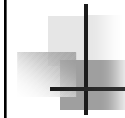# Electrical Symbols and Line Diagrams

Chapter 3

Material taken from Chapter 3 of Electric Motor Controls, G. Rockis, 2001

One-Line Diagrams

- One-line diagram – a diagram that uses single lines and graphic symbols to indicate the path and components of an electrical circuit.

- One-line diagrams are used when information about a circuit is required but detail of the actual wire connections and operation of the circuit are not.

Line Diagrams

- A line (ladder) diagram is a diagram that shows the logic of an electrical circuit or system using standard symbols.
- A line diagram is used to show the relationship between circuits and their components but not the actual location of the components.
- Line diagrams provide a fast, easy understanding of the connections and use of components.
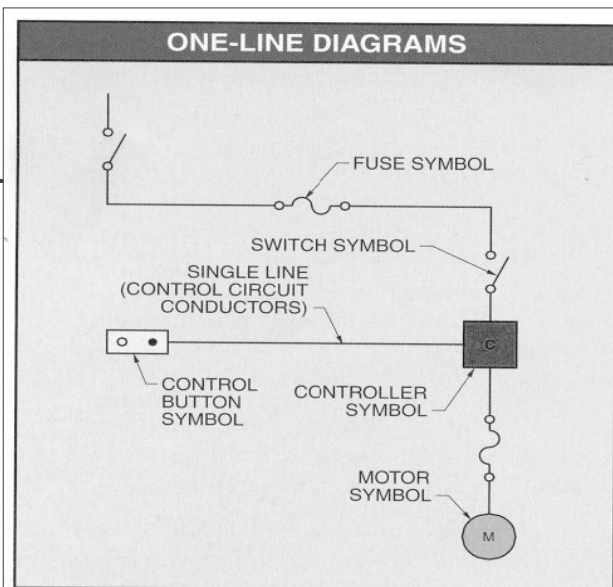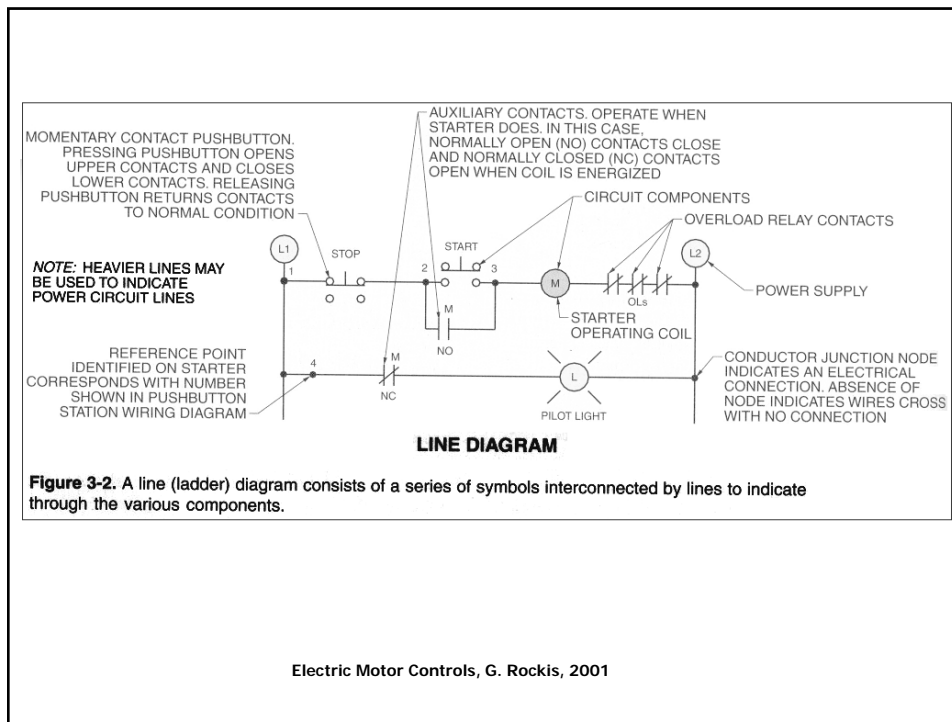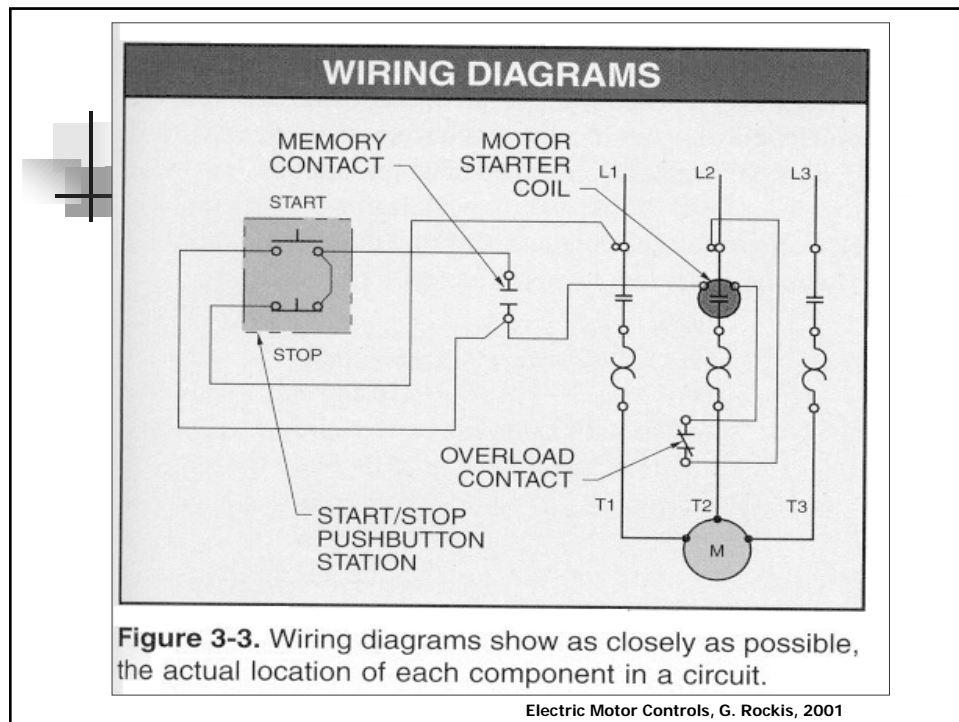

ONE-LINE DIAGRAMS

FUSE SYMBOL

SWITCH SYMBOL

SINGLE LINE
(CONTROL CIRCUIT
CONDUCTORS)

CONTROL BUTTON SYMBOL

CONTROLLER SYMBOL

MOTOR SYMBOL

Figure 3-1. A one-line diagram uses single lines and graphic symbols to indicate the path and components of an electrical circuit.

Electric Motor Controls, G. Rockis, 2001

MOMENTARY CONTACT PUSHBUTTON. PRESSING PUSHBUTTON OPENS UPPER CONTACTS AND CLOSES LOWER CONTACTS. RELEASING PUSHBUTTON RETURNS CONTACTS TO NORMAL CONDITION

AUXILIARY CONTACTS. OPERATE WHEN STARTER DOES. IN THIS CASE, NORMALLY OPEN (NO) CONTACTS CLOSE AND NORMALLY CLOSED (NC) CONTACTS OPEN WHEN COIL IS ENERGIZED

CIRCUIT COMPONENTS

OVERLOAD RELAY CONTACTS

NOTE: HEAVIER LINES MAY BE USED TO INDICATE POWER CIRCUIT LINES

POWER SUPPLY

STARTER OPERATING COIL

REFERENCE POINT IDENTIFIED ON STARTER CORRESPONDS WITH NUMBER SHOWN IN PUSHBUTTON STATION WIRING DIAGRAM

CONDUCTOR JUNCTION NODE INDICATES AN ELECTRICAL CONNECTION. ABSENCE OF NODE INDICATES WIRES CROSS WITH NO CONNECTION

LINE DIAGRAM

Figure 3-2. A line (ladder) diagram consists of a series of symbols interconnected by lines to indicate through the various components.

