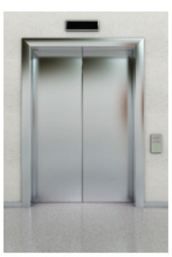

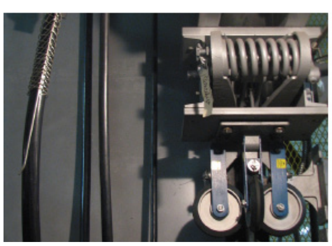

Elevator: Electrical Systems

Course 214

PARTICIPANT GUIDE

Transit Elevator/Escalator Maintenance Training Consortium

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Elevator Specific Electrical Systems

Participant Guide

Transit Elevator/Escalator Maintenance Training Consortium

COURSE 214

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LIST OF FIGURES

HOW TO USE THE PARTICIPANT GUIDE

Purpose of the Course

The purpose of the *Elevator:Electrical Systems* course is to assist the participant in demonstrating a working knowledge of the way a transit elevator's electrical systems work. A very introductory look is also taken at maintenance of a transit traction elevator. This will be covered more in depth in a later course.

Approach of the Book

Each course module begins with an outline, a statement of purpose and objectives, and a list of key terms. The *outline* will discuss the main topics to be addressed in the module. A list of *key terms* identifies important terminology that will be introduced in this module. *Learning objectives* define the basic skills, knowledge, and abilities course participants should be able to demonstrate to show that they have learned the material presented in the module. A list of *key terms* identifies important terminology that will be introduced in each course module.

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Module 1

GENERAL ELECTRICAL SAFETY PROCEDURES

Outline

Purpose and Objectives

The purpose of this module is to provide the participants with a basic knowledge of safety procedures and demonstrate "best practice" safety behaviors including proper selection of personal protective equipment (PPE) during the testing and maintenance of vertical transportation electrical systems.

Following the completion of this module, the participant should be able to complete the objectives with an accuracy of 75% or greater:

- Identify safety oversight organizations
- Discuss and list the safety rules for avoiding electrical shock
- Determine dangerous levels of electrical current as it relates to the human body.
- Describe several causes of electrical burns.
- Describe the types of Personal Protective Equipment (PPE) which may be required when working on live equipment
- Explain shock protection boundaries of energized electrical equipment
- Demonstrate Lockout/Tagout Procedures
- Explain the reason for grounding of electrical equipment.
- Identify general safety practices
- Identify effective emergency response actions

Key Terms

- Approach Boundaries
- Arc Blast
- Arc Flash
- ASME A17.1
- Elevator Industry Employees' Field Safety Handbook
- LOTO
- National Electrical Code (NEC)
- National Fire Protection Association (NFPA)
- Occupational Safety & Health Administration (OSHA)
- Personal Protective Equipment (PPE)
- Qualified person
- Related agency Standard Operating Procedures (SOP and Practices
- Transit Agency Safety Handbook
- Zero Energy State

1-1 OVERVIEW

An estimated 30,000 non-fatal electrical shock accidents occur each year. Over 200 people die from electrocution each year on average in the United States. Electrocution remains the fourth (4th) highest cause of industrial fatalities with approximately 3000 reported flash burn incidents reported annually along with approximately 350 deaths.

Safety with regards to electricity in the maintenance of elevators is critical. This module will review oversight organizations connected to electrical safety, basic electrical safety principles, electrical physiological effects, PPE, safe practices, and emergency response as related to electrical hazards and problems.

1-2 SAFETY OVERSIGHT ORGANIZATIONS

Several organizations exist and operate to ensure the safety of workers in the United States. Organizations and handbooks overseeing and defining safety as related to electricity along with other hazards are described below and include the National Fire Protection Association (NFPA), the National Electrical Code, Occupational Safety and Health Administration (OSHA), The Elevator Industry Employees' Field Safety Handbook, and American Society of Mechanical Engineers (ASME). Technicians in the elevator industry should be knowledgeable of and reference these organizations as needed.

- The **National Fire Protection Association (NFPA)** is an independent U.S. voluntary-membership nonprofit (tax-exempt) organization whose mission is to reduce the worldwide burden of fires and other hazards on the quality of life by providing and advocating scientifically-based consensus codes and standards, research, training and education. NFPA is an American organization charged with creating and maintaining minimum standards and requirements for fire prevention and suppression activities, training, and equipment, as well as other life-safety codes and standards. This includes the creation of NFPA 70 –National Electrical Code (NEC). The code is purely advisory as far as the NFPA is concerned and is made available for both public and private use in the interest of life and property protection. The NEC has been adopted by the 50 states and local jurisdictions for regulatory and standardization purposes.

- The **National Electrical Code (NEC) [NFPA 70]** states the requirements for safe electrical installations into a single, standardized source, and is part of the National Fire Codes series published by the National Fire Protection Association (NFPA). While not a U.S. law, NEC use is commonly mandated by state or local law. The "authority having jurisdiction" inspects for compliance with these minimum standards. ("National Electrical Code" and "NEC" are registered trademarks of the NFPA). Article 620 covers the electrical standards for elevators, dumbwaiters, escalators, moving walks, platform lifts, and stairway chairlifts.*(cite: http://www.nfpa.org)*

- The **Occupational Safety and Health Administration (OSHA)** is an agency of the United States Department of Labor. OSHA regulations are often described as the "Shall" and NFPA 70E (NEC) as the "How" for electrical safety in the workplace. OSHA's interpretation is: "Industry consensus standards, such as NFPA 70E, can be used by employers as guides to making the assessments and equipment selections required by the standard. Similarly, in OSHA enforcement actions, they can be used as evidence of whether the employer acted reasonably."

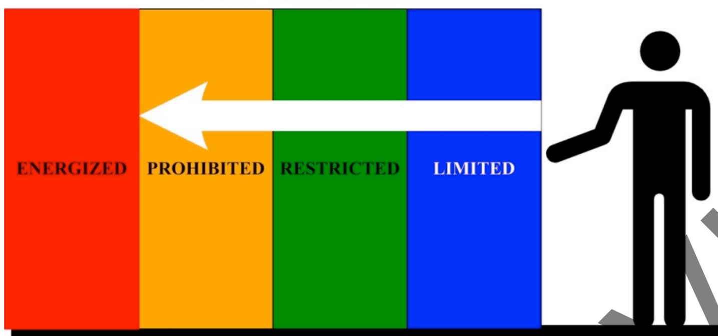
- The **Elevator Industry Employee's Field Safety Handbook** is intended to promote safety on the job through adherence to OSHA safety regulations affecting the elevator/escalator industry and is to be used as a supplement to the transit agencies safety program. Section 5 covers electrical safety, section 6 cover proper use of jumpers and section 7 covers lockout and tagout.

