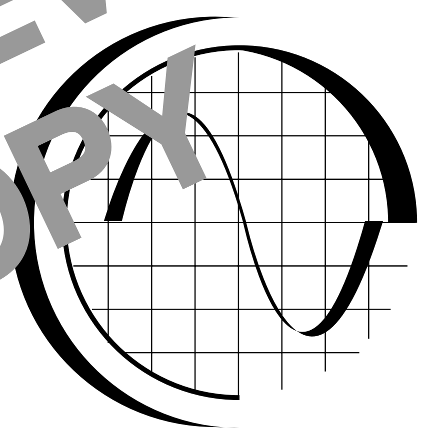
Table of Contents

06-1

AC CONTROL EQUIPMENT

Lesson One

Motor Starters



TPC Training Systems

20901

Lesson

1 Motor Starters

TOPICS

Selecting Motor Controls
Motor Controllers
Controller Enclosures
Starters
Manual Motor-Starting Switches
Magnetic Controls
Armature Assemblies
Magnetic Circuits
Shading Coil
Magnet Coils
Effects of Voltage Variation
NEMA Sizes for Magnetic Starters
AC Hum
Magnetic Starter Control Circuits
Auxillary Contacts
Reversing Starters
Combination Starters

OBJECTIVES

After studying this lesson, you should be able to…

- Describe the difference between a manual starter and a magnetic starter.
- Explain the function of a shading coil in a magnetic starter.
- Explain the effects of low voltage on a controller.
- State the reason why holding-circuit contacts are required on magnetic starters and contactors.
- Demonstrate how to reverse the shaft rotation of a three-phase motor.

KEY TECHNICAL TERMS

Motor controller 1.04 a device used for starting, stopping, and controlling the operation of an electric motor
Motor starter 1.09 the simplest form of controller
Shading coil 1.25 a single turn of copper or aluminum in the face of a magnetic core
Pick-up voltage 1.32 the minimum potential difference that will move the armature of a magnetic coil
Seal-in voltage 1.32 the minimum potential difference that will seat the armature against the pole faces of a magnetic core

All motors require some means for starting and stopping. Speed regulation, overload and low-voltage protection, low-voltage release, motor reversal, and machine and operator safety are other factors requiring some means of control.

Motor starters and controllers are devices used in meeting the control requirements. A controller may perform only one, some, or all of the functions necessary to the operation of the motor.

This lesson explains various motor starters and controls and their applications in the plant. It describes provisions and standards set forth in the National Electrical Code for selecting and using motor-controlled devices. NEMA classifications for controller enclosures are also explained.

Selecting Motor Controls

1.01 The motor, machine, and motor controller are interrelated, and need to be considered as a package when choosing a specific device for a particular application. The motor should be matched to the electrical service and correctly sized for the machine load. Other considerations include the motor's speed and torque. To select the proper protection for the motor, you must know its full-load current rating, service factor, and time rating. You will find these values on the motor's nameplate.

1.02 Motor-control equipment is designed to meet the provisions of the National Electrical Code (NEC). Code sections applying to industrial control devices include Article 430 on motors, motor circuits, and controllers, and Articles 500-503 on hazardous locations.

1.03 Standards established by the National Electrical Manufacturers Association (NEMA) can help you select the proper control equipment. Underwriters Laboratories (UL) tests equipment for conformity to national codes and standards.

Motor Controllers

1.04 The fundamental job of a *motor controller* is to start and stop the motor. It also protects the motor, the machine, and the operator.

1.05 Motor controllers are also used for more complex functions, including reversing, changing speed, jogging or inching, plugging, sequence control, overload protection, overcurrent protection, and pilot-light indication. The controller can also provide control for auxiliary equipment, and may control either a single motor or a group of motors.

Controller Enclosures

1.06 Controller enclosures provide protection for operating personnel by preventing accidental contact with live parts. In certain applications, the controller itself must be protected from a variety of environmental conditions, including damage from the following materials:

- water, rain, snow, or sleet
- dirt or noncombustible dust
- cutting oils, coolants, or lubricants.

1.07 In addition, both people and property need protection in hazardous environments. A hazardous environment is one that contains explosive gases or combustible dusts.

1.08 Enclosures are classified by the National Electrical Manufacturers Association according to the degree of protection the enclosures provide. The NEMA enclosure classifications include the following:

- **NEMA 1.** A *general-purpose enclosure* that protects against dust and indirect splashing of water. It is not dusttight.
- **NEMA 2.** A *driptight enclosure* suitable for applications where moisture condensation may be severe. Examples of such locations include cooling rooms and laundries.

- **NEMA 3.** A *weather-resistant enclosure* suitable for use outdoors. It is splashproof, weatherproof, sleetproof, and moisture resistant.

- **NEMA 4.** A *watertight enclosure* suitable for outdoor applications and for use in dairies, breweries, and other wet locations.

- **NEMA 7.** A *hazardous-location—class I enclosure* for use where flammable gases or vapors may be present.

- **NEMA 9.** A *hazardous-location—class II enclosure* for locations where combustible dust may be present.

