

Elevators

Complex Electrical Systems in Today's World

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Qualifications:

- BSEE – Drexel University – 1971
- MSEE – Drexel University (Power) – 1976
- Licensed Electrical Contractor 1971 -1976
- Officer - US Army Reserve 1971 – 1979
- Delmarva Power & Light Co.1972 – 1974
- Day & Zimmermann, Inc. 1974 -1978
- Maida Engineering, Inc. – 1978 – Present
- PE Licenses – PA -1975 (NJ, NY & DE 1976)
- PE Licenses – ID, MA, NC, GA, FL, TX, IA, WV, AK, TN, MD, KS, MO, VA, SC, NM, OR, LA and MN
- LEED Accredited Professional - June 2009
- PA UCC Review and Advisory Council 2009 -2011
- Patent – Wind Tunnel Motor/Drive/Control - 2020



ELEVATORS

An elevator is a cable-assisted, hydraulic cylinder-assisted, pneumatic assisted or roller-track assisted machine that vertically transports people or freight between floors, or levels of a building or other structure.

Elevators are typically powered by an electric motor that drives traction cable and counterweight system, or pumps hydraulic fluid into a cylindrical piston that raises the cab or car from below



ELEVATORS

Technical Question #1

Why do most elevators use counterweights?

Answer:

The counterweight reduces the horsepower of the machine because the machine only needs to lift the difference between the cab's weight and the counterweight weight.



ELEVATORS

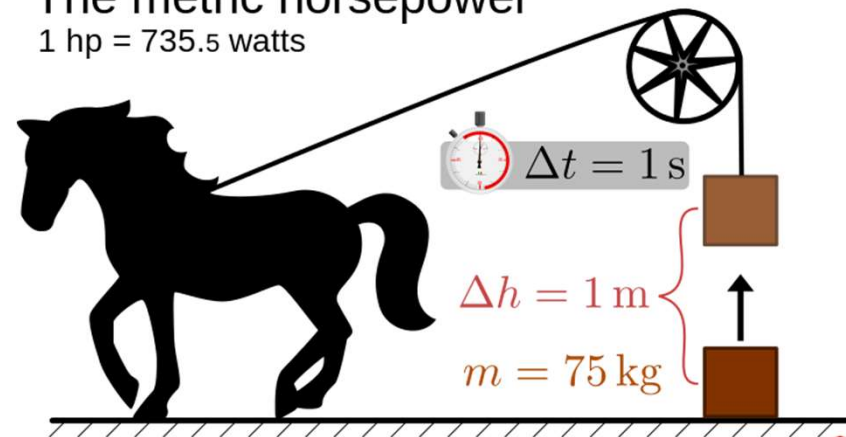
Technical Question #2

Define Horsepower?

Answer:

**Force required to
lift 33,000 pounds,
1 foot
in 1 minute**

The metric horsepower
 $1 \text{ hp} = 735.5 \text{ watts}$



ELEVATORS

HISTORY

The earliest known reference to an elevator is in the works of the Roman architect Vitruvius, who reported that Archimedes (c. 287 BC – c. 212 BC) built his first elevator probably in 236 BC.

Sources from later periods mention elevators as cabs on a hemp rope, powered by people or animals.

ELEVATORS

HISTORY

The Roman Colosseum, completed in AD 80, had roughly 25 elevators that could carry about 600 pounds (270 kg) (roughly the weight of two lions) 23 feet (7.0 m) up when powered by up to eight (8) men.*

How much power would it take to raise 270 kg up 7 meters in fifteen minutes?

1 Horsepower = .746 Kilowatts

1 foot = .3048 Meters



ELEVATORS

HISTORY

In 1845, the Neapolitan architect Gaetano Genovese installed the "Flying Chair" in the Royal Palace of Caserta , an elevator ahead of its time, covered with chestnut wood outside and with maple wood inside. It included a light, two benches and a hand-operated signal, and could be activated from the outside, without any effort by the occupants.



ELEVATORS

Trivia Question

What major city is near the “Royal Palace of Caserta”?



Picture of its Garden

Answer
Naples, Italy

ELEVATORS

HISTORY

The Flying Chair's Traction was controlled by a motor mechanic utilizing a system of toothed wheels.

A safety system was designed to take effect if the cords broke, consisting of a beam pushed outwards by a steel spring.



ELEVATORS

In 1852, Elisha Otis introduced the safety elevator, which prevented the fall of the cab if the cable broke. He demonstrated it at the New York exposition in the Crystal Palace in a dramatic, death-defying presentation in 1854, and the first such passenger elevator was installed at 488 Broadway in New York City on 23 March 1857.

<https://en.wikipedia.org/wiki/Elevator>



ELEVATORS

Attendance Question #1

Recently added to the Code, what device grabs the wire ropes connected to the elevator car if there is a mechanical or electrical failure?

- A – Rope Gripper**
- B – Rope Clamp**
- C – Does not exist**

Answer #1 – A



ELEVATOR HYBRED

In 1962 Richard Browser combined Elevator and Ferris Wheel technology to create the tram system that would carry eight (8) - five passenger cabs from a below grade station, along a curved tract that would invert the cabs by more than 180 degrees, to a station 720 feet above grade for over 50 years.

The traction systems were powered by a Ward Leonard Power Systems.



ELEVATORS

Attendance Question #2

Do the North and South Trams in the St. Louis Arch have a mechanical devices that will stop the tram from free falling?

A – Yes

B – No

Answer #2 – A



ELEVATORS

Attendance Question #3

Are elevators in high rise buildings required to have mechanical devices that keep them from free falling?

A – Yes

B – No

C – Not Specifically

Answer #3 – C



ELEVATORS

Technical Question #3

What does is the elevator's "governor" an measure?

Answer:

The Governor is a speed monitoring device on traction elevators that triggers a safety switch when the elevator reaches high speeds in either direction.



ELEVATOR HYBRED

In 2005 Harvey D. Hnatiuk, PE a Vice President with Maida Engineering, Inc. and now Past President of the National Society of Professional Engineers oversaw the preparation of an Evaluation of the Gateway Arch Tram System.

Harvey has overseen the implementation of most of recommendations made in the Evaluation over the last 17 years.



ELEVATOR HYBRED

The arch was shut down during the 2016 winter season. During the shutdown, the Ward Leonard Systems were replaced with new traction machines, variable speed drives and PLC Based Control Systems designed by Maida Engineering, Inc.

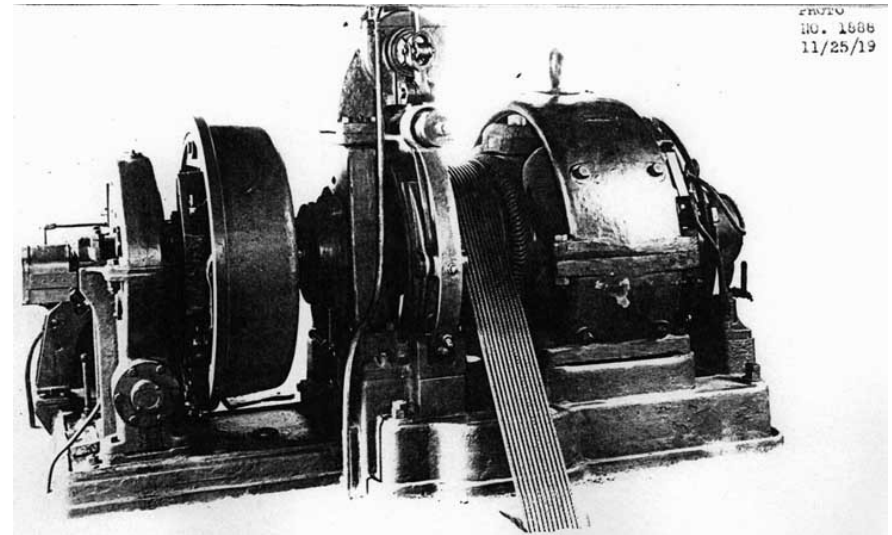
Since April 28, 2017, the trams have safely transported Arch Visitors using Equipment and Systems Engineered and Designed by Maida Engineering Inc.



ELEVATORS

Ward Leonard Variable Speed Control

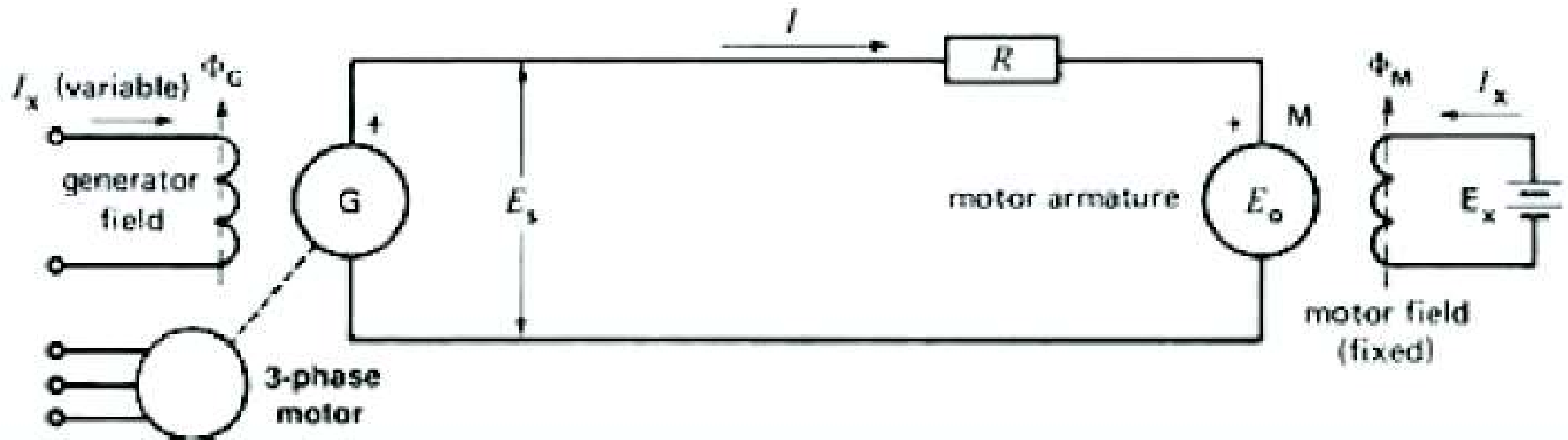
- ❖ Introduced in 1891 by Harry Ward Leonard
- ❖ Used for elevators from 1900 to 1970's for Elevators
- ❖ Three Major Components
 - ❖ AC Induction Motor
 - ❖ DC Dynamo or Generator
 - ❖ DC Motor
- ❖ Electric Brake
- ❖ Cable Sheave



Otis Gearless DC Machine
Circa 1915

ELEVATORS

Ward Leonard Variable Speed Control



Four Quadrant - Regenerative Control

- 3 Phase Motor runs all of the time
- 3 Phase Motor requires a reduced voltage starter

ST. LOUIS ARCH TRAMS



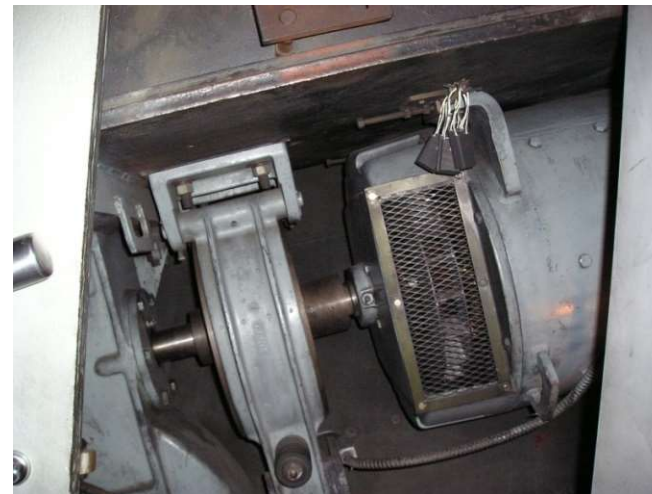
Wye Delta Starter



AC Motor



DC Generator



DC Motor and Brake

Ward Leonard – Installed in 1969



ELEVATORS

Attendance Question #4

How many resistors were used to control the tram speeds for the Arch Trams from 1961 to 2016?

