value of load. Reducing the speed, by increasing the rotor resistance, results in increased I^2R loss in the rotor. When this occurs, the efficiency decreases in direct proportion to the increased slip and rotor resistance.

It is also possible that the conveyor *load is too light for the motor, keeping in mind load is necessary for effective speed reduction. As this point is frequently overlooked when slipring motors* are used it is suggested that a wattmeter be connected to the motor and the true load readings obtained.

Study of the above curves shows the speed regulation of a slipring motor *poor as the motor increases its speed* with a reduction of load, or vice versa. *Ira A Butcher, Piney River, Virginia.*

Formula and Proof Shown

THE FORMULA TO DETERMINE secondary resistance in a slipring motor is:

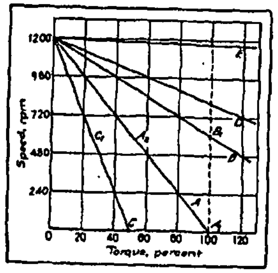
$$R = \frac{Hp \times 249}{I^2}$$

$$= \frac{150 \times 249}{(190)^2} = 1.04 \text{ ohms}$$

Where R equals external secondary resistance in ohms per phase causing motor to exert 100% torque at zero speed; Hp is the full-load rating (150); I equals full-load secondary current (190 amp).

If three 1.04-ohm resistors are connected in Y, the motor will not start under full load. This includes internal rotor resistance which we can neglect for practical purposes. Under this condition, all the rotor energy is being dissipated in the resistor.

To get a clear picture of what the speed-load conditions are, refer to the above curve. Point A_1 shows motor speed as zero at 100% load. If the load is reduced by half, speed is 600 rpm as indicated by point A_2.



JHV does not state what speed he wants at full load. If he changes the variable resistor from 1.04 to 0.52 ohms per phase, speed will vary according to curve B. When carrying full load the speed would be 600 rpm. On the other hand, if resistances are doubled to *2.08 per phase, we get curve C and the* motor won't start until the load is re*duced 50%. At half speed the load is* reduced to 25% (point C_1 on curve C).

JHV says the speed is 800 rpm at full load. This would correspond to curve D and by interpolation it is evident that the resistance per phase is less than that used in curve B. *Curve E is drawn to show the motor speed with rings* short circuited.

Following is proof of the formula:

$$Hp = \frac{I^2R}{249}$$

With sufficient resistance in the motor secondary to barely stall the motor under full load, a total of 150 hp is being dissipated in heat. In other words, the current squared in each leg multiplied by 3, since there are 3 rings, is $3I^2R$. Divide this amount by 746 for 746 watts = 1 hp. Hence: $3I^2R \div 746 = I^2R \div 249$ = hp dissipated, which in this case = 150 hp.—RFE

Space Taps Evenly, Adjust With Load

VALUES OF rotor current and rotor voltage between rings are necessary to find the required resistance. The following formula is used to find the ring voltage:

$$E_2 = \frac{hp \times 746}{1.73 \times I_2 \times K}$$

Where E_2 = voltage between rings, I_2 = rotor current, Hp = horsepower, $K = 1 - \%$ slip. The slip is 4.15% with rings short circuited at full load. Hence:

$$E_2 = \frac{150 \times 746}{1.73 \times 190 \times .9585} = 358 \text{ v}$$

Resistance required for a given starting torque is found as follows:

$$\text{Resistance per phase} = \frac{E_2}{1.73 \times I_2 \times T}$$

Where T = torque required on first step of controller, expressed for 100% full-load torque as 1.00, or 150% flt as 1.50, and so on. Assuming 100% flt:

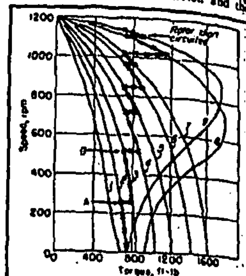
$$\text{Res per phase} = \frac{358}{1.73 \times 190 \times 1.00} =$$

1.09 ohms per leg in a Y-connection.

To obtain even acceleration, I would space the taps on the grids equal resistance values apart *and make corrections under actual* operating conditions.

On curve below, marked lines show torque-speed relations as motor is accelerated. Only nine steps are shown.

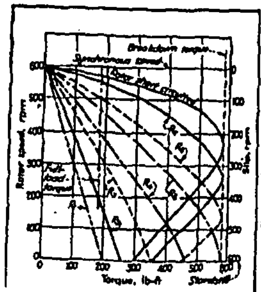
Assuming the motor can just start the load on the second notch and the torque required by the load is the full-load value, the motor will accelerate to *point A on curve No. 2* corresponding to 260 rpm. On further movement to third notch, the rotor speed shifts to No. 3 curve and steadies away at point *B*, or 520 rpm. This is repeated as controller is moved until rotor is short circuited at the rings. *J A Coulden, Hamilton, Ontario.*



Curve showing speed-torque relations assuming constant torque. Numbers correspond to various controller notches.

Torque Curves Analyzed

IF HE TAKES MEASUREMENTS as indicated, *JHV* can plot curves like those shown. Typical readings and calculations are given as an example for a 3-phase 440-v 60-cycle induction motor.



(Continued on page 138)