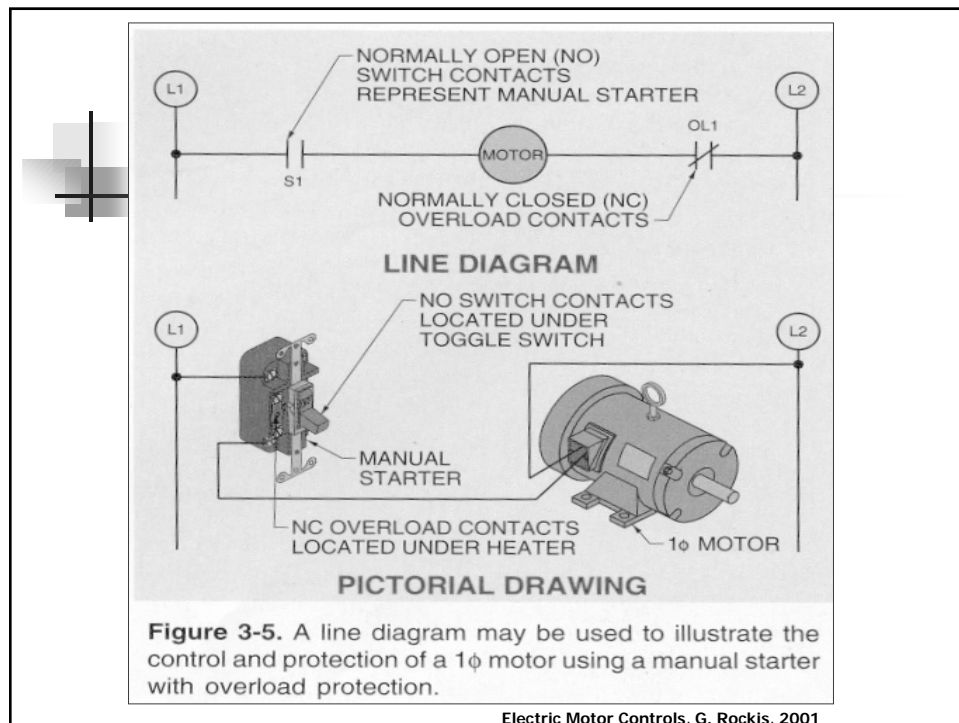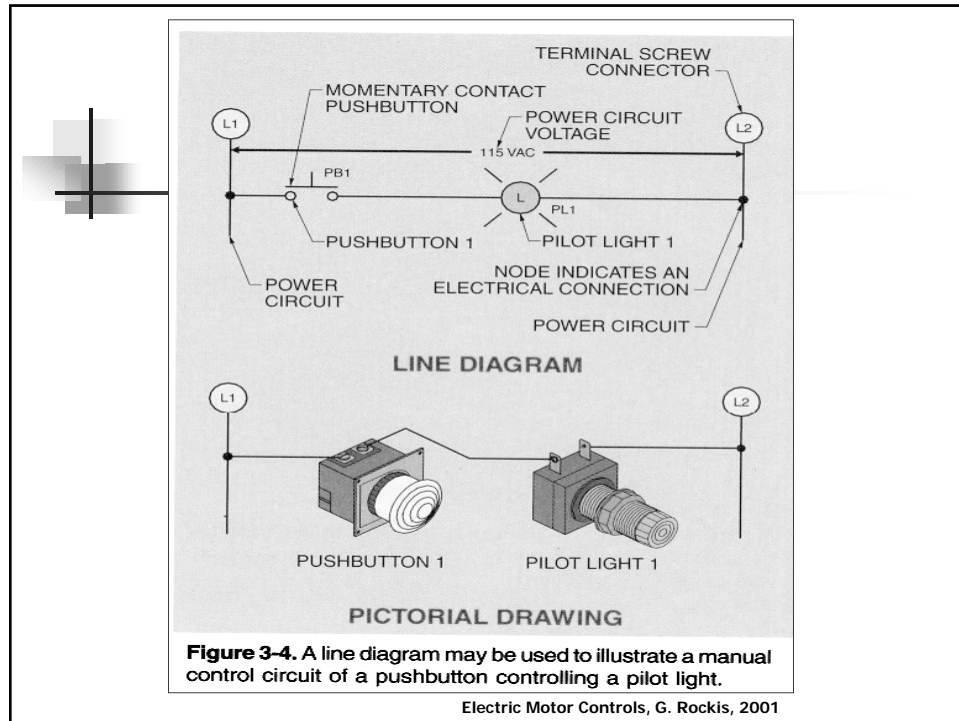Electric Motor Controls, G. Rockis, 2001

Wiring Diagrams

- Wiring (connection) diagram – a diagram that shows the connection of an installation or its component devices or parts.
- Wiring diagrams show, as closely as possible, the actual location of each component in a circuit, including the control circuit and the power circuit.

3

WIRING DIAGRAMS

MEMORY CONTACT

MOTOR STARTER COIL

START

STOP

L1 L2 L3

OVERLOAD CONTACT

START/STOP PUSHBUTTON STATION

T1 T2 T3

M

Figure 3-3. Wiring diagrams show as closely as possible, the actual location of each component in a circuit.
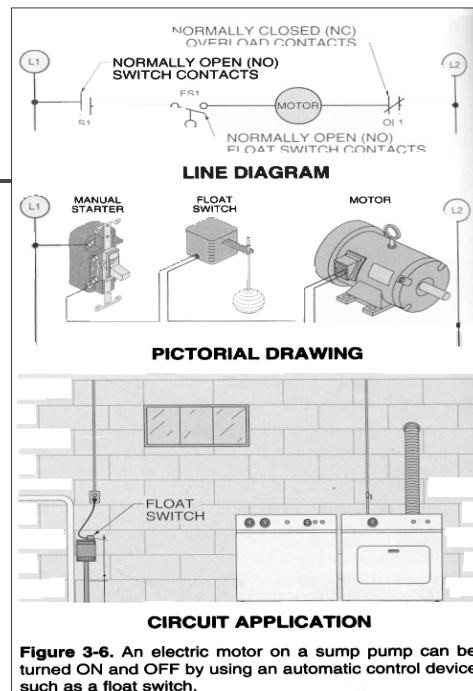
Electric Motor Controls, G. Rockis, 2001

Manual Control Circuits

- Manual control circuit – any circuit that requires a person to initiate an action for the circuit to operate.
- A line diagram may be used to illustrate a manual control circuit of a pushbutton controlling a pilot light.
- A line diagram may be used to illustrate the control and protection of a 1φ motor using a manual starter with overload protection.

Figure 3-4. A line diagram may be used to illustrate a manual control circuit of a pushbutton controlling a pilot light.

Electric Motor Controls, G. Rockis, 2001

Figure 3-5. A line diagram may be used to illustrate the control and protection of a 1φ motor using a manual starter with overload protection.

