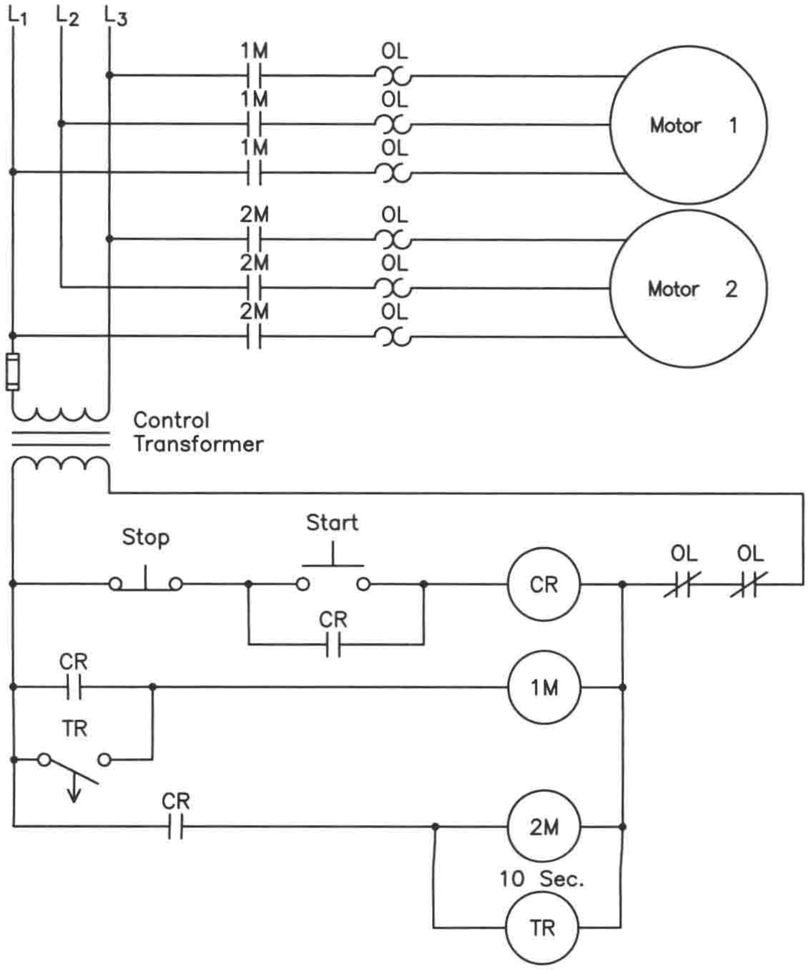

Figure 33-5 Off-delay timer circuit using a pneumatic timer.

LABORATORY EXERCISE

Name ______________________________ Date __________

Materials Required

Three-phase power source

Control transformer

2 three-phase motors or equivalent motor load

2 three-phase motor starters with at least two normally open and one normally closed auxiliary contacts

8-pin or 11-pin on-delay timer with appropriate socket

11-pin control relay with 11-pin socket

Connecting the Circuit

1. Using the circuit shown in Figure 33-6, place pin numbers beside the control components that mount into tube sockets. These components will probably be the control relay and the timer. Be sure to place pin numbers beside contacts as well as coils. Circle the pin numbers to distinguish them from wire numbers.

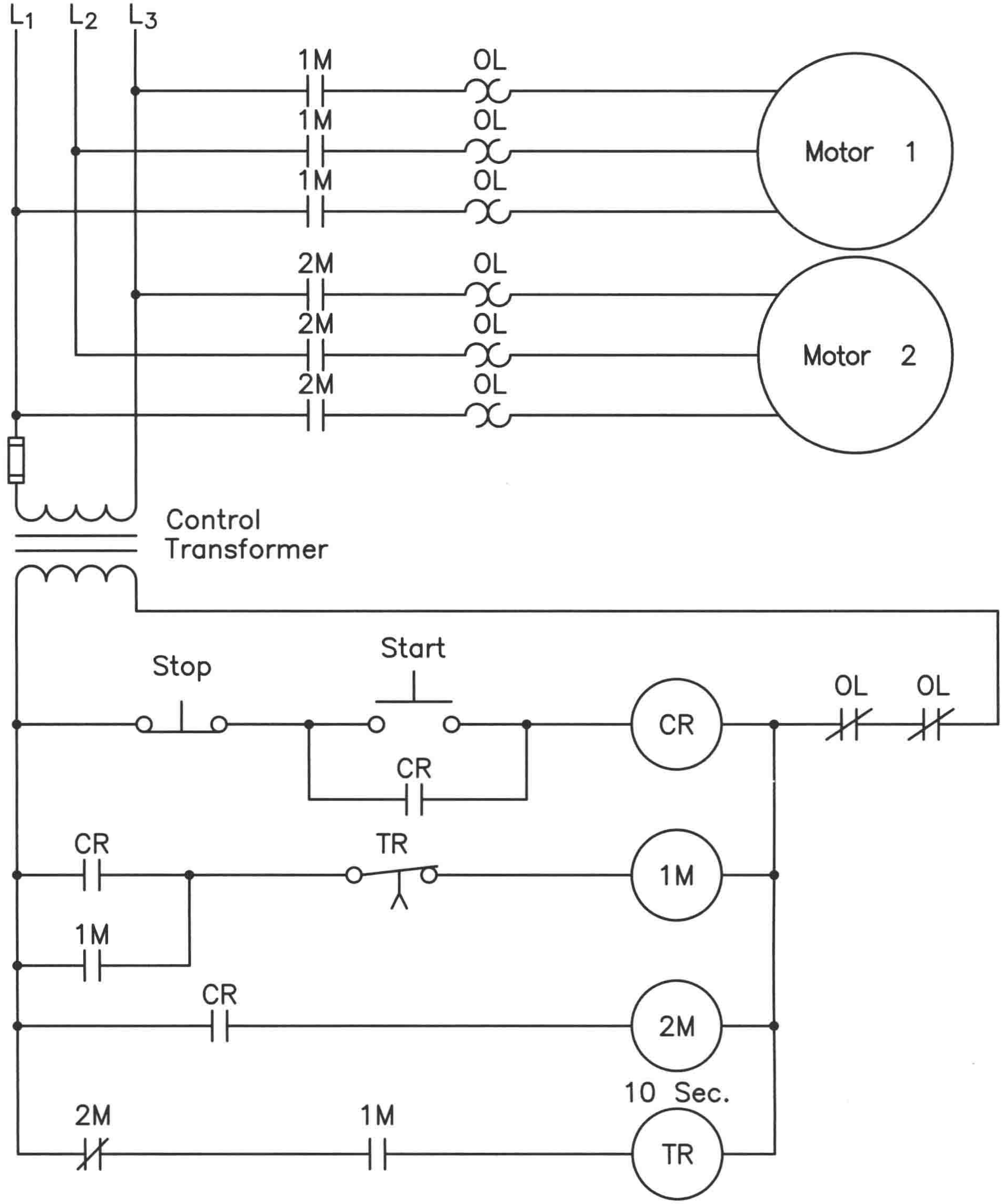

Figure 33-6 Modifying the circuit for an on-delay timer.

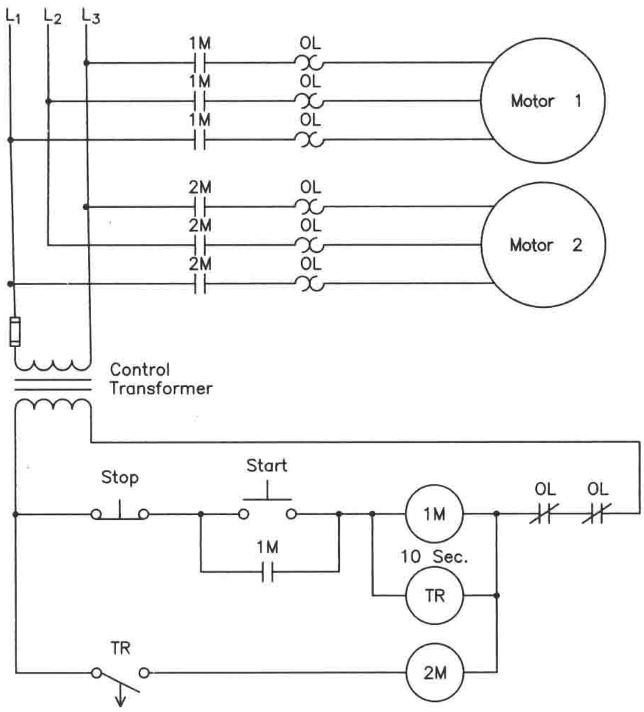

Figure 33-7 Both motors start at the same time.

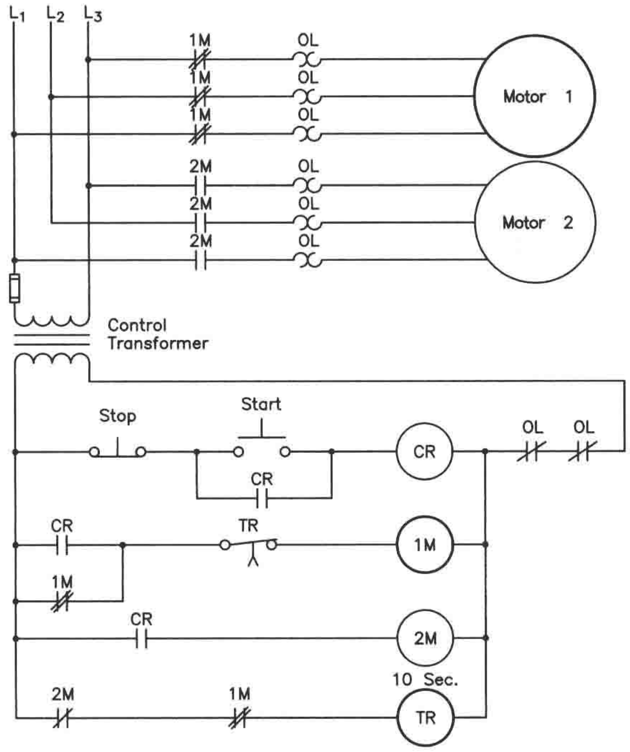

Figure 33-8 Starter 2M de-energizes; timer TR starts its time sequence.

2. Place wire numbers on the schematic diagram.
3. Connect the control part of the circuit.
4. Turn on the power and test the circuit for proper operation.
5. If the control part of the circuit operates properly, **turn off the power** and connect the motors or equivalent motor loads.
6. Turn on the power and test the entire circuit for proper operation.
7. **Turn off the power** and disconnect the circuit.

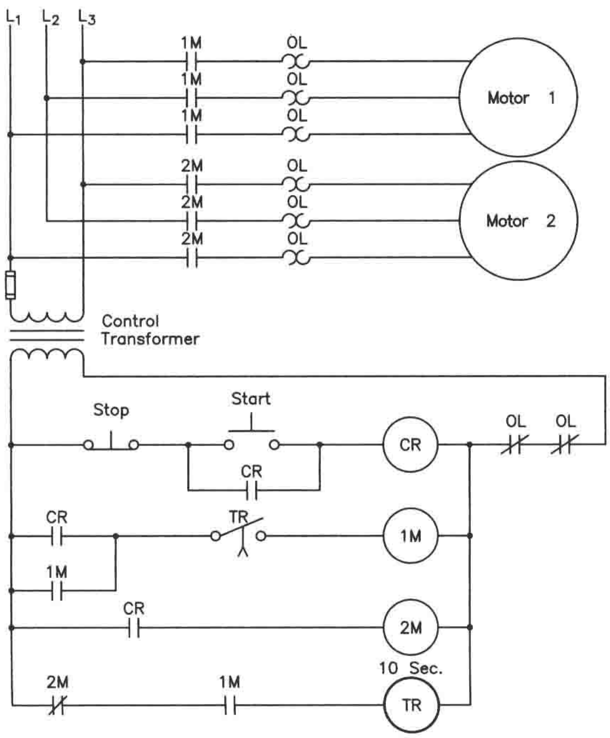

Figure 33-9 Timed contact de-energizes starter 1M.

Review Questions

1. Why do some companies purchase only on-delay timers?

2. Refer to the circuit shown in Figure 33-10. This circuit assumes the use of a pneumatic off-delay timer. It is also assumed that the timer is set for a delay of 10 seconds. Describe the operation of this circuit when the start push button is pressed.

3. Assume that the circuit in Figure 33-10 is in operation. Describe the action of the circuit when the stop button is pressed.

4. The circuit shown in Figure 33-10 employs a pneumatic off-delay timer. Redraw the circuit in the space provided in Figure 33-11 to use an electronic on-delay timer. Make certain that the logic of the circuit is the same.
5. After your instructor has approved the redrawn circuit, connect the circuit in the laboratory.
6. Turn on the power and test the circuit for proper operation.
7. **Turn off the power** and return the components to their proper place.

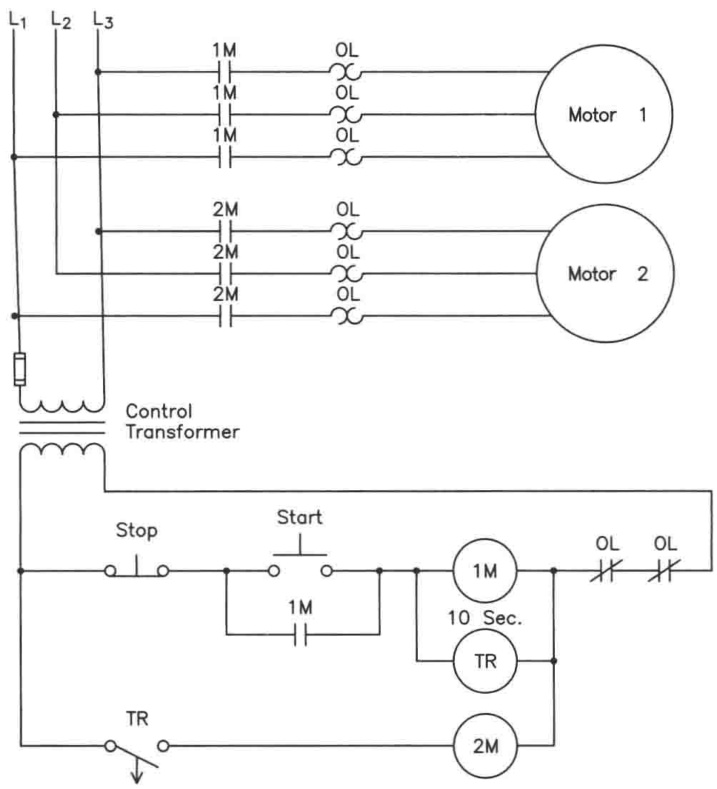

Figure 33-10 Motor 1 stops operating before motor 2.

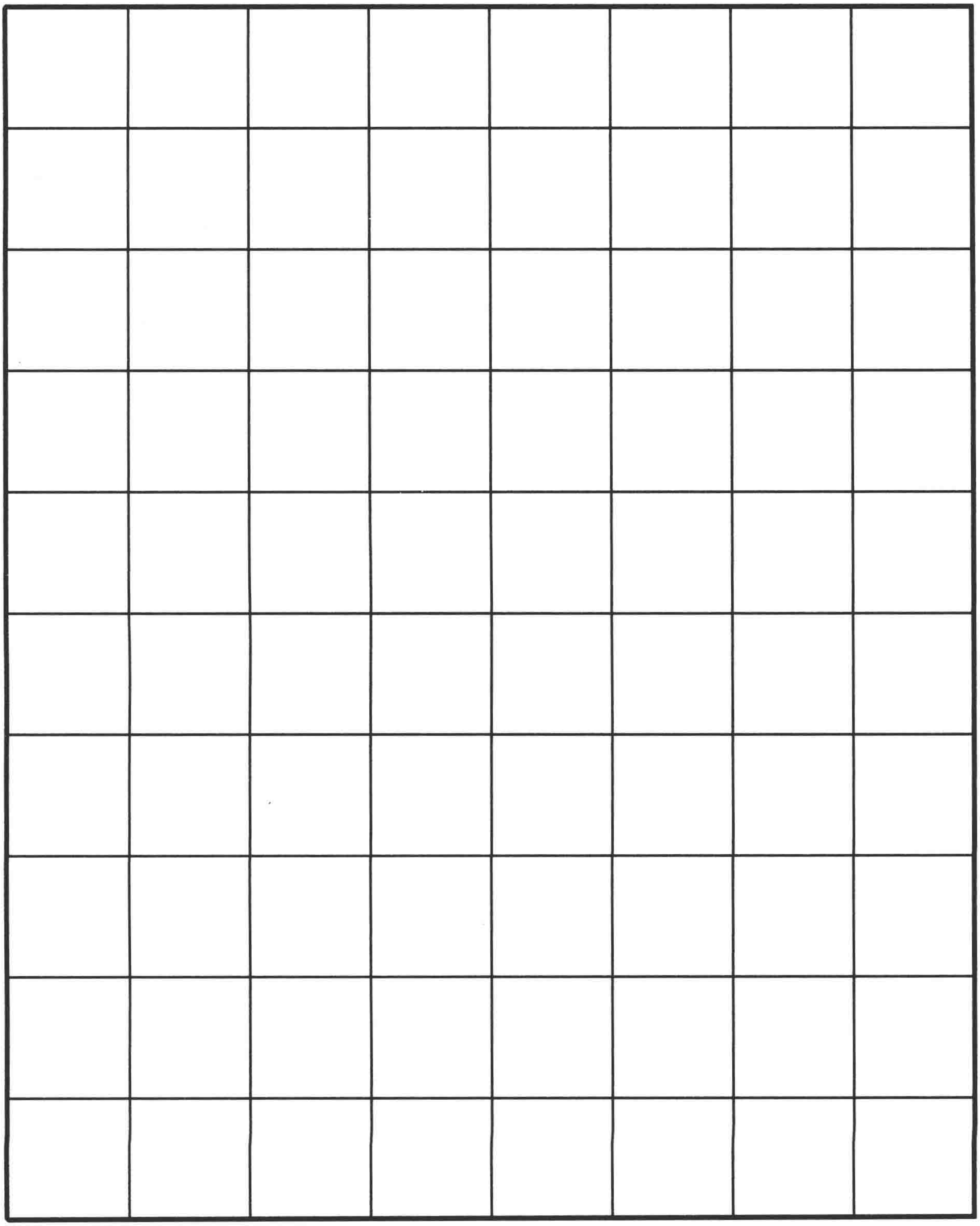

Figure 33-11 Circuit redesign.

Unit 34 Designing a Printing Press Circuit

Objectives

After studying this unit, you should be able to:

- Describe a step-by-step procedure for designing a motor control circuit.
- Design a basic control circuit.
- Connect the completed circuit in the laboratory.

