Jogging Control Circuits

UNIT OBJECTIVE

Upon completion of this unit, you will be able to understand how friction brakes work, and connect selected jogging control circuits.

DISCUSSION OUTLINE

The Discussion of Fundamentals covers the following points:

- Friction brakes

DISCUSSION OF FUNDAMENTALS

Jogging, or **inching**, is defined as the quickly repeated closure of a circuit to start a motor, for the purpose of accomplishing small movements of the driven machine. Compared to the running mode, the jogging mode has no holding circuit.

Jogging can be used to accomplish precise positioning in machine tools. It may also be used in lifting appliances (see Figure 4-1), where the operator is required to be present to make the machine accomplish a movement, hence improving the security level. Additionally, jogging can be practical to perform checks during maintenance operations.

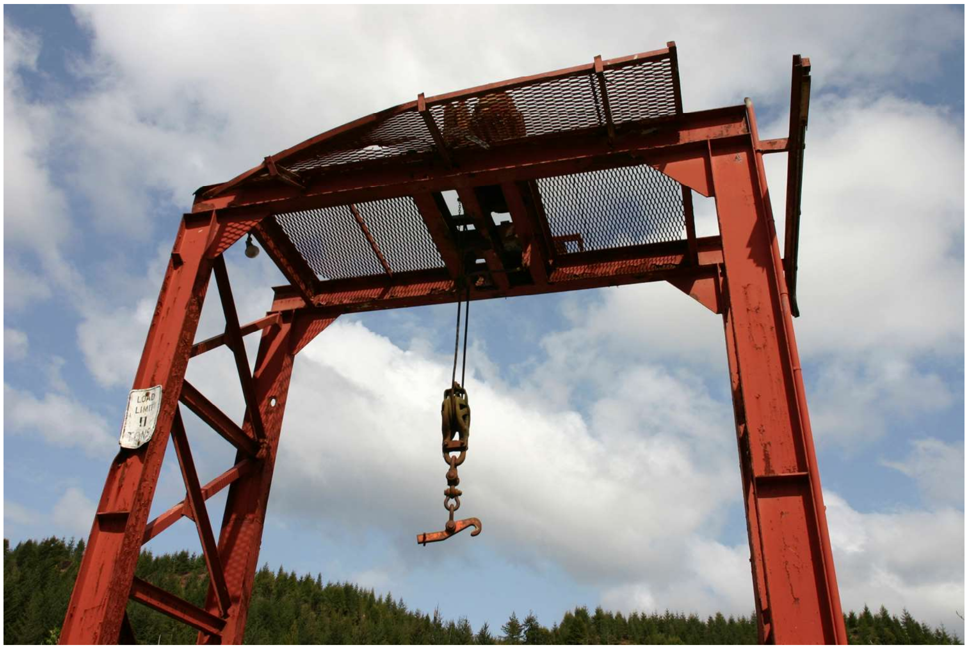
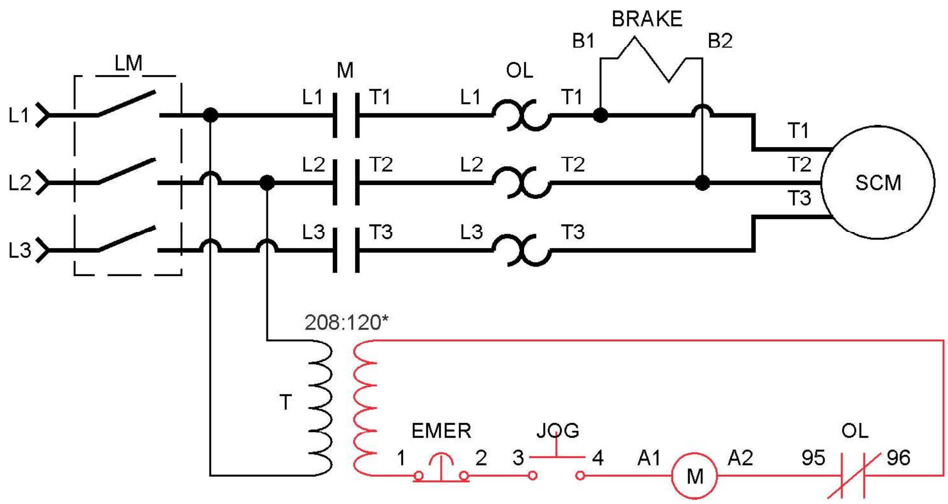


Figure 4-1. Overhead traveling crane.

Figure 4-2 is a diagram of a simple jogging control circuit. Pressing the JOG push button momentarily closes the power contacts of the contactor. The motor then runs only as long as the JOG push button is pressed, because no holding contact is present to keep the contactor energized.



*208:120 FOR 120 V - 60 Hz NETWORK
380:110 FOR 220 V - 50 Hz NETWORK
415:110 FOR 240 V - 50 Hz NETWORK
380:120 FOR 220 V - 60 Hz NETWORK

LEGEND

BRAKE	=	SOLENOID ACTUATED BRAKE COIL
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
SCM	=	SQUIRREL CAGE MOTOR
JOG	=	JOG PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
LM	=	LOCKOUT MODULE

Figure 4-2. Simple jogging circuit.

Many other configurations of jogging control circuits can be implemented. For example, many circuits will include a reversing starter for running and jogging operations, in both forward and reverse directions. For that purpose, arrangements of push buttons, control relays, and selector switches can be made. Exercise 4-3 presents some reversing circuits with jogging.

Friction brakes

Friction brakes are a common way of holding a position, in applications where the load is subject to a force such as gravity. For instance, they can be utilized in lifting appliances to prevent objects from falling in case of power losses. Friction brakes provide a faster and more precise means of stopping a motor than simply disconnecting power from the motor. That is why they are often used in jogging circuits. Friction brakes are also called **magnetic brakes**.

Friction Brakes

EXERCISE OBJECTIVE Understand the construction and operation of friction brakes.

DISCUSSION

Friction brakes, or magnetic brakes, are used to secure (hold) the position of a motor in lifting appliances. They are also used to reduce motor stopping time and execute precise control.