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Automatic Control Circuits

- Automatically-controlled devices have replaced many jobs that were once performed manually.
- As a part of automation, control circuits are designed to replace manual devices.

Figure 3-6. An electric motor on a sump pump can be turned ON and OFF by using an automatic control device such as a float switch.

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Magnetic Control Circuits

- Although manual controls are compact and sometimes less expensive than magnetic controls, industrial and commercial installations often require that electrical control equipment be located in one area while the load device is located in another.
- Solenoids, contactors, and magnetic motor starters are used for remote control of devices.

Solenoids

- A solenoid is an electrical device that converts electrical energy into a linear mechanical force.

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SOLENOIDS

PLUNGER

FRAME

COIL

Guardian Electric Mfg. Co.
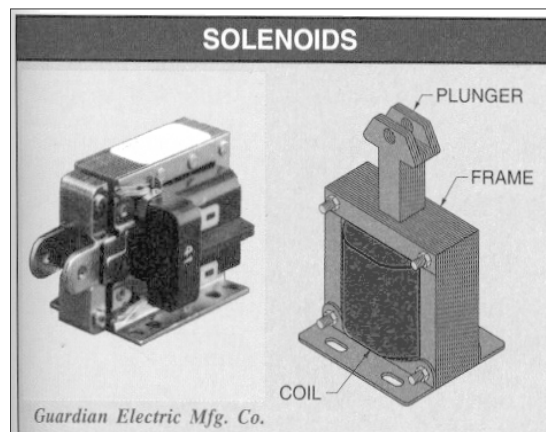
Figure 3-8. A solenoid is an electric output device that converts electrical energy into a linear mechanical force.

Figure 3-9. A solenoid may be used to control a door lock which is opened only when a pushbutton is pressed.
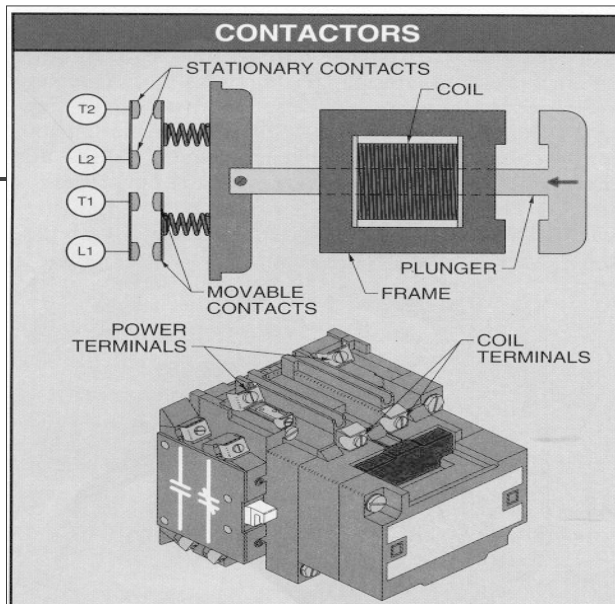
Electric Motor Controls, G. Rockis, 2001
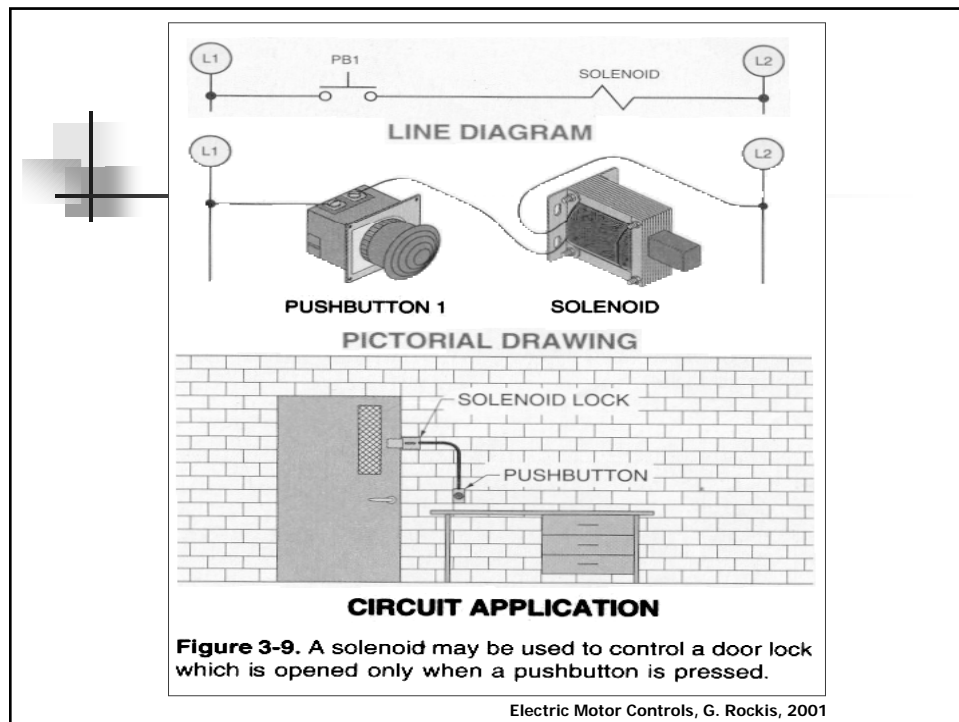
Contactors

- Contactor – a control device that uses a small control current to energize or de-energize the load connected to it.
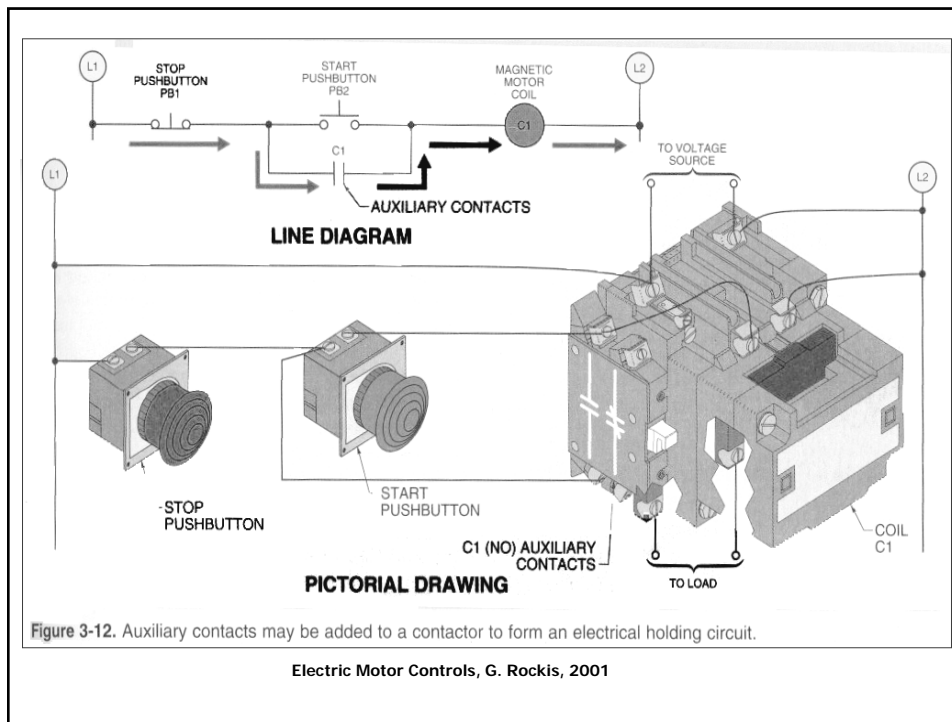- A contactor does not include overload protection.
- A contactor has a frame, plunger, and coil like a solenoid.