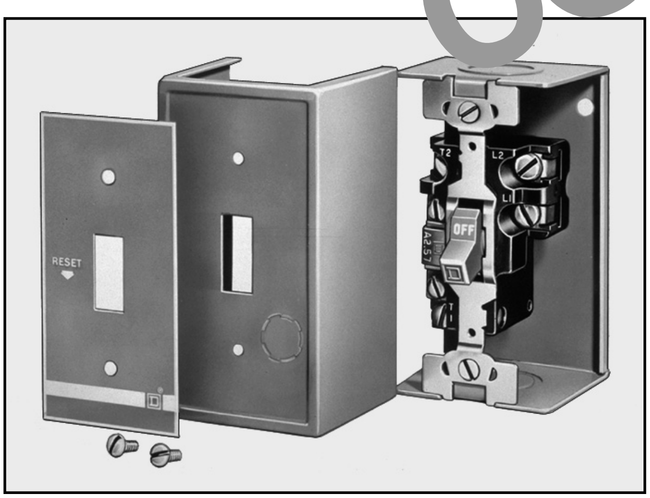
- **NEMA 12.** An *industrial-use enclosure* designed to exclude dust, lint, oil, and coolants. There are no conduit openings or knockouts in this enclosure. You must punch your own as required.

Starters

1.09 The terms *starter* and *controller* have almost the same meaning. Strictly speaking, a starter is the simplest form of controller. It can start and stop the motor, and it provides overload protection.

1.10 A manual starter is shown in Fig. 1-1. It is a motor controller with a contact mechanism operated by hand. A toggle handle usually operates the mechanism through a mechanical linkage. A thermal unit and direct-acting overload mechanism provide overload protection. Basically, a manual starter is an ON/OFF switch with overload relays.

Fig. 1-1. Single-phase manual starter



1.11 Manual starters are used on small devices, including machine tools, fans and blowers, pumps, compressors, and conveyors. They are simple and they provide quiet operation. Moving a handle to the ON position closes the contacts. The contacts remain closed until the handle is moved to the OFF position.

1.12 Manual starters are used on either fractional- or integral-horsepower motors. They usually provide across-the-line starting. Manual starters cannot provide low-voltage protection or low-voltage release. If power fails, the contacts remain closed, and the motor will restart when power returns. This is an advantage for pumps, fans, compressors, and oil burners. But on machinery, it can be dangerous to people or equipment.

Manual Motor-Starting Switches

1.13 Manual motor-starting switches provide on/off control of single-phase or three-phase ac motors where overload protection is not required, or where it is provided separately. Two-pole or three-pole switches are available with ratings up to 5 hp, 600 A, three phase. The continuous-current rating for such switches is typically 30 A at 250 V maximum, and 20 A at 600 V maximum.

1.14 Integral-horsepower manual starters are available in two-pole and three-pole versions. They can control single-phase motors up to 5 hp, and three-phase motors up to 10 hp.

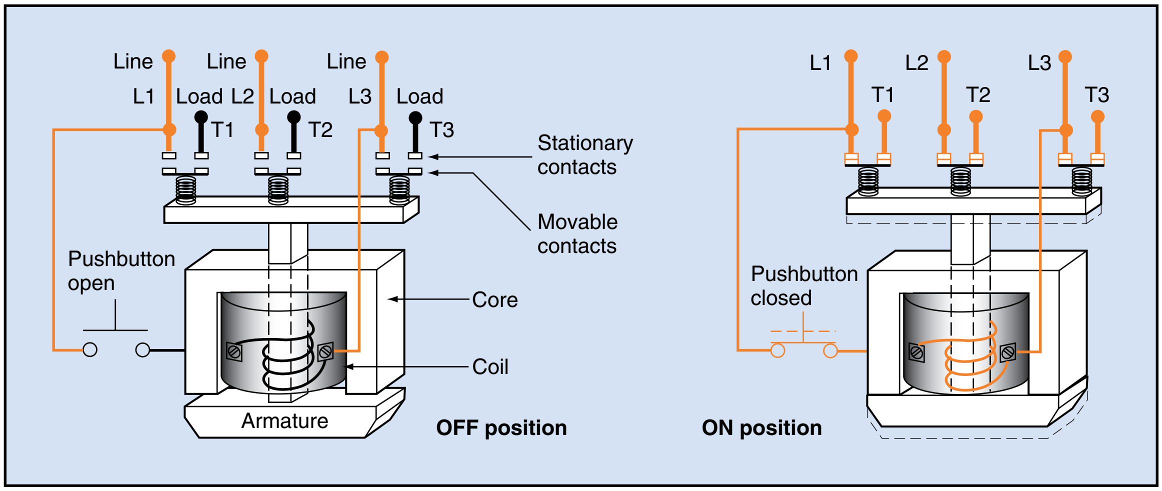
1.15 Two-pole starters have two thermal overloads. Three-pole starters have three thermal overloads.

1.16 When an overload relay trips, the starter mechanism unlatches, opening the contacts to stop the motor. The contacts cannot be reclosed until the starter mechanism has been reset by moving the handle to the RESET position. The thermal unit must cool before resetting.