Friction brakes operate in a manner similar to automobile brakes. Braking is accomplished by friction surfaces (shoes or pads), which come in contact with a disk mounted on the motor shaft. A solenoid usually controls the brake shoes or pads.

The action of friction brakes is smooth in either direction. This can be very useful when working with high inertia loads. As a result, they are often found on cranes, hoists, elevators, and other machines where soft braking is desirable.

Friction brakes can operate in two different ways:

- **Fail-safe**: Power is required to disengage the brake. Otherwise, the brake is set by default. Also called spring set, power off, electrically released, or safety brakes.
- **Non-fail-safe**: A braking force is applied when the brake solenoid is energized. Also called spring return, power on, or electrically set.

Friction brakes are rated according to their braking torque, which should be equal to or greater than full-load motor torque. The latter can be calculated from the following formula:

$$T = \frac{K \times P}{N} \times SF$$

where
- T Is the motor full-load torque in N·m (lbf·ft)
- P Is the is the power rating kW (hp)
- N is the motor rotation speed (r/min)
- SF is the service factor
- K is a constant 9549 (5252)

1 N • m = 0.738 lbf •ft

Brake maintenance primarily consists of shoe and pad replacements. To avoid inadvertent brake activation, the brake solenoid should be connected directly into the motor circuit, not into the control circuit.

Figure 4-3 shows the friction brake, which is coupled to the end bell of the Brake Motor, Model 3176-A. The brake is released as long as its solenoid is actuated. But as soon as the solenoid de-energizes, the pads are pressed against the braking disk, forcing the motor to stop and hold its position. A label on the end bell of the Brake Motor shows how to wire the brake depending on the supplied voltage.

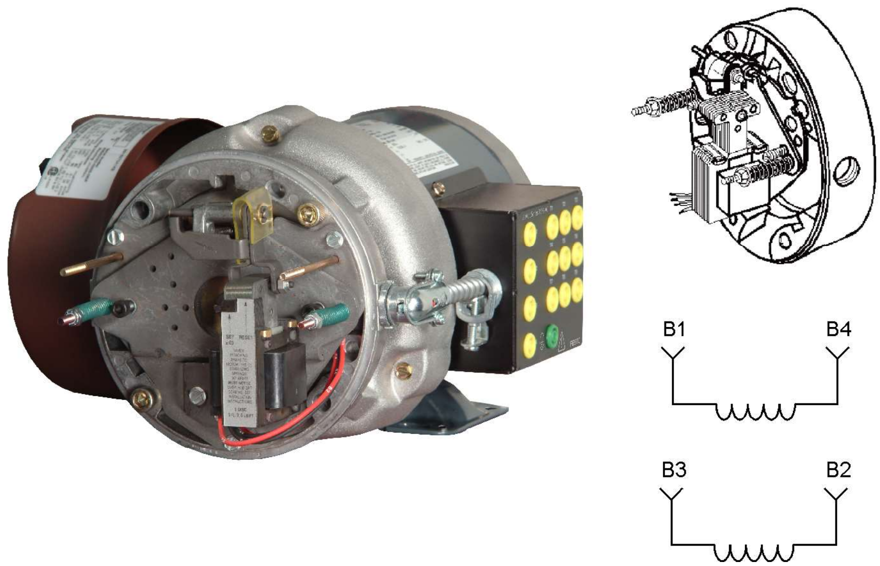
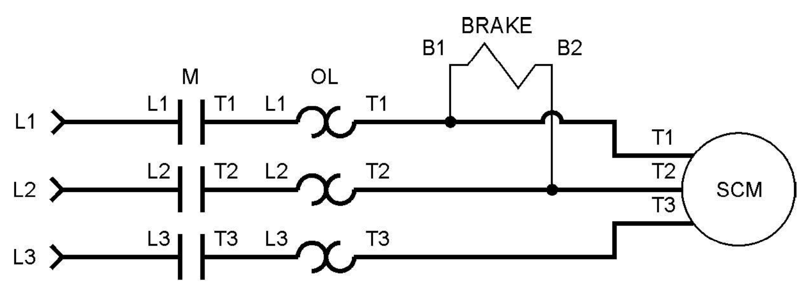


Figure 4-3. Friction brake.

The circuit shown in Figure 4-4 is a simplified motor circuit with a brake coil. When the motor is powered, the brake solenoid energizes. The friction brake then releases the pressure off the motor shaft, and the motor runs normally. Once power to the motor is removed, the brake coil de-energizes, pressure is applied to the shaft, and the motor stops smoothly. It is important to be aware that friction brakes will apply instantly in case of a power failure.



LEGEND

BRAKE = SOLENOID ACTUATED BRAKE COIL
M = MAIN CONTACTOR
OL = OVERLOAD RELAY
SCM = SQUIRREL CAGE MOTOR

Figure 4-4. Friction brake in a motor circuit.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Basic setup
- Brake torque calculation
- Brake coil testing
- Motor stopping with and without friction brake

PROCEDURE

In the first part of this exercise, you will examine a friction brake label to determine its braking torque. You will then verify that this value is greater than the full-load motor torque, calculated from the ratings of the motor nameplate.

In the second part of the exercise, you will release and apply the brake manually. You will subsequently do the same via the Manual Starter, to make sure that the shaft turns freely when the brake is released and is blocked otherwise.

Finally, you will set up a simple motor starter circuit to test how the friction brake reduces the motor stopping time.

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

1. Perform the Basic Setup and Lockout/Tagout procedures.

Brake torque calculation

2. Install the Brake Motor, and the Inertia Wheel.

3. What is the braking torque rating indicated on the brake label?

The braking torque rating is the same for the 208 V – 60 Hz/380 V – 50 Hz/415 V – 50 Hz/380 V – 60 Hz versions. If the SI values are not shown on the brake label, use the Imperial units for your calculations.

Braking torque:________

4. Enter the rating of the following parameters shown in the motor nameplate.

Power rating (hp): ________

Service factor: ________

Rotation speed (r/min): ________

5. Determine the full-load torque (T) of the motor using the formula of the DISCUSSION section and the ratings shown in the motor nameplate.