Contactors

- The action of the plunger, however, is directed to close (or open) sets of contacts.
- The closing of the contacts allows electrical devices to be controlled from remote locations.

CONTACTORS

STATIONARY CONTACTS
COIL
T2
L2
T1
L1
PLUNGER
MOVABLE CONTACTS
FRAME
POWER TERMINALS
COIL TERMINALS

Figure 3-10. A contactor is a control device that uses a small control current to energize or de-energize the load connected to it.

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STOP PUSHBUTTON PB1

START PUSHBUTTON PB2

MAGNETIC MOTOR COIL

C1

AUXILIARY CONTACTS

LINE DIAGRAM

TO VOLTAGE SOURCE

STOP PUSHBUTTON

START PUSHBUTTON

C1 (NO) AUXILIARY CONTACTS

COIL C1

TO LOAD

PICTORIAL DRAWING

Figure 3-12. Auxiliary contacts may be added to a contactor to form an electrical holding circuit.

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Magnetic Motor Starters

- A magnetic motor starter is an electrically-operated switch (contactor) that includes motor overload protection.

- Magnetic motor starters are identical to contactors except that they have overloads attached to them.

Magnetic Motor Starters

- The overloads have heaters or electronic overloads (located in the power circuit) which sense excessive current flow to the motor.

- The heaters open the NC overload contacts (located in the control circuit) when the overload becomes dangerous to the motor.

Figure 3-14. A line diagram may be used to illustrate the use of a magnetic starter with overloads.

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11
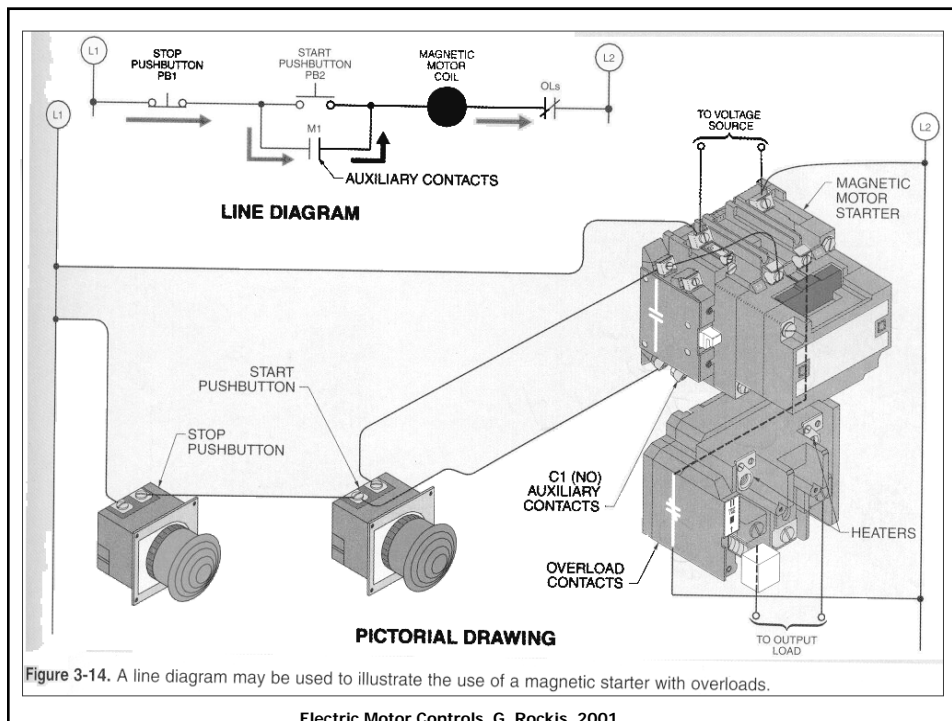
Logic Applied to Line Diagrams
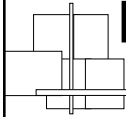
Chapter 4

Material taken from Chapter 4 of Electric Motor Controls,
G. Rockis, 2001

Basic Rules

- The electrical industry has established a universal set of symbols and rules on how line diagrams (circuits) are laid out.

One Load Per Line

- No more than one load should be placed in any one circuit line between L1 and L2.

- A pilot light can be connected into a circuit with single-pole switch.
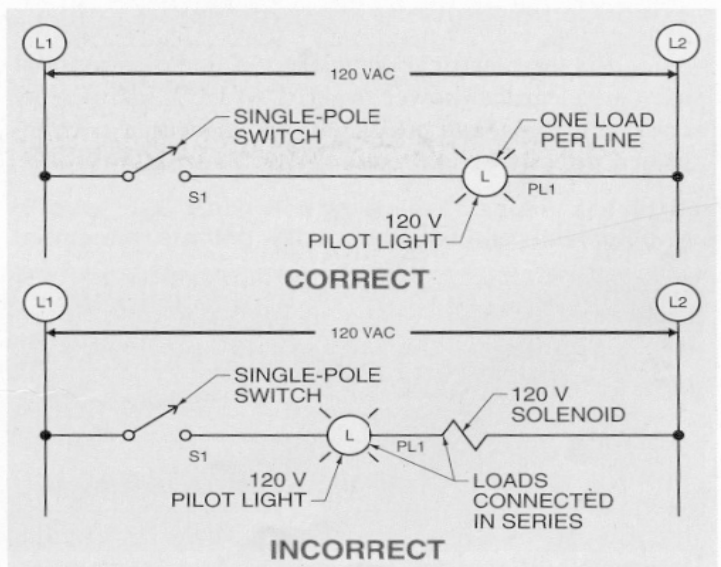
Figure 4-1. No more than one load should be placed in any one circuit line between L1 and L2.

One Load Per Line

- Two loads must not be connected in series on one line of a line diagram.
- If the two loads are connected in series, then the voltage between L1 and L2 must divide across both loads when S1 is closed.
- The result is that neither device receives the entire 120 V necessary for proper operation.

One Load Per Line

- Loads must be connected in parallel when more than one load must be connected in the line diagram.
- This circuit has two lines, one for the pilot light and one for the solenoid.
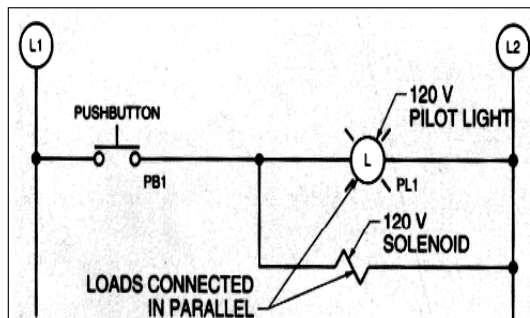
Figure 4-2. Loads must be connected in parallel when more than one load must be connected in the line diagram.

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Load Connections

- A load is the electrical device in the line diagram that uses the electrical power from L1 to L2.