LABORATORY EXERCISE

Name ____ Date ________

Materials Required

Three-phase power supply

Three-phase motor starter

8- or 11-pin on-delay relay with appropriate socket

Three-phase motor or equivalent motor load

Pilot light

Buzzer or simulated load

Control transformer

8-pin control relay and 8-pin socket

In this experiment a circuit for a large printing press will be designed in a step-by-step procedure. The owner of a printing company has the following concern when starting a large printing press:

The printing press is very large and the surrounding noise level is high. There is a danger that when the press starts, a person unseen by the operator may have his or her hands in the press. To prevent an accident, I would like to install a circuit that sounds an alarm and flashes a light for 10 seconds before the press actually starts. This would give the person time to get clear of the machine before it starts.

To begin the design procedure, list the requirements of the circuit. List not only the concerns of the owner but also any electrical or safety requirements that the owner may not be aware of. Understand that the owner is probably not an electrical technician and does not know all the electrical requirements of a motor control circuit.

1. There must be a start and stop push-button control.
2. When the start button is pressed, a warning light and buzzer turn on.

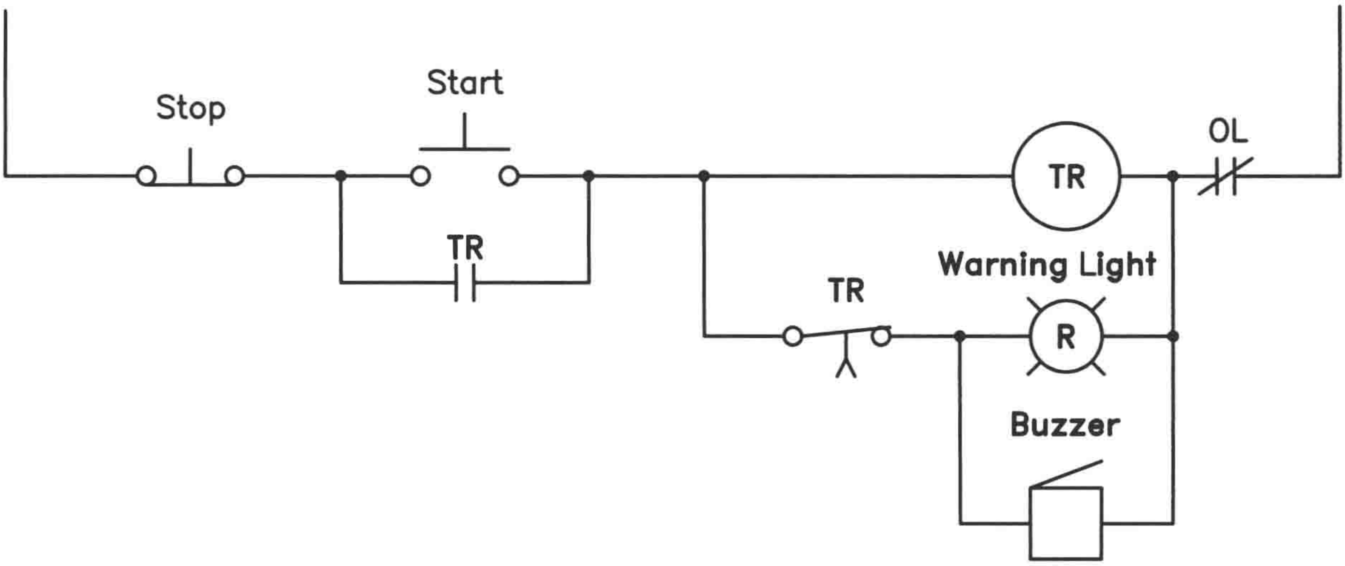

Figure 34-1 First step in the circuit design.

3. After a delay of 10 seconds, the warning light and buzzer turn off and the press motor starts.
4. The press motor should be overload protected.
5. When the stop push button is pressed, the circuit will de-energize even if the motor has not started.

To begin design of the circuit, fulfill the first requirement of the logic: "When the start button is pressed, a warning light and buzzer turn on for a period of 10 seconds." This first part of the circuit can be satisfied with the circuit shown in Figure 34-1. In this example a timer is used because the warning light and buzzer are to remain on for only 10 seconds. Since the warning light and buzzer are to turn on immediately when the start button is pressed, a normally closed timed contact is used. This circuit also assumes that the timer contains an instantaneous contact that is used to hold the circuit in after the start button is released.

The next part of the logic states that after a delay of 10 seconds the warning light and buzzer are to turn off and the press motor is to start. As the present circuit is shown in Figure 34-1, when the start button is pressed, TR coil will energize. This causes the normally open instantaneous TR contacts to close and hold TR coil in the circuit when the start button is released. At the same time, timer TR starts its timing sequence. After a delay of 10 seconds, the normally closed TR timed contact connected in series with the warning light and buzzer will open and disconnect them from the circuit.

The only remaining circuit logic is to start the motor after the warning light and buzzer have turned off. This can be accomplished with a normally open timed contact controlled by timer TR (Figure 34-2). At the end of the timing sequence, the normally closed TR contact will open and disconnect the warning light and buzzer. At the same time, the normally open TR timed contact will close and energize the coil of M starter. The normally closed overload contact connected in series with the rest of the circuit will de-energize the entire circuit in the event of motor overload.

Now that the logic of the control circuit has been completed, the motor load can be added, as shown in Figure 34-3.

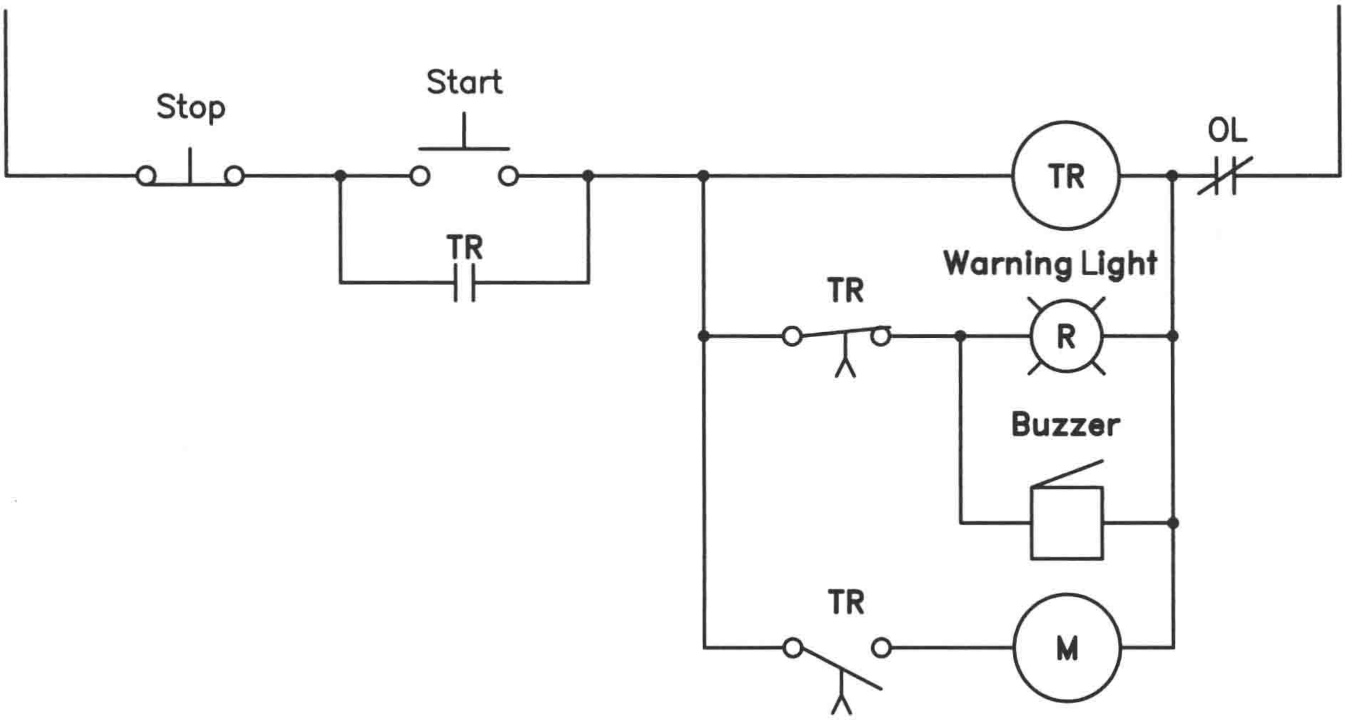

Figure 34-2 Completing the circuit logic.

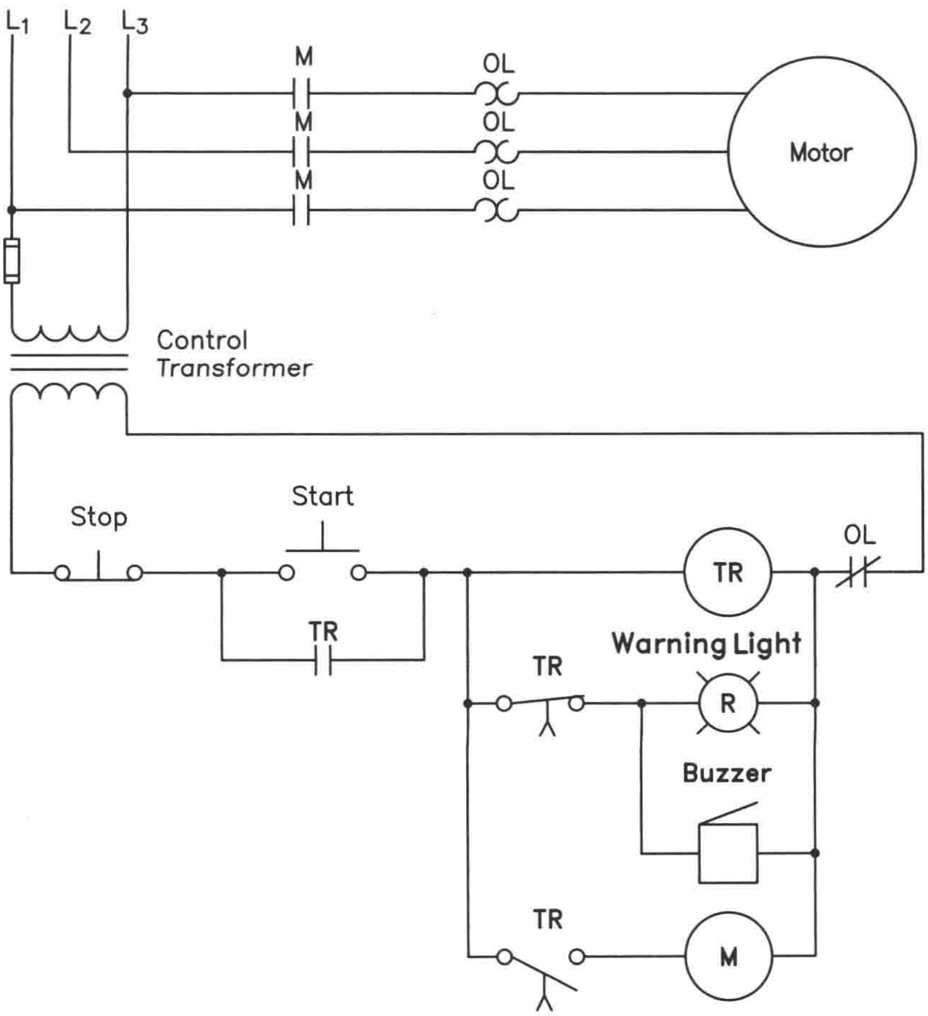

Figure 34-3 The complete circuit.

Addressing a Potential Problem

The completed circuit shown in Figure 34-3 assumes the use of a timer that contains both timed and instantaneous contacts. This contact arrangement is common for certain types of timers such as pneumatic and some clock timers, but most electronic timers do not contain instantaneous contacts. If this is the case, a control relay can be added to supply the needed instantaneous contact by connecting the coil of the control relay in parallel with the coil of TR timer (Figure 34-4).

Connecting the Circuit

1. It will be assumed that the timer in this circuit is the electronic type. Therefore, it will be assumed that a control relay will be used to provide the normally open holding contacts. Assuming the use of an electronic on-delay timer and an 8-pin control relay, place pin numbers beside the components of the timer and control relay shown in Figure 34-4. Circle the numbers to distinguish them from wire numbers.
2. Place wire numbers beside the components in Figure 34-4.
3. Connect the control portion of the circuit. (*Note*: It may be necessary to use a pilot light for the buzzer if one is not available.)
4. Turn on the power and test the control part of the circuit for proper operation.
5. **Turn the power off.**
6. If the control part of the circuit operated properly, connect the motor or simulated motor load to the circuit.
7. Turn on the power and test the entire circuit for proper operation.
8. **Turn off the power** and return the components to their proper location.

Review Questions

1. What should be the first step when beginning the design of a control circuit?

___

___

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2. Why is it sometimes necessary to connect the coil of a control relay in parallel with the coil of a timer?

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3. Refer to the circuit shown in Figure 34-3. Assume that the on-delay timer is replaced with an off-delay timer. Describe the action of the circuit when the start button is pressed.

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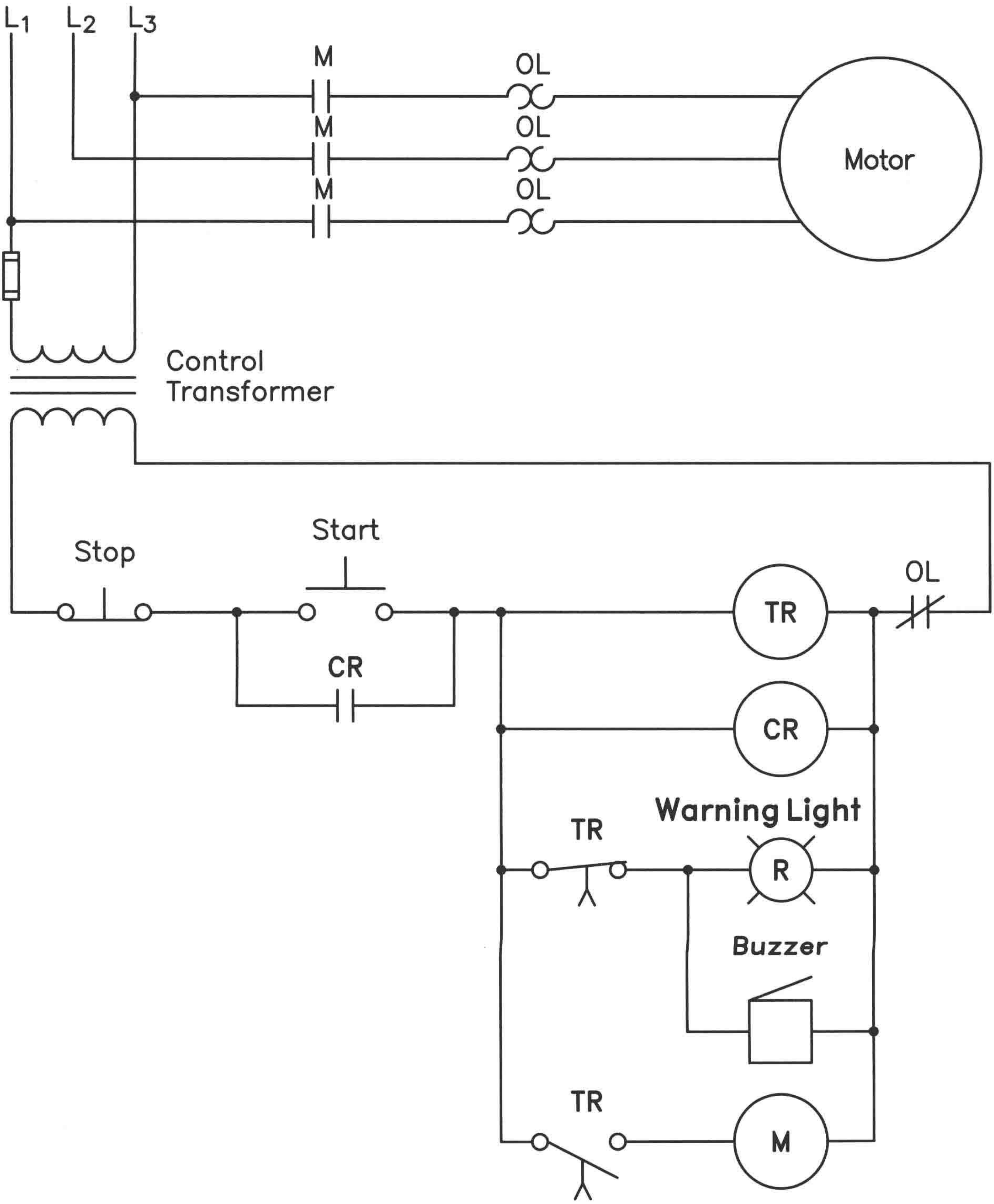

Figure 34-4 Adding a control relay.

4. Describe the operation of the circuit when the stop button is pressed. Assume the circuit is running with an off-delay timer as described in question 3.

___

___

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5. Refer to the circuit shown in Figure 34-4. Assume the owner decides to change the logic of the circuit as follows:

   When the operator presses the start button, a warning light and buzzer turn on for a period of 10 seconds. During this 10 seconds, the operator must continue to hold down the start button. If the start button should be released, the timing sequence will stop and the motor will not start. At the end of 10 seconds, provided the operator continues to hold the start button down, the warning light and buzzer will turn off and the motor will start. When the motor starts, the operator can release the start button and the press will continue to run.

   Amend the circuit in Figure 34-4 to meet the requirement.

Unit 35 Sequence Starting and Stopping for Three Motors

Objectives

After studying this unit, you should be able to:

- Discuss the step-by-step procedure for designing a circuit.
- Change a circuit designed with pneumatic timers into a circuit to use electronic timers.
- Connect the circuit in the laboratory.
- Troubleshoot the circuit.

LABORATORY EXERCISE

Name ____ Date __________

Materials Required

Three-phase power supply

Control transformer

2 eight-pin control relays and 8-pin sockets

3 three-phase motor starters

4 electronic timers (Dayton model 6A855 or equivalent) and 11-pin sockets

3 three-phase motors or equivalent motor loads

In this experiment a circuit will be designed and connected. The requirements of the circuit are as follows:

1. Three motors are to start in sequence from motor #1 to motor #3.
2. There is to be a time delay of 3 seconds between the starting of each motor.
3. When the stop button is pressed, the motors are to stop in sequence from motor #3 to motor #1.
4. There is to be a time delay of 3 seconds between the stopping of each motor.
5. An overload on any motor will stop all motors.