- The **American Society of Mechanical Engineers (ASME)** ASME is one of the oldest standards-developing organizations in the world. One of the standards it produces is the A17.1 Safety Code for Elevators and Escalators. The Code is written in a form that is suitable for enforcement by state, municipal, and other jurisdictional authorities; and as such, the text is concise, without examples or explanations. For these reasons, ASME determined that a handbook would be useful to augment the Code by providing a commentary on the Code requirements. This Handbook contains the rationale for Code requirements; explanations, examples, and illustrations of the implementations of the requirements; plus, excerpts from other nationally recognized standards which are referenced by the Code. This information is intended to provide the users of the ASME A17.1 Code with a better understanding of, and appreciation for, the requirements contained in the Code. *(cite: http://www.asme.org)*

APPROACH BOUNDRIES FOR TO LIVE PARTS SHOCK PROTECTION
Table Voltage Range - < 50 Volts to 36000 Volt

Nominal System Voltage Range, Phase to Phase	**LIMITED APPROACH BOUNDRY** **Exposed Movable Conductor**	**Exposed Fixed Circuit Part**	**RESTRICTED APPROACH BOUNDRY**	**PROHIBITED APPROACH BOUNDRY**	**FLASH PROTECTION BOUNDARY**
Less than 50	Not Specified	Not Specified	Not Specified	Not Specified	On the subject of arc-flash, NEC requires a flash hazard analysis. This analysis shall determine a flash protection boundary and the personal protective equipment (PPE) requirements when working within that boundary
50 to 300	10 feet, 0 inches	3 feet, 6 inches	1 foot, 0 inches	0 feet, 1 inch	
301 to 750	10 feet, 0 inches	3 feet, 6 inches	2 feet, 2 inches	0 feet, 7 inches	
750 to 15000	10 feet, 0 inches	5 feet, 0 inches	2 feet, 7 inches	0 feet, 10 inches	
15000 to 36000	10 feet, 0 inches	6 feet, 0 inches	2 feet, 9 inches	1 foot, 5 inches	

LIMITS OF APPROACH
LIMITED APPROACH BOUNDARY



The closest distance an "unqualified" person can approach, unless escorted by a "qualified" person

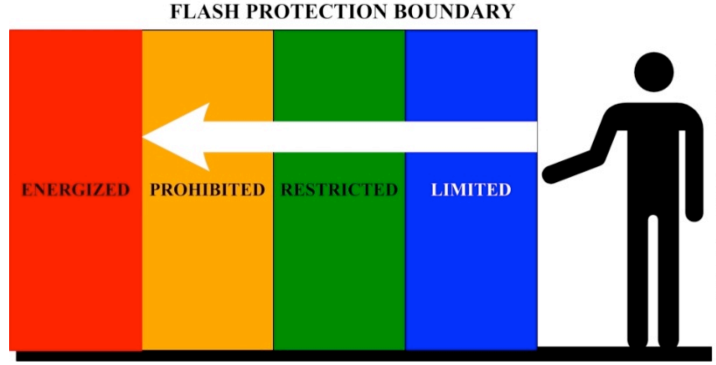
LIMITS OF APPROACH
RESTRICTED APPROACH BOUNDARY

The closest distance to exposed live parts a "qualified" person can approach without the proper PPE and tools. To cross this boundary the qualified person must wear PPE and have proper tools

LIMITS OF APPROACH
PROHIBITED (SHOCK) BOUNDARY

Crossed **ONLY** by a "qualified" person, which when crossed by a body part or object, requires the same protection as if direct contact was made with the live part.

LIMITS OF APPROACH
FLASH PROTECTION BOUNDARY



The distance from exposed live parts within which a person could receive a second degree burn if an arc flash were to occur.

Arc flash PPE is required within this boundary.

Distance may be less than or greater that shock protection boundaries

Module 2

INTERPRETING ELECTRICAL DIAGRAMS

Outline

5-1 Electrical Symbols
5-2 Basic Single Speed Control
5-3 Elevator Car Controls
5-4 Speed Control Diagrams
5-5 Advanced Elevator Control Diagrams
5-6 Summary
5-7 Review Exercises

Purpose and Objectives:

The purpose of this unit is to explain and discuss the principles of interpreting elevator electrical diagrams. The key concepts discussed will aid the trainee in their future applications of elevator concepts and terminology.
Following the completion of this module, with the aid of an elevator electrical diagram, the trainee should be able to complete the following tasks with an accuracy of 75% or greater:

- Locate and describe the function of specific components in an elevator control circuit.
- Identify the sources of both AC and DC power within the system
- Locate and identify the safety circuit devices.
- Locate and identify various control devices
- Identify and describe the car leveling circuit
- Describe the sequence of operation of a hydraulic elevator
- Describe the sequence of operation of a traction elevator

Materials, Training Aids and References

1. Elevator World Educational Package and Reference Library – Volume 1 – Elevator Control & Operation – Elevator World – pages IV-1 through IV-21; IV-29 through IV52; IV-58 through IV-75.
2. Elevator Maintenance – Elevator World – 2003 – ISBN 1-886536-27-9, pages 87- 130

Lesson Plan

Instructional Outline	Courseware Reference	Notes
2-1 Electrical Symbols • Locate and describe the function of specific components in an elevator control circuit	Volume 1 – Elevator Control & Operation: pages IV-4 and IV-5 Elevator Maintenance: Appendix A Pages 109-126	Use this text symbols as a reference for the diagram discussions. Use this text symbols list as a reference for different elevator manufacturers.
2-2 Basic Single Speed Control • Identify the sources of both AC and DC power within the system • Locate and identify the safety circuit devices.	Volume 1 – Elevator Control & Operation Lessons I thru VI pages IV-1 thru IV-21 Elevator Maintenance: Pages 87-88, 94	These 6 lessons discuss a simplified elevator control diagram (C-0303-AA) Complete all review questions for each lessons. General discussion of diagrams, safety string, brake circuits, and timing circuits
2-3 Elevator Car Controls • Locate and identify various control devices • Identify and describe the car leveling circuit	Volume 1 – Elevator Control & Operation Lessons VIII thru XI pages IV-29 thru IV-36	These 4 lessons discuss call circuitry, direction control, door control starting and stopping of the car using diagram (C-1238-A) Complete all review questions for each lessons

Instructional Outline	Courseware Reference	Notes
2-4 Speed Control Diagrams • Locate and identify the safety circuit devices. • Locate and identify various control devices • Identify and describe the car leveling circuit	Volume 1 – Elevator Control & Operation Lessons XII thru XVII pages IV-39 thru IV-52	These 5 lessons disclose safety circuits, interlocks, limits, stop switches, call buttons, governor contacts, speed control ,leveling, and door operation using diagram (C-1272-B)
2-5 Advanced Elevator Control Diagrams • Locate and identify the safety circuit devices. • Locate and identify various control devices • Identify and describe the car leveling circuit • Describe the sequence of operation of a hydraulic elevator • Describe the sequence of operation of a traction elevator	Volume 1 – Elevator Control & Operation: Lessons XX thru XXX pages IV-58 thru IV-75 Handout: Sequence of Operation for WMATA Hydraulic Elevator Controllers and Electric Traction (see attached)	These 10 lessons discloses troubleshooting techniques and speed control circuitry using diagram (C-1469-A) This is a simplified discussion of the sequence of operation for a standard hydraulic elevator and electric traction elevator systems (Line Numbers refer to Control Drawing Number E841801C)
2-6 Summary		