Full-load torque: _______

6. Is the braking torque greater than the motor full-load torque?

❑ Yes ❑ No

7. Set the friction brake knob to the RELEASE position.

Does the motor Inertia Wheel turn freely (no lead is connected to the motor terminals)?

❑ Yes, in both ways ❑ Yes, but in on direction only ❑ No

8. Explain what happens inside the friction brake.

____

____

9. Turn the friction brake knob to the normal position (applied). Does the motor Inertia Wheel turn freely?

❑ Yes, in both ways ❑ Yes, but in on direction only ❑ No

10. Explain what happens inside the friction brake.

____

____

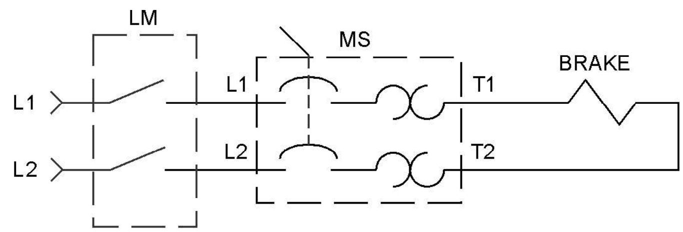
Brake coil testing

⚠ CAUTION

The friction brake is dual voltage. Be careful to use the appropriate connection for your system power supply, as indicated on the brake label.

11. Connect the circuit shown in Figure 4-5.

No lead is connected to the motor power terminals.



LEGEND

BRAKE = SOLENOID ACTUATED BRAKE COIL
MS = MANUAL STARTER (CIRCUIT BREAKER WITH OVERLOAD)
LM = LOCKOUT MODULE

Figure 4-5. Brake coil testing circuit.

12. Set the overload potentiometer of the Manual Starter to the lowest value, and the knob to the O position.

Perform the Energizing procedure.

Set the knob of the Manual Starter to the I position.

A sound should come from the friction brake enclosure. Does the motor Inertia Wheel turn freely?

❑ Yes, in both ways ❑ Yes, but in on direction only ❑ No

13. Return the knob of the Manual Starter to the O position. Does the motor Inertia Wheel turn freely?

❑ Yes, in both ways ❑ Yes, but in on direction only ❑ No

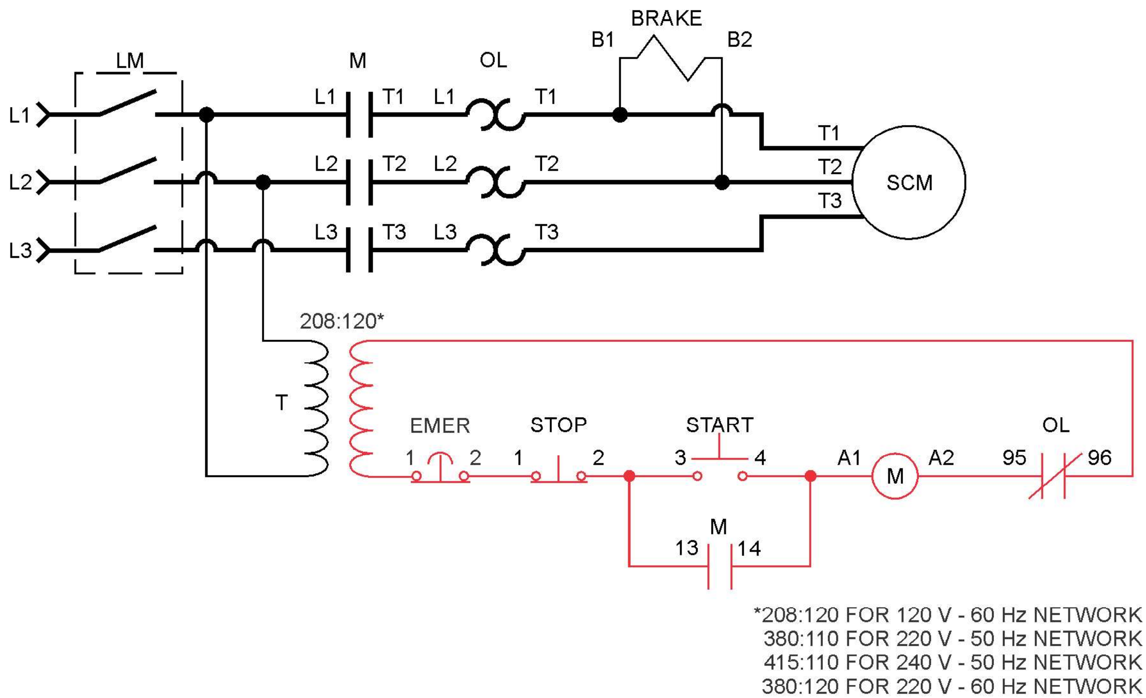
14. Following your last observations, in what manner does the brake operate?

❑ Fail-Safe ❑ Non-fail-safe

15. Perform the Lockout/Tagout procedure.

Motor stopping with and without friction brake

16. Connect the circuit shown in Figure 4-6.



LEGEND

BRAKE = SOLENOID ACTUATED BRAKE COIL
M = MAIN CONTACTOR
OL = OVERLOAD RELAY
SCM = SQUIRREL CAGE MOTOR
START = START PUSH BUTTON (MOMENTARY CONTACT)
STOP = STOP PUSH BUTTON (MOMENTARY CONTACT)
T = CONTROL VOLTAGE TRANSFORMER
EMER = EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
LM = LOCKOUT MODULE

Figure 4-6. Motor starter circuit with friction brake.

17. Apply the friction brake.

Install the Safety Guard.

Perform the Energizing procedure.

Press the START push button to start the motor.

Start the chronometer as you press the STOP push button. How long does it take for the motor to come to a complete stop?

Complete stop time: _______

18. Turn off the Lockout Module.

Disconnect the friction brake from the power lines.

Manually disengage the friction brake.

Turn on the Lockout Module.

Press the START push button to start the motor.

Start the chronometer as you press the STOP push button. How long does it take for the motor to come to a complete stop?

