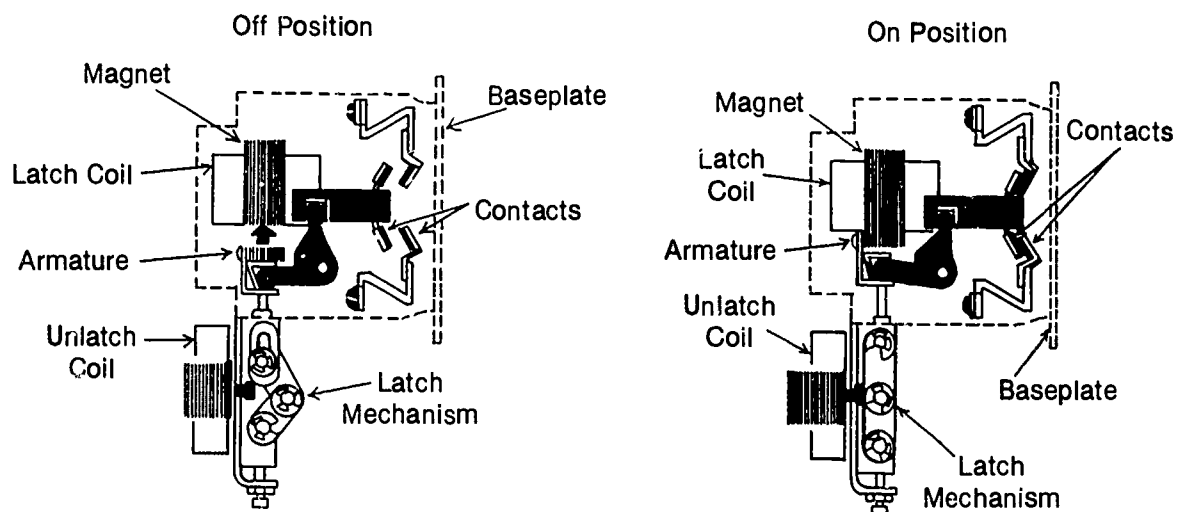


#### III. Uses for control relays

- A. Control of fluid or pneumatic power valves
- B. Control of multiple circuits

## INFORMATION SHEET

### IV. Parts of a latching relay or contactor

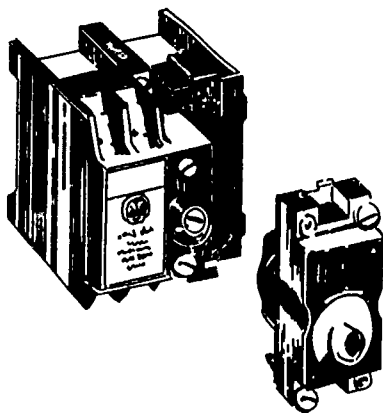


- V. **Uses for latching relays or contactors** — To maintain contacts in their operated condition during power off periods

(NOTE: Some applications are lighting contactors or control circuits that must remain on until a specific event occurs.)

### VI. Types of timing relays

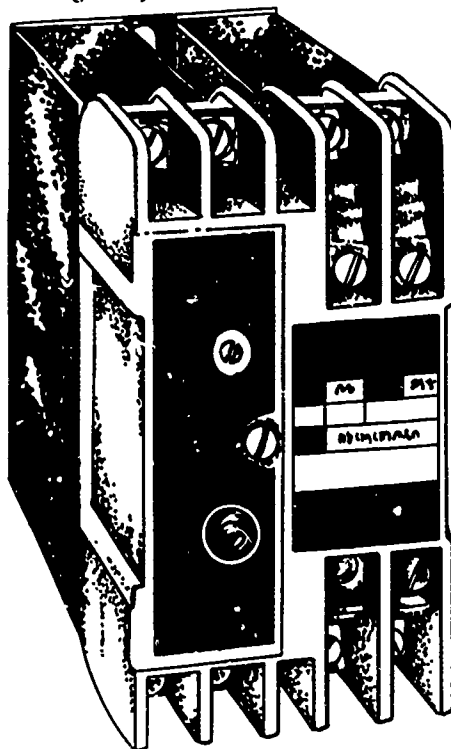
- A. Pneumatic timing relay



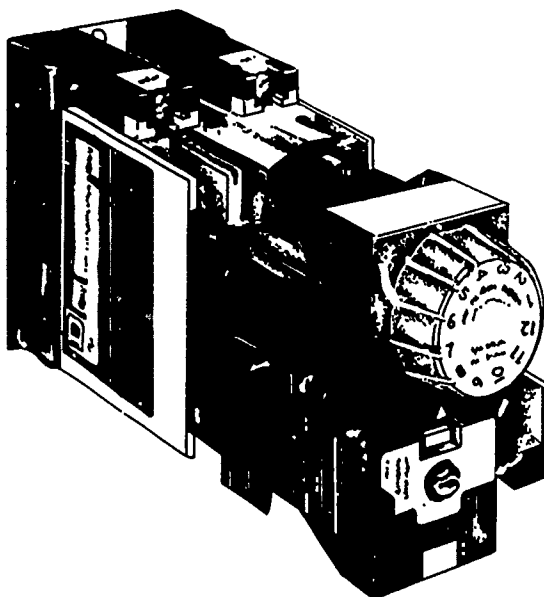
590

## INFORMATION SHEET

## B. Solid state timing relay

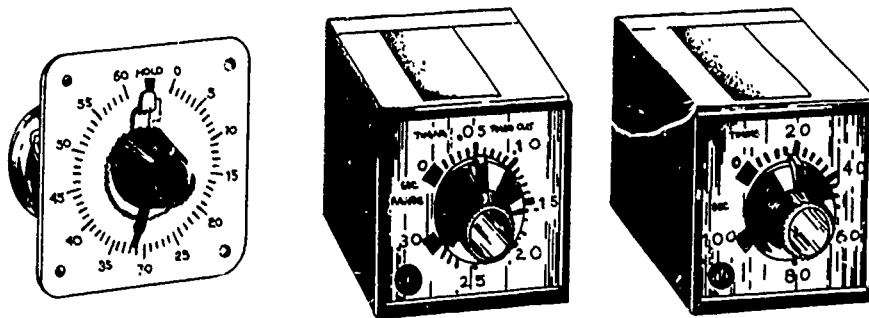


## C. Motor driven timing relay



## INFORMATION SHEET

## D. Timers



(NOTE: Timers require a manual operation of the timer to start operation. It will run the selected time then stop automatically.)

## VII. Applications for timing relays

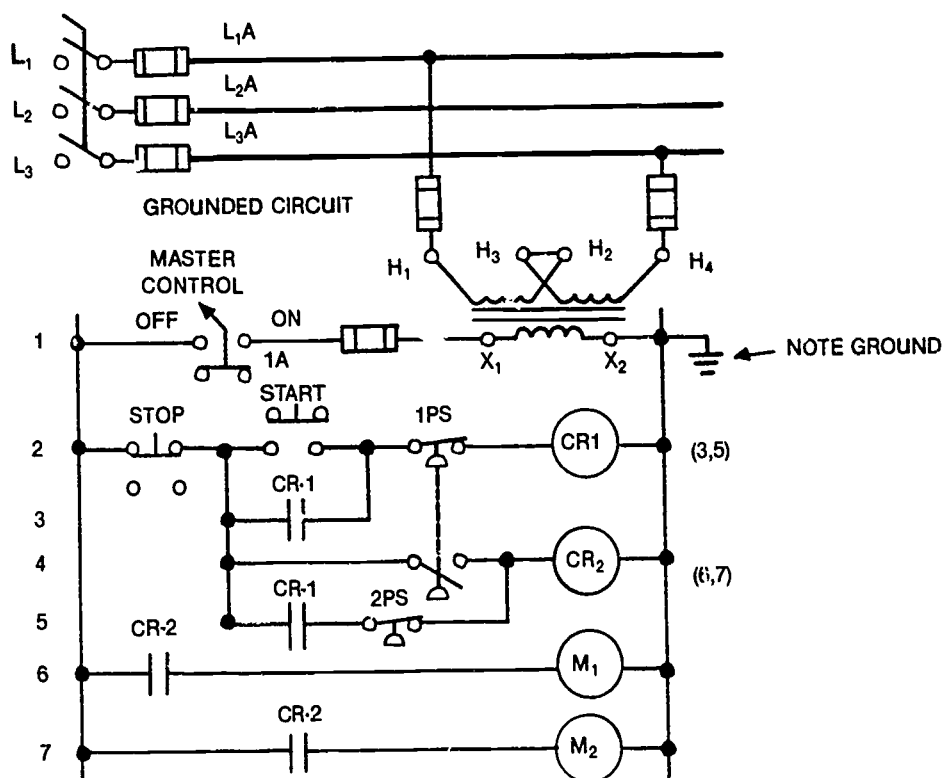
- A. To control the accelerating contactors of motor starters
- B. To control a timed sequential start-up of industrial machinery
- C. To sequence large loads on for energy management systems

## INFORMATION SHEET

### VIII. Ground fault indicator circuits

- A. If a ground fault occurs in the control circuit the fuse will blow disabling the machine.

#### CONVENTIONALLY WIRED CONTROL CIRCUIT

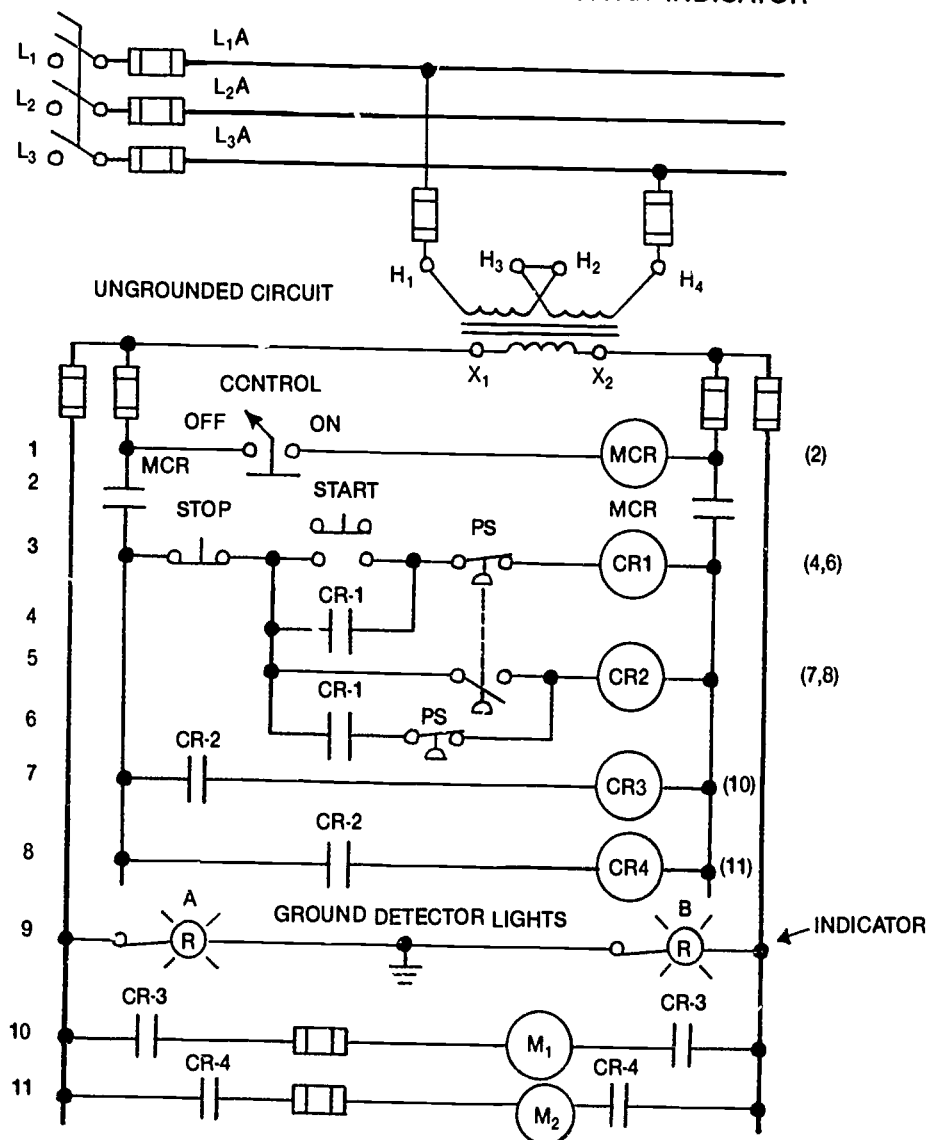


# INFORMATION SHEET

- B. When the system has *no* grounds both lights will glow at half brilliance since they are connected in series. If a ground occurs the light on the side without the ground will glow at full brilliance. The ground will be on the side with the non-functioning light. In most cases a ground can occur and the system will continue to operate.

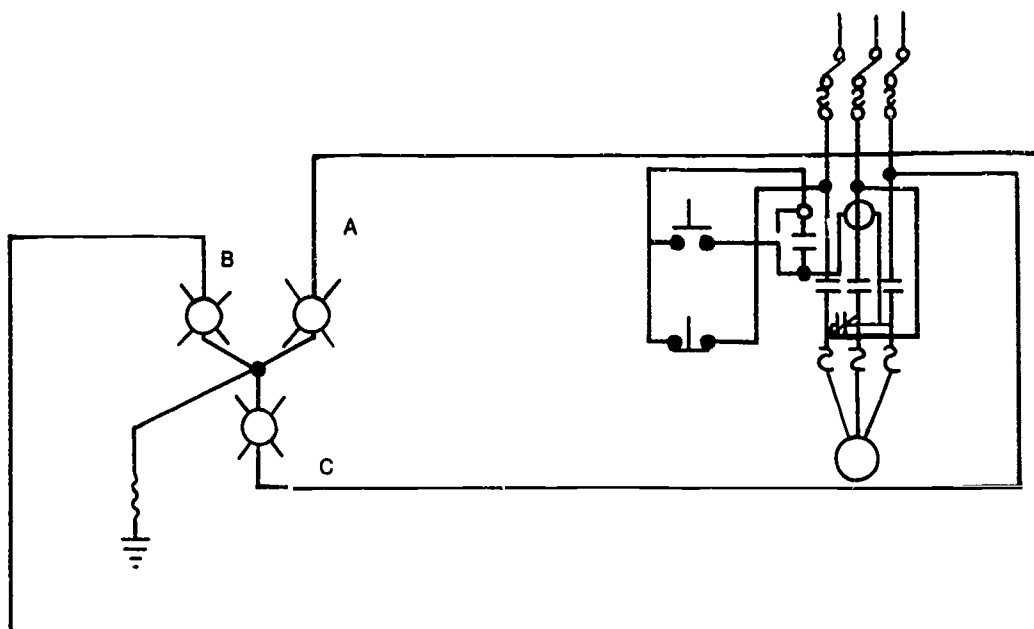
(NOTE: This system is generally used on 208 or 480 volt "Y" systems. With the lamps connected in a "Y" configuration.)

## CONTROL CIRCUIT WITH GROUND FAULT INDICATOR

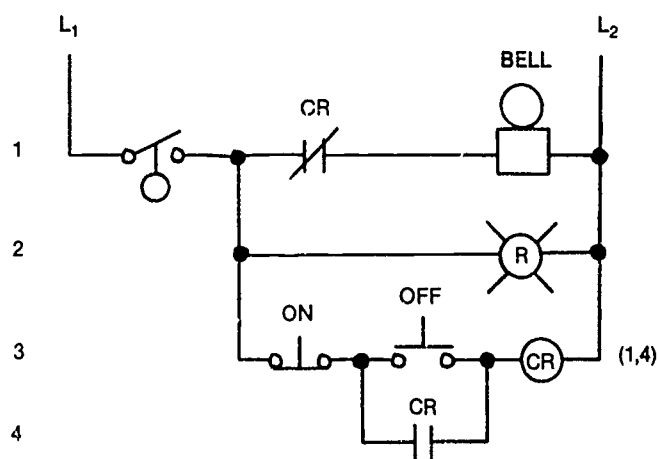


## INFORMATION SHEET

- C. If phase A, B, or C grounds out, obviously a fuse should blow; in any case the difference of potential will effectively be eliminated and the lamp connected to the grounded phase will cease to operate.



- IX. **How an alarm silencing circuit is used** — Alarms are commonly used in industry to warn operatives or other personnel of hazardous or dangerous conditions. Normally the alarm will consist of an audible signal such as a horn or bell, and a visual signal such as a warning light. In this case when an alarm condition occurs the audible and visual alarms will activate and the maintenance personnel will silence the audible signal, but the visual signal will remain until the condition has been corrected.



## **SPECIAL CONTROL CIRCUITS UNIT XIV**

### **JOB SHEET #1 — BUILD A RELAY CONTROL CIRCUIT**

#### **A. Equipment and materials needed**

1. Pouch tools
2. Four 120 volt pilot lights
3. Four 4-pole relays with 120 volt coils (N/O)
4. N/C push button
5. Four N/O push buttons
6. 20' #16 THWN

#### **B. Procedure**

1. Design a control system to solve the following scenario problem:

A contest for industrial electricity students has been organized to test the students over National Electrical Code knowledge. Four students will participate. They will be seated at desks containing a push button station. A question will be asked by the facilitator. The first contestant with the answer will press his push button. This action will energize a pilot light in front of his desk. It will also lock out the other three contestants lights. The facilitator upon receiving a correct response to his question may then reset the system by pressing a push button. You have been asked to design and build the control system.



**JOB SHEET #1**

2. Draw a ladder diagram of your control system in the space provided below. (Be sure to reference your diagram.)

3. In complete sentences explain in detail how your system operates.

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4. Have your instructor approve your diagram and explanation.
5. Build a prototype of the system on a work bench.
6. Have your instructor evaluate your job.
7. Disassemble, clean work area, and store all equipment and materials.

