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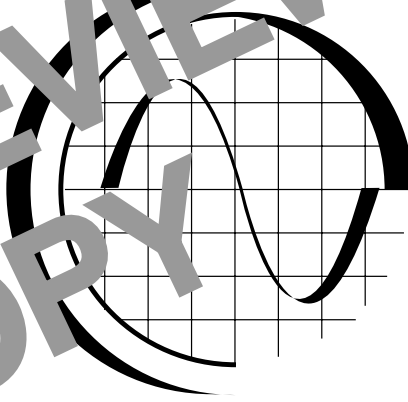
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***ELECTRICAL TROUBLESHOOTING***

***Lesson One***

***Troubleshooting  
with Electrical  
Schematics***

PREVIEW  
COPY



***TPC Training Systems***

21001

**Lesson**

# **Troubleshooting with Electrical Schematics**

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## TOPICS

Standard Symbols and Diagram Identification  
 Elementary Diagrams  
 Reading the Schematic Diagram  
 Power Circuit  
 Control Circuit  
 Motor-Starting Circuit

Identifying Conductors  
 Numbering Components  
 Locating Relay Contacts  
 Control-Panel Layouts  
 Sequence of Operation  
 Related Schematic Information

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## OBJECTIVES

After studying this lesson, you should be able to...

- Identify a control relay on an electrical schematic.
- State the NEC requirements for fuses in ungrounded conductors.
- Explain component numbering on electrical schematics.

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## KEY TECHNICAL TERMS

**JIC** 1.01 Joint Industrial Conference, an organization that has set specifications for mass-produced electrical equipment used in industry

**Elementary diagram** 1.05 a schematic diagram of the control circuit for a machine

**Sequence of operation** 1.39 a diagram indicating the progression of operations for all devices on a machine

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**Automatic operation and precision control of modern electrical equipment necessitates the use of complex wiring circuits. When trouble develops in a circuit, extended periods of downtime may result while the electrician tries to locate and solve the problem.**

**Electrical schematics are the electrician's guides to troubleshooting circuits. However, in order to be of any use, any schematic must contain complete and accurate information and the electrician must fully understand the symbols used and be adept at following the diagram.**

**A good understanding and proper application of electrical schematics will make the electrician's work easier and more effective. It will also reduce downtime. This lesson explains the electrical schematic, the information it contains, and how to interpret the information when troubleshooting and diagnosing electrical circuits of plant equipment.**

### Standard Symbols and Diagram Identification

1.01 For the sake of conformity, *Joint Industrial Conference* (JIC) standards are used throughout this course. The purpose of JIC electrical standards is to provide detailed specifications for mass-produced industrial equipment used for electrical system applications.

1.02 Equipment manufacturers furnish diagrams of the electrical systems, including the serial number and other information needed for identification of the equipment. Electrical diagrams, including panel layout, stock list, and sequence of operation, are shown on one sheet. Subassembly diagrams are usually drawn on separate sheets. Standard electrical diagrams are drawn on 24 by 36 in. paper.

1.03 Standard electrical symbols are used in diagrams. If no standard symbol has been established, special symbols are devised and then identified on the diagram.

1.04 The symbols for devices are identified by a number or a number-letter combination. Standard abbreviations are listed in Table 1-1 on page 15. Any special abbreviations used should be identified on the diagrams.

### Elementary Diagrams

1.05 *Elementary diagrams* are drawn between vertical lines that represent the source of control power. All control devices are drawn between these lines, as shown in Fig. 1-1, on the following page.

- Actuating coils are shown on the right.
- Contacts are shown between the coils and the left vertical line.

1.06 When internal wiring diagrams of subassemblies are furnished on separate sheets, they are shown as rectangles in the elementary diagram. Coils and contacts internal to the subassemblies are shown in the rectangle connected to their terminal points.

1.07 Symbols for control devices are usually shown in the order in which the controls are energized, and are so positioned on the diagram for clarity. A cross-reference system used in conjunction with each relay coil helps you locate associated contacts easily on the diagram. Only those contacts that are actually used are shown.