- Control relay coils, solenoids, and pilot lights are loads that are connected directly or indirectly to L2.
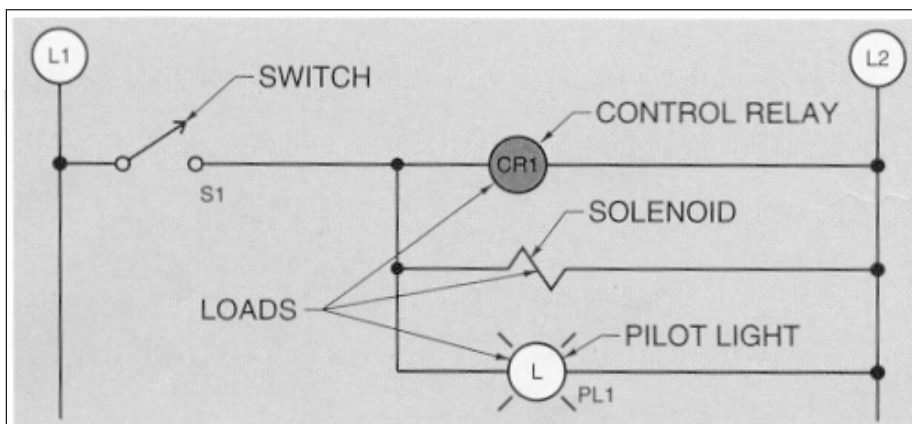
Figure 4-3. Control relays, solenoids, and pilot lights are loads that are connected directly or indirectly to L2.

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Load Connections

- Magnetic motor starter coils are connected to L2 indirectly through normally closed overload contacts.

- Anywhere from 1 to 3 NC overload contacts are shown between the starter and L2 in all line diagrams.

- To avoid confusion, it is common practice to draw one set of NC overload contacts and mark these contacts all overloads (OLs).
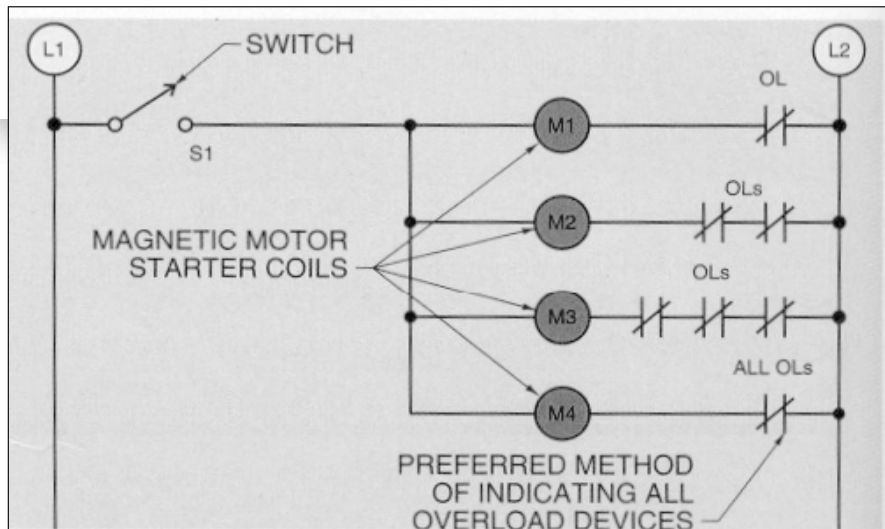
Figure 4-4. Magnetic motor starter coils are connected to L2 indirectly through NC overload contacts.

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Control Device Connections

- Control devices are connected between L1 and the operating coil (or load).
- Operating coils of contactors and starters are activated by control devices such as pushbuttons, limit switches, and pressure switches.
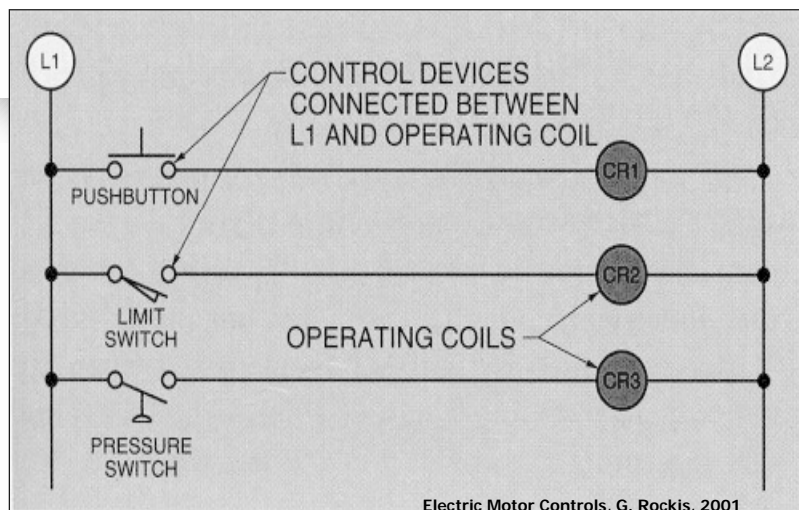
Figure 4-5. Control devices are connected between L1 and the operating coil.

Control Device Connections

- Each line includes at least one control device.

- The operating coil is ON all the time if no control device is included in a line.

- A circuit may contain as many control devices as is required to make the operating coil function as specified.
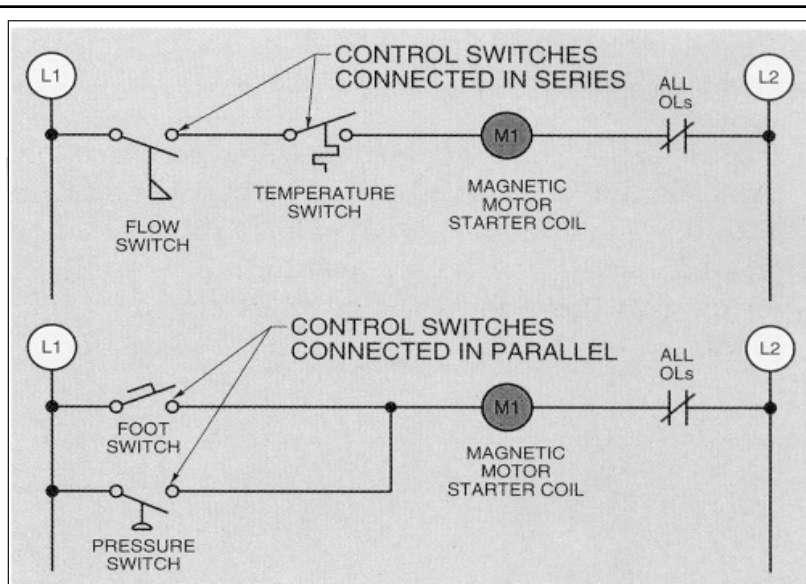
Figure 4-6. Two control devices may be connected in series or parallel to control a coil in a magnetic motor starter.

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Line Number Reference

- Each line in a line diagram should be numbered starting with the top line and reading down.
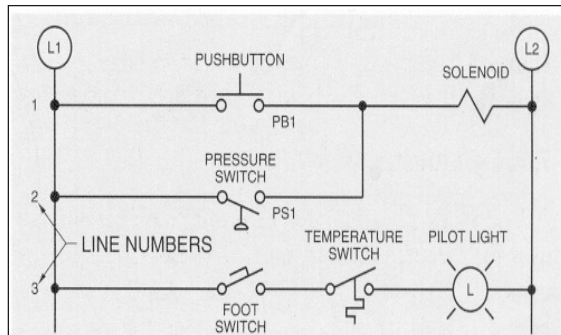
Figure 4-7. Each line in a line diagram should be numbered starting with the top line and reading down.

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Numerical Cross-Reference Systems

- Numerical cross-reference systems are required to trace the action of a circuit in complex line diagrams.
- Common rules help to quickly simplify the operation of complex circuits.