Magnetic Controls

1.17 Many applications require the controller to be operated from a remote location. Or it may need

Fig. 1-2. Magnetic starter



to operate automatically in response to a signal from a thermostat, a pressure switch, a float switch, a limit switch, or some other remote sensing device. Low-voltage release or low-voltage protection may also be needed. Manual starters cannot provide this kind of control. Therefore, magnetic starters are necessary.

1.18 The use of an electromagnet distinguishes a magnetic starter from a manual starter. An *electromagnet* consists of a coil of wire wrapped around an iron core. The construction is shown in Fig. 1-2. When there is an electric current in the coil, the iron of the core becomes magnetized, attracting the armature. This action closes the contacts to start the motor.

Armature Assemblies

1.19 The armature of the electromagnet is mechanically connected to a set of contacts. When the armature moves to its closed position, the contacts close. The controller is then said to be *picked up,* and the armature is said to be *seated* or *sealed in.*

1.20 There are three basic kinds of armature mechanisms. Each kind is shown in Fig. 1-3 and described on the following page.

- **Clapper.** The armature is hinged. As it pivots to the sealed-in position, the movable contacts close against the stationary contacts.

Fig. 1-3. Armature mechanisms

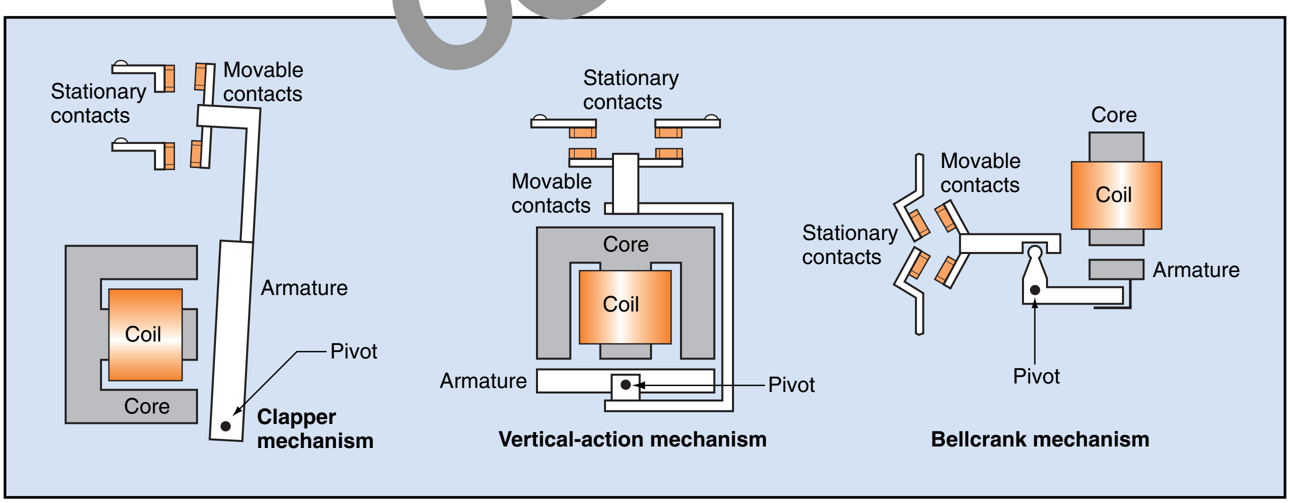
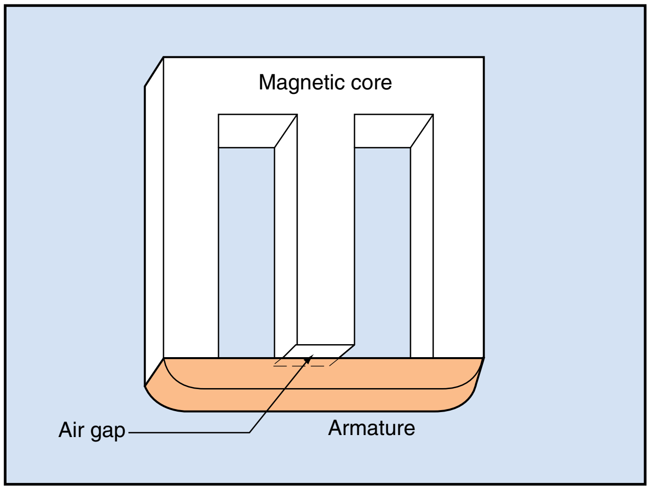


Fig. 1-4. Air gap in a magnet assembly



- **Vertical action.** The action is a straight-line motion, with the armature and contacts being guided so that they move in a vertical plane.

- **Bellcrank.** A bellcrank lever transforms the vertical action of the armature into a horizontal contact motion. The shock of armature pickup is not directly transmitted to the contacts, resulting in minimum contact bounce and longer contact life.

Magnetic Circuits

1.21 The magnetic circuit of a controller consists of the *magnet assembly,* the *coil,* and the *armature*. The current in the coil creates a magnetic field in the iron. The changing magnetic field produced by an ac current increases the temperature in the magnetic circuit, because of eddy currents. The temperature rise is kept to a minimum by laminating the magnet core and the armature.