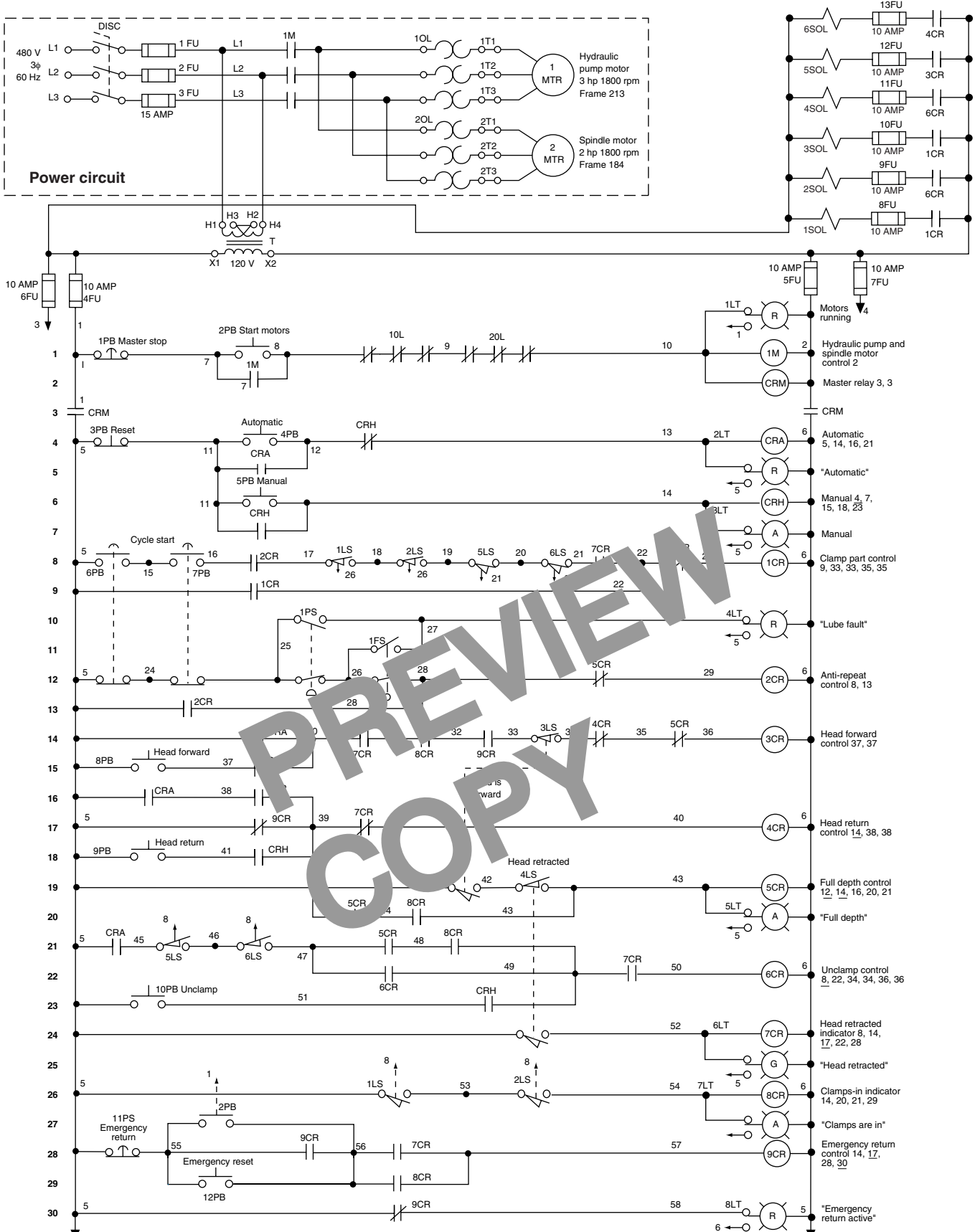
1.08 The symbols for switches (including limit, pressure, float, flow, and temperature-sensitive switches) are shown on the diagram with all utilities turned off. The utilities include electric power, air, gas, oil, water, and any others that may be provided. In other words, the equipment is in its normal starting condition.

### Reading the Schematic Diagram

1.09 A schematic diagram looks complex when viewed as a whole, but you can simplify it by breaking it down into basic circuits. The overall diagram is then easier to understand.

1.10 Control systems are usually designed so that each individual circuit controls only one function of a

Fig. 1-1. Elementary diagram



machine. For example, the start-stop function of a motor may be controlled by a single circuit, which may involve pushbuttons, control solenoids, or limit switches. There are many individual variations. The main fact to remember is that each basic circuit controls one basic machine function.

1.11 The schematic diagram shown in Fig. 1-1 is divided into two parts:

- the power circuits, at the top left
- the control circuits, below.

**Power Circuit**

1.12 The power circuit in Fig. 1-1 is the simplest part of the diagram and the easiest to follow. This schematic shows that the feeder lines are 480 V, three phase, 60 Hz. The circuit has a three-pole disconnect (labeled DISC) and three fuses (FU). The three branch-circuit lines are labeled L1, L2, and L3.

1.13 Three contact symbols are next in the circuit, with the label 1M above them on the diagram. The 1M over the contact symbols indicates that the contacts are controlled by the coil of the No. 1 motor starter (shown on line 1 of the control circuit).

1.14 From the contacts, the line divides to supply two motors. Overload relays (labeled OL) protect each motor. Note the motor-terminal designations (1T1, 1T2, 1T3, 2T1, 2T2, and 2T3).

- All terminals labeled 1T are for motor No. 1.
- Terminals labeled 2T are for motor No. 2.
- If a third motor were connected to the same contacts, its terminals would be labeled 3T, and so on.

The function, horsepower, speed, and frame size of each motor are listed next to the symbol.