Module 3

ELECTRICAL SYSTEMS TESTING

Outline

Purpose and Objectives:

The purpose of this module is to introduce the participant to safe elevator electrical testing methods on both elevator power and controls circuits using the Motion Control Engineering (MCE) controller HMC-1000-PHC Programmable Hydraulic Controller as an illustrative model.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 75% or greater:

- Identify safe troubleshooting methods for elevator electrical systems.
- Perform electrical power measurements to confirm a fault condition using a schematic diagram.
- Perform electrical control measurements to confirm a fault condition using a schematic diagram.

Key Terms

- Control Circuit
- Dielectric Mat
- Door Zone (DZ)
- Derating Ampacity
- Effective Communications
- Input Signals
- Pre-job Briefing
- Line side
- Load side
- Output Signals
- Pre-job Briefing
- Primary side
- Power Circuit
- Output Signals
- Secondary Side

3-1 OVERVIEW

Electrical system testing is often required in diagnosing and troubleshooting elevator systems. Knowing how to test electrical systems safely as well as basic concepts of electrical testing will be covered in this module.

3-2 INTRODUCTION TO TESTING ELEVATOR ELECTRICAL SYSTEMS

Safe Troubleshooting Methods for Elevator Electrical Systems

In response to an elevator shutdown you will be required to perform various electrical tests as part of the troubleshooting and diagnostics process. There are certain procedures that should be followed prior to and during the testing process which will ensure not only your safety, but also the safety of the general public as well as other participants in the testing process. This should include, but is not limited to, the following:

- Effective Communications
- Following Established Safety Procedures
- Surveying The Worksite

Effective Communications

During any troubleshooting scenario, it is imperative that you maintain communication between yourself and all others involved in the process. Two very important steps to take prior to beginning work are:

1. Notify Station Management

Upon your arrival to the work site, notify Station Management of what your intentions are regarding the elevator and the time they can expect that it will be returned to service. It is important that you state clearly what you will be doing, approximately how long the job will take, which areas of the station will be affected as well as how you will notify them when the job is completed.

2. Conduct a Pre-job Briefing

One of the most important steps to be taken in job preparation is to conduct a Pre-Job Briefing. This is the time to discuss all aspects of the job and should include everyone that will be directly involved in the testing process. Items to discuss in the pre-job briefing include but are not limited to the following:

- Clearly define each person’s responsibilities.

- Clearly communicate an emergency plan of action in the event that something goes wrong.
- Take inventory to ensure that you have the tools and test equipment that are necessary to perform the job.
- Create and clearly communicate a plan of action regarding the steps you will be following during the testing process.

Follow Established Safety Procedures

Follow your Transit Authority's safety policies as well as the established procedures set forth in the *Elevator Industry Field Employee's Safety Handbook*. There may be situations where your Transit Authority's safety policy may not clearly state which Personal Protective Equipment (PPE) should be used while working on live electrical equipment such as Fire Resistive Clothing (FR). However, the *Elevator Industry Field Employee's Safety Handbook* does have specific language stating what type of clothing should be worn when troubleshooting live electrical circuits.

For example in the *Elevator Industry Field Employee's Safety Handbook 2005* - Section 5 Electrical Safety- 5.1 General Precautions states:

> **(b) THE FOLLOWING PERSONAL PROTECTIVE EQUIPMENT SHALL BE WORN WHEN TROUBLESHOOTING LIVE ELECTRICAL CIRCUITS:**
>
> - Long-sleeved natural-fiber or FR-rated shirts and pants, long-sleeved FR-rated coveralls or other company-approved arc-flash-hazard protection
> - Nonconductive safety glasses
> - EH-rated footwear or rubber mats
> - Clean leather gloves

In any case, it is important that you know your Transit Authority's safety policies as well as any applicable from the Elevator Industry Field Employee's Safety Handbook before you begin the job.

Worksite Survey

An important aspect of safe electrical troubleshooting is to inspect the worksite for any unsafe conditions that may exist prior to starting the job. This may include but is not limited to the following conditions:

- Exposed live wires and connections that may be easily contacted during testing
- Any water or dampness on the floor in the immediate vicinity of the controller
- Oil spills or any other potentially hazardous material
- The presence of a dielectric mat shown in Figure 3.1 which acts as an insulator between you and earth ground.

3-3 TESTING AN ELEVATOR'S ELECTRICAL POWER SYSTEM USING A SCHEMATIC DIAGRAM

There are many ways that an elevator can shut down due to something of an electrical nature, such as a malfunction in the controller's power circuit. For the purposes of this exercise we are going to use the Motion Control Engineering (MCE) Programmable Hydraulic Controller Model HMC-1000-PHC Series to test the power circuit to determine why power was lost to the entire control circuit. (See Figure 3.2) We will be using various sections of the schematic diagrams that accompany the Controller Manual.