1.22 The magnet assembly is the stationary part of the magnetic circuit. The coil is supported by the magnetic core.

1.23 When the armature has been attracted into its sealed-in position, the magnetic circuit is completed. To provide maximum pull for closing the contacts, the magnet assembly is machined to a very close tolerance.

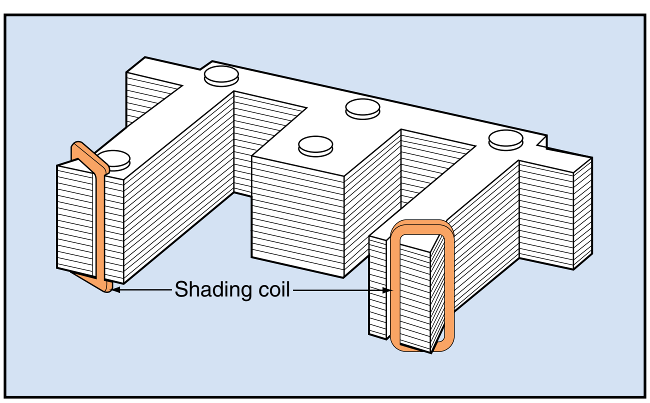
1.24 When a controller's armature has sealed in, it is held tightly against the magnetic core. However, a small air gap is always left in the magnetic circuit. You can see this air gap in the diagram shown in Fig. 1-4. Even when the coil is de-energized, some residual magnetism always remains. If it were not for the air gap in the magnetic circuit, the residual magnetism would eventually become strong enough to hold the armature in the sealed-in position.

Shading Coil

1.25 A *shading coil* is a single turn of copper or aluminum mounted in the face of the magnetic core. An example of a core with shading coils is shown in Fig. 1-5. The alternating magnetic field induces a current in the shading coil. This current creates an auxiliary magnetic field that is out of phase with the main magnetic field.

1.26 The auxiliary magnetic field produces a magnetic force on the armature that is out of phase with the force exerted by the main magnetic field. This force keeps the armature from releasing when the main magnetic field falls to zero. The field drops to zero every time the current reverses—120 times per second if the magnet operates on 60 Hz electricity. Without the shading coil, the armature would vibrate, causing noise, a high rate of wear on the magnet faces, and heat.

Fig. 1-5. Shading coils



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

1-1. The fundamental job of a motor controller is to ________.	1-1. START AND STOP THE MOTOR Ref: 1.04
1-2. A(n) ________ is the simplest form of motor controller.	1-2. STARTER Ref: 1.09
1-3. A(n) ________ is an ON/OFF switch with overload relays.	1-3. MANUAL STARTER Ref: 1.10
1-4. What kind of starting is usually provided by manual starters?	1-4. ACROSS-THE-LINE Ref: 1.12
1-5. Manual motor-starting switches provide on/off control where ________ protection is not required.	1-5. OVERLOAD Ref: 1.13
1-6. What device distinguishes a magnetic starter from a manual starter?	1-6. ELECTROMAGNET Ref: 1.18
1-7. When a controller's armature has sealed in, a small ________ is left in the magnetic circuit.	1-7. AIR GAP Ref: 1.24
1-8. The purpose of a(n) ________ is to keep the armature from releasing when the main magnetic field falls to zero.	1-8. SHADING COIL Ref: 1.26

Magnet Coils

1.27 Magnet coils have many turns of insulated copper wire wound on an insulated spool. Most coils are surrounded by an epoxy molding, which protects them against mechanical damage.

1.28 When a controller is in the OFF position, there is a large opening (not to be confused with the built-in air gap) in the magnetic circuit. The armature is at its greatest distance from the core. The impedance of the coil is relatively low because of this space. Therefore, when the coil is energized, the current is high. As the armature moves closer to the magnet assembly, the space is reduced. The coil current decreases as the space is reduced until the armature becomes sealed in.

1.29 The final current in the coil is called the *sealed current*. The in-rush current is approximately six to ten times the sealed current. The ratio varies with the magnet design. After the controller has been energized for some time, the coil gets hot. The temperature rise reduces the coil current to about 80% of the value when the coil is cold.

1.30 AC magnet coils should never be connected in series. The increased impedance would reduce the coil current. If one device were to seal in ahead of the others, the slower devices might not pick up. If they did pick up, they might not seal. For this reason, ac contactor coils must always be connected in parallel.

1.31 Magnet coils are usually rated in volt-amperes (VA). For example, suppose a magnetic starter has a coil rated at 600 VA in-rush and 60 VA sealed. The in-rush current of a 120 V coil is 5 A, and the sealed current is 0.5 A. The same starter with a 480 V coil has an in-rush current of 1.25 A and a sealed current of 0.125 A.

1.32 The minimum potential difference that will cause the armature to start to move is called the *pick-up voltage*. The *seal-in voltage* is the minimum potential difference that will cause the armature to seat against the pole faces of the core. In devices using a vertical-action magnet and armature, the seal-in voltage is higher than the pick-up voltage. The extra potential difference provides the extra force needed for good electrical contact.