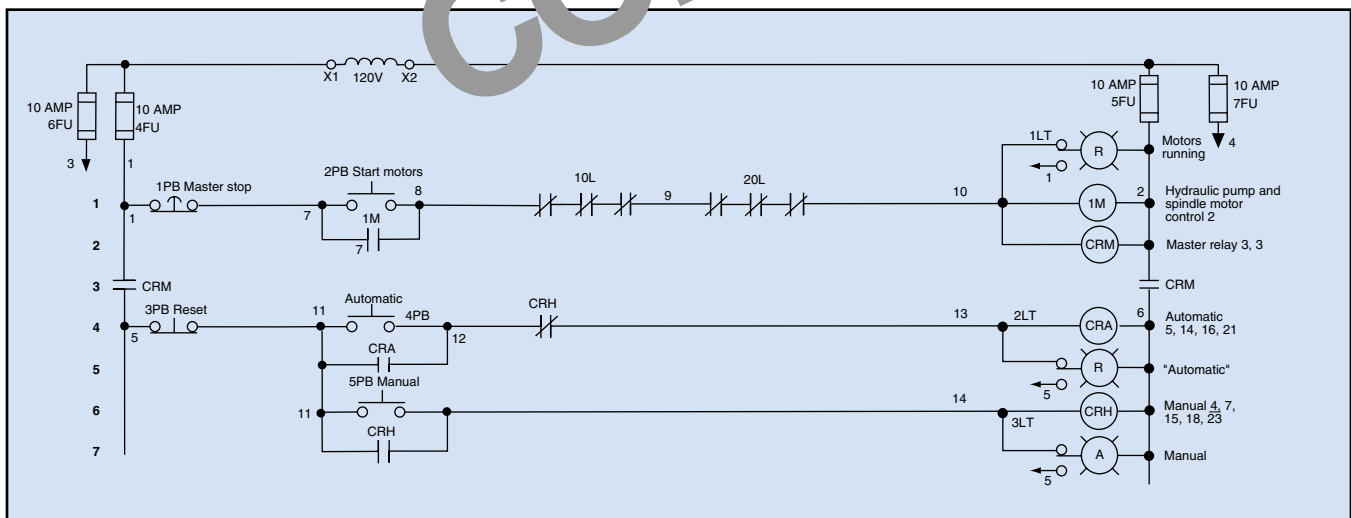
1.15 A control transformer (480/120 V) is connected to two lines of the branch circuit. Reducing the potential difference from 480 to 120 V for the control circuit is a recommended practice. The lower potential difference is safer for operating personnel.

**Control Circuit**

1.16 The upper portion of the control circuit in Fig. 1-1 is reproduced in Fig. 1-2. The left-hand solid vertical line on the schematic is the hot conductor. The right-hand solid vertical line is the common conductor, sometimes called the “neutral” conductor in 120 V ac circuits.

1.17 The drawing shows fuses in both the hot and common lines. The National Electrical Code requires a fuse in ungrounded conductors. The common conductor is sometimes grounded. If the common conductor is grounded, then no fuse is used in that line. The Code does not allow a grounded conductor to be fused.

**Fig. 1-2. Motor-starting circuit**



### Motor-Starting Circuit

1.18 The motor-starting circuit is usually the first circuit shown in a diagram. Starting from the left and proceeding to the right on Line 1 of Fig. 1-2, you can see the following parts of the motor-starting circuit.

- The first device is the master STOP pushbutton, a normally closed mushroom head pushbutton switch labeled 1PB.
- The START pushbutton, a normally open switch labeled 2PB, is shown in parallel with the normally open holding (or seal) contacts, labeled 1M.
- Connected to the START switch are the overload relay contacts (normally closed) in series with coil 1M, which is connected to the common conductor at the right.

This circuit provides the means of starting and stopping the motor with nonlatching contacts.

1.19 Now you can analyze the motor-starting circuit.

- When the START pushbutton 2PB is pressed and held momentarily, the circuit is completed from the hot line, through the normally closed STOP switch 1PB, continuing through the OLs to coil 1M, and on to the common line.
- Coil 1M is energized, closing the motor-run contacts 1M in the power circuit and the auxiliary 1M contacts, which are in parallel with the START switch and complete the holding circuit, bypassing the START switch 2PB, which no longer needs to be held in to keep 1M energized.
- At the time coil 1M is energized, light 1LT comes on to indicate that the motors are running.
- Control relay master CRM is energized. It closes two sets of contacts, one in the hot line and the other in the common line. These contacts energize the rest of the control circuit.

1.20 The contacts labeled CRM prevent the other control devices from functioning when the machine is turned off, either intentionally or because of a power outage, motor overload, or other malfunction. With contacts CRM closed, the machine is ready to perform as soon as the operator presses START switch 4PB for automatic operation. For manual operation, the operator must press switch 5PB.

### Identifying Conductors

1.21 Each conductor in a motor-control circuit is identified by a number, letter, or number-letter combination. Consecutive numbering is preferred. The identification number is used only once in the electrical control system. Each conductor has the same identification at all terminals and tie points. All conductors connected to the same terminal or tie point have the same identification.

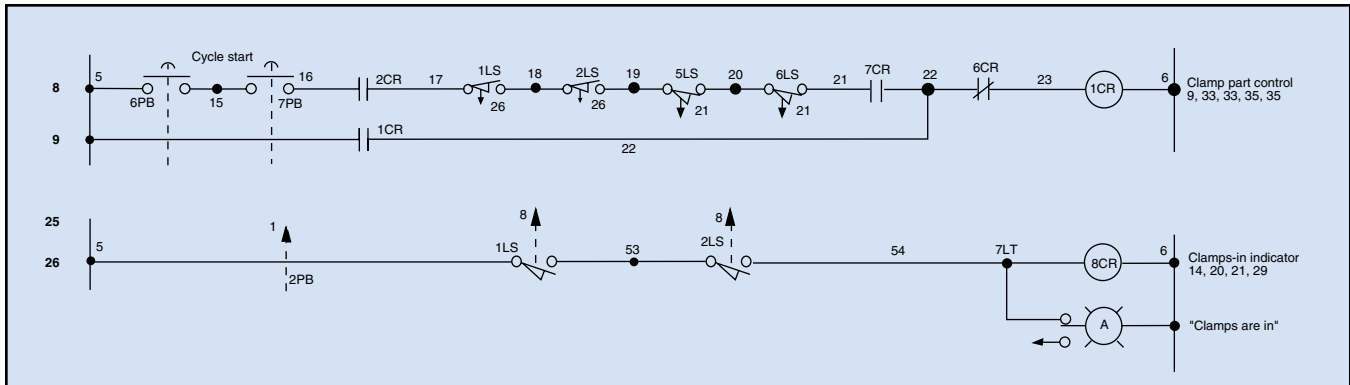
1.22 The vertical conductors are numbered first, beginning with the hot conductor on the left.