A – Six (6)

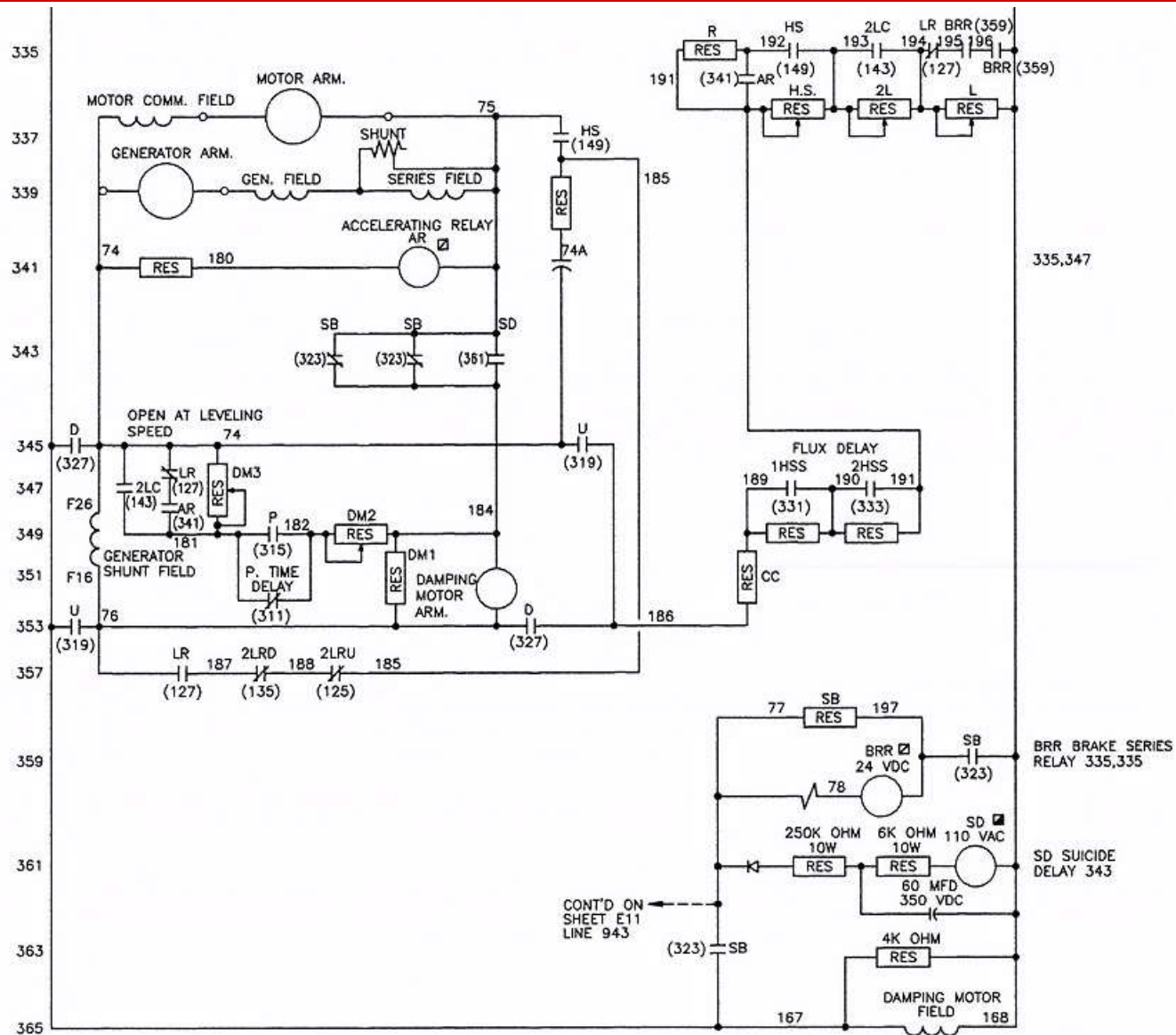
B – Nine (9)

C – Fifteen (15)

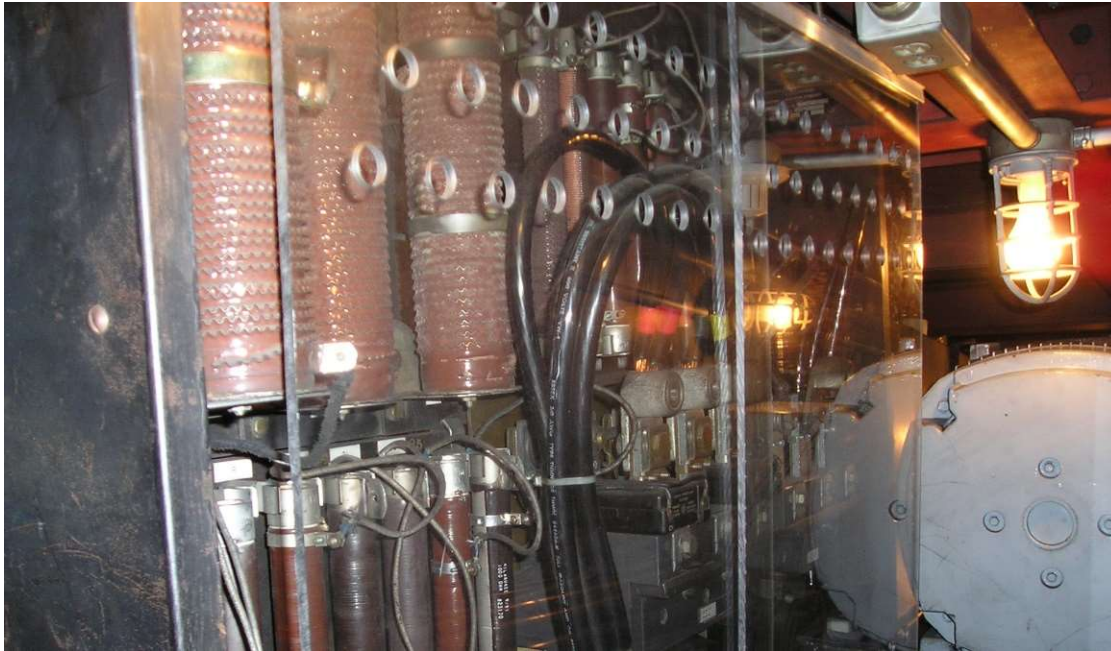
Answer #4 – B



ELEVATORS



ELEVATORS

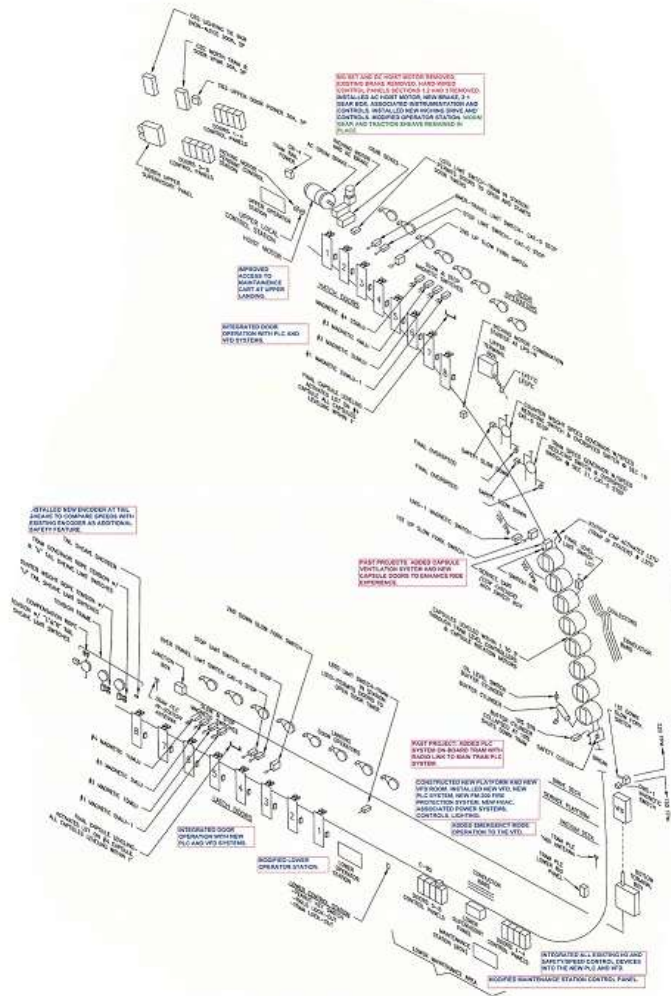


Resistors for Speed Control



Relays that connect the resistors

ELEVATORS



System Components



ELEVATORS

Sizing The New AC Motor for St. Louis Arch

The DC Motor's RPM (N), Torque (T) and Horsepower (HP) are directly proportional to the Current, I, in the generator/motor armature windings circuit.

The following formula applies.

$$\text{HP} = \frac{\text{Torque X Speed}}{5252} = \frac{I \times E_s}{746}$$



ELEVATORS

Trivia Questions

What is the likelihood that you have been in an elevator powered and controlled by a Ward Leonard System?

Answer: Likely

Are DC Motors being replaced by AC motors in variable speed applications?

Answer: Yes



CODES & STANDARDS

Complex Machines in Today's World

- ❖ Numerous Codes and Standards
- ❖ Major Advances in Safety Control
- ❖ Development of New Technology
- ❖ Enhancements of Codes and Standards

CODES & STANDARDS

ASME A17. 1-2019 Safety Code for Elevators and Escalators

**Is intended to provide safety of life and limb and
promote public welfare.**

**It covers not only elevators, escalators, moving
walks, dumbwaiters, material lifts, and related
equipment, but also their associated parts,
rooms, spaces, and hoistways.**



CODES & STANDARDS

ASME A17. 1-2019 Safety Code for Elevators and Escalators

- ✓ Intended to serve as the basis for the design construction, installation, operation, testing, inspection, maintenance, alteration, and repair of elevators.*
- ✓ Safety codes and standards are intended to enhance public health and safety.*

* Reference - ASME A17.1 – 2016



CODES & STANDARDS

ASME A17. 1-2019 Safety Code for Elevators and Escalators

- ✓ Revisions result from committee consideration of factors such as technological advances, new data, and changing environmental and industry needs.*
- ✓ Revisions do not imply that previous editions were inadequate.*

* Reference - ASME A17.1 – 2016



CODES & STANDARDS

National Electrical Code – NEC® NFPA 70 -2023

NEC covers the installation of electrical equipment and wiring used in connection with elevators, dumbwaiters, escalators, moving walks, platform lifts, and stairway chairlifts.

The purpose of the NEC is the practical safeguarding of persons and property from hazards arising from the use of electricity. This Code is not intended as a design specification or an instruction manual for untrained persons*



* NFPA 70- 2023

CODES & STANDARDS

National Fire Alarm and Signaling Code NFPA 72 -2022

NFPA 72 covers the application, installation, location, performance, inspection, testing, & maintenance of fire alarm systems, supervising station alarm systems, public emergency alarm reporting systems, fire warning equipment & emergency communications systems & their components.



