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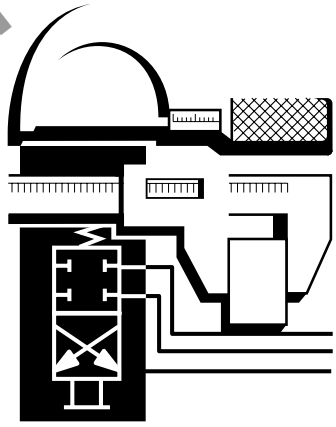
READING SCHEMATICS AND SYMBOLS

Lesson One

Introduction to Schematics and Symbols



TPC Training Systems

10201

Lesson

1 Introduction to Schematics and Symbols

TOPICS

Symbols in Schematics
Using Schematics
Electrical Schematics
Pneumatic and Hydraulic Schematics
Piping Schematics
Value of Schematics
Looking for Flow
Electric Current
Fluid Flow

OBJECTIVES

After studying this lesson, you should be able to…

- State the definition of a schematic.
- List some characteristics of schematics.
- Identify a schematic among other kinds of technical drawings and diagrams.
- Explain how flow is indicated on a schematic.

KEY TECHNICAL TERMS

Symbol 1.01 simple sign for a device
Schematic 1.03, 1.04 drawing using symbols and lines
Fluid 1.14 liquid or gas
Direct current 1.33 electric current that flows in a single direction
Alternating current 1.35 electric current that constantly reverses direction

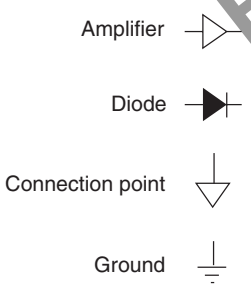
It would be almost impossible to show most electrical or fluid systems in a full-scale detailed drawing. The drawing would be too difficult to make and too large to handle. Instead, symbols are used to represent the parts of a system. The symbols can be combined to show a complete system and how the parts connect with each other. Such a diagram is called a schematic diagram. The symbols and connecting lines on a schematic diagram are standard. Even complex systems are easy to understand if you know how to read the symbols.

This course is a step-by-step approach to the understanding of schematic drawings and flow diagrams. It begins in this lesson with a discussion of the meaning and the value of schematic drawings, plus a description of the different types of drawings that maintenance specialists use on the job. Later lessons in the course describe the symbols that represent the parts of various systems, then portions of systems, and finally complete systems.

Symbols in Schematics

1.01 In several ways, the symbols used in schematics are like the letters of a non-English alphabet or the signs used in mathematics.

- Consider the symbol Δ for example. It is the Greek letter *delta*, and in math it represents a change or difference. Figure 1-1 uses the delta, or triangle, to designate common electrical connections (∇_c), as well as other component parts of the circuit, as shown below:



The circuit may be grounded to the earth (earth ground), or to a metal framework around the circuit (chassis ground).

- The symbols are connected in a meaningful way. Greek symbols are combined to form words and then sentences. Schematic symbols are connected by lines to represent a system.

- Understanding either a foreign language or a schematic requires special training. Maintenance specialists are expected to read and understand a schematic like the one shown in Fig. 1-1. Learning to do so is part of their training. The task may look difficult at first. But it is not—if you learn it one step at a time.

1.02 The word schematic comes from the word *schema*. In Greek, this word means "to form." In Latin, it means "a figure." The word scheme has the same origin. A *scheme* is some kind of plan that has been formed.

1.03 A workable modern definition of the word *schematic* is a line drawing made for a technical or scientific purpose. You can see that Fig. 1-1 is a line drawing made for a technical purpose. But it is more.

Fig. 1-1. Electrical schematic

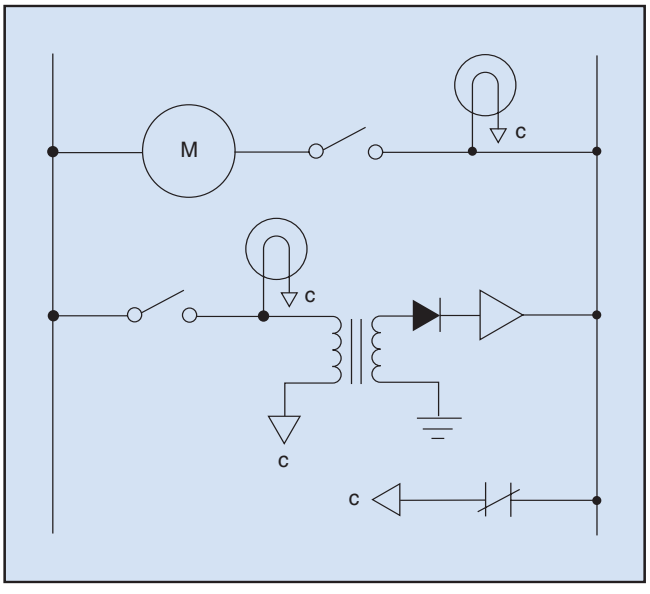
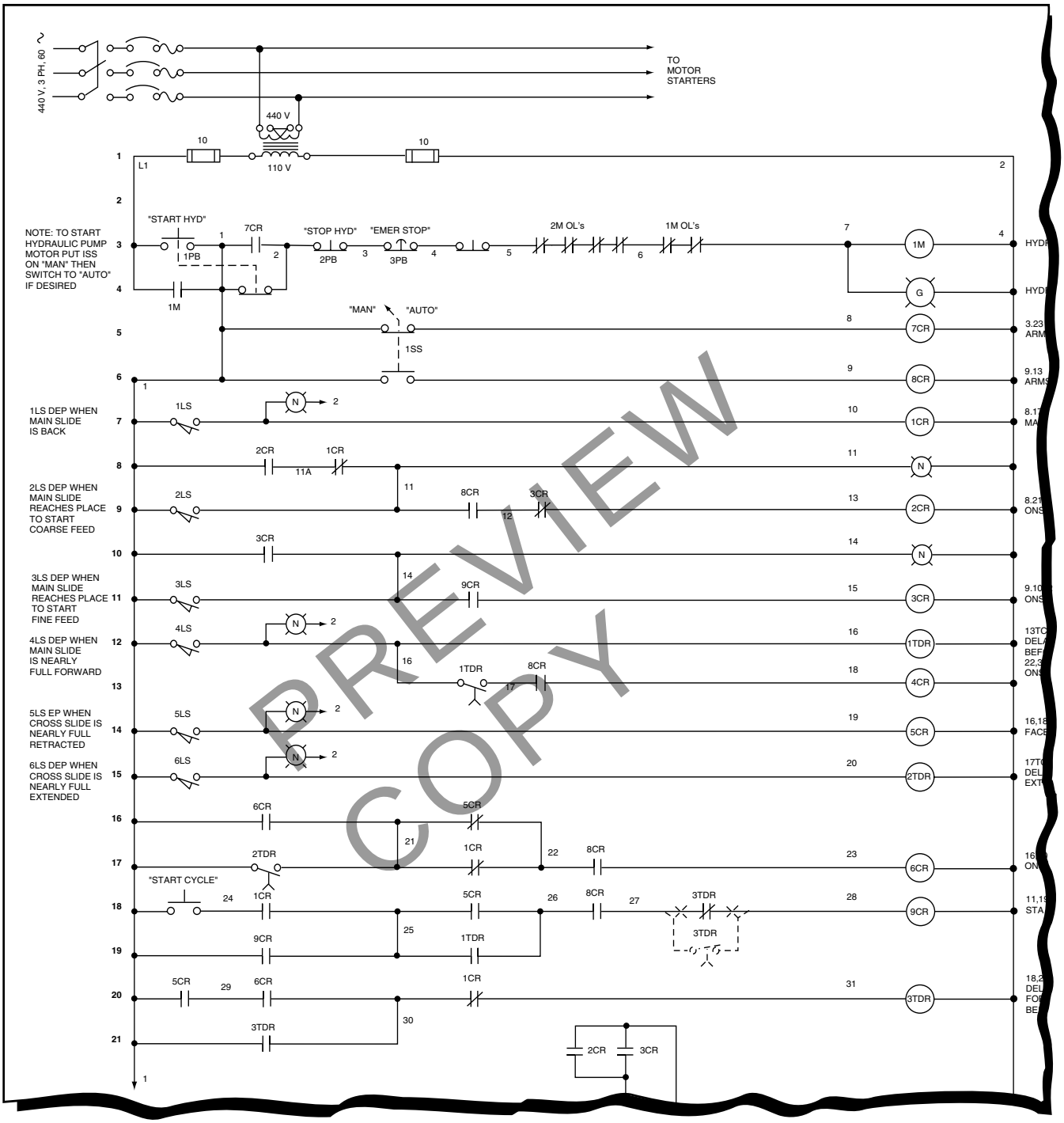


