With new insulations, steels, designers obtain more motor per

With 85% of industry's machines powered by motors, changes in practice have wide significance. One is a swing to full-voltage starting, even for motors up to 3000 hp. This means simple, less-costly control, less maintenance. But before adopting it, check your generating equipment or utility supply to be sure it can handle the starting currents.

Another trend: Growing use of adjustable-speed equipment and dc motors meets the precision and production-volume demands of modern machines.

Perhaps most important: Motor manufacturers pack more horsepower into each pound of motor. This has been going on for years. But, as of Jan. 1954, you'll see the first trickle of new NEMA rerated motors coming into industry. Some will fit twice as much horsepower into the same sizes.

Today's frames pack more hp

For the time being, this NEMA rerating of motors is confined to integral sizes to 30 hp. How did it come about? Remember, many motor frame sizes used today were established 25 years ago. During that time there have been two significant advances: better insulations and better lamination materials.

Motor insulations, based on 1929 standards, included cotton-covered wire, paper and cotton slot and phase coverings. Impregnating varnishes were made of natural resins, oils and solvents. So to get suitable dielectric strength, a considerable mass of insulation was needed.

Insulations today incorporate synthetic materials. For example, today's synthetic-resin coating on wire is thinner but offers higher resistance to leakage than the old double-cotton covering. *Synthetic materials in slots, between the phases and in lead protection, are doing an all-around better job.* Synthetic varnishes more thoroughly impregnate, bind and protect the windings.

Thus synthetics mean less insulation mass is required. Less mass of insulation means more copper can be put into a stator slot. Right off, this gives a stronger magnetic circuit. But a big secondary advantage is in heat transfer. Less mass of insulation means greater heat transfer from copper through to the iron and off to the cooling medium.

Better lamination materials give reduced iron loss. These rerated motors will operate at higher flux densities, meaning less iron required for a given horsepower.

But while frame sizes come down, shafting sizes hold the same. *Why? There have been no comparable advances in shafting design and materials, so more output from a given frame size means a proportionately larger shaft.*

This NEMA rerating is a recommendation *only*, so all manufacturers don't have to adopt it. But they will. To you, rerating will mean need to stock additional renewal parts and some additional motors during the transition period. Will you get the same degree of liberality in design? Yes. More horsepower is being packed into smaller frames, but each motor *will hold to all existing NEMA performance standards* covering torque, starting current, temperature rise, etc.

For most jobs, ac motors suit

To get the proper perspective on today's motor picture, remember that the ac polyphase induction motor is used in 9 out of 10 industrial applications. This group includes the ever-popular squirrel-cage, the wound-rotor, and the adjustable-speed commutator motor. The squirrel cage is the granddaddy and the widest used. In one form or another, it drives more machines in industry than any other motor type. It is simplest in construction, has lowest wearing parts. This boils down to low maintenance and low first cost.

The usual squirrel-cage motor runs at constant speed. The "multi-speed" type has additional windings, permitting it to operate at two or more fixed speeds. Whatever the speed, it is held reasonably steady regardless of load changes. And because most industrial machines do run at a constant speed, the one or more fixed rates available from a squirrel cage make it suitable for many applications.

The second polyphase induction machine is the wound rotor, often called the slip-ring type. Speed can be adjusted but will vary with load when far below rated speed. The wound-rotor type fits on a conveyor drive, for example; torque can be increased or decreased to meet changes in the load. Keep it in mind also on power systems with limited capacity: it provides high starting ability with low inrush current.

Third in the polyphase induction group is the adjustable-speed commutator motor. Although little used compared to its brothers in the induction group, this motor offers a speed variation of about 4:1 for continous operation and over 20:1 for intermittent operation. This type often takes the place of a squirrel-cage motor combined with an adjustable-speed mechanical transmission.

When it comes to synchronous motors, we find most of them driving heavy machines. They can start and accelerate even *the heaviest loads, pull them at constant speed.* About 500 rpm is dividing line between so called low and high speed.