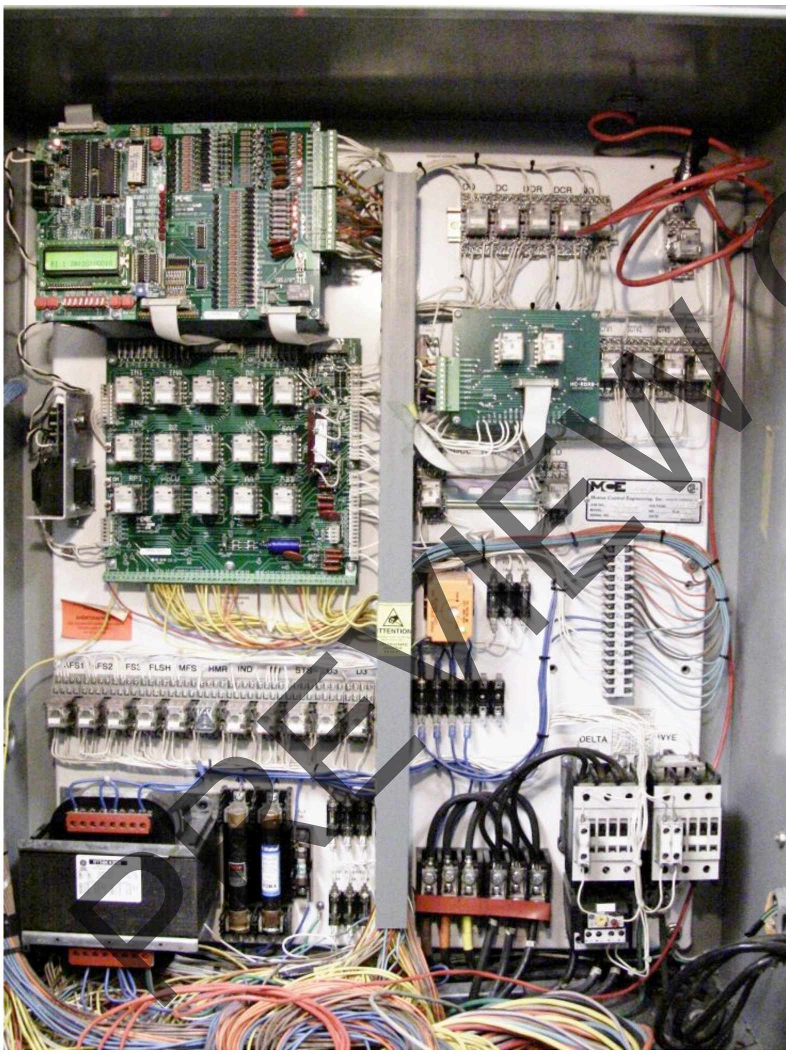


Figure 3.2 MCE Programmable Hydraulic Controller Model HMC-1000-PHC - Courtesy of SEPTA

Module 4

WIRING SYSTEMS (NEC CODE COMPLIANCE)

Outline

Purpose and Objectives:

The purpose of this module is to review and discuss the different types of conductors and conduits, and installation techniques related to elevator maintenance.

Following the completion of this module, the trainee should be able to complete exercises related to these objectives with an accuracy of 75% or greater:

- Use the correct tables from the National Electrical Code to properly select and size conductors
- Determine conductor voltage rating by the conductor insulation code
- Select the proper size and type of conduit according to electrical code
- Discuss the methods used for the proper installation of conduit and raceways.
- Discuss electrical code requirements with regard to an elevator traveling cable

Materials, Training Aids and References

1. Electrical Systems based on the 2011 NEC, Michael l. Callanan & Bill Wusinich, ATP Publishing.

2. National Electrical Code (2011): Article 620.21(Elevator Wiring) and Article 620.41 (traveling cable)

Lesson Plan

Instructional Outline	Courseware Reference	Notes
4-1 Conductors & Overload Protection • Use the correct tables from the National Electrical Code to properly select and size conductors • Determine conductor voltage rating by the conductor insulation code	Electrical Systems-Text, Chapter 5, Conductors and Overcurrent Protection, p 154-166, Supplemental Text (see attached)	Review chapter competencies, summarizing information presented in the chapter. Have learners complete review questions for chapter 5. Review answers with participants. Evaluate mastery of each competency required.
4-2 Wiring Methods • Select the proper size and type of conduit according to electrical code • Discuss the methods used for the proper installation of conduit and raceways.	Electrical Systems-Text, Chapter 7, Wiring Methods p 249-277 and , Chapter 9, Wiring Materials - Switches, Switchboards, and Panelboards, p 329-337	Review chapter competencies, summarizing information presented in the chapter. Have participants complete review questions for chapters 7 & 9. Review answers with learners. Evaluate mastery of each competency required.
4-3 NEC Code Compliance • Discuss the methods used for the proper installation of conduit and raceways. • Discuss electrical code requirements with regard to an elevators traveling cable.	National Electrical Code (2011) Article 620.21(Elevator Wiring) and 620.41 (traveling cable)	Review all sections of Article 620 with the main focus on section 3 (Wiring) and section 5 (Traveling Cables)
4-4 Summary		Review all course objectives with the participants

National Electrical Code Explanations: Conduit Fill

What's the rule on conduit fill? The answer is there are many rules!

First, let's expand things a bit. Conduit is a specific kind of raceway. So, we're really talking about *raceway* fill--whether that raceway is conduit, EMT, NMT or some other kind of raceway. The NEC index cross-references "conduit fill" as *conductor fill*.

The basic NEC reference is 300.17. The NEC does not provide a specific fill number, here. It merely says the number and size of conductors can't be more than will permit heat dissipation and the ready withdrawal of conductors without damaging them.

Notice, I said the *basic* NEC reference. Just below 300.17, you'll find an FPN. This one happens to be highly detailed. The fill requirements are specified by first by raceway type in 342.22 - 388.22. Then, they are specified by application as follows:

- Underfloor, 390.5
- Fixture wire, 402.7
- Theaters, 520.6
- Signs, 600.31(C)
- Audio signal processing, 640.23 and 640.24
- Class I, II, III circuits, Article 725
- Fire alarm circuits, Article 760
- Fiberoptics, Article 770.

Now, you can simplify all of this by understanding something the FPN doesn't tell you. Most of these various references tell you to use Table 1 of Chapter 9. It's probably left out of the FPN to avoid duplication of information (the result of which is invariably conflict and confusion), and to allow each standards committee to decide whether to refer to Table 1 or not. Article 770, for example, says that Table 1 does *not* apply [770.12(A)].

Going to Table 1, Chapter 9, we don't find a whole heck of a lot. One wire can fill only 53% of a raceway, and two wires can fill only 31%. And if you have more than 2 conductors in a raceway, the maximum fill is 40%.

That 40% is subject to further downward adjustment, though. The Authority Having Jurisdiction (AHJ) can require even less fill--so, use common sense. Read the FPN in Table 1 thoroughly. Don't assume that 50% fill is OK, because it's close. It's not close--it's over the limit. But don't assume 40% is always OK, either. Circumstances may dictate otherwise, and the NEC provides some examples on that point.

Some people get confused on which conductors count for raceway fill. They all count. The confusion results from misapplying 310.15(B)(6) to raceway fill. But 310.15(B)(6) is about ampacity calculations, not raceway fill calculations. You exclude grounding or bonding conductor(s) when determining the number of current carrying conductors for purposes of selecting an ampacity table. But you don't exclude them from determining the raceway fill. Keep Articles 300 and 310 separate!

Do the math

Conduit fill requires calculation. In the past, this involved determining the circular mils for various conductors. Fortunately, the NEC now provides tables to reduce the amount of calculation in the field.

To determine how much wire you can run in a given raceway:

1. Find the raceway type and size you're running, in Table 4 of Chapter 9. The number you want is Total Area. This is expressed in square inches. Multiply by 0.4, and you'll know your total permissible wire fill for that raceway.
2. Find the wire type and size you're running, in Table 5 of Chapter 9. The number you want is approximate area. This is expressed in square inches.
3. Add the results of Step 2 for each wire you want to run as you go, and stop when you reach your total permissible wire fill for that raceway. Most likely, you'll stop before you reach it, as you are not allowed to exceed it.