Complete stop time: _______

19. Did the motor stop faster or slower with the help of the friction brake?

❑ Faster ❑ Slower

20. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, remove the magnetic labels, and return the equipment to the storage location.

CONCLUSION

In friction brakes, the movement of a solenoid makes shoes or pads come in contact with a disk mounted on the motor shaft. Fail-safe brakes, which apply automatically when power is turned off, provide an extra level of security to weight-lifting equipment.

Friction brakes are used in applications where a motor has to hold a certain position, and when quick and precise stops are required. Additionally, they provide a smooth braking action that can be useful with high inertia loads.

To stop a motor, the braking torque must be greater than the motor torque. Therefore, friction brakes usually provide a braking torque greater than the full-load motor torque.

REVIEW QUESTIONS

1. In Figure 4-6, what would happen if the motor was running and the power was interrupted momentarily?

   a. Friction brake would apply as soon as power is removed.

   b. Motor would slowly come to a stop.

   c. Friction brake would apply after a preset time delay.

   d. The overload relay would trip.

2. What devices usually control the action of magnetic brakes?

   a. Control relays

   b. Solenoids

   c. Starting resistors

   d. Contactors

3. How is most of the friction produced in a magnetic brake?

   a. Back-and-forth movement of the solenoid.

   b. Magnetic field between the shaft and the friction disk.

   c. Pressure between the shoes or pads and a disk mounted on the motor shaft.

   d. Pressure applied directly by the solenoid on the motor shaft.

4. What is the most common maintenance operation on friction brakes?

   a. Replacement of shoes or pads.

   b. Replacement of the solenoid.

   c. Adjustment of spring tension.

   d. Adjustment of solenoid position.

5. What should a friction brake's solenoid be connected to?

   a. Reduced AC voltage circuit.

   b. Reduced DC voltage circuit.

   c. Control circuit.

   d. Motor circuit.

Motor Starters with Jogging

EXERCISE OBJECTIVE

- Connect and test motor starter circuits with jogging capabilities.
- See the effect of friction brakes on position control.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Jog/Run circuits

DISCUSSION

Jogging (also called inching) is used when an operator desires to make a motor accomplish small movements, without having to press the stop button every time. With jogging control circuits, the starter is energized only as long as the jog button is pressed.

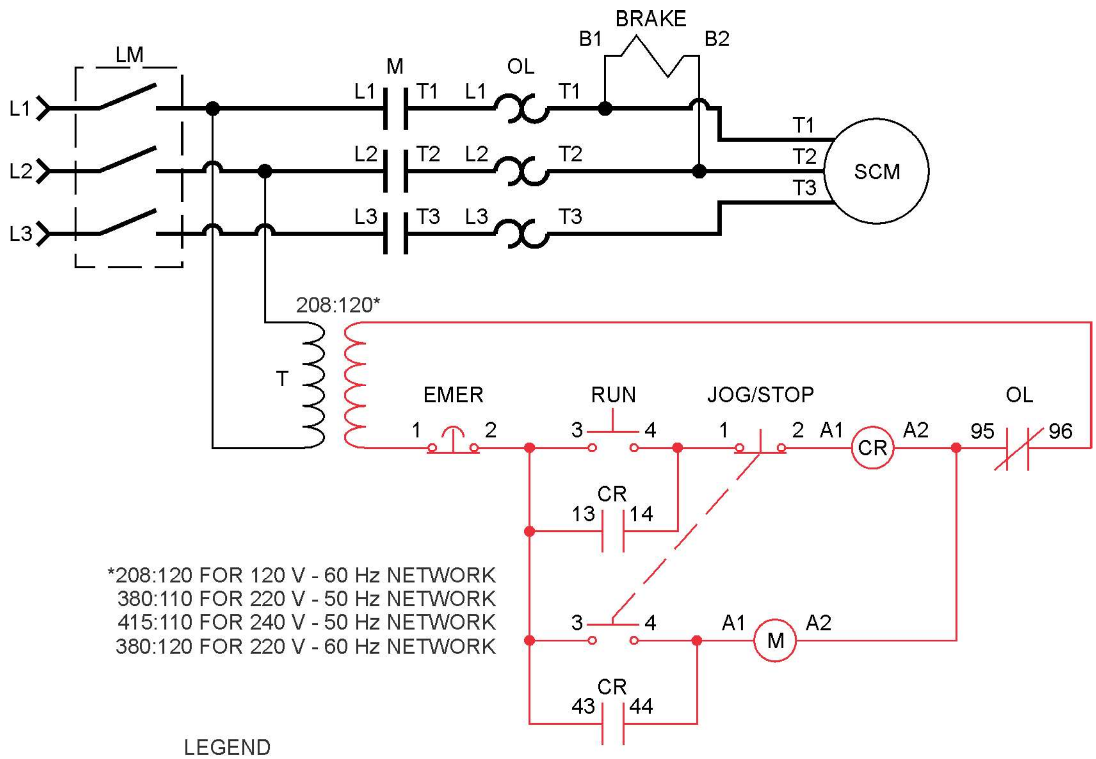
In jogging applications where precision is an important factor, the use of a friction brake greatly improves position control by stopping the motor rapidly. Repeated stops, however, reduce the life expectancy of brakes. Jogging operation is also tough for power contacts, the rapid and repeated switching of inrush currents considerably diminishing contactors' life.

Jog/Run circuits

Figure 4-7 shows a jog/run circuit using a control relay. When the RUN push button is pressed on, the control relay (CR) is energized and holding circuits are formed for both the control relay (CR) and the main contactor (M). The motor then starts and keeps running until the JOG/STOP push button is pushed, causing the control relay (CR) to de-energize.

Pressing the JOG/STOP push button when the system is at rest causes the motor to start and run normally until the JOG/STOP push button is released.

The friction brake applies when the motor stops.



LEGEND

BRAKE	=	SOLENOID ACTUATED BRAKE COIL
CR	=	CONTROL RELAY
EMER	=	EMERGENCY PUSHBUTTON (MAINTAINED CONTACT)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
SCM	=	SQUIRREL CAGE MOTOR
RUN	=	START PUSH BUTTON (MOMENTARY CONTACT)
JOG/STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 4-7. Jogging circuit with control relay.