When designing a control circuit, satisfy one requirement at a time. This may at times lead to an unforeseen dead end, but don't let these dead ends concern you. When they happen, back up and redesign around them. In this example the first part of the circuit is to start three motors in sequence from motor #1 to motor #3 with a 3-second delay

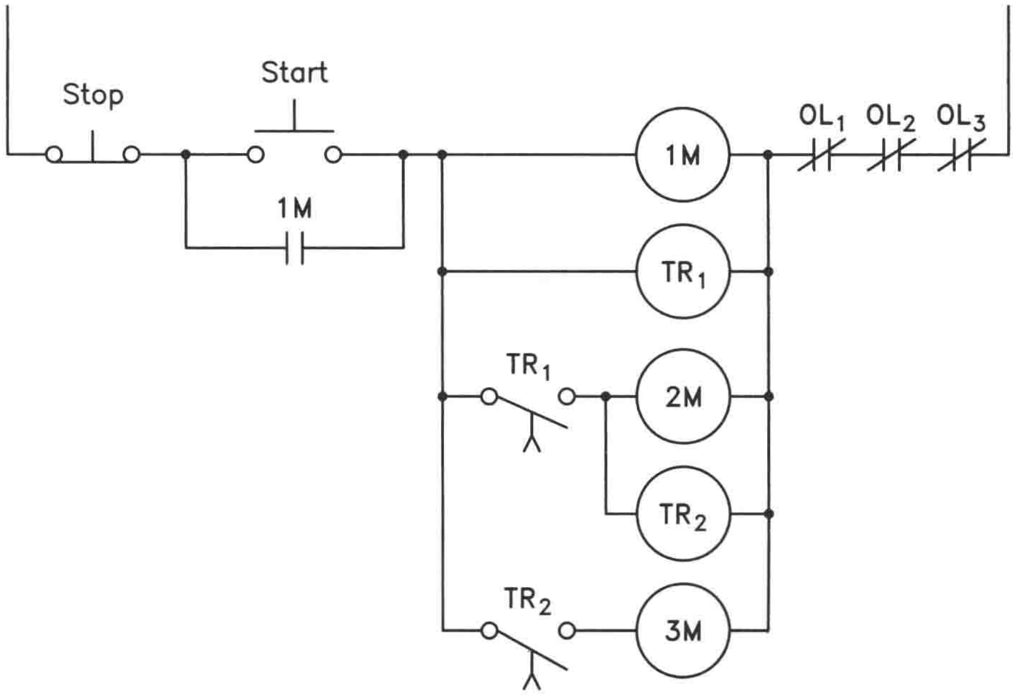

Figure 35-1 The motors start in sequence from 1 to 3.

between the starting of each motor. This is also the time to satisfy the requirement that an overload on any motor will stop all motors. The first part of the circuit can be satisfied by the circuit shown in Figure 35-1. (Note: In this experiment the motor connections will not be shown because of space limitations. It is to be assumed that the motor starters are controlling three-phase motors. It is also assumed that all timers are set for a delay of 3 seconds.)

When the start button is pressed, coils 1M and TR_1 energize. Starter 1M starts motor #1 immediately, and timer TR_1 starts its time sequence of 3 seconds. After a delay of 3 seconds, timed contact TR_1 closes and energizes coils 2M and TR_2. Starter 2M starts motor #2 and timer TR_2 begins its 3-second timing sequence. After a delay of 3 seconds, timed contact TR_2 closes and energizes motor #3. The motors have been started in sequence from #1 to #3 with a delay of 3 seconds between the starting of each motor. This satisfies the first part of the circuit logic.

The next requirement is that the circuit stop in sequence from motor #3 to motor #1. To fulfill this requirement, power must be maintained to starters 2M and 1M after the stop button has been pushed. In the circuit shown in Figure 35-1, this is not possible. Since all coils are connected after the M auxiliary holding contact, power will be disconnected from all coils when the stop button is pressed and the holding contact opens. This circuit has proven to be a dead end. There is no way to fulfill the second requirement with the circuit connected in this manner. Therefore, the circuit must be amended in such a manner that it will not only start in sequence from motor #1 to motor #3 with a 3-second time delay between the starting of each motor but also be able to maintain power after the start button is pressed. This amendment is shown in Figure 35-2.

To modify the circuit so that power can be maintained to coils 2M and 1M, a control relay has been added to the circuit. Contact $1CR_2$ prevents power from being applied to coils 1M and TR_1 until the start button is pressed.

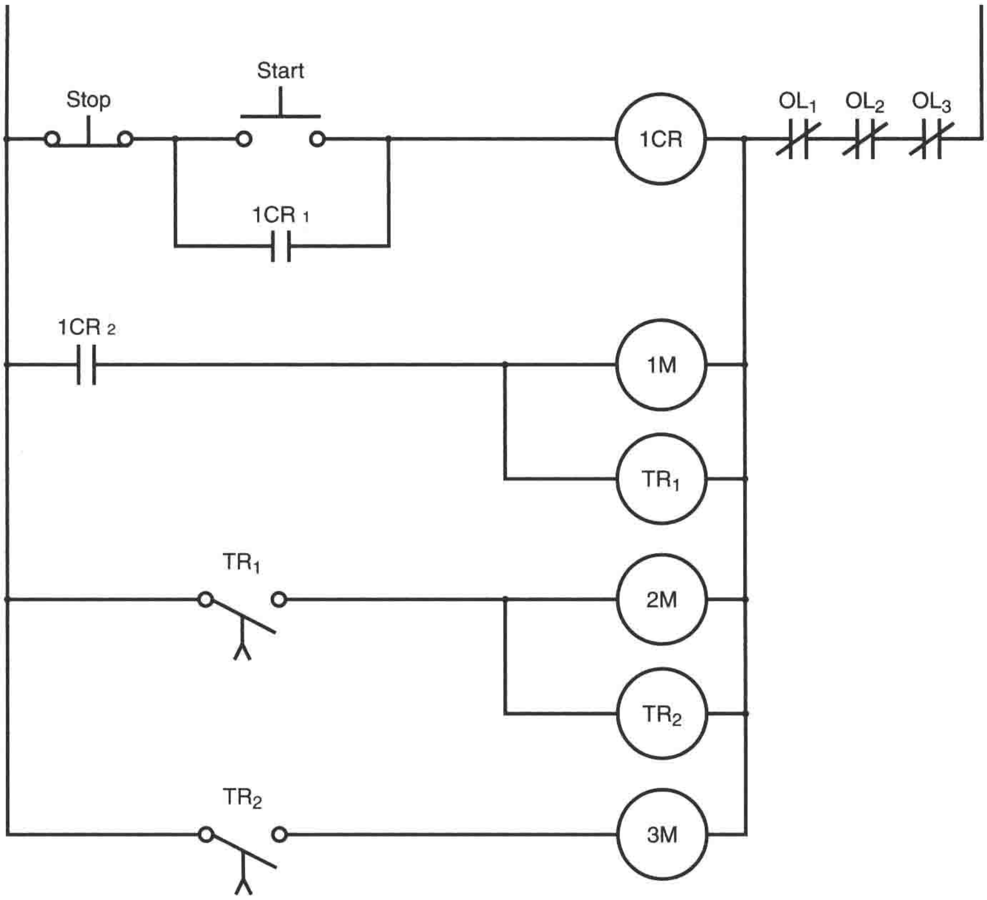

Figure 35-2 A control relay is added to the circuit.

Designing the Second Part of the Circuit

The second part of the circuit states that the motors must stop in sequence from motor #3 to motor #1. Do not try to solve all the logic at once. Solve each problem as it arises. The first problem is to stop motor #3. In the circuit shown in Figure 35-2, when the stop button is pressed, coil 1CR will de-energize. This will cause contact $1CR_2$ to open and de-energize coils 1M and TR_1. Contact TR_1 will open immediately and de-energize coils 2M and TR_2, causing contact TR_2 to open immediately and de-energize coil 3M. Notice that coil 3M does de-energize when the stop button is pressed, but so does everything else. The circuit requirement states that there is to be a 3-second time delay between the stopping of motor #3 and motor #2. Therefore, an off-delay timer will be added to maintain connection to coil 2M after coil 3M has de-energized (Figure 35-3).

The same basic problem exists with motor #1. In the present circuit, motor #1 will turn off immediately when the stop button is pressed. To help satisfy the second part of the problem, another off-delay relay must be added to maintain a circuit to motor #1 for a period of 3 seconds after motor #2 has turned off. This addition is shown in Figure 35-4.

Motors #2 and #1 will now continue to operate after the stop button is pressed, but so will motor #3. In the present design, none of the motors will turn off when the stop button is pressed. To understand this condition, trace the logic step-by-step. When the start button is pressed, coil 1CR energizes and closes all 1CR contacts. When contact $1CR_2$ closes, coils 1M and TR_1 energize. After a period of 3 seconds, timed contact TR_1 closes and energizes coils 2M, TR_2, and TR_4. Timed contact TR_4 closes immediately to bypass contact $1CR_2$. After a delay of 3 seconds, timed contact TR_2 closes and energizes coils 3M and TR_3.

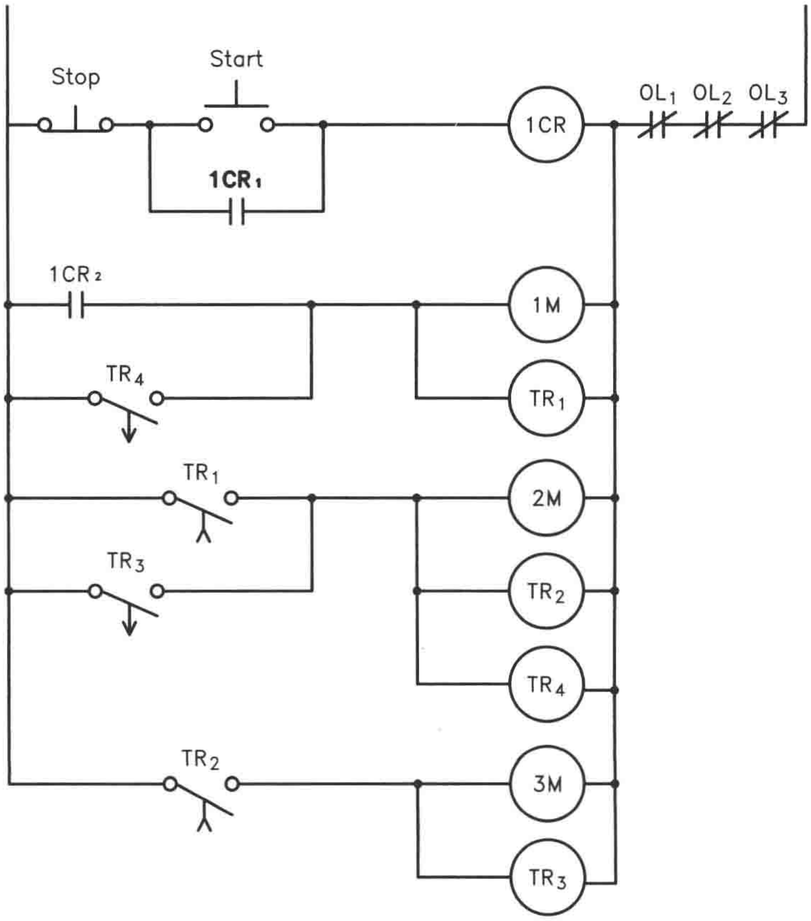

Figure 35-3 Timer TR_3 prevents motor 2 from stopping.

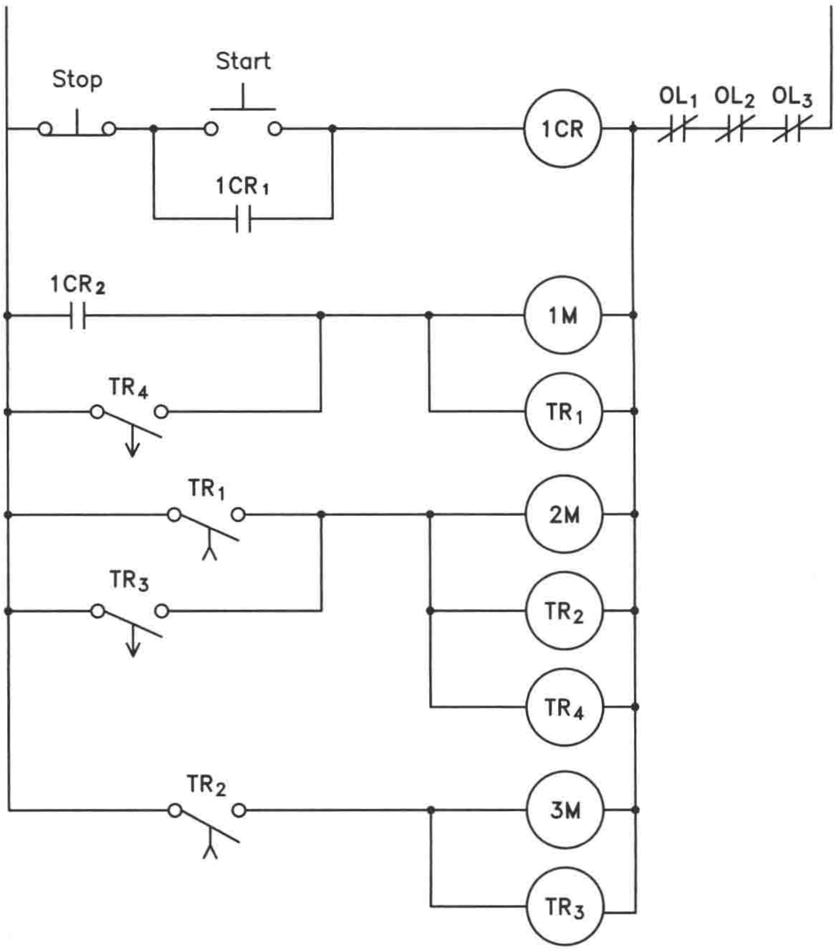

Figure 35-4 Off-delay timer TR_4 prevents motor 1 from stopping.

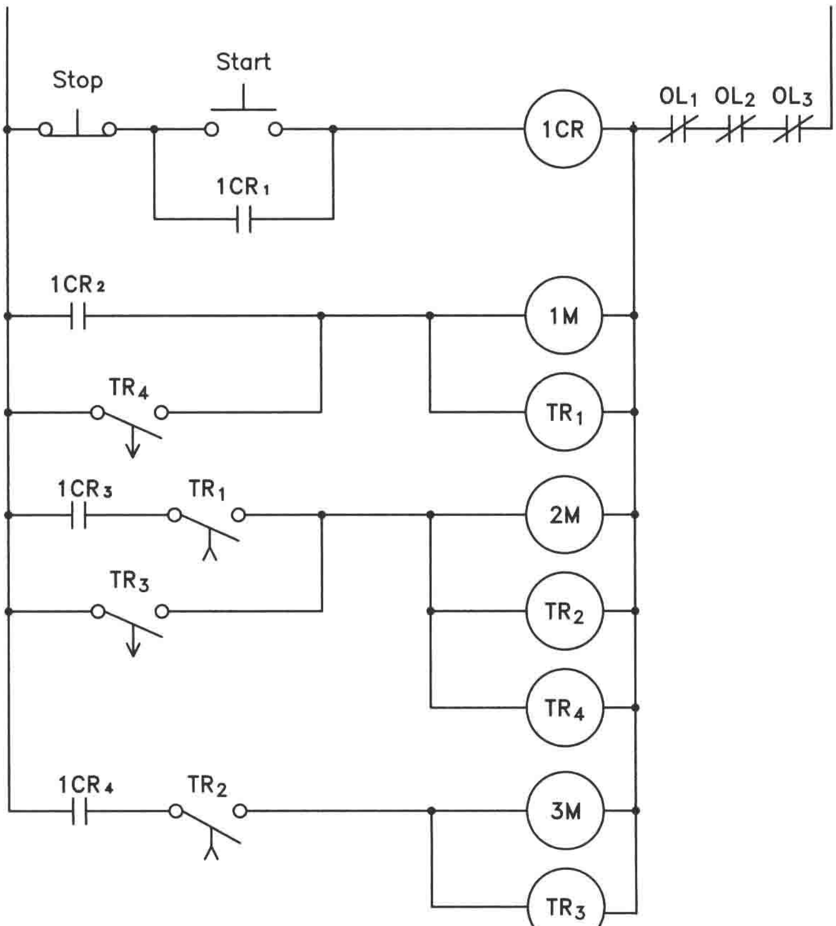

Figure 35-5 Control relay contacts are added to permit the circuit to turn off.

Timed contact TR_3 closes immediately and bypasses contact TR_1. When the stop button is pressed, coil 1CR de-energizes and all 1CR contacts open, but a circuit is maintained to coils 1M and TR_1 by contact TR_4. This prevents timed contact TR_1 from opening to de-energize coils 2M, TR_2, and TR_4, which in turn prevents timed contact TR_2 from opening to de-energize coils 3M and TR_3. To overcome this problem, two more contacts controlled by relay 1CR will be added to the circuit (Figure 35-5). The circuit will now operate in accord with all the stated requirements.

Modifying the Circuit

The circuit in Figure 35-5 was designed with the assumption that all the timers are of the pneumatic type. When this circuit is connected in the laboratory, 8-pin control relays and electronic timers will be used. The circuit will be amended to accommodate these components. The first change to be made concerns the control relays. Notice that the circuit requires the use of four normally open contacts controlled by coil 1CR. Since 8-pin control relays have only two normally open contacts, it will be necessary to add a second control relay, 2CR. The coil of relay 2CR will be connected in parallel with 1CR, which will permit both to operate at the same time (Figure 35-6).

Timers TR_1 and TR_2 are on-delay timers and do not require an adjustment in the circuit logic to operate. Timers TR_3 and TR_4, however, are off-delay timers and do require changing the circuit. The coils must be connected to power at all times. Assuming the use of a Dayton timer model 6A855, power would connect to pins 2 and 10. Starter 3M will be used

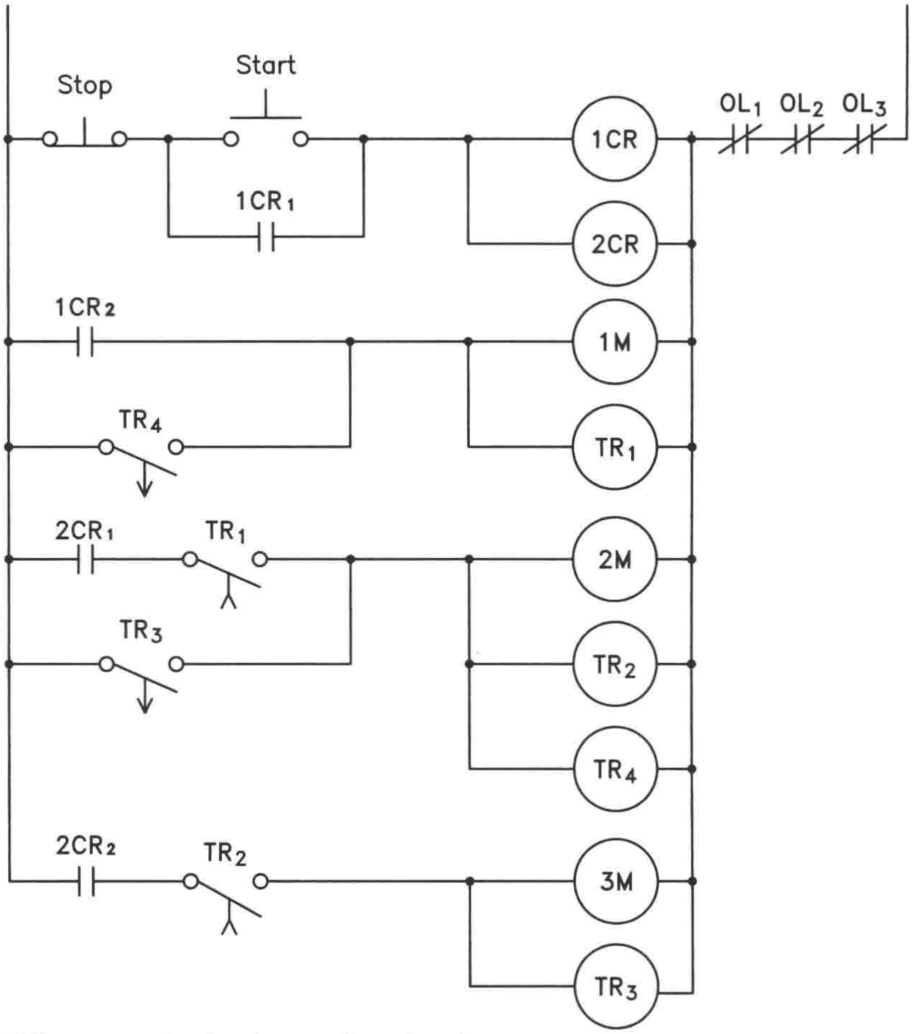

Figure 35-6 Adding a control relay to the circuit.

to control the action of timer TR_3 by connecting a 3M normally open auxiliary contact to pins 5 and 6 of timer TR_3 (Figure 35-7). Starter 2M will control the action of timer TR_4 by connecting a 2M normally open auxiliary contact to pins 5 and 6 of that timer. The circuit is now complete and ready for connection in the laboratory.