## SPECIAL CONTROL CIRCUITS UNIT XIV

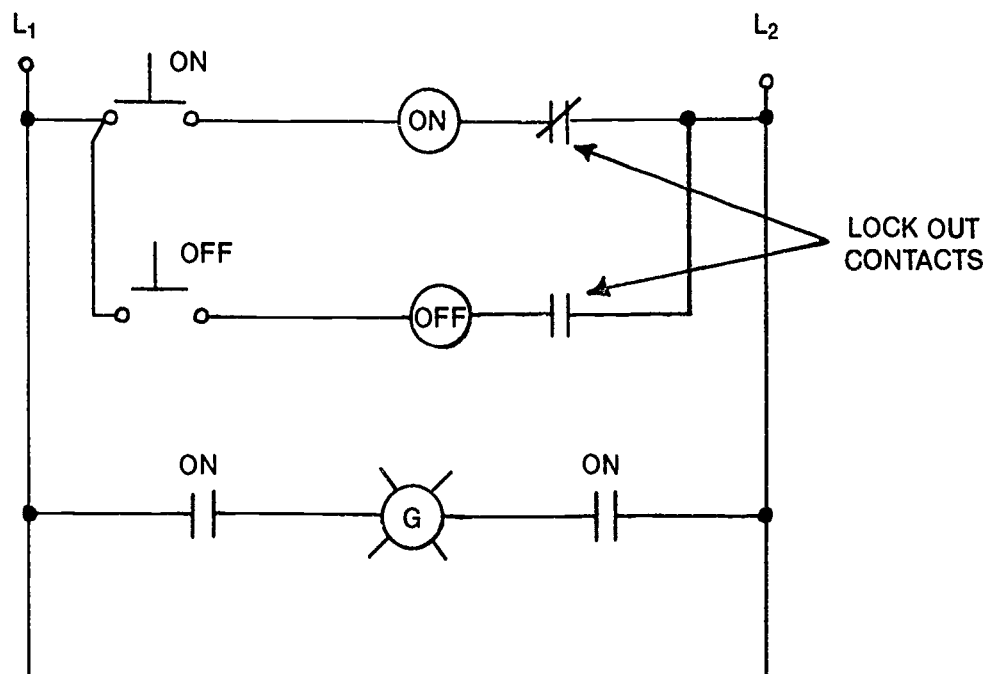
### JOB SHEET #2 — WIRE A LATCHING RELAY OR CONTACTOR

#### A. Equipment and materials needed

1. Pouch tools
2. 4-pole latching relay (2 N/O - 2 N/C) (120v coils)
3. Two N/O push buttons and enclosures
4. Pilot light (120 volt) and enclosures
5. 10' #14 THHN
6. Six #10 × 1" sheet metal screws
7. Mounting board

#### B. Procedure

1. Using the following diagram, wire a latching relay to operate a lighting load.



**JOB SHEET #2**

2. Have your instructor evaluate your job.
3. Disassemble, clean work area, and store all equipment and materials.

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## SPECIAL CONTROL CIRCUITS UNIT XIV

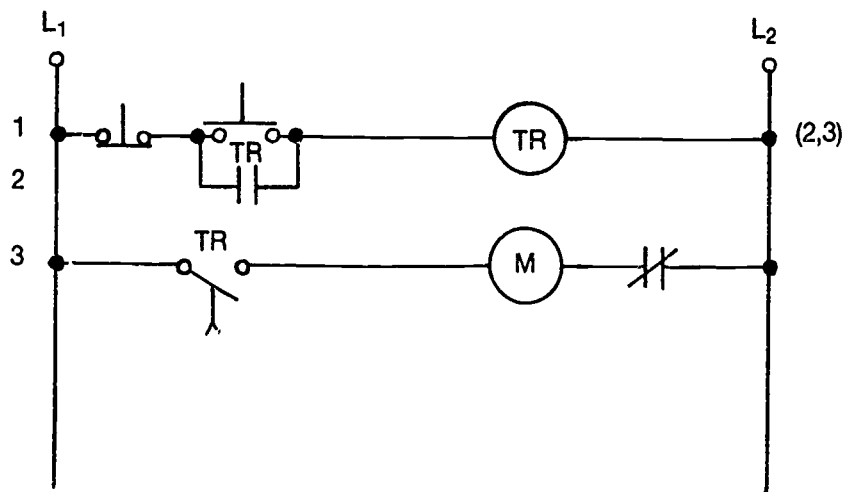
### JOB SHEET #3 — WIRE A TIMED ON CIRCUIT

#### A. Equipment and materials needed

1. Pouch tools
2. Time delay relay with timed closed contacts (120v coil)
3. Three-phase motor starter (120 volt coil)
4. Start/stop station
5. Eight #10 x 1" sheet metal screws
6. Mounting board
7. 15' #16 THHN

#### B. Procedure

1. Using the following diagram build an on delay circuit.



**JOB SHEET #3**

2. In complete sentences explain the sequence of operation of the circuit.

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3. Have your instructor approve your explanation.
4. Build the circuit.
5. Have your instructor evaluate your job.
6. Disassemble, clean work area, and store all equipment and materials.

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## SPECIAL CONTROL CIRCUITS UNIT XIV

### JOB SHEET #4 — WIRE A TIMED OFF CIRCUIT

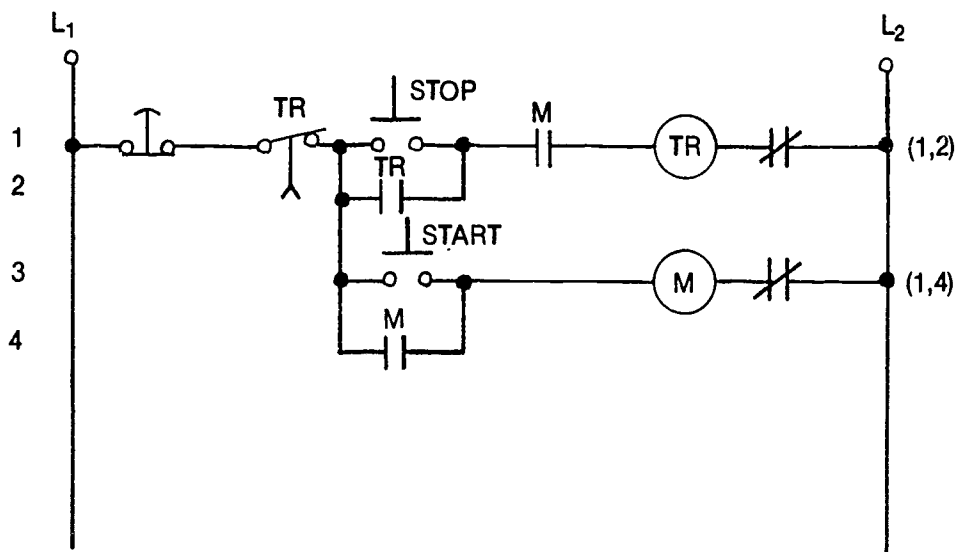
#### A. Equipment and materials needed

1. Pouch tools
2. Time delay relay with timed open contacts (12v coil)
3. Three-phase motor starter
4. Two N/O push buttons with enclosure
5. N/C push button with mushroom head and enclosure
6. Ten #10 x 1" sheet metal screws
7. Mounting board
8. 15' #16 THHN

#### B. Procedure

1. Using the following diagram build an **off** delay circuit.

(NOTE: Any time an off delay is used, an emergency shut down button must be installed.)



**JOB SHEET #4**

2. In complete sentences explain the sequence of operation of the circuit.

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3. Have your instructor approve your explanation.
4. Build the circuit.
5. Have your instructor evaluate your job.
6. Disassemble, clean work area, and store all equipment and materials.

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## **SPECIAL CONTROL CIRCUITS UNIT XIV**

### **JOB SHEET #5 — ENERGIZE THREE STARTERS IN A TIMED SEQUENTIAL ORDER**

**A. Equipment and materials needed**

1. Pouch tools
2. Two time delay relays (NOTC) 120v coil
3. Three 3 $\phi$  starters, 120v coils
4. N/O push button
5. N/C push button
6. 3-element control station
7. Mounting board
8. Twenty #10 x 1" sheet metal screws
9. 20' #16 THHN

**B. Procedure**

1. Design and build a circuit to act as follows:
  - a. Depress start
    - 1) Starter 1 energizes instantly
    - 2) 10 second delay then starter 2 energizes
    - 3) 10 second delay then starter 3 energizes
  - b. Depress stop — All systems de-energize



**JOB SHEET #5**

2. In complete sentences, write a detailed explanation of how your system operates.

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3. Have your instructor evaluate steps 1 and 2.
4. Build the circuit.
5. Have your instructor evaluate your job.
6. Proceed to Job Sheet #6.

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## **SPECIAL CONTROL CIRCUITS UNIT XIV**

### **JOB SHEET #6 — DE-ENERGIZE THREE STARTERS IN A TIMED SEQUENTIAL ORDER**

**A. Equipment and materials needed**

1. Pouch tools
2. Circuit from Job Sheet #5
3. N/O push button
4. Three time delay relays (NCTO) 120v coils
5. Six #10 x 1" sheet metal screws
6. 10' #16 THHN

**B. Procedure**

1. Revise the diagram from Job Sheet #5 to act as follows:
  - a. Depress start
    - 1) Starter 1 energizes instantly
    - 2) 10 second delay then starter 2 energizes
    - 3) 10 second delay then starter 3 energizes
  - b. Depress stop
    - 1) Starter 3 de-energizes instantly
    - 2) 10 second delay then starter 2 de-energizes
    - 3) 10 second delay then starter 1 de-energizes
  - c. Depress emergency stop — All systems de-energize

**JOB SHEET #6**

2. In complete sentences, explain in detail how your system operates.

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3. Have your instructor evaluate steps 1 and 2.
4. Build the circuit.
5. Have your instructor evaluate your job.
6. Disassemble, clean work area, and store all equipment and materials.

## **SPECIAL CONTROL CIRCUITS UNIT XIV**

### **JOB SHEET #7 — BUILD A GROUND FAULT INDICATOR CIRCUIT**

#### **A. Equipment and materials needed**

1. Pouch tools
2. Control transformer 240/120
3. Three-phase starter
4. Start/stop station
5. Two 120 volt pilot lights and 2-element enclosure
6. Eight #10 x 1" sheet metal screws
7. 15' #16 TFF
8. Mounting board
9. 240 volt power source
10. Two fuse holders
11. Two 6/10 amp fuses

#### **B. Procedure**

1. Design and build a three-wire control system to operate a 3 $\phi$  starter. The control circuit should be equipped with a ground fault indicator.

**JOB SHEET #7**

2. Have your instructor approve your diagram.
3. Build the circuit.
4. Have your instructor evaluate your job.
5. Disassemble, clean work area, and store all equipment and materials.

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## SPECIAL CONTROL CIRCUITS UNIT XIV

### JOB SHEET #1 PRACTICAL TEST — BUILD A RELAY CONTROL CIRCUIT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Read and interpreted scenario.                                  | _____ | _____ |
| 3. Drew ladder diagram.  | _____ | _____ |
| 4. Completed detailed explanation.                                 | _____ | _____ |
| 5. Built prototype.  | _____ | _____ |
| 6. Checked in/put away tools and materials.                        | _____ | _____ |
| 7. Cleaned the work area.  | _____ | _____ |
| 8. Used proper tools correctly.                                    | _____ | _____ |
| 9. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 10. Practiced safety rules throughout procedure.                   | _____ | _____ |
| 11. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Explanation correct				
Workmanship				
System operates				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4	— Skilled — Can perform job with no additional training.
3	— Moderately skilled — Has performed job during training program; limited additional training may be required.
2	— Limited skill — Has performed job during training program; additional training is required to develop skill.
1	— Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SPECIAL CONTROL CIRCUITS UNIT XIV

### JOB SHEET #2 PRACTICAL TEST — WIRE A LATCHING RELAY OR CONTACTOR

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Mounted equipment.	_____	_____
3. Wired circuit.	_____	_____
4. Tested circuit.	_____	_____
5. Checked in/put away tools and materials.	_____	_____
6. Cleaned the work area.	_____	_____
7. Used proper tools correctly.	_____	_____
8. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
9. Practiced safety rules throughout procedure.	_____	_____
10. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_



## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Workmanship				
Circuit operates correctly				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SPECIAL CONTROL CIRCUITS UNIT XIV

### JOB SHEET #3 PRACTICAL TEST — WIRE A TIMED ON CIRCUIT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES      NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Read and interpreted diagram.                                   | _____ | _____ |
| 3. Completed explanation.  | _____ | _____ |
| 4. Built system.   | _____ | _____ |
| 5. Checked in/put away tools and materials.                        | _____ | _____ |
| 6. Cleaned the work area.  | _____ | _____ |
| 7. Used proper tools correctly.                                    | _____ | _____ |
| 8. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 9. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 10. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Explanation correct	4	3	2	1
Workmanship	4	3	2	1
System operates	4	3	2	1
Compliance to NEC	4	3	2	1

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SPECIAL CONTROL CIRCUITS UNIT XIV

### JOB SHEET #4 PRACTICAL TEST — WIRE A TIMED OFF CIRCUIT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Read and interpreted diagram.                                   | _____ | _____ |
| 3. Completed explanation.  | _____ | _____ |
| 4. Built system.   | _____ | _____ |
| 5. Checked in/put away tools and materials.                        | _____ | _____ |
| 6. Cleaned the work area.  | _____ | _____ |
| 7. Used proper tools correctly.                                    | _____ | _____ |
| 8. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 9. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 10. Provided satisfactory responses to questions asked.            | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Explanation correct				
Workmanship				
Circuit operates correctly				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SPECIAL CONTROL CIRCUITS UNIT XIV

### JOB SHEET #5 PRACTICAL TEST — ENERGIZE THREE STARTERS IN A TIMED SEQUENTIAL ORDER

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. . \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES      NO

- |  |       |       |
|--|-------|-------|
| 1. Checked out proper tools and materials.                         | _____ | _____ |
| 2. Drew ladder diagram.  | _____ | _____ |
| 3. Completed explanation.  | _____ | _____ |
| 4. Built circuit.  | _____ | _____ |
| 5. Performed steps in a timely manner (____hrs. ____min. ____sec.) | _____ | _____ |
| 6. Practiced safety rules throughout procedure.                    | _____ | _____ |
| 7. Provided satisfactory responses to questions asked.             | _____ | _____ |

EVALUATOR'S COMMENTS: \_\_\_\_\_

## JOB SHEET #5 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Explanation correct				
Workmanship				
System operates				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SPECIAL CONTROL CIRCUITS UNIT XIV

### JOB SHEET #6 PRACTICAL TEST — DE-ENERGIZE THREE STARTERS IN A TIMED SEQUENTIAL ORDER

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Revised diagram.	_____	_____
3. Completed explanation.	_____	_____
4. Built circuit.	_____	_____
5. Checked in/put away tools and materials.	_____	_____
6. Cleaned the work area.	_____	_____
7. Used proper tools correctly.	_____	_____
8. Performed steps in a timely manner (____hrs. ____min. ____sec.)	_____	_____
9. Practiced safety rules throughout procedure.	_____	_____
10. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_



## JOB SHEET #6 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Explanation correct				
Workmanship				
Circuit operates properly				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

PERFORMANCE EVALUATION KEY	
4 —	Skilled — Can perform job with no additional training.
3 —	Moderately skilled — Has performed job during training program; limited additional training may be required.
2 —	Limited skill — Has performed job during training program; additional training is required to develop skill.
1 —	Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## SPECIAL CONTROL CIRCUITS UNIT XIV

### JOB SHEET #7 PRACTICAL TEST — BUILD A GROUND FAULT INDICATOR CIRCUIT

STUDENT'S NAME \_\_\_\_\_

DATE \_\_\_\_\_

EVALUATOR'S NAME \_\_\_\_\_

ATTEMPT NO. \_\_\_\_\_

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

1. Checked out proper tools and materials.
2. Drew ladder diagram.
3. Built circuit.
4. Checked in/put away tools and materials.
5. Cleaned the work area.
6. Used proper tools correctly.
7. Performed steps in a timely manner (\_\_\_\_hrs. \_\_\_\_min. \_\_\_\_sec.)
8. Practiced safety rules throughout procedure.
9. Provided satisfactory responses to questions asked.

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #7 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ladder diagram correct				
Workmanship				
Circuit operates properly				
Compliance to NEC				

EVALUATOR'S COMMENTS: \_\_\_\_\_

\_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# SPECIAL CONTROL CIRCUITS UNIT XIV

## TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

\_\_\_\_\_a. Relay whose timed contacts are operated through the action of a variable speed, extremely small motor

\_\_\_\_\_b. Contactors or relays used in starting motors at low speed then increasing to maximum speed in preset timed steps

\_\_\_\_\_c. Relay whose timed contacts are operated by an electronic timer (microchip)

\_\_\_\_\_d. Relay whose timed contacts are operated through the action of an air bellows and needle valve

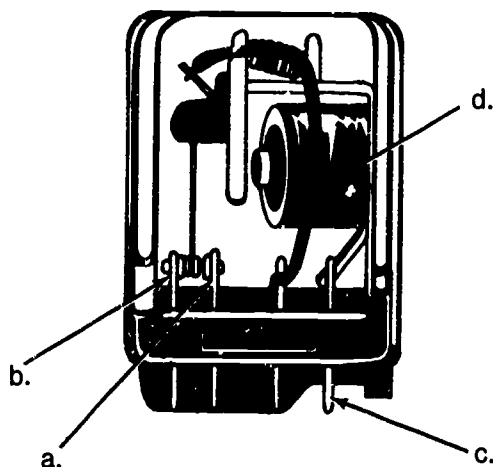
1. Accelerating contactors

2. Motor driven timing relay

3. Pneumatic timing relay

4. Solid state timing relay

2. Identify the parts of the control relay shown below.



a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

d. \_\_\_\_\_

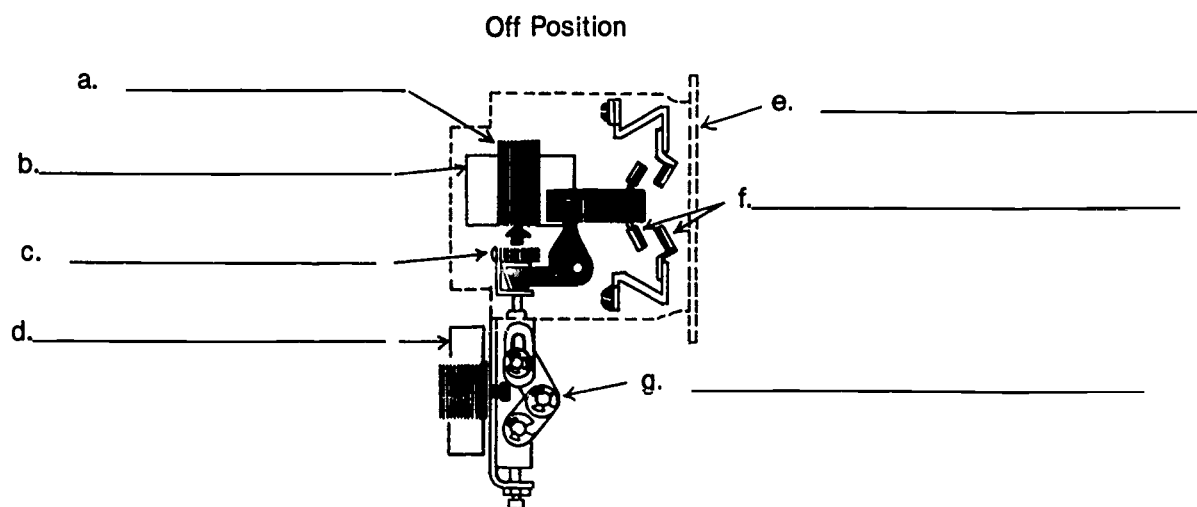
## TEST

3. List two uses for control relays.

a. \_\_\_\_\_

b. \_\_\_\_\_

4. Identify the parts of the latching relay shown below.



5. Describe the uses for latching relays.

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6. List four types of timing relays.