Many other jogging circuits can be implemented. For example, a selector switch can be employed to switch between run and jog modes, the jog mode simply disabling the holding contacts.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Basic setup
- Simple jogging circuit
- Jog/Run circuit with selector switch
- Additional exercise
  Jog/Run circuit using a control relay.

PROCEDURE

In the first part of this exercise, you will set up a simple jogging circuit. You will make it work to verify that the motor only works when the JOG push button is pressed. You will also see that using a friction brake adds precision to the stop.

In the second part of the exercise, you will implement a jog/run circuit that uses a selector switch to change between jog and run modes.

In an additional exercise, you will be asked to replace the preceding circuit with one that includes three push buttons and a control relay.

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

1. Perform the Basic Setup and Lockout/Tagout procedures.

Simple jogging circuit

2. Install the Brake Motor, Inertia Wheel, and Safety Guard.

   Connect the circuit shown in Figure 4-2.

   Do not connect the friction brake coil at this moment.

3. Manually disengage the friction brake.

   Perform the Energizing procedure.

   Press the JOG push button. Does the motor start to run?

   ❑ Yes ❑ No

4. Release the JOG push button. Does the motor keep running?

❑ Yes ❑ No

5. Turn off the Lockout Module.

Connect the friction brake to the power lines.

Turn on the Lockout Module.

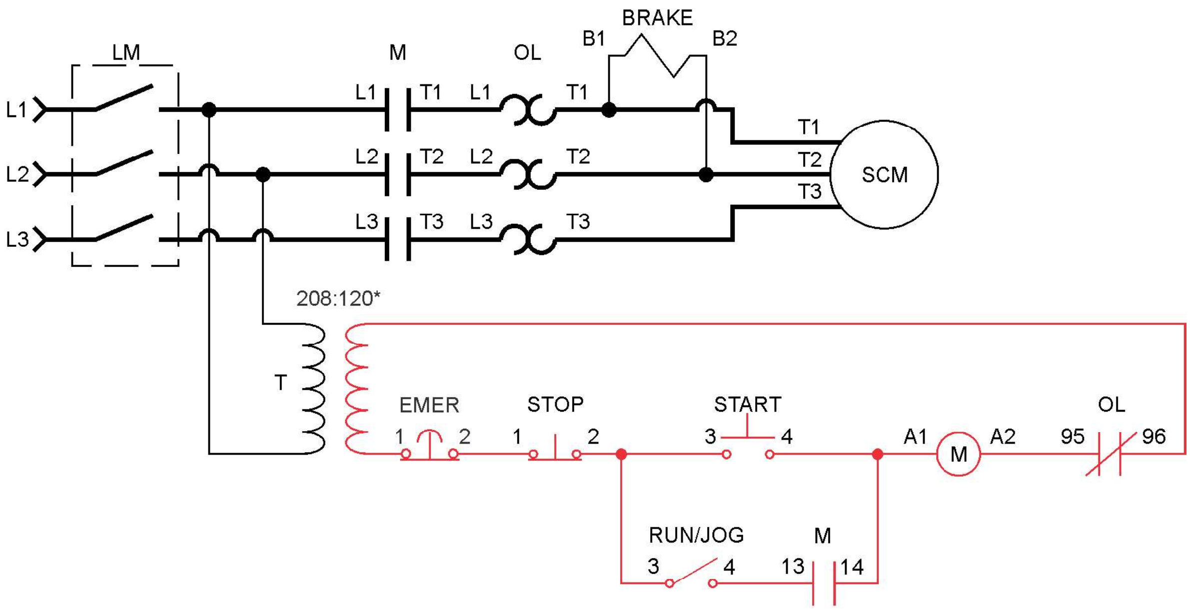
Press and release the JOG push button. Is stopping more precise when the friction brake is connected?

❑ Yes ❑ No

6. Perform the Lockout/Tagout procedure.

Jog/Run circuit with selector switch

7. Connect the circuit shown in Figure 4-8. Use the SS-1 contact of the Selector Switches module.



LEGEND

BRAKE = SOLENOID ACTUATED BRAKE COIL
M = MAIN CONTACTOR
OL = OVERLOAD RELAY
RUN/JOG = RUN/JOG SELECTOR SWITCH (MAINTAINED CONTACT)
SCM = SQUIRREL CAGE MOTOR
START = START PUSH BUTTON (MOMENTARY CONTACT)
STOP = STOP PUSH BUTTON (MOMENTARY CONTACT)
T = CONTROL VOLTAGE TRANSFORMER
EMER = EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
LM = LOCKOUT MODULE

Figure 4-8. Jog/Run circuit with selector switch.

8. Set the RUN/JOG selector switch of the Selector Switches to the O position (open contact).

Perform the Energizing procedure.

Press and release the START push button. What happens to the motor?

❑ The motor starts and stops.
❑ The motor stays off.
❑ The motor starts and keeps running.

9. Does the START push button work like a normal jog push button?

❑ Yes ❑ No

10. Set the RUN/JOG selector switch of the Selector Switches to the L position (closed contact).

Press and release the START push button. What happens to the motor?

- ❑ The motor starts and stops.
- ❑ The motor stays off.
- ❑ The motor starts and keeps running.

11. Does the START push button work like a normal start/stop motor starter circuit?

❑ Yes ❑ No

12. Do your observations confirm that a selector switch can be adequately used to select between jog and run modes?

❑ Yes ❑ No

13. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, remove the magnetic labels, and return the equipment to the storage location.

Additional exercise

Jog/Run circuit using a control relay

Your client wants you to change the control circuit of Figure 4-8 to include three different push buttons: one for jogging, one for starting, and one for stopping.

To implement the new circuit, you decide to set up a jogging circuit with a control relay. Implement the Figure 4-7 circuit and verify that it corresponds to what the client wants.

CONCLUSION

In jogging control circuits, the motor starter remains energized only as long as the jog push button is pressed. No holding circuit is operating. Because of the repeated switching of high currents, jogging greatly reduces the life expectancy of contactors.