Connecting the Circuit

1. Using the circuit shown in Figure 35-7, place pin numbers beside the proper components. Circle the pin numbers to distinguish them from wire numbers.
2. Place wire numbers on the schematic.
3. Connect the control circuit in the laboratory.
4. Turn on the power and test the circuit for proper operation.
5. **Turn off the power** and connect the motor loads to starters 1M, 2M, and 3M.
6. Turn on the power and test the complete circuit.
7. **Turn off the power.**
8. Disconnect the circuit and return the components to their proper places.

Review Questions

Refer to the circuit in Figure 35-7 to answer the following questions. It is assumed that all the timers are set for a delay of 3 seconds.

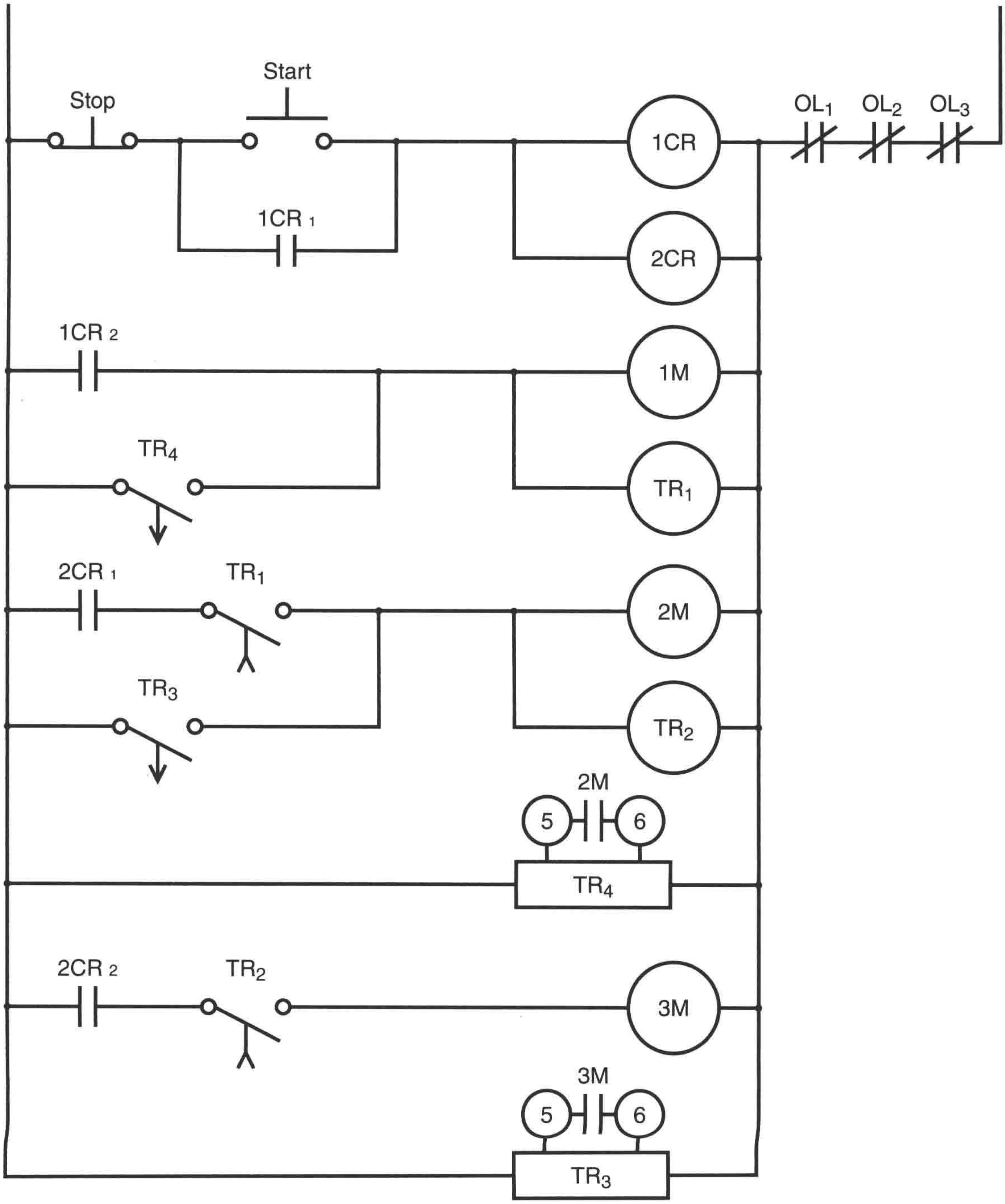

Figure 35-7 Changing pneumatic timers for electronic timers.

1. When the start button is pressed, motor #1 starts operating immediately. Three seconds later motor #2 starts, but motor #3 never starts. When the stop button is pressed, motor #2 stops operating immediately. After a delay of 3 seconds, motor #1 stops running. Which of the following could not cause this condition?
   a. TR_3 coil is open.
   b. 3M coil is open.
   c. TR_2 coil is open.
   d. 2CR coil is open.

2. When the start button is pressed, motor #1 starts operating immediately. Motor #2 does not start operating after 3 seconds, but after a delay of 6 seconds motor #3 starts operating. When the stop button is pushed, motors #3 and #1 stop operating immediately. Which of the following could cause this condition?
   a. 2CR coil is open.
   b. TR_1 coil is open.
   c. TR_3 coil is open.
   d. 2M coil is open.
3. When the start button is pressed, all three motors start normally with a 3-second delay between the starting of each motor. When the stop button is pressed, motor #3 stops operating immediately. After a delay of 3 seconds, both motors #2 and #1 stop operating at the same time. Which of the following could cause this problem?
   a. Timer TR_1 is defective.
   b. Timer TR_2 is defective.
   c. Timer TR_3 is defective.
   d. Timer TR_4 is defective.
4. When the start button is pressed, nothing happens. None of the motors start. Which of the following could *not* cause this problem?
   a. Overload contact OL_1 is open.
   b. 1CR relay coil is open.
   c. 2CR relay coil is open.
   d. The stop button is open.
5. When the start button is pressed, motor #1 does not start, but after a delay of 3 seconds motor #2 starts, and 3 seconds later motor #3 starts. When the stop button is pressed, motor #3 stops running immediately and after a delay of 3 seconds motor #2 stops running. Which of the following could cause this problem?
   a. Starter coil 1M is open.
   b. TR_1 timer coil is open.
   c. Timer TR_4 is defective.
   d. 1CR coil is open.

Unit 36 Hydraulic Press Control Circuit

Objectives

After studying this unit, you should be able to:

- Discuss the operation of this hydraulic press control circuit.
- Connect the circuit in the laboratory.
- Operate the circuit using toggle switches to simulate limit and pressure switches.

LABORATORY EXERCISE

Name ____ Date __________

Materials Required

Three-phase power supply

Control transformer

Three-phase motor starter with at least two normally open auxiliary contacts

5 double-acting push buttons (N.O./N.C. on each button)

Pilot light

3 toggle switches that can be used to simulate two limit switches and one pressure switch

1 three-phase motor or equivalent motor load

2 solenoid coils or lamps to simulate solenoid coils

3 control relays with three sets of contacts (11-pin) and 11-pin sockets

3 control relays with two sets of contacts (8-pin) and 8-pin sockets

The next circuit to be discussed is a control for a large hydraulic press (Figure 36-1). In this circuit, a hydraulic pump must be started before the press can operate. Pressure switch PS closes when there is sufficient hydraulic pressure to operate the press. If switch PS should open, it will stop the operation of the circuit. A green pilot light is used to tell the operator that there is enough pressure to operate the press.

Two run push buttons are located far enough apart so that both of the operator's hands must be used to cause the press to cycle. This is to prevent the operator from getting his hands in the press when it is operating. Limit switches UPLS and DNLS are used to determine when the press is at the bottom of its downstroke and when it is at the top of its upstroke. In the event one or both of the run push buttons are released during the cycle, a reset button can be used to reset the press to its top position. The up solenoid causes the press to travel upward when it is energized, and the down solenoid causes the press to travel downward when it is energized.

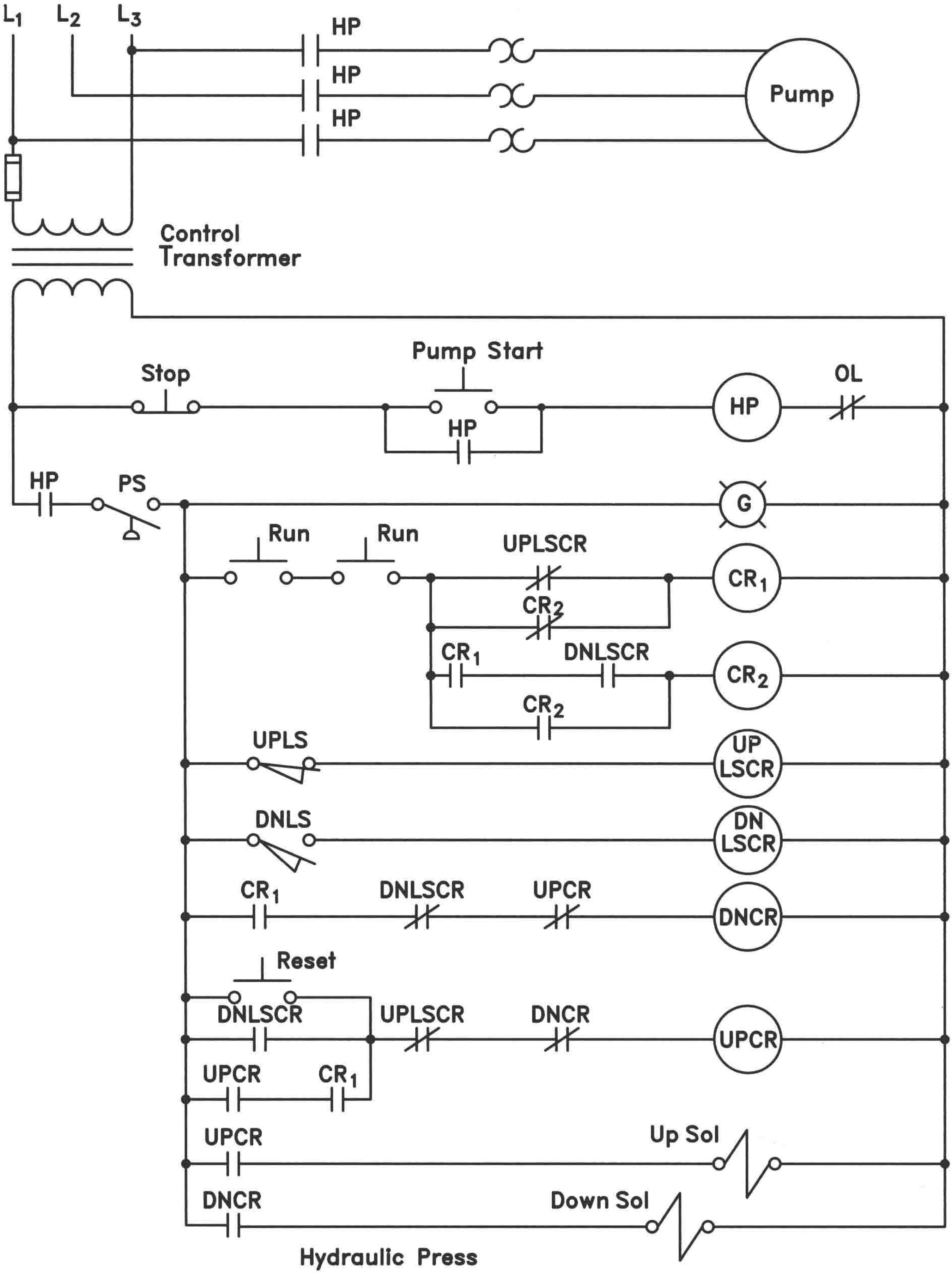

Figure 36-1 Hydraulic press control circuit.

To understand the operation of this circuit, assume that the press is in the up position. Notice that limit switch UPLS is shown normally open held closed. This limit switch is connected normally open, but when the press is in the up position it is being held closed. Now assume that the hydraulic pump is started and that the pressure switch closes. When pressure switch PS closes, the green pilot light turns on and UPLSCR (Up Limit Switch Control Relay) energizes, changing all UPLSCR contacts (Figure 36-2).

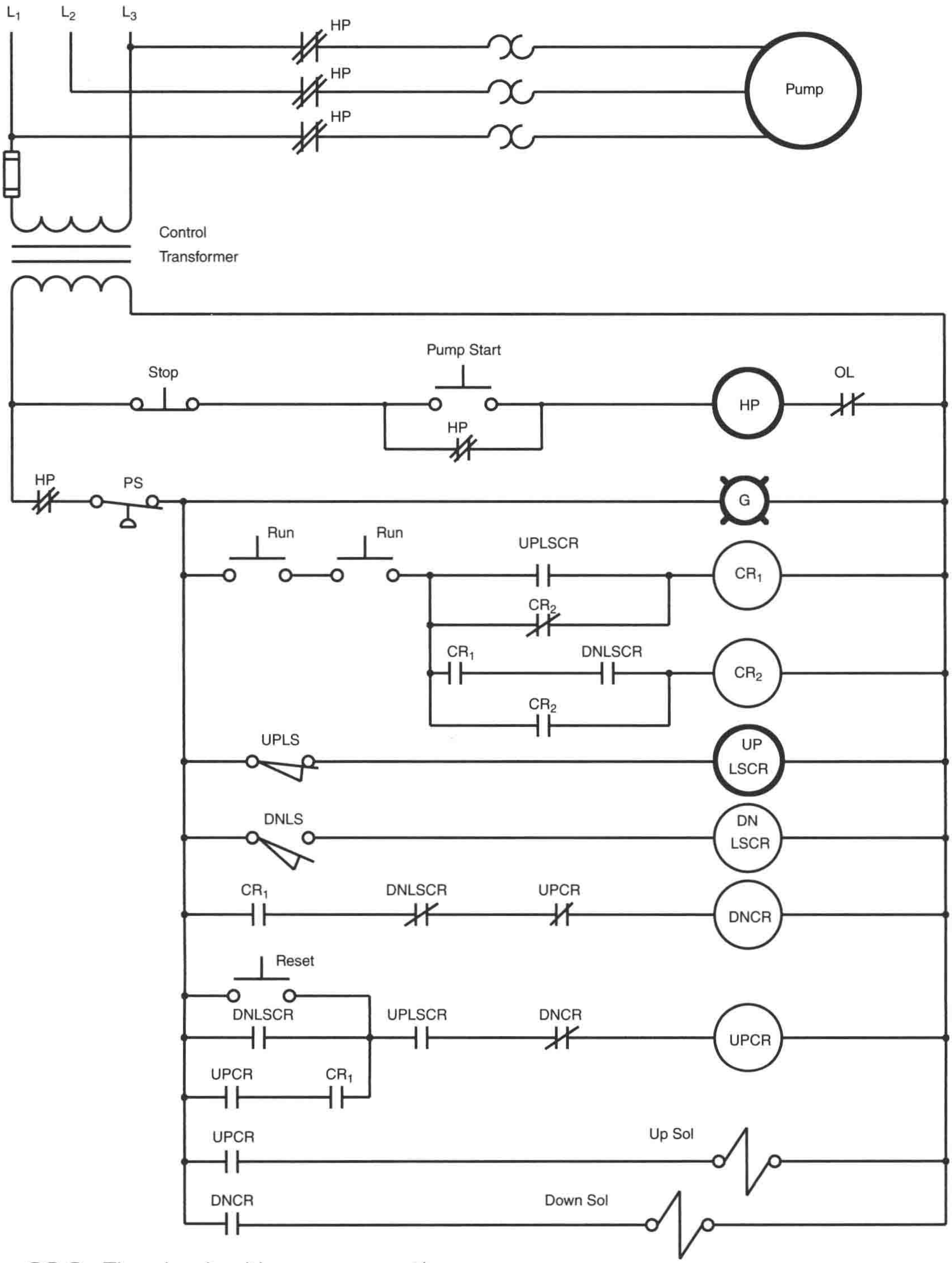

Figure 36-2 The circuit with pump operating.