NO Contacts

- Relays, contactors, and magnetic motor starters normally have more than one set of auxiliary contacts.
- These contacts may appear at several different locations in the line diagram.
- Numerical cross-reference systems quickly identify the location and type of contacts controlled by a given device.
- A numerical cross-reference system consists of numbers in parenthesis to the right of the line diagram.
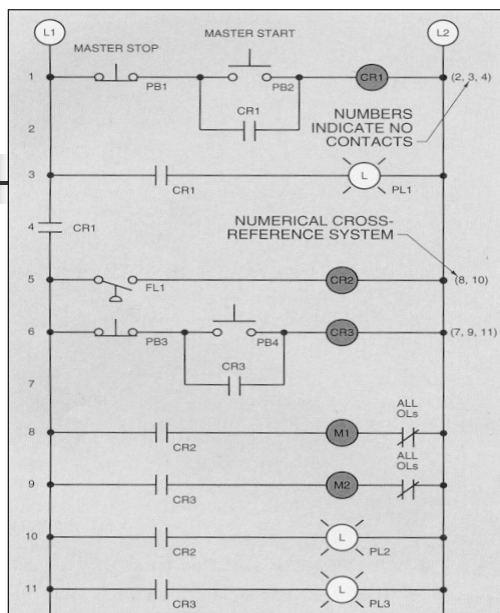
Figure 4-8. The location of NO contacts controlled by a device is determined by the numbers on the right side of the line diagram.

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NC Contacts

- In addition to NO contacts, there are also NC contacts in a circuit.

- To differentiate between NO and NC, NC contacts are indicated as a number which is underlined.

Figure 4-9. NC contacts are indicated by numbers which are underlined to distinguish them from NO contacts.

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Wire-Reference Numbers

- Each wire in a control circuit is assigned a reference point (number) on a line diagram to keep track of the different wires that connect the components in the circuit.

- Each reference point is assigned a reference number.

- Reference numbers are normally assigned from the top left to the bottom right.
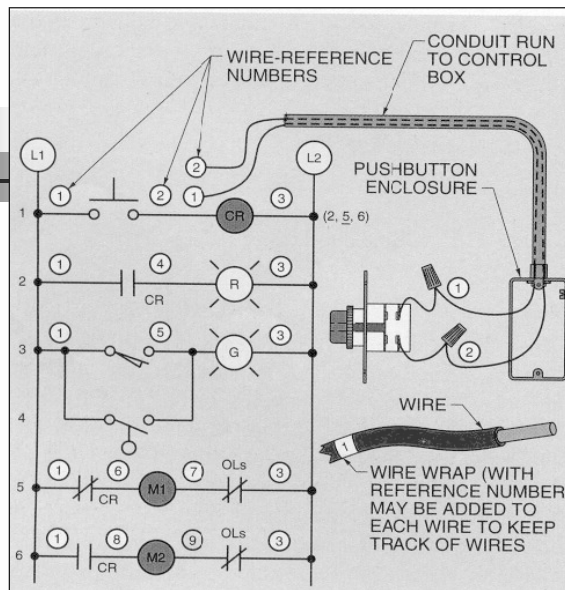
Figure 4-10. Each wire in a control circuit is assigned a reference point on a line diagram to keep track of the different wires that connect the components in the circuit.

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Manufacturer's Terminal Numbers

- Manufacturers of electrical relays, timers, counters, etc., include numbers on the terminal connection points.

- These terminal numbers are used to identify and separate the different component parts (coil, NC contacts, etc) included on the individual pieces of equipment.

- Manufacturer's terminal numbers are often added to a line diagram after the specific equipment to be used in the control circuit is identified.
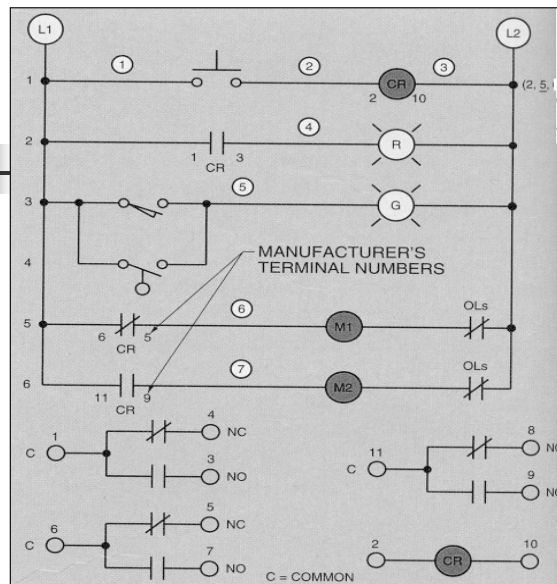
Figure 4-11. Manufacturers include terminal numbers to identify and separate the different component parts included on individual pieces of equipment.

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Signals, Decisions, and Action

- A circuit must respond as designed, without any changes.
- To accomplish this consistency, all control circuits are composed of three basic sections: the signals, the decisions, and the action sections.
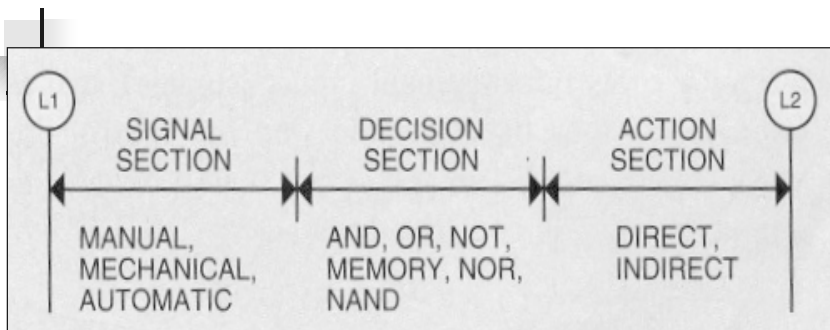
Figure 4-13. All control circuits are composed of signals, decisions, and action sections.

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Signals

- A signal starts or stops the flow of current by closing or opening the control device's contacts.
- Current is allowed to flow through the control device if the contacts are closed.
- Current is not allowed to flow through the control device if the contacts are opened.

Signals

- Pushbuttons, limit switches, flow switches, foot switches, temperature switches, and pressure switches may be used as the signal section of a control circuit.

Signals

- All signals depend on some condition that must take place. This condition can be manual, mechanical, or automatic.
- A manual condition is any input into the circuit by a person. Foot switches and pushbuttons are control devices that respond to a manual condition.

Signals

- A mechanical condition is any input into the circuit by a mechanically moving part.
- A limit switch is a control device that responds to a mechanical condition.

Signals

- An automatic condition is any input which responds automatically to changes in a system.
- Flow switches, temperature switches, and pressure switches respond to automatic conditions.

Decisions

- The decision section of a circuit determines what work is to be done and in what order the work is to occur.
- The decision section of a circuit adds, subtracts, sorts, selects, and redirects the signals from the control devices to the load.

Decisions

- The way the control devices are connected into the circuit gives the circuit logic.
- The basic logic functions are AND, OR, NOT, NOR, and NAND logic.
- The decision section of the circuit accepts informational input (signals), makes logical decisions based on the way the control devices are connected into the circuit, and provides the output signal that controls the load.

Action

- Once a signal is generated and the decision has been made within a circuit, some action (work) should result.
- In most cases it is the operating coil in the circuit which is responsible for initiating the action.

Action

- This action is direct when devices such as motors, lights, and heating elements are turned ON as a direct result of the signal and the decision.
- This action is indirect when the coils in solenoids, magnetic starters, and relays are energized.

Logic Functions

- Control devices such as pushbuttons, limit switches, and pressure switches are connected into a circuit so that the circuit can function in a predetermined manner.
- All control circuits are basic logic functions.
- Logic functions are common to all areas of industry.