- The hot conductor below fuse 4FU is number 1.
- The common conductor below fuse 5FU is number 2.
- Conductor number 3 is at fuse 6FU. This is another vertical conductor for a different part of the control circuit.
- Conductor number 4 is at fuse 7FU.

1.23 The numbers on the vertical conductors change when the conductor is interrupted by a set of contacts.

- The hot conductor is number 1 above contacts CRM, and number 5 below.
- The common conductor is number 2 above contacts CRM, and number 6 below.
- Numbers 5 and 6 are common to the rest of the control circuit and do not change.

1.24 Note the number 1 below fuse 4FU, and the connection point on the left side of the schematic in Fig. 1-2. The wire going from 4FU to the terminal on 1PB has the number 1 at both ends. The wire from

**Fig. 1-3. Limit switches in two control functions**


4FU to the contact of CRM also has a number 1 at both ends. Wherever wires make a common junction point, they all have the same identifying number.

1.25 Continuing from the right-hand terminal of the STOP switch to the START switch, there is a junction labeled number 7. The wire between the STOP switch and the START switch has a number 7 at each end, and the wire from the STOP switch to one contact of 1M also has a number 7.

1.26 The numbers continue to the right with wire number 8 to 1 OL, then 9 between 1 OL and 2 OL. Number 10 is between 2 OL and 1M. Then number 2 goes to fuse 5FU and the common line, completing the motor-control circuit.

1.27 The numbering continues at the left on the next line, with number 11 between 3PB and 4PB, and proceeds to the right in Fig. 1-2.

- All wires connected to the vertical line on the left side below contacts CRM have a number 5.
- Likewise, all wires connected to the vertical line on the right side have the number 6 below contacts CRM.

### Numbering Components

1.28 The relays in control panels may be of the same size or of different sizes. On a schematic, one symbol designates all sizes. The symbol does not tell

you the physical size or other features of the relay, so a way has been devised to distinguish the control relay or switch. Control relays are usually numbered in progression from top to bottom as 1CR, 2CR, 3CR (or as CR1, CR2, CR3), and so on.

1.29 Limit switches are numbered in the same way—1LS, 2LS, 3LS (or as LS1, LS2, LS3), and so on. Relay contacts have the same number as the control relay. All 1CR contacts are marked 1CR, no matter where they appear on the schematic. The same is true of limit switches and pushbutton switches.

1.30 Some limit switches have two or more sets of contacts activated by the same arm. In Fig. 1-1, limit switches 1LS and 2LS are that type of switch. Whenever the switches are used, they are labeled 1LS and 2LS, as shown in Fig. 1-3.

1.31 Switches 1LS and 2LS have arrows pointing down with the number 26 at the bottom, which means that the switches also appear on line 26. On line 26, limit switches 1LS and 2LS are shown with arrows pointing up with the number 8, referring to line 8. This system provides cross-references to the different locations of the switches on the diagram.

**The Programmed Exercises on the following page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.**



## 10 Programmed Exercises

<p>1-1. All control devices shown on an elementary diagram are drawn between vertical lines that represent _____.</p>	<p>1-1. THE SOURCE OF CONTROL POWER Ref: 1.05</p>
<p>1-2. How are internal wiring diagrams of subassemblies, furnished on separate sheets, shown on an elementary diagram?</p>	<p>1-2. AS RECTANGLES Ref: 1.06</p>
<p>1-3. What is the order in which control devices are shown on an elementary diagram?</p>	<p>1-3. THE ORDER IN WHICH THEY ARE ENERGIZED Ref: 1.07</p>
<p>1-4. You can simplify a complex schematic by breaking it down into _____.</p>	<p>1-4. BASIC CIRCUITS Ref: 1.09</p>
<p>1-5. When using a schematic, the main fact to remember is that each _____ controls one _____.</p>	<p>1-5. CIRCUIT; MACHINE FUNCTION Ref: 1.10</p>
<p>1-6. The numbers on the vertical conductors shown on a motor-control circuit change when the conductor is interrupted by a(n) _____.</p>	<p>1-6. SET OF CONTACTS Ref: 1.23</p>
<p>1-7. On a schematic, control relays are usually numbered in progression from _____ to _____.</p>	<p>1-7. TOP; BOTTOM Ref: 1.28</p>
<p>1-8. What is the meaning of an arrow next to the symbol for a switch if the arrow points downward and has the number 12 beneath it?</p>	<p>1-8. THE SWITCH ALSO APPEARS BELOW, ON LINE 12 Ref: 1.31</p>

### Locating Relay Contacts

1.32 Some relays have more than one set of contacts. Their contacts are used in different parts of the control circuit, and it takes time to find them on a complex schematic.