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

d. \_\_\_\_\_

**TEST**

7. Complete the following list of applications for timing relays by inserting the word which best completes each application.
- a. To control the \_\_\_\_\_ contactors of motor starters
  - b. To control a timed \_\_\_\_\_ of industrial machinery
  - c. To sequence large loads on, for \_\_\_\_\_ systems
8. Describe how a ground fault indicator works.

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9. Describe how an alarm silencing circuit is used.

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(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

10. Demonstrate the ability to:
- a. Build a relay control circuit. (Job Sheet #1)
  - b. Wire a latching relay or contactor. (Job Sheet #2)
  - c. Wire a timed *on* circuit. (Job Sheet #3)
  - d. Wire a timed *off* circuit. (Job Sheet #4)
  - e. Energize three starters in a timed sequential order. (Job Sheet #5)
  - f. De-energize three starters in a timed sequential order. (Job Sheet #6)
  - g. Build a ground fault indicator circuit. (Job Sheet #7)

## SPECIAL CONTROL CIRCUITS UNIT XIV

### ANSWERS TO TEST

1.   a.    2           c.    4  
     b.    1           d.    3
2.   a.    Normally open contacts  
     b.    Normally closed contacts  
     c.    Coil terminals  
     d.    Relay coil
3.   a.    Control of fluid or pneumatic power valves  
     b.    Control of multiple circuits
4.   a.    Magnet  
     b.    Latch coil  
     c.    Armature  
     d.    Unlatch coil  
     e.    Baseplate  
     f.    Contacts  
     g.    Latch mechanism
5.   To maintain contacts in their operated position during power off periods
6.   a.    Pneumatic timing relay  
     b.    Solid state timing relay  
     c.    Motor driven timing relay  
     d.    Timers
7.   a.    Accelerating  
     b.    Sequential start-up  
     c.    Energy management
8.   When system has no grounds both lights will glow at half brilliance. If a ground occurs, the light on the side without the ground will glow at full brilliance
9.   To warn operators or other personnel of dangerous conditions. In an alarm condition an audible and visual signal are activated. The audible signal may be silenced, but the visual signal will remain on until the condition is cleared
10.   Performance skills evaluated to the satisfaction of the instructor

## **PROGRAMMABLE CONTROLS UNIT XV**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to discuss programmable controllers as well as distinguish between common input/output devices. Competencies will be demonstrated by completing the assignment sheets and the unit test with a minimum score of 85 percent.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to programmable controllers with their correct definitions.
2. Select from a list programmable controller functions.
3. List the three stages necessary to control a process.
4. Identify input devices.
5. Identify output devices.
6. Identify components of a programmable controller.
7. Complete statements concerning states of contacts.
8. Name three types of I/O modules.
9. Identify the parts of an optical coupler.
10. Identify the basic PC ladder logic symbols.
11. Explain why a stop button is wired normally closed.



**OBJECTIVE SHEET**

12. List the basic numbering systems used in programmable controls.
13. Match I/O devices with their functions. (Assignment Sheet #1)
14. Convert between numbering systems. (Assignment Sheet #2)

## PROGRAMMABLE CONTROLS UNIT XV

### SUGGESTED ACTIVITIES

- A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

- B. Make transparency from the transparency masters included with this unit.
- C. Provide students with objective sheet.
- D. Discuss unit and specific objectives.
- E. Provide students with information and assignment sheets.
- F. Discuss information and assignment sheets.

(NOTE: Use the transparency to enhance the information as needed.)

- G. Integrate the following activities throughout the teaching of this unit:

1. Visit an industry that uses programmable controls.
2. Have PC sale engineers demonstrate their product line.
3. Show examples of input and output devices to class.
4. Provide students with catalogs describing various types of programmable controls and their specific features.

EXAMPLES: Telemecanique, Cutler-Hammer, Square D

5. Provide students with glossary of terms related to programmable controls.
6. Explain the different numbering systems and how they may apply to programmable controls.
7. Design lessons specific to the PC used at your facility. Due to the varied brands and types of programmable controls used in the different training facilities, it is impossible to include any job sheets in this unit. It is suggested that each instructor develop a series of job sheets designed to instruct the student in the step by step use of the PC manuals. Job sheets should begin with extremely simple programs and progress to scenario type jobs including all the previous steps.
8. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas of improvement.

## SUGGESTED ACTIVITIES

- H. Give test.
- I. Evaluate test.
- J. Reteach if necessary.

## REFERENCES USED IN WRITING THIS UNIT

- A. Rexford, Kenneth B. *Electrical Control For Machines*. Third Edition. Albany, NY: Delmar Publisher. 1987.
- B. Tel-A-Train Workbook for PC's. Chattanooga, TN: Tel-A-Train, Inc.

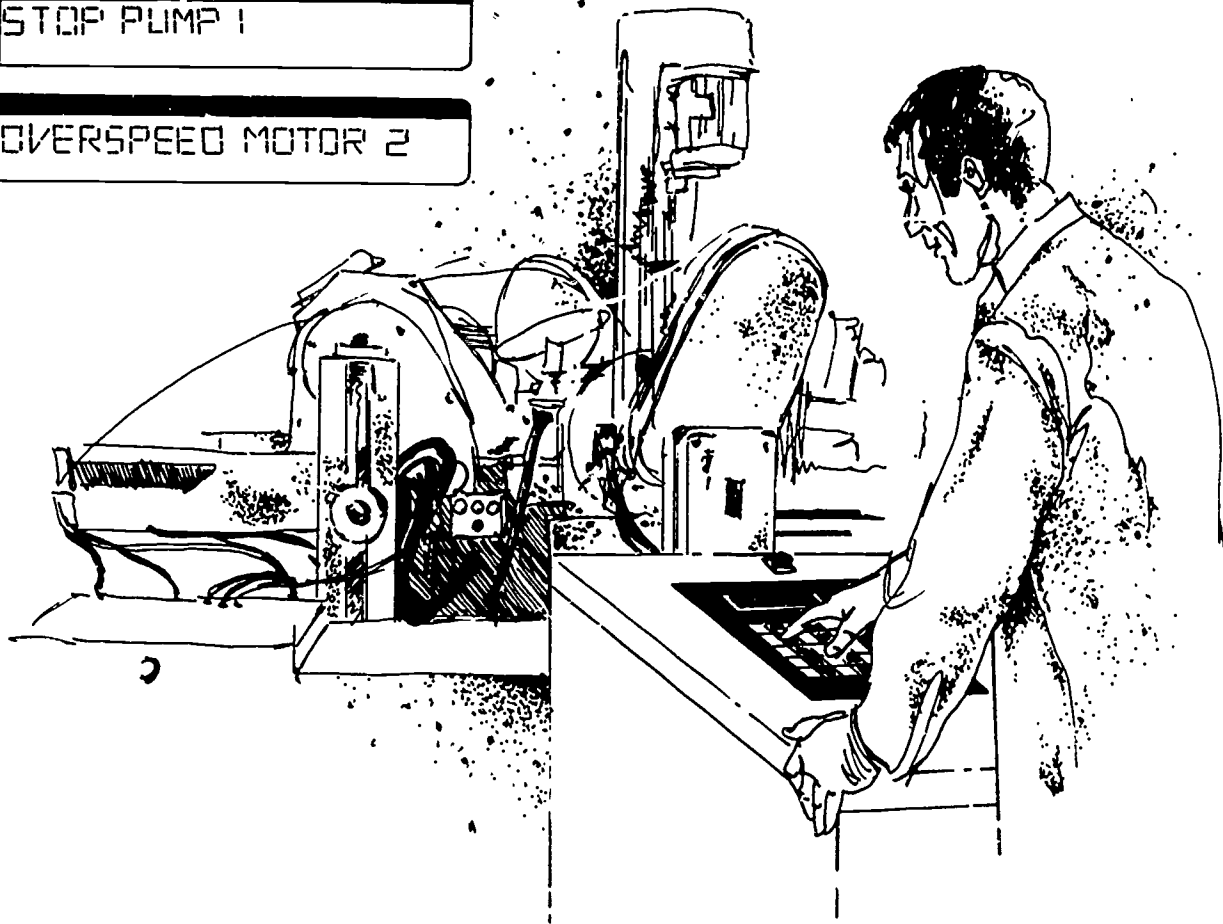
## SUGGESTED SUPPLEMENTAL MATERIAL

Film — *Programmable Controllers*. Seven-part series. Tel-A-Train, Inc., Chattanooga, TN.

# Application of Programmable Controls

STOP PUMP 1

OVERSPEED MOTOR 2



Courtesy of Telemechanique.

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633

# PROGRAMMABLE CONTROLS UNIT XV

## HANDOUT #1 — GLOSSARY

(NOTE: The following glossary has been reprinted with permission of Tel-A-Train, Inc., Chattanooga, Tennessee.)

### A

**Abort:** a signal to terminate the current process.

**Active Light:** (see Status Light)

**Address:** a coded value used to identify a specific I/O Channel or Module, or the location of a Register in Memory.

**Alphanumeric:** series of characters, usually code, which contain a combination of letters, numerals, and/or special characters. e.g. B678\$.

**Analog Signal:** a signal which varies proportionally with some aspect of the environment, e.g., the signal from a pressure transducer which varies with the amount of pressure being applied.

**Analog I/O Module:** an I/O Module which performs Analog-to-Digital (Input) or Digital-to-Analog (Output) conversions so that the Controller can communicate with Analog Field Devices.

**And Circuit:** a Series Circuit which allows power flow in the Logic only when all the conditions have been met.

**ANSI:** American National Standards Institute.

**Application Program:** (see User Program)

**Arithmetic Function:** a function which compares the contents of two or more registers arithmetically (addition, subtraction, multiplication, division, etc.) and may take action as a result.

**ASCII:** standard alphanumeric characters established by the American Standards Institute.

### B

**Baud:** the number of bits transmitted every second.

**BCED (Binary-Coded Decimal):** a system which uses four Binary Digits to represent each Decimal Digit (0-9) in a Decimal Number.

**Binary:** a numeric base 2 system which values represented only by the numbers 0 and 1 (OFF/ON).

**Bit:** contraction for Binary Digit. A single digit whose value can be either 0 or 1. The smallest division of a PC word.

**Bugs:** software errors which cause unwanted behavior, or functional problems due to faulty hardware.

**Bus:** an electronic channel used to send or receive data.

**Byte:** a string of Binary Digits operated on as a unit. unless otherwise specified, a byte normally contains eight bits.

### C

**Cascading Functions:** connecting two or more Functions together to Control one Output. timers and Counters can be Cascaded together to produce results which cannot be achieved using one Counter or one Timer.

## HANDOUT #1

**Channel:** a group of I/O Modules that are separately connected to the Controller.

**Checksum:** an error detection technique which adds up the Bytes or Words of data and compares them.

**Chip:** a very small section of semi-conductor material, usually made of silicon, containing electronic circuits.

**Clear:** to return memory to a nonprogrammed state.

**CMOS Memory:** an advanced form of semiconductor Memory which requires very little DC Power to retain its contents.

**Code:** programmed instructions.

**Coil:** an element in the logic program which will react in a discrete manner to the operations performed by the Programmable Controller. Its ON and OFF status can be output to the real world via an Output Module, and it may be used in other logical operations. Coils are normally turned OFF when power is removed from the Controller. (see Latched Coil)

**Computer:** a device which has a CPU, Memory, I/O Facilities, and a Power Supply. It accepts information, processes the data in a programmed manner, and gives you a result.

**Computer Interface:** circuitry which allows a Controller's Processor to communicate with a computer.

**Contact:** 1. the junction point on a ladder rung which when closed allows a complete path for power flow. 2. the points on a Relay which open or close when the Relay coil is Energized.

**Counter:** a logic element in a PC User Program which is used to simulate the operation of electro-mechanical Counters.

**CPU (Central Processing Unit):** the "brain" of the Controller System, consisting of the power supply, memory, and processor. All logic solving and decision making is performed here by the Processor. May also be called the MAINFRAME. Sometimes the term "CPU" is used to refer only to the processor.

**CRT:** a cabinet containing a Cathode Ray Tube to display programs such as Ladder Logic Diagrams. The CRT Might also be used to display data lists and application reports.

**Cursor:** a visible movable pointer on a CRT or Programming Panel which indicates where an instruction is to be entered or an edit is to be made.

## D

**Diagnostic Program:** a test program you can use to help isolate hardware problems in the PC and Application Equipment.

**Digital:** having discrete states. Digital Logic can have up to 16 states. However, most Digital Logic is Binary Logic with two states, ON and OFF.

**Disable:** the ability to disconnect a Coil or discrete Input from its normal control. Usually done prior to Forcing. (see Forcing)

**Discrete Reference:** a two-state reference in the User Program which can be either ON or OFF. A discrete reference can be an Input, Output, or Internal Logic Element.

**Disk Drive:** a device used to read and write data on a magnetic disk.

**Diskette:** thin magnetically sensitive material which is placed in a Disk Drive for the purpose of storing data and loading the memory contents of a computer.

## HANDOUT #1

**Documentation:** an orderly collection of data and diagrams explaining the hardware and software involved in a Control System.

**Down Load:** transferring the User Program from the Controller to some other device, usually a programming device.

**Dump:** recording the entire contents of User Memory onto a storage medium (e.g., magnetic tape, floppy disk, etc.)

## E

**EAROM:** Electrically Alterable Read-Only Memory.

**Edit:** to deliberately modify the user program.

**EEPROM:** Electrically Erasable Programmable Read-Only Memory.

**EIA:** Electronic Industries Association, an agency which sets standards in electronics.

**Element:** the basic building block of the PC ladder logic diagram. An element might be a relay contact, a horizontal short, vertical short, a fixed numeric value, register reference, coil, or higher function. These are sometimes called logic elements.

**Enable:** to reconnect a logic coil or discrete input after it has been disabled. The opposite of "Disable."

**EPROM:** Erasable Programmable Read-Only Memory. This type of ROM can be erased with ultraviolet light and then reprogrammed.

**Executive (Memory):** an operating system which processes the User Program.

## F

**FIFO Operation:** data management which assures that the First In will be the First Out.

**Force:** the operation which can be done to change a reference's status. The reference can be changed from OFF to ON or ON to OFF. This allows you to energize or not energize an Output by means of the Programming Device to aid in troubleshooting.

## H

**Hard Copy:** a printed copy of information from a computer, such as a Ladder Logic Program listing.

**Hardware:** the mechanical, electrical, and electronic devices which make up a complete Programmable Controller System.

**Holding Register:** a storage block of the Memory which holds a value and can be accessed through its Address.

**Hexidecimal:** the base 16 Number System often used to present error codes to the User.

## I

**Image Table:** a table in the Memory which contains the status of all Inputs, Coils, and Registers.

**Input:** a signal which provides the Controller information about the system. It can be discrete (pushbutton, relay contacts, limit switches, etc.) or Numeric (thumbwheel, external solid-state device, etc.), or Analog.

**Input Field Devices:** devices which supply data to the PC.

## HANDOUT #1

**Input Module:** a device which connects the Controller with Input Devices. The Input Module contains the circuitry required to convert the incoming signals to voltages which can be used by the PC.

**I/O:** Input/Output, the Controller's connection to the field devices; includes both discrete and register signals.

**Isolated I/O:** designed to enable the connection of field devices powered from different sources to a single module; this type of I/O is electrically isolated from all other circuits in the Module.

**Interface:** circuitry which allows communication between the Processor and the Field.

## L

**Ladder Diagram:** an industry standard for representing Control Logic along Rungs in a ladder arrangement and using relay equivalent symbology.

**Ladder listing:** a hard copy listing of the User Logic Program.

**Latched Coil:** a type of Coil which will return to its last state after a power failure has been rectified. These Coils are unlike normal Coils which reset to OFF at Powerup. (see "Retentive" if your Controller allows this function.)

**LDC (Liquid Crystal Display):** a reflective visual readout which offers the advantage of extremely low power consumption.

**LED:** Light Emitting Diode.

**Logic:** a system which contains digital switching functions, circuits, or devices, as in Programmable Controllers.

**Logic Diagram:** a graphic representation of Logic Functions and conditions.

**Logic Element:** any one of the symbols or functions which can be used in a Ladder Logic Diagram.

## M

**Machine Language:** a Program which has been written in Binary.

**Mainframe:** (see Processor)

**Memory:** storage area for Binary Data and Programs.

**Memory Map:** a diagram which shows where in the Controller's Memory various kinds of data are held.

**Memory Protect:** a hardware feature usually under keylock control which prevents a portion of the Memory from being altered by an external device.

**Microprocessor:** the control and processing section of a small Computer.

**Microsecond:** one millionth of a second.

**Millisecond:** one thousandth of a second.

**Modem:** a device which converts digital signals to analog signals suitable for transmission over a telephone line and vice-versa.

**Move Function:** the capability, in some PCs, which allows data to be transferred from a Register to a Table and from a Table to a Register.

**Multiplexing:** the ability to transfer a number of different data signals through a single channel.

## N

**Network:** a group of logic elements which has been connected together to perform a single function. In some Controllers, it is a subdivision of the User Program.



## HANDOUT #1

**Node:** the point on a PC Ladder Rung where a logic element is entered into a Ladder Logic Diagram.

**Noise:** random unwanted electrical signals, usually generated outside the Controller, which can cause errors in a PC managed system.

**Non-Volatile Memory:** memory which does not lose its information when power is turned off.

**Normally Open Contact (Examine On Contact):** a Contact whose not active state is OPEN. It is examining for an ON Signal in order to go active and close.

**Normally Closed Contact; (Examine Off Contact):** a Contact whose not active state is Closed. It is examining for an OFF Signal in order to pass power. If it finds a voltage ON signal at an input location, it goes Active, opens, and will not pass power.

## O

**Octal:** the Base Eight Numbering System which is used by some PC Manufacturers for Addressing I/O terminals and Referencing Registers.

**Off-Line Operation:** equipment or devices which are operating, but not affecting the system.

**On-Line Operation:** operations where the PC is directly controlling a machine or process.

**One-Shot:** a discrete reference, usually a Logic Coil, which is energized for exactly one scan of the Controller's Logic.