Fig. 1-2. Schematic of electric control circuit

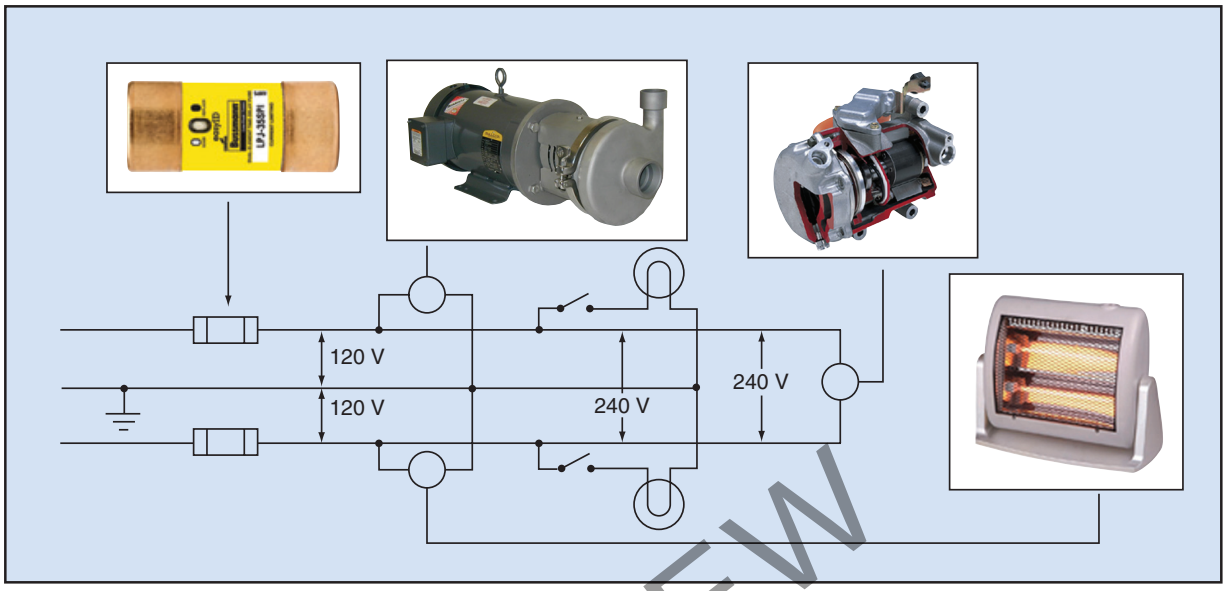


It conveys a special kind of information. It does so by the use of symbols. These symbols are connected so that the schematic shows what is happening in the electric circuit. To a person who has learned to read schematics, the diagram presents a clear picture of the flow of electricity through the circuit.

1.04 Therefore, a better definition of a schematic is a line drawing made for a scientific or technical purpose that uses symbols and connecting lines to show how a system works.

1.05 This definition has five parts:

Fig. 1-3. Electrical schematic using pictures



1. A schematic is a line drawing.
2. It is made for a scientific or technical purpose.
3. It shows how a system works.
4. Symbols are used instead of pictures.
5. The symbols are connected to show how the system operates.

Using Schematics

1.06 This definition of schematics makes it clear why they are used:

- They reduce a complicated system to a manageable drawing that can be understood. Note the complexity of the circuits diagramed in Fig. 1-2. Without this schematic diagram, it would be unlikely that anyone could figure out where to look for the cause of any trouble in the system. Getting a system into a readable form is an important reason for using a schematic. Do not worry if you cannot read the diagram shown in Fig. 1-2 yet. You will, by the time you finish this course.
- They show what is happening. In Fig. 1-2, the relationships among the various elements are shown by connecting lines. A skilled reader of schematics can see how the system is intended to work.
- They standardize the drawings of systems. One of the most important features of Fig. 1-2 is that it can be read by anyone who understands electrical schematics. The symbols and lines are standard. You need very little written information in addition to the schematic to complete the description of how the system works.