1.33 You can see on the schematic in Fig. 1-1 that the horizontal lines are numbered along the left side, starting with line number 1 at the top. On the right side of the schematic, certain lines have a series of numbers listed horizontally. The numbers appear only on lines that have a control relay (CR).

1.34 As an example, look at line 19 in Fig. 1-4. The horizontal series of numbers at the right consists of the numbers 12, 14, 16, 20, and 21. The control relay on that line is 5CR. The numbers indicate the lines on which you will find the contacts of relay 5CR. Notice that the numbers 12 and 14 are underlined, indicating that on these lines the contacts of 5CR are normally closed.

### Control-Panel Layouts

1.35 A control-panel layout shows the general physical arrangement of all components. Devices are represented by rectangles or squares, each identified with the same marking used on the elementary diagram.

1.36 Spare panel space is dimensioned. The drawings include a layout of the operator's console or pushbutton station, but terminal markings are not shown. This layout may be combined on the same drawing with the interconnection diagram or wiring table. An example of a control-panel layout is shown in Fig. 1-5, on the following page.

1.37 An interconnection diagram or a wiring table indicates the conductors between all terminals on each terminal block. The diagram includes every panel and chassis in the complete electrical system. Each connection is identified or shown on the elementary diagram. Blank spaces and spare terminals are also shown.

1.38 A stock list shows the quantity, manufacturer's name, type or model, and catalog number of each device used. For motors, it also lists the horsepower, frame size, type of enclosure, and speed. Any other information necessary for ordering replacement electrical and electronic parts is also included. A portion of a typical stock list is shown in Fig. 1-6, on page 13.

### Sequence of Operation

1.39 The *sequence of operation* indicates the progression of operation for all the devices shown and identified on the elementary diagram. On machine electrical diagrams having many circuits, where the

Fig. 1-4. Locating relay contacts

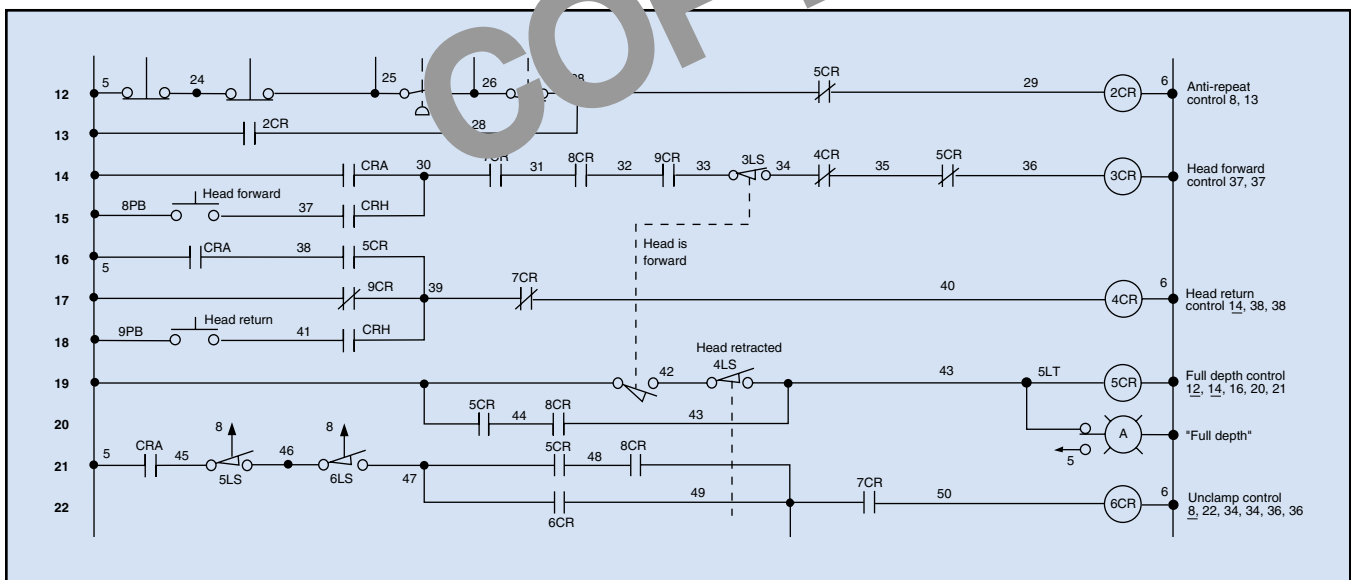
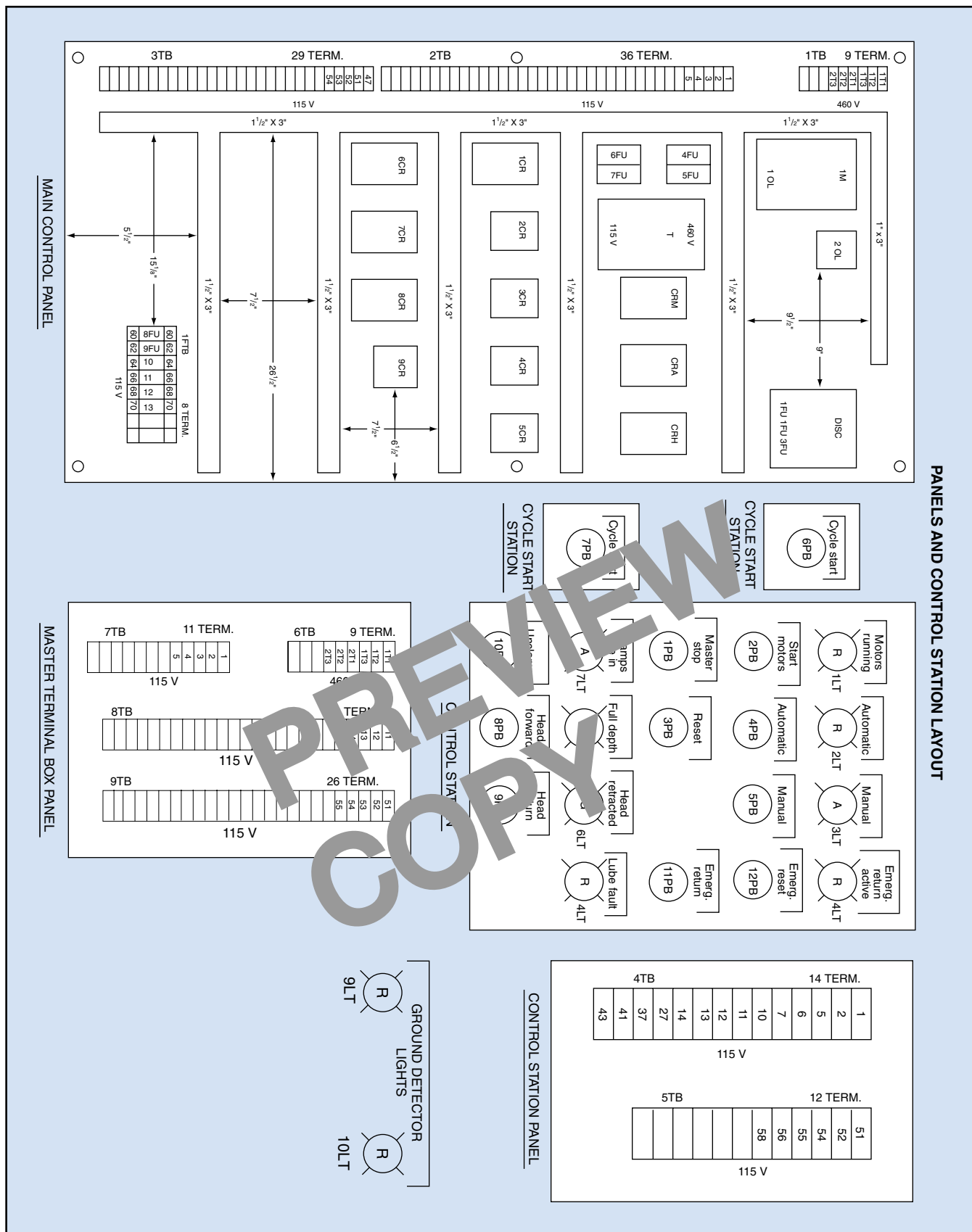