CODES & STANDARDS

ANSI 117.1 – American National Standard for Accessible and Usable Buildings and Facilities.

The intent of this standard is to allow a person with physical disability to independently get to, enter, and use a site, facility, building or element

CODES & STANDARDS

Standard for the Installation of Sprinkler Systems

NFPA 13 - 2022

NFPA 13 provides the minimum requirements for the design and installation of automatic fire sprinkler systems and exposure protection sprinkler systems covered within the standard



CODES & STANDARDS

International Building Code (IBC)

Pennsylvania - 34 Pa. Code § 405

**New Jersey Administrative Code > TITLE 5.
COMMUNITY AFFAIRS > CHAPTER 23.
UNIFORM CONSTRUCTION CODE >
SUBCHAPTER 12. ELEVATOR SAFETY
SUBCODE**

Building Code of New York State



CODES & STANDARDS

**ADAAG - The Americans with Disabilities Act
Accessibility Guidelines for Buildings and
Facilities at 28 CFR Part 36 App.**

**IEC/EN 62061 "Safety of machinery —
Functional safety of safety-related electrical,
electronic and programmable electronic
control systems"**

**EN ISO 13849-1 "Safety of machinery — Safety
related parts of control systems"**



CODES & STANDARDS

Attendance Question #5

Is there a general, or an article specific,
“grandfather clauses” in the
National Electrical Code?

A – No

B – Yes

Answer #5 – A



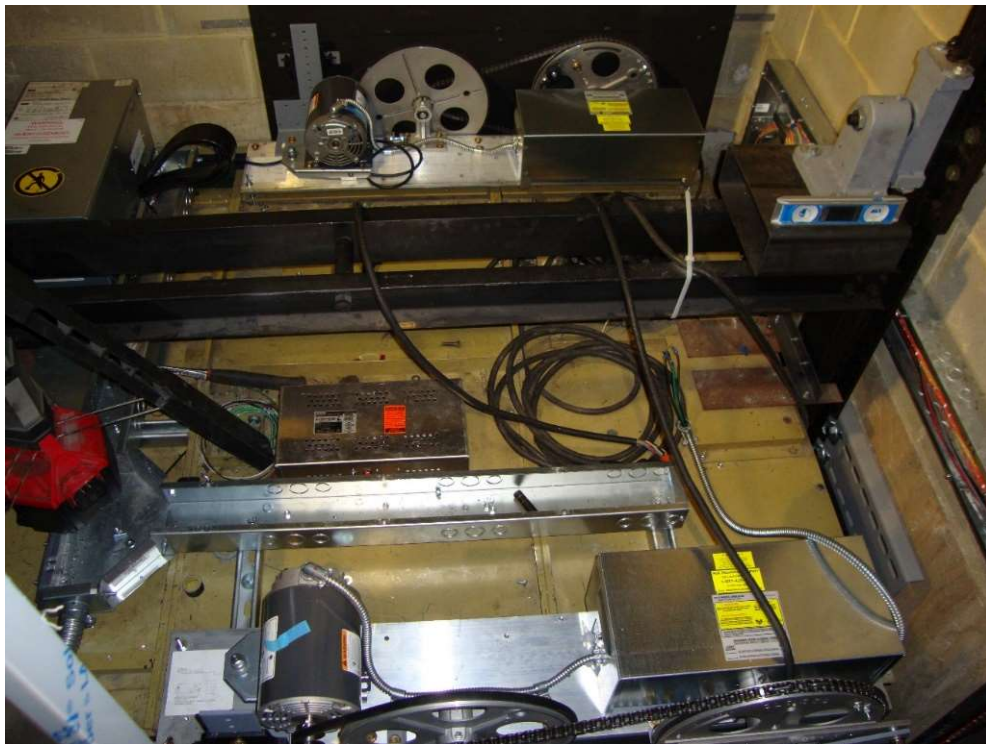
ELEVATOR COMPONENTS

MAJOR COMPONENTS

- ❖ **SHAFT AND ENVIRONMENT**
- ❖ **LANDINGS AND LANDING DOORS**
- ❖ **CAR AND CAR DOORS**
- ❖ **ELEVATOR MACHINE AND COMPONENTS**
- ❖ **ELECTRIC POWER SYSTEM**

ELEVATOR COMPONENTS

TOP OF CAR



Door Motors



Safety Railing

ELEVATORS

TYPES OF BUILDING ELEVATORS

Four (4) Main Types of Elevators

❖ Hydraulic

❖ Traction

❖ Machine-Room-Less

❖ Vacuum (Air Driven)

ELEVATORS

Attendance Question #6

How many Types of Elevators were described in the course?

A – Six (6)

B – Five (5)

C – Four (4)

Answer #6 – B

Roller Track Assisted



ELEVATORS

Hydraulic Elevator Machine

- Use the compression created by hydraulic fluid pumped into a cylinder to lift the car and occupants with a plunger.
- The plunger travels inside a cylinder.
- The hydraulic fluid is stored in a tank and pumped by an electric motor, often referred to as the Hydraulic Power Unit (HPU).
- Generally used for elevators less than 60 feet tall and often for heavy loads

ELEVATORS

Hydraulic Elevators

- ✓ **Hydraulic jack: a unit consisting of a cylinder equipped with a **plunger** (ram) or piston, that applies the energy provided by a liquid under pressure.***
- ✓ **Hydraulic machine: a unit consisting of pump, motor, valves, and associated internal piping, that converts electrical energy and supplies it as a liquid under pressure.***

ELEVATORS

Hydraulic Elevators Jack



ELEVATORS

Hydraulic Elevator Machine



❖ Tank

❖ Pump

❖ Valve

ELEVATORS

Hydraulic Elevators

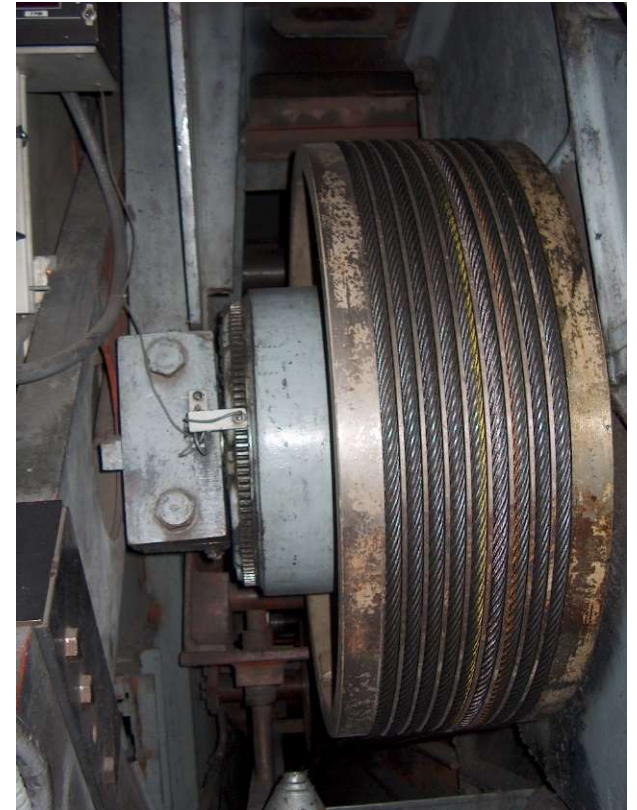
Plunger Gripper: an Optional Mechanical Device attached to a supporting structure in the pit, that stops and holds the car by gripping the plunger.



ELEVATORS

Traction Elevators

- ❖ Traction elevators raise the elevator car using steel wire ropes that wrap around a deeply grooved pulley, commonly called a 'sheave'.
- ❖ The friction between the ropes and the pulley produces the traction which gives this type of elevator its name.



ELEVATORS

Traction Elevators

- ❖ The sheave is powered by a shaft connected to an electric motor either directly or through a gear box.
- ❖ The shaft has an electric brake that engages when the car is stopped.



**DC Motor and Brake
Replaced in
2016**

ELEVATORS

St. Louis Arch Tram System

After 50 years, the Ward Leonard MG Sets and Relays were replaced with a **Variable Frequency Drive (VFD)** and a **Programmable Logic Controller (PLC)**.

Like the Ward Leonard MG Set, The VFD must be re-generative with an active, IGBT front end versus a passive, diode front end.



ELEVATORS



VFD at the St. Louis Arch

ELEVATORS



**PLC Cabinet and VFD Room Fire Suppression System
At the St. Louis Arch**

ELEVATORS

St. Louis Arch Tram System

Considered to be Permanent Amusement Attraction, like major theme park rides, the St. Louis Arch Tram System was designed with multiple redundancies, not to have any latent single points of failure, to be self diagnosing, a simple to operate.



ELEVATORS

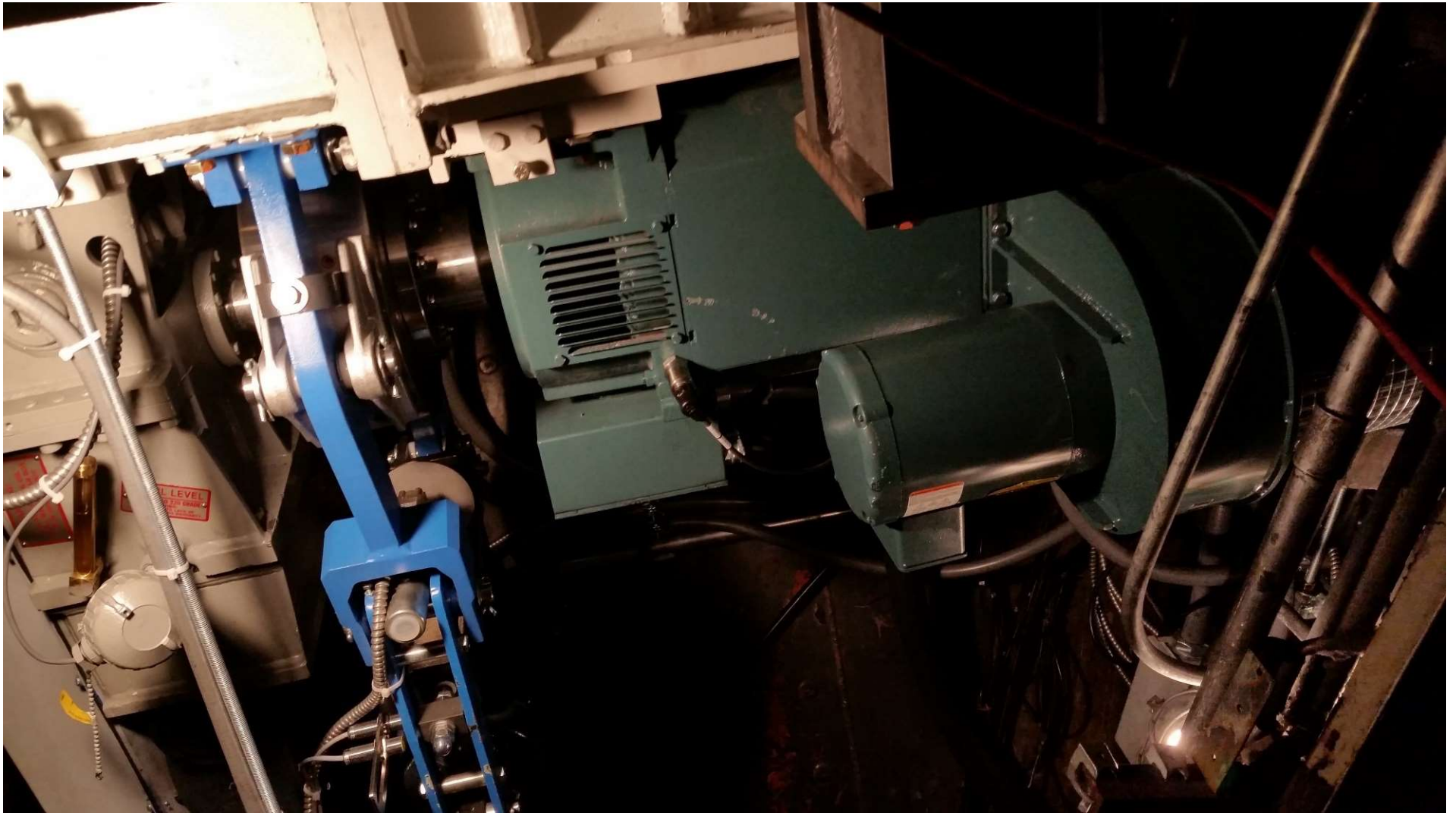
Technical Question #4

Does the VFD eliminate the need for Reduced Voltage Starters

Answer:

Although VFDs can generally eliminate the need for reduced voltage starters, sometime reduced voltage starters are the better or, when **selectivity is required, the only choice.**

ELEVATORS

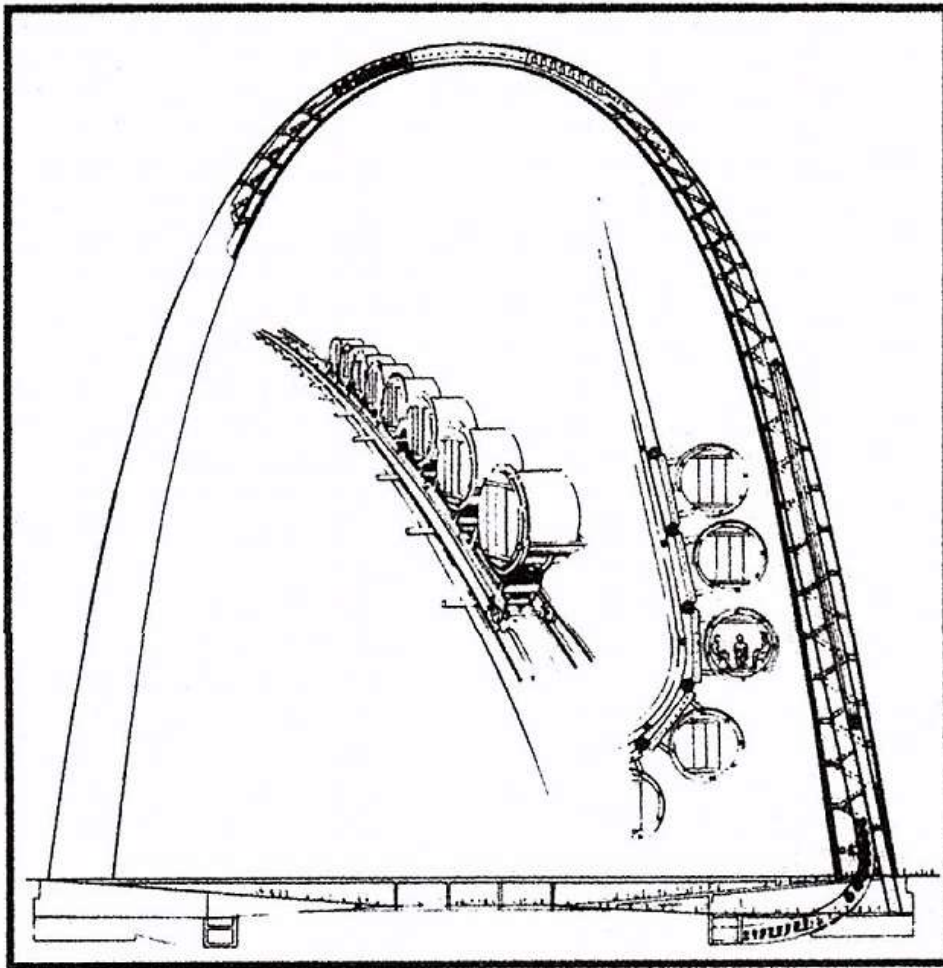


St. Louis Arch Machine



ELEVATORS

St. Louis Arch



Tram Diagram



Pods or Cars

ELEVATORS



Service Platform before 2106



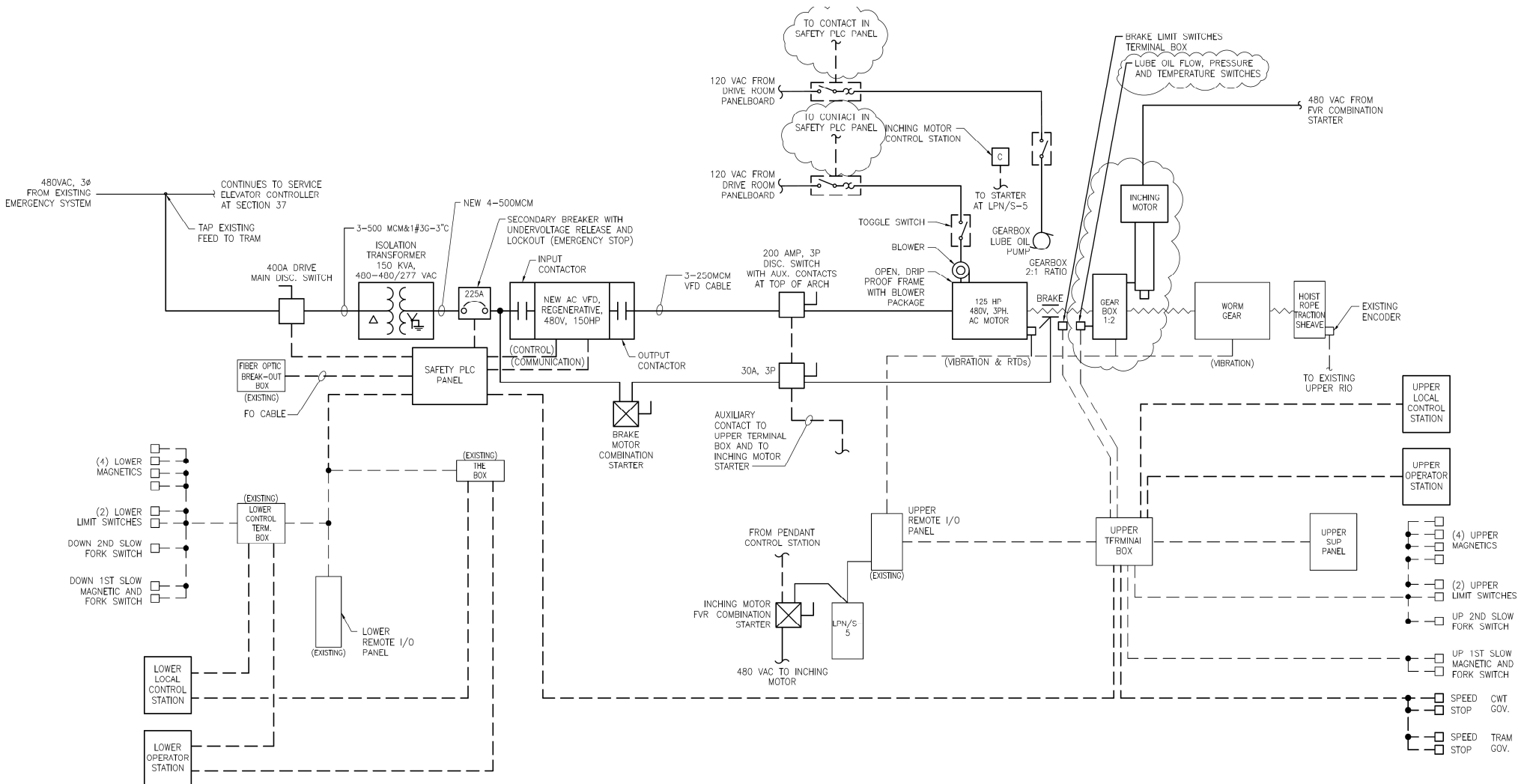
ELEVATORS

St. Louis Arch Custom Machine

❖ Features of some Traction Elevator Machine

- Inverter Duty Induction Motor with thermistor
- Electric Brake
- 2:1 Gearbox to enable use of physically smaller motor
- External Motor Cooling Fan
- Wormgear
- Sheave

ELEVATORS

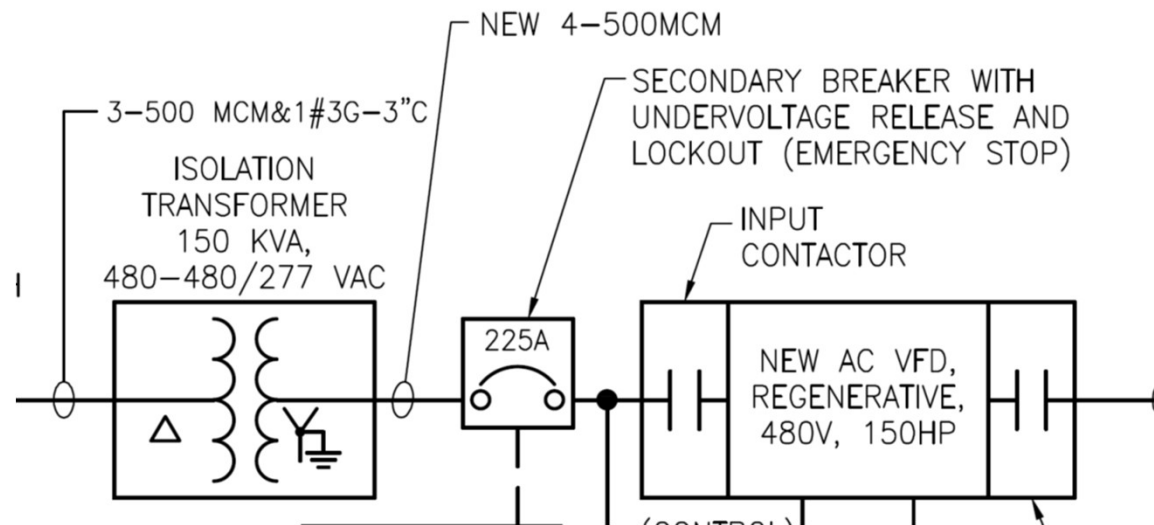


Power One Line and Control Interconnection Diagram



ELEVATORS

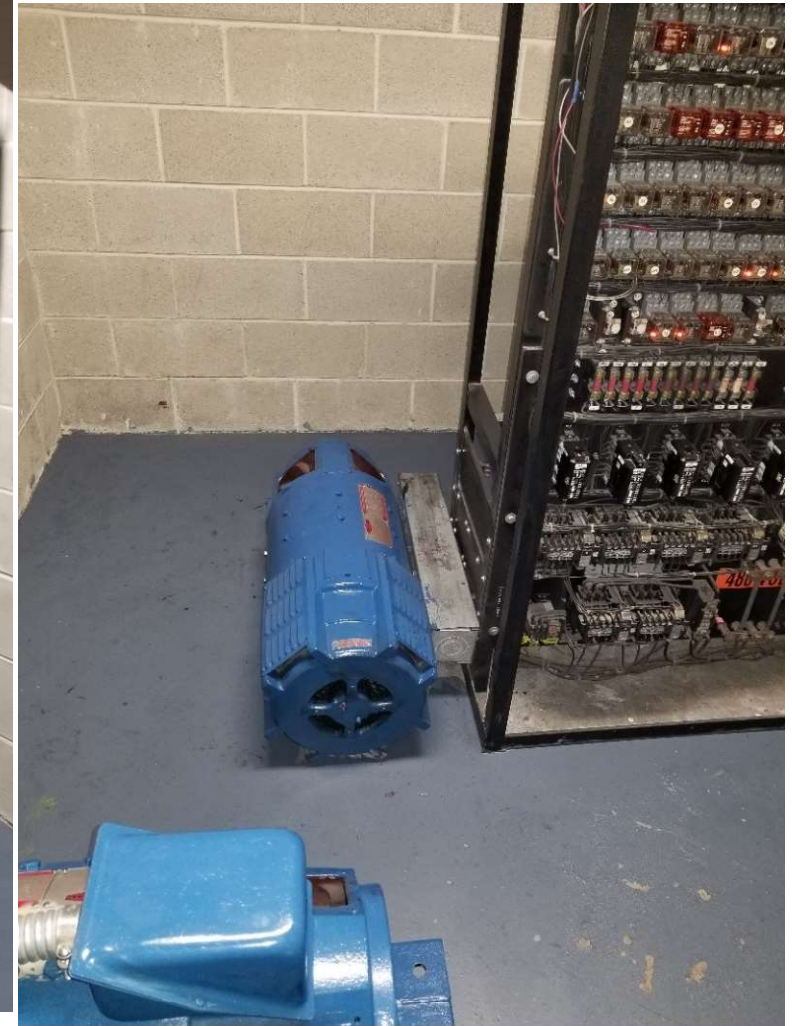
Technical Question #5



Applying NEC Article 620 Elevators - Were the Isolation Transformer required by the NEC and why?