1.07 Schematics are important to maintenance specialists. When a breakdown occurs in a system, they read the schematic and figure out what might have gone wrong. From the diagram, they can tell where the power source is and how to turn it off. They can tell how the different components are connected in the system, so they can make intelligent guesses about how one component affects the others. Finally, when they discover the problem, they see how to make the corrections necessary to get the system back in working order.

1.08 The question of how schematics are used has multiple answers:

- To describe the parts of the system.
- To show how the system works.

- To help maintenance personnel repair a system that has failed.

1.09 You will use schematic diagrams in many ways. They are important sources of information. This course describes three major kinds of schematics—electrical, fluid power, and piping. When you understand schematic diagrams in these areas, you will have little difficulty understanding other uses of schematics.

Electrical Schematics

1.10 Electrical schematics can show all kinds of circuits, from the very simple to the very complex. Figure 1-3, on the previous page, shows an electric circuit that probably is similar to some of the circuits in your plant. Look at Fig. 1-3 closely. You might already know how to read some or all of it.

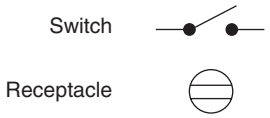
1.11 Are electrical diagrams really schematics? The definition of a schematic appeared earlier in this lesson. The definition, remember, has five parts. By comparing those five parts with Fig. 1-3, you can judge whether this electrical drawing is a schematic.

1. **A schematic is a line drawing.** Figure 1-3 is a line drawing. The lines form the symbols and show the connections among all the elements in the circuit.

2. **It is made for a scientific or technical purpose.** Because electricity is technical in nature, the electrical diagram is prepared for a technical purpose.

3. **It shows how a system works.** The purpose of Fig. 1-3 is to show how this system works in a plant.

4. **Symbols are used instead of pictures.** Here there is a catch, because the diagram on contains pictures of some components. The pump, compressor, heater, and fuse are shown by pictures rather than by symbols. Even so, Fig. 1-3 does contain symbols—for example, the symbol that represents an electrical switch and the symbol that represents a receptacle for plugging in a piece of electrical equipment.



5. **The symbols are connected to form a complete system.** In Fig. 1-3, they are. You can trace a path along the connecting lines from any one of the symbols or pictures to any other element.

Fig. 1-4. Electrical schematic using only symbols

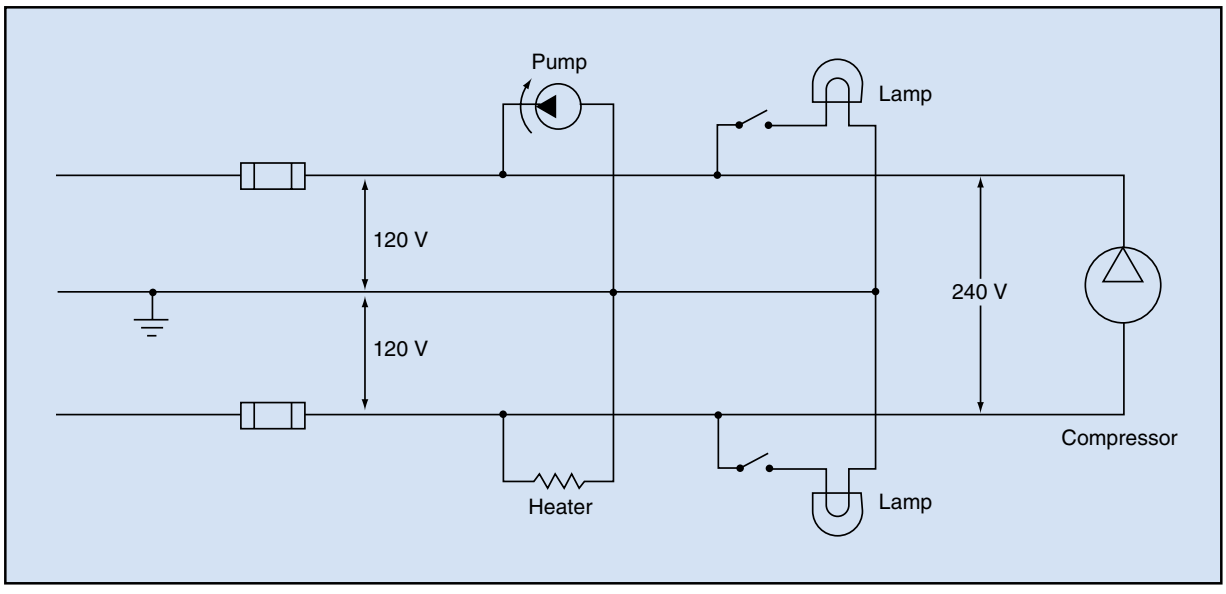
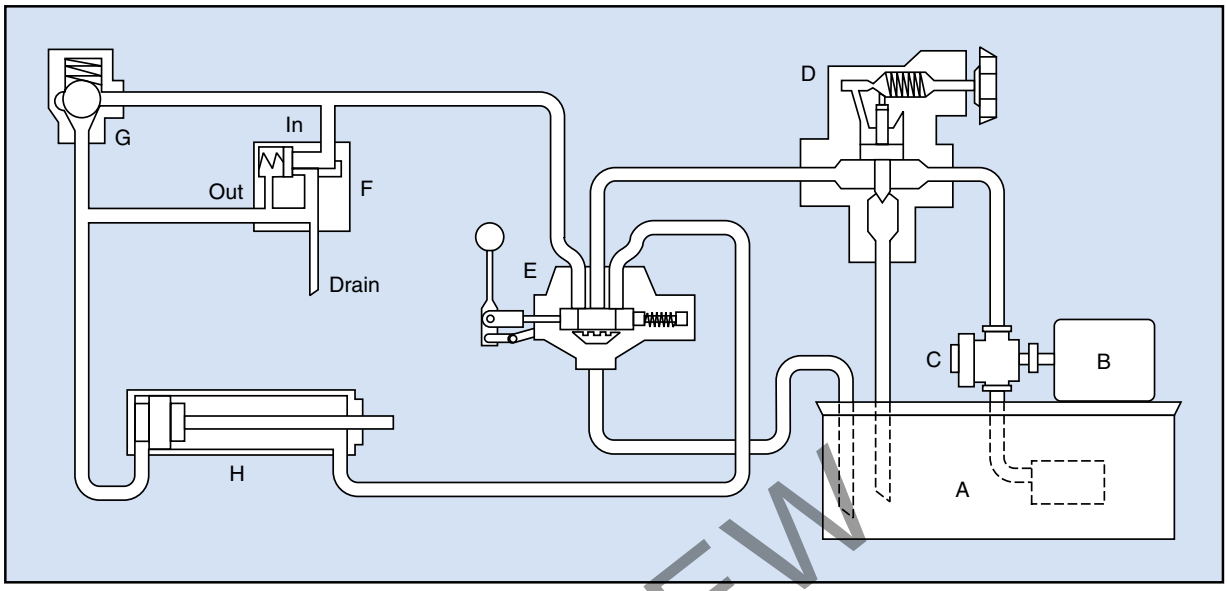


Fig. 1-5. Cutaway diagram



1.12 Figure 1-4 is a true schematic drawing of the same system. The pictures have been changed to symbols to agree with the definition. Does this change improve a diagram? Yes, because it is not always possible to provide pictures that actually look like the devices in the circuit. A complete pictorial representation of every device in a complex electrical system would be expensive and time consuming. The result would be very large. Moreover, a change in the shape of one device would make the whole diagram out of date.