Various jogging circuits can be implemented, depending on the requirements of the application:

- Start and stop push buttons can be used along with a jogging circuit to enable continuous motor operation.
- Selector switches enable the choice between run and jog operating modes for the same start push button.

- Control relays make it possible for more specialized circuits. For example, in a jog/run circuit, they can make jogging independent of normal (run) operation.

Friction brakes improve control in jogging operations by reducing stopping time.

Review Questions

1. In the circuit of Figure 4-2, the motor runs

   a. continuously after the JOG push button is pressed.

   b. continuously after the JOG push button is released.

   c. only during the time the JOG push button is pressed.

   d. as long as the JOG push button is not pressed.

2. In the Figure 4-7 circuit, what happens if the motor is running continuously and the JOG push button is pressed and released?

   a. A short-circuit occurs.

   b. Both coils (CR and M) de-energize and the motor stops running.

   c. The overload trips and the motor stops.

   d. The control relay de-energizes after the JOG push button is released, opening the holding circuits and making the motor stop.

3. When is the holding circuit of the Figure 4-8 circuit closed?

   a. During jogging operation.

   b. During normal (run) operation.

   c. While the motor is not running.

   d. When the overload is tripped.

4. In jogging circuits, which device uses its power contacts prematurely due to rapid and repeated switching of inrush current?

   a. Contactor

   b. Push button

   c. Friction brake

   d. Selector switch

5. Which device is best suited to reduce stopping time during jogging?

   a. Control relay

   b. Inertia

   c. Friction brake

   d. Selector switch

Reversing Starters with Jogging

EXERCISE OBJECTIVE

Connect reversing starter circuits with jogging capabilities.

DISCUSSION

Some machine tool processes require both forward and reverse jog controls. When repeated clockwise and counterclockwise inching is necessary, a jogging control circuit with a reversing starter can be implemented.

Figure 4-9 is a schematic diagram of a jogging control circuit made of a reversing starter and a control relay. This circuit can be jogged while the motor is at a standstill or is rotating in either direction.

Pressing the FWD push button starts and runs the motor in the forward direction. Pressing the REV push button runs the motor in the reverse direction. The FJOG/STOP, or RJOG/STOP, push button must be pressed to stop the motor before changing direction, due to the mechanical interlock between the two contactors.

Pressing the FJOG/STOP push button runs the motor in the forward direction. Once the push button is released, the motor stops. The RJOG/STOP push button operates in the same manner, only in the reverse direction.