Answer: YES, Selectivity

EXISTING ELEVATOR



Ward Leonard MG-Set that Will be replaced in 2023



ELEVATORS

MRL Traction Elevators

- ❖ **With the introduction of permanent magnet motors, machine room less traction elevators are replacing hydraulic elevators which had been used for elevators that do not having many landings.**
- ❖ **Being installed in many new residential townhouses.**
- ❖ **May be using an electrical brake or a rope gripper to mechanically secure the wire ropes when the the elevator comes to a landing.**

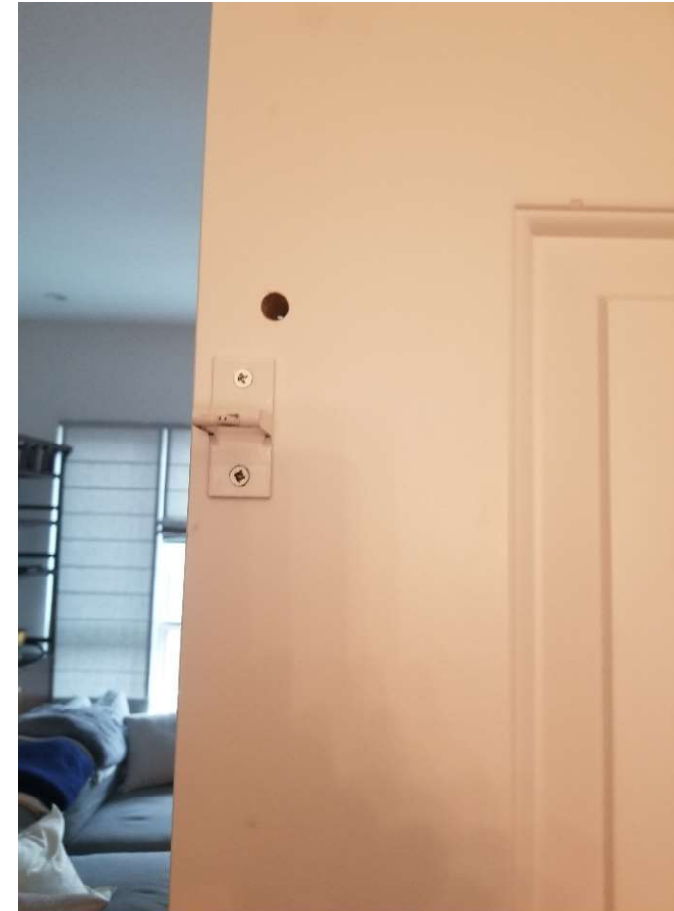
ELEVATORS

MRL Traction Elevator



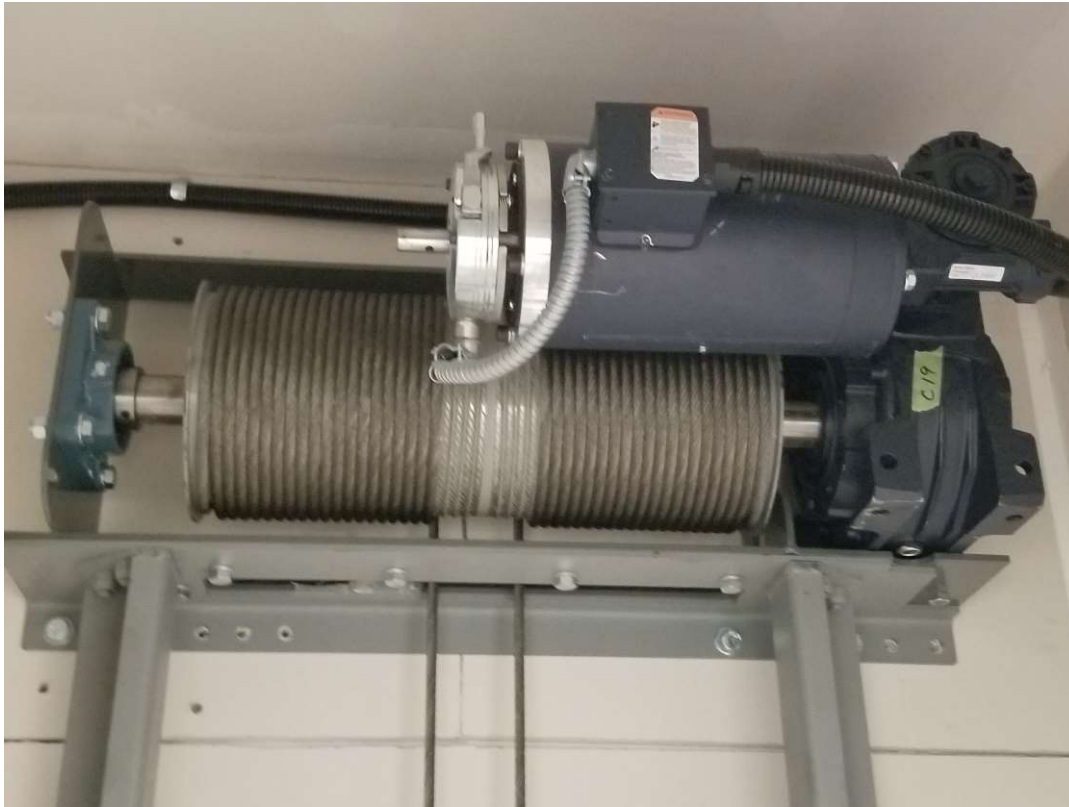
ELEVATORS

MRL Traction Elevators



ELEVATORS

MRL Traction Elevators



Motor, Brake and Sheave



Top of Car Control & LEDs

ELEVATORS

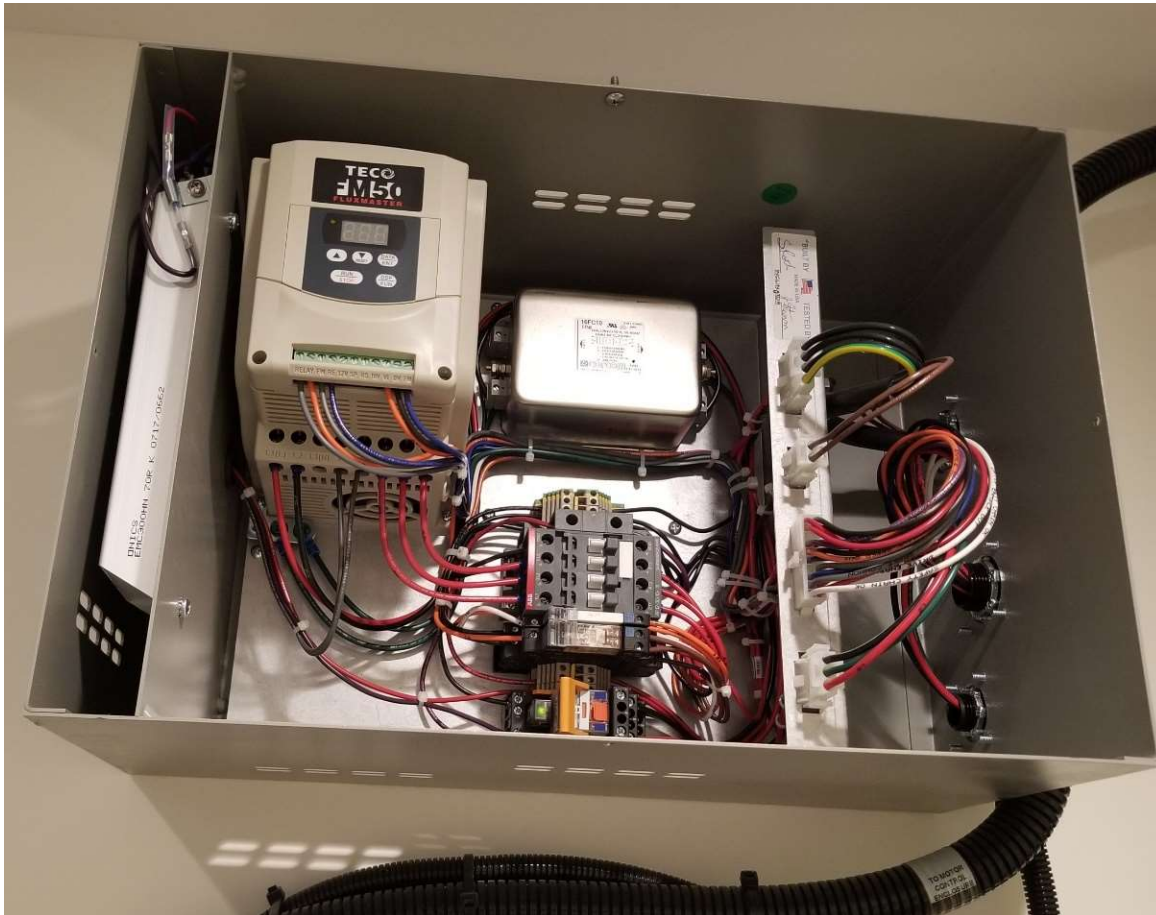
MRL Traction Elevators



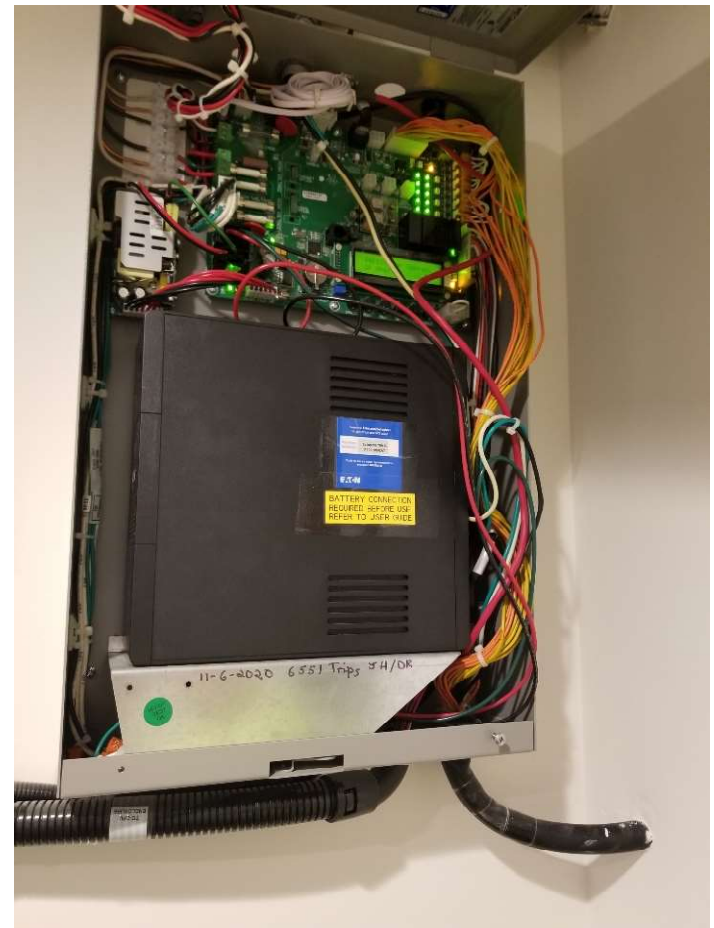
Four Floor Elevator Shaft

ELEVATORS

MRL Traction Elevators



VFD and Controls



Power Disconnect and Battery

ELEVATORS

Vacuum (Pneumatic) Elevators

- **Consists of transparent self-supporting modular tubes that easily fitted into one another. A steel top tube provides air-tight closures with suction inlets and valves.**
- **The elevator car runs inside the tube. Turbines on the top tube connect to the valves and control to control the movement of the car.**

ELEVATORS

Vacuum Elevators

- The vacuum pump of the elevator generates higher and lower atmospheric pressures above or below the elevator car, which causes the car to move the elevator upwards and downwards.