1.13 In your maintenance work, you may come across diagrams that include pictures or simple outline drawings of component parts. As long as the drawing meets all the other parts of the definition, you can consider it a schematic. You will see this type of drawing again in this course, just as you will see it occasionally on the job.

Pneumatic and Hydraulic Schematics

1.14 The second major area in which schematics are used involves the flow of fluids in machinery. A *fluid* is any substance that can flow. All liquids and gases are fluids. A system that works by flowing gas is called a *pneumatic* system, based on the Greek word *pneuma*, meaning "air." A system that works by a flowing liquid is called a *hydraulic* system, based on the Greek *hydro*, referring to water.

1.15 Four kinds of pneumatic and hydraulic diagrams are commonly used in plants:

- The *cutaway* diagram is a double-line drawing showing a system in some detail. Figure 1-5 shows a cutaway diagram.
- The *pictorial* diagram is a single-line drawing in which simple outline drawings represent the components of the system. Figure 1-6 shows a pictorial diagram. In this diagram, the components are also listed.

Fig. 1-6. Pictorial diagram

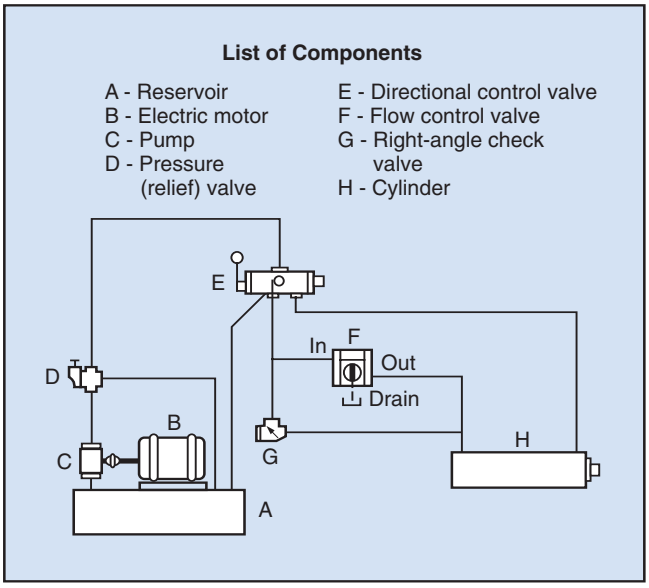
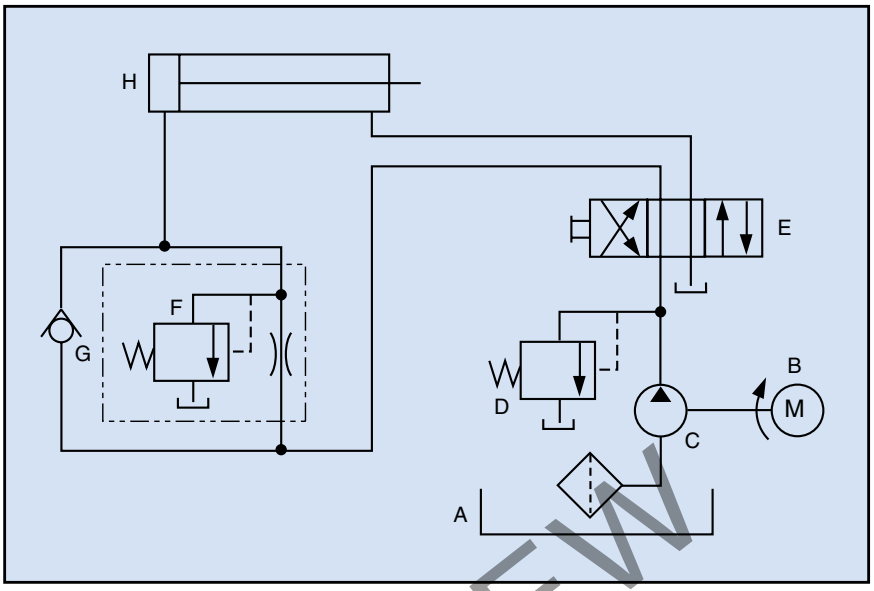


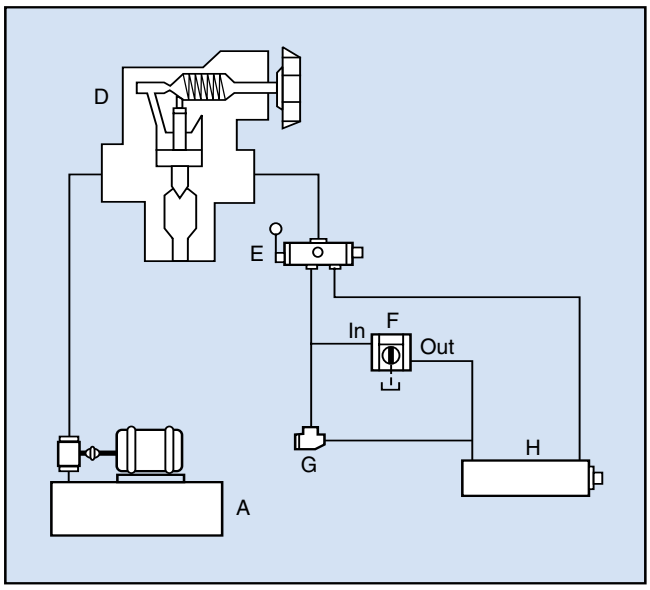
Fig. 1-7. Schematic drawing



- The *schematic* diagram is a single-line diagram that fits the definition of a true schematic. Figure 1-7 is an example of a schematic diagram. Note the use of symbols. The schematic is the most important kind of diagram to the maintenance specialist.