1.33 Control devices using the bellcrank armature have different force characteristics than the vertical-action armature. Devices using the bellcrank mechanism are designed to operate with a seal-in voltage that is lower than the pick-up voltage. This arrangement extends the life of the contacts and reduces contact damage under abnormal voltage conditions. If the voltage is high enough for pick-up, it is also high enough to seat the armature.

1.34 If the control voltage is reduced sufficiently, the controller will open. The potential difference at which this happens is called the *drop-out voltage*. It is always lower than the seal-in voltage.

Effects of Voltage Variation

1.35 If the potential difference across the coil is too great, the coil will draw more than its rated current. Its temperature then becomes too high, which causes early failure of the electrical insulation. The magnetic force also becomes too high, causing the armature to slam into the core too hard. The magnet faces wear rapidly, shortening the life of the controller. The contacts may also bounce too much, shortening their life as well.

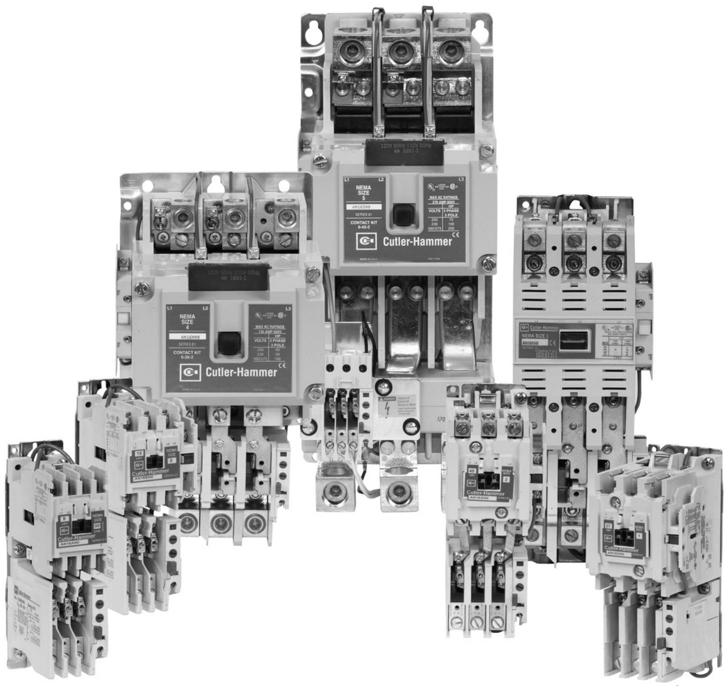
1.36 If the potential difference across the coil is too low, the coil will draw less current than it should. The low current reduces the magnetic force. On a vertical-action mechanism, the current may be enough for pick-up, but not enough for seal-in. The coil is not designed to carry more than its sealed current continuously, so it will quickly get very hot and burn out. The armature will chatter, and the magnet faces will undergo rapid wear.

1.37 In both the vertical-action and bellcrank mechanisms, the contacts will not close with enough force if the armature does not seal. Arcing will raise the temperature and possibly weld the contacts as the controller attempts to carry current with insufficient contact force.

NEMA Sizes for Magnetic Starters

1.38 The power-circuit contacts of a starter carry the motor load. The starter must also be able to interrupt the motor circuit under locked-rotor current conditions. NEMA standards have been established to rate the ability of the contacts to carry the full-load

Fig. 1-6. Relative sizes of NEMA motor starters 00 through 5



current without exceeding a rated temperature rise. The standards also specify the isolation of adjacent contacts.

1.39 There are twelve standard NEMA sizes for starters. They range from Size 00 (rated at 9 A) to Size 9 (rated at 2250 A). Figure 1-6 shows the relative physical sizes of NEMA starters 00 through 5.

1.40 The NEMA sizes for starters are listed in Table 1-1, on the following page. For each size, the table lists the maximum continuous current rating and the horsepower rating corresponding to the operating potential difference across the motor for both single-phase and three-phase motors.

1.41 You can use Table 1-1 to find the size of the starter required for a specific installation. For example, suppose you need a starter for a 100 hp three-phase motor operating at 480 V. You can look down the three-phase column until you find the 100 hp entries. The entry corresponding to 480 V is in the group for NEMA Size 4 starters. According to the table, a Size 4 starter can handle up to 135 A continuously. If your motor were to run at only 240 V, you would need a starter rated as NEMA Size 5, because the motor would require twice as much current.

1.42 Notice that the subtitle of Table 1-1 is *Separate control—120 V*. This subtitle tells you the coil of the electromagnet operates at 120 V. The control circuits for starters usually operate at a lower potential difference than the motor does. The lower potential difference is a safety precaution. Operating personnel come in contact with pushbuttons and other devices. The devices are safer if they operate at only 120 V, rather than the full motor voltage.

1.43 The most popular starter is NEMA Size 1. It is used for motors rated at 3 to 10 hp on 480 V. Sizes 00 and 0 are seldom used.