Fig. 1-5. Layout of panels and control station



operation is not obvious, a sequence of operation is given as shown in Fig. 1-7.

1.40 The sequence of operation is very useful when troubleshooting. For example, suppose the head does not return. All the operations have been satisfactory up to this point.

1.41 From the sequence of operation, you can see that the head should return at C4. Relay 4CR and solenoid 6SOL are energized by relay 5CR. Relay 5CR is energized (C3) when the limit switch 3 LS is activated with the head in the forward position.

1.42 From the schematic diagram in Fig. 1-1, you can see that you need to check fuses 4FU, 5FU, 6FU, and 7FU to make sure power is available to the circuits. Then you can isolate the trouble by making sure the head is fully forward and 3LS is activated. If the head is not fully forward and 3LS is not activated, look for a mechanical malfunction that keeps the head from traveling the full distance.

1.43 If the head is fully forward and 3LS is activated, then check for proper potential difference

**Fig. 1-6. Stock list**

2	1-2LS	Switch limit CRS Co. W224			
1	CRA	Relay TEK Co. 7N310			
AMT	SYM	DESCRIPTION			
PART NO.	SHEET	SHEETS	DWG. NO.	PURCHASER'S DWG NO.	
X4100A	2				
DES. BY	DET. BY	TITLE			
TEK	D.R.	<b>ELECTRICAL DIAGRAMS</b>			
CHECKED BY	SAFETY OK				
CRS	R.J.				
DATE	SCALE	PLANT	DIVISION	TEK MACHINE CO.	
8-2-03	None	5	A		

across coil 5CR. If the potential difference is zero, the connection between 3LS and 5CR may be bad. Or, 3LS may be defective, or perhaps power is not reaching 3LS. You should check for power at 3LS.

1.44 If 5CR is energized, measure the potential difference across coil 4CR and solenoid 6SOL. If there is a potential difference across 4CR, but not

**Fig. 1-7. Sequence of operation**

**Sequence of Operation**

A. Press START (OTC) push button 1PB. Motors start. MOTORS RUNNING lamp 1LT and CRM are energized.

B. Press either automatic 4PB or manual 5PB push button. Corresponding relay and lamp are energized.

Note: To switch from manual to automatic, operator must press RESET pushbutton 3PB before pressing automatic push button 4PB.

C. *Automatic cycle:* With motors running and CRA energized, machine is set for automatic cycle. Head must be retracted and part unclamped to start cycle.