ELEVATOR COMPONENTS

OTHER MAJOR COMPONENTS

❖ TELEPHONE

❖ FIRE ALARM

❖ SPRINKLER SYSTEMS

❖ ELECTRIC POWER



ELEVATORS

Telephone

Elevator telephone(s) must meet code requirements and use a dedicated telephone line.

Non-residential elevators should not require voice communication and must include visual and communication signals for hearing impaired individuals.



ELEVATORS

Attendance Question #7

Can elevator phones be completely wireless?

A – Yes

B – Sometimes

C – No

Answer #7 – C



ELEVATORS

FIRE ALARM

Unless otherwise required by the AHJ, only the elevator lobby, elevator hoistway, and elevator machine room smoke detectors, or other automatic fire detection as permitted by 21.3.9, shall be used to recall elevators for fire fighters' service.

Exception: A waterflow switch shall be permitted to initiate elevator recall upon activation of a sprinkler installed at the bottom of the elevator hoistway (the elevator pit), provided the waterflow switch and pit sprinkler are installed on a separately valved sprinkler line dedicated solely for protecting the elevator pit, and the waterflow switch is provided without time-delay capability.



ELEVATORS



FIRE ALARM



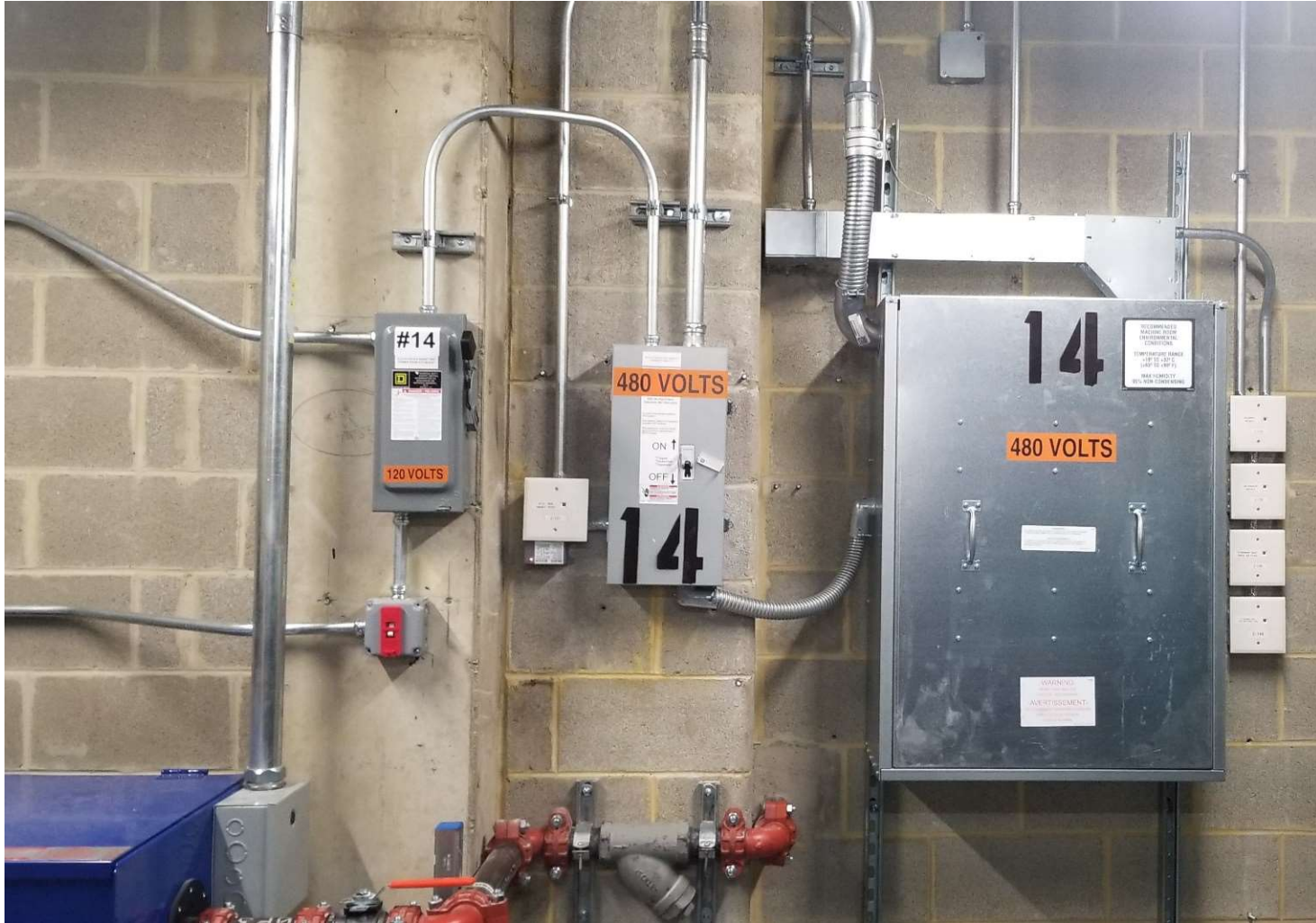
ELEVATORS

SRINKLER SYSTEM

If sprinklers are installed in hoistways, machine rooms, control rooms, machinery spaces, or control spaces, the disconnecting means shall be permitted to automatically open the power supply to the affected elevator(s) prior to the application of water.

ELEVATORS

SRINKLER SYSTEM



SHUT TRIP CIRCUIT BREAKER

ELEVATORS

AUXILIARY POWER LOWERING DEVICE

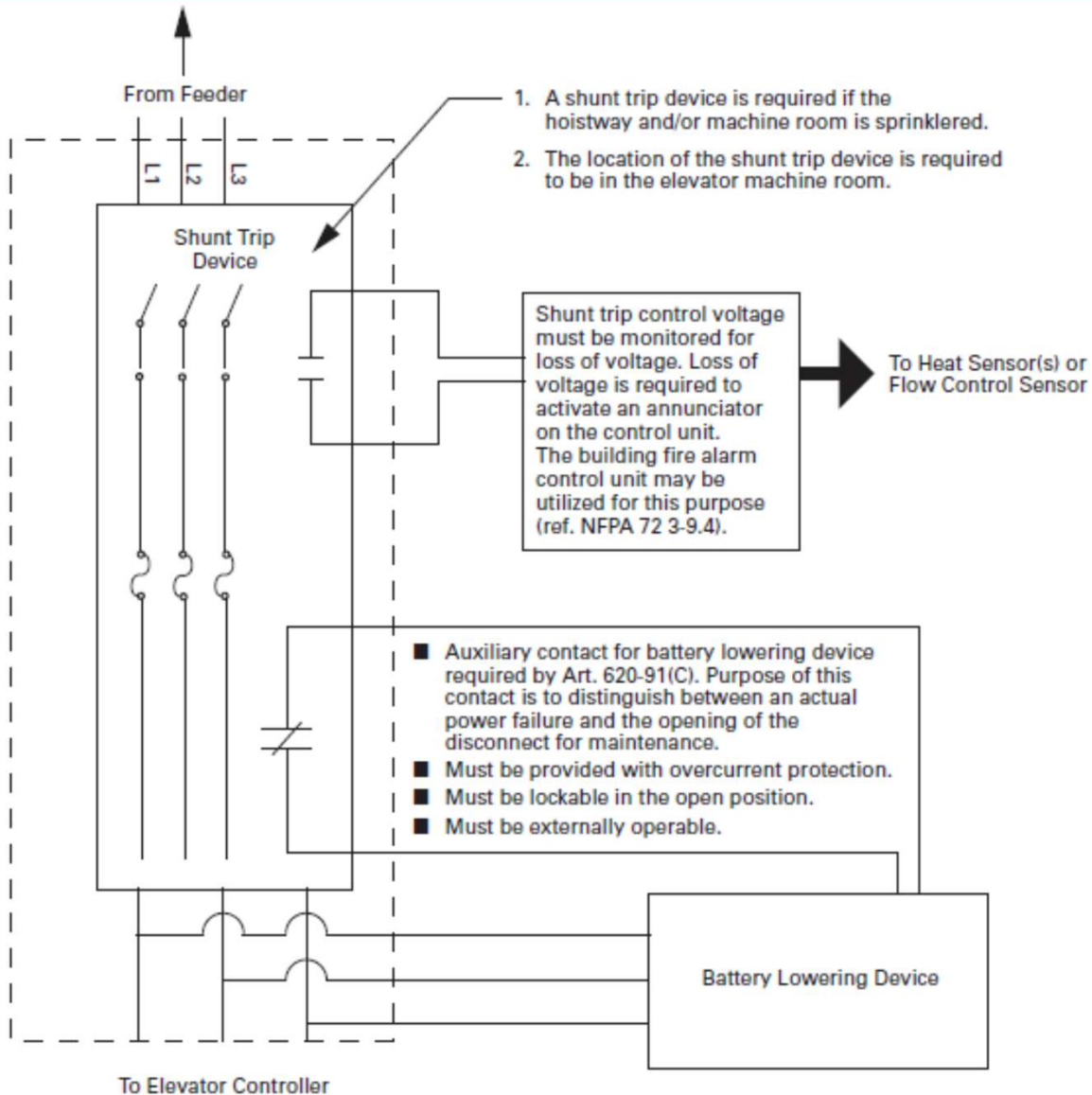
An alternatively powered, auxiliary control system that will, upon failure of the main power supply, allow a hydraulic elevator to descend to a lower landing.