AND Logic

- AND logic is used in industry when two pushbuttons are connected in series to control a solenoid.
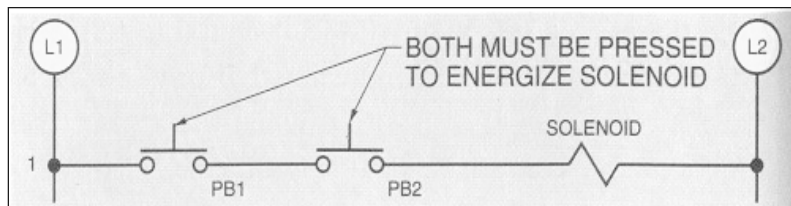

Figure 4-14. In AND logic, the load is ON if both of the control signal's contacts are closed.

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OR Logic

- OR logic is used in industry when a pushbutton and a temperature switch are connected in parallel.
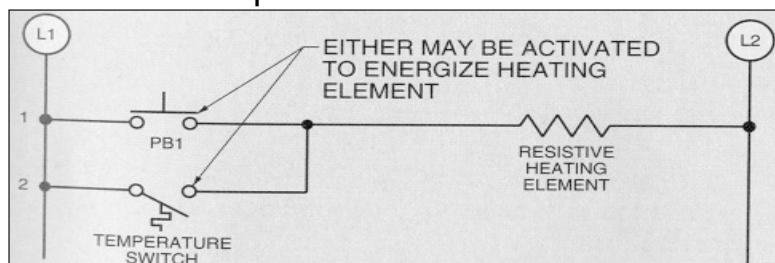
Figure 4-15. In OR logic, the load is ON if any one of the control signal's contacts is closed.

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AND/OR Logic Combination

- The decision section of any circuit may contain one or more logic functions.
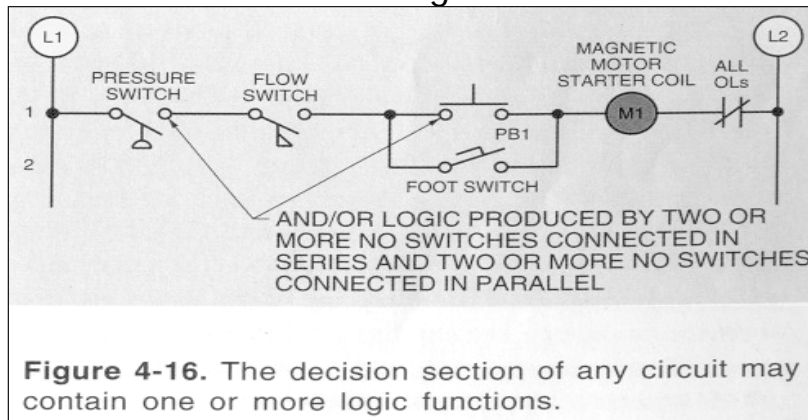
Figure 4-16. The decision section of any circuit may contain one or more logic functions.

NOT Logic

- NOT logic has an output if the control signal is OFF.
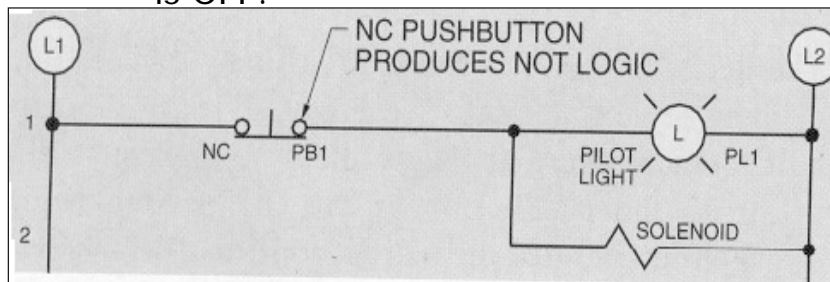
Figure 4-17. In NOT logic, the load is ON only if the control signal contacts are closed.

NOR Logic

- NOR logic is an extension of NOT logic in that two or more NC contacts in series are used to control a load.

- In this circuit, additional operator safety is provided by adding several emergency stop pushbuttons (NOT logic) to the control circuit.
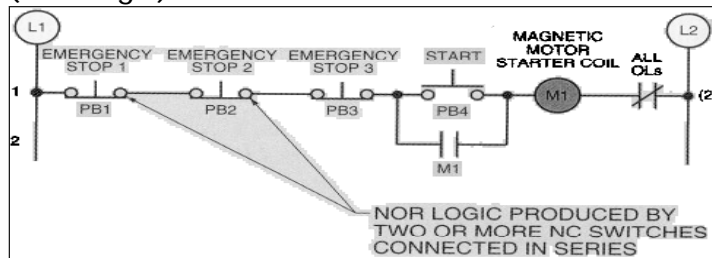
Figure 4-18. NOR logic is an extension of NOT logic in that two or more NC contacts in series are used to control a load.

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NAND Logic

- NAND logic is an extension of NOT logic in which two or more NC contacts are connected in parallel to control a load.
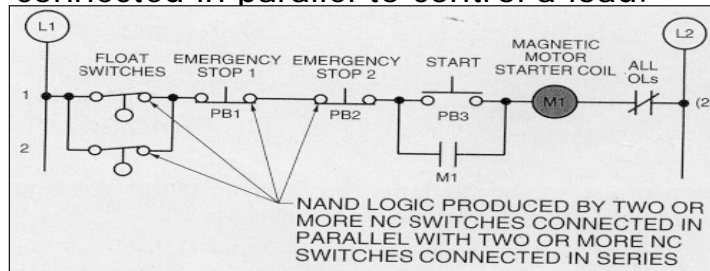
Figure 4-19. NAND logic is an extension of NOT logic in which two or more NC contacts are connected in parallel to control a load.

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Memory

- In industrial control circuits, it is more common to find pushbuttons with return spring contacts (momentary contacts) than those with mechanically stay held in one position (maintained contacts).

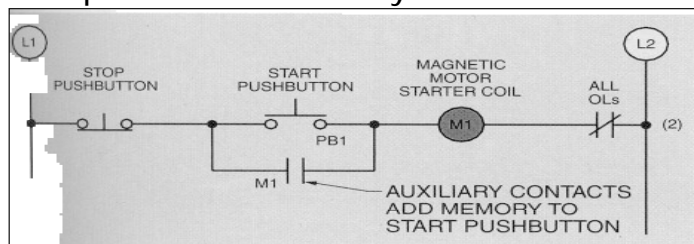- Auxiliary contacts are added to give circuits with pushbuttons memory.

Figure 4-20. Auxiliary contacts are added to give circuits with pushbuttons **memory.**   Electric Motor Controls, G. Rockis, 2001
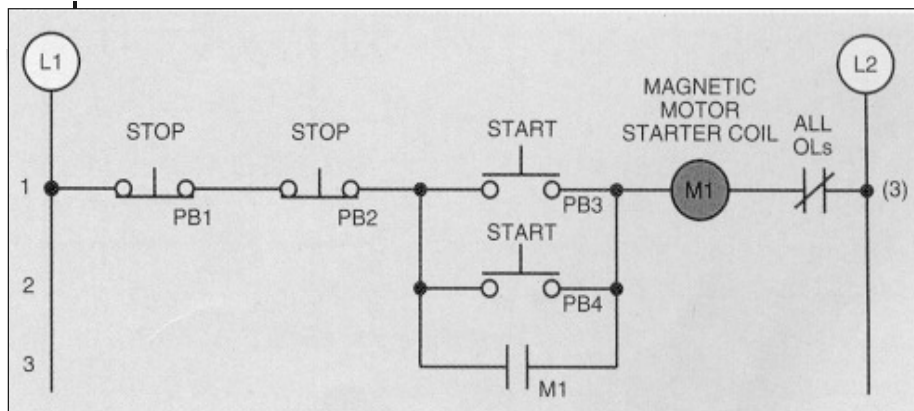
Start/Stop Stations Controlling Magnetic Starters

Figure 4-22. Two stop pushbuttons connected in series and two start pushbuttons connected in parallel are used to control a motor from two locations.