**Optical Coupler:** a device which uses a light source and a detector to link two points and provide electrical isolation. Often found in I/O Modules.

**OR Circuit:** a Parallel Circuit which allows one or more alternate paths for power flow in the Logic.

**Output Signal:** a signal coming from the Controller to the Field Devices in an operation. It can be discrete, turning Field Devices OFF and ON. Or it can be Numeric, displaying values stored in Registers. Or it can be Analog, sending a proportional signal to a Field Device.

**Output Field Devices:** devices such as Solenoids, Motor Starts, and Readouts which receive signals from the PC.

**Output Module:** a device used to connect the PC with working devices in the field. It serves two primary functions: converting PC signals to usable output voltages and isolating the PC from power fluctuations in the Field.

## P

**Parity Check:** an error test which counts the number of "1s" in a binary Digit and records whether it is odd or even.

**Parallel Circuit:** (see OR Circuit)

**Peripheral Equipment:** units which may communicate with a PC but are not part of it.

**Port:** an I/O connection point on a Controller or Peripheral Device.

**Processor:** the "brain" of the PC which performs all the decision-making in the Controller.

**Programmable Controller (PC):** a solid-state Control System which contains a User Programmable Memory for the storage of instructions to perform specific functions in an operation. A PC consists of a Central Processing Unit and an I/O Interface. It requires a Programming Device to enter a User Program into its Memory.

## HANDOUT #1

**Programming Device:** a device designed to allow inserting, monitoring, and editing a User Program in the PC.

**PROM (Programmable Read-Only Memory):** a retentive Memory used to store data.

## R

**RAM (Random Access Memory):** a portion of the Memory which is used to store the Information necessary to control a particular operation. This information can be accessed at Random by the processor when it is needed.

**Reference Numbers:** numbers which identify Elements of the Relay ladder Logic. These Elements can be either Discrete or Numeric.

**Register:** a piece of the Controller's Memory which has been set aside for the storage of Numeric Values. The contents of these Registers can be referenced and used by the PC during its operation.

**Register Module:** sometimes called Numeric and Analog Modules, these I/O Modules allow numerical data to pass between the PC and the Field Devices.

**Relay:** an electromechanical device which controls other devices in an electrical system.

**Relay Element:** a Logic Symbol used to simulate the effect of an electromechanical Relay in a User Program.

**Retentive Elements:** on certain Controllers, these Logic Elements will retain their state or value under specified conditions, e.g., a Retentive Latched Coil may remain latched when power is removed from the PC; a Retentive Timer will retain its Accumulated Time during a power outage provided battery power is supplied.

**ROM (Read Only Memory):** a portion of Memory which is usually programmed by the Manufacturer and contains basic instructions for the PC.

**Rung:** a single horizontal line in the Ladder Logic which may contain User Program Elements.

## S

**Scan:** the cycle a PC performs several times each second, during which it reads the inputs, solves the User Program, and sets the outputs.

**Scratch Pad Memory:** a temporary portion of Memory where the PC stores the data it needs to perform calculations or control an operation. Often this area is used because it offers faster access time than the Main Memory.

**Sequencer:** a Logic Element which allows events to be programmed to follow a certain order under specified conditions.

**Series Circuit:** (see AND Circuit)

**Skip Function:** on certain Controllers, this function allows certain portions of a Program to be skipped when the Logic is being scanned.

**Software:** application and internal programs which are used to support the performance of the Controller.

**Solid-State:** circuitry using only integrated circuits, transistors, diodes, etc., and containing no electromechanical devices or vacuum tubes.

**Status Light:** an LED Indicator found on most I/O Modules which can be used as a maintenance aid. It usually lights to indicate that an Output Module is receiving valid data from the Processor, or that an Input Module is receiving a signal from a Field Device.

## HANDOUT #1

## T

**Table:** a group of consecutive Memory Registers used to store numerical values.

**Timer:** a Logic Element which uses the PC's internal clock to time an event or sequence of events. (see Retentive if your Controller allows this function.)

**Traffic Cop:** a portion of Executive Memory which controls how input and output data is handled.

**Transitional Contact:** a Contact which will pass power for exactly one scan whenever the Coil or Discrete Input to which it is referenced goes from OFF to ON or ON to OFF (depending upon the transitional type selected).

**Triac:** a semiconductor device which acts as an electronic switch for AC loads.

**Truth Table:** a listing which shows the state of an Output under all the possible Input conditions.

## U

**Up-Load:** transferring data to the PC from a device such as a Programmer.

**User Memory:** the area in memory where the Application, or User Program is stored.

**User Program (Application Program):** a set of Instructions written by the user and stored in the Memory. These Instructions "tell" the Processor how to control a specific operation.

## V

**Volatile Memory:** a type of Memory which will lose its information if power is removed from it.

## W

**Watchdog Timer:** a safety circuit which uses a Timer to check constantly for CPU failure. When the CPU is operating correctly, the Timer is periodically reset so it never Times Out. In the event of failure, the Timer Times Out and the entire system is shut down.

**Word:** a grouping of bits (usually 16) into a sequence which is treated as a unit.

**Write:** the act of putting data into a storage location.

# **PROGRAMMABLE CONTROLS**

## **UNIT XV**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Analog signal — A signal which varies proportionally with some aspect of the environment; the signal from a pressure transducer which varies with the amount of pressure being applied
- B. Counter — A logic element in a PC user program which is used to simulate the operation of electro-mechanical counters
- C. Discrete — A two-state reference in the user program which can be either on or off
- D. Fiber optics — Transfer of discrete signals through glass fibers with light
- E. Input — A signal which provides the controller information about the system; can be discrete, numeric, or analog
- F. Logic — A system which contains digital switching functions, circuits, or devices
- G. Networking — Tie in of multiple PCs to communicate with each other in the performance of a process
- H. Output — A signal coming from the controller to field devices; can be discrete, numeric, or analog
- I. Programmer — A device designed to allow inserting, monitoring, and editing a user program in the PC
- J. Programmable controller (PC) (PLC) — A solid state control system which contains a user programmable memory for the storage of instructions to perform specific functions in an operation

#### **II. Programmable controller functions**

- A. The replacement of electromechanical relays, counters, timers, and analog devices with reliable solid-state circuitry
- B. To facilitate the change of a process at minimum expense and down time
- C. The performance of arithmetic operations, which might be required for controlling certain operations
- D. Fault locating, alarming, and regulation of devices which rarely need attention
- E. The control of dangerous devices or devices in a dangerous environment

## INFORMATION SHEET

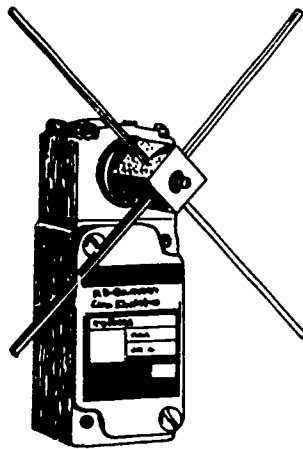
### III. Three stages necessary to control a process

- A. Input
- B. Logic
- C. Output

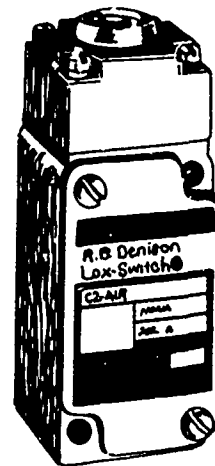
### IV. Input devices

#### A. Limit switches

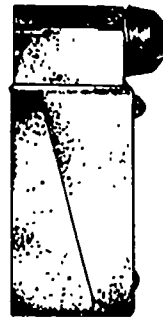
##### 1. Turnstile



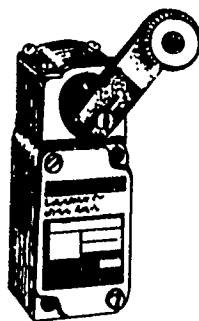
##### 2. Air operated



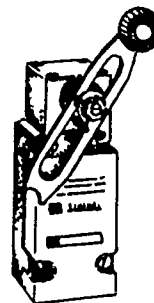
##### 3. Two-step sequence



##### 4. Turret head



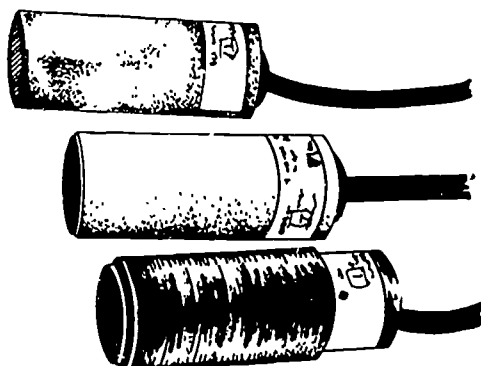
##### 5. Precision turret



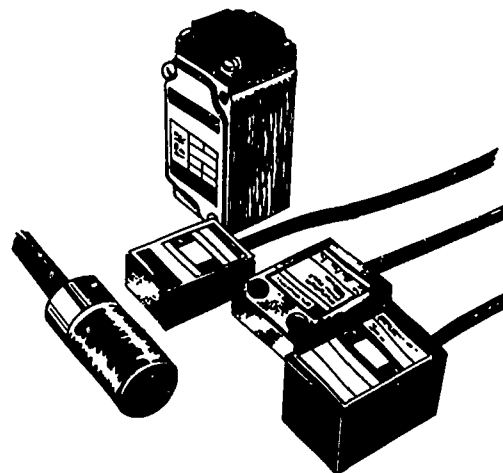
## INFORMATION SHEET

## B. Proximity switches

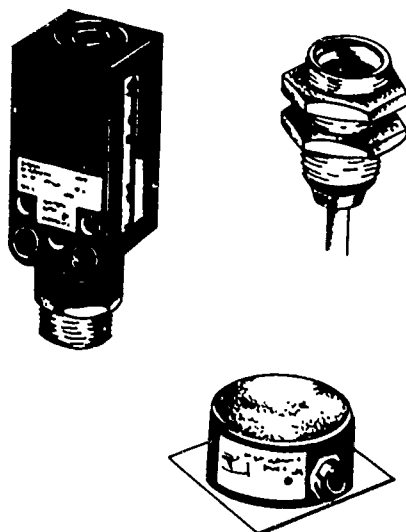
## 1. Capacitive



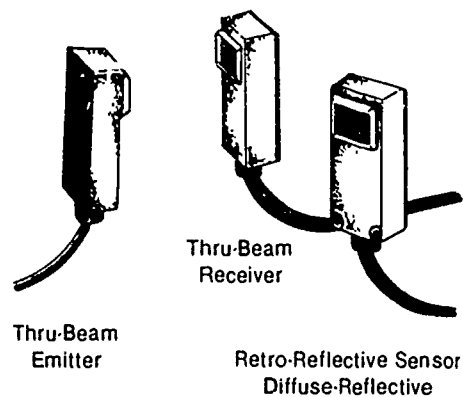
## 2. Magnetic



## 3. Inductive



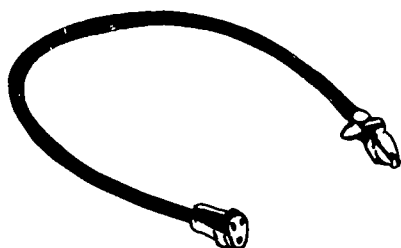
## 4. Photoelectric



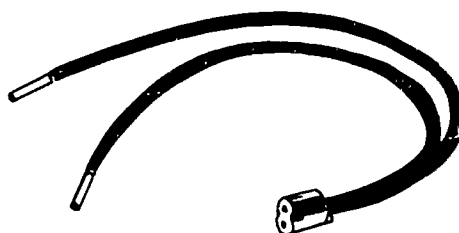
## INFORMATION SHEET

## C. Fiber optic probes

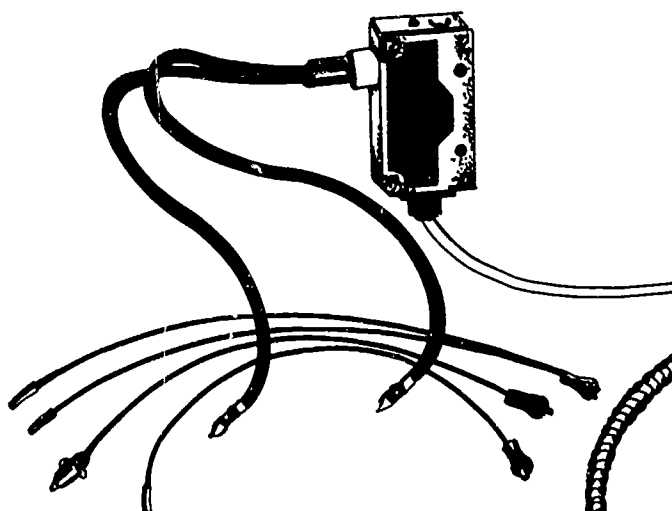
1. Coaxial reflective



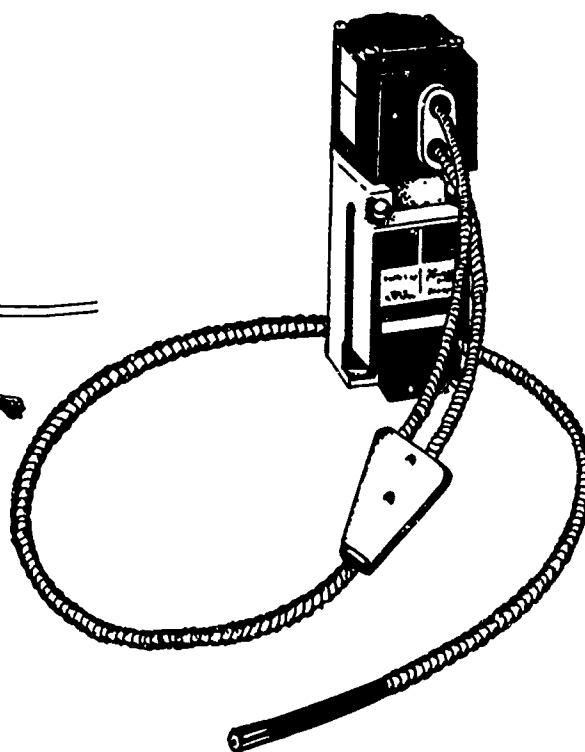
2. Thru-beam



3. Thru-beam and reflective scanners



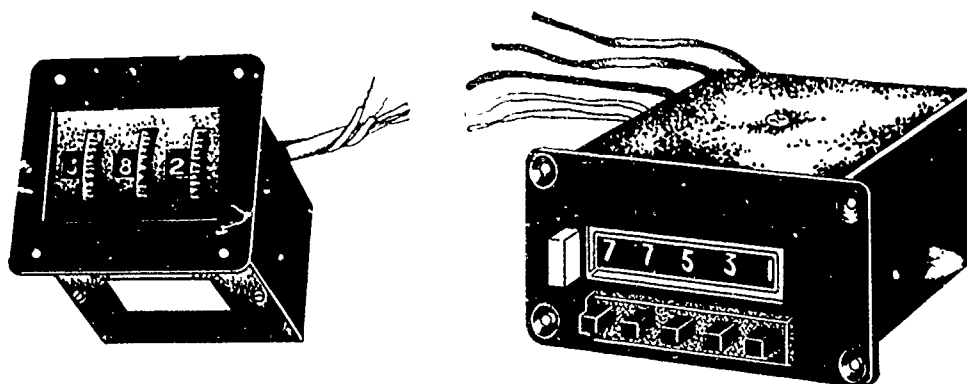
4. Scanner cable



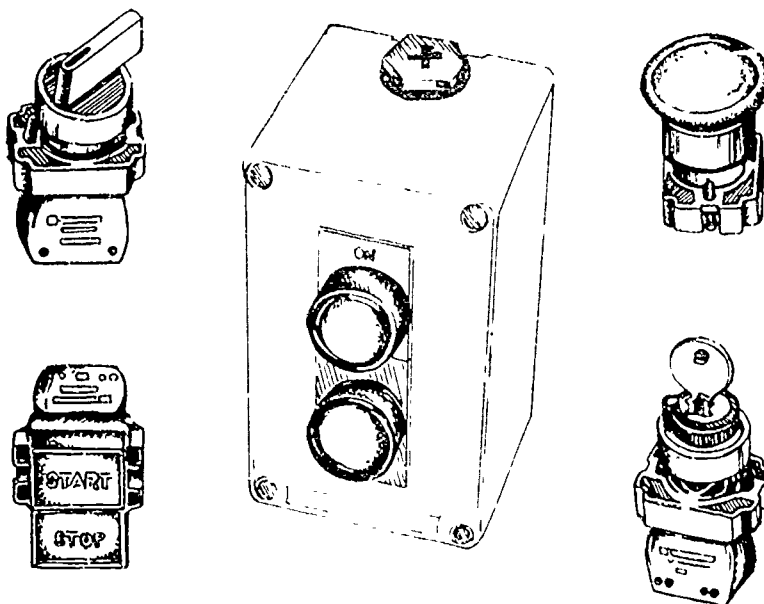
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## INFORMATION SHEET

