Appendix C: Glossary

Material for this glossary was taken in part from the following sources:

- *1981 Fundamentals.* Atlanta, Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 1981.

- *Cooling and Heating Load Calculation Manual.* Atlanta, Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 1979.

- *Dictionary of Mechanical Engineering.* Prepared by J.L. Nayler and G.H.F. Nayler. New York, N.Y.: Hart Publishing Company. 1967.

- "Energy Savings Potential in California's Existing Office and Retail Buildings." Staff Report. Sacramento, Calif.: California Energy Commission. 1984.

- *Glossary of Frequently Occurring Motor Terms.* Wallingford, Conn.: EMS, Inc. 1983.

- *Guide to HVAC Equipment.* Sacramento, Calif.: California Energy Commission. 1980.

- *Guidelines for Saving Energy in Existing Buildings: Building Owners and Operators Manual.* ECM 1. Washington, D.C.: Federal Energy Administration. 1975.

- *IEEE Standard Dictionary of Electrical and Electronics Terms.* New York, N.Y.: Institute of Electrical and Electronics Engineers. 1988.

- *Terminology of Heating, Ventilation, Air-Conditioning, and Refrigeration.* Atlanta, Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 1986.

Actuator: A device, either electrically, pneumatically, or hydraulically operated, that changes the position of a valve or damper.

Adjustable speed drive (ASD): A motor accessory that enables the driven equipment (e.g., fan or pump) to be operated over a range of speeds. The two general categories of ASDs are mechanical units (installed between the motor and the driven load) and electronic units (installed in the electrical wiring to the motor).

Air transport system: A system that distributes air to the various spaces in a building, generally comprised of fans, ducts, dampers, registers, etc. It is sometimes referred to as a ventilation system, but the air transport of warm or cool air for space conditioning may be separate from the mechanical ventilation system in some buildings.

Alternating current (AC): Electric current that is characterized by the electrons flowing back and forth along the conductors that constitute the circuit. Normal building wiring in the United States is alternating current with a frequency of back-and-forth flow of 60 cycles per second. See

direct current.

Ambient: Surrounding (e.g., ambient temperature is the temperature in the surrounding space).

Amperes (amps): Equal to the flow of 6.25×10^{18} electrons per second, or one coulomb per second.

> **Full-load amps (FLA)**: The amount of current the motor can be expected to draw under full-load (torque) conditions when operating at the rated voltage. Also known as nameplate amps.
> **Locked-rotor amps (LRA)**: This is the amount of current the motor can be expected to draw under starting conditions when full voltage is applied. Also known as starting inrush.
> **Service-factor amps**: The amount of current the motor will draw when it is subjected to a percentage of overload equal to the service factor on the nameplate of the motor. For example, many motors have a service factor of 1.15, meaning that the motor can handle a 15% overload.

See c*urrent.*

Amps: See *amperes***.**

Apparent efficiency: The product of a motor's efficiency and its power-factor.

ASHRAE 90: Comprised of voluntary building standards for new buildings, developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers. These standards include minimum equipment efficiencies, building envelope characteristics, and required control strategies for nonresidential buildings.

Average efficiency: See *nominal efficiency*.

Avoided cost: Cost to the utility of the marginal kilowatt-hour produced. When conservation or an alternative supply allows a utility to reduce its own power production, the savings to the utility are its avoided cost. This quantity (which includes avoided operations and maintenance, transmission and distribution, and capacity costs) varies depending on a wide range of factors, including fuel cost, generation type (which may vary over the course of the day and the year), etc.

Basic Model: All units of a given type of covered equipment manufactured by a single manufacturer and, with respect to electric motors, that have the same rating and essentially identical electrical and efficiency characteristics (Federal Register 1999).

Bearings: The supports that hold a revolving shaft in its correct position. In the context of motors, the two rotor shaft bearings (mounted in the motor frame) allow rotary motion of the shaft relative to the enclosure while preventing axial or radial motion. Bearings come in a wide variety of types. Most integral-horsepower motors use ball bearings with rolling steel balls that contact the two main parts ("races") of the bearing to allow the relative motion. Many fractional-horsepower motors (especially the smallest sizes) use sleeve or journal bearings with a bearing lubricant to keep the spinning shaft from contacting the stationary bearing.

Belt: A band of flexible material (usually rubber or plastic reinforced with fabric or steel) for transmitting power from one shaft to another by running over flat, grooved, or toothed pulleys. See Figure 3-15 for illustrations. The common belt types include:

> **Flat belts**: Smooth belts with a flat cross section, riding on corresponding smooth pulleys. Flat belts are thinner and wider than V-belts used in the same applications.
> **Synchronous belts**: Belts with a flat cross section and teeth formed in the inner belt surface. The belt teeth engage the teeth of the pulleys, preventing any slippage (hence the name).
> **V-belts**: Belts with a V-shaped cross section and a smooth or cogged inner belt surface. V-belts ride in pulleys (sheaves) with corresponding smooth, V-shaped grooves. The "cogged" V-belts are toothed with transverse groves or notches. These notches do not interface with a notched sheaves but rather increase the contact force between the belt and the smooth sheave, reducing slippage while making the belt more flexible by reducing bending due to heating.

Bipolar transistor: Three-terminal electronic switch in which the current between two terminals (the collector and the emitter) is controlled by the third terminal (the base). The base current is typically 50–100 times smaller than the output current.

Brushes: Conductors, usually composed in part of carbon, serving to maintain an electrical connection between the stationary and rotating parts of a motor. Brushes contact either slip rings (in AC wound-rotor motors) or the contacts of the commutator (in DC motors).