HYDRAULIC ELEVATOR ONLY



ELEVATORS

POWER SYSTEM REQUIREMENTS



Hydraulic Elevator Control Switch



ELEVATORS

POWER SYSTEM REQUIREMENTS

- ❖ **The Elevator Control Panel (ECP) must have a Short Circuit Current Rating higher than the available short circuit current rating and the SSCR must be marked on the ECP.**
- ❖ **A single means for disconnecting all ungrounded main power supply conductors to the ECP shall be provided and be designed so that no pole can be operated independently.**
- ❖ **The disconnecting means shall be an enclosed externally operable fused motor circuit switch or circuit breaker that is lockable in the open position.**
- ❖ **The disconnecting means shall be a listed device.**



ELEVATORS

Attendance Question #8

**Is an Auxiliary Power Lowering Device
Required for all Hydraulic Elevators?**

A – Yes

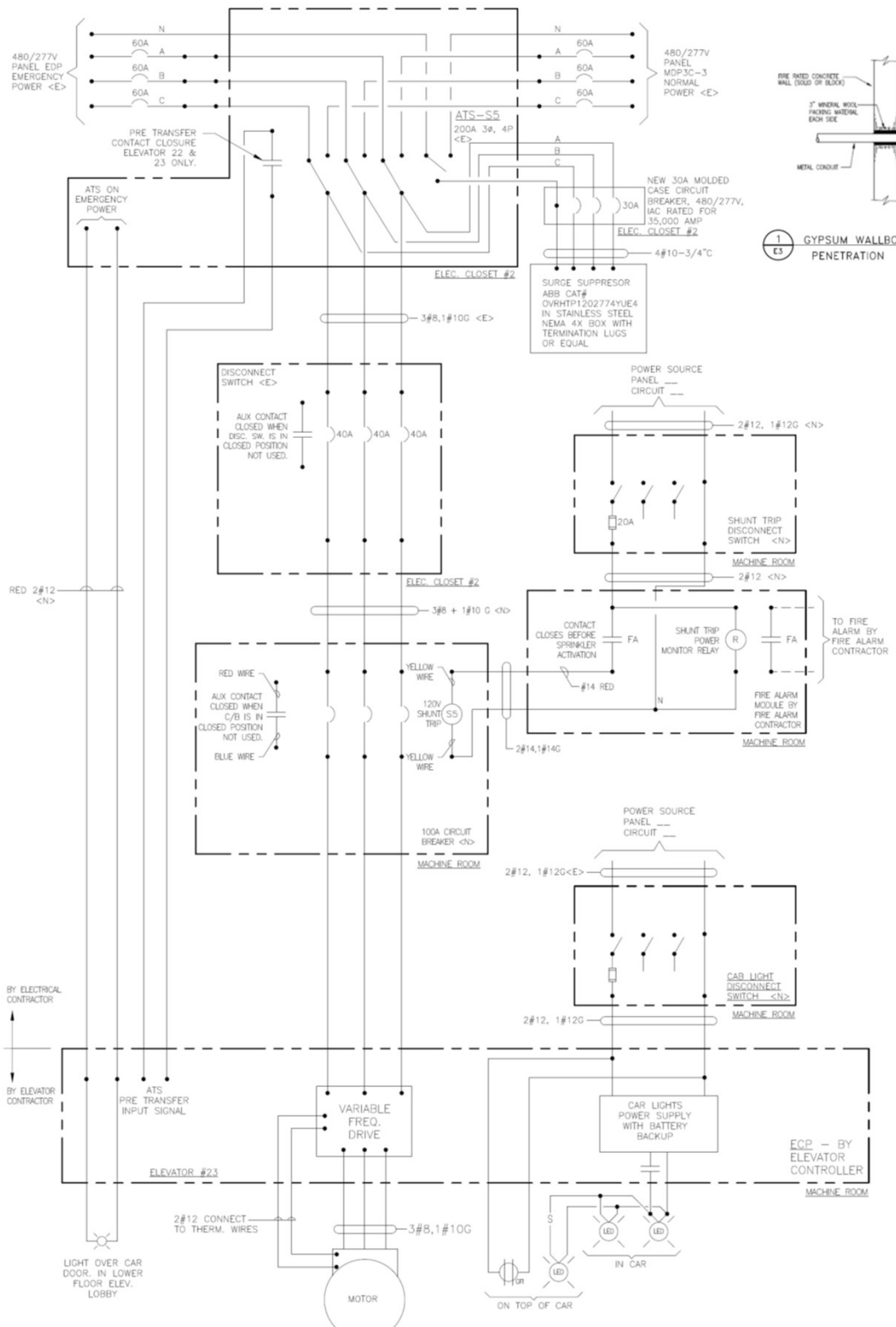
B - No

Answer #8 – B



Elevator Power Source Diagram

- Surge Protection
- Shunt Trip before Sprinkler Activation
- Disconnect in the machine room
- Pre-transfer notification
- Emergency Power Indication



ELEVATORS

POWER SYSTEM

Separate branch circuits, with the branch circuit overcurrent devices in the elevator machine room or control room/machinery space or control space, shall be provided for the following shall be

- **Car lights, receptacle(s), auxiliary lighting power source, and ventilation on each car.**
- **Car Air Conditioning and Heating Source**
- **Other Utilization Equipment**

ELEVATORS

POWER SYSTEM

Separate and dedicated branch circuits shall be provided for the following:

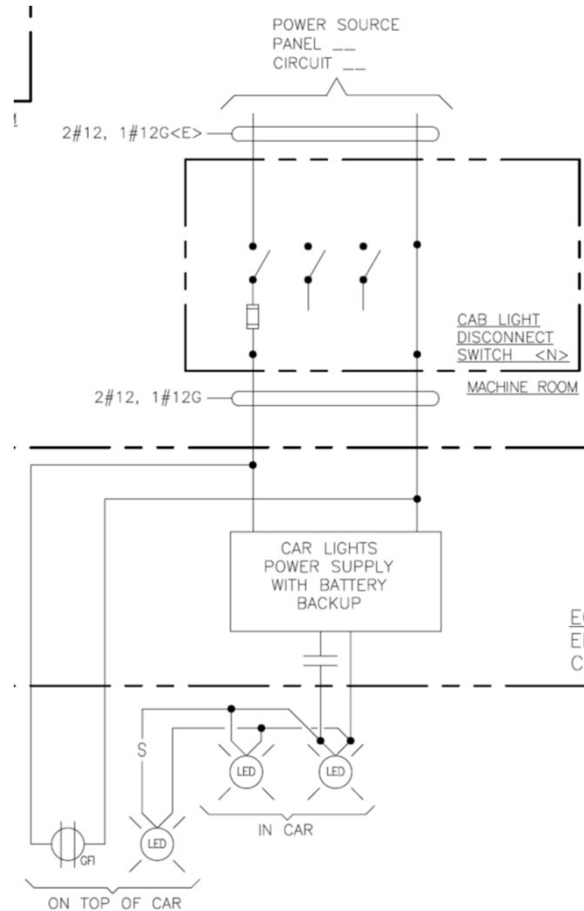
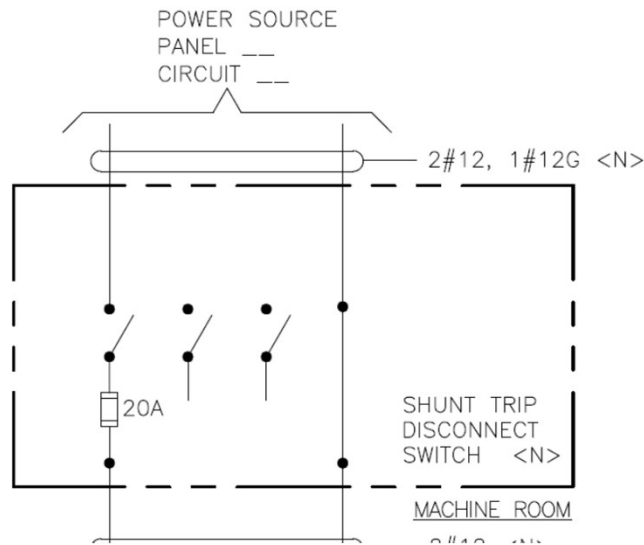
- **Lighting for machine rooms, control rooms, machinery spaces, or control spaces.**
- **Pit Lighting and 125-volt, 15- or 20-ampere duplex GFI Receptacles**

ELEVATORS

POWER SYSTEM

A branch circuits shall be provided for the following:

- **125-volt, 15- or 20-ampere duplex GFI/RC receptacle in the for machine rooms, control rooms, machinery spaces, or control spaces.**

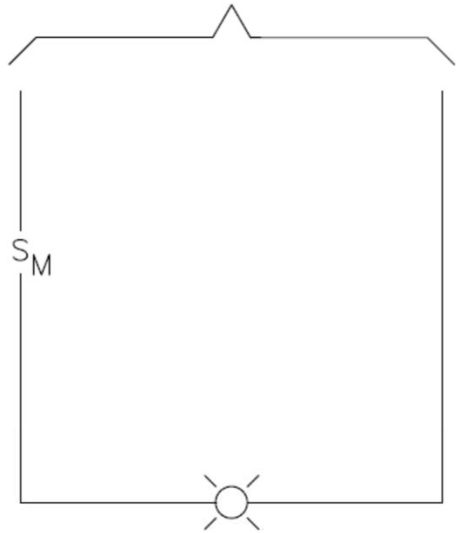


Elevator Power Source Diagram

- **Shunt trip**
- **Car Lights & optional top of car light & GFCI receptacle**
- **Machine Room Light**
- **Machine Room GFCI Receptacle**
- **Pit Light and GFCI Receptacle**

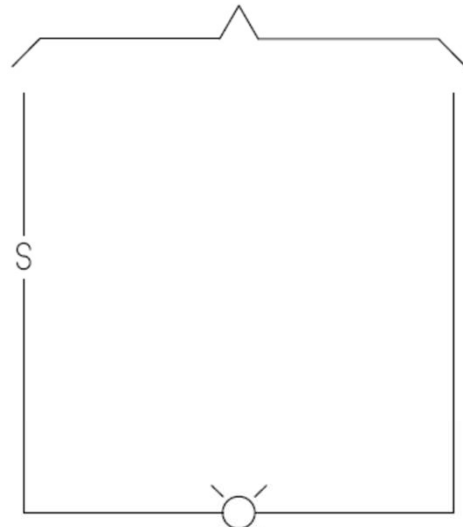
Elevator Power Source Diagram

DEDICATED BRANCH CIRCUIT
PANEL _____ CIRCUIT _____



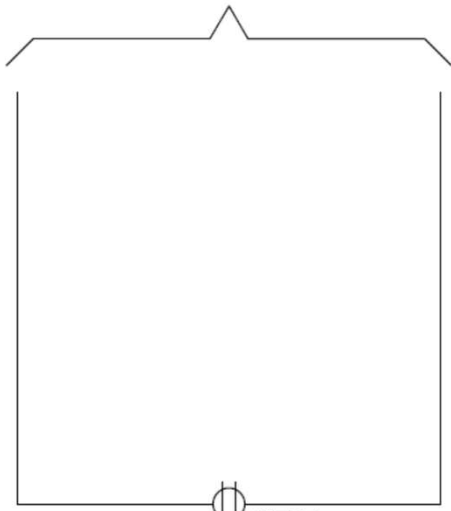
MACHINE ROOM
LIGHTING

DEDICATED BRANCH CIRCUIT
PANEL _____ CIRCUIT _____



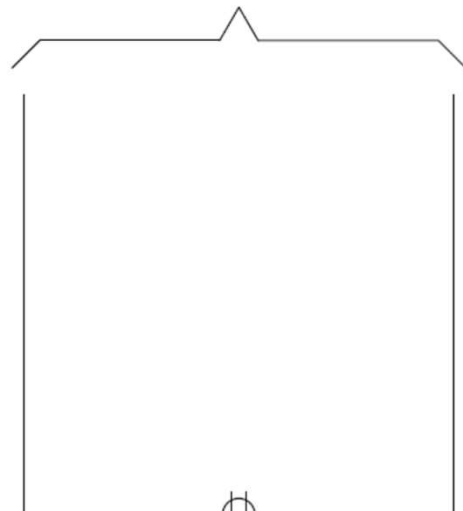
PIT
LIGHTING

DEDICATED BRANCH CIRCUIT
PANEL _____ CIRCUIT _____



GFCI
MACHINE
ROOM
RECEPTACLE

DEDICATED BRANCH CIRCUIT
PANEL _____ CIRCUIT _____



GFCI
PIT ROOM
RECEPTACLE

- **Shunt trip**
- **Car Lights and top of car GFCI receptacle**
- **Machine Room Light**
- **Machine Room GFCI Receptacle**
- **Pit Light and GFCI Receptacle**



ELEVATORS

Attendance Question #9

Must a signal be sent to an elevator that is being powered from an emergency source prior to the ATS switching to normal power?