Many plants today are specifiying synchronous motors with 0.8 leading power factor for all big drives. In addition to constant speed and power factor improvement, synchronous motors are also used because: (1) they often cost less than other motors when properly applied (2) they offer a power-cost saving. This results from high efficiency — up in the 93 to 97% range. But when examining the high-efficiency angle keep in mind the somewhat greater maintenance resulting from dc excitation, brushes, slip rings and rotating field.

For speed control, dc gets nod

Where an ac motor won't do the job satisfactorily, consider a dc motor. They are premium priced products, especially in larger sizes. But they offer topnotch adjustable speed, effective and simple control of torque, acceleration and deceleration. Even with limitations of a commutator they can and do *handle tough duty cycles.*

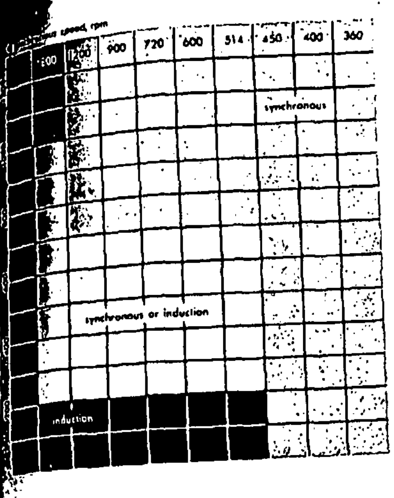
Yes, the dc motor is growing rather than slipping. Need for critical speed adjustment in continuous processes often finds dc motors operated in tandem with speed of each unit changing proportionally over a wide range.

Speed can be adjusted in the dc motor in two ways. *Armature voltage can be varied, or you can vary field current.* In some cases, both are varied. Raising armature voltage speeds up the motor, raising field current slows it.

A few words about dc motor size: Rule of thumb says that maximum economical size is not exceeded as long as product of horsepower and speed is less than 1.5 million.

Voltage-wise, think in terms of 250 volts for units up to 250 hp, 600 v for 600 to 1000 hp, 700 or 900 v above 1000 hp.

Where do you get the dc voltage? A close tally today shows that 95% of all dc motors operate from ac systems, through conversion equipment (see pp 120, 121).



Synchronous or induction?

One of today's *big* motor questions is when to use a synchronous unit and when an induction. Here's the thinking:

Synchronous motors *can* be used for any application a NEMA design-B squirrel-cage will handle. But whether a synchronous *should* be used is another matter. Cost-wise, here's a handy rule: Synchronous motors are less expensive than squirrel-cage if rating exceeds 1 hp per rpm. But this doesn't take into account the higher power factor and efficiency of the synchronous motor. These two factors alone are mighty important in low-speed motors (450 rpm or less), where pf and efficiency of squirrel-cage motors are poor.

For especially low starting kva, when controllable torque, kva or variable speed is wanted, either a wound rotor or a constant-speed motor and slip coupling may be used. Power factor and efficiency of today's 3600-rpm squirrel-cage motors are good. And this holds too for 1800 rpm. So unless pf improvement is especially important, squirrel-cage motors are logical first choice. But rarely will you find induction motors doing a good job below 500 rpm because of low pf and efficiency; synchronous motors, with leading or unity pf, show good efficiencies down to 72 rpm.