Capacitor: A component containing a dielectric (nonconducting) material sandwiched between two metallic layers. Capacitors are widely used for power-factor compensation and filters. See *power-factor*.

CEE premium-efficiency motor: A motor that meets or exceeds the minimum-efficiency level specified by the Consortium for Energy Efficiency. These levels represent an efficiency level above that of EPAct motors. This specification is used by many entities as the qualifying efficiency level for participation in motor programs. See *Consortium for Energy Efficiency* and *EPAct motors*.

Centrifugal chiller: A machine that produces cold water by using centrifugal action in its compressor to raise the pressure level of the refrigerant gas. Centrifugal chillers are commonly used in large commercial buildings to supply chilled water to cooling coils in the buildings' HVAC systems. Chiller unloading (operating at cooling loads below maximum) is generally regulated by varying the flow of the refrigerant gas with variable-inlet vanes on the input side of the compressor.

Centrifugal fan: A device for propelling air by centrifugal action. Forward-curved fans have blades that are sloped forward relative to the direction of rotation while backward-curved fans have blades that are sloped backward and are generally more efficient at high pressures than forward-curved fans.

Chiller: A refrigeration machine that produces cooled water, generally at a temperature of 40–

55EF. Types include reciprocating, screw, centrifugal (named for the type of compressor used in the motor-driven compression-expansion cycle), and absorption (for the heat-driven absorption cycle).

Chopper: A device that converts DC power into a square wave. When used with an output filter, a chopper can be used with a constant-voltage input to create a variable-voltage output by altering the ratio of on-time to off-time in the square wave.

Code letter: An indication of the amount of locked rotor (inrush) current required by the motor when it is started. See *amperes, locked-rotor.*

Coefficient of performance (COP): A measure of the efficiency of cooling or refrigeration equipment. COP is defined as the ratio of cooling output to energy input, with both quantities in the same units of measure (kilowatt or British thermal unit per hour). Electric cooling equipment has COPs ranging between approximately 2 and 6. See *energy efficient ratio.*

Compressor: A mechanical device that increases the pressure, and thereby the temperature, of a gas. Refrigerant compressors are the most common in building applications, followed by air compressors.

Condenser: A heat exchanger in which a refrigerant is condensed from a vapor to a liquid. Common types of condensers are: air-cooled (either by natural air flow as in the coil on the back of many residential refrigerators, or fan-forced as in air conditioners); water-cooled (as in most large chillers for commercial buildings); and evaporative, where water is sprayed on the outside of the refrigerant tubes and a fan forces air to evaporate a portion of the water, providing a cooling effect.

Consortium for Energy Efficiency (CEE): A nonprofit organization located in Boston, Massachusetts, that develops and deploys market transformation programs for member utilities, government agencies, and public interest groups. CEE's motor committee has developed several motor system initiatives. See *market transformation*.

Cooling load: The heat and moisture that accumulate in a building and that must be removed in order to maintain comfortable temperature and humidity conditions.

Cooling tower: A device that cools water directly by evaporation and is typically used to reject heat from one or more condensers.

Covered motor: A motor, defined within EPAct regulations, to which EPAct specifications apply (see Appendix B for further explanation).

Current: The flow of electrons in an electrical circuit. Current is measured in amperes. See *amperes.*

Current signature: the unique distortions in the current profile caused by an operating electromechanical device.

Current-source inverter (CSI): A type of electronic ASD that works by converting the AC input to controlled-current DC, then synthesizing the variable-frequency AC output by using a DC-to-AC inverter. See *adjustable speed drive, variable-frequency drive*, and *voltage-source inverter.*

Cycloconverter: An AC converter in which the AC supply from the grid is converted directly into another AC voltage waveform with a lower frequency, without an intermediate DC stage. The output frequency ranges between 0% and 50% of the input frequency.

Damper: A restrictive device used to vary the volume of air passing through an air outlet, inlet, or duct.

Demand charge: The amount charged by the utility per kilowatt of peak power used (demanded) by the customer. Demand charges are usually billed per month; the peak demand is measured by a special demand meter that records the highest average demand (typically over a 15- or 30-minute interval) during the month. The charge may be fixed or variable according to the time of day, season, and level of demand.

Demand-side management (DSM): These programs focus on reducing energy consumption by energy end-users and, in general, are operated by utilities, government, and public benefit entities. Projects may focus on education, incentives, or market transformation. See *public benefit fund* and *market transformation*.

Design: The design letter on a motor nameplate is an indication of the shape of the torque-speed curve. Figure 2-9 shows the typical shape of the most commonly used NEMA design letters (A, B, C, D, and E). Design B is the standard industrial-duty motor, which has reasonable starting torque with moderate starting current and good overall performance for most industrial applications. Design C is used for hard-to-start loads and is specifically designed to have high starting torque. Design D is the so-called high-slip motor, which tends to have very high starting torque with high slip at full-load torque. The motors are particularly suited for low-speed punch press, hoist, and elevator applications. Generally, the efficiency of Design D motors at full load is rather poor, and thus they are normally used on those applications where the torque characteristics are of primary importance. Design A motors are not commonly specified, but specialized motors used for injection molding applications have characteristics similar to Design A. The most important characteristic of this type is that the pull-out torque is somewhat higher than Design B's; otherwise A and B are quite similar. Design E motors are comparable in specification to Design A motors with high starting currents and limited pull-up torques but require special starters and are therefore predominately used in HVAC fan applications. See *slip, torque, pull-out* and *torque, pull-up*.

