torque at low starting current, because a wound rotor motor with its 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 or wound rotor motors are shown in Specification D at end of chapter.

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

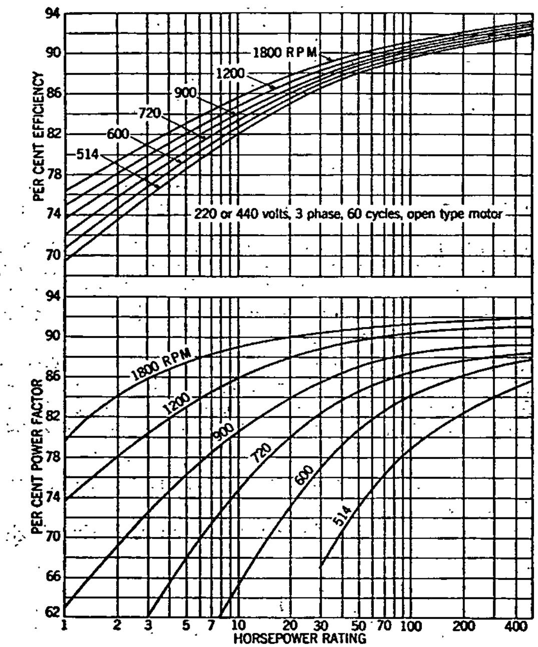

Fig. 8. Efficiencies and Power Factors for Squirrel-Cage Induction Motors

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 the power factor. With purchased power, if the rates include a clause embodying a penalty for low power factor, or a bonus for high power factor, the saving in power costs may often make a very good return on the investment required for the corrective equipment.

Synchronous motors are used to drive fans, blowers, pumps, compressors and other applications. Compressor applications having a high peak torque require the use of flywheels to smooth out power peaks, and should always be referred to the electrical manufacturer for recommendations.

Synchronous motors are provided with built-in damper windings on the rotor and operate during the starting period similarly to squirrel-cage motors. After the motor is nearly up to speed, field excitation is applied

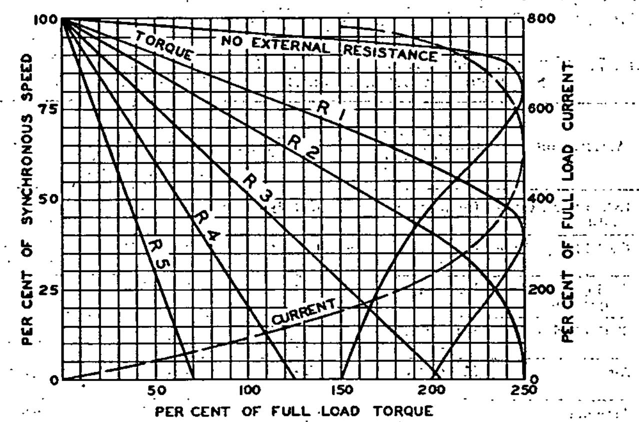

Fig. 9. Performance Characteristics of A Wound Rotor Motor with External Resistance

and the motor draws into step at synchronous speed. After excitation is applied the motor runs at exactly constant speed and will remain at this speed until a load approaching the pull-out load is reached, whereupon the motor pulls out of synchronism and stops.

In applying synchronous motors consideration must be given to the torque the motor can develop on pull-in, that is, at the instant when field excitation is applied. Table 7 shows typical application requirements of synchronous motor drives, listing starting, pull-in, and pull-out torques.

Typical specifications for synchronous motors are shown in Specification E at end of chapter.

Multi-Speed motors provide flexibility in many types of drives. Synchronous motors can be furnished only with a 2 to 1 ratio in speed, single 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