AC Hum

1.44 All ac devices that incorporate a magnet produce a characteristic hum. This noise is caused by changes in the magnetic force as the magnetic field changes. The frequency of the hum is always twice the frequency of the power supply, because the magnetic field reaches a maximum value twice during each cycle.

1.45 The changing magnetic force produces a mechanical vibration. This vibration can cause excessive noise in contactors, starters, and relays as a result of any of the following conditions:

Table 1-1. Starter sizes

Separate control—120 V									
			Horsepower					Horsepower	
NEMA size	Continuous current rating (amperes)	Volts	Single phase	Three phase	NEMA size	Continuous current rating (amperes)	Volts	Single phase	Three phase
00	9	208	1	$1\frac{1}{2}$	5	270	208		100
		240	1	$1\frac{1}{2}$			240	—	100
		480	—	2			480		200
		600	—	2			600		200
0	18	208	2	3	6	540	208		200
		240	2	3			240	—	200
		480	—	5			480		400
		600	—	5			600		400
1	27	208	3	$7\frac{1}{2}$	7	810	208		300
		240	3	$7\frac{1}{2}$			240	—	300
		480	—	10			480		600
		600	—	10			600		600
2	45	208	$7\frac{1}{2}$	15	8	1215	208		450
		240	$7\frac{1}{2}$	15			240	—	450
		480	—	25			480		900
		600	—	25			600		900
3	90	208	15	30	9	2250	208		800
		240	15	30			240	—	800
		480	—	50			480		1600
		600	—	50			600		1600
4	135	208	—	50					
		240		50					
		480		100					
		600		100					

- broken shading coil
- low operating voltage
- wrong coil
- misalignment between the armature and magnet assembly, which prevents the armature from seating properly
- dirt, rust, and filings on the magnet faces, preventing the armature from sealing in completely
- jamming or binding of moving parts, preventing full travel of the armature
- mounting of the controller on a thin surface, which acts as a sounding board.

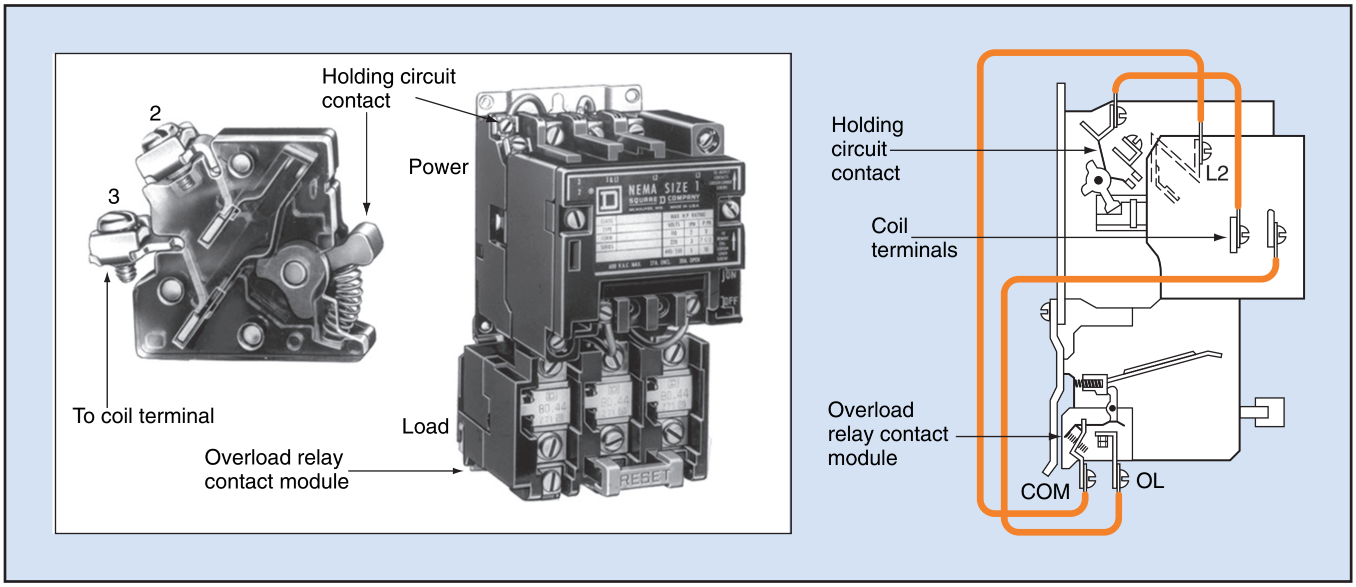
Magnetic Starter Control Circuits

1.46 The circuit to the magnet coil, which causes a magnetic starter to pick up and drop out, is distinct from the power circuit, as shown in Fig. 1-7. Although the power circuit can be either single phase or three phase, the coil circuit is always a single-phase circuit.

1.47 A coil circuit includes the following elements:

- the magnet coil
- the contacts of the overload relay assembly
- a momentary- or maintained-contact device, as for example a pushbutton station, a pressure switch, a temperature switch, or a limit switch
- the contacts of a relay or timer, instead of a pilot device

Fig. 1-7. Magnetic starter control circuit



- an auxiliary contact on the starter, designated as a holding circuit contact in certain control circuits.

