speed and varies widely with a change in load, especially with high series resistance. Fig. 3 illustrates typical speed characteristics of this type of motor for different values of armature resistance.

The addition of series resistance in the armature circuit reduces the motor speed by lowering the voltage on the armature. At one-half speed the voltage is approximately one-half of line voltage. Consequently, with rated full load current the power delivered by the motor will be only one-half of the maximum, *e.g.*, it will be 5 hp from a 10 hp motor, because the other 5 hp will be lost in the resistance. It is, therefore, evident that the efficiency of the motor is reduced at reduced speeds due to the loss in the resistor.

Control for the adjustable varying speed motor is similar to that for the constant speed motor, with the exception that the starting resistor must be designed for speed regulating duty and must therefore be capable

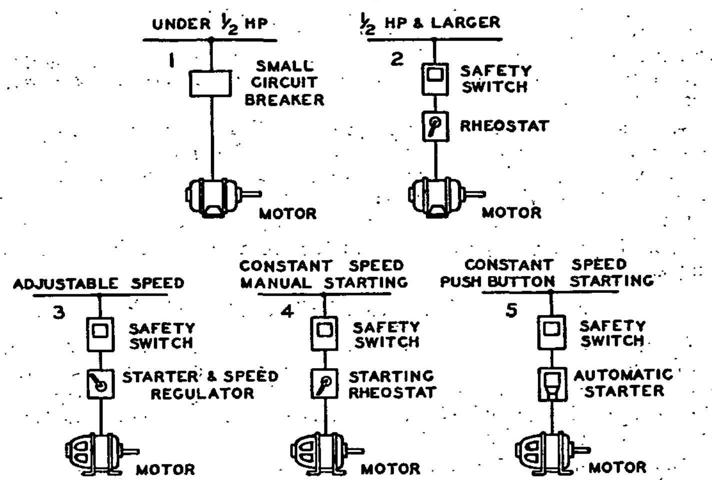

FIG. 2. RECOMMENDED CONTROLS FOR d-c MOTORS

of carrying the motor current continuously. Speed controllers are available both for constant torque applications and varying torque drives (such as required by fans) in which the torque is reduced considerably at reduced speed.

The *Adjustable Voltage* type of speed control is also often known as the variable voltage or Ward-Leonard system. For machines requiring a wide range in speed control and a large number of steps of control this type of system is used most extensively. The drive consists of one or more d-c motors, the armatures of which are supplied with power from a d-c generator, and the fields of all machines are excited from a constant voltage exciter. A schematic diagram of connections for an adjustable voltage drive is shown in Fig. 4. In most cases the d-c generator is a part of a three-unit set including a constant speed a-c driving motor, and a constant voltage exciter. As the voltage on the generator, and consequently on the d-c motor or motors, is adjusted by a rheostat in the generator field circuit, a great many steps are thus obtained in an efficient manner. With

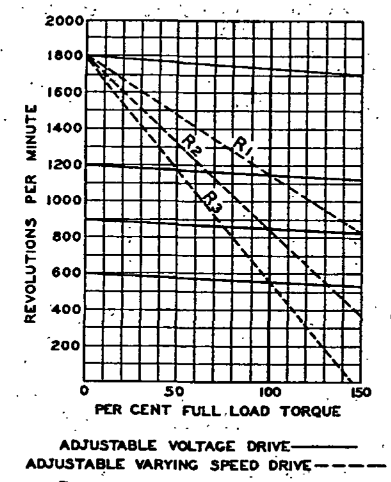

FIG. 3. SPEED TORQUE CHARACTERISTICS OF ADJUSTABLE VARYING SPEED DRIVE AND ADJUSTABLE VOLTAGE DRIVE

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 in Specification B at end of chapter.

ALTERNATING CURRENT MOTORS

Alternating current motors are divided into two main classifications: *polyphase* and *single phase* (see Table 5), 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

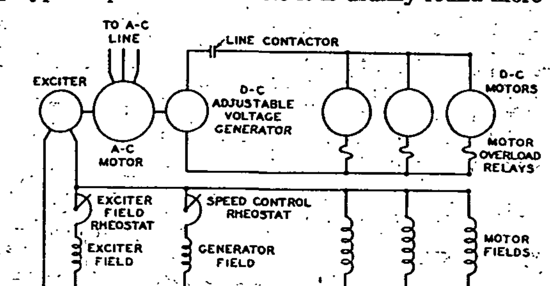

FIG. 4. COMPONENT PARTS OF AN ADJUSTABLE VOLTAGE DRIVE