A – Yes

B – No

Answer #9 – B



ELEVATORS

Attendance Question #10

Must the power source for the shunt trip device that will remove power to elevator controller be monitored ?

A – Yes

B – No

Answer #10 – A



ELEVATORS

620.62 Selective Coordination. Where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent protective devices in each disconnecting means shall be selectively coordinated with any other supply side overcurrent protective devices.

Selective coordination shall be selected by a licensed professional engineer or other qualified person engaged primarily in the design, installation, or maintenance of electrical systems.

The selection shall be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

ELEVATOR POWER SYSTEM



ELEVATORS

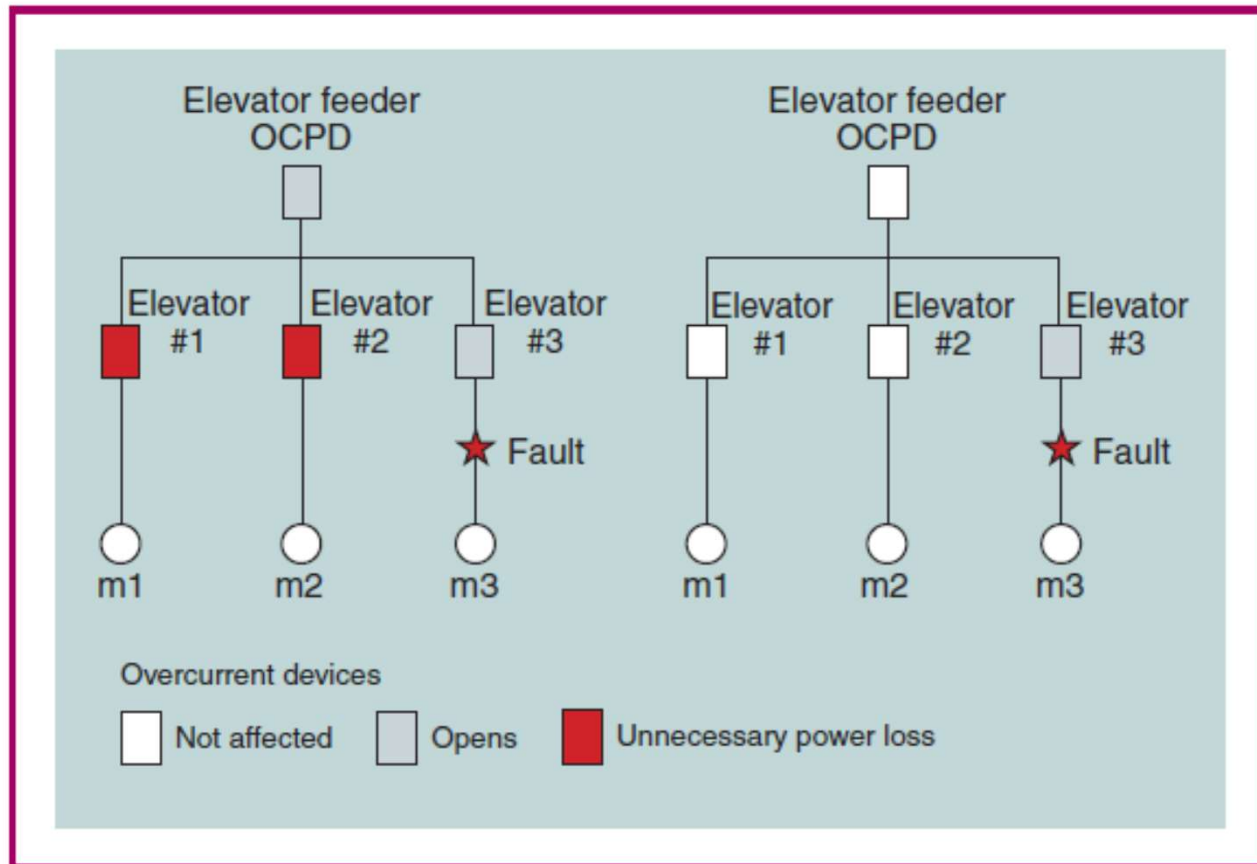
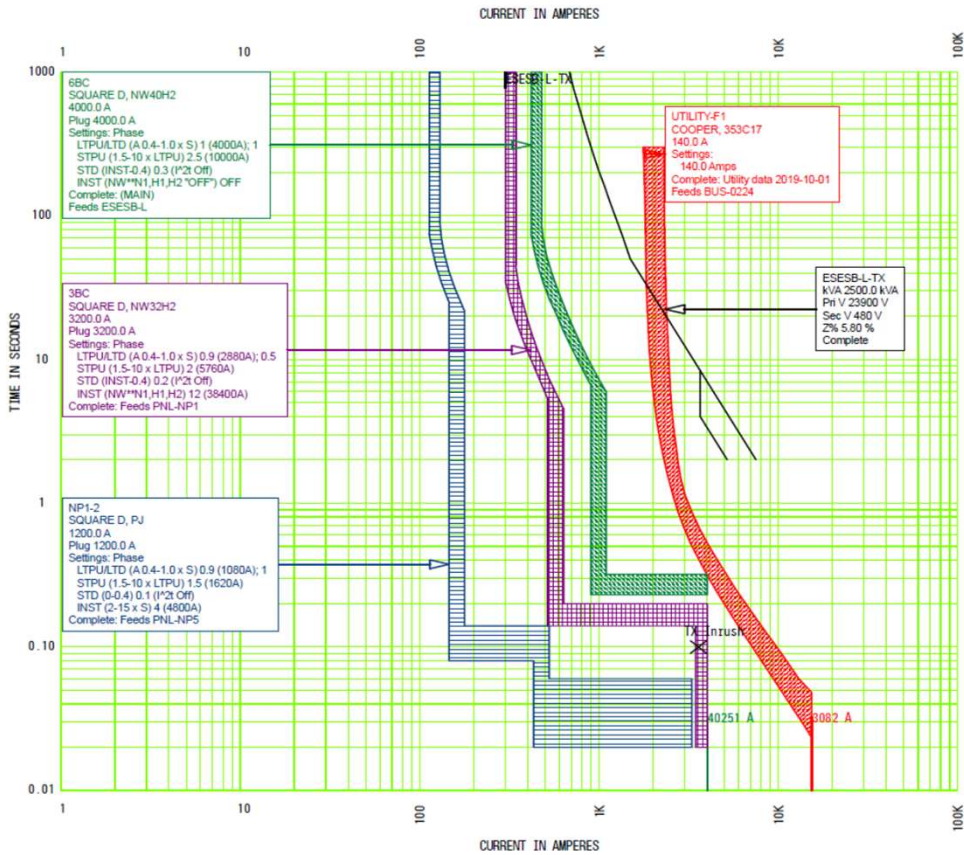
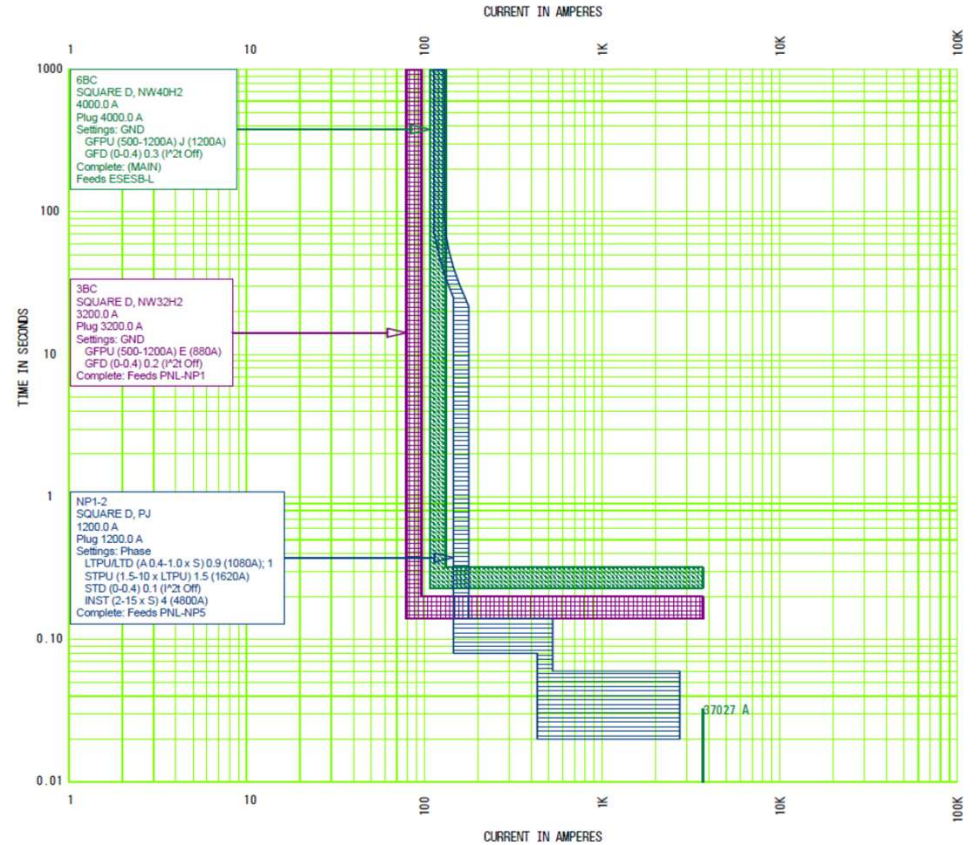


EXHIBIT 620.6 Examples of a system of OCPDs that are not selectively coordinated (left) and a system where selectively coordinated overcurrent protection limits the power outage to only the elevator circuit in which the fault has occurred (right).

Case Studies



PHASE CURRENTS



GROUND CURRENTS

TCC - FEEDER FOR 480 VOLT, 500 HP VFD



ELEVATORS

Technical Question #5

For a 480 volt power system with a 1,200 Amp Main Service Breaker, which must have Ground Fault Protection, that feeds the three (3) dedicated 100 Amp Elevator Feeder Circuit Breakers without Ground Fault Protection and a diode short circuit occurs in the VFD for the elevator, which circuit breaker will trip?



ELEVATORS

Technical Question #6

**Are Elevator Control Panels Required to be
labeled with its
Short Circuit Current Rating?**

Answer - Yes



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Technical Question #7

What is the difference between a Ground Fault Circuit Interrupter (GFCI) Circuit Breaker and a Circuit Breaker with Ground Fault Protection?

Answer

**GFCI provides people protections
GFP provides equipment protection**



The 2020 NEC – Non-Residential Power Systems

110.16 Arc-Flash Hazard Warning.

(A) **General.** Electrical equipment, such as switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers, that is in other than dwelling units, and is likely to require examination, adjustment, servicing, or maintenance while energized, shall be field or factory marked to warn qualified persons of potential electric arc flash hazards. The marking shall meet the requirements in 110.21(B) and shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

Article 110.16 was added to the 2002 NEC



ELEVATORS

Technical Question #7

When do Elevator Control Panels require an arc flash warning label?

Answer

When the incident energy at 18" from an exposed energized part or conductor within the Elevator Control Panel is 1.2 calories/cm² or higher, a label must be installed.





THANK YOU

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