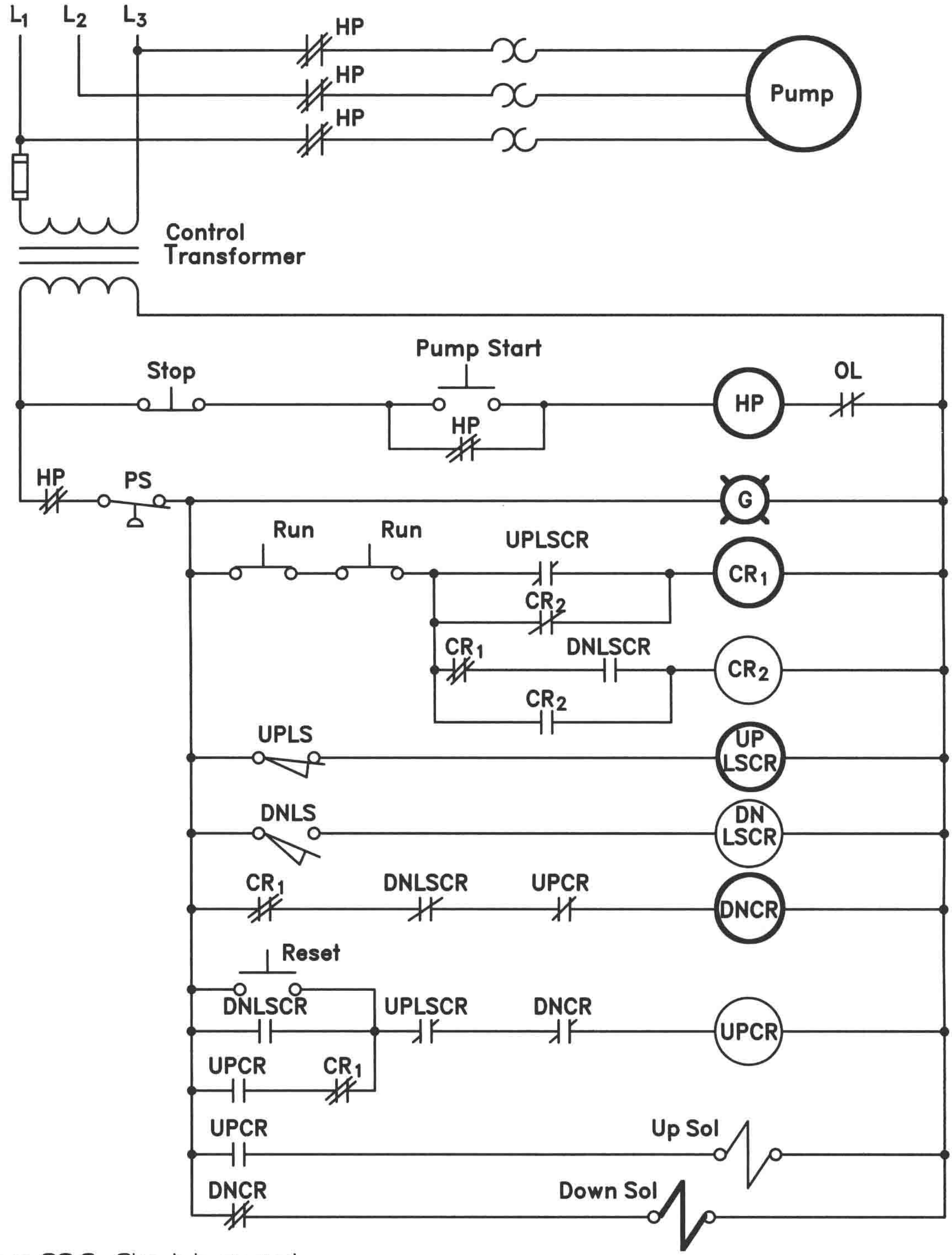

Figure 36-3 Circuit is started.

When both run push buttons are held down, a circuit is completed to CR_1 relay, causing all CR_1 contacts to change position (Figure 36-3). The CR_1 contact connected in series with the coil of DNCR closes and energizes the relay, causing all DNCR contacts to change position. The DNCR contact connected in series with the down solenoid coil closes and energizes the down solenoid.

As the press begins to move downward, limit switch UPLS opens and de-energizes coil UPLSCR, returning all UPLSCR contacts to their normal position (Figure 36-4).

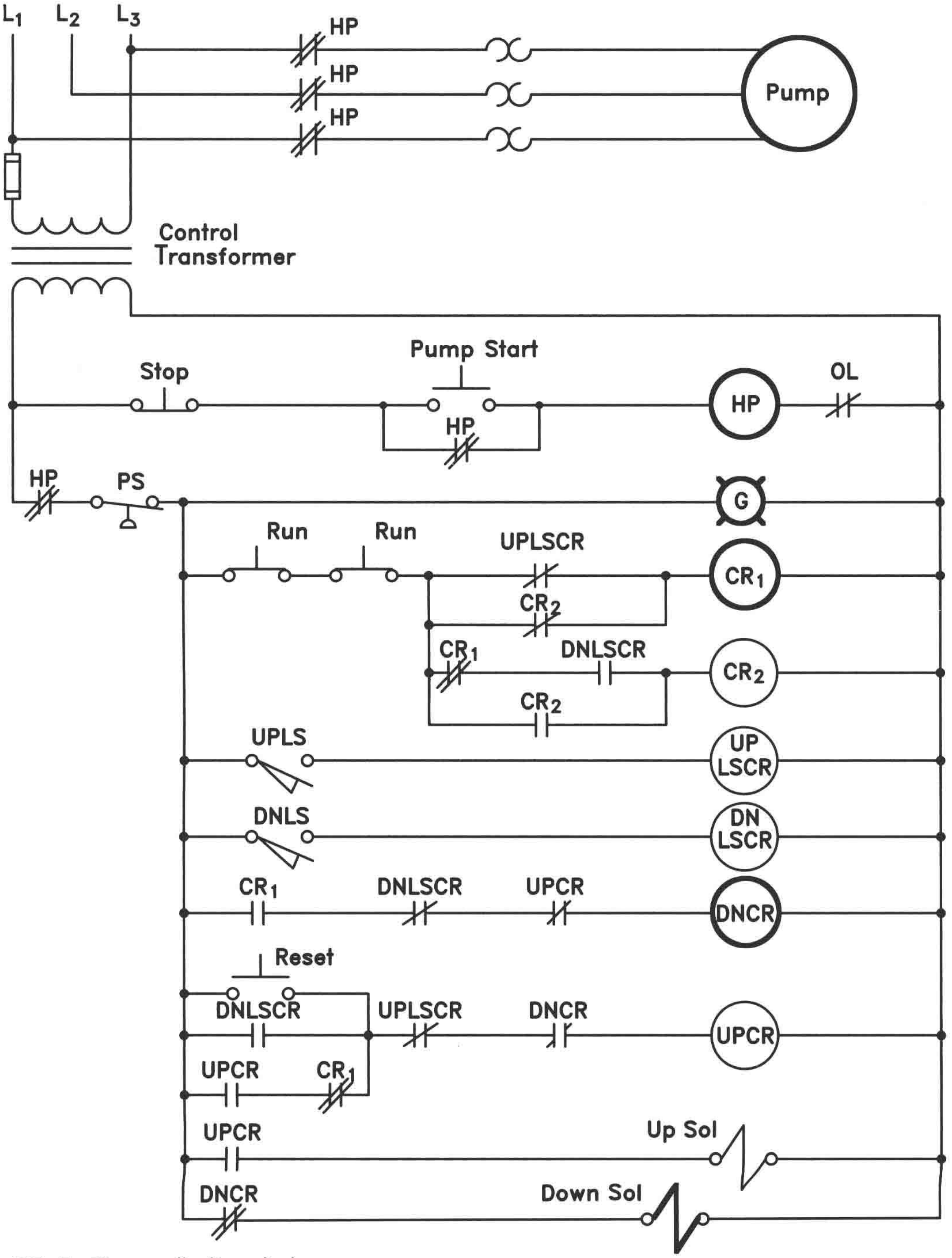

Figure 36-4 The up limit switch opens.

When the press reaches the bottom of its stroke, it closes down limit switch DNLS. This energizes the coil of the down limit switch control relay, DNLSCR, causing all DNLSCR contacts to change position (Figure 36-5). The normally open DNLSCR contact connected in series with the coil of CR_2 closes and energizes that relay, causing all CR_2 contacts to change position. The normally closed DNLSCR contact connected in series with DNCR coil opens and de-energizes that relay. All DNCR contacts return to their normal positions. The normally open contact connected in series with the down solenoid coil opens and de-energizes the solenoid. The normally closed DNCR contact connected in series with UPCR coil recloses and provides a current path to that relay.

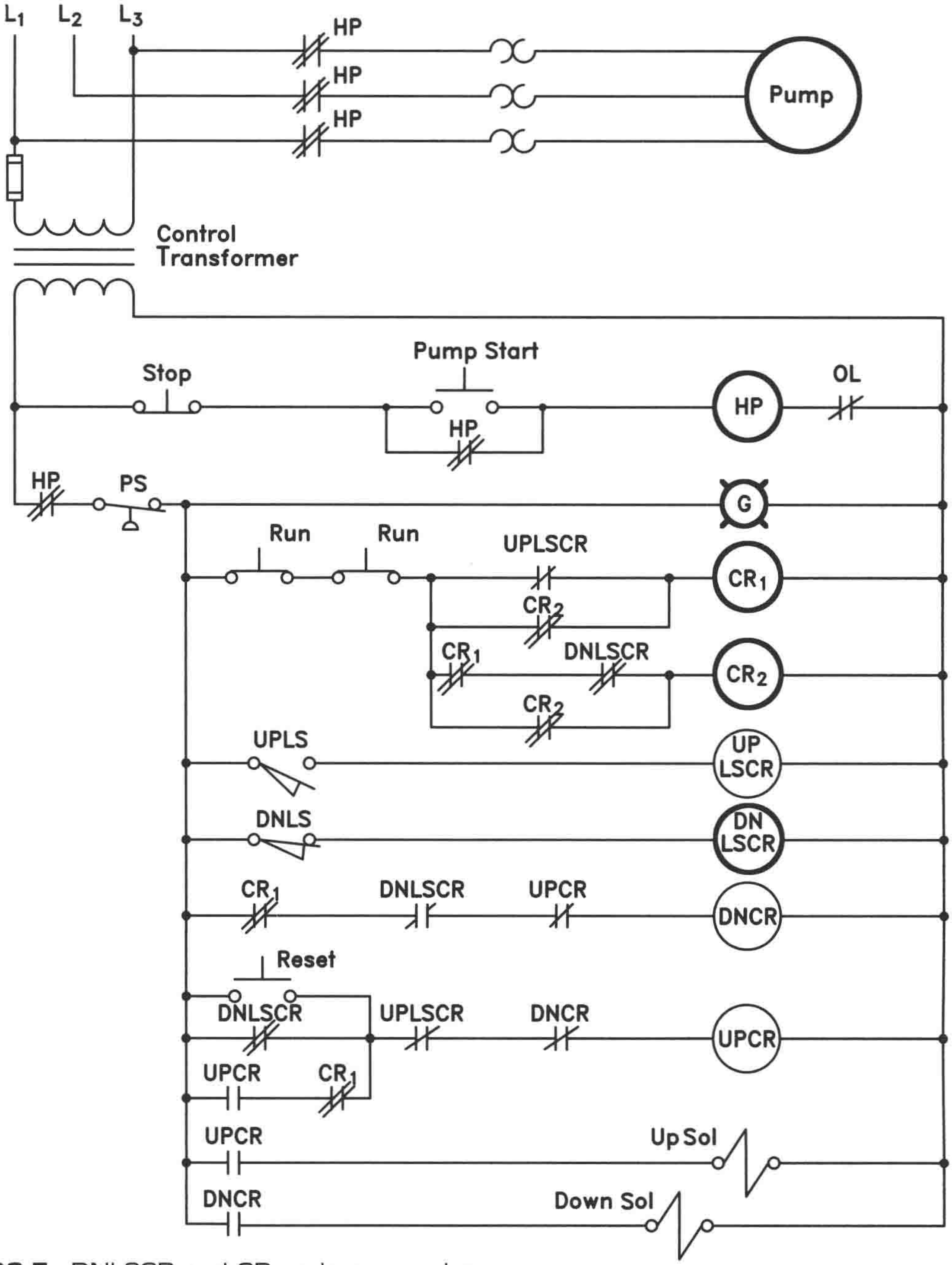

Figure 36-5 DNLSCR and CR_2 relays energize.

The UPCR contact connected in series with coil DNCR opens and prevents coil DNCR from re-energizing when coil DNLSCR de-energizes. The normally open UPCR contact connected in series with the up solenoid closes and provides a current path to the up solenoid. When the press starts upward, limit switch DNLS reopens and de-energizes coil DNLSCR. A circuit is maintained to UPCR coil by the now closed UPCR contact connected in series with the CR_1 contact (Figure 36-6).

The press will continue to travel upward until it reaches its upper limit and closes limit switch UPLS, energizing coil UPLSCR (Figure 36-7). This causes both UPLSCR contacts to change position. The UPLSCR contact connected in series with coil UPCR opens and de-energizes the up solenoid. Notice that control relays CR_1 and CR_2 are still energized.

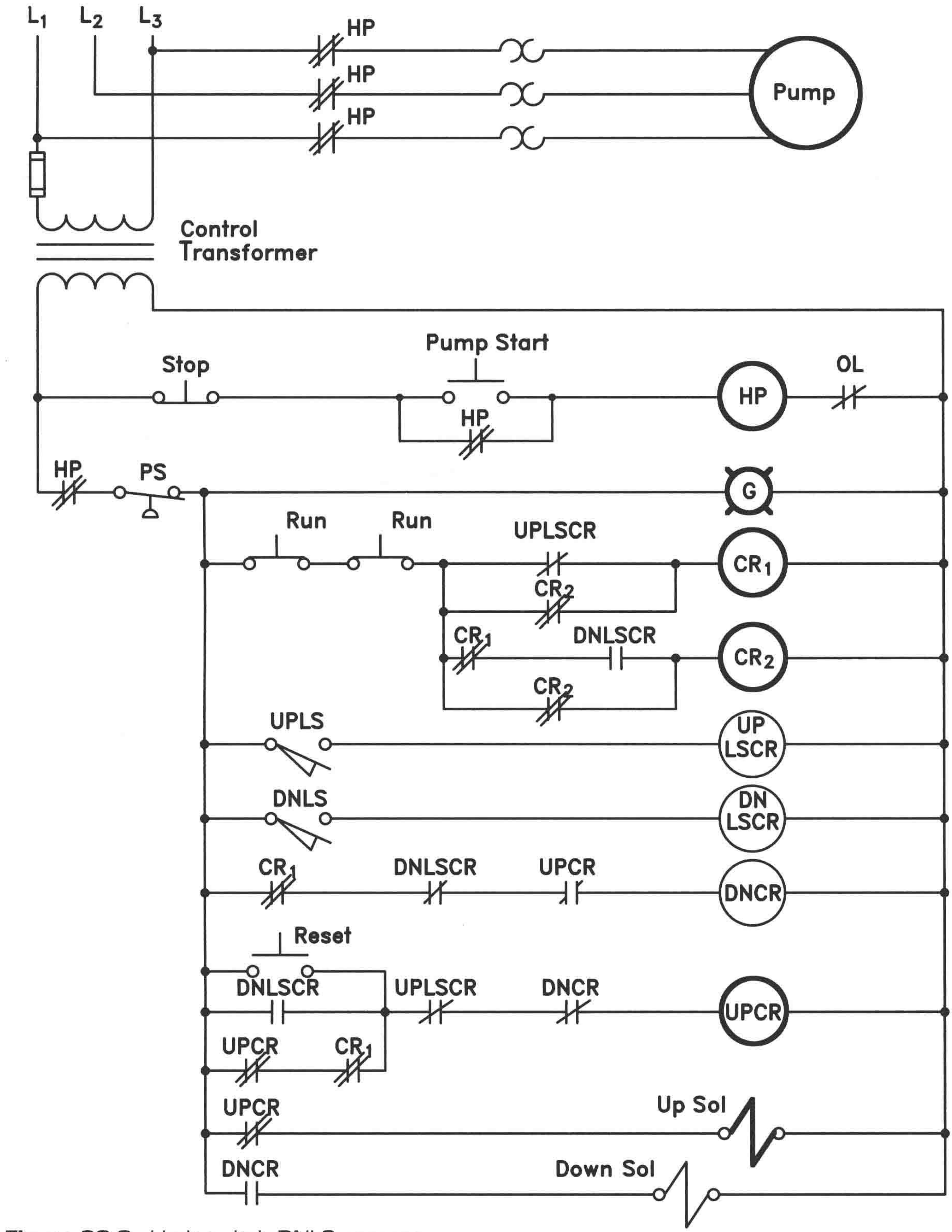

Figure 36-6 Limit switch DNLS reopens.

Before the press can be re-cycled, one or both of the run buttons must be released to break the circuit to the control relays. This will permit the circuit to reset to the state shown in Figure 36-2. If for some reason the press should be stopped during a cycle, the reset button can be used to return the press to the starting position.

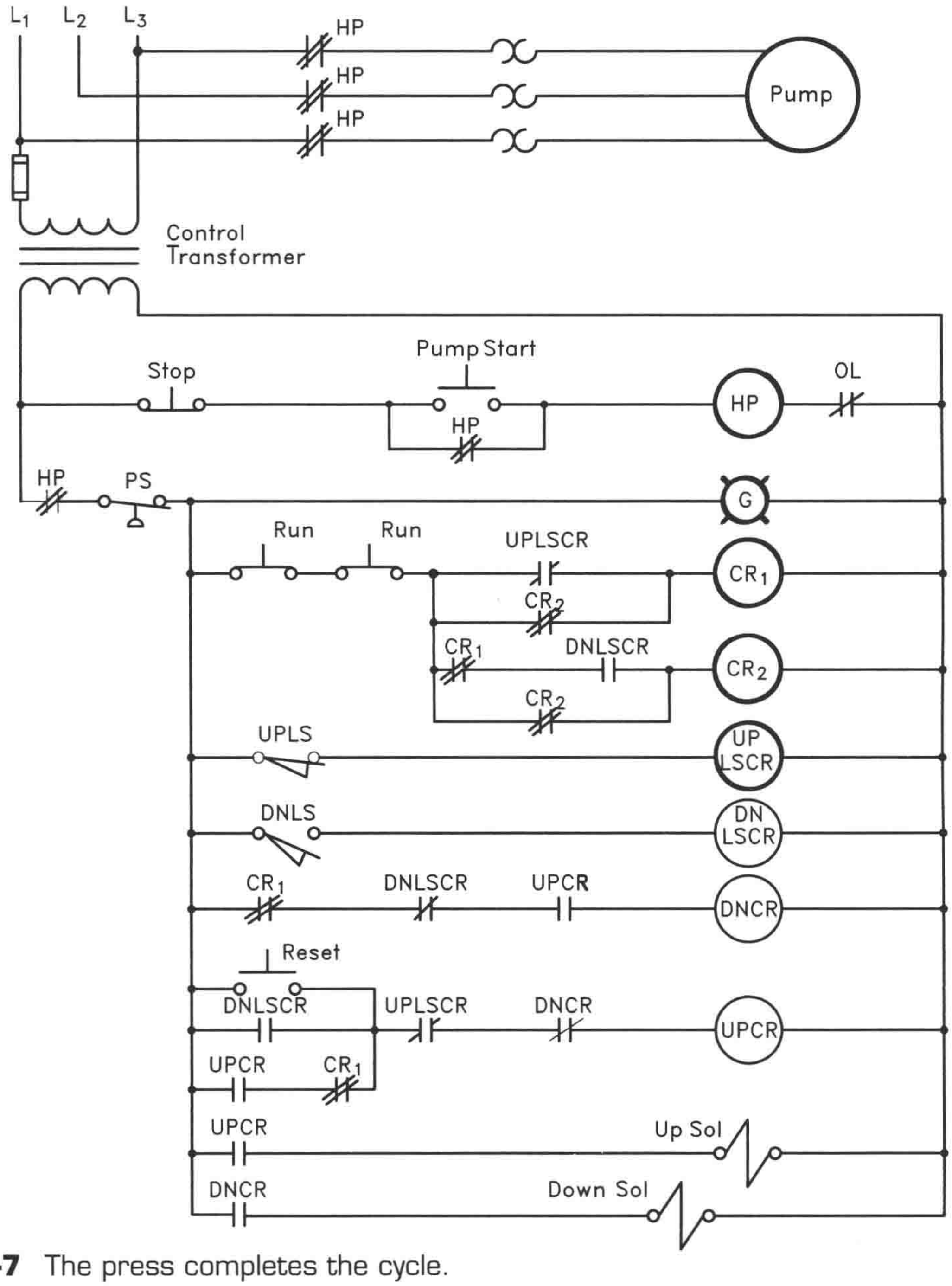

Figure 36-7 The press completes the cycle.