- A *combination* diagram includes elements of the first three kinds. Figure 1-8 shows a combination diagram. Combinations are sometimes encountered on the job.

Fig. 1-8. Combination diagram



Piping Schematics

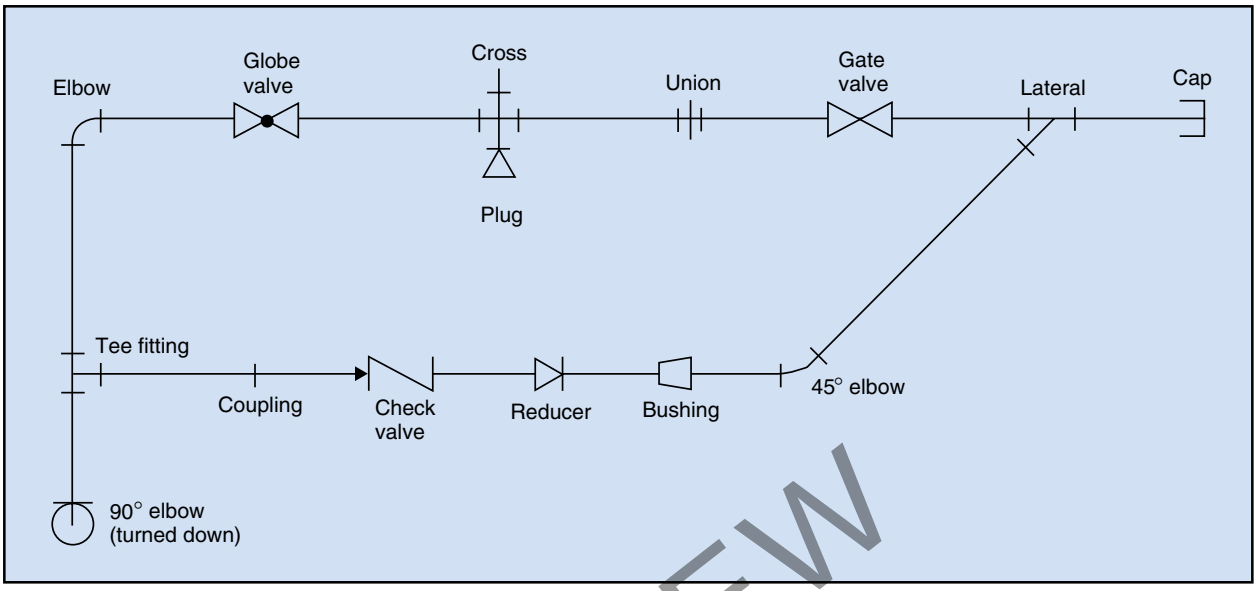
1.16 The third major area in which schematics are used is piping. Figure 1-9 typifies all piping diagrams in that it shows piping, fittings, and valves. In order to do your job well, you should learn to understand this kind of diagram.

1.17 In the typical plant, piping is used in almost every work area. It serves many purposes. Fluids of all kinds flow through pipes during production, distribution, and final use. Whether you are dealing with air in a pressure line or acids in a chemical process, piping plays a key role in your plant.

1.18 Maintaining pipes, fittings, and valves is crucial to the continuing success of any piping system. A leak in a hydraulic or pneumatic system can cause the entire system to fail. Even more important, a leak can be dangerous. Therefore, preventive maintenance of a piping system is more important than repairing the system after a breakdown.

1.19 Schematic drawings of a piping system provide the information you need to maintain the system. If a breakdown occurs, the drawing shows you where the shutoff valves are and where to check to locate the problem.

Fig. 1-9. Single-line piping diagram



1.20 There are two general kinds of piping diagrams—single line and double line. A single-line drawing is shown in Fig. 1-9. A double-line drawing is shown in Fig. 1-10.

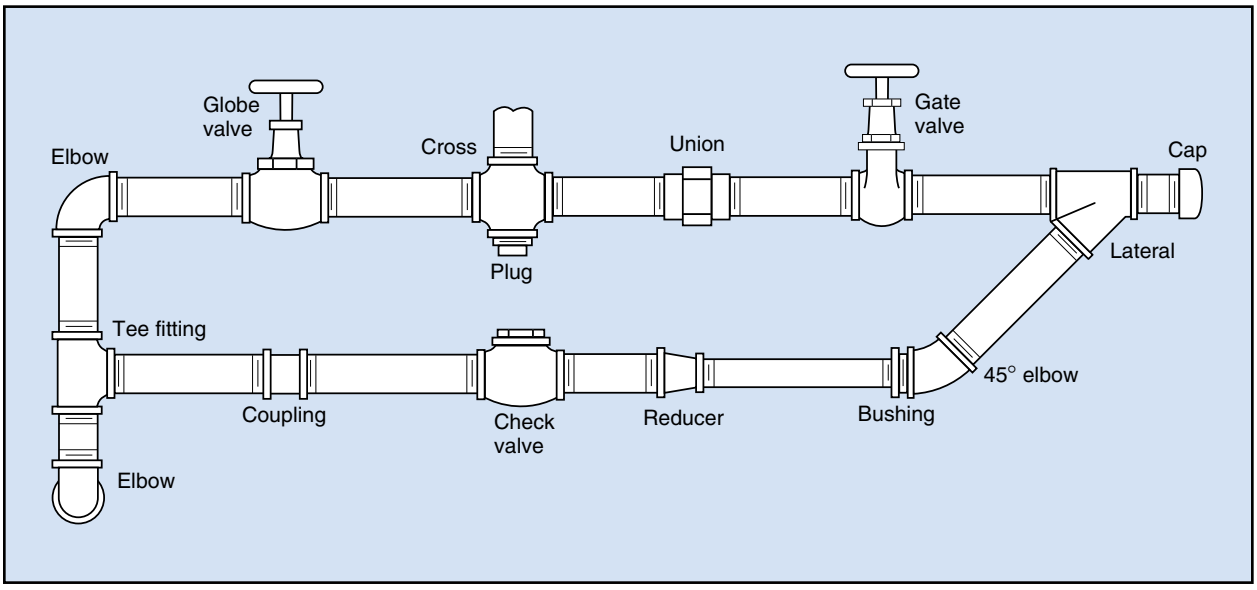
1.21 The *single-line drawing* is similar to an electrical schematic. It uses symbols for all the components of the drawing. Like the electrical schematic, the single-line drawing fulfills all five parts of the definition of a schematic.