## D. Thumbwheels



## E. Push buttons

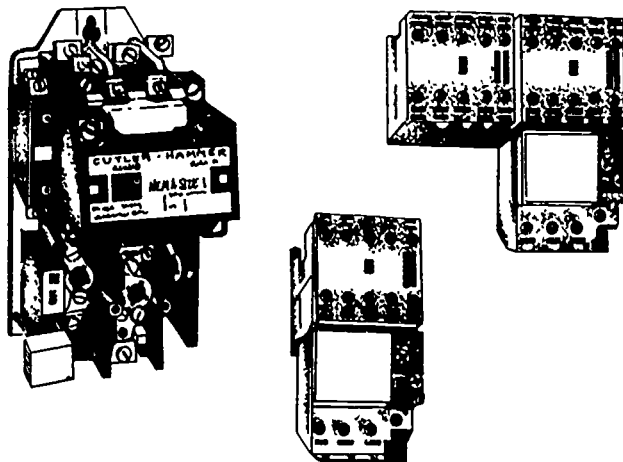




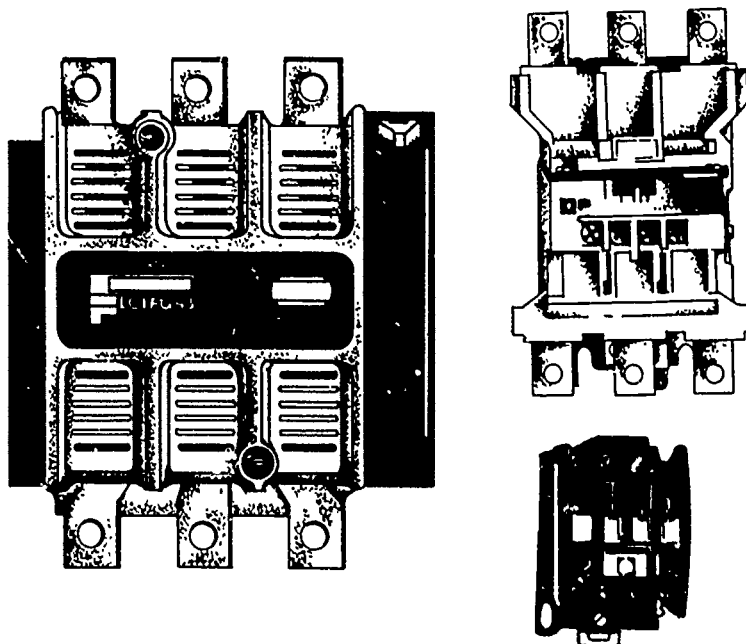
## INFORMATION SHEET

## V. Output devices

## A. Motor starters



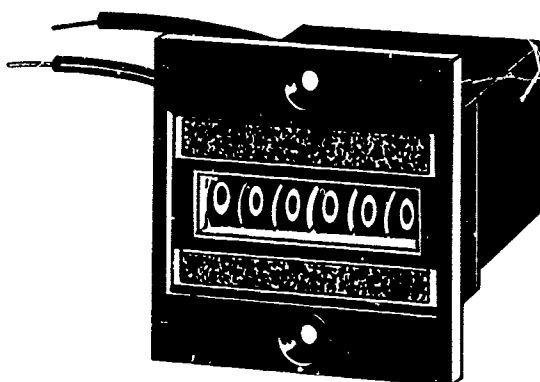
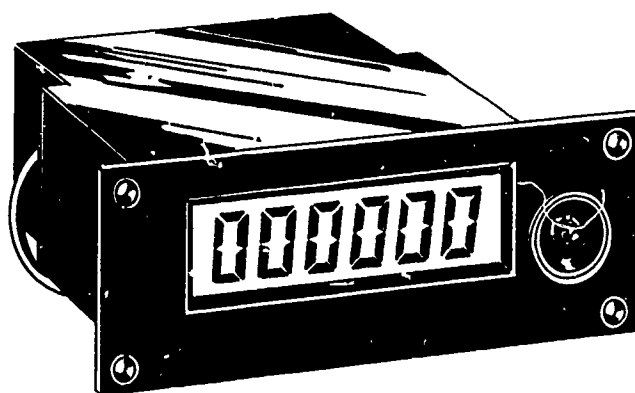
## B. Contactors and relays



646

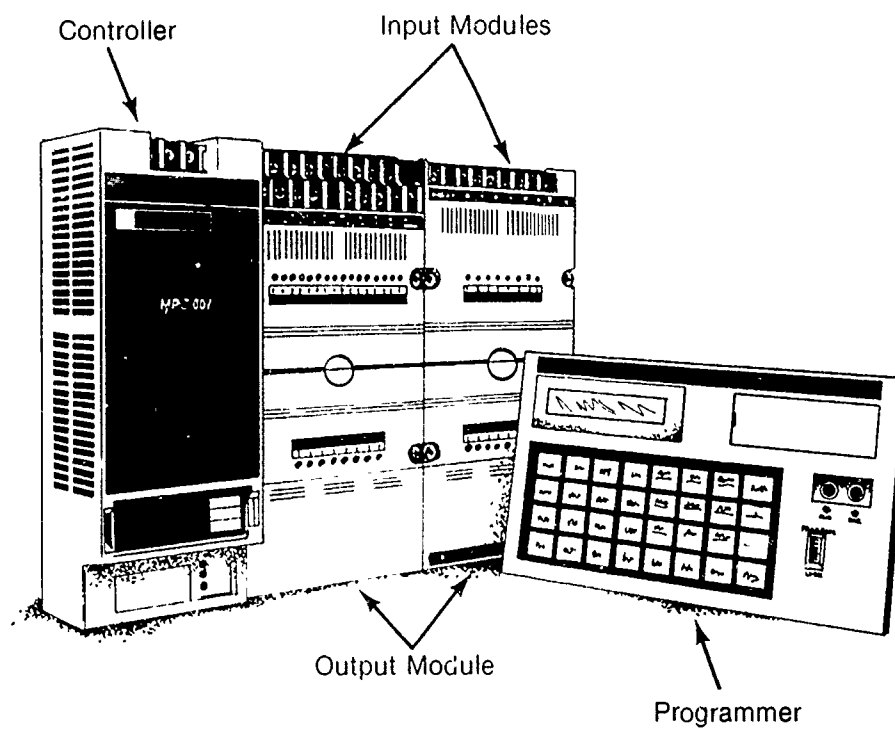
## INFORMATION SHEET

## C. Counters



## INFORMATION SHEET

## VI. Components of a programmable controller



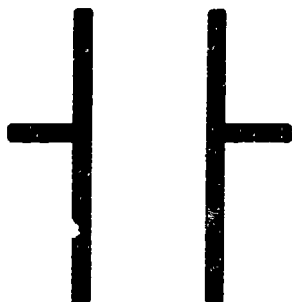
Courtesy of Telemechanique.

## INFORMATION SHEET

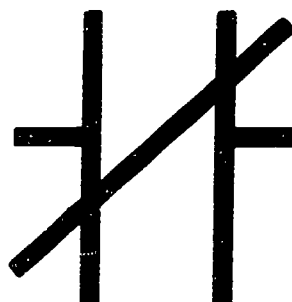
### VII. States of contacts

- A. A **normally closed** contact will be **closed** and passing power when it is **inactive**.
- B. A **normally open** contact will be **open** and not passing power when it is **inactive**.
- C. When **activated**, contacts change to the opposite state from their normal (not active) state. In other words, a **normally open** contact will close and a **normally closed** contact will open.

Normally Open Contact



Normally Closed Contact



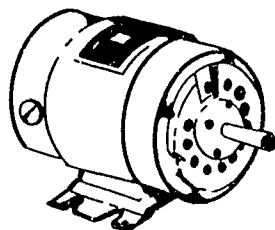
Reprinted with permission of Tel-A-Train, Inc., Chattanooga, Tennessee.

(NOTE: It is important to remember that all relays have contacts associated with them which become **active** when the coil **energizes**. Switches also contain contacts which will go **active** when the switch is **activated**. All contacts have a **normal state**, either **open** or **closed**, which is the position they are in when they are **inactive**.)

### VIII. Types of I/O modules

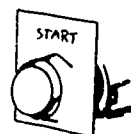
- A. Discrete I/O modules

(NOTE: These are used for simple two-state, on/off field devices.)



Motor

Push Button

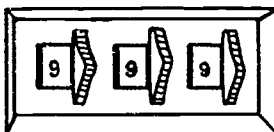


## INFORMATION SHEET

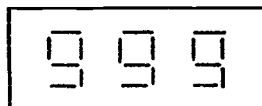
### B. Numerical I/O modules

(NOTE: These are used for field devices such as thumbwheels and LED readouts, which send and receive numbers.)

Thumbwheel

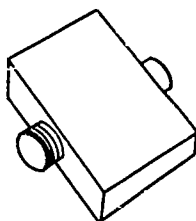


LED Display

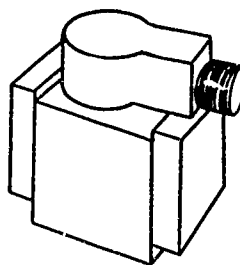


### C. Analog I/O modules

(NOTE: These are used for field devices which must send or receive voltage signals that change continuously.)



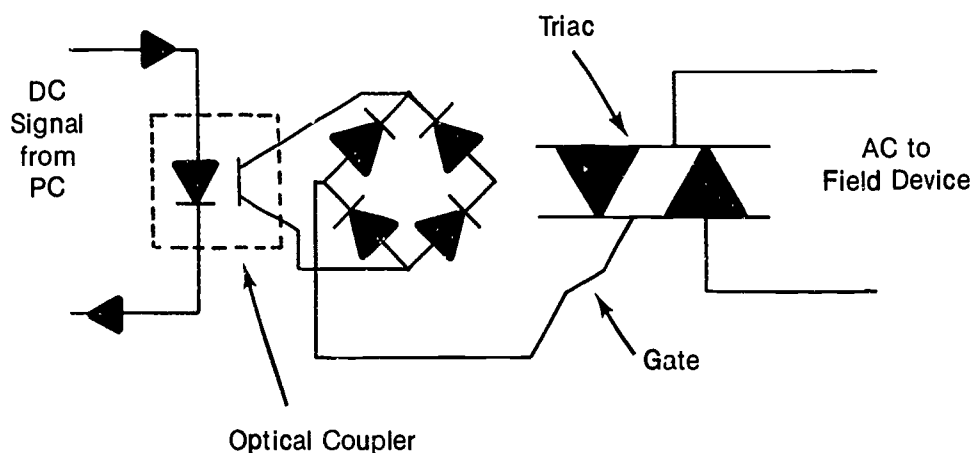
Pressure  
Transducer



Proportional  
Analog Valve

## INFORMATION SHEET

### IX. Parts of an optical coupler



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(NOTE: Two basically independent circuits meet at a **Triac** which is an electronic switch. When the low voltage DC signal from the PC is applied to the gate of the **Triac**, a switch in the **Triac** will close, allowing AC to flow in the output device's circuit. This system is used to optically isolate the PC circuitry from the field circuitry, thus protecting the PC from transients, spikes, etc.)

### X. Basic ladder logic symbols

(NOTE: Signals from the input devices in the field are changed by the I/O modules into data which the PC can use. When this data is a simple on/off signal, it enters the logic through contacts on ladder rungs in the user program.)

#### A. Normally open contact (examine on)



(NOTE: **Normally open contacts** are contacts which remain **open** and **do not** pass power when they are not receiving a signal from the input module. They are sometimes called **examine on** contacts because they are looking for an **on** signal to pass power.)

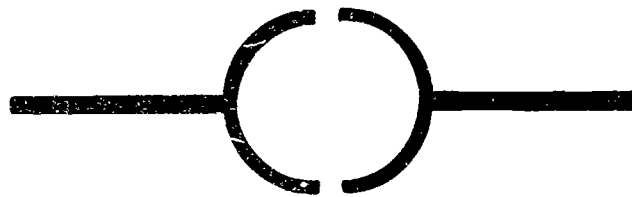
# INFORMATION SHEET

- B. Normally closed contacts (examine off)



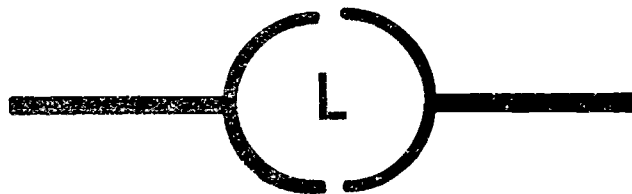
(NOTE: **Normally closed contacts** are contacts which remain **closed** and **do** pass power when they are not receiving a signal from the **input** module. They are sometimes called **examine off** contacts because they are looking for an **off** signal to pass power.)

- C. Normal output coils



(NOTE: Normal coils have two states. They can be **energized** and sending a signal to the output module or **not energized** and not sending a signal.)

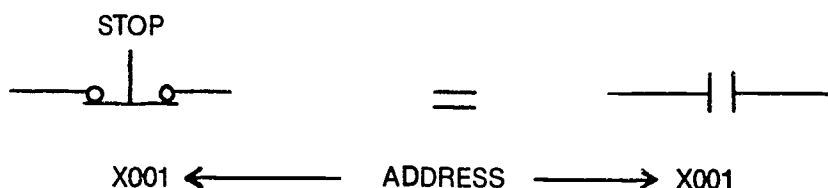
- D. Latched output coils



(NOTE: This is often referred to as a retentive coil. On most controllers, a latched coil will remain in its latched state, even when the **rung** changes state. When this is the case, an unlatching coil is often required to **change** the state of the output. Please consult the PC's User Manual for the details on latching coils in your controller.)

## INFORMATION SHEET

- XI. **Normally closed stop buttons** — Input devices such as stop switches and high limit switches are wired **normally closed** in the field. However, in the logic the **normally closed** contact is programmed **normally open**. The N/C input device is passing power to the I/O module. Sensing this voltage, the I/O sends an **on** signal to the controller. Since this signal means the device has not been activated, power will flow along the rung as long as the signal is received.



## XII. Basic numbering systems

(NOTE: Most programmable controllers can perform at least some arithmetic. They do this by comparing the values in one register to one or more different registers.)

- A. Decimal (Base 10)
- B. Binary (Base 2)
- C. Octal (Base 8)
- D. Hexidecimal (Base 16)



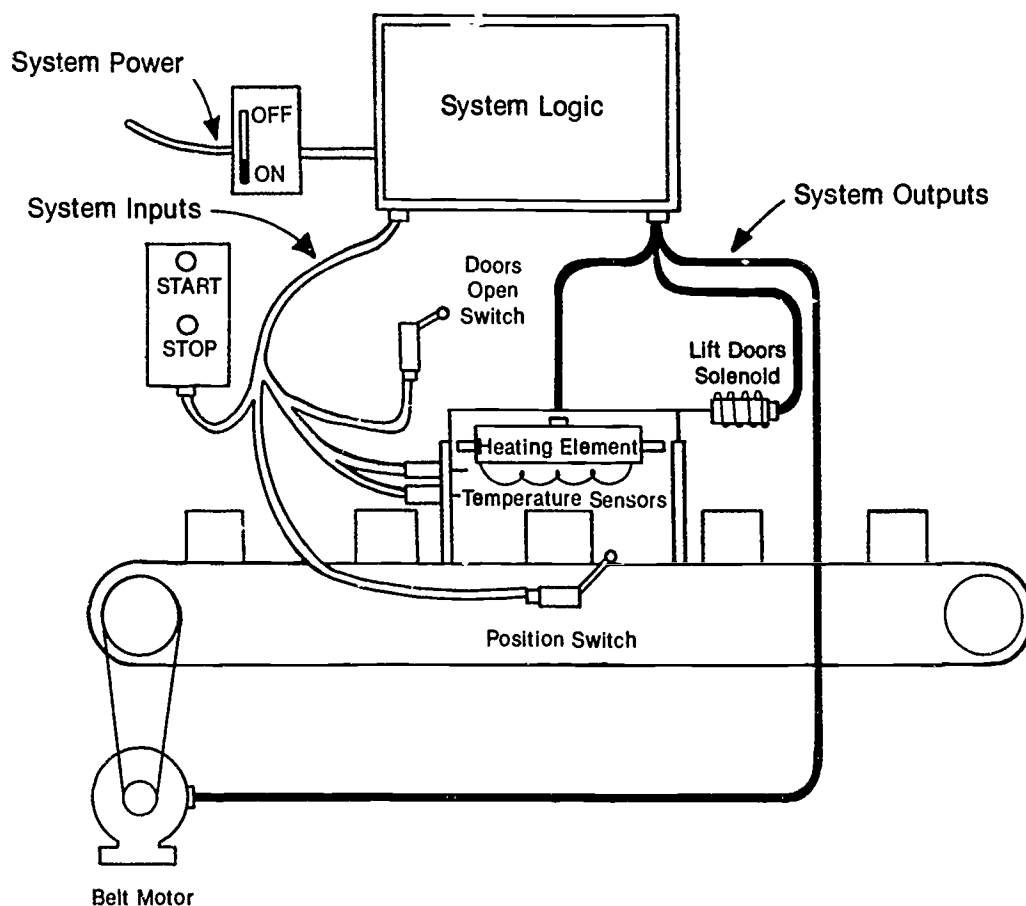
# PROGRAMMABLE CONTROLS UNIT XV

## ASSIGNMENT SHEET #1 — MATCH I/O DEVICES WITH THEIR FUNCTIONS

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions: Using the pictorial drawing of a PC managed system, match I/O devices with their correct functions.



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## ASSIGNMENT SHEET #1

- |         |  |                       |
|---------|--|-----------------------|
| _____a. | It deactivates, signaling the logic to begin the heating cycle           | 1. Doors open switch  |
| _____b. | It signals the logic to begin the process and start the belt moving      | 2. Position switch    |
| _____c. | Allows the heat to only reach a certain level                            | 3. Start button       |
| _____d. | Signals the logic that a workpiece is in the oven and to close the doors | 4. Temperature sensor |

# PROGRAMMABLE CONTROLS UNIT XV

## ASSIGNMENT SHEET #2 — CONVERT BETWEEN NUMBERING SYSTEMS

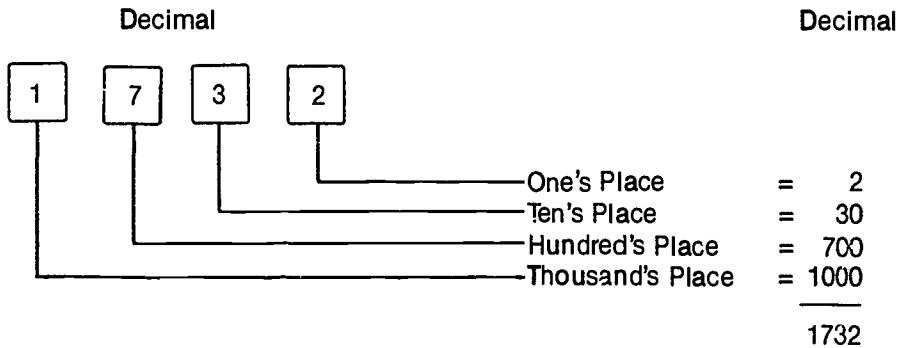
NAME \_\_\_\_\_

SCORE \_\_\_\_\_

Directions:

### Decimal

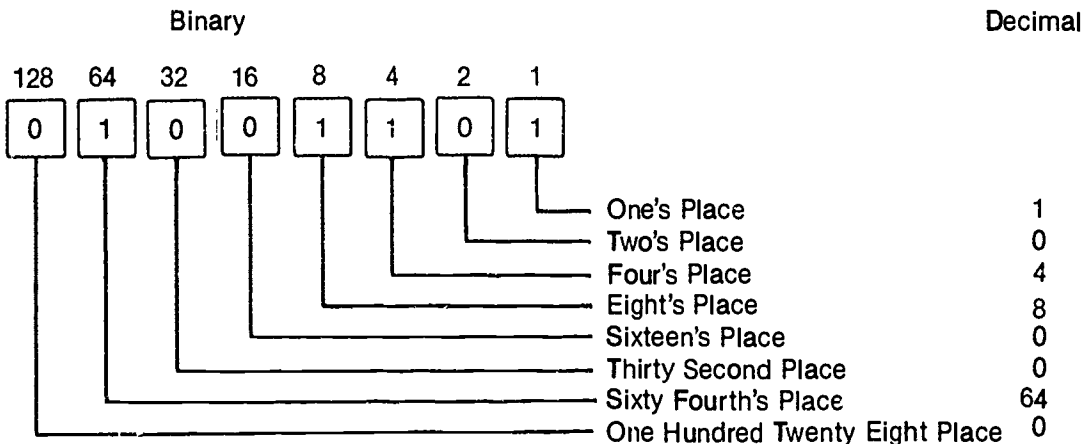
The numbering system you are familiar with is called the decimal system. It uses ten unique characters. Each character represents a power of ten.