Connecting the Circuit

In this exercise toggle switches will be used to simulate the action of the pressure switch and the two limit switches. Lights may also be substituted for the up and down solenoid coils.

1. Refer to the circuit shown in Figure 36-1. Count the number of contacts controlled by each of the control relays to determine which should be 11-pin and which should be 8-pin. Relays that need three contacts will have to be 11-pin, and relays that need two contacts may be 8-pin.
2. After determining whether a relay is to be 11-pin or 8-pin, identify the relay with some type of marker that can be removed later. Identifying the relays as CR_1, CR_2, and so on can make connection much simpler.
3. Place the pin numbers on the schematic in Figure 36-1 to correspond with the contacts and coils of the control relays. Circle the numbers to distinguish them from wire numbers.

4. Place wire numbers beside each component on the schematic.
5. Connect the circuit. (*Note:* When connecting the two run push buttons, connect them close enough together to permit both to be held closed with one hand.)

Testing the Circuit

To test the circuit for proper operation:

1. Set the toggle switches used to simulate the pressure and down limit switch in the open (off) position. Set the toggle used to simulate the up limit switch in the closed (on) position.
2. Press the "pump start" button and the motor or simulated motor load should start operating.
3. Close the pressure switch. The pilot light and UPLSCR relay should energize.
4. Press and hold down both of the run push buttons. Relays CR_1 and DNCR should energize. The down solenoid should also turn on.
5. The press is now traveling in the down direction. Open the up limit switch. This should cause UPLSCR to de-energize. The down solenoid should remain turned on.
6. Close the down limit switch to simulate the press reaching the bottom of its stroke. DNLSCR, CR_2, and UPCR should energize. The press is now starting to travel upward.
7. Open the down limit switch. DNLSCR should de-energize, but the UPCR should remain energized.
8. Close the up limit switch to simulate the press reaching the top of its stroke. The up solenoid should turn off. Control relays CR_1 and CR_2 should both remain on as long as the two run buttons are held closed.
9. To restart the cycle, release the run buttons and reclose them.

Review Questions

1. Assume that the hydraulic pump is running and the pilot light is turned on indicating that there is sufficient pressure to operate the press. Now assume that the up limit switch is not closed. What will be action of the circuit if both run buttons are pressed?

____

____

____

2. Assume that the press is in the middle of its downstroke when the operator releases the two run push buttons. Explain the action of the circuit.

____

____

____

3. Referring to the condition of the circuit as stated in question 2, what would happen if the two run push buttons are pressed and held closed? Explain your answer.

____

____

____

4. Referring to the condition of the circuit as stated in question 2, what would happen if the reset button is pressed and held closed? Explain your answer.

5. Assume that the press traveled to the bottom of its stroke and then started back up. When it reached the middle of its stroke, the power was interrupted. After the power has been restored, if the two run buttons are pressed, will the press continue to travel upward to complete its stroke, or will it start moving downward?

Unit 37 Design of Two Flashing Lights

Objectives

After studying this unit, you should be able to:

- Design a circuit from a written statement of requirements.
- Connect the circuit in the laboratory after the design has been approved.

LABORATORY EXERCISE

Name ____ Date ________

Materials Required

Materials depend on the circuit design

In the space provided in Figure 37-1, draw a schematic diagram of a circuit that will fulfill the following requirements. Use two separate timers. Do not use an electronic timer set in the repeat mode. Remember that there is generally more than one way to design any circuit. Try to keep the design as simple as possible. The fewer components a circuit has, the less it is likely to fail.

1. An on-off toggle switch is used to connect power to the circuit.
2. When the switch is turned on, two lights will alternately flash on and off. Light #1 will be turned on when light #2 is turned off. When light #1 turns off, light #2 will turn on.
3. The lights are to flash at a rate of on for 1 second and off for 1 second.

When completed, have your instructor approve the design. After the design has been approved, connect it in the laboratory.

Review Questions

1. When designing a control circuit that requires the use of a timing relay, what type of timer is generally used during the design?

____

____

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2. Should schematic diagrams be drawn to assume that the circuit is energized or de-energized?

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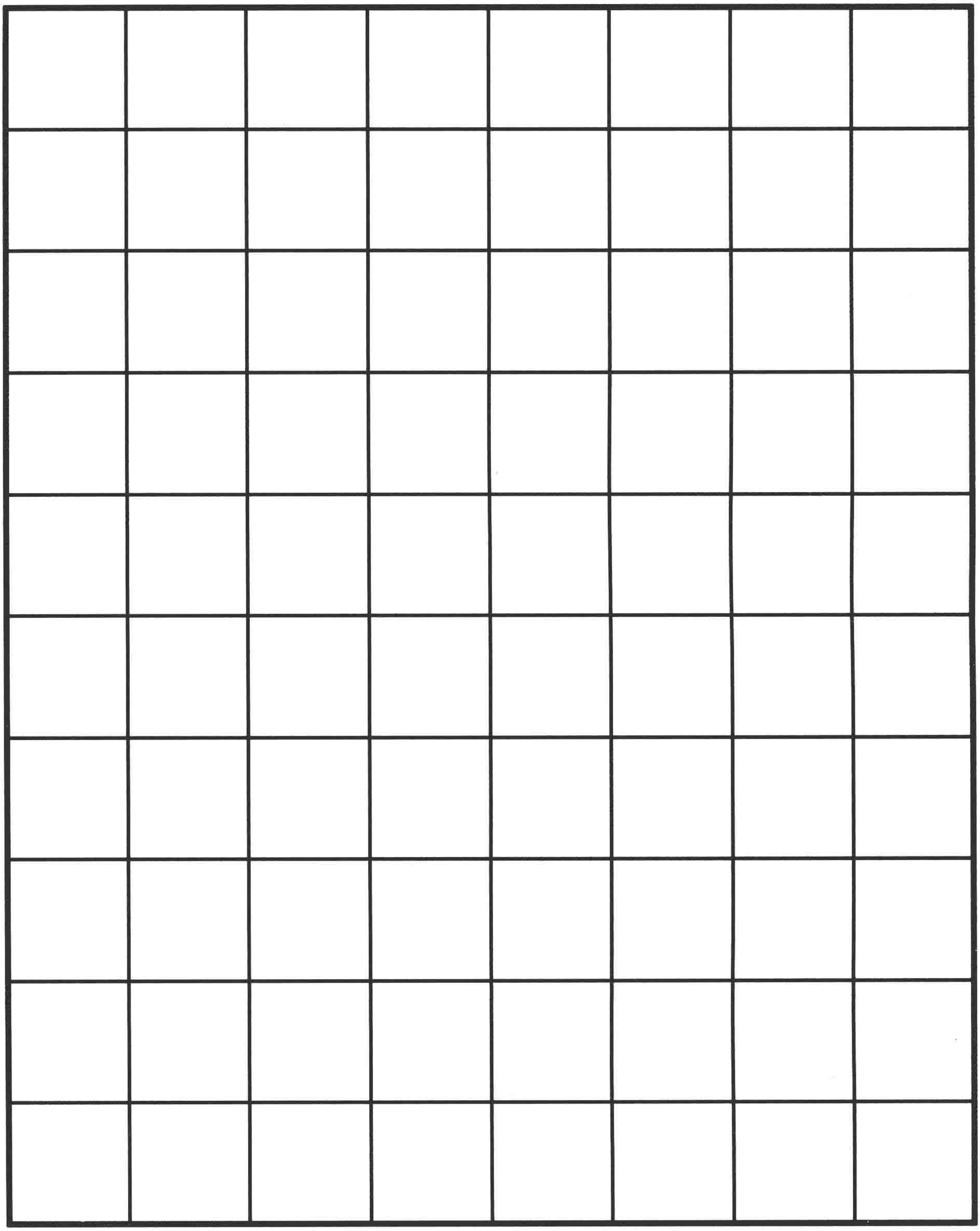

Figure 37-1 Design of two flashing lights.

3. Explain the difference between a schematic and a wiring diagram.

____

____

____

4. In a forward-reverse control circuit, a normally closed F contact is connected in series with the R starter coil, and a normally closed R contact is connected in series with the F starter coil. What is the purpose of doing this and what is this contact arrangement called?

____

____

____

5. What type of overload relay is not sensitive to changes in ambient temperature?

____

____

____

Unit 38 Design of Three Flashing Lights

Objectives

After studying this unit, you should be able to:

- Design a motor control circuit using timers.
- Discuss the operation of this circuit.
- Connect this circuit in the laboratory.

LABORATORY EXERCISE

Name ____ Date __________

Materials Required

Materials depend on the design of the circuit

The design of this circuit will be somewhat similar to the circuit in Unit 37. This circuit, however, contains three lights that turn on and off in sequence. Use the space provided in Figure 38-1 to design this circuit. The requirements of the circuit are as follows:

1. A toggle switch is used to connect power to the circuit. When the power is turned on, light #1 will turn on.
2. After a delay of 1 second, light #1 will turn off and light #2 will turn on.
3. After a delay of 1 second, light #2 will turn off and light #3 will turn on.
4. After a delay of 1 second, light #3 will turn off and light #1 will turn back on.
5. The lights will repeat this action until the toggle switch is opened.

Procedure

1. After the design of your circuit has been approved by your instructor, connect the circuit in the laboratory.
2. Test the circuit for proper operation.
3. Disconnect the circuit and return the components to their proper location.

Review Questions

1. A 60 hp, three-phase squirrel cage induction motor is to be connected to a 480-volt line. What size NEMA starter should be used to make this connection?

____

____

____

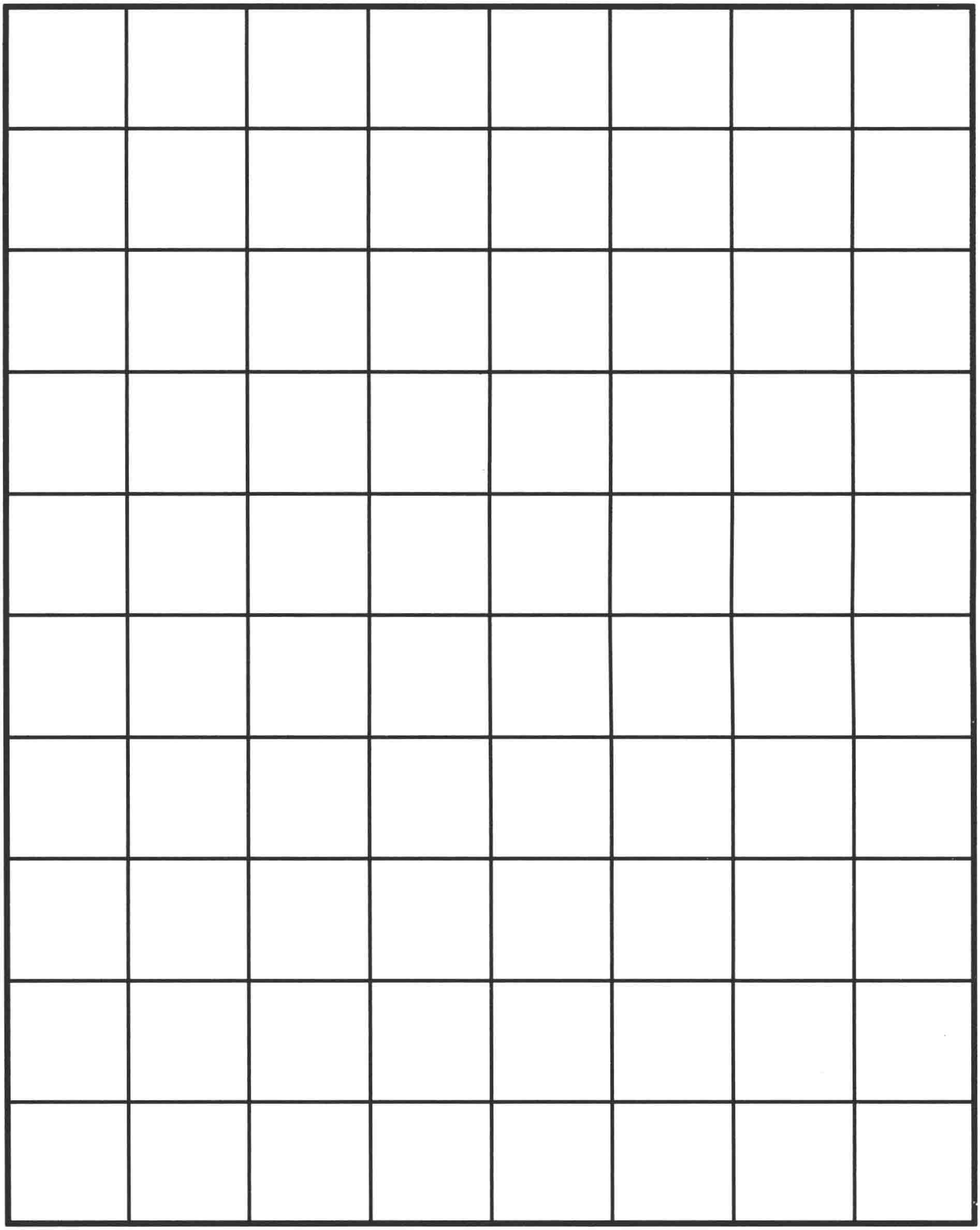

Figure 38-1 Design of three lights that turn on and off in sequence.

2. An electrician is given a NEMA size 2 starter to connect a 30 hp, three-phase squirrel cage motor to a 575 volt line. Should this starter be used to operate this motor?

3. Assume that the motor in question 2 has a design code B. What standard size inverse time circuit breaker should be used to connect the motor?

4. The motor described in questions 2 and 3 is to be connected with copper conductors with type THHN insulation. What size conductors should be used? The termination temperature rating is not known.

5. Assume that the motor in question 2 has a nameplate current rating of 28 amperes and a marked service factor of 1. What size overload heater should be used for this motor?

Unit 39 Control for Three Pumps

Objectives

After studying this unit, you should be able to:

- Analyze a motor control circuit.
- List the steps of operation in a control circuit.
- Connect this circuit in the laboratory.

LABORATORY EXERCISE

Name ______________________________ Date __________

Materials Required

Three-phase power supply

Control transformer

3 motor starters with normally open auxiliary contacts

6 toggle switches to simulate auto-man switches and float switches

8-pin control relay and 8-pin socket

3 three-phase motors or equivalent motor loads

1 normally open and 1 normally closed push button

One of the primary duties of an industrial electrician is to troubleshoot existing control circuits. To troubleshoot a circuit, the electrician must understand what the circuit is designed to do and how it accomplishes it. To analyze a control circuit, start by listing the major components. Next, determine the basic function of each component. Finally, determine what occurs during the circuit operation.

To illustrate this procedure, the circuit previously discussed in Unit 36 will be analyzed. The hydraulic press circuit is shown in Figure 39-1. In order to facilitate circuit analysis, wire numbers have been placed beside the components. The first step will be to list the major components in the circuit.

1. Normally closed stop push button
2. Normally open push button used to start the hydraulic pump
3. Two normally open push buttons used as run buttons
4. Normally open push button used for the reset button
5. Normally open pressure switch
6. Two normally open limit switches

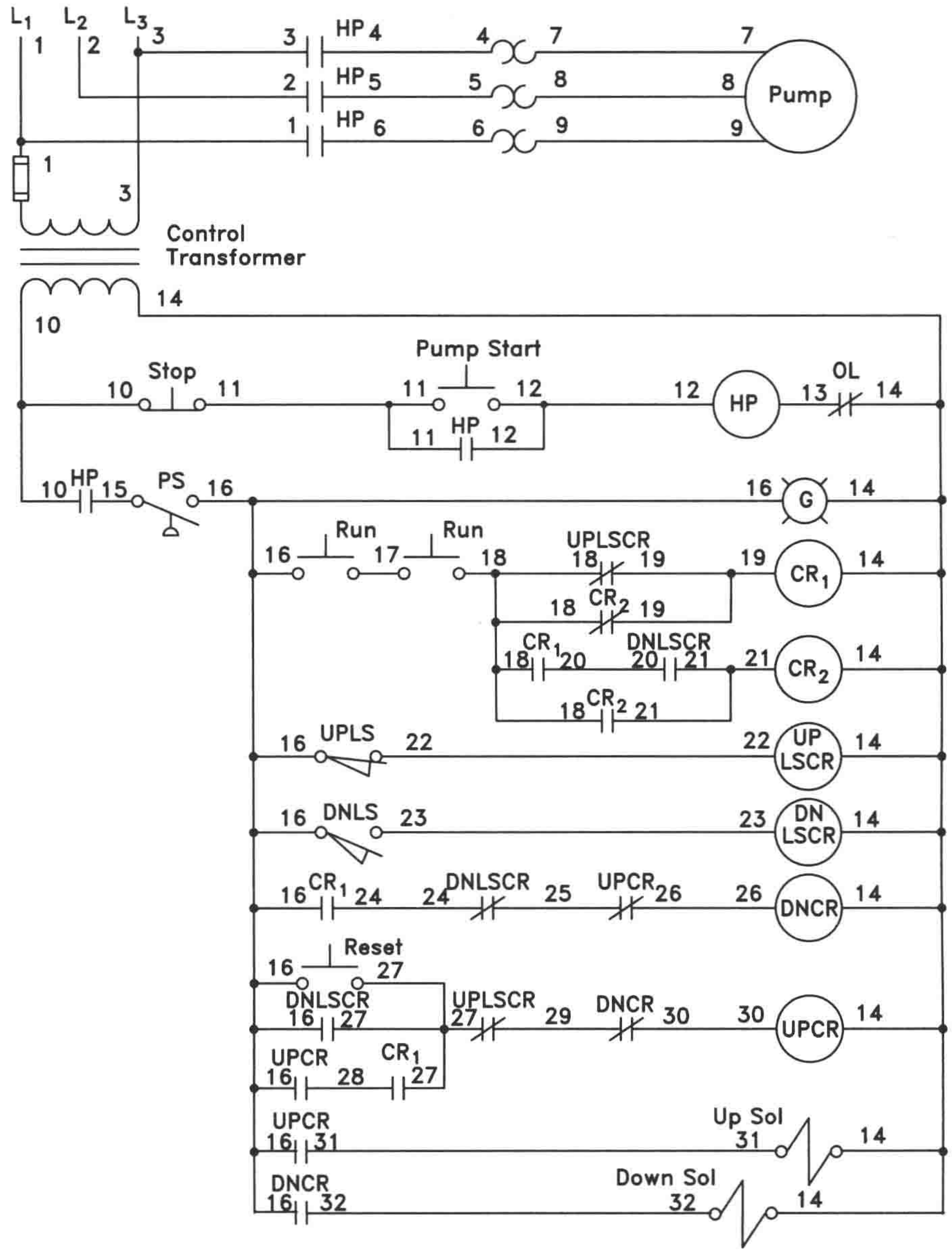

Figure 39-1 Analyzing the circuit.