1. Operator loads part in fixture and presses both CYCLE START pushbuttons 6PB and 7PB, energizing 1CR (1SOL and 3SOL) to clamp part.
2. Clamped part trips 1LS and 2LS, energizing 8CR. Relay 3CR (5SOL) is energized momentarily, starting head forward in rapid advance. Head cams valve into feed.
3. When head is in forward position, 3LS is activated, energizing relay 5CR.
4. 5CR contact energizes relay 4CR (6SOL) and head returns.
5. When head is fully retracted, 4LS is activated, de-energizing 4CR and energizing 7CR, which energizes 6CR (2SOL and 4SOL), unclamping part.
6. When part is unclamped, 5LS and 6LS are activated, de-energizing relay 6CR.
7. Relay 2CR prevents machine from recycling if both CYCLE START pushbuttons are not released.

**Fig. 1-8. Limit switches**

1LS ( 8, 26)	Activated when part is clamped
2LS ( 8, 26)	Activated when part is clamped
3LS (14, 19)	Activated when head is forward
4LS (19, 24)	Activated when head is retracted
5LS ( 8, 21)	Activated when part is unclamped
6LS ( 8, 21)	Activated when part is unclamped
1PS (10, 12)	Operated by lube system overpressure
1FS (11, 12)	Operated by adequate lube supply

across 6SOL, check the fuse in series with 6SOL. Replace the fuse if it is defective. If the fuse is good, check relay contacts of 4CR and the connection between 4CR contacts and the solenoid.

1.45 By using the elementary diagram and the sequence of operation, you will not waste time by starting at the beginning of the sequence and working toward the possible trouble. If all the devices functioned up to the point of failure, you can limit your troubleshooting to the area of possible trouble.

#### Related Schematic Information

1.46 A list of the limit, pressure, and float switches also appears on the elementary diagram. The example shown in Fig. 1-8 is a list of the limit switches for the circuit shown in Fig. 1-1.

1.47 Limit switches are listed in the order of their operation. The numbers in parentheses are the lines on the elementary diagram on which the switch appears. The statement following the parentheses tells when the switch is activated. This information is also helpful in troubleshooting a limit switch that is suspected of being faulty or improperly aligned.

1.48 Other information appears on the elementary diagram. Examples include the following:

- location of layouts for panels and control stations

- locations of hydraulic diagrams
- locations of lubrication diagrams
- last wire number used
- last relay number used
- supplier's drawing number
- supplier's name
- purchase-order number
- serial number of machine
- machine number.

1.49 The last wire number and last relay number used are important for two reasons.

- When troubleshooting and circuit tracing, you need to know the last wire or relay number used without having to hunt through the whole schematic to find it.
- When adding or revising the circuitry, any new wiring or added relays will be assigned the next number. Then the new last number is recorded on the revised schematic.

1.50 The elementary electrical diagram is a tool. Familiarize yourself with the symbols and essential basic information that appear on the electrical diagram. Although JIC standard notations were used in this lesson, not all manufacturers follow this standard entirely. When you know the JIC standards, other electrical diagrams can be easily interpreted, because they are usually similar to the standard.

1.51 The elementary diagram will help you in everyday troubleshooting of electrical systems and devices. Usually the elementary diagram is placed in the pocket of the control-panel door. When you are in doubt about the nature or cause of trouble, refer to the diagram. It will reduce your troubleshooting time.

**Table 1-1. Standard designations for devices**

Designation	Device	Designation	Device
A	Accelerating contactor or relay	LS	Limit switch
ABE	Alarm or annunciator bell	LT	Pilot light
ABU	Alarm or annunciator buzzer	M	Motor starter
AH	Alarm or annunciator horn	MB	Magnetic brake
AM	Ammeter	MC	Magnetic clutch
AT	Autotransformer	MCS	Motor-circuit switch
B	Brake relay	MF	Motor starter, forward
CAP	Capacitor	MR	Motor starter, reverse
CB	Circuit breaker	MSH	Meter shunt
CH	Chassis or frame (not necessarily grounded)	MTR	Motor
CI	Circuit interrupter	NLT	Neon light
CON	Contact	OL	Overload relay
COS	Cable-operated (emergency) switch	PB	Pushbutton
CR	Control relay	PL	Plug
CRA	Control relay, automatic	PLS	Plugging switch
CRE	Control relay, emergency	POT	Potentiometer
CRH	Control relay, manual	PRS	Proximity switch
CRL	Control relay, latch	PS	Pressure switch
CRM	Control relay, master	PSC	Photosensitive cell
CRU	Control relay, unlatch	R	Reverse
CS	Cam switch	REC	Rectifier
CT	Current transformer	RECP	Receptacle
CTR	Counter	RES	Resistor
D	Diode	RH	Rheostat
DB	Dynamic braking contactor or relay	RSS	Rotary selector switch
DISC	Disconnect switch	S	Switch
F	Forward	SCR	Silicon-controlled rectifier
FA	Field accelerating contactor or relay	SOC	Socket
FB	Fuse block	SC	Switch control
FD	Field decelerating contactor or relay	SS	Selector switch
FF	Full-field contactor or relay	T	Transformer
FL	Field-loss contactor or relay	TACH	Tachometer generator
FLD	Field	TS	Temperature-actuated switch
FLS	Flow switch	T	Terminal block
FS	Float switch	T/C	Thermocouple
FTB	Fusible terminal	TCS	Thermocouple switch
FTS	Foot switch	TGS	Toggle switch
FU	Fuse	TR	Time-delay relay
FW	Field weakening	TR	Variable autotransformer
GRD	Ground	V	Voltmeter
HTR	Heating element	VLT	Work light
INST	Instrument	W	Wattmeter
IOL	Instantaneous overload	W	Reactor
LO	Lock-out coil (in plugging switch)		