To determine what size raceway you need for a given wire run:

1. Find the wire type and size you're running, in Table 5 of Chapter 9. The number you want is Approximate Area. This is expressed in square inches.
2. Perform Step 1 for each wire you want to run, and add the results as you go. The final total is your total wire area. Divide this number by 0.40, and you'll know your minimum raceway area.
3. Find the raceway type you're running, in Table 4 of Chapter 9. Look down the column until you find an area number that is greater than the minimum raceway area you calculated in Step 2. You must use a raceway at least this size.

Module 5

SAFETY CIRCUITS

Outline

Purpose and Objectives:

The purpose of this module is to explain and discuss the functions of elevator electrical safety circuit devices. The key concepts discussed will aid the trainee in their future applications of elevator concepts and terminology.

Following the completion of this module, given a scenario for an elevator safety circuit activation, the trainee should be able to complete the following tasks with an accuracy of 75% or greater:

- Explain the electrical function of specific devices of a safety circuit string
- Discuss circuit fault conditions as they relate to the safety circuit
- Identify the locations of safety circuit components

Materials, Training Aids and References

1. Elevator World Educational Package and Reference Library – Volume 1 – Elevator Control & Operation – Elevator World – pages IV-1 thru IV-21, IV-29 thru IV52, IV58 thur IV 75

2. Elevator Maintenance – Elevator World – 2003 – ISBN 1-886536-27-9, pages 94

3. Elevators 101- Elevator World – 2007 – ISBN 1-886536-73-2

4. ASME A17.1-2007: Table2.26.4.3.2

Lesson Plan

Instructional Outline	Courseware Reference	Notes
5-1 Safety Circuit Functions • Explain the electrical function of specific devices of a safety circuit string. • Discuss circuit fault conditions as they relate to the safety circuit	Volume 1 – Elevator Control & Operation Lessons II and III Elevator Maintenance: Appendix A Page 94	This provides a brief explanation of the electrical principles of the safety string. Explanation of the safety circuit string and schematic examples.
5-2 Safety Circuit Device Locations • Identify the locations of safety circuit components • Discuss circuit fault conditions as they relate to the safety circuit	Elevator Maintenance: Pages94 Elevators 101- pages-56,-58, 100-110 ASME A17.1-2007 SIL for Electrical Protective Devices and Other Electrical Safety Functions	Examples of locations for doors and gate safety devices Table 2.26.4.3.2 Listing of safety devices, by name, function, code requirement, and Safety Integrity Level (SIL)

5-3 SUMMARY

The following text is used with kind permission from ©Schindler Elevator Company.

Elevator Safety Features

Today's elevator systems incorporate a wide variety of features designed to help reduce the chances of accidents and give passengers a quick, dependable ride.

There are two basic types of elevator systems, "Traction" and "Hydraulic." Because they differ in the way they operate, some of their safety systems differ as well.

Traction Elevators

Most elevators which travel six or more floors are "traction" design. Traction elevators are suspended by strong steel cables propelled by a hoisting machine. Counterweights help balance the load and make it easier for the machine to move the elevator. The steel cables are very strong, and can safely hold several times the weight of the elevator and its full load of passengers.

The safety brake, together with a speed-sensing governor, acts to stop an elevator if it should overspeed in the down direction. If an elevator overspeeds, the governor makes the safety grasp the rails on which the car travels, bringing the elevator to a safe emergency stop.

The door system on a modern elevator also includes several safety devices. Sensors detect passengers or objects in the door opening, preventing the continued closing of the doors. Older systems use mechanical "safety edges" which cause the doors to stop or retract when they make contact with a person or object. More modern systems use a large number of invisible light rays to detect people or objects in the doorway and reverse or stop the doors without having to make physical contact.

Door operators contain devices which limit the amount of closing force. Newer systems are better able to keep the closing force consistent even under unusual conditions such as the "stack effect" which can cause heavy air movement in elevator shafts.

Interlocks on the hoistway doors help assure that the elevator cannot leave a landing unless the doors are fully closed and secured. Should the doors be forced open, the interlock circuit will be broken, causing the elevator to immediately stop.

Various switches in the elevator shaft detect the presence of the car at certain stages of its journey. They initiate slowdowns and stops at the proper points, and help prevent over-travel in the up or down direction.

To discourage the very dangerous practice of passengers trying to open the door of a stalled elevator, door restraints can allow normal operation of the door when the car is near the floor level, but will restrict forcible movement of the door when the car is away from the floor.

The emergency evacuation hatch on most elevators is designed to be opened only from the outside, by trained emergency personnel. This too is intended to help prevent any passenger from gaining access to the dangerous elevator shaftway.

Buffers, located in the "pit" below the car, serve to cushion any unplanned travel below the lowest landing.

In the elevator cab you'll find several items to help increase safety. An emergency alarm switch will sound an alarm when activated by a passenger. In most elevators, an emergency telephone or intercom can serve as a link to assistance if the car should stall. And, in the event of a power failure, emergency lighting maintains illumination for hours. In some systems, emergency power is available to permit movement of the elevator and evacuation of the passengers.

In many elevator systems, a special fire emergency system has been installed. It may be manually activated, or may respond to smoke sensors in the building. Exact operation varies by local codes, but generally such systems return the elevator to the main floor, open the doors to allow passengers to exit, and make the elevators available to emergency personnel.

Hydraulic Elevators

Hydraulic elevators are propelled by a jack mounted below the elevator. A pump moves hydraulic oil into the jack, causing it to raise the elevator. For the down trip, valves control the oil's to return to the system's storage tank, safely lowering the elevator car.

Because of their bottom-supported design, hydraulic elevators do not utilize the type of safety brake found on traction elevators. However, for installations with older jack designs, Schindler has developed the LifeJacket® safety brake that can be added to existing elevators, offering an increased factor of safety in the remote chance of corrosion causing the rupture of the underground jack casing or piping.

Other systems on hydraulic elevators are essentially identical to those on traction systems, and have similar safety features

Module 6

CONTROL CIRCUITS

Outline

Purpose and Objectives:

The purpose of this module is to provide an overview of the basics of the elevator control systems and the electrical control diagrams found in transit agencies.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 75% or greater:

- Discuss the different types of control systems encountered in transit elevator systems
- Describe the control circuits to perform the functions of starting, controlling speed, direction, and stopping the motor a transit hydraulic elevator
- Describe the control circuits to perform the functions of starting, controlling speed, direction, braking, and stopping the motor on a transit traction elevator
- Trace and identify various controls, switches, and systems in a working transit hydraulic elevator system using an electrical diagram
- Trace and identify various controls, switches, and systems in a working transit traction elevator systems

Key Terms

- Car Operating Station (COS)
- Contactors
- Control Devices
- Control Circuit
- Control Relays
- Controller
- Governor
- Hallway Call Station
- Mainline Disconnect Switch
- Motor circuit
- Pit-Stop Switch
- Pilot Device
- Programmable Logic Controller (PLC)

6-1 OVERVIEW

Control Circuits are an important part of the elevator system for the effective operation of the system. In this module, control systems along with control circuits for traction and hydraulic elevators and their related electrical drawings will be covered.