Electric Motor Controls, G. Rockis, 2001

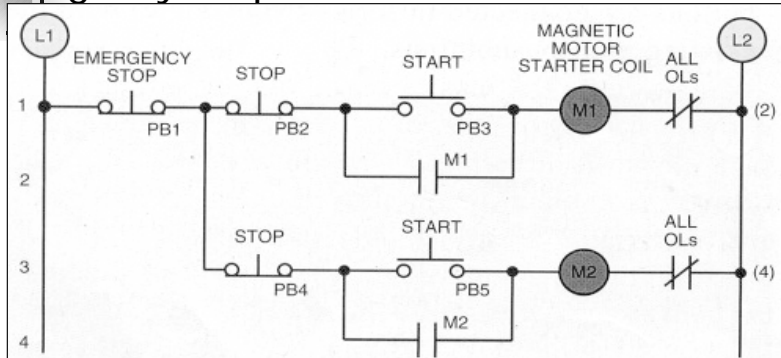# Two Magnetic Starters Operated by Two Start/Stop Stations with Common Emergency Stop

Figure 4-23. Two start/stop stations are used to control two separate magnetic motor starter coils with a common emergency stop protecting the entire system.

Electric Motor Controls, G. Rockis, 2001

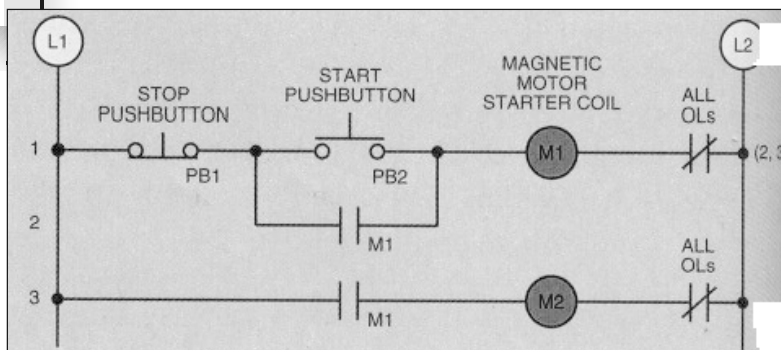# Start/Stop Station Controlling Two or More Magnetic Starters

Figure 4-24. Two motors can be started almost multaneously from one location to prevent produ separation or stretching.

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Pressure Switch with Pilot Light Indicating Activation

- Pilot lights are manufactured in a variety of colors, shapes, and sizes to meet the needs of industry.
- The illumination of these lights signals an operator that any one of a sequence of events may be taking place.
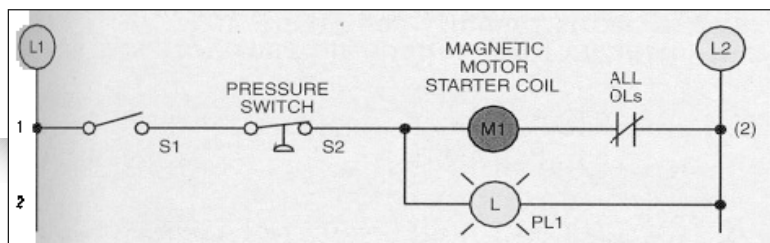

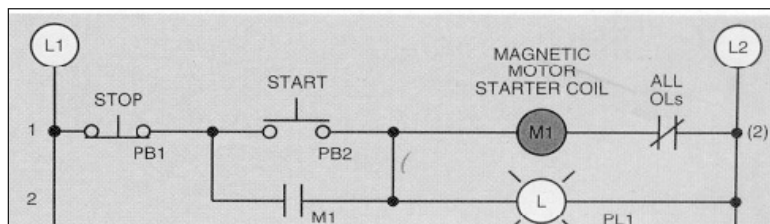Figure 4-25. A pilot light is used with a pressure switch to indicate when a device is activated.

Figure 4-26. A pilot light is used with a start/stop station to indicate when a device is activated.

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Start/Stop Station with Pilot Light Indicating NO Device Activation

- Pilot lights may be used to show when an operation is stopped as well as when it is started.
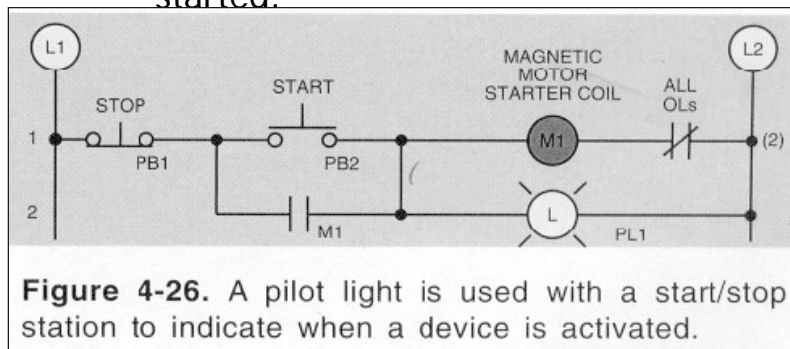

Figure 4-26. A pilot light is used with a start/stop station to indicate when a device is activated.

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Pushbutton Sequence Control

- Conveyor systems often require one conveyor system to feed boxes or other materials onto another conveyor system.
- A circuit is needed to prevent the pileup of material on the second conveyor if the second conveyor is stopped.
- A sequence control circuit does not let the first conveyor operate unless the second conveyor has started and is running.
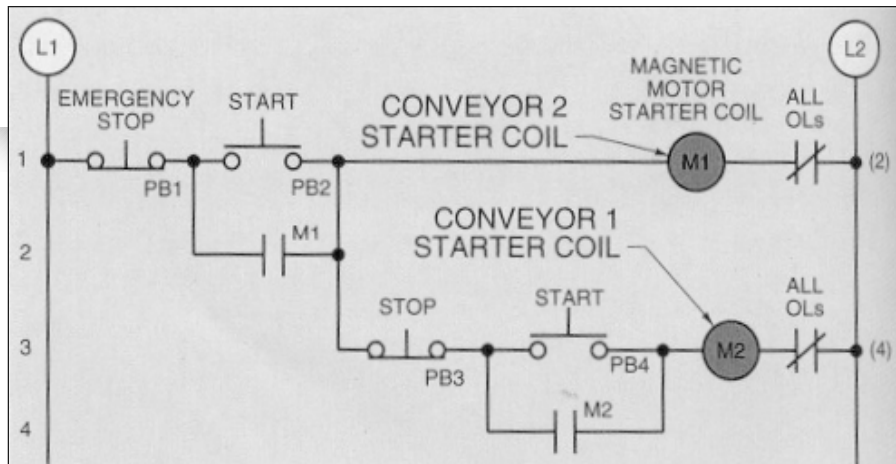
Figure 4-28. A sequence control circuit does not let the first conveyor operate unless the second conveyor has started and is running.

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