VARIABLE SPEED MOTOR CONTROL.

INTRODUCTION BY PRESIDENT SCOTT.

The applications of electricity lead to the revolution of old methods, as well as to the evolution of new ones. Electrical apparatus not only replaces that which it supersedes and performs the work more efficiently, but it also broadens the field and leads to developments which were impossible by former methods. For example, the electric light does not simply replace indoor lamps and flickering street lights, but it has revolutionized the whole art and practice of illumination. The first railway motors were made to have a little greater power than the horses or mules which they replaced, but electric cars have increased in size and in speed, they have extended out from the city to the suburbs, they connect adjacent towns, and in a dozen years great systems have developed which have little in common with the horse cars. The electric crane has been the prime factor in modernizing the methods of manufacturing where heavy work is to be turned out. The electric distribution of power to the machines in a factory not only accomplishes more effectively the service which other systems of power distribution had accomplished, but it is capable of other things as well. Because volts and amperes are more easily measured than speed and torque, the power consumption of tools may now be definitely known. The electric motor affords an effective means of securing speed variation.

The revolution of old methods and the evolution of new ones are both taking place in the machine shop through the application of the electric motor to the driving of tools. Plenty of power effectively applied with a speed control which is wide and flexible, together with new kinds of cutting tools and heavier

machines in which to use them, make possible an increase of output which seems almost incredible.

In a sense, speed variation is a purely mechanical matter. The two factors which determine mechanical work are speed and torque. The relations between speed and torque may be varied in definite ratios by means of belts and pulleys or by gearing. There is, however, no general mechanical solution of the mechanical problem of speed variation, or variable speed control. There are devices by which either of several fixed ratios may be selected; for example, common cone pulleys which allow the shifting of a belt from one pair of pulleys to another having different diameters, or the counterpart of this, several sets of gears, either one of which may be selected at will. There are indeed a number of mechanical variable speed devices by which the speed ratio may be changed by very small increments. Many of these devices are quite successful over a certain limited range of speed variation or of power capacity. In general, those which are satisfactory over a fairly wide range are limited in the amount of power which they can transmit.

On the other hand, speed variation by the electric motor can be so successfully effected that it is quite common to think that the whole problem of speed control should properly be turned over to the electrical engineer. It is regarded as a matter of course that all mechanical means for accomplishing the result are to be discarded if possible, and the difficulties which the mechanical engineer has failed to overcome in the purely mechanical problem of varying the ratio between speed and torque are to be imposed upon the electric motor.

It is reasonable to presume that the solution of a problem which has proved so difficult mechanically may involve electrical difficulties as well. Although electrical apparatus may be provided which will accomplish the desired purpose, yet this may be at the expense of added complication, additional apparatus, or increased cost. It is not proper, therefore, to decide *a priori* that because speed variation *can* be effected by an electric motor that the variable speed motor should *always* be used regardless of conditions, specific requirements and cost.

Electric motors for continuous current may be divided into two types, represented by the series motor in which the speed varies when the load changes, and the shunt motor which in general has a speed which is constant with different loads. The series motor is particularly adapted for railway service,

crane service and the like. The shunt or constant speed motor may operate at the same speed at all times, or the speed may be changed at the will of the operator, and the motor will then run at a desired speed independent of the load. The speed of the motor depends upon the number of turns in series in its armature, the strength of its field and the e.m.f. applied to its armature. In practice, speed changes are produced by one of these three methods, or by combinations of them. When the shunt motor is arranged to run at different speeds over a considerable range, it will usually be found that the generating plant and the supply circuits are of special type, or the controlling devices are of complicated form, or the motor is of greater weight and cost than it would be if it operated at one speed only. Therefore, a constant speed direct current shunt motor is to be preferred *per se* to a variable speed motor.

The alternating current induction motor like the shunt motor is inherently adapted for constant speed service. It may be used also for variable speed work with characteristics analogous to those obtained with the rheostatic control of a shunt motor with unvaried field. It may also be wound so that either of several numbers of poles may be used, thereby securing either of several definite speeds, which are sensibly constant with varying load. Just as a shunt motor may be operated at different speeds from generators giving different voltages, so the induction motor may be operated at different speeds from generators giving different frequencies. The single speed induction motor is, however, the type usually used.

In selecting the apparatus for a new plant it is proper to consider the problem as a whole, to take a general view before concentrating attention upon specific parts. What proportion of the power is to be supplied at constant speed? What proportion of the variable speed work cannot be served satisfactorily from a constant speed drive with variable pulley ratios or variable gear ratios? What proportion of the work which requires delicate speed adjustment falls within the range of simple and satisfactory mechanical speed changing devices? What advantage in lessened cost of equipment will be secured by group driving, by furnishing a single large motor for delivering the average power required by a number of machines instead of a large number of small motors each for delivering the maximum power of the machine to which it is connected? What advantage will there be under the particular surroundings of the installation in

reducing the complication and the amount of auxiliary apparatus and putting in motors of the simplest possible type? Taking the plant as a whole, what are the general advantages of one type of apparatus over another, and does the general balance sheet show that the advantages of individual speed control by means of the motors themselves are of sufficient moment to dictate the scheme and plan for the whole installation? The varying answers which will be given to these questions in different cases will necessitate different solutions to the problem of selecting the best system.

We are fortunate, this evening, in having presented to us several methods of speed control of continuous current motors. These methods are not theoretical and untried; they have the prestige of being methods which are in actual commercial operation, and of having been selected by manufacturing companies as being well adapted for general service. Although speed control can be effected so admirably by the electric motor, it is fitting that we should not go too far and apply the variable speed motor indiscriminately. The various methods of control which we are to consider this evening must be taken as specific ways by which certain ends can be accomplished; and it must be recognized at the same time that there is the larger problem to be determined in connection with each proposed installation; viz., whether on the whole speed variation by the motor itself should be chosen.