Direct current (DC): Electrical current characterized by electrons flowing in one direction only. See *alternating current.*

Discharge dampers: Dampers that regulate the flow of air on the outlet side of a fan in variable-air-volume systems. Dampers are the least efficient method of regulating air flow.

Drivepower: Energy consumed by motors and motor-driven equipment.

EASA-Q: A certification program developed by the Electrical Apparatus Service Association for quality motor repair practices. See *Electrical Apparatus Service Association* and *motor repair.*

ECM or ECPM: Electronically commutated permanent magnet motor. See *permanent-magnet motors.*

Eddy (or eddy-current) losses: See *magnetic losses.*

Efficiency (motor): In general, this is the ratio of the mechanical power output to the electrical power input. See other efficiencies: *apparent, minimum,* and *nominal*.

Electrical Apparatus Service Association (EASA): A trade association representing many motor repair shops, principally in North America. EASA also develops standards for motor repair practices.

Electromagnetic interference (EMI): Impairment of a transmitted electromagnetic signal by an electromagnetic disturbance; it's particularly relevant to communications and data processing applications.

Energy charge: The amount charged by the utility for each kilowatt-hour of energy used by the customer. The energy charge may be fixed or variable, depending on the time of day, season, and level of usage.

Energy-efficient motor (EEM): A motor that meets or exceeds the minimum-efficiency levels specified in NEMA MG 1, Table 12-10. These levels correspond with the minimum-efficiency levels specified in the *Energy Policy Act of 1992*. See *EPAct motor* and *NEMA MG 1*.

Energy efficiency ratio (EER): A U.S. measure of cooling equipment efficiency, defined as

(cooling output in Btu/h)/(electric input in watts)

EER = COP x 3.412. See *seasonal energy efficiency ratio*.

Energy Policy Act of 1992 (EPAct): Federal legislation that amended the *Energy Policy and Conservation Act of 1978*. Among other actions, it established minimum-efficiency standards for integral-horsepower, general purpose, polyphase induction motor less than or equal to 200 hp.

EPAct: See *Energy Policy Act of 1992.*

EPAct motor: A motor that complies with the minimum-efficiency levels specified in the Energy Policy Act of 1992. These motors also meet the NEMA definition of *energy efficient*. See *energy-efficient motor* and *Energy Policy Act of 1992.*

Explosion-proof (EXP): A type of motor package ("enclosure") designed to withstand the explosion of a specified gas or vapor within it and to prevent ignition of a specified external gas or vapor by sparks, flashes, or explosions that may occur within the motor casing.

First cost: The initial cost of a project, including design, procurement, equipment, and installation costs.

Forced commutation inverter: Inverter in which a special commutation circuit is required to turn off the thyristor, making the inverter design more complex. See *thyristor*.

Fractional-horsepower motor: A motor with a rated output power of less than 1 hp. See *horsepower* and *integral-horsepower motor.*

Frame size: Motors come in various physical sizes to match the requirements of the application. In general, the frame size gets larger with increasing horsepower or with decreasing speed. In order to promote standardization, NEMA prescribes standard frame sizes for certain horsepower, speed, and enclosure combinations. Frame size specifies the mounting and shaft dimensions of standard motors. For example, a motor with a frame size of 56 will always have a shaft height above the base of 3.5 inches. Frame sizes are usually listed as a combination of a number and a letter, with the number indicating the relative size and the letter the general frame type (such as T, U, etc.). See *frame type.*

Frame type: This is the general characteristics of a motor's size and mounting configuration, usually expressed by a letter. For example, NEMA T-frame motors (base-mount, single-ended shaft) are the most commonly made three-phase frame type; the similar but larger U-frame motors were most common until the 1960s. U-frame and T-frame motors have the same shaft size for the same power and speed. Another early design of the same type, A-frame motors, differ from T-frames in both motor size and shaft size. C- and J-frame motors are end-mounted and designed to be bolted directly to the driven equipment. L-frame motors are similar to C-frames except that they are designed to mount vertically above the load (usually a pump). Fractional-horsepower motors generally do not have a letter designation. See *frame size.*

Free rider: A participant in a promotional conservation program who would have performed the conservation action even without the program.

Frequency: The rate of oscillation of an alternating current, expressed in cycles per second (or hertz). In North America, the predominant frequency of AC power is 60 Hz.

Full-load speed: The approximate speed that the motor will run when it is operating at full rated output torque or horsepower.

Gate turn-off thyristor (GTO): An electronic switch with the same properties as a thyristor, but it is possible to turn off the device by applying a small control signal in the gate. This is in contrast to standard thyristors, which must have the voltage across the main terminals brought close to zero in order to turn it off (requiring the use of such techniques as forced commutation). See *thyristor.*

Gears: A mechanical system for transmitting rotation through the use of toothed wheels in direct engagement. Gears are used to change the speed, direction, or orientation of rotation from one shaft to another. There are a great many types and combinations of gears; four of the most common types of gears are bevel, helical, worm, and spur gears. Helical and worm gears are shown and described in Figure 3-12. Spur gears are cylindrical gear wheels in which the teeth are parallel to the shaft and are used for transmitting power between parallel shafts. Bevel gears are beveled in order to transmit rotation between nonparallel shafts and are commonly used to transmit power at 90Eto the output shaft, that is, between shafts with intersecting axes at right angles.

General purpose motors: NEMA defines a general purpose motor as an open or closed motor, 500 hp or less, rated for continuous duty, without special mechanical construction, that can be used in typical service conditions without restrictions to a particular application or type of application.

Harmonics: Electrical signals with frequencies that are integral multiples of the fundamental frequency. For example, in a 60 Hz application, a 180 Hz component is called the third harmonic.