## 16 Programmed Exercises

1-9. What does underlining tell you about the contacts of relays on following lines of a schematic?	1-9. THE CONTACTS ON THESE LINES ARE NORMALLY CLOSED  Ref: 1.34
1-10. A control-panel layout shows the general _____ of all components.	1-10. PHYSICAL LAYOUT  Ref: 1.35
1-11. A(n) _____ indicates the conductors between all terminals on each terminal block.	1-11. INTERCONNECTION DIAGRAM OR WIRING TABLE  Ref: 1.37
1-12. All information necessary for ordering replacement electrical and electronic parts is given on the _____.	1-12. STOCK LIST  Ref: 1.38
1-13. What indicates the progression of operation for all devices shown on the elementary diagram?	1-13. SEQUENCE OF OPERATION  Ref: 1.39
1-14. The elementary diagram and the sequence of operation can help you limit your troubleshooting to the devices located _____.	1-14. AT AND BEYOND THE POINT OF FAILURE  Ref: 1.45
1-15. In what order are limit switches listed on an elementary diagram?	1-15. ORDER OF OPERATION  Ref: 1.47
1-16. You can interpret most electrical symbols if you know the _____ standards.	1-16. JIC (Joint Industrial Conference)  Ref: 1.50

Answer the following questions by marking an "X" in the box next to the best answer.

- 1-1. On an electrical diagram, what is the meaning of the abbreviation CR?
- a. Center
  - b. Compressor
  - c. Control relay
  - d. Current rectifier
- 1-2. Control systems are usually designed so that each individual circuit controls
- a. all functions of the machine
  - b. at least two functions
  - c. only one device
  - d. only one function
- 1-3. The designations 1T1, 1T2, and 1T3 identify
- a. terminal 1 on each of three different motors
  - b. terminals 1, 2, and 3 on a single motor
  - c. terminals 1, 2, and 3 on three motors
  - d. three terminals wired together on a motor
- 1-4. According to the National Electrical Code, a fuse should be installed in a(n) \_\_\_\_\_ conductor, but not in a(n) \_\_\_\_\_ conductor.
- a. common; ungrounded
  - b. grounded; common
  - c. grounded; ungrounded
  - d. ungrounded; grounded
- 1-5. Each conductor in a motor-control circuit
- a. has its own identification
  - b. is identified by number or letter
  - c. is numbered differently at its two ends
  - d. all of the above
- 1-6. On a schematic, the numbers on the vertical conductors
- a. are assigned to hot conductors only
  - b. are the last ones assigned
  - c. are the same along each conductor
  - d. change at each set of contacts
- 1-7. An arrow pointing downward next to the symbol for a limit switch means that the switch
- a. also appears on a lower line of the schematic
  - b. is normally open
  - c. is turned off
  - d. operates when a mechanical part moves downward
- 1-8. On a schematic, underlined numbers in a series tell you the contacts on the relay are \_\_\_\_\_ on that line of the schematic.
- a. especially important
  - b. normally closed
  - c. normally open
  - d. omitted
- 1-9. The physical arrangement of all components in a control panel is shown on the control-panel
- a. layout
  - b. schematic
  - c. stock list
  - d. wiring table
- 1-10. What indicates the progression of operation of all the devices shown on the elementary diagram?
- a. Operating guide
  - b. Operator's manual
  - c. Sequence of operation
  - d. Step-function guide



**SUMMARY**

Electrical diagrams are the electrician's guide to circuits that control the operation of automatic and precision equipment. When a circuit malfunctions, the electrician's skill in using such a diagram to troubleshoot the circuit may determine the amount of downtime that results.

The elementary diagram is a schematic of the control circuit for a machine. Standard electrical symbols are used and symbols for control devices are usually shown in the order in which the controls are energized. A schematic diagram is easier to read if you break it down into basic circuits.

The power circuit is the simplest part of the diagram. The motor-starting circuit is usually the

first circuit shown in a diagram. Each conductor in the circuit is identified by a number, letter, or number-letter combination.

Control relays and limit switches are numbered in progression from top to bottom. A control-panel layout shows the general physical arrangement of all components.

The sequence of operation shows the progression of operation for all the devices shown and identified on the elementary diagram. By using the elementary diagram and the sequence of operation in troubleshooting, you can limit your search to the area of possible trouble without having to test the entire circuit.

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**Answers to Self-Check Quiz**

- 1-1. c. Control relay. Ref: Table 1-1
- 1-2. d. Only one function. Ref: 1.10
- 1-3. b. Terminals 1, 2, and 3 on a single motor. Ref: 1.14
- 1-4. d. Ungrounded; grounded. Ref: 1.17
- 1-5. b. Is identified by number or letter. Ref: 1.21
- 1-6. d. Change at each set of contacts. Ref: 1.23
- 1-7. a. Also appears on a lower line of the schematic. Ref: 1.31
- 1-8. b. Normally closed. Ref: 1.34
- 1-9. a. Layout. Ref: 1.35
- 1-10. c. Sequence of operation. Ref: 1.39
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