6-2 CONTROL SYSTEMS

Control circuits for elevator systems are vital to the proper performance and protection of modern equipment. A complete **motor circuit** is usually divided into control and power systems. The power circuit includes the motor and therefore operates under higher voltage. On the other hand, the control part mostly contains the switching devices and typically operates under lower voltage.

The control devices are part of the Control System and circuitry. These control devices command the operation of the drive and braking motors via their open or closed contacts via a control current. Examples of control devices include the maintenance inspection station, pushbuttons, limit switches, sensors, and key switches. **Contactors** and **control relays** are devices that use electromagnetic induction to open and close contacts. Contactors are part of the motor starter power switching devices. Control relays are used as control switching devices because they are designed to withstand lower electrical currents. Motor starters are systems comprised of switching and overload-protection components.

The type of **control circuit** used is either a permissive, interlock, or both.

The control circuit is protected through the inclusion of fail-safe circuitry, circuit breakers, fuses, and overload protection devices. Fail-safe circuitry is incorporated to ensure the system defaults to the safest mode in the event of wiring or circuit failure. Circuit-breakers and fuses protect the motor from very high currents. Overload protection devices are safeguards against prolonged and relatively high current levels.

The **PLC (programmable logic controller**) is the heart of the control system for a modern transit elevator. The PLC interfaces with all the safety, maintenance, and operational controls to ensure safe accurate control of the drive and braking systems. The PLC is also capable of interfacing with a maintenance supervisory monitoring system for remote monitoring of the status of the system. Through the operator's interface controls of the PLC, the mechanic is provided a means to test and troubleshoot the control parameters of the elevator. Note: the elevator controller may receive inputs from other buildings systems' safety devices such as fire alarms devices, and smoke detectors.

6-3 CONTROL DEVICE LOCATIONS

The elevator has six control device locations. These locations will be identified and described on the following pages. Sometimes these operating devices are referred to as **pilot devices**.

The six control device locations are:

- Hallway Call Station
- Car Operating Station (inside of cab)
- Elevator Pit
- Top of Car
- Elevator Machine Room.
- Hoistway

Hall Call Station

The hall call station is an external control panel. Elevators are typically controlled from the outside by up and down buttons at each stop. When pressed at a certain floor, the elevator arrives to pick up more passengers. If the particular elevator is currently serving traffic in a certain direction, it will only answer hall calls in the same direction unless there are no more calls beyond that floor.

In a group of two or more elevators, the call buttons may be linked to a central dispatch computer, such that they illuminate and cancel together. This is done to ensure that only one car is called at one time.

Key switches may be installed on the ground floor so that the elevator can be remotely switched on or off from the outside.

In destination control systems, one selects the intended destination floor (in lieu of pressing "up") and is then notified which elevator will serve their request.

In Figure 6.1, the Hallway Control components are:

- Hall Call (push buttons by elevator hall doors)
- Hall chimes (gongs)
- Position indicators, or PI (Arrow or direction indicators)
- Fire Service switches
- Note: Some elevator hall call station have On/Off key switches

Car Operating Station [COS]

Located inside of the car door is the **Car Operating Station**, or **COS** (Figure 6.3). The COS consists of:

- Indicator Push buttons & lights (landing area signs)
- Stop Switch
- Door controls
- Emergency non-operational controls (including emergency bell & phone)

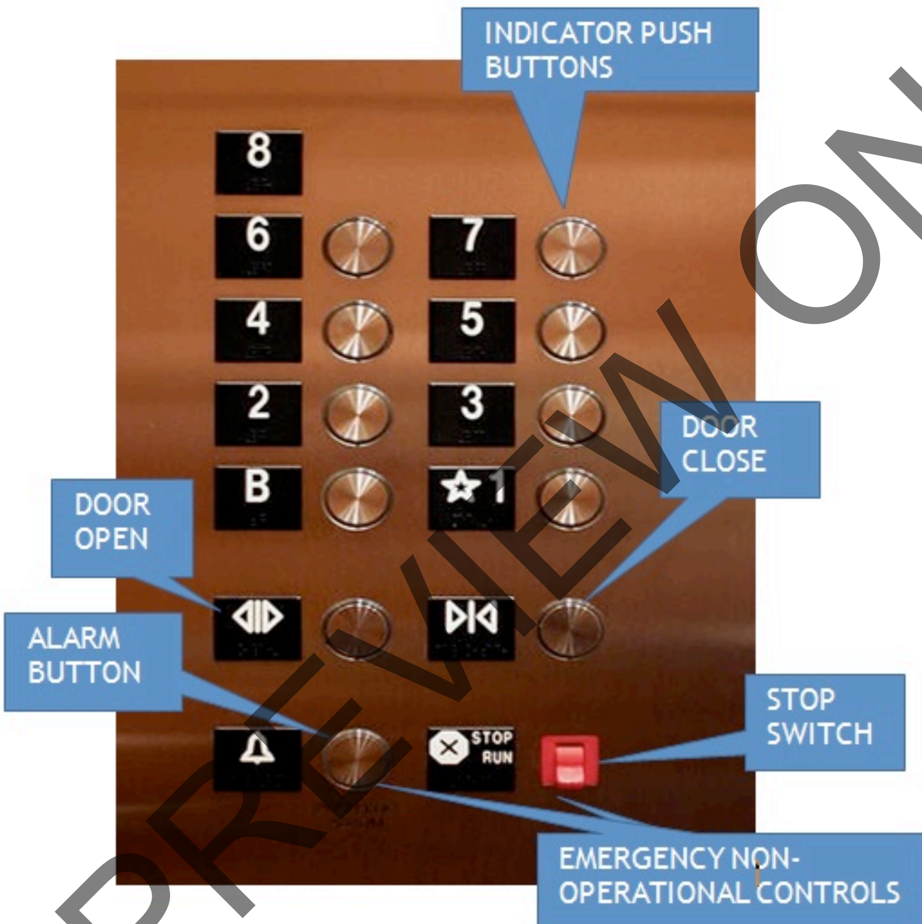


Figure 6.3 Car Operating Panel or Station (COS)

*Indicator Push Buttons (note the Braille, star next to floor 1 button means main egress floor in case of emergency)

Module 7

DRIVE MOTOR CIRCUITS

Outline

7-1 Overview
7-2 Drive Motors
7-3 Drive Power Circuits
7-4 Motor Faults and Protection
7-5 Starters
7-6 Wiring Configuration
7-7 Motor Exchange
7-8 Summary

Purpose and Objectives:

The purpose of this module is to provide an overview of the circuits that operate the drive motor system.