1.48 The coil circuit is generally identified as the *control circuit*. Contacts in the control circuit carry the coil load.

Auxillary Contacts

1.49 A *holding-circuit contact* is required on standard magnetic starters and contactors. It is a normally open (NO) contact. It closes when the coil is energized, completing a holding circuit, and it stays closed after the operator released the START button.

1.50 A starter may be equipped with external *electrical contacts* in addition to the main contacts and the holding-circuit contact. A starter with external contacts is shown in Fig. 1-8. Contacts are rated to carry control-circuit currents, not motor currents. Both NO or NC contacts are available.

1.51 Auxillary contacts can be used for controlling other magnetic devices where sequenced operation is required. In addition, they can prevent other controllers from being energized at the same time. They can also make and break circuits to indicating devices, including pilot lights, bells, and other signals. Auxillary contacts are packaged in kits so that they can be installed easily in the field.

Reversing Starters

1.52 Many installations require the ability to reverse the rotation of the motor shaft. Three-phase motors can be reversed simply by reversing any two of the three line connections to the motor. The reconnection can be made by the proper wiring of two contactors.

1.53 In the power circuit shown in Fig. 1-9, on the following page, the contacts of the forward contactor connect lines L1, L2, and L3 to motor terminals T1, T2, and T3. As long as the forward contacts are closed, mechanical and electrical interlocks prevent the reverse contactor from being energized.

Fig. 1-8. External auxillary contacts

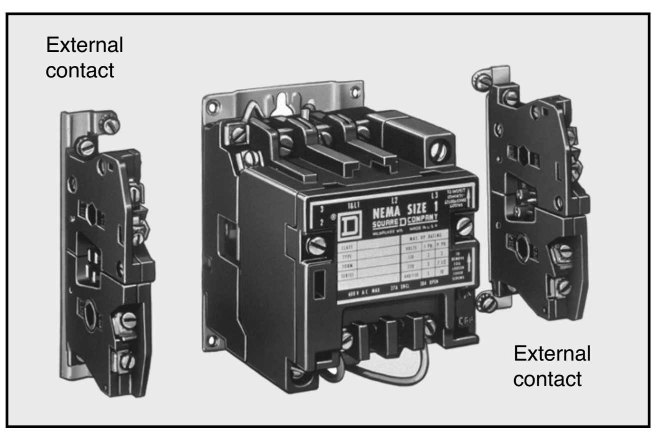
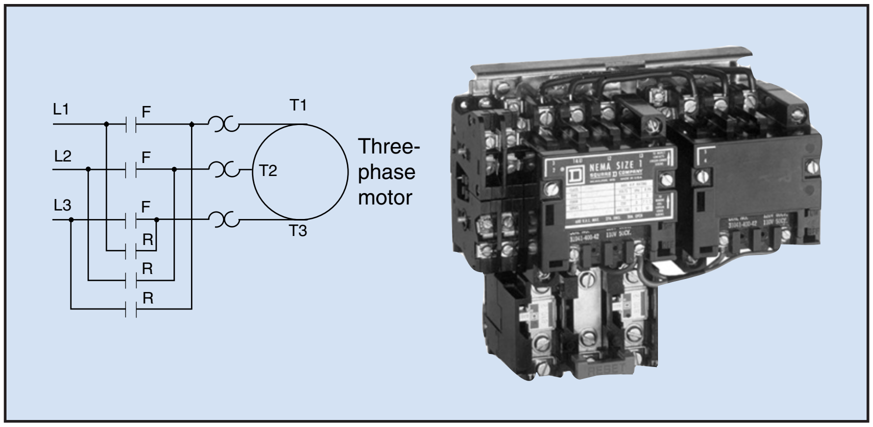


Fig. 1-9. Reversing magnetic starter



1.54 When the forward contactor is de-energized, the reverse contactor can be picked up. Closing this contactor reconnects the lines to the motor. Line L1 is reconnected to motor terminal T3, and line L3 is reconnected to motor terminal T1. Line L2 remains connected to motor terminal T2. The motor will now run in reverse.

Fig. 1-10. Combination starter

1.55 Whether operating through either the forward or reverse contactor, the power connections are made to an overload relay assembly. This assembly provides motor overload protection.

1.56 A magnetic reversing starter consists of a starter and contactor with both electrical and mechanical interlocking. The interlocks prevent the two coils from being energized at the same time.

Combination Starters

1.57 Combination starters have both a disconnecting means and a magnetic starter in a single enclosure, as shown in Fig. 1-10. This arrangement takes up less space than a separately mounted disconnect and motor starter. It also takes less time to install and wire, and it provides greater safety. Safety to operating personnel is ensured because the door is mechanically interlocked so that it cannot be opened without first opening the disconnect.

1.58 Combination starters can be furnished with either circuit breakers or fuses to provide overcurrent protection. They are available in both reversing and nonreversing versions.