### Binary

The on/off status of a switch is easily read by a computer. The binary system is the basis of computer operations. The binary system uses two unique characters (1 and 0). Each character represents a power of two.

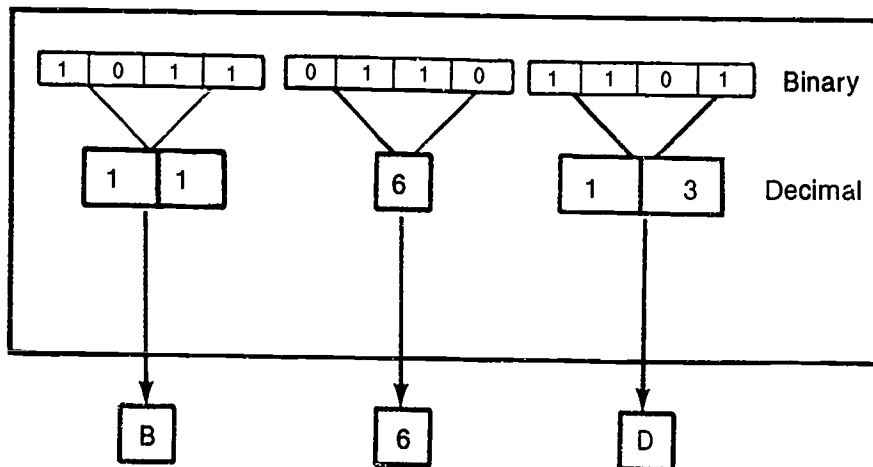
When translating a binary number to a decimal number, include the columns which contain a one, and disregard the columns which contain a zero binary.



## ASSIGNMENT SHEET #2

### Hexidecimal

Hex allows the PC to display a larger number of binary combinations as a three column read-out. The hex system uses sixteen unique characters (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F). Letters A through F represent the decimal numbers 10 through 15.



Binary	Decimal	Hexidecimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

(NOTE: Since a computer operates in binary, a coding system was developed to allow the decimal numbers on thumbwheels and readouts to be used by a PC. It is called "Binary Coded Decimal" or "BCD".)

# ASSIGNMENT SHEET #2

Convert the following as indicated.

A. Decimal 078 =

— — — — — BCD

B. Decimal 493 =

— — — — — BCD

C. Decimal 206 =

— — — — — BCD

D. Decimal 851 =

— — — — — BCD

E. 0101-0001-0110 BCD =

— — — — Decimal

F. 0011-1001-0010 BCD =

— — — — Decimal

G. 0010-1000-0111 BCD =

— — — — Decimal

H. 1010-1001 1111 BCD =

— — — — Hex

I. 0111-1101-1100 BCD =

— — — —

J. 0110-0101-1011 BCD =

— — — —

## PROGRAMMABLE CONTROLS UNIT XV

### ANSWERS TO ASSIGNMENT SHEETS

#### Assignment Sheet #1

- A. 1
- B. 3
- C. 4
- D. 2

#### Assignment Sheet #2

- A. 0000-0111-1000
- B. 0100-1001-0011
- C. 0010-0000-0110
- Γ 1000-0101-0001
- E. 516
- F. 392
- G. 287
- H. A9F
- I. 7DC
- J. 65E

# PROGRAMMABLE CONTROLS UNIT XV

## TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match the terms on the right with their correct definitions.

- |         |  |                             |
|---------|--|-----------------------------|
| _____a. | A logic element in a PC user program which is used to simulate the operation of electro-mechanical counters  | 1. Analog signal            |
| _____b. | A two-state reference in the user program which can be either on or off  | 2. Counter                  |
| _____c. | A system which contains digital switching functions, circuits, or devices  | 3. Discrete                 |
| _____d. | A signal which provides the controller information about the system; can be discrete, numeric, or analog   | 4. Fiber optics             |
| _____e. | A device designed to allow inserting, monitoring, and editing a user program in the PC.  | 5. Input                    |
| _____f. | A signal which varies proportionally with some aspect of the environment; the signal from a pressure transducer which varies with the amount of pressure being applied | 6. Logic                    |
| _____g. | A signal coming from the controller to field devices; can be discrete, numeric, or analog  | 7. Networking               |
| _____h. | A solid state control system which contains a user programmable memory for the storage of instruction to perform specific functions in an operation                    | 8. Outputs                  |
| _____i. | Transfer of discrete signals through glass fibers with light   | 9. Programmer               |
| _____j. | Tie in of multiple PCs to communicate with each other in the performance of a process  | 10. Programmable controller |

## TEST

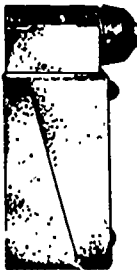
2. Select from the following list programmable controller functions by placing an "X" in the blanks preceding the correct functions.

- \_\_\_\_\_a. The control of dangerous devices or devices in a dangerous environment
- \_\_\_\_\_b. To eliminate the need for retraining employees
- \_\_\_\_\_c. To facilitate the change of a process at minimum expense and down time
- \_\_\_\_\_d. The performance of arithmetic operations which might be required for controlling certain operations
- \_\_\_\_\_e. In order to facilitate 24-hour production of a product
- \_\_\_\_\_f. Fault locating, alarming, and regulation of devices which rarely need attention

3. List the three stages necessary to control a process.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

4. Identify the following input devices.

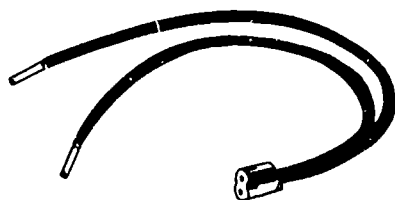


a. \_\_\_\_\_

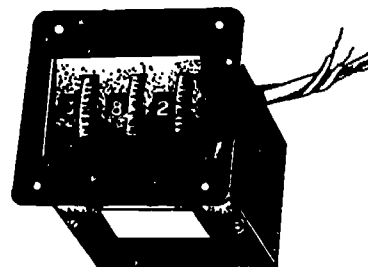
b. \_\_\_\_\_



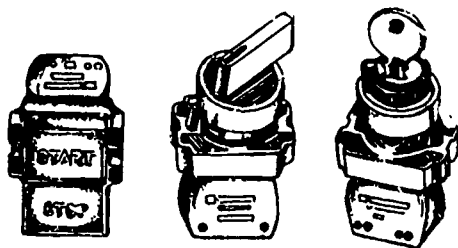
## TEST



c. \_\_\_\_\_

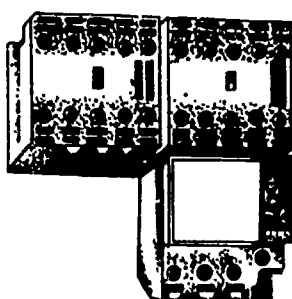
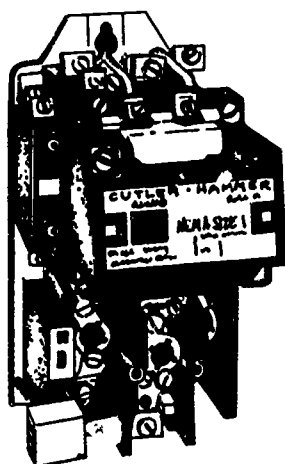


d. \_\_\_\_\_



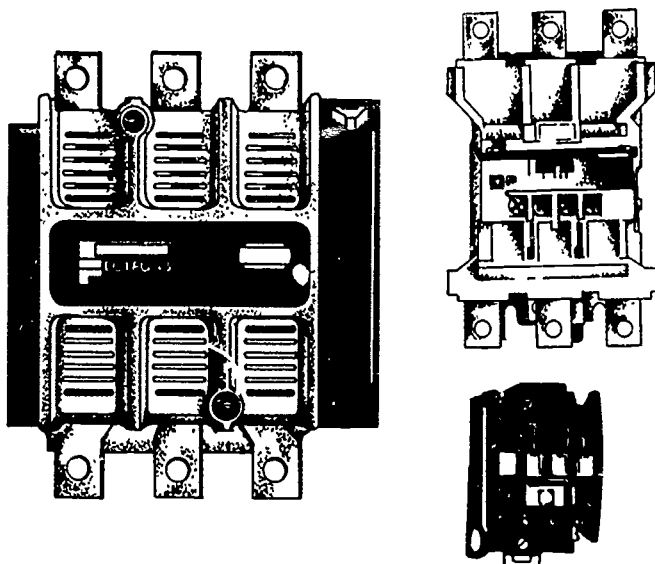
e. \_\_\_\_\_

5. Identify the following output devices.

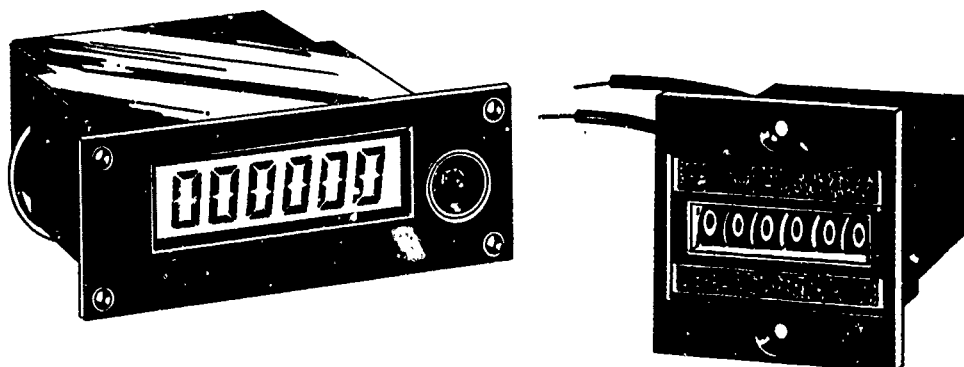


2. \_\_\_\_\_

## TEST



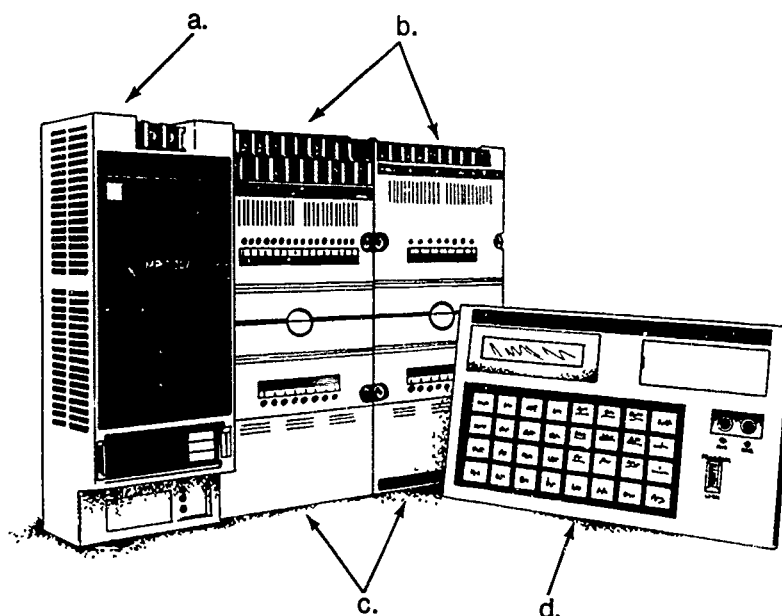
b. \_\_\_\_\_



c. \_\_\_\_\_

## TEST

6. Identify the components of the programmable controller shown below.



- a. \_\_\_\_\_ b. \_\_\_\_\_
- c. \_\_\_\_\_ d. \_\_\_\_\_

7. Complete the following statements concerning states of contacts by inserting the word which best completes each statement.

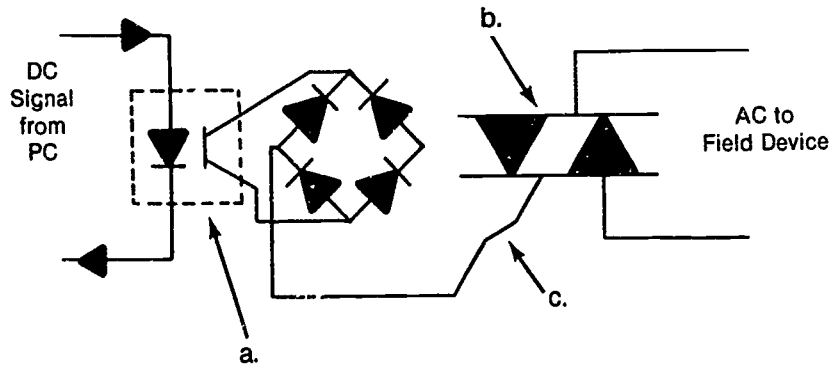
- a. Normally closed contact will be closed and passing power when it is \_\_\_\_\_.
- b. A normally open contact will be open and not passing power when it is \_\_\_\_\_.
- c. When \_\_\_\_\_ contacts change to the opposite state from their normal state.

8. Name three types of I/O modules.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

## TEST

9. Identify the parts of the optical coupler shown below.



a. \_\_\_\_\_ b. \_\_\_\_\_

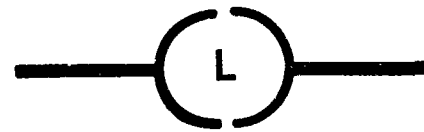
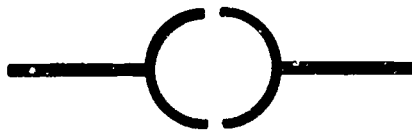
c. \_\_\_\_\_

10. Identify the basic PC ladder logic symbols shown below.



a. \_\_\_\_\_

b. \_\_\_\_\_



c. \_\_\_\_\_

d. \_\_\_\_\_

**TEST**

11. Explain why a stop button is wired normally closed.

---

---

---

---

12. List the basic numbering systems used in programmable controls.

a. 

---

b. 

---

c. 

---

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Match I/O devices with their functions. (Assignment Sheet #1)
14. Convert between numbering systems. (Assignment Sheet #2)

## PROGRAMMABLE CONTROLS UNIT XV

### ANSWERS TO TEST

1.   a.    2                   e.    9                   i.    4  
      b.    3                   f.    1                   j.    7  
      c.    6                   g.    8  
      d.    5                   h.   10
2.   a, c, d, f
3.   a.    Inputs  
      b.    Logic  
      c.    Outputs
4.   a.    Limit switches  
      b.    Proximity  
      c.    Fiber optic probe  
      d.    Thumbwheels  
      e.    Push buttons
5.   a.    Motor starters  
      b.    Contactors and relays  
      c.    Counters
6.   a.    Controller  
      b.    Input modules  
      c.    Outputs  
      d.    Programmer
7.   a.    Inactive  
      b.    Inactive  
      c.    Active
8.   a.    Discrete  
      b.    Numerical  
      c.    Analog
9.   a.    Optical coupler  
      b.    Triac  
      c.    Gate

**ANSWERS TO TEST**

10.
  - a. Normally open (examine on)
  - b. Normally closed (examine off)
  - c. Normal output coils
  - d. Latched output coils
  
11. The N/C input is passing power to the I/O module. Sensing this voltage, the I/O sends an **on** signal to the controller.
  
12.
  - a. Decimal
  - b. Binary
  - c. Hexidecimal
  
- 13.-14. Evaluated to the satisfaction of the instructor

## **SCENARIOS SPECIAL SUPPLEMENT**

### **SUGGESTIONS TO THE INSTRUCTOR**

The following scenarios are designed to develop in the student the critical thinking skills necessary to make competent judgments based on available data or information. The problems provided in these scenarios will encompass most of the skills learned in the commercial and industrial wiring curriculum. Application of these problems should also develop skills in work ethics and give the student a basic understanding of the economics of the electrical industry. The student should also show marked improvement in communication skills and trade related mathematics.

1. Two-wire control applications
2. Timed operation applications
3. Reversing applications
4. Oil field applications
5. Reversing alternative applications
6. Limitation of movement applications
7. Back spin protection applications
8. Hazardous mixing applications
9. Sequential starting applications
10. Sequential shutdown applications

In order to implement the above scenarios, the instructor should provide:

1. Electrical labor units manual
2. Electrical supply catalogs
3. Pricing books
4. Overhead and markup multipliers (based on local prices)
5. Varied motor control components

It is also suggested that the instructor review the scenarios and construct work stations for each problem. The work stations should have all starters, motors and raceways installed. The student should be required to determine appropriate control devices as well as conductor size and overcurrent and overload protection. Many of the problems require a bid or price figure. Assist each student with the basics of pricing, overhead, and markup.



## SUGGESTIONS TO THE INSTRUCTOR

Each scenario problem will require a technical report. A detailed explanation of the sequence of operation of the circuit should be included. It should be referenced to the ladder diagram. Any additional, pertinent information should also be included, ie. why a particular NEMA type of enclosure is necessary.

The problems will increase in the difficulty as the student progresses through the supplement. The student should be encouraged to perform any necessary research on his/her own. Your role should change from instructor to technical consultant/evaluator.

No answer sheets have been provided for these scenarios due to the varied methods of problem solving.

## SCENARIOS SPECIAL SUPPLEMENT

### SUGGESTIONS TO THE STUDENT

All of the scenarios presented in this supplement are real situations. You will be required to apply all of the knowledge you have gained to this point. Many of the problems provided in these scenarios will require some research in solving the design aspect of the problem. Use the resource materials which are available as well as your imagination. **You are encouraged to create your own solutions.** Do not depend on anyone for assistance except your instructor. Remember, when you begin working in the field you may be required to solve similar problems.

Problems may include bids or a material list. Remember, the electrical market is highly competitive. You must not "gold plate" a job. Your solution should conform to current NEC and industry standards. Safety and the customer should always be of the utmost importance.

Scenarios included in this supplement include:

1. Two-wire control applications
2. Timed operation applications
3. Reversing applications
4. Oil field applications
5. Reversing alternative applications
6. Limitation of movement applications
7. Back spin protection applications
8. Hazardous mixing applications
9. Sequential starting applications
10. Sequential shutdown applications

Each of the scenarios listed above will require a technical report as part of the problem solving process. The report should include a detailed explanation of the operation of the circuit and should be referenced to your ladder diagram. In addition, include any other pertinent information such as why a particular NEMA type of enclosure was chosen.