Following the completion of this module, the participant should be able to complete the exercises with an accuracy of 75% or greater:

- Identify the types of drive motors associated with each type of elevator system.
- Describe the types of overload protection and their method of operation.
- List and describe the different types of possible motor faults.
- List and describe the different types of starters.
- Identify and trace the wiring configuration for a drive motor using a schematic.
- Describe the method used to change out a drive motor specific to the elevator.

Key Terms

- Drive Motor
- Drive Systems
- Alternating-Current (Ac)
- Direct-Current (DC)
- Motor Overload Protection
- Running Protection
- Short Circuit Protection
- Slip Velocity
- AC Variable-Voltage/Variable-Frequency (VVVF)
- DC Silicon-Controlled Rectifier (SCR)
- DC Pulse-Width Modulation Drives (PWM)

7-1 OVERVIEW

Elevator drive systems are required to not only accelerate and decelerate at speeds which provide a smooth ride for the passengers, but they must also meet the need of accurate positioning when stopping at each landing. Cost is always a consideration when choosing the type of elevator installation for a facility. Modern techniques with solid-state drive technology have helped to somewhat reduce the costs of installation and long-term maintenance.

Within transit systems there are two basic types of elevator drive systems: hydraulic and electric. In electric elevator systems, the elevator motor drive adjusts motor torque output to achieve desired acceleration, deceleration, and travel speed independent of car loading. The drive's efficiency is an important component of overall elevator efficiency. Outdated, inefficient drives that may be part of existing elevator systems but are no longer on the market include alternating-current (AC) two-speed, AC variable-voltage, and direct-current (DC) motor-generator sets (Ward Leonard). Modern, efficient drives include AC variable-voltage/variable-frequency (VVVF), DC silicon-controlled rectifier, and DC pulse-width modulation drives (PWM).

Hydraulic elevator drives incorporate a motor, pump, control valve system to move the elevator between levels. A hydraulic elevator's rate of rise is determined by the specific installation and the same principles apply with regard to acceleration and deceleration.

In this module, we will look at the drive motor systems and their controls in the various electric traction and hydraulic installations.

7-2 DRIVE MOTORS

Motors

Motors are the driving force in an elevator providing the mechanical power to start, accelerate, decelerate, level, and stop the elevator.

You may recall motor generators are made up of an AC induction motor and a DC generator. AC motors are known to have difficulty in controlling the speed; therefore it was common to use this system with a gearbox (known as a *geared traction system*). However, the use of AC variable frequency drives has made the use of AC systems without a gearbox more efficient (*gearless systems*). This has led to the use of machine and brake systems being connected directly to the top of the elevator car (Direct Drive System).

The two types of motors found in transit elevator systems are a Direct Current (DC) motor/generator set providing DC power for the DC motor, or an Alternating Current (AC) Induction motor with a drive. These motors and their drives are typically housed in what is known as the elevator machine room.

Early electric-traction elevator systems used DC motor/generator sets. These generator-field controls were used to operate the elevator, and some are still around today. In these early elevator systems, the DC motors operated by generating a force between the interaction of a magnetic field and current-carrying conductors. As an electric current passes through a current-carrying wire bent into a loop with two right-angles, the magnetic field experienced forces in opposite directions. The electromagnetic arrangement, or field coils as they are sometimes known as, produces the magnetic field. By passing the current through this arrangement, the opposing forces then created a torque, or turning force, to rotate the coil. Motors typically have several coils to provide a uniform torque. These motors were found in machine rooms located near the elevator shaft and offered excellent speed and control.

Today, the DC motor/generator sets are not seen very often in the transit industry and are usually limited to mid and high-rise building elevator systems. Typically in the transit industry, three phase induction motor are used in elevator systems. Advantages to the AC induction motor includes no brushes or commutator for easier manufacturing, no wear, no sparks, no ozone production and associated loss of energy

AC Induction Motors

An induction or asynchronous motor is a type of AC motor where power is supplied to the rotor by means of electromagnetic induction. A squirrel-cage induction motor is one in which the rotor is electrically isolated from the stator. In overall shape, the squirrel-cage rotor is a cylinder mounted on a shaft. Internally it contains longitudinal conductive bars (usually made of aluminum or copper) set into grooves and connected together at both ends by shorting rings forming a cage-like shape. The name is derived from the similarity between this rings-and-bars winding and a squirrel cage (or, as it is commonly known, a hamster wheel).

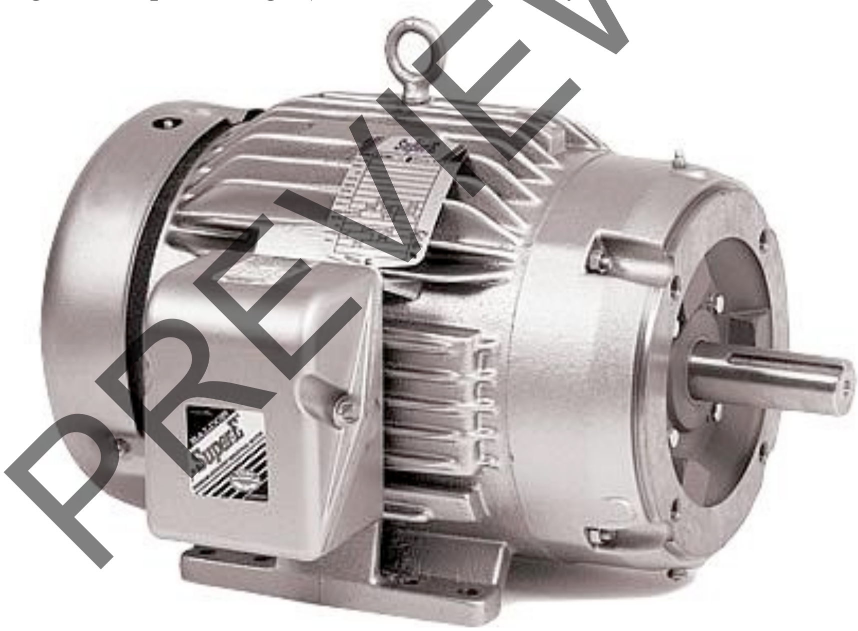


Figure 7.1 Totally Enclosed Fan Cooled (TEFC) Three Phases Induction Motor

The stator windings of an AC induction motor are distributed at 120o intervals around the stator to produce a roughly sinusoidal distribution. When three phase AC voltages are applied to the stator windings, a rotating magnetic field is produced. When the three currents flow through the three symmetrically placed stator windings, these sine waves distribute a magnetic flux across the air gap between the stator and the rotor generating sinusoidal currents within the rotor. The interaction of the sinusoidal wave form distributed air gap magnetic flux and induced rotor currents produces a torque on the rotor. The rotating magnetic field of the stator forces the rotor to turn. The rotor does not quite keep up with the rotating magnetic field of the stator. It falls behind or slips as the field rotates. The mechanical angular velocity of the rotor is lower than the angular velocity of the flux wave by so-called slip velocity.