What about leading-power-factor motors? They're generally less efficient than unity-pf. But they do double duty. Use them in *your plant* when: (1) you need power-factor correction (2) you want motors to handle exceptionally high starting, pull-in or pull-out torque.

summary of motor characteristics and applications

dc and single-phase motors

Speed Regulation	Speed Control	Starting Torque	Breakdown Torque	Applications
SERIES				
[illegible]	Zero to maximum depending on control and load	High. Varies as square of voltage. Limited by commutation, heating line capacity	High. Limited by commutation, heating and line capacity	Where high starting torque is required and speed can be regulated. Traction, bridges, hoists, gates, car dumpers, car retarders
SHUNT				
[illegible]	Any desired range depending on design, type of system	Good. With constant field, varies directly as voltage applied to armature	High. Limited by commutation, heating and line capacity	Where constant or adjustable speed is required and starting conditions are not severe. Fans, blowers, centrifugal pumps, conveyors, wood and metal-working machines, elevators
COMPOUND				
[illegible]	Any desired range, depending on design, type of control	Higher than for shunt, depending on amount of compounding	High. Limited by commutation, heating and line capacity	Where high starting torque and fairly constant speed is required. Plunger pumps, punch presses, shears, bending rolls, geared elevators, conveyors, hoists
SPLIT-PHASE				
[illegible]	None	75% for large to 175% for small sizes	150% for large to 200% for small sizes	Constant-speed service where starting is easy. Small fans, centrifugal pumps and light-running machines, where polyphase is not available
CAPACITOR				
[illegible]	None	150 to 350% of full load depending on design and size	150% for large to 200% for small sizes	Constant-speed service for any starting duty and quiet operation, where polyphase current cannot be used
COMMUTATOR-TYPE				
[illegible]	Repulsion-induction, constant. Brush-shifting types, 4 to 1 at full load	250% for large to 350% for small sizes	150% for large to 250% for small sizes	Constant-speed service for any starting duty where speed control is required and polyphase current cannot be used

2- and 3-phase motors

Speed Regulation	Speed Control	Starting Torque	Breakdown Torque	Applications
GENERAL-PURPOSE SQUIRREL-CAGE (Design B)				
Drops about 3% for large to 5% for small sizes	None, except multi-speed types, designed for 2 to 4 fixed speeds	150% of full load for 2-pole to 105% for 16-pole designs	200% of full load	Constant-speed service where starting torque is not excessive. Fans, blowers, rotary compressors, and centrifugal pumps
HIGH-TORQUE SQUIRREL-CAGE (Design C)				
Drops about 3% for large to 5% for small sizes	None, except multi-speed types, designed for 2 to 4 fixed speeds	250% of full load for high-speed to 200% for low-speed designs	200% of full load	Constant-speed where fairly high starting torque is required infrequently with starting current about 550% of full load. Reciprocating pumps and compressors, crushers, etc.
HIGH-SLIP SQUIRREL-CAGE (Design D)				
Drops about 10 to 15% from no load to full load	None, except multi-speed types, designed for 2 to 4 fixed speeds	225 to 300% of full load, depending on speed with rotor resistance	200%. Will usually not stall until loaded to max. torque, which occurs at standstill	Constant-speed and high starting torque, if starting is not too frequent, and for high-peak loads with or without flywheels. Punch presses, shears, elevators, etc.
LOW-TORQUE SQUIRREL-CAGE (Design F)				
Drops about 3% for large to 5% for small sizes	None, except multi-speed types, designed for 2 to 4 fixed speeds	50% of full load for high-speed to 90% for low-speed designs	135 to 170% of full load	Constant-speed service where starting duty is light. Fans, blowers, centrifugal pumps and similar loads
WOUND-ROTOR				
With rotor rings short-circuited, drops about 3% for large to 5% for small sizes	Speed can be reduced to 50% by rotor resistance. Speed varies inversely as load	Up to 300% depending on external resistance in rotor circuit and how distributed	300% when rotor slip rings are short circuited	Where high starting torque with low starting current or where limited speed control is required. Fans, centrifugal and plunger pumps, compressors, conveyors, hoists, cranes etc.
SYNCHRONOUS				
Constant	None, except special motors designed for 2 fixed speeds	40% for slow- to 160% for medium-speed 80% pf. Specials develop higher	Unity-pf motors 170%; 80%-pf motors 225%. Specials up to 300%	For constant-speed service, direct connection to slow-speed machines and where power-factor correction is required