Header: The manifold into which multiple pumps or compressors discharge.

Heating, ventilation, and air conditioning (HVAC) system: A system that provides one or more of the functions of heating, ventilation, and air conditioning (cooling) for a building.

Hertz (Hz): Frequency of AC power in cycles per second. The predominant frequency of power in North America is 60 Hz; in most other countries it's 50 Hz. See *frequency.*

High-inertia load: A load that has a relatively high flywheel effect (or moment of inertia). Large fans, blowers, punch presses, centrifuges, industrial washing machines, and similar loads can be classified as high-inertia loads. See *inertia*.

Horsepower (hp): A unit of power equal to 746 watts or 33,000 ft-lb/minute. In the United States, horsepower is used to indicate the rated output (shaft) power of a motor. One horsepower = torque (ft-lb) x speed (rpm)/5,252. In compressor sizing, it is the full-load output rating of the electric motor driving the compressor.

Hysteresis losses: See *magnetic losses.*

Inductance: The property of an electrical device or circuit by virtue of which a varying current induces an electromotive force in that circuit, thereby resisting the change in current.

Induction motor: The most common type of AC motor in which a primary winding on one member (usually the stator) is connected to the power source and a secondary winding (in the case of wound-rotor induction motors) or a squirrel cage of metal bars (in the case of squirrel cage induction motors). On the other member (usually the rotor), the induced current is carried.

The changing magnetic field created by the stator induces a current in the rotor conductors, which in turn creates the rotor magnetic field. The interaction of the stator and rotor magnetic fields causes the motor to rotate.

Inductors: Generally, they are devices with a magnetic core around which windings of wire are wrapped, a construction that results in high inductance relative to the size of the device. An electromagnet is a type of inductor.

Industrial Best Practices: Motors**,** formerly *Motor Challenge*: See Chapter 9.

Inertia: That property of a body by which it tends to resist a change in its state of rest or uniform motion. Inertia is measured by mass (equivalent to weight) when linear accelerations are considered. In the context of motor systems where rotational acceleration is the primary concern, inertia is measured by the moment of inertia, about the axis of rotation. The moment of inertia is the Σmr^2, where m is the mass of a part of the rotating equipment and r is its perpendicular distance from the axis of rotation. That is, the moment of inertia depends on the weight of the rotating system and how far the weight is from the axis of rotation (the farther it is, the more effect the same weight will have).

Inlet vanes: Variable vanes on the inlet side of a fan that regulate airflow in a variable-air-volume system. Inlet vanes are also used in centrifugal chillers.

Insulated gate transistor (IGT): A three-terminal electronic switch with an input stage that is an MOS transistor and an output stage that is a bipolar transistor. In this way, the IGT combines the best properties of both transistors (requires negligible input power to control the transistor and results in low losses in the conduction state when the IGT is fully on). See *MOS transitor.*

Insulation class: A measure of the resistance of the insulation components of a motor to their degradation from heat. The four major classifications of insulation used in motors are, in order of increasing thermal capabilities, Class A, B, F, and H. Class A is no longer used in integral-horsepower motors; the designations C through E and G were never used.

Integral-horsepower motor: This motor has an output power rating of 1 hp or above. See *fractional-horsepower motor* and *horsepower.*

Inverter: A device or system that changes DC power to AC power.

Inverter drive: A type of adjustable speed drive that varies the motor speed, changing the frequency of the motor input current. See *adjustable speed drive, variable-frequency drive*, and *voltage-source inverter*.

Inverter Duty Motor: A motor manufactured in conformance with NEMA MG 1, Part 31 and has a higher class of insulation that allows the safe operation of inverter drives. See *inverter drive* and *NEMA MG 1*.

Isolation transformer: A transformer with primary and secondary windings physically

separated, thus preventing primary circuit voltage from being forced onto the secondary circuits. Isolation transformers are often used with large ASDs to reduce the power quality degradation caused by the ASD.

Kilovolt-ampere (kVA): The product of the voltage (in volts) and current (in amperes) in an electrical circuit, divided by one thousand. In DC circuits, kilovolt-ampere equals kilowatt flowing. In AC circuits, the kilovolt-ampere equals the kilowatt if the power-factor equals one; otherwise the kilovolt-ampere is higher than the kilowatt. See *kilowatt* and *power-factor.*

Kilowatt (kW): A unit of (usually) electrical power equal to one thousand watts, or the flow of one thousand joules of energy per second. Equivalent to 3,412 British thermal units (Btu) per hour of thermal power or 1.34 hp. Other than in the United States, it is commonly used to indicate motor output (shaft) power. See *horsepower* and *kilovolt-ampere.*

Kilowatt-hour (kWh): A unit of electrical energy equal to one kilowatt of power flowing for one hour, i.e. 3,600,000 joules of energy. Equivalent to 3,412 Btus of thermal energy or 1.34 hp/hr. Kilowatt-hour is the most common unit used for metering electricity. See *kilowatt***.**

Laminations: Thin steel sheets stacked together and used in electromagnetic devices. In motors, they form the core of the stator and rotor magnets. In inductors and transformers, laminations provide the magnetic core around which the windings of wire are placed.

Leakage reactance: The motor reactance associated with that fraction of the magnetic flux generated by the stator winding that does not cross the air gap and therefore does not reach the rotor (and vice versa, from the rotor to the stator). The leakage reactance is a trade-off value: for example, a high degree of leakage reactance results in lower starting current (a desirable result), but with undesirable reductions in steady-state motor performance. The leakage reactance increases with the air gap size and is also a function of other motor design parameters such as slot design, saturation of the magnetic circuit, and winding configuration.