1.22 The *double-line drawing* is a pictorial view of the pipe, joints, valves, and other components. It is similar to the electrical drawing shown in Fig. 1-3, in that it fulfills some of the five parts of the definition of a schematic.

Value of Schematics

1.23 Schematic diagrams are valuable for the following reasons:

Fig. 1-10. Double-line piping diagram



- They make complicated systems easier to understand.
- They show what is happening in electrical, fluid-power, and piping systems.
- They use standard symbols.

As a maintenance specialist, you will learn to depend on schematics. They will help you understand what is happening in a system. You would find it very difficult to understand even a simple system without the proper schematic.

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.

1-1. The following are _____ used in electric circuits. 	1-1. SYMBOLS Ref: 1.01
1-2. Symbols are connected by _____ in a schematic diagram.	1-2. LINES Ref: 1.01
1-3. According to the definition, a schematic is made for a(n) _____ purpose.	1-3. TECHNICAL or SCIENTIFIC Ref: 1.04
1-4. When a breakdown occurs in a system, maintenance specialists read the _____ to determine what went wrong.	1-4. SCHEMATIC Ref: 1.07
1-5. Pictures are not as useful as _____ for showing the components of a system on a schematic.	1-5. SYMBOLS Ref: 1.12
1-6. Is a cutaway diagram a single-line drawing?	1-6. NO Ref: 1.15
1-7. A pictorial diagram of a fluid-power system is a _____ -line diagram that uses _____ to represent components.	1-7. SINGLE; OUTLINE DRAWINGS Ref: 1.15
1-8. The two types of diagrams used as schematics of piping systems are _____ diagrams and _____ diagrams.	1-8. SINGLE-LINE; DOUBLE-LINE Ref: 1.20

Looking for Flow

1.24 When a system fails, there is a breakdown in flow. That is, the movement of electricity or fluid through the system is interrupted. In an electrical system, an interruption may result from a short circuit that opens a circuit breaker, or from a broken connection. In both cases, the result is a halt in the flow of electricity, usually producing obvious signs. Figure 1-11 shows the result of such an interruption of electric current. In a piping system, the flow may continue. If it does, a leak appears at the point of breakdown.

1.25 Any breakdown—any interruption of flow in a system—results in a call to the maintenance department. If you are sent out on the job, you might find the problem so obvious that you can fix it on the spot, without using any diagrams at all. But for more complicated problems, you will probably need to use a schematic of the system. The first thing you will want to know is how electricity or fluid should flow through that system.

1.26 In order to understand how electricity or fluid flows through a system, you must know how to look for the indications of flow on an electrical or a piping schematic.

Electric Current

1.27 The flow of electricity is similar to the flow of fluids. Fluids flow from higher pressure to lower pressure. Electricity flows from higher voltage to lower voltage. But you must be careful to avoid confusion between positive and negative values in electricity.

1.28 Electric current is the flow of electrons within a conductor. An *electron* is one of the most basic particles of matter. It is much smaller than an atom, and its mass is only a tiny fraction of the mass of the smallest atom. Every electron carries a negative electric charge. That is, the charge matches the charge found on the negative terminal of a battery.

1.29 Electrons flow from negative to positive. Because like charges repel each other, the negative charge of a battery terminal repels the negative charge of the electron. The positive charge on the other terminal of the battery attracts the negative charge of the electron. An electron is at higher charge, or potential, at the negative terminal than at the positive terminal.

1.30 Unfortunately, Benjamin Franklin and other scientists of his time began labeling the terminals of batteries "positive" and "negative" before the electron was discovered and before anyone understood electric current. In those days, people thought *something* was flowing in an electric current. They assumed it was flowing from positive to negative. By the time the details were discovered, electricity was so widely used that it was too late to change.