7. Two solenoid valves
8. Three 8-pin control relays (CR_2, UPLSCR, and DNCR)
9. Three 11-pin control relays (CR_1, DNLSCR, and UPCR)
10. Control transformer
11. Green pilot light

The next step in the process is to give a brief description of the function of each listed component:

1. (Normally closed stop push button)—Used to stop the operation of the hydraulic pump motor.
2. (Normally open push button used to start the hydraulic pump)—Starts the hydraulic pump.
3. (Two normally open push buttons used as run buttons)—Both push buttons must be held down to start the action of the press.

4. (Normally open push button used for the reset button)—Resets the press to the topmost position.
5. (Normally open pressure switch)—Determines whether or not there is enough hydraulic pressure to operate the press.
6. (Two normally open limit switches)—Determine when the press is at the top of its stroke and when it is at the bottom of its stroke.
7. (Two solenoid valves)—The up solenoid valve opens on energize to permit hydraulic fluid to move the press upward. The down solenoid valve opens on energize to permit hydraulic fluid to move the press downward.
8. (Three 8-pin control relays [CR_2, UPLSCR, and DNCR])—Part of the control circuit.
9. (Three 11-pin control relays [CR_1, DNLSCR, and UPCR])—Part of the control circuit.
10. (Control transformer)—Reduces the value of the line voltage to the voltage needed to operate the control circuit.
11. (Green pilot light)—Indicates there is enough hydraulic pressure to operate the pump.

The final step is to analyze the operation of the circuit. To analyze circuit operation, trace the current paths each time a change is made in the circuit. Start by pressing the pump start button.

1. When the pump start button is pressed, a circuit is completed to the coil of starter HP.
2. When coil HP energizes, all HP contacts change position. The three load contacts close to connect the pump motor to the line. The HP auxiliary contact located between wire points 11 and 12 closes to maintain the circuit after the pump start button is released, and the HP auxiliary contact located between wire numbers 10 and 15 closes to provide power to the rest of the circuit.
3. After the hydraulic pump starts, the hydraulic pressure in the system increases and closes the pressure switch.
4. When the pressure switch closes, a current path is provided to the green pilot light to indicate that there is sufficient hydraulic pressure to operate the press. A current path also exists through the normally open held closed up limit switch to control relay (UPLSCR) coil.
5. When UPLSCR relay energizes, both UPLSCR contacts open. The UPLSCR contact located between wire numbers 18 and 19 opens to break a current path to CR_1 coil. UPLSCR contact located between wire numbers 27 and 29 opens to break the current path to coil UPCR.
6. Both run push buttons must be held down to provide a current path through the normally closed CR_2 contact located between wire numbers 18 and 19 to the coil of CR_1 relay.
7. When CR_1 relay coil energizes, the CR_1 contact located between wire numbers 18 and 20 closes to provide a path to CR_2 coil in the event that the DNLSCR contact should close. The CR_1 contact located between wire numbers 16 and 24 closes to provide a current path to the down control relay (DNCR). The CR_1 contact located between wire numbers 28 and 27 closes to provide an eventual current path to the up control relay (UPCR).
8. When DNCR coil energizes, the DNCR contact located between wire numbers 29 and 30 opens to provide interlock with the up control relay. The DNCR contact between wire numbers 16 and 32 closes and provides a current path to the down solenoid valve.

9. When the down solenoid valve energizes, the press begins its downward stroke. This causes the normally open held closed up limit switch to open and de-energize the UPLSCR coil.
10. Both UPLSCR contacts reclose.
11. When the press reaches the bottom of its stroke, the down limit switch located between wire numbers 16 and 23 closes to provide a current path to the coil of the down limit switch control relay (DNLSCR).
12. All DNLSCR contacts change position. The DNLSCR contact located between wire numbers 20 and 21 closes to provide a current path through the now closed CR_1 contact to the coil of CR_2 relay. The DNLSCR contact located between wire numbers 24 and 25 opens and breaks the current path to DNCR relay. The DNLSCR contact located between wire numbers 16 and 27 closes to provide a current path to UPCR relay when the DNCR contact located between 29 and 30 recloses.
13. When CR_2 coil energizes, the normally closed CR_2 contact located between wires 18 and 19 opens to prevent a maintained current path to CR_1 when the UPLSCR contact reopens. The normally open CR_2 contact located between 18 and 21 closes to maintain a current path to the coil of CR_2 in the event that CR_1 or DNLSCR contacts should open.
14. When the DNCR relay coil de-energizes, the DNCR contact located between wires 29 and 30 recloses to permit coil UPCR to be energized. The DNCR contact located between 16 and 32 reopens to break the current path to the down solenoid valve.
15. When the UPCR coil energizes, the normally closed UPCR contact located between wires 25 and 26 opens to provide interlock with the DNCR relay coil. The UPCR contact located between 16 and 28 closes to maintain a circuit through the now closed CR_1 contact to the coil of UPCR. The UPCR contact located between 16 and 31 closes and provides a current path to the up solenoid valve.
16. When the up solenoid valve opens, hydraulic fluid causes the press to begin its upward stroke.
17. When the press starts upward, the down limit switch reopens and de-energizes the coil of DNLSCR relay.
18. When coil DNLSCR de-energizes, the DNLSCR contact located between wires 20 and 21 reopens, but a current path is maintained by the now closed CR_2 contact. The DNLSCR contact located between 24 and 25 recloses, but the current path to DNCR coil remains broken by the UPCR contact located between 25 and 26. The DNLSCR contact located between wires 16 and 27 reopens, but a current path is maintained by the now closed UPCR and CR_1 contacts.
19. When the press reaches the top of its stroke, the up limit switch again closes and provides a current path to the coil of UPLSCR relay.
20. The UPLSCR contact located between wires 18 and 19 opens to break the current path to CR_1 coil. The UPLSCR contact located between wires 27 and 29 opens to break the current path to the coil of UPCR.
21. When CR_1 coil de-energizes, all CR_1 contacts return to their normal position. The CR_1 contact between wires 18 and 20 reopens, CR_1 contact between wires 16 and 24 reopens to prevent a current path from being established to the DNCR relay coil, and CR_1 contact between wires 27 and 28 reopens.

22. When coil UPCR de-energizes, its contacts return to their normal position. The UPCR contacts located between wires 16 and 28 reopen, and the UPCR contact located between wires 16 and 31 reopens to break the circuit to the up solenoid.
23. Before the circuit can be restarted, the current path to relay CR_2 must be broken by releasing one or both of the run push buttons. This will return all contacts back to their original state.
24. In the event the press should be stopped in the middle of its stroke, the up limit switch will be open and coil UPLSCR will be de-energized. The DNCR coil will also be de-energized. If the reset button is pressed and held, a circuit will be completed through the normally closed DNLSCR and DNCR contacts to the coil of UPCR. This will cause the up solenoid valve to energize and return the press to its up position.

Determining What the Circuit Does

The circuit in this experiment is intended to operate three pumps. The pumps are used to pump water from a sump to a roof storage tank. The water in the storage tank is used for cooling throughout the plant. After the water has been used for cooling, it returns to the sump to be recooled. Three float switches are used to detect the water level in the storage tank. As the water is drained out of the tank, the level drops and the float switches turn on the pumps to pump water from the sump back to the storage tank (Figure 39-2).

List the Components

In the space provided, list the major components in the control circuit shown in Figure 39-3.

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______

Describe the Components

In the space provided, give a brief description of the function of the components in this circuit.

1. ______

______

______

2. ______

______

______

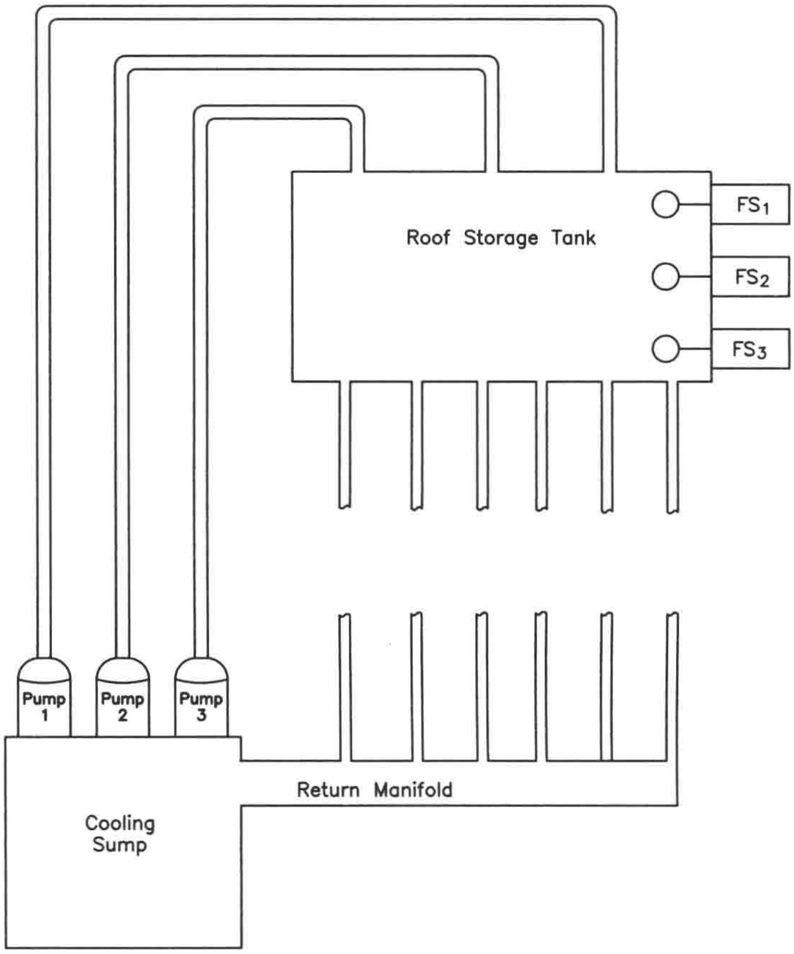

Figure 39-2 Roof-mounted tank for plant cooling system.

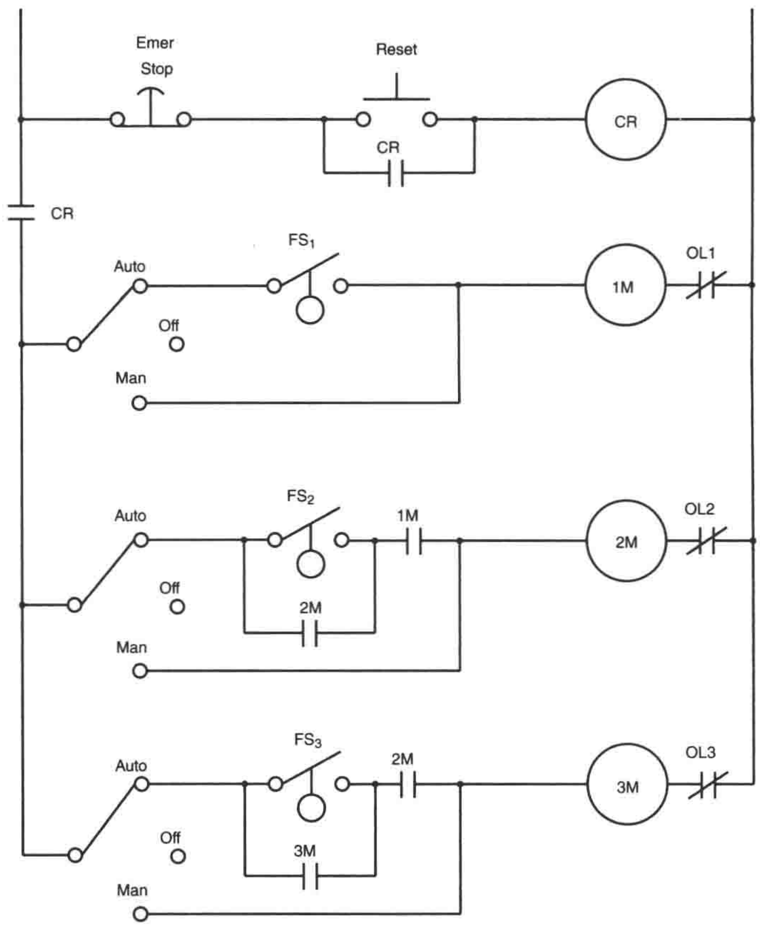

Figure 39-3 Control circuit for three pumps.

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

7. ______________________________

8. ______________________________

9. ______________________________

10. ______________________________

Describing the Circuit Operation

In the space provided, describe the operation of the circuit. Assume that in the normal state the roof storage tank is filled with water, and all the auto-off-man switches are set in the auto position. Also, assume that the three motor starters control the operation of the three pumps, although the pumps are not shown on the schematic.

1. ______________________________

2. ______________________________

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

14. ____

____

____

15. ____

____

____

Review Questions

To answer the following questions, refer to the circuit shown in Figure 39-3.

1. Assume that all three pumps are operating. What would be the action of the circuit if the auto-off-man switch of pump #2 were to be switched to the off position?

____

____

____

2. Assume that the auto-off-man switch of pump #3 is set in the manual position. What will be the operation of the circuit if float switch FS_1 closes?

____

____

____

3. Assume that the roof storage tank empties completely, but none of the pumps have started. Which of the following could not cause this condition?
   a. The emergency stop button has been pushed and the control relay is de-energized.
   b. The auto-off-man switch of pump #1 has been set in the off position.
   c. The auto-off-man switch of pump #1 has been set in the manual position.
   d. 1M coil is open.
4. Assume that all three pumps are in operation and OL_3 contact opens. Will this affect the operation of the other two pumps?

____

____

____

5. Assume that FS_2 float switch is defective. If the water level drops enough to close float switch FS_3, will pump #3 start running?

____

____

____

Unit 40 Oil Pressure Pump Circuit for a Compressor

Objectives

After studying this unit, you should be able to:

- Analyze a motor control circuit.
- List the steps of operation in a control circuit.
- Connect this circuit in the laboratory.

LABORATORY EXERCISE

Name ______________________________ Date __________

Materials Required

Three-phase power supply

2 motor starters

Control transformer

2 electronic timers (Dayton model 6A855) and 11-pin tube sockets

2 pilot lights

2 double-acting push buttons

In the circuit shown in Figure 40-1, the oil pump must start for some time before the compressor is started. When the start button is pressed, the oil pump should continue to run for some time after the compressor stops operating.

List the Components

In the space provided, list the circuit components.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

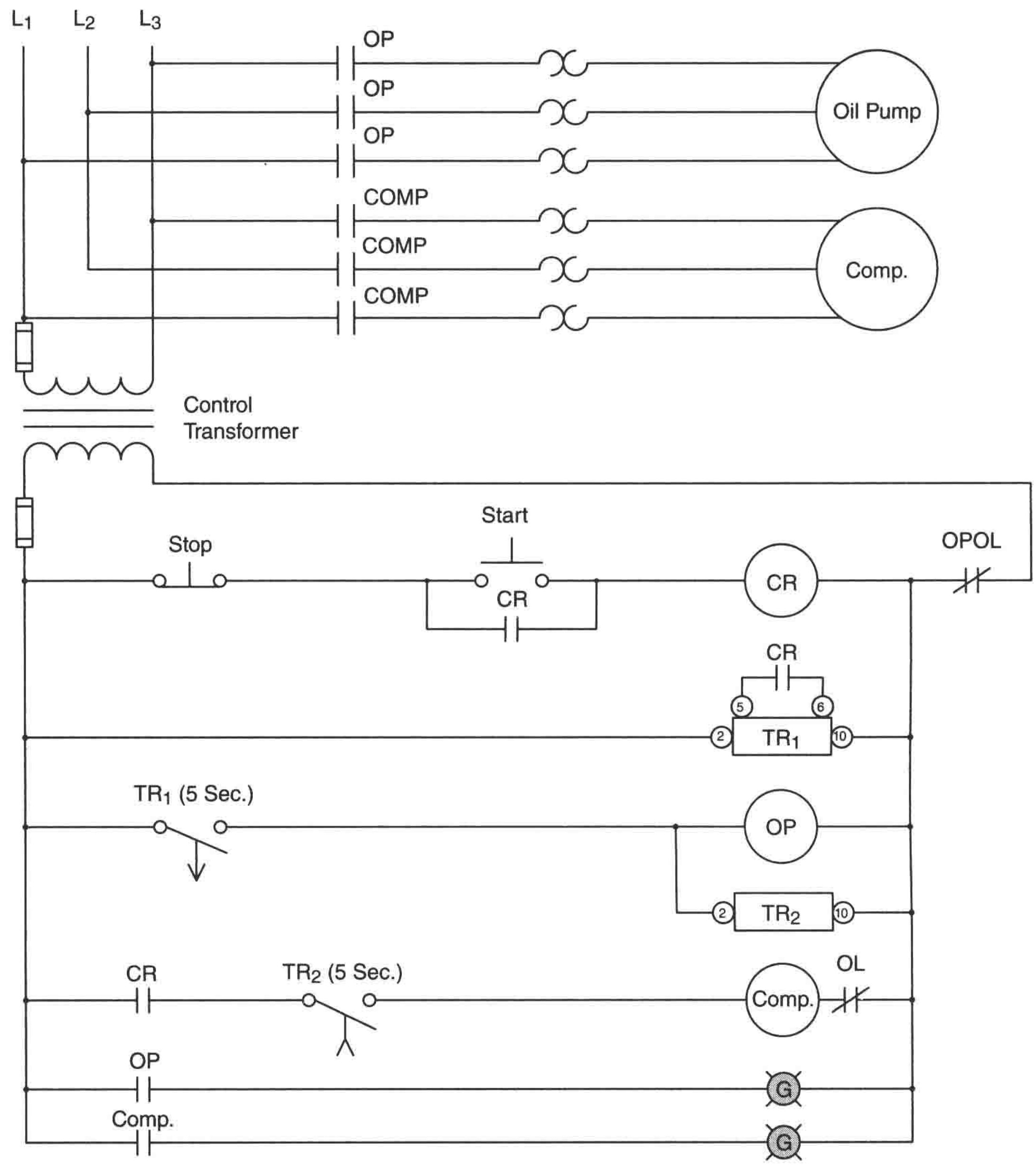

Figure 40-1 Compressor oil pump circuit.

Describe the Components

In the space provided, give a brief description of what function is performed by each component.