1-9. AC magnet coils should never be connected in ________.	1-9. SERIES Ref: 1.30
1-10. In devices using a vertical-action magnet and armature, is the seal-in voltage higher or lower than the pick-up voltage?	1-10. HIGHER Ref: 1.32
1-11. The power-circuit contacts of a starter must be able to carry the ________.	1-11. MOTOR LOAD Ref: 1.38
1-12. Do the control circuits for starters operate at a higher or lower potential difference than the motor does?	1-12. USUALLY LOWER Ref: 1.42
1-13. Broken shading coils and low operating voltage can cause excessive ________ in contactors, starters, and relays.	1-13. NOISE Ref: 1.45
1-14. A(n) ________ contact is required on standard magnetic starters and contactors.	1-14. HOLDING-CIRCUIT Ref: 1.49
1-15. Three-phase motors can be reversed by reversing any two of the three ________ to the motor.	1-15. LINE CONNECTIONS Ref: 1.52
1-16. A(n) ________ starter has both a disconnect means and a magnetic starter in a single enclosure.	1-16. COMBINATION Ref: 1.57

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

1-1. To select the proper protection for a motor, you need to know all the following *except* the

- ☐ a. ambient temperature
- ☐ b. full-load current rating
- ☐ c. service factor
- ☐ d. time rating

1-2. The most suitable controller enclosure for use where flammable gases or vapors may be present is NEMA

- ☐ a. 5
- ☐ b. 7
- ☐ c. 9
- ☐ d. 12

1-3. An ON/OFF switch with overload relays is called a

- ☐ a. combination starter
- ☐ b. magnetic control
- ☐ c. manual starter
- ☐ d. reversing starter

1-4. An armature mechanism in which a lever transforms the vertical action of the armature into horizontal motion of the contacts is called a ________ mechanism.

- ☐ a. bellcrank
- ☐ b. clapper
- ☐ c. lever-action
- ☐ d. vertical-action

1-5. Which of the following reduces vibration, noise, wear, and heat in the armature?

- ☐ a. Centrifugal switch
- ☐ b. Electromagnet
- ☐ c. Holding-circuit interlock
- ☐ d. Shading coil

1-6. When a controller is in the OFF position, the armature is at its greatest distance from the core and the impedance is

- ☐ a. half the current
- ☐ b. high
- ☐ c. low
- ☐ d. zero

1-7. The pick-up voltage is the minimum potential difference that will cause the

- ☐ a. armature to seat against the pole faces
- ☐ b. armature to start moving
- ☐ c. controller to open
- ☐ d. current to become stable

1-8. If the potential difference across the coil is too great, the coil will

- ☐ a. become too hot
- ☐ b. draw too much current
- ☐ c. produce too much magnetic force
- ☐ d. all of the above

1-9. What kind of interlocking does a magnetic reversing starter provide?

- ☐ a. Electrical
- ☐ b. Mechanical
- ☐ c. Both electrical and mechanical
- ☐ d. Neither electrical nor mechanical

1-10. All the features listed below are characteristics of a combination starter, *except* one. Which one is it?

- ☐ a. Available only in nonreversing version
- ☐ b. Ensures safety of operating personnel
- ☐ c. Includes both a disconnecting means and a magnetic starter
- ☐ d. Takes less time to install and wire

SUMMARY

A motor controller is designed to start and stop a motor and also to protect the motor, the machine, and the operator. The values given on the motor's nameplate provide the information needed to select the proper protection for the motor. You should also refer to the National Electrical Code and to the standards published by the National Electrical Manufacturer's Association.

A motor starter is the simplest form of controller. Its purpose is to start and stop the motor and to provide overload protection. Manual starters are ON/OFF switches with overload relays. They are best suited for use on small devices with either fractional- or integral-horsepower motors. Manual motor-starting switches provide on/off control of single- or three-phase ac motors where built-in overload protection is not required, or where it is provided separately.

Magnetic controls provide automatic operation and low-voltage release or low-voltage protection. Magnetic controls have shading coils. This coil prevents vibration in the armature of the controller. A holding-circuit contact, usually a NO contact, is required on standard magnetic starters and contactors. External electrical contacts may also be required, depending on the application.

Three-phase motors can be reversed by reversing any two of the three line connections to the motor. The reconnection is made by the proper wiring of two contactors and an overload relay.

Answers to Self-Check Quiz

1-1. a. Ambient temperature. Ref: 1.01

1-2. b. 7. Ref: 1.08

1-3. c. Manual starter. Ref: 1.10

1-4. a. Bellcrank. Ref: 1.20

1-5. d. Shading coil. Ref: 1.26

1-6. c. Low. Ref: 1.28

1-7. b. Armature to start moving. Ref: 1.32

1-8. d. All of the above. Ref: 1.35

1-9. c. Both electrical and mechanical. Ref: 1.56

1-10. a. Available only in nonreversing version. Ref: 1.57, 1.58

Contributions from the following sources are appreciated:

Figure 1-1. Square D Company
Figure 1-6. Eaton Corporation
Figure 1-7. Square D Company
Figure 1-8. Square D Company
Figure 1-9. Square D Company
Figure 1-10. Square D Company