Fig. 1-11. Interruption in flow usually produces an obvious sign

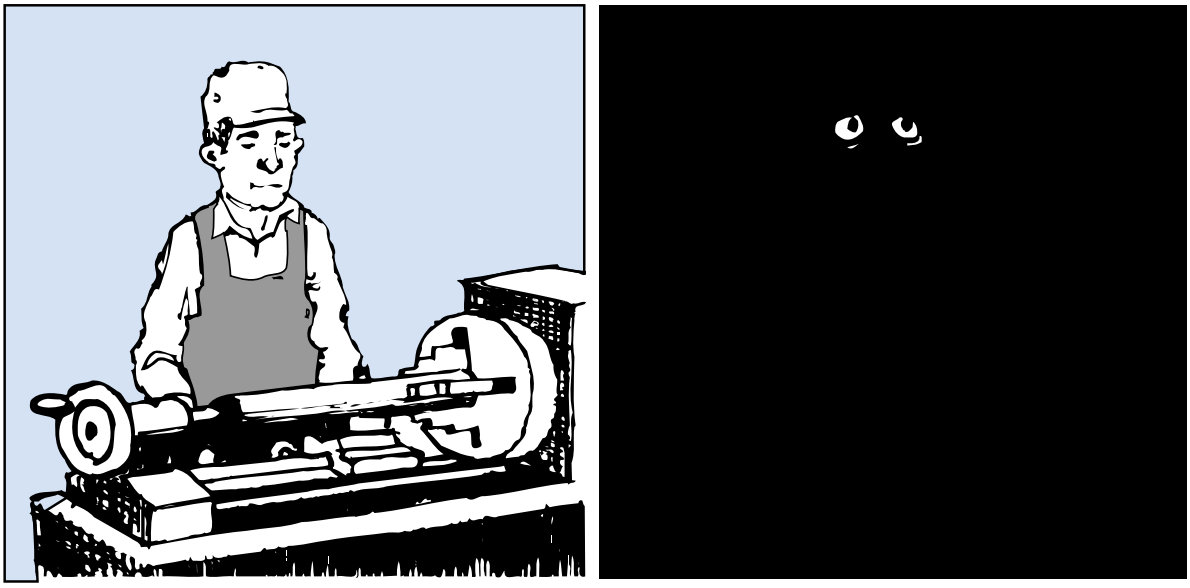


Fig. 1-12. Simple dc circuit

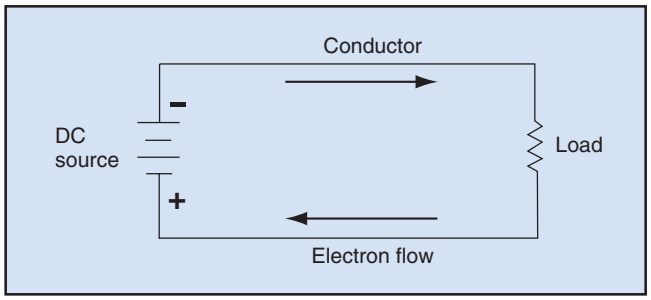
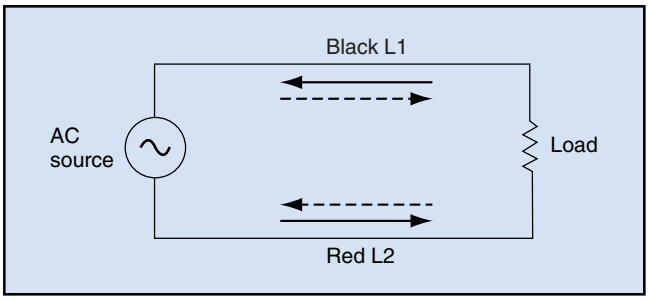


Fig. 1-13. Simple ac circuit



1.31 Today, you must be careful to avoid confusion between positive and negative. Some people refer to a flow of imaginary positive particles, moving from positive to negative. Others refer to current as electron flow—from negative to positive. Almost everyone needs to shift back and forth from one idea to the other.

1.32 In order to avoid confusion, this lesson and the remainder of this course will stick to just one idea of current. In this book and others like it, the term *current* will always mean the flow of electrons—from negative to positive.

1.33 **Direct current.** Even though you stick to this one idea of electron flow from negative to positive, you must distinguish between two ways in which current can be made to flow. Electric current that flows steadily in one direction is called *direct current,* abbreviated *dc*.

1.34 To understand the flow of electrons in a dc circuit, you must first locate the source of voltage on the schematic. Then you can follow the paths of the electrons through the wires and devices to the other terminal of the voltage source or to the ground. Figure 1-12 shows a schematic for a simple dc circuit.

1.35 **Alternating current.** Many electric circuits use current that constantly changes direction. The current flows in one direction, then reverses, and then changes back to the first direction. It normally goes through this cycle 60 times per second. A current that alternates from one direction to another continuously is called *alternating current,* abbreviated *ac*.

1.36 You can think of alternating current in much the same way as direct current. Even though the current keeps reversing, the power of an ac circuit behaves in the same way as the power in a dc circuit.

1.37 There are no positive or negative signs on the schematic for an ac (alternating current) circuit. To trace current flow, you must look for other labels or for colors. Common labels are L1 and L2 (for Line 1 and Line 2). Common colors are black, red, and white. Figure 1-13 shows a schematic for a simple ac circuit.

Fluid Flow

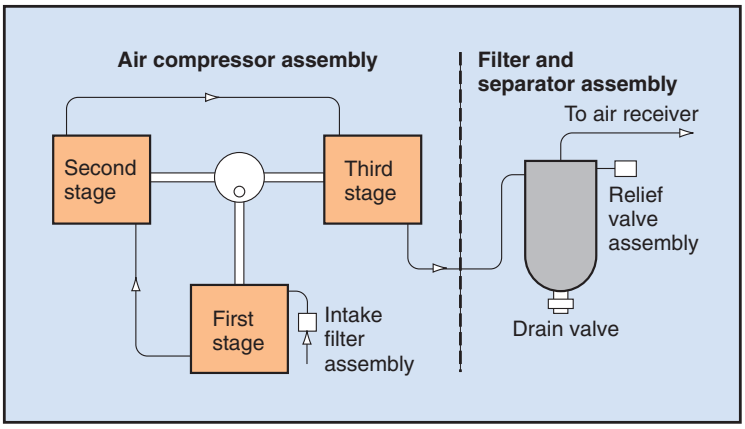
1.38 The primary way to indicate flow in piping diagrams is with arrows. Figure 1-14, on the following page, shows how arrows are used in a piping diagram.

1.39 Alternate flow is sometimes shown in a separate, smaller diagram. In Fig. 1-15, on the following page, the main diagram shows the flow when the control valve is "up." But the valve also has a "down" position, which reverses the direction of flow in some pipes. This reversal may be shown in a *supplementary diagram* next to the main diagram. Figure 1-15 includes such a supplementary diagram, showing fluid flow with the control in the "down" position.

1.40 Most of the time, the arrows will not be as obvious as in Fig. 1-14 and Fig. 1-15. In piping schematics, the flow is usually shown by arrowheads drawn directly on the lines.

1.41 What do you do when there are no arrows at all in a diagram of a piping system? It sometimes happens. Then you have to use your own judgment, based on what you have learned from your training and