1. ______________________________
____

2. ______________________________
____

3. ______________________________
____

4. ______________________________
____

5. ______________________________
____

6. ______________________________

7. ______________________________

8. ______________________________

9. ______________________________

10. ______________________________

Circuit Operation

In the space provided, describe the operation of the circuit in a step-by-step sequence.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

7. ______________________________

8. ______________________________

9. ______________________________

10. ______________________________

11. ______________________________

12. ____

____

13. ____

____

14. ____

____

15. ____

____

Connecting the Circuit

1. Connect the circuit shown in Figure 40-1.
2. After checking with the instructor, turn on the power and test the circuit for proper operation.
3. **Turn off the power** and disconnect the circuit. Return the components to their proper location.

Review Questions

To answer the following questions, refer to the circuit shown in Figure 40-1.

1. Assume that the start button is pressed and the oil pump starts operating. After a delay of 5 seconds, the COMP pilot light turns on, but the compressor motor does not start. Which of the following could cause this condition?
   a. TR_2 timer is defective.
   b. COMP starter coil is defective.
   c. The compressor motor is defective.
   d. All of the above.
2. Assume that the circuit is in operation. When the stop button is pressed, both the compressor and oil pump stop operating immediately. Which of the following could cause this condition?
   a. CR relay is defective.
   b. TR_1 timer is defective.
   c. OP starter is defective.
   d. Timer TR_2 is defective.
3. When the start button is pressed, the oil pump starts operating immediately. After a delay of 5 seconds, the oil pump motor turns off. An electrician finds that the control transformer fuse is blown. Which of the following could cause this condition?
   a. TR_1 coil is shorted.
   b. OP coil is shorted.
   c. TR_2 coil is shorted.
   d. COMP coil is shorted.

4. When the start button is pressed, the oil pump motor starts operating immediately. After a long time delay, it is determined that the compressor motor will not start. Which of the following could not cause this condition?
   a. OP coil is defective.
   b. TR_2 coil is defective.
   c. COMP coil is defective.
   d. The compressor overload contact is open.
5. When the start button is pressed, the oil pump motor starts operating immediately. When the start button is released, however, the oil pump motor turns off. The operator then presses the start button and holds it down for a period of 10 seconds. This time the oil pump motor starts operating immediately, but the compressor motor never starts. When the start button is released, the oil pump motor again immediately turns off. Which of the following could cause this condition?
   a. CR coil is defective.
   b. TR_1 coil is defective.
   c. TR_2 coil is defective.
   d. COMP coil is defective.

Unit 41 Autotransformer Starter

Objectives

After studying this unit, you should be able to:

- Discuss the operation of an autotransformer starter.
- Explain the operation of an autotransformer starter.
- Connect an autotransformer starter in the laboratory.

Autotransformer starters are used to reduce the amount of inrush current when starting a large motor. The autotransformer starter accomplishes this by reducing the voltage applied to the motor during the starting period. If the voltage is reduced by one-half, the current will be reduced by one-half, and the torque will be reduced to one-fourth of normal.

There are several different ways to construct an autotransformer starter. Some use three transformers, and others use two transformers. In this experiment, two transformers connected as an open delta will be used. Two 0.5 kVA control transformers will be employed. Since these transformers are to be used as autotransformers, only the high-voltage windings will be connected. The low-voltage windings (X_1 and X_2) will not be used in this experiment. The high-voltage windings can be identified by the markings on the terminal leads of H_1 through H_4. These high-voltage windings are to be connected in series by connecting a jumper between terminals H_2 and H_3. This jumpered point provides a center tap for the entire winding.

Obtaining Enough Contacts

A schematic diagram of this connection is shown in Figure 41-1. Notice that there are a total of five starting contactor (SC) load contacts needed during the starting period. Contactors that contain five load contacts can be purchased, but they are difficult to obtain and they are expensive. For this reason, two three-phase contactors will be used to provide the needed load contacts. This can be accomplished by connecting the coil of SC_1 and SC_2 contactors in parallel with each other.

Circuit Operation

When the start button is pressed, coils CR, TR, SC_1, and SC_2 energize. When the SC_1 and SC_2 load contacts close, the motor is connected to the center tap of the open delta autotransformer. Since the transformers have been center tapped, the motor is connected to half of the line voltage. A basic schematic diagram of this connection is shown in Figure 41-2. The normally closed SC_1 and SC_2 auxiliary contacts connected in series with the R coil open to provide interlock and prevent the R contactor from energizing as long as SC_1 or SC_2 is energized.

After some time, TR timer reaches the end of its timing sequence and the two timed TR contacts change position. The normally closed TR contact connected in series with coils SC_1 and SC_2 opens and de-energizes these contactors. This causes all SC_1 and SC_2 load contacts to open and disconnect the autotransformer from the line. The normally closed SC_1 and SC_2 auxiliary contacts connected in series with R coil reclose.

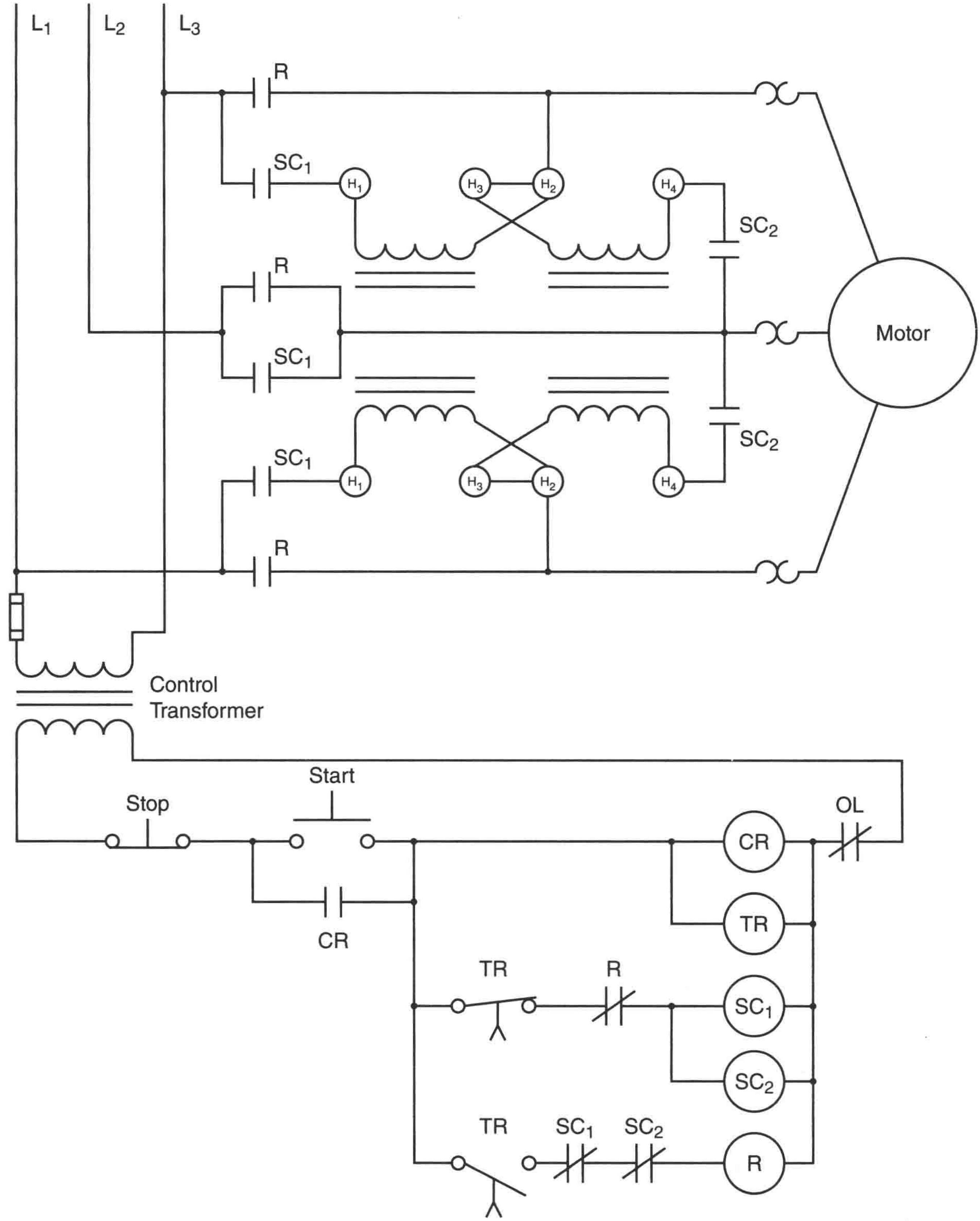

Figure 41-1 Autotransformer starter.

When the normally open TR contact connected in series with R coil closes, the R contactor energizes and closes all R load contacts. This connects the motor directly to the power line. The normally closed R auxiliary contact connected in series with coils SC_1 and SC_2 opens to provide interlock. The motor will continue to run until the stop button is pressed or an overload occurs.

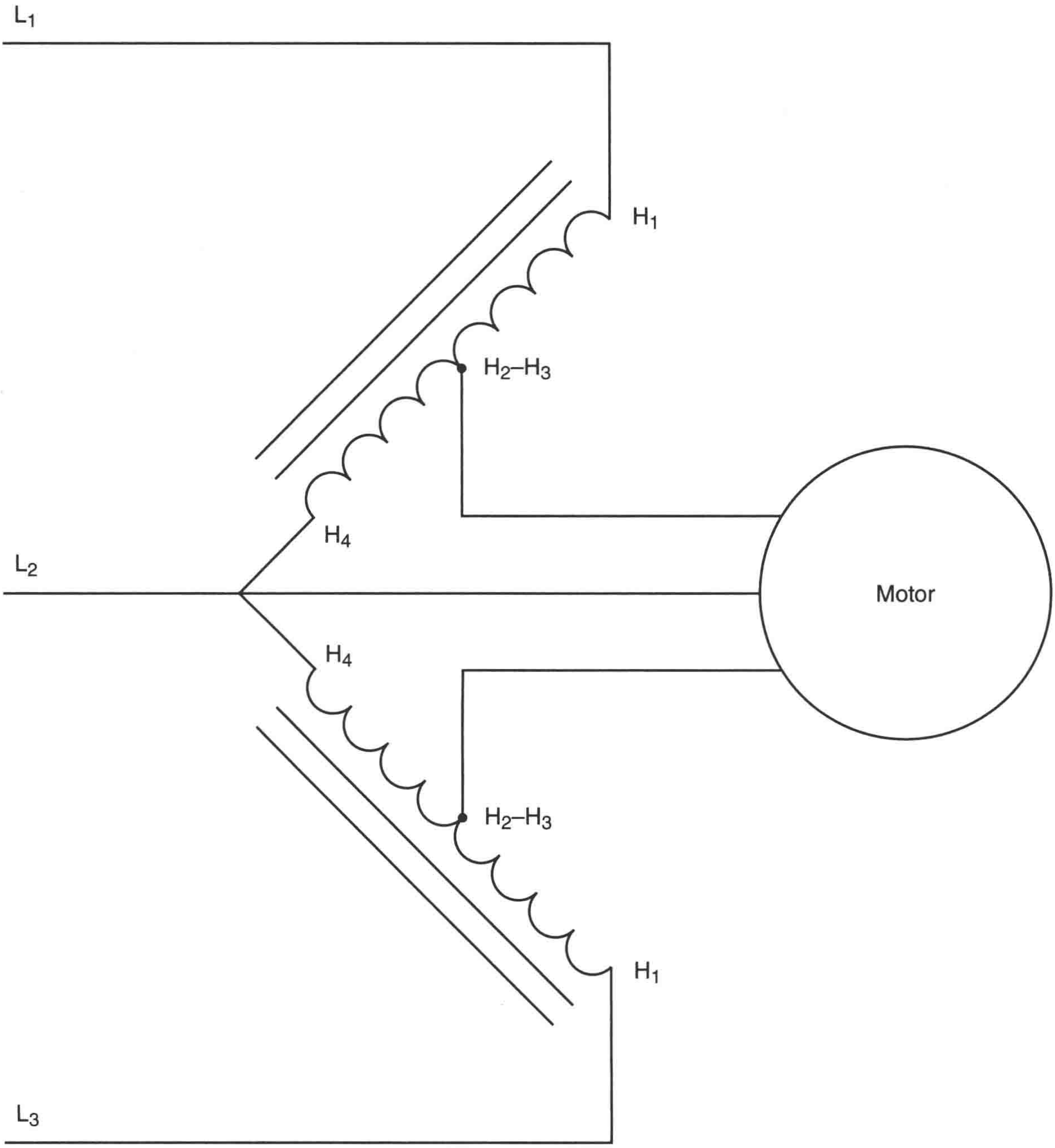

Figure 41-2 Schematic diagram of a basic autotransformer connection.

LABORATORY EXERCISE

Materials Required

Three-phase power supply

Control transformer

3 three-phase contactors with at least one normally open and one normally closed auxiliary contact

2 0.5-kVA control transformers (480/240-120)

Three-phase motor or equivalent motor load

On-delay timer (Dayton model 6A855 or equivalent) and 11-pin tube socket

8-pin control relay and 8-pin tube socket

2 double-acting push buttons (N.O./N.C. on each button)

Three-phase overload relay or three single-phase overload relays with the overload contacts connected in series

(In this circuit it is possible to replace the two SC contactors with a single contactor that contains five load contacts, if one is available. Also, if true contactors are not available, it is permissible to use motor starters for the two SC contactors.)

1. Assuming that relay CR is an 8-pin control relay, and that timer TR is a Dayton model 6A855, place pin numbers beside the components of CR and TR in Figure 41-1. Circle the pin numbers to distinguish them from wire numbers.
2. Place wire numbers beside all circuit components in Figure 41-1.
3. Place corresponding wire numbers beside the components, as shown in Figure 41-3. Make certain to make the connection between H_2 and H_3 on the high-voltage side of the control transformers.
4. Connect the control section of the circuit, as shown in Figure 41-1.
5. Set the timing relay for a delay of 5 seconds.
6. Turn on the power and test the control section of the circuit for proper operation.
7. **Turn off the power.**
8. Connect the load section of the circuit.
9. Turn on the power and test the circuit for proper operation. (*Note*: Connect a voltmeter across the motor or equivalent motor load terminals and monitor the voltage. When the circuit is first energized, the voltage applied to the motor should be one-half the full-line value. After a delay of 5 seconds, the voltage should increase to full value.)
10. **Turn off the power** and disconnect the circuit. Return the components to their proper places.

Review Questions

1. How does the autotransformer reduce the amount of starting current to a motor?

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2. Is the autotransformer used in this experiment connected as a wye, delta, or open delta?

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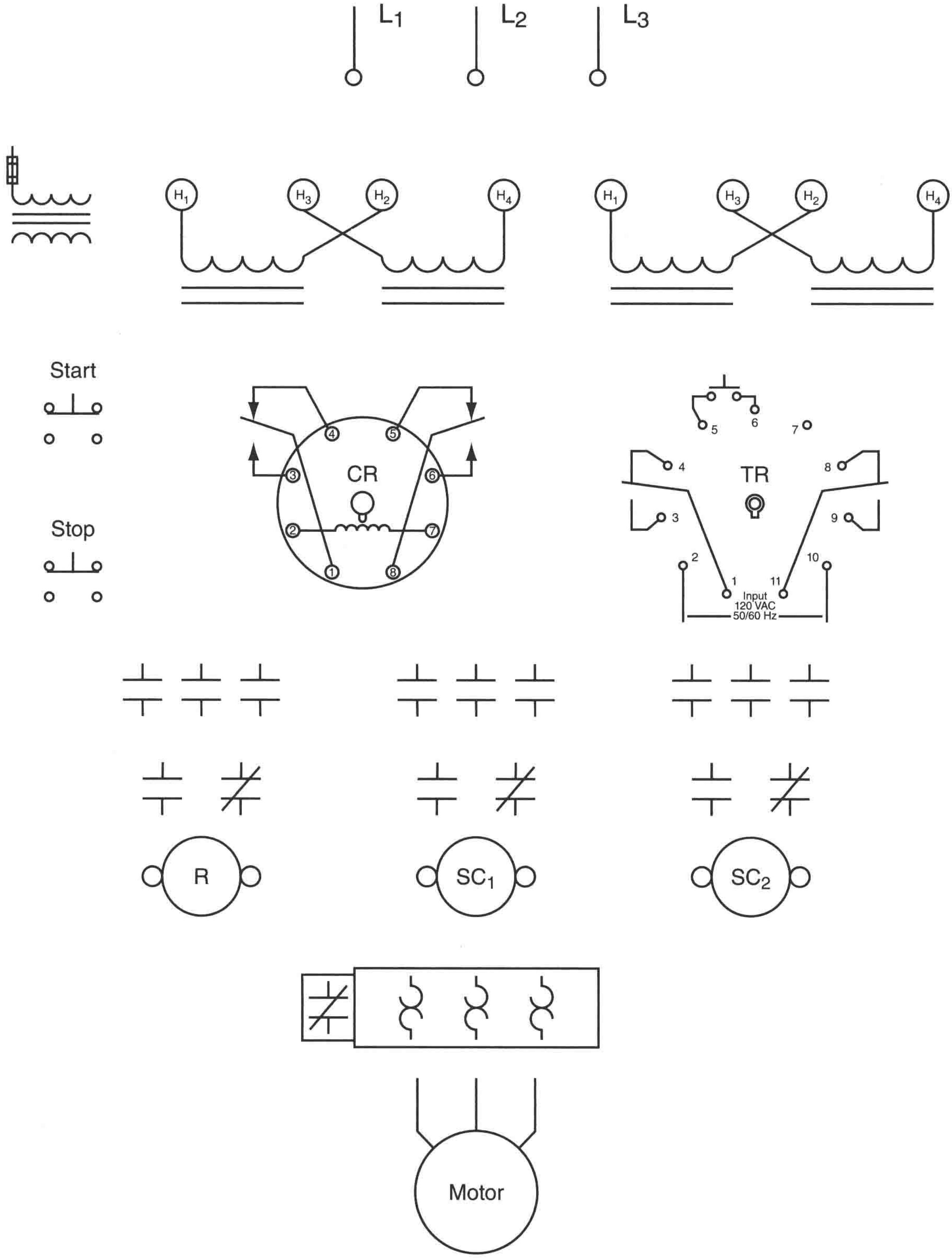

Figure 41-3 Developing a wiring diagram.

3. What is the advantage, if any, of using an open delta connection as opposed to a closed delta or wye?

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4. Assume that the line-to-line voltage in Figure 41-1 is 480 volts. Also, assume that when the start button is pressed, the motor starts with 240 volts applied to the motor. When the start button is released, however, the motor stops running. Which of the following could cause this problem?

   a. SC_1 coil is open.

   b. CR coil is open.

   c. TR coil is open.

   d. The stop push button is open.

5. Refer to the circuit shown in Figure 41-1. When the start button is pressed, nothing happens for 5 seconds. After 5 seconds, the motor suddenly starts with full voltage connected to it. Which of the following could cause this problem?

   a. CR coil is open.

   b. TR coil is open.

   c. R coil is open.

   d. R normally closed auxiliary contact is open.

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