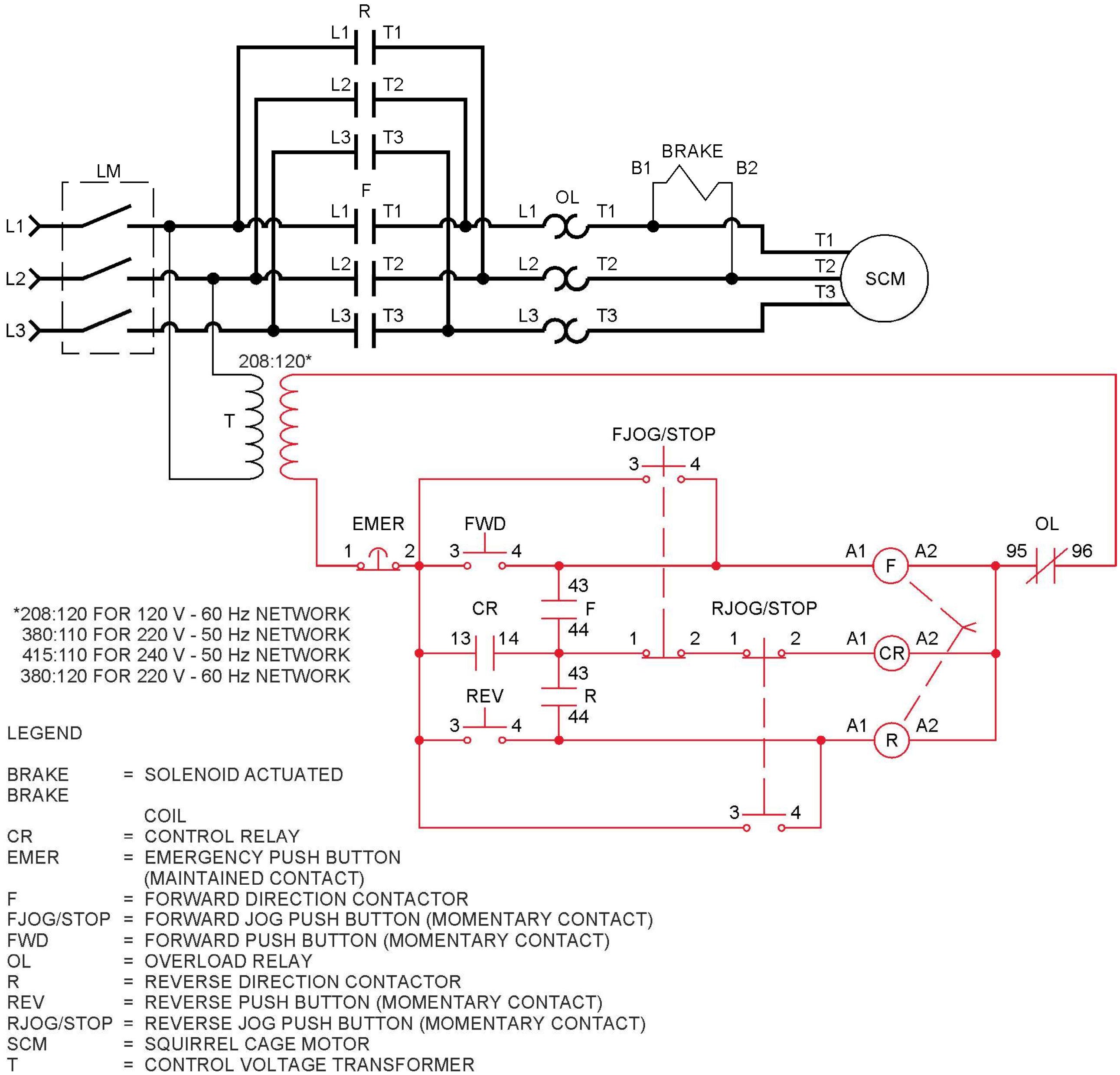
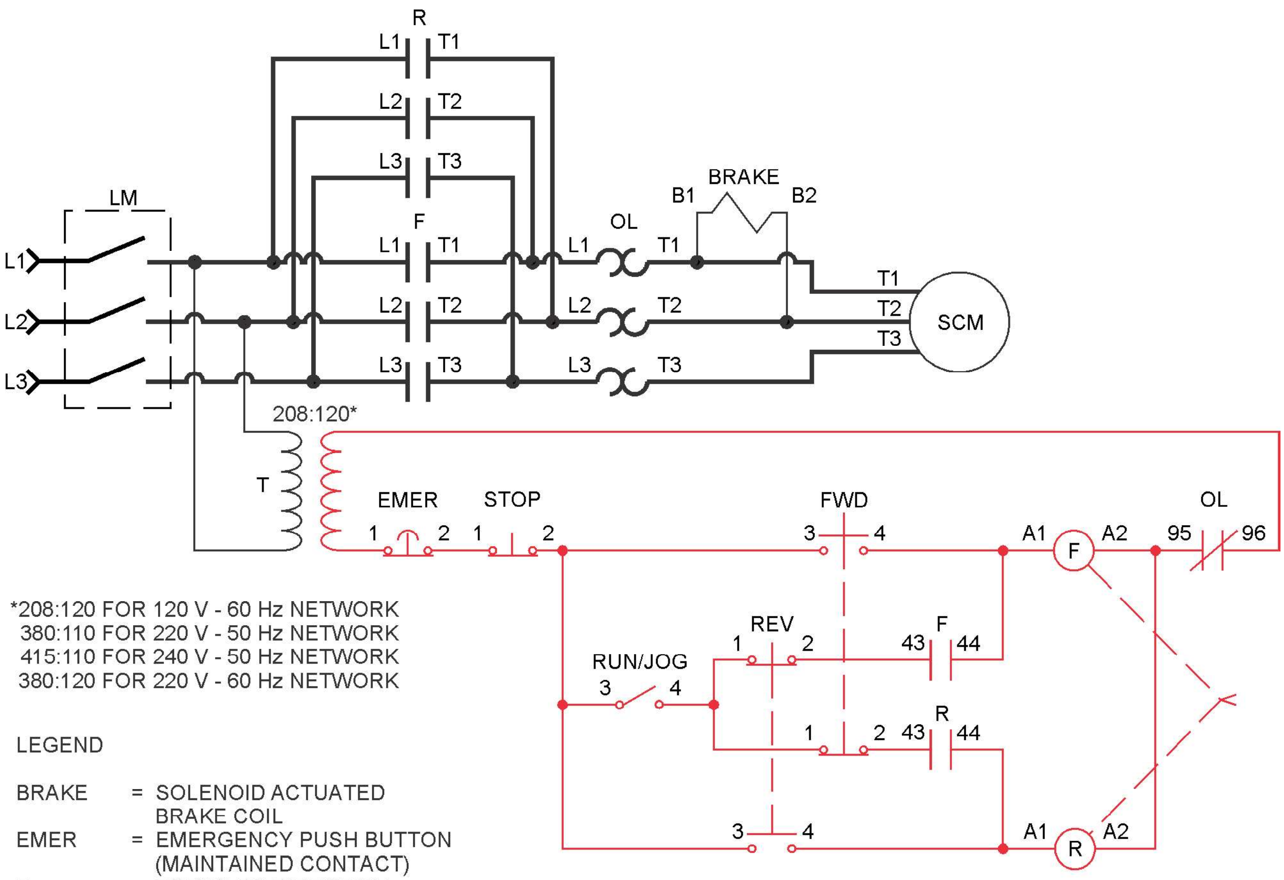


Figure 4-9. Reversing starter circuit with push button jogging.

Many other configurations of reversing circuits with jogging can be implemented. For example, a selector switch may be utilized to switch between jogging and running modes. Such a circuit is shown in Figure 4-10 and is proposed as an additional exercise.



LEGEND

BRAKE	=	SOLENOID ACTUATED BRAKE COIL
EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
F	=	FORWARD DIRECTION CONTACTOR
FWD	=	FORWARD PUSH BUTTON (MOMENTARY CONTACT)
OL	=	OVERLOAD RELAY
R	=	REVERSE DIRECTION CONTACTOR
REV	=	REVERSE PUSH BUTTON (MOMENTARY CONTACT)
RUN/JOG	=	RUN/JOG SELECTOR SWITCH (MAINTAINED CONTACT)
SCM	=	SQUIRREL CAGE MOTOR
STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 4-10. Reversing starter circuit with selector switch jogging.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Basic setup
- Reversing starter with jogging circuit using push buttons and a control relay
- Additional exercise
  Jog/Run reversing circuit using a selector switch.

PROCEDURE

In the first part of this exercise, you will implement a reversing starter having jogging and running capabilities in both motor rotation directions. The circuit will use push buttons, as well as a control relay and a dual contactor with mechanical interlock to provide the aforementioned features. You will subsequently test the different push button combinations to verify that the circuit functions correctly.

An additional exercise is also proposed, in which you are asked to set up a comparable circuit that uses a selector switch to enable and disable jogging.

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

1. Perform the Basic Setup and Lockout/Tagout procedures.

Reversing starter with jogging circuit using push buttons and a control relay

2. Install the Brake Motor, Inertia Wheel, and Safety Guard.

   Connect the circuit shown in Figure 4-9.

3. Perform the Energizing procedure.

   Press the FWD push button. Does the motor start and keep running?