All calculations must also be included in the report. These should include voltage drop calculations, branch circuit sizing, and overcurrent protection.

## SUGGESTIONS TO THE STUDENT

When determining the material list, be sure you include all necessary materials such as:

1. Starter (size and type)
2. Overload heaters
3. Disconnect (size and type)
4. Fuses
5. Conduit
6. Connectors and couplings
7. Liquidtight
8. Flex
9. Junction boxes and covers
10. Screws
11. Straps
12. Etc.

## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #1 — TWO WIRE CONTROL

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

**PART I: Evaluation**

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	— 30 Pts.
Conformity to Code	— 25 Pts.
Workmanship	— 20 Pts.
Time	— 25 Pts.
Technical Report	— 100 Pts.

Start Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total

**SCENARIO #1****PART II: Problem**

A trucking company with an extremely large loading dock has a problem with standing water after every heavy rain. The area where the trucks back in has been excavated to a depth of 5.5 feet below the street level. Since this is below the level of the city storm sewer it is impossible to drain the area with gravity. A plumbing company has installed two lift pumps to force the water uphill to drain it to the sewer.

One pump is 160 feet from the panel, the other is 240 feet from the panel. Both motors are  $\frac{3}{4}$  HP 240V 3 $\phi$  squirrel cage units. It will be necessary to operate the controls by float switches located in sumps.

This job will be done on a cost-plus basis. You will need a complete material list for billing purposes.

TIME LIMIT \_\_\_\_\_

## SCENARIO #1

## ELECTRICAL PRICING SHEET

JOB	
WORK	

ESTIMATE NO	
SHEET NO.	OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

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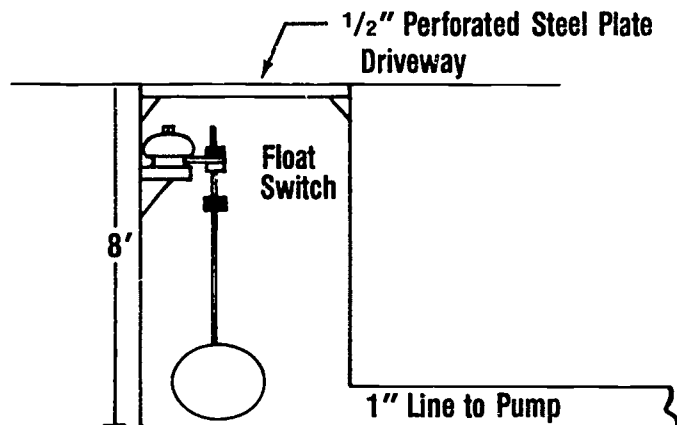
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MATERIAL ►

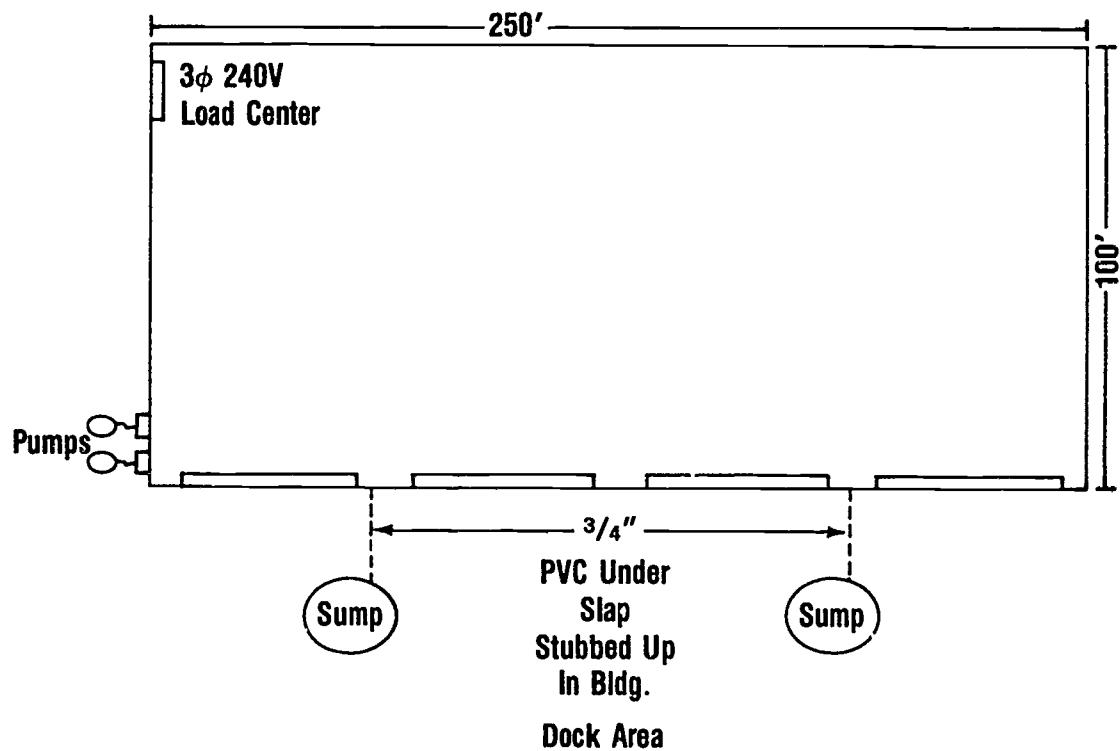
LABOR ►

## SCENARIO #1

Detail



Floor Plan



## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #2 — TIMED OPERATION

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

**PART I: Evaluation**

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	— 30 Pts.
Conformity to Code	— 25 Pts.
Workmanship	— 20 Pts.
Time	— 25 Pts.
Technical Report	— 100 Pts.

Start Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total



**SCENARIO #2****PART II: Problem**

A chemical company has contracted your firm to install a control system to operate a mixing pump. The pump must run for 1 hour, then shut down for 1 hour. This cycle must continue 24 hours a day. There must also be a means of turning the pump on manually, and a way to turn it off for tank cleaning. The mixing pump is a 7.5 HP, 240 volt, 3 $\phi$  unit. It is located 475 feet from the distribution panel. The chemicals held in the tank are non-corrosive, non-explosive mixtures. The tank is located in the main building. The building is a steel structure.

This job will be billed cost-plus. You will be required to make a complete material list and price (your cost) each item.

TIME LIMIT \_\_\_\_\_

## SCENARIO #2

## ELECTRICAL PRICING SHEET

JOB
WORK

ESTIMATE NO.	
SHEET NO	OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

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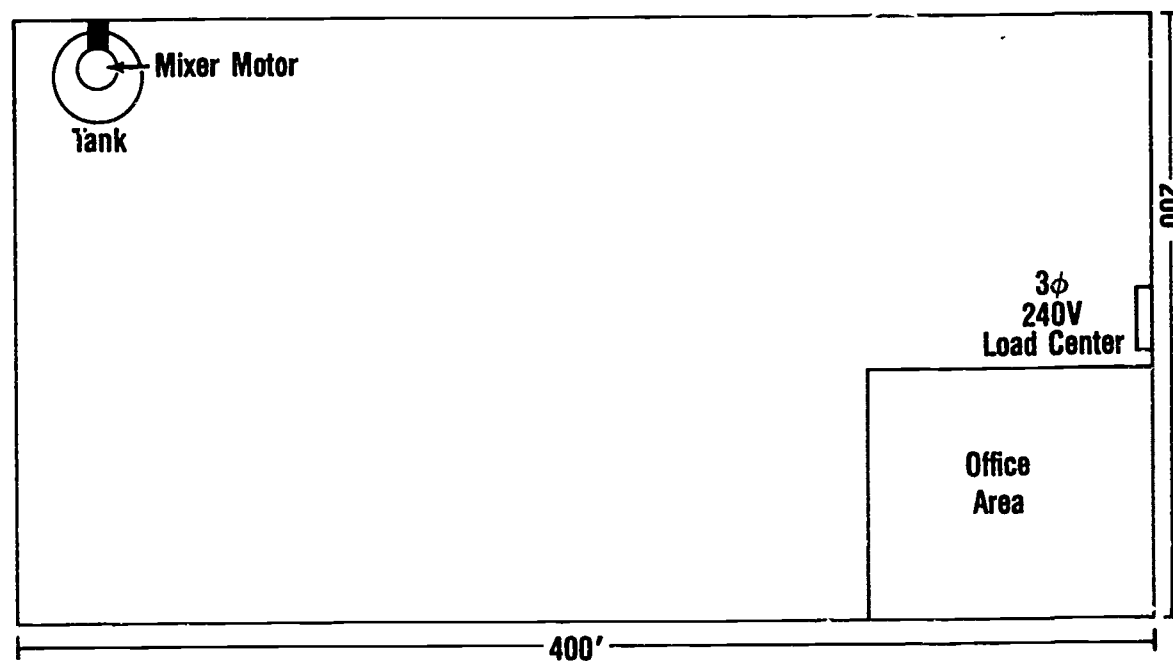
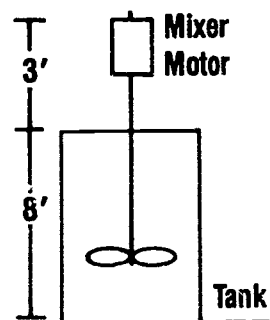
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MATERIAL ▶

LABOR ▶

## Detail



SCENARIO #2

680

681

## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #3 — REVERSING APPLICATIONS

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

**PART I: Evaluation**

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	— 30 Pts.
Conformity to Code	— 25 Pts.
Workmanship	— 20 Pts.
Time	— 25 Pts.
Technical Report	— 100 Pts.

Start Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total

**SCENARIO #3****PART II: Problem**

A call has just come into the dispatcher of your electrical contracting firm. The customer has requested that you install a control to reverse the rotation of a large fan located in the gable end of his automotive repair shop. It will be used to exhaust fumes, and to bring in fresh air. The customer wants two control stations, one located directly below the fan, the other in the office. The fan motor is a 3 $\phi$ , 3 HP 208 volt unit. The owner has requested that you prepare a proposed cost figure before doing the job. He has furnished you with a rough drawing of his building for bidding purposes. The building is a wooden structure, no ceilings in the shop area, and the interior walls of the shop are covered with 1/2" plywood. The fan is 17 feet above the floor.

TIME LIMIT \_\_\_\_\_

583

# SCENARIO #3

## ELECTRICAL PRICING SHEET

JOB
WORK

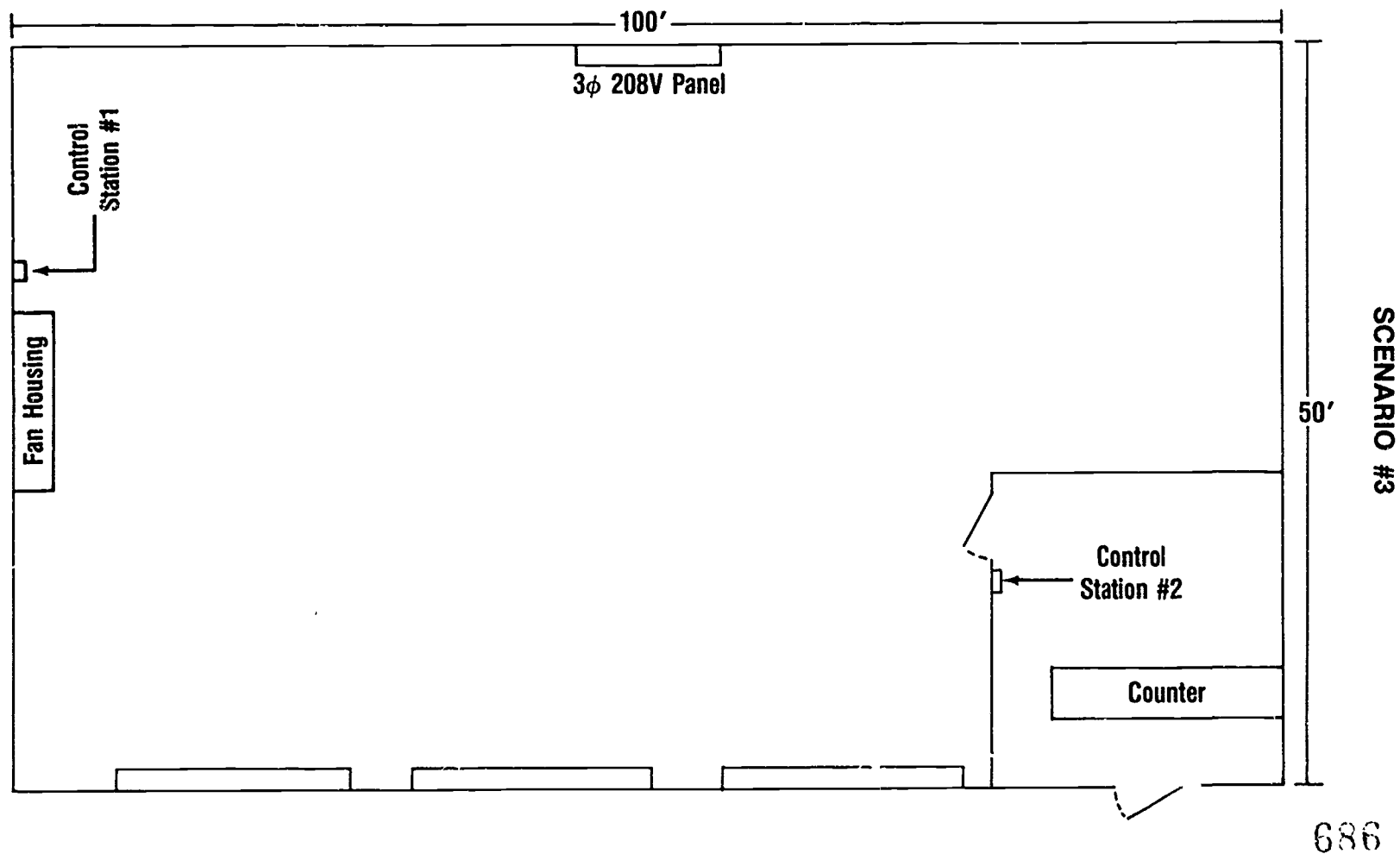
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SHEET NO	OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

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## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #4 — OIL FIELD APPLICATIONS

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

**PART I: Evaluation**

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	— 30 Pts.
Conformity to Code	— 25 Pts.
Workmanship	— 20 Pts.
Time	— 25 Pts.
Technical Report	— 100 Pts.

Start Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total



**SCENARIO #4****PART II: Problem**

Wildcat Oil Company, a steady customer, has requested that you install a 480 volt, 5 HP, 3 $\phi$  motor on a small pumping unit. This job will include the complete rebuilding and rewiring of a Cutler Hammer Pump Panel. Remember, when wiring a pump jack it is necessary to ground your equipment at the wellhead to eliminate any difference of potential. The job will not require a material list, however, your technical report must list the overload and overcurrent protection requirements.

TIME LIMIT \_\_\_\_\_

## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #5 — REVERSING ALTERNATIVES

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

#### PART I: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	— 30 Pts.
Conformity to Code	— 25 Pts.
Workmanship	— 20 Pts.
Time	— 25 Pts.
Technical Report	— 100 Pts.

Start Time \_\_\_\_\_ Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_ Instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total

**SCENARIO #5****PART II: Problem**

A meat processing plant has an overhead chain conveyor used to transport halves of beef from the cutting room to the cooler. Occasionally it is necessary to run the conveyor in reverse. Since this happens only a few times a month the owner does not want to go to the expense of installing a reversing starter. A drum switch would be the perfect alternative. The conveyor already has a motor starter and a start/stop station in place. Your job is to install the drum switch to reverse the motor. It will be necessary to check the overcurrent and overload protective devices to assure they are of the proper size. This job is cost plus so you must list all materials used as well as hours on the job.

TIME LIMIT \_\_\_\_\_

## SCENARIO #5

## ELECTRICAL PRICING SHEET

JOB	
WORK	

ESTIMATE NO	
SHEET NO	OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

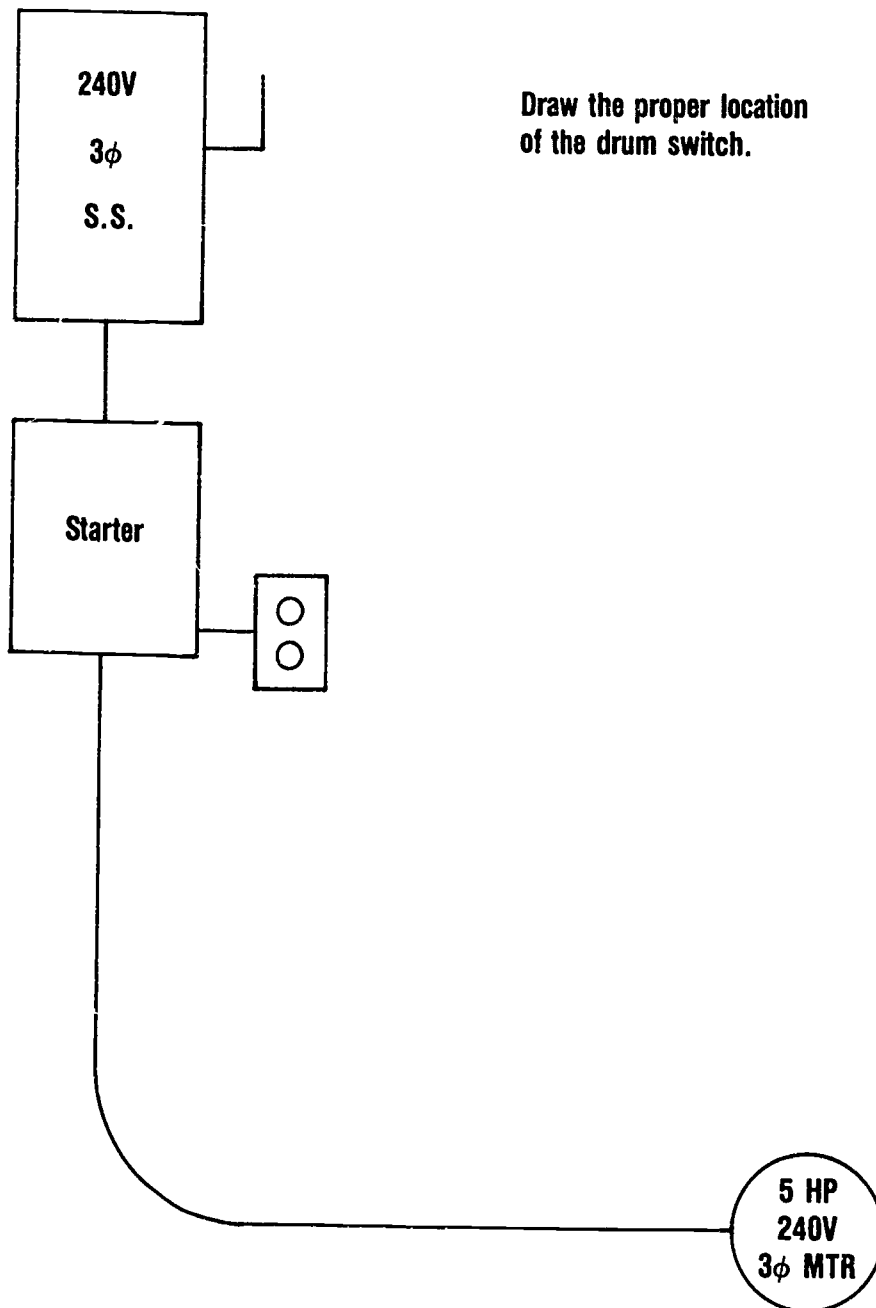
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## MATERIAL ▶

**LABOR** ▶

## SCENARIO #5



## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #6 — LIMITATION OF MOVEMENT

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

**PART I: Evaluation**

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	— 30 Pts.
Conformity to Code	— 25 Pts.
Workmanship	— 20 Pts.
Time	— 25 Pts.
Technical Report	— 100 Pts.