A limited number of internal components mean fewer problems in three phase AC induction motors than their DC counterparts. Three-phase motors have fewer components that may malfunction than other motor types. Therefore, three-phase motors usually operate for many years without any problems. If a three-phase motor is the problem, the motor is serviced or replaced. Servicing usually requires that the motor be sent to a motor repair shop for rewinding. An example of a good servicing practice is, if the motor is less than 1 HP and more than five years old, it is replaced. If the motor is more than 1 HP, but less than 5 HP, it may be serviced or replaced. If the motor is more than 5 HP, it is usually serviced.

Induction motors are widely used in transit elevator drives, particularly three-phase induction motors, because they are robust and have no brushes. Their speed can be controlled with a variable frequency drive. With standard direct-on-line (DOL), the speed of an AC induction motor is determined by two factors:

- Number of pole windings in the motor
- The frequency of the line voltage source.

Because it is very difficult to change the number of physical poles in motors larger than ½ horsepower, the only means of controlling the speed is through the use of a variable frequency voltage source. With the advent of newer solid-state devices, variable frequency drives are now capable of developing the power necessary to drive large horsepower motors.

In adjustable speed applications, many AC motors are powered by **variable frequency drives (VFD)**. The VFD converts low frequency (60 Hz) AC to DC and then inverts the DC power to a **pulse width modulated (PWM**) AC power at the required frequency and amplitude. The inverter consists of three half-bridge units (one per phase) where the upper and lower switches are controlled complimentarily. During the switching process, the solid-state power device's turn-off time is longer than its turn-on time; some dead-time must be inserted between the turn-off of one transistor (or SCR) of the half-bridge and turn-on of its complementary device. The output voltage is created by a pulse width modulation (PWM) technique. The three-phase voltage waves are shifted 120° to one another similar to the incoming line waveforms however, that is where the similarity ends. These simulated drive outputs can now be controlled through the microprocessor's PLC that controls the drive units. With this type of drive, it is now possible to control not only the amplitude of the waveforms but, the frequency of the waveform is variable as well.

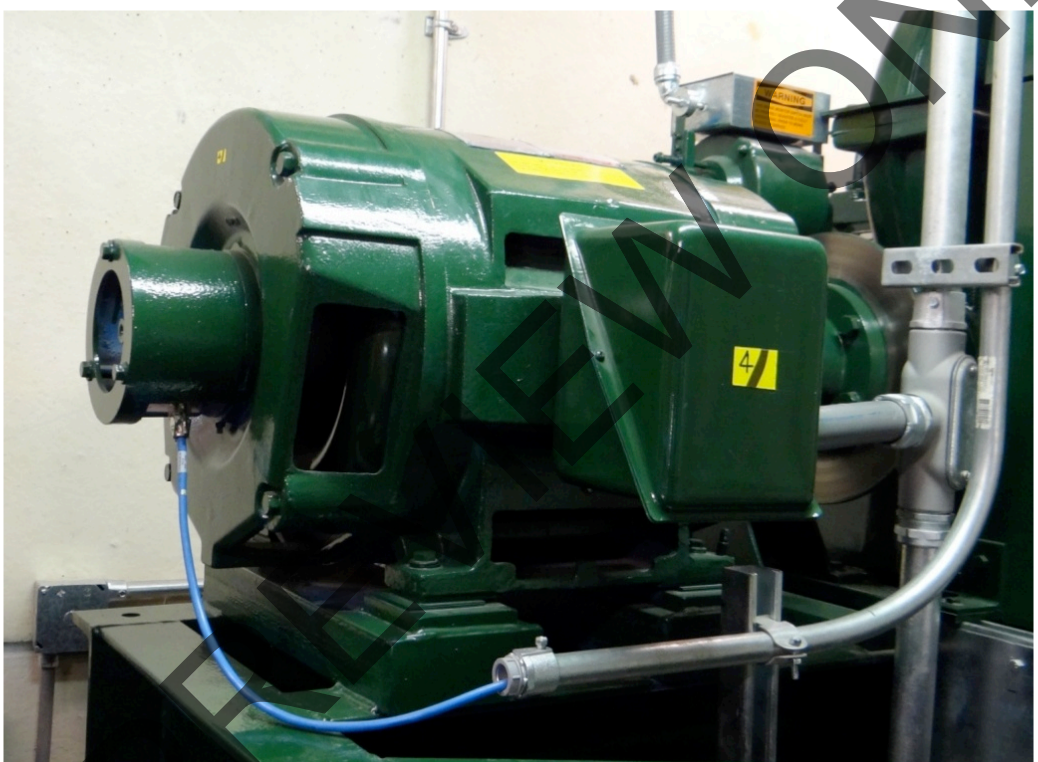


Figure 7.4 Three-Phase AC Induction Motor- Courtesy of WMATA

More advanced systems use permanent-magnet AC motors that are slightly more efficient and smaller than induction motors. These motors require a high-efficiency variable-frequency drive and contain fewer moving parts. Sometimes, these motors are mounted directly in the elevator shaft which eliminates the need for a machine room. In this case, the elevator is known as a **machine room-less elevator** and is ideal for low-rise buildings where space is a premium, such as in the transit industry.

The pump pulley should then be removed and will be reinstalled on the new pump shaft. Position of the pulley on the shaft should be marked to be properly positioned on the new pump shaft.

Last, install the pulley on to the new pump shaft, and then install the new pump. Re-install the plumbing and adjust belt tension with the jacking bolts the belt. After making sure all is aligned & secure, open up valves or remove caps if installed.

Removing and Replacing a Submersible Pump

First, bring elevator down to lowest level. As with all other motors, turn the power off, lock-out, and tag out.

Next, shut off all the passages of the hydraulic oil to the pump by means of the shut off valve. Next, the hydraulic tank should be drained. This is an authority specific procedure and one should proceed accordingly.

Then, loosen the motor mounting bolts. Remove all plumbing/pipes and electrical connections to the pump motor. Remove the pump.

Last, install the new pump. Re-install the plumbing and electrical connections. After making sure all is aligned & secure, refill the tank open up valves or remove caps if installed.

Removing and Replacing a Master Control Valve

Once again and like the pump exchange, bring car into lowest level. Turn power off, lock-out, and tag-out.

Remove any excess pressure from the system and close off all shut off valves. Identify and label coils before carefully securing the coils.

Remove plumbing pipes from valve body and remove valve body.

Install new valve body, reinstall plumbing, and reconnect electrical.

Finally, open valves. Valves may need to be adjusted after power is restored.

7-8 SUMMARY

In transit, there are two basic types of elevator drive systems: hydraulic and electric traction. These drive systems have evolved with changing technology to improve upon passenger comfort as well as space and energy needs for the systems. This module covered the various types of basic drive motor circuits and related information found in transit authorities at this time.