Fig. 1-14. Arrows show direction of flow in a piping system

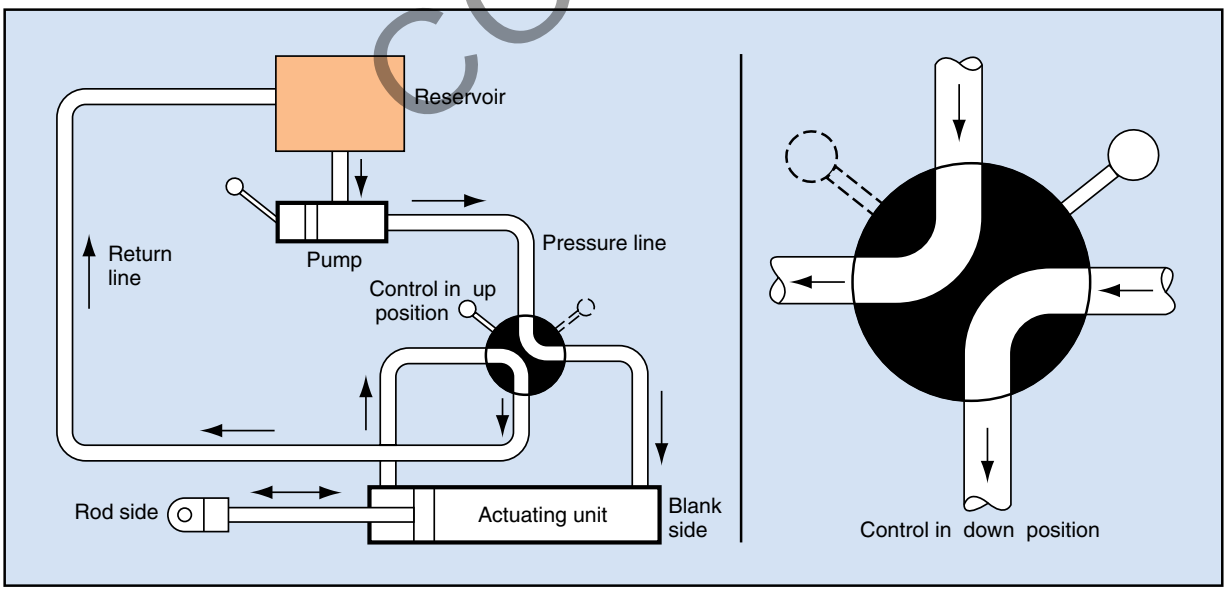


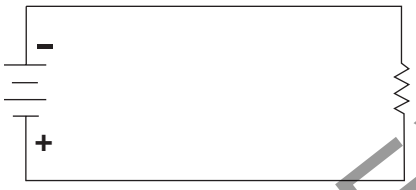
experience. In some cases, you may need to test the system to determine the direction of flow. But in most systems, you can figure out the direction if you look for clues.

1.42 Certain clues usually appear in a schematic. You may be able to see the starting point of a flow by noticing the location of symbols for pumps, boilers, and other equipment. The final destination of a fluid may be found by looking for control valves, return lines, or reservoirs. The basic design of the system may give you important clues about the direction of flow.

1.43 Once you have determined the direction of flow at one point or at a few points, you can probably trace the fluid through the system even if the diagram shows no arrows. Sometimes the pattern of the piping can help you make good judgments. But watch out and always think things through. For example, a Y-fitting may use one arm of the Y to bring extra fluid into the system, or to take fluid out of the system.

Fig. 1-15. Supplementary diagram shows reversed flow directions



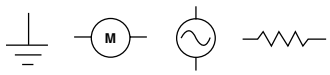
1-9. When a system breaks down there is an interruption in a(n) _____.	1-9. FLOW Ref: 1.24
1-10. Electrons flow from the _____ terminal to the _____ terminal in a dc circuit.	1-10. NEGATIVE; POSITIVE Ref: 1.29
1-11. The schematic below describes a(n) _____. 	1-11. SIMPLE DC CIRCUIT Ref: Fig. 1-12
1-12. On schematics of ac circuits, the conductors are usually identified with _____ or _____.	1-12. COLORS, LABELS Ref: 1.37, Fig. 1-13
1-13. In piping schematics, flow is usually shown by _____ drawn directly on the lines.	1-13. ARROWHEADS Ref: 1.40
1-14. When there are no arrows on a piping schematic, you must look for other _____ on the diagram.	1-14. CLUES Ref: 1.41
1-15. To find the final destination of a fluid, look for _____.	1-15. CONTROL VALVES, RETURN LINES, AND RESERVOIRS Ref: 1.42

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

1-1. A schematic helps you understand what is happening in a system through

- ☐ a. pictures and lines
- ☐ b. symbols and lines
- ☐ c. words
- ☐ d. words and pictures

1-2. The following is *not* a schematic drawing, because



- ☐ a. lines do not connect the symbols
- ☐ b. no symbols are used
- ☐ c. the components are not labeled
- ☐ d. the lines are only single lines

1-3. A schematic is useful because it

- ☐ a. gives plant location of components
- ☐ b. lists catalog numbers for parts
- ☐ c. shows a system in readable form
- ☐ d. shows how to install components

1-4. The three major areas for which schematics are drawn are

- ☐ a. electrical, chemical, and plumbing
- ☐ b. electrical, fluid power, and piping
- ☐ c. electrical, piping, and chemical
- ☐ d. heating, piping, and plumbing

1-5. A cutaway drawing is best described as a

- ☐ a. double-line drawing that shows the details of a system
- ☐ b. double-line drawing that uses symbols instead of pictures
- ☐ c. single-line diagram that fits all five parts of the definition of a schematic
- ☐ d. single-line diagram that shows the elements of the system with symbols

1-6. Valves and fittings are shown on double-line piping diagrams by

- ☐ a. a legend
- ☐ b. drawings
- ☐ c. photographs
- ☐ d. symbols

1-7. Interruption of flow within an electrical system is usually indicated by

- ☐ a. arrows in a diagram
- ☐ b. obvious signs
- ☐ c. reversal of the current
- ☐ d. too much electric power

1-8. In a dc circuit, the electrons flow

- ☐ a. from lower to higher voltage
- ☐ b. from positive to negative
- ☐ c. in two directions, continuously reversing
- ☐ d. steadily in one direction

1-9. The direction of flow in a piping diagram is shown

- ☐ a. by arrows
- ☐ b. by instructions
- ☐ c. by lines
- ☐ d. in the legend

1-10. More than one arrangement of flow within a piping system is often indicated by

- ☐ a. a supplementary diagram
- ☐ b. a written explanation
- ☐ c. pictures
- ☐ d. two separate schematics

SUMMARY

A schematic has five distinct features:

- **It is a line drawing.**
- **It is made for technical purposes.**
- **It shows how a system works.**
- **It uses symbols rather than pictures.**
- **The symbols are connected by lines.**

Even when pictures are used, the diagrams serve the same purpose as schematics and you can read them as such.

Schematic drawings have many functions. Electrical schematics show how electricity flows.

Pneumatic and hydraulic schematics show the flow of fluids in machinery. Piping schematics show the flow of liquids and gases.

If you know how to read schematics, you will be able to understand how the apparatus is intended to work. This knowledge will help you figure out how to repair a system if it breaks down. Even more important, you will be able to check it to prevent a breakdown. Prevention of problems is the best kind of maintenance. It almost always involves reading a schematic.

Answers to Self-Check Quiz

1-1. b. Symbols and lines. Ref: 1.04

1-2. a. Lines do not connect the symbols. Ref: 1.05

1-3. c. Shows a system in readable form. Ref: 1.06

1-4. b. Electrical, fluid power, and piping. Ref: 1.09

1-5. a. Double-line drawing that shows the details of a system. Ref: 1.15

1-6. b. Drawings. Ref: 1.22, Fig. 1-10

1-7. b. Obvious signs. Ref: 1.24

1-8. d. Steadily in one direction. Ref: 1.33

1-9. a. By arrows. Ref: 1.38

1-10. a. A supplementary diagram. Ref: 1.39

Contributions from the following sources are appreciated:

Figure 1-3. Bussmann, TPC photo Brandt & Associates