Start Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total

**SCENARIO #6****PART II: Problem**

A welding shop has just gotten a contract to build pressure vessels. Since these items are so large, it has become necessary to cut a larger door in the side of their metal building. The door is so large that it is impossible to use an overhead door. This one will run on a track and slide along the wall. Your job is to install the electrical power and control circuits. You will be competing for the job with several other electrical contractors. You visit the shop and make a sketch of the building, panel location, and door location. This sketch will be used for bidding purposes.

You must install limit switches to limit the travel of the door when opening or closing. Remember, when the door is open fully and against the limit switch, you must be able to close it or vice versa.

TIME LIMIT \_\_\_\_\_

## SCENARIO #6

## ELECTRICAL PRICING SHEET

JOB
WORK

ESTIMATE NO.	
SHEET NO.	OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

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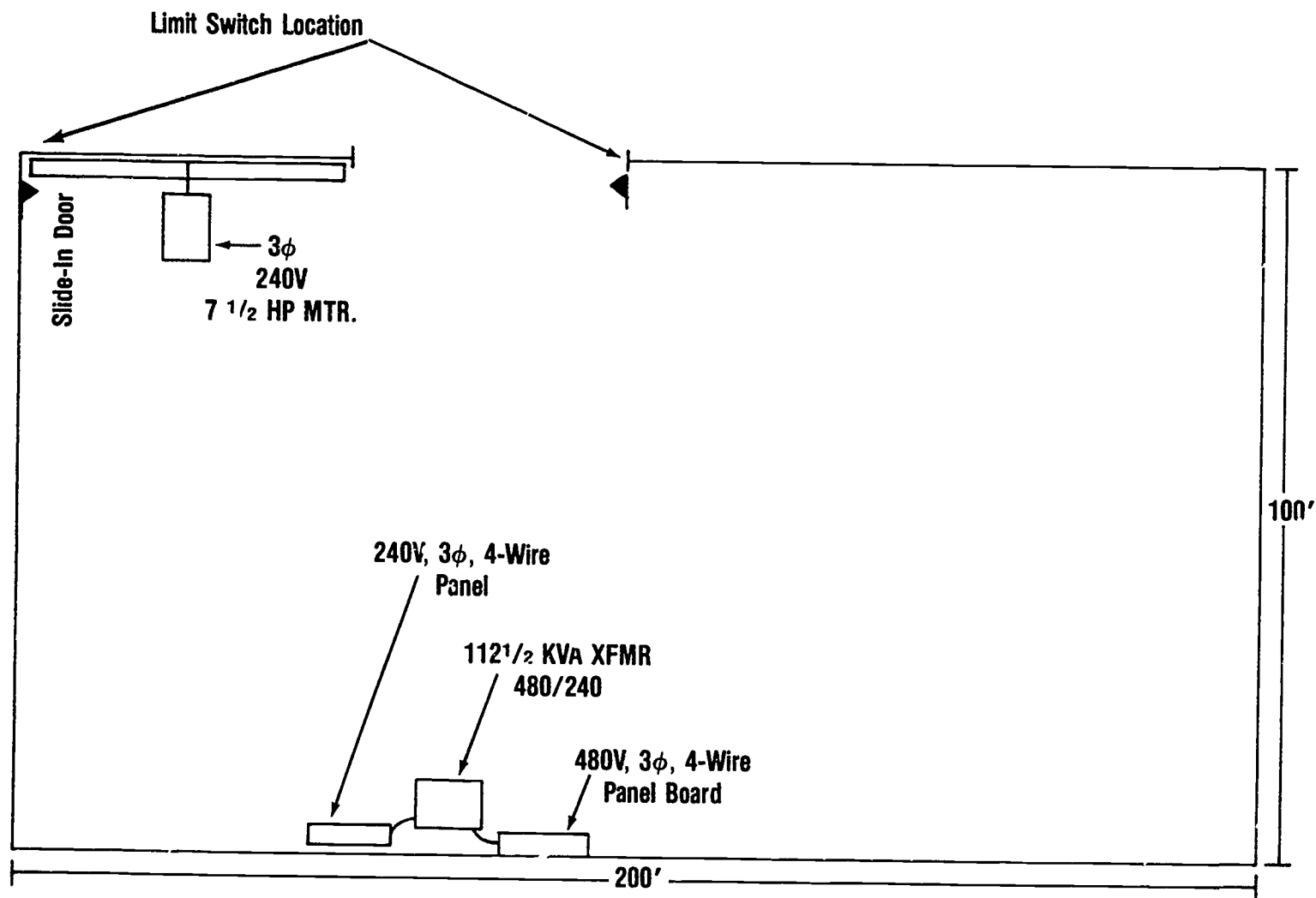
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LABOR ►

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## SCENARIO #6



636

637

## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #7 — BACK SPIN PROTECTION

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

**PART I: Evaluation**

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	— 30 Pts.
Conformity to Code	— 25 Pts.
Workmanship	— 20 Pts.
Time	— 25 Pts.
Technical Report	— 100 Pts.

Start Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total

**SCENARIO #7****PART II: Problem**

You have been contacted by the city water department. It seems as if they have come across a problem that is typical of submerged pumps in deep wells. When the water pressure in the tank is to a point to allow the "down hole" pump to shut down, the water begins to flow back down the hole forcing the pump's impeller to spin in reverse. If the pressure drops to a point to call for the pump to start while this "backspin" is in progress, the pump motor can be severely damaged.

Your job is to correct this problem using your knowledge of motor controls and time delay systems. The pump motor is a 100 HP, 480 volt, 3 phase unit. Upon arrival at the job site you discover that the motor starter is too small. The director of the water department approves a work order to change the starter while the pump is out of operation.

The conductors feeding the starter and the motor are of the proper size. The existing controls consist of a murphy switch at the top of the tank, to shut the pump down and a murphy switch at the bottom of the tank to start the pump. (See attached drawings.)

You will be competing with several contractors for the job so a bid will be necessary.

TIME LIMIT \_\_\_\_\_

## SCENARIO #7

## ELECTRICAL PRICING SHEET

JOB _____
WORK _____

ESTIMATE NO. _____	
SHEET NO. _____	OF SHEETS _____

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

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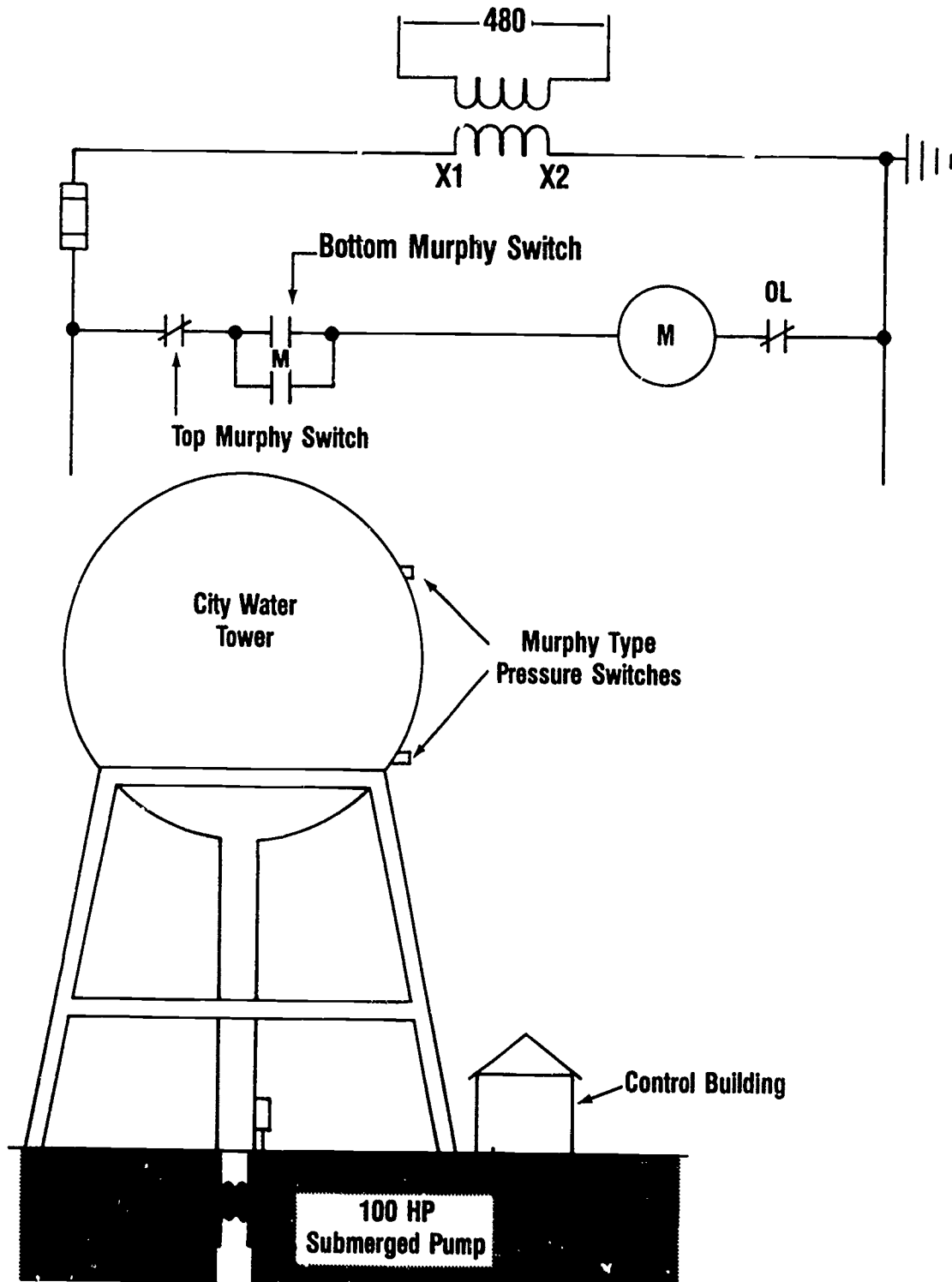
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**SCENARIO #7****Existing Controls**

## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #8 — HAZARDOUS MIXING

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

#### PART I: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	— 30 Pts.
Conformity to Code	— 25 Pts.
Workmanship	— 20 Pts.
Time	— 25 Pts.
Technical Report	— 100 Pts.

Start Time \_\_\_\_\_ Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_ Instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total

**SCENARIO #8****PART II: Problem**

A chemical tank farm has requested you to design and build a delay system for its 3 inch main pump. The pump is used to load trucks (in CW rotation), and to unload trucks (in CCW rotation). In order to avoid any "back-spin" damage to the motor, you have been asked to design and build a system to delay the start of the motor in either direction, after the stop button has been depressed.

The pump and controls existing are:

2-forward/reverse/stop stations

1-3 phase reversing square "D" starter

You must also add a pilot light to indicate the system is running.

Include a complete material list of the necessary items to complete the job.

TIME LIMIT \_\_\_\_\_

# SCENARIO #8

## ELECTRICAL PRICING SHEET

JOB _____
WORK _____

ESTIMATE NO. _____	
SHEET NO. _____	OF SHEETS _____

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

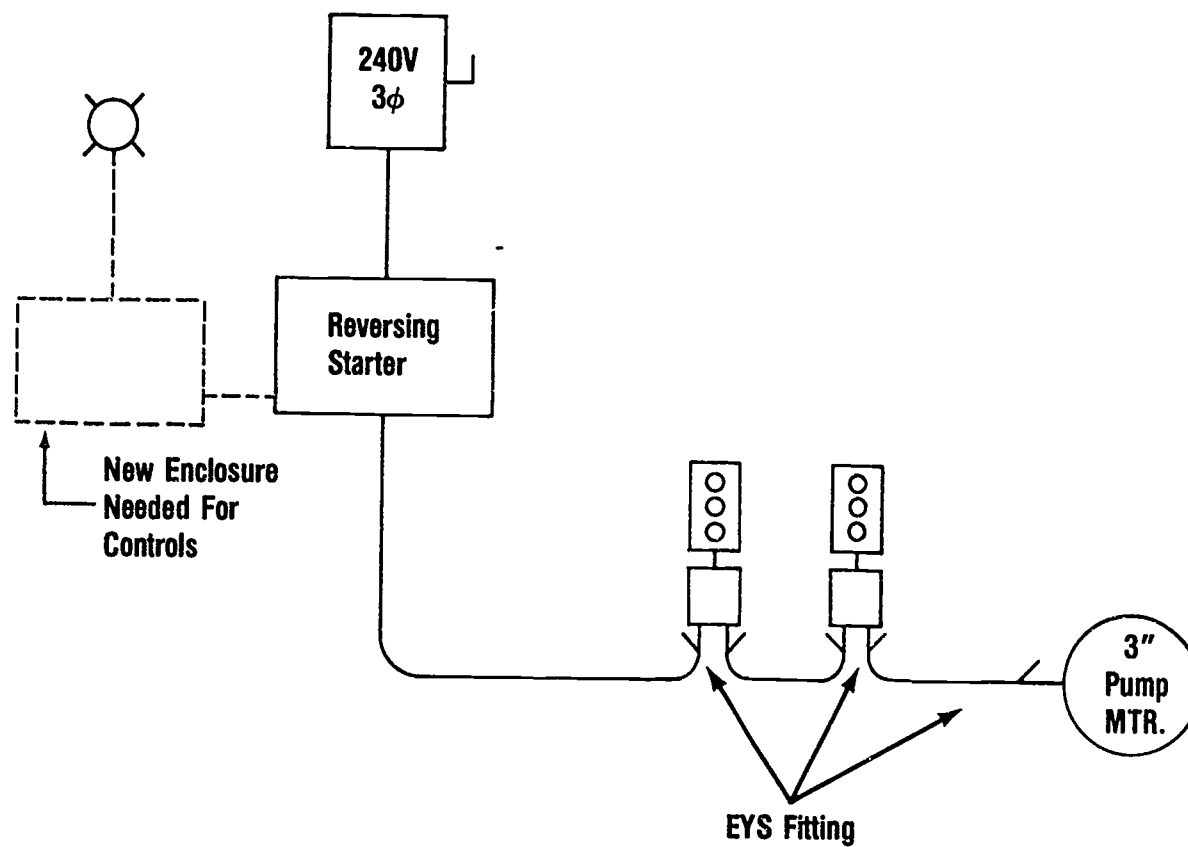
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## One Line Diagram



SCENARIO #8

705

706

## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #9 — SEQUENTIAL STARTING

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

**PART I: Evaluation**

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	—	30 Pts.
Conformity to Code	—	25 Pts.
Workmanship	—	20 Pts.
Time	—	25 Pts.
Technical Report	--	100 Pts.

Start Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_

Instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total

**SCENARIO #9****PART II: Problem**

A small aluminum processing company has asked you to install a start-up system in their plant that will allow for an orderly start-up of all equipment in a timed sequential order. As an electrician you welcome the opportunity for such a challenge. There are seven (7) pieces of equipment that must be included in the start-up.

1. Feed conveyor
2. Shaker #1
3. Grinder
4. Shaker #2
5. Process conveyor #1
6. Process conveyor #2
7. Waste conveyor

Upon actuation of the start button the feed conveyor will immediately start. A red light will come on to warn all personnel.

One minute later Shaker #1 and #2 will start.

Forty seconds later the grinder will start.

One minute later the process conveyors will start.

Thirty seconds later the waste conveyor will start.

When the stop button is depressed all systems will stop. When all systems have ceased to operate an alarm will sound for fifteen seconds.

Please design a ladder diagram of your control system and submit it with your written report to your instructor for approval before constructing the control system.

TIME LIMIT \_\_\_\_\_

## SCENARIOS SPECIAL SUPPLEMENT

### SCENARIO #10 — SEQUENTIAL SHUTDOWN

NAME \_\_\_\_\_ SCORE \_\_\_\_\_

#### PART I: Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report.

Circuit Design	— 30 Pts.
Conformity to Code	— 25 Pts.
Workmanship	— 20 Pts.
Time	— 25 Pts.
Technical Report	— 100 Pts.

Start Time \_\_\_\_\_ Instructor's Initials \_\_\_\_\_

Completion Time \_\_\_\_\_ instructor's Initials \_\_\_\_\_

Possible Pts.	Pts. Deducted/Reason	Pts. Earned/Comments
Design 30		
Code 25		
Workmanship 20		
Time 25		
		Total Pts. Earned
Technical Report 100		Total Report Pts. Earned
		Grand Total

**SCENARIO #10****PART II: Problem**

In Problem #9 you designed and built a system for a timed sequential start-up of an aluminum processing plant. In almost all cases, if a timed sequential start-up is required, a time sequential shut-down is also necessary. Consider the following:

**DEPRESS START**

1. Waste conveyors start — 30 second delay
2. Process conveyor 2 starts — 30 second delay
3. Process conveyor 1 start — 30 second delay
4. Shaker 2 starts — 1 minute delay
5. Grinder starts — 1 minute delay
6. Shaker 1 starts — 45 seconds delay
7. Feed conveyor starts

**DEPRESS STOP**

1. Red pilot light energizes and feed conveyors stop — 1 minute delay
2. Shakers 1 and 2 shut down — 40 second delay
3. Grinder shuts down — 1 minute delay
4. Process conveyors shut down — 30 second delay
5. Waste conveyors shut down and alarm sounds for 15 seconds.

Please complete the ladder diagram of your system with your written explanation and submit these to your instructor for approval before building the system.

TIME LIMIT \_\_\_\_\_