Load profile: Distribution over time of the heating, cooling, ventilation, electrical, or any other loads of a building or process. Load profile is usually expressed on an hourly basis over a day but may also be expressed on a seasonal basis over a year.

Load types:

Constant-horsepower: Loads where the torque requirement decreases as the speed increases, and vice versa. Constant-horsepower loads are usually associated with applications such as traction (in electric vehicles, for example) and metal removal (e.g., drill presses, lathes, and milling machines).

Constant-torque: Loads where the amount of torque required to drive the machine is constant regardless of the speed at which it is driven. For example, most conveyors and many reciprocating compressors are constant-torque loads.

Variable-torque: Loads that require low torque at low speeds and increasing torque as the speed is increased. Centrifugal fans and pumps are typical examples of variable-torque loads.

Magnetic losses: When the iron core in the motor is subjected to a changing magnetic field, as it is during normal operation, there are two types of losses: eddy current and hysteresis. Eddy-current (or simply eddy) losses are due to the currents induced in the iron by the change in the magnetic flux, with losses growing with the square of the flux density and the square of the frequency. Eddy losses can be minimized by using thinner laminations and silicon steel with a higher electric resistivity. Hysteresis losses are due to the rotation of groups of iron atoms as they are excited by the changing magnetic field. Hysteresis losses are proportional to the square of the flux density and to the frequency. Hysteresis losses can be decreased by using high-performance silicon steel with high permeability and a narrow hysteresis cycle. Both types of magnetic losses can be decreased by using a lower magnetic flux density, which means using larger cross sections in the magnetic circuit (i.e., more iron in the motor).

Market transformation: This concept involves programs and measures that seek to permanently change the market's structure or behavior to a desired goal (e.g., procurement of energy-efficient products). Strategies can involve education, targeted incentives, or formation of new market structures. These efforts are frequently carried out by government, public interest, public benefit, or utility entities. See *demand-side management*.

Mechanical cooling: Cooling by energy-using equipment such as chillers and air conditioners. Cooling accomplished through use of outside air or by evaporative coolers is generally not considered mechanical cooling.

MG 1: See *NEMA MG 1*.

Microelectronic: Electronic devices characterized by highly integrated circuits (many semiconductor devices on one chip of silicon) that are usually used for computation and control, and generally operate at currents well below 1 ampere with voltages below 10 V. See *power electronic devices.*

Minimum efficiency: The minimum level of efficiency for a group of motors of the same specification. Up to 5% of motors can have an efficiency lower than the minimum efficiency. Minimum efficiency is sometimes guaranteed by the motor manufacturer. The NEMA minimum efficiency levels are set at two standard increments of efficiency below the NEMA nominal efficiency. See *nominal efficiency*.

Minimum-efficiency standard or specification: A standard or specification requiring a particular type of equipment to meet a minimum level of operating efficiency. In the case of motors, such standards generally set different minimum levels of nominal motor efficiency according to the motor size (in horsepower output rating). See *CEE premium-efficiency motor*, *efficiency*, *EPAct motor*, *NEMA MG 1, NEMA Premium Motor™,* and *nominal efficiency*,

MOS transistor: A three-terminal electronic switch in which the conduction between the two main terminals (the drain and the source) is controlled by the voltage applied between the third terminal (the gate) and the source. The input current in the gate is almost zero, and the input power required to control the transistor is negligible. This leads to simple control circuits and improved efficiency.

Motor (electric): A machine that converts electrical power into mechanical power in the form of a rotating shaft. See *induction motor* and *synchronous motor*.

***Motor Challenge* program,** now *Industrial Best Practices: Motors*: See Chapter 9.

Motor repair: This area covers a range of services that involve the maintenance and repair of electric motors. These services can range from cleaning, preventive maintenance, and mechanical repair, to the replacement of the electrical winding. See *Electric Apparatus Service Association* and *motor rewind*.

Motor rewind: This procedure involves the removal of the motor stator winding and replacing it with a new winding. A rewind is usually performed on a motor that has experienced an electrical failure. Rewinding usually also involves other mechanical and electric repairs such as cleaning and bearing replacement. See *motor repair.*

National electrical code: The standards document setting forth accepted sizing and installation practices for electrical equipment, used as a reference in setting local building codes.

Natural commutation: A circuit in which the voltage applied to the thyristors reverses in polarity, leading to the turnoff of the device when the voltage crosses zero.

NEMA: National Electrical Manufacturers Association.

NEMA MG 1: A standard issued by the Motor Generator Committee of NEMA that provides design, labeling and application specifications for electric motors and generators. Table 12-10 provides the specification of energy-efficient motors that was incorporated in the EPAct Motor Standard. See *energy-efficient motor*, *EPAct*, *NEMA*, and *NEMA Premium Motor™.*

NEMA Premium Motor™: A minimum-efficiency specification for motors issued by NEMA. See *minimum-efficiency specification* and *NEMA.*

NEMA TP-1: A NEMA standard issued in 1996, entitled the *Guide for Determining Energy Efficiency for Distribution Transformers.* This standard specifies how cost of ownership for distribution transformers should be calculated and provides a default table, Table 4-2, of minimum-efficiency levels for different classes of transformers to be labeled "energy efficient." See *NEMA*.

Nominal efficiency: The average expected efficiency for a group of motors of the same specification. Half of the motors are expected to fall below the nominal value, and half above. NEMA's nominal efficiency (a rating indicating that the motor's nominal efficiency falls within a certain range) is now being stamped on the nameplate of most domestically produced integral-horsepower electric motors. See *minimum efficiency.*

Open drip-proof (ODP): A type of motor package ("enclosure") in which cooling is provided by an internal fan(s) forcing air through the motor. The ventilation openings are positioned to

keep out liquid or solid particles falling at any angle from 0" to l5" from the vertical.

