winding. Squirrel-cage induction motors may be 2, 3 or 4 speed. Two-speed induction motors are usually of single winding type, having a 2 to 1 speed ratio such as 600 rpm and 1200 rpm, or may be double winding. Three-speed induction motors are always two-winding, and four-speed motors are usually two winding with a 2 to 1 speed ratio in each winding. Motors can be provided in constant torque, varying torque, or constant horsepower ratings. The constant horsepower type of motor is considerably larger than the constant torque motor, due to the fact that the same horsepower must be developed at either reduced speed or high speed.

In selecting two-speed motors for fan, pump, blower, or compressor applications, it is usually found that two winding motors are more expensive than the single winding type. The control cost for two-speed, two winding motors, however, is more economical, and therefore the combined

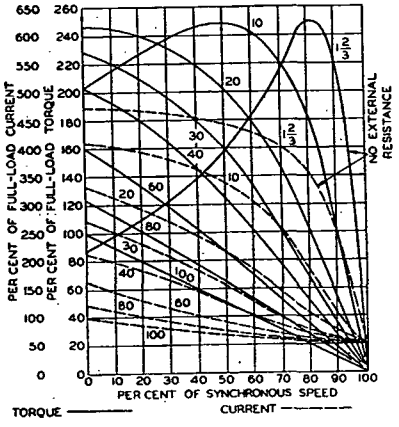

FIG. 3. SPEED-TORQUE SPEED-CURRENT CHARACTERISTICS OF WOUND ROTOR MOTORS

price of both motor and control for the two winding motor is only slightly higher. Because of the improved performance of the two winding motors, and because of the factor of safety provided by two independent windings, the increased cost is frequently worth the difference.

Single Phase Motors

Single phase induction motors have auxiliary windings or devices for starting, and are classified by the method used.

Capacitor start motors develop high starting torque in fractional horsepower ratings, and moderate starting torque in larger ratings. They are used for constant speed drive such as fans, blowers and centrifugal pumps. During the starting period, a winding with a capacitor in series is connected to the motor circuit and when the motor comes up to speed, a centrifugal switch cuts the capacitor and second winding out of the circuit.

Two-value capacitor motors develop high starting torque employing a starting capacitor and a running capacitor. The starting capacitor gives high starting ability, but is suited for short time operation only, and is cut out for the running condition by a centrifugal switch. The running capacitor gives high efficiency at full speed. These motors are used on compressors, reciprocating pumps and similar equipment which may start under heavy load.

Permanent split capacitor motors have low starting torque and are ideally suited for small fan drives. Operation is similar to the capacitor start motor, except that the capacitor is not cut out when running.

Repulsion-Start Induction-Run motors develop high starting torque. The motors have a wound rotor connected to a commutator for starting. A centrifugal switch shorts the commutator bars when the motor comes up to speed to obtain a winding approximately like the squirrel cage in its function.

Repulsion-Start Induction-Run motors are suitable for applications, such as industrial compressors, requiring high breakaway torque, and where commutator and brush noise are not factors.

TABLE 5. TYPICAL APPLICATION REQUIREMENTS OF SYNCHRONOUS MOTOR DRIVES SHOWING STARTING, PULL-IN AND PULL-OUT TORQUES

	Application	Method of Connecting Motor to Load	Starting Conditions	Torques			Remarks
				Starting	Pull-in	Pull-Out	
Fans	Exhaust and ventilating	Coupled or belted	Usually loaded	50	60–125	150	WR^2 of fan must be considered
Blowers	Cycloidal positive	Coupled or engine type	Unloaded	40–60	40–60	150	Two-speed motors sometimes used
Blowers	Blowing engines reciprocating	Engine type	Unloaded	40	40–60	150	
Blowers	Turbo high speed	Direct connected or step up gear	Unloaded (intake closed)	30	50	150	WR^2 of blower must be considered
Compressors	Air	Engine type	Unloaded	40	30	150	Flywheel effect important
Compressors	Ammonia and ammonia booster	High speed—belted Low speed—engine type occasionally coupled	Unloaded (by by-pass)	40	30	150	Flywheel effect important
Compressors	Freon	High speed—belted Low speed—engine	Unloaded (by by-pass)	45	50	150	Flywheel effect important
Compressors	Gas reciprocating	High speed—belted Low speed—engine	Unloaded (by by-pass)	40	30	150	Flywheel effect important

Split Phase motors have a high resistance auxiliary winding which is in the circuit during starting, but is disconnected through the action of a centrifugal switch as the motor comes up to speed. Under running conditions it operates as a single phase induction motor with one winding in the circuit. These units are available for the small horsepower ratings, and when equipped with a high slip rotor, may be used for adjustable varying speeds through line voltage control. The motors are ideally suited for fan duty.

Speed-torque characteristics of single phase motors are shown in Fig. 4.

Full voltage starting of single phase motors is general practice, but since most of these motors are connected to secondary distribution systems located in light load density areas, power companies check carefully the starting currents in order to prevent objectionable voltage dips. This is particularly important for motors started frequently, such as those controlled by pressure or temperature sensitive devices and applied to refrigerators, stokers, oil burners, and water pumps.