   ❑ Yes ❑ No

4. Which NO contact(s) is(are) kept closed?

   ❑ F (forward contactor)
   ❑ CR (control relay)
   ❑ R (reverse contactor)
   ❑ None

5. What happens when you momentarily press the FJOG/STOP push button?

   ❑ The motor keeps running.
   ❑ The motor stops and restarts.
   ❑ The motor stops completely.

6. Does the FJOG/STOP push button act as a stop push button?

   ❑ Yes ❑ No

7. Press the FJOG/STOP push button. What happens to the motor while you keep the FJOG/STOP push button pressed?

- ❑ The motor starts and stops.
- ❑ The motor stays off.
- ❑ The motor keeps running.

8. What happens when the FJOG/STOP push button is released?

- ❑ The motor stops.
- ❑ The motor stays off.
- ❑ The motor keeps running.

9. Does the FJOG/STOP push button act as a jog push button?

❑ Yes ❑ No

10. Which contact(s) is(are) closed while you keep the FJOG/STOP push button pressed?

- ❑ F (forward contactor)
- ❑ CR (control relay)
- ❑ R (reverse contactor)
- ❑ None

11. Explain how the control circuit operates while you keep the FJOG/STOP push button pressed?

____

____

____

12. Repeat your observations in the reverse direction.

13. Make the motor run in the forward direction.

Press and hold the RJOG/STOP push button.

What happens to the motor when the RJOG/STOP push button is pressed?

- ❑ The motor keeps running in the same direction.
- ❑ The motor stops completely.
- ❑ The motor stops rapidly and starts in the reverse rotation direction.

14. What happens to the motor when the RJOG/STOP push button is released?

❑ The motor keeps running in the same direction.
❑ The motor comes to a stop.
❑ The motor stops rapidly and starts in the reverse rotation direction.

15. Do your observations confirm that the control circuit acts as a reversing starter having jogging and running capabilities in both motor rotation directions?

❑ Yes ❑ No

16. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, remove the magnetic labels, and return the equipment to the storage location.

Additional exercise

Jog/Run reversing circuit using a selector switch

Your client wants you to change the control circuit of Figure 4-9 to incorporate a selector switch. He does not like the idea of having a control relay and wants the circuit to be simpler. He also wants a push button interlock permitting immediate reversal of motor rotation direction.

Finally, he would like to have a selector switch that, when turned to the JOG position, permits switching off a motor running continuously.

To fulfill the demands of the client, implement the Figure 4-10 circuit and verify that it corresponds to what the client wants.

CONCLUSION

A jogging control circuit using a reversing starter can be implemented when repeated clockwise and counterclockwise inching is necessary.

Push buttons and control relays can be utilized to set up a reversing control circuit with jogging. Using a selector switch permits employing the same push buttons for jogging and running modes.

REVIEW QUESTIONS

1. In the Figure 4-9 circuit, what happens if the lead between the RJOG/STOP NC contact and the control relay coil is disconnected?

   a. The control circuit acts as if the stop button was pressed.

   b. The FWD and REV buttons will also act as jogging buttons.

   c. The control relay activates and the motor runs continuously as soon as power is applied to the circuit.

   d. The overload relay trips and the motor is stopped.

2. In the Figure 4-9 circuit, what happens if both jog buttons (FJOG/STOP and RJOG/STOP) are pressed simultaneously?

   a. The control circuit acts as if the stop button was pressed.

   b. The mechanical interlock prevents the two contactors from being energized simultaneously.

   c. The control relay activates and the motor runs continuously.

   d. The overload relay trips and the motor is stopped.

3. In the Figure 4-9 circuit, what happens if both start buttons (FWD and REV) are pressed simultaneously?

   a. The motor runs continuously.

   b. The mechanical interlock prevents the two contactors from being energized simultaneously.

   c. The control relay activates.

   d. All of the answers above are correct.

4. In the Figure 4-10 circuit, what happens when the selector switch is turned to the JOG position?

   a. The holding circuits are closed.

   b. The holding circuits are opened.

   c. The mechanical interlock is disabled.

   d. The overload relay is disabled.

5. In the Figure 4-10 circuit, what happens if the emergency button is pressed?

   a. The motor only runs in one direction.

   b. The motor only runs in JOG mode.

   c. The motor only runs in RUN mode.

   d. The whole control circuit is deactivated.

Unit Test

1. Why are friction brakes used on electrical motors?

   a. Holding a motor position.
   b. Quicker stops.
   c. More precise stops.
   d. All of the answers above are correct.

2. What can friction brakes be used for?

   a. Brake a motor in both directions.
   b. Control machine tools.
   c. Secure cranes.
   d. All of the answers above are correct.

3. How do fail-safe friction brakes normally react in case of a power failure?

   a. The brake is applied only for a limited time.
   b. The power failure does not affect the brake state.
   c. The brake is automatically disengaged.
   d. The brake is applied automatically.

4. What is the effect of jogging on power contacts?

   a. It has no particular effect.
   b. It improves their conductivity.
   c. It reduces their life expectancy.
   d. It increases their life expectancy.

5. What is the alternate name for jogging?

   a. Inching
   b. Starting
   c. Running
   d. Maintaining

6. What is the main purpose of jogging?

   a. Accomplish small movements with a motor.
   b. Accomplish large movements with a motor.
   c. Start a motor continuously.
   d. Reverse the motor rotation direction.

7. Which of the following designations is not an alternate name for fail-safe brakes?

   a. Safety brakes
   b. Spring-set brakes
   c. Power-on brakes
   d. Electrically-released brakes

8. What is the difference between jogging and running modes?

   a. In jogging mode, the stop button is disabled.
   b. In running mode, the stop button is disabled.
   c. In jogging mode, the holding circuit is disabled.
   d. In running mode, the holding circuit is disabled.

9. In a jogging control circuit with reversing starter, why would a control relay be used?

   a. For the holding circuit of the jogging mode.
   b. For the holding circuit of the running mode.
   c. For emergency stopping.
   d. As an interlocking means.

10. In most applications, the braking torque of friction brakes should be

   a. Equal or less than ten times the full-load motor torque.
   b. Equal or greater than ten times the full-load motor torque.
   c. Equal or less than full-load motor torque.
   d. Equal or greater than full-load motor torque.