Participation rate: The fraction (or percentage) of the eligible customers taking part in a program.

Part-load ratio: The ratio of instantaneous output from a piece of equipment to the equipment's rated output. For example, if a piece of cooling equipment is exercising 60% of its full cooling capacity, the part-load ratio is 0.6.

Peak cooling load: The maximum rate of cooling that occurs in a building during the year.

Penetration rate: The degree to which a technology has become the standard in a marketplace. For example, if energy-efficient motors are sold for 10% of the general-purpose motor applications, then they have achieved a 10% penetration rate in that market. The market context must be clarified for the penetration rate to be meaningful. For example, one needs to know if the target market is new applications or the existing stock.

Permanent-magnet (PM) motors: A family of motors in which a permanent magnet replaces the stator winding. In some small PM DC motors, the rotor is still fed by a conventional brush-and-commutator system. A more important type of PM motor has a stator with three windings producing a rotating field, as in induction and synchronous motors. The rotor consists of one or more permanent magnets that interact with the rotating field so as to align the poles in the rotor with the poles of the rotating field. The speed of the motor is the speed of the rotating field. Because there is no rotor current and the rotor magnetic field is constant, there are no losses in the rotor, helping to make PM motors more efficient (by five to ten percentage points in small sizes) than induction motors. The most common form of a PM motor is the brushless DC motor, also known as an electronically commutated motor (ECM).

Phase: The indication of the type of power supply for which the motor is designed. The two main categories are single-phase and three-phase (sometimes referred to as polyphase).

Poles: The ends of a magnet, which are always present in a pair consisting of a north and a south pole. Thus, the number of poles is always even. Poles may be located on permanent magnets or electromagnets. In AC motors, the synchronous speed is determined by the frequency of the power supply and the number of poles; four different motors operating at 60 Hz with two, four, six, and eight poles will have synchronous speeds of 3,600, 1,800, 1,200, and 900 rpm, respectively.

Positive displacement: A term used to describe mechanical equipment (such as compressors, pumps, and blowers) characterized by a reduction of the internal volume of a chamber, usually by a piston.

Power conditioning equipment: Electronic devices intended to correct power quality problems such as low power-factor or harmonics.

Power electronic devices: Electronic devices used for the direct control of electrical power to

various types of equipment, including motors. Power electronic devices are available with ratings up to about 5,000 V and 5,000 amperes, with a trend toward ever higher ratings.

Power-factor: The ratio between the real power (measured in watts or kilowatts) and apparent power (the product of the voltage times the current measured in volt-amperes or kilovolt-amperes). Power-factor is expressed either as a decimal fraction (zero to one) or a percentage (0% to 100%). In the case of pure sinusoidal waveforms (those not distorted by harmonics), the power-factor is equal to the cosine of the phase angle between the voltage and current waves in an AC circuit. This value is known as the displacement power-factor because it deals with the time displacement between the voltage and current. Since cosine values range from 0 to 1, the apparent power is always greater than or equal to the real power. If the power-factor is less than 1, more current is required to deliver a unit of real power at a certain voltage than if the power-factor were 1. In the case of waveforms that include harmonics, the harmonic current adds to the total current without contributing to the real power, so the power-factor is reduced. Many power electronic devices (such as ASDs) have high displacement power-factors (over 90%) but overall power-factors that are significantly lower, depending on design and operating conditions (see *current* and *voltage*). This higher current is undesirable because the energy lost to heat in the wires supplying power is proportional to the square of the current. In motors and other inductive loads operating in AC circuits, the current wave lags behind the voltage wave. When a capacitive load is applied to an AC circuit, the voltage wave lags behind the current wave. Since these are opposite effects, they can be used to cancel one another. Thus, capacitors can be (and very commonly are) used to correct low power-factor. In DC circuits, the power-factor is always 1. See *kilovolt-ampere* and *kilowatt*.

Public benefit fund: A fund collected as a surcharge on energy sales that is used to sponsor activities that benefit the public such as conservation and efficiency programs, low-income energy programs, and energy research and development. See *demand-side management*.

Pulley: See *sheaves.*

Reciprocating compressor: A machine that uses positive displacement pistons for compression. The pistons move back and forth within their cylinders, much as in a standard automobile engine. Common applications of reciprocating compressors are refrigeration, air conditioning (including reciprocating chillers), and compressed-air systems.

Rectifier: A two-terminal (a positive anode and a negative cathode) electronic device that conducts a current in one direction with low resistance and blocks the current flow in the opposite direction. Rectifiers are mainly used to convert AC power into DC power. The most common rectifiers produced are solid-state silicon devices. In the past, mercury rectifiers (using liquid mercury in a vacuum tube) were commonly used in high-current applications. See *inverter*.

Regeneration capability (also called regenerative braking): This is the return of energy to the supply system when a motor is braking, in which case the motor is working as a generator. The input stage of the ASD must have the capability to work as an inverter to pump the energy back to the AC supply.

Resistance: A property of electrical conductors that, depending on their dimensions, material, and temperature, determines the current produced by a given voltage difference across the resistance. Resistance is the property of a material that impedes current and results in the dissipation of power in the form of heat. It is measured in ohms; one ohm is the resistance through which a voltage difference of one volt will produce a current of one ampere.

Resistor: A device connected into an electrical circuit to introduce a specified *resistance.*

Retrofit: To replace an operating piece of equipment with a more efficient product (in contrast to replace on failure).

