generator field circuit; a great many steps are thus obtained in an efficient manner. With constant field excitation on the motor the speed of the motor will vary approximately as the voltage on the generator.

Extremely wide speed ranges are possible with the adjustable voltage type of drive. Ranges as high as 10 to 1 are common and, by the addition of field control on the motors, ranges as high as 40 to 1 are permissible. This type of drive provides the advantage of good speed regulation over the entire speed range, as shown in Fig. 3 in which this type of drive is compared with the adjustable varying speed drive.

Typical specifications for d-c motor control are shown on page 613.

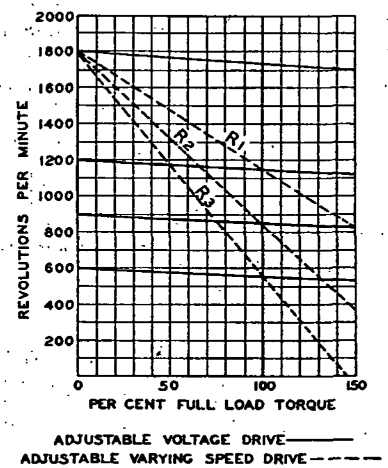

FIG. 3. SPEED TORQUE CHARACTERISTICS OF ADJUSTABLE VARYING SPEED DRIVE AND ADJUSTABLE VOLTAGE DRIVE

ALTERNATING CURRENT MOTORS

Alternating current motors are divided into two main classifications: *polyphase* and *single phase* (see Table 1), according to the type of power supply used. They are further subdivided as to the type of motor winding.

When polyphase power is available it is usually found more economical to apply polyphase motors in preference to single phase motors. A typical 5 hp, 1200 rpm capacitor start-induction run single phase motor, for instance, will cost approximately twice as much as the corresponding three phase Class B squirrel-cage motor. In addition, the polyphase motor has the advantages of higher power factor and higher efficiency.

Polyphase Motors

The three types of polyphase motors are: *squirrel-cage induction* motors, *wound rotor induction* motors, and *synchronous* motors.

Squirrel-Cage motors are specified by *NEMA* in classes providing a variety of speed and torque characteristics. Class A motors provide normal starting torque at normal starting current and are suitable for constant speed application, to equipment such as fans and blowers, in which *starting current need not be limited.* Class B motors provide normal starting torque at low starting current and are used for the same type of application as Class A *where starting current must be limited.* Class C

motors provide high starting torque with low starting current and are used on compressors, started without unloaders, and on reciprocating pumps. Class D motors have high slip* and are used with flywheels for widely pulsating loads on equipment such as reciprocating compressors and pumps where other motors would draw high peak currents.

Figs. 5, 6, 7, and 8 illustrate the characteristics of squirrel-cage motors. It will be noticed by inspection of Fig. 6 that both power factor and efficiency are improved if the motors are operating as near rated load as possible. In addition, as shown in Fig. 8, power factor and efficiency are better for higher speed motors.

Typical specifications for squirrel-cage motors are shown on page 613.

Wound Rotor motors are used for applications requiring high starting torque at low starting current, because a wound rotor motor with its

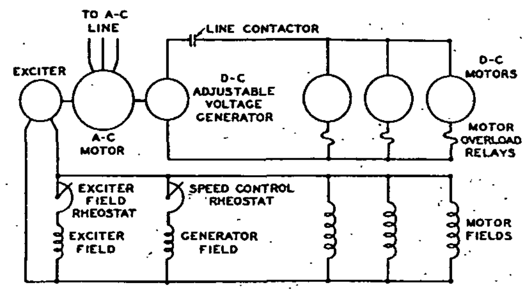

FIG. 4. COMPONENT PARTS OF AN ADJUSTABLE VOLTAGE DRIVE

controller and resistance can develop full load torque when starting with about full load current. For comparison, a squirrel-cage motor would require from 3 to 5 times as much current to develop full load torque at starting. The wound rotor motor is also used for varying speed service to drive fans, blowers, and other continuous duty apparatus. Typical specifications for wound rotor motors are shown on page 616.

The addition of resistance to the secondary winding of the wound rotor motor changes the speed torque characteristics as indicated in Fig. 9. The motor speed, with the resistance added, is dependent on load and consequently the motor has very poor speed regulation when secondary resistance is added to reduce the speed to values below 50 per cent.

Synchronous motors are used for continuous duty applications at constant speed where efficiency and power factor are important. Another advantage of these motors is that of lower initial cost in large sizes and for low speeds when compared with squirrel-cage type motors.

The outstanding advantage of the synchronous motor is that its power factor can be changed to compensate for the low power factor of other drives in the same location. Lagging power factor is an inherent characteristic of all induction apparatus, such as induction motors and neon signs. Unless synchronous motors or capacitors are installed, the plant power factor may be comparatively low. This does not necessarily mean that corrective equipment must always be installed, but in most cases it is desirable to determine what advantages may be gained by improving

*Refer to Glossary at end of Chapter.