Rewind damage: Damage to a motor resulting from improper repair practices such as overheating the motor core during winding removal.

Rewinding: See *motor rewind*.

Root mean square (RMS): The constant value of a periodic current or voltage that when applied to a resistance would produce the same amount of power. RMS is also known as equivalent DC. The RMS value of a periodic quantity is equal to the square root of the average of the squares of the instantaneous values of the quantity for the period. For example, the mathematical expression of the RMS value of a current is

$$I_{RMS} = \sqrt{\frac{1}{\tau}\int_{t_1}^{t_2} I^2(t)dt}$$

where τ = the period of time for one cycle
t_1 = the time measurement starts
t_2 = the time measurement ends
$I^2(t)$ = the square of instantaneous value of the current at a time t between t_1 and t_2.

A similar expression applies to the RMS voltage and power values. If the quantity is a sine wave (the nominal form for voltage and current in AC circuits), the RMS value is 0.707 times the peak value of the wave.

Rotary compressor: A positive-displacement compressor that changes the internal volume of its compression chamber(s) by the rotary motion of its positive-displacement member(s). Two common types of rotary compressors are:

> **Rolling-piston compressor**: A small rotary compressor with its rotor aligned eccentrically within the stator; used in domestic refrigerators and some room air conditioners.
> **Screw compressor**: A rotary compressor that produces compression with two intermeshing helical rotors. Applications include medium-to-large refrigeration, and HVAC (including screw chillers) and compressed-air systems.

Rotor: The part of the motor that rotates.

SCR: See *thyristor*.

Screw compressor, screw chiller: See *rotary compressor.*

Seasonal energy efficiency ratio (SEER): A U.S. rating measure for unitary air conditioning equipment. Measured in a standard test that averages across different part-load ratios of equipment throughout a simulated cooling season. See *energy efficiency ratio.*

Self-commutation: Circuits that use electronic devices, such as transistors and gate-turnoff thyristors, that turn off by applying a small control signal at their input.

Service factor: The service factor is a multiplier that indicates the amount of overload a motor can be expected to handle. For example, a motor with a 1.0 service factor cannot be expected to handle more than its nameplate horsepower on a continuous basis. Similarly, a motor with a 1.15 service factor can be expected to safely handle continuous loads of 15% beyond its nameplate horsepower.

Servodriver: See *servomotor*.

Servomotor: A low-power electric motor that performs a positioning function. Examples include actuators for dampers, valves, and adjustable pulleys.

Shaded-pole motor: The shaded-pole motor, a type of single-phase induction design, is most commonly used in packaged equipment applications below 0.17 (1/6) hp. Although shaded-pole motors are cheaper than single-phase squirrel-cage motors, their efficiency is poor (below 20%) and their use should be restricted to low-power applications with a limited number of operating hours.

Sheaves: Grooved wheels attached to the motor shaft and to the shaft of the driven equipment, such as a fan. Sheaves transmit mechanical power by means of one or more belts that ride in the grooves of the pair of sheaves. Another name for sheave is pulley.

Silicon-controlled rectifier (SCR): See *thyristor*.

Slip: The difference between motor operating speed and synchronous motor speed, expressed either directly in revolutions per minute or as a percentage of synchronous speed (see *synchronous speed*). For example, an l,800 rpm motor operating at a full-load speed of 1,725 rpm is running at a s1ip of 75 rpm or 4.2%. Most standard induction motors run at a full-load slip of 2% to 5%.

Slip rings: In an AC motor, they are a set of metal rings that are mounted on the rotor shaft, and conduct current into or out of the rotor through stationary brushes.

Space conditioning loads: A building's heat losses and gains that need to be counteracted by heating or cooling in order to maintain a comfortable temperature and humidity.

Squirrel cage induction motor: A type of induction motor with a squirrel cage winding consisting of a number of conducting bars connected at each end by metal rings that are located in slots in the rotor core. The bars are parallel to the motor shaft; the rings are concentric with the axis of the shaft. This motor is the most common type in use. In order to deliver torque to a load, its shaft must run with slip, or below synchronous speed. See *induction motor, slip,* and *synchronous speed.*

Stator: The nonrotating magnetic section of a motor. In most induction motors, the stator contains the windings.

Synchronous motor: An AC motor in which the speed of operation is exactly proportional to the frequency of power to which it is connected (the motor operates with no slip). Synchronous motors generally have the rotor electromagnets supplied with DC power through slip rings. Since these motors produce little torque except at speeds near to the synchronous speed, they need special methods for starting.

Synchronous speed: The speed at which the motor's magnetic field rotates. It approximates the speed of no-load operation. A four-pole motor running on 60-cycle-per-second power will have a synchronous speed of 1,800 rpm; a two-pole motor at the same frequency will have a synchronous speed of 3,600 rpm. See *slip.*

TEFC (totally enclosed fan-cooled): A type of motor package ("enclosure") in which there is no air exchange between the inside and outside of the motor. The fan is located in a cover opposite the driving (power output) shaft and is driven by an extension of the motor shaft through the housing.

Temperature, ambient: The maximum safe room temperature surrounding the motor if it is going to be operated continuously at full load. In most cases, the standardized ambient temperature rating is 40EC (104EF). Certain types of applications, such as ships and boiler rooms, may require motors with a higher ambient temperature capability such as 50EC or 60EC. Note that this definition is specific to motors, in contrast to the general definition of *ambient.*

Temperature rise: The amount of temperature increase that can be expected within the windings of the motor when going from nonoperating (cool condition) to its temperature at full load and continuous operation. Temperature rise is normally expressed in degrees Celsius.

Throttle: A device that regulates the flow of a gas or liquid by directly restricting the flow. Discharge dampers, inlet vanes, and valves can all be throttles.

Thyristor (also called silicon-controlled rectifier [SCR] or phase-controlled rectifier): Electronic devices that have both the same capabilities as rectifiers and a third terminal (the gate). The gate allows conduction control from 0% to 100% when the polarity applied to the main terminals is positive. If the polarity is negative, the thyristor blocks the current like a rectifier.

Time rating: Most motors are rated for continuous duty, meaning that they can operate at full-

load torque continuously without overheating. Motors used in certain applications (such as waste disposers, valve actuators, hoists, and other intermittent loads) will frequently be rated for short-term duty such as 5 minutes, 15 minutes, 30 minutes, or 1 hour.

Torque: The twisting force exerted by the motor shaft on the load. Torque is measured in units of length times force in foot-pounds or inch-pounds (or for small motors, inch-ounces). For an illustration of the following types of torque, see Figure C-1.

Figure C-1. Typical Torque-Speed Curve

Breakdown torque: See *pull-out torque.*

Full-load torque: The rated continuous torque that the motor can support without overheating within its time rating.

Peak torque: Many types of loads, such as reciprocating compressors, have cycling torques where the amount of torque required varies depending on the position of the machine. The actual maximum torque requirement at any point is called the peak torque requirement. Peak torques are involved in types of loads (such as punch presses) that have an oscillating torque requirement. A motor's pull-up torque must be greater than the load's peak torque requirement to prevent stalling the motor.

Pull-out torque: The maximum amount of torque that is available from the motor shaft when the motor is operating at rated voltage and running at full speed. Also known as breakdown torque.

Pull-up torque: The lowest point on the torque-speed curve for a motor accelerating a load up to speed. Pull-up torque limits a motor's ability to accelerate its load and to meet a load's peak torque requirement. Some motor designs (typically NEMA Designs A and B) do not have a separate value for pull-up torque because the lowest point may occur at the locked rotor (starting) point. In this case, pull-up torque is the same as starting torque.

Starting torque: The amount of torque the motor produces when energized at full-rated voltage with the shaft locked in place. It is the amount of torque available when the motor is energized to break the load away (start it moving) and begin accelerating it up to speed. Also known as locked-rotor torque.

TP-1: See *NEMA TP-1*.

Transformer: The most common form of transformers is a device to increase or decrease the voltage in an AC system. The primary side of the transformer is connected to the source of power; the secondary side to the load. A step-down transformer (the most common type in transmission and distribution systems) reduces the primary voltage to the secondary voltage. A step-up transformer (used, for example, at power plants to increase the generation voltage to the transmission voltage) increases the primary voltage to the secondary voltage. Transformers work by using the current in the primary winding to create a changing magnetic field, which is used to induce a voltage (and thus, current, when connected to a load) in the secondary winding. Another common transformer type is the *isolation transformer*. Efficient transformers are specified in the *NEMA TP-1* standard.

Transistor: See *bipolar transistor*, *insulated gate transistor*, and *MOS transistor*.

Variable-air-volume (VAV): An HVAC system in which the amount of cooling is controlled by changing the air flow rate; VAV heating systems are also used, as well as VAV controls of room pressurization.

Variable-frequency drive (VFD): Another name for the most common type of electronic adjustable speed drive. This type of drive uses an electronic package between the fixed-frequency AC input and the motor. The speed is varied by supplying the motor with synthesized AC power of changing frequency. See *adjustable speed drive.*

Variable speed drive: See *adjustable speed drive.*

Ventilation: The introduction of fresh air into a building specifically for the purpose of maintaining good air quality. Air is usually drawn from outdoors but can also be purified, recirculated air. Often, the term ventilation is used loosely to include transport of any air, not just of fresh air. See *air transport system.*

Venturi: A constricted throat in an air passage creating a vacuum.

Voltage: The rated voltage under which a motor or related electrical equipment is designed to operate. In general, voltage is the electrical potential at any point relative to some reference point in a circuit. The voltage represents the energy level of a quantity of electrical charge (electrons) at that point in the circuit. In the Systeme Internationale system of measurement, the unit of voltage is the volt, which equals one joule of energy per one coulomb of charge (see *current*). When there is a flow of charge at a given voltage, this stream of energy is electrical power. This power is measured in watts (joules per second), which at any instant is equal to the product of the voltage and the current in the circuit.

Voltage-source inverter (VSI): A type of electronic ASD that converts the AC input to controlled-voltage DC, then synthesizes the variable-frequency AC output by using a DC-to-AC inverter. See *adjustable speed drive*, *current-source inverter*, and *variable-frequency drive.*

Watt: A unit of (usually) electrical power equal to one joule of energy flowing per second. See *kilowatt*.

Windage: Motor loss resulting from the aerodynamic drag of the spinning motor rotor.

Winding: Windings are the turns of insulated wire (usually copper) wrapped around the core of steel laminations in motor stators, transformers, inductors, and electromagnets. The stator windings are generally connected to the power supply. In squirrel cage motor rotors, the windings are several bars of uninsulated aluminum or copper, arranged in a cylinder and connected together at both ends by rings of the same material. The windings of wound rotor motors are similar to those of the motor stator. When a motor is rewound, the insulated wire is removed and replaced with new wire.

Wk^2: The symbol used for moment of inertia and measured in lb-ft^2. See *inertia.*

Wound-rotor induction motors: This class of motors feature insulated copper windings in the rotor similar to those in the stator. The rotor windings are fed with power using slip rings and brushes.