drill has usually been from 25 to 35 feet per minute. With the new drills these speeds have been more than doubled, with compounding increase of the feed and an even greater difference in the total number of inches drilled. This means a stiffer machine, more belt power, and the use of positively geared feeds.

The milling machine is beginning to feel the new influence, and both speeds and feeds are being increased, more particularly the latter. A feed of two or three inches per minute used to be considered good practice. To-day ten or even fifteen inches per minute are not excessive for the travel of the table.

Experience has shown that increasing the feed is more profitable than speeding up the cutter. The principal changes that are noticeable as a result of the new practice are a strengthening and stiffening of the support for the cutter arbor and a substitution of geared for belted feed motions.

It is to be noted, however, that the increase in power required with the new steels is not so great as the increase in output secured. There are numerous instances where the work done has been more than doubled,, while the power increase required has not been more than 50 per cent. The average consumption of power by carbon steels is usually 0.05 or 0.06 horse-power per pound of metal removed per hour, and the new steel will require only 0.03 or 0.04 horse-power.

The increasing use of electric motors is, or should be, a factor in the development of machine design. Except in a very few instances, however, little modification has been made in adapting machine tools to the new motive power. In most cases the change has meant a bracket cast or bolted to some convenient part of the frame and the connection of the motor by belt, gears or chain to the driving mechanism; in other words, merely substituting the motor for a countershaft.

At the present time there is no standard type of motor for such service, and most tool builders are advertising their willingness to adapt their machines in a tentative way to whatever motor the customer may elect.

In many shops the group system of driving is the more economical, and no modifications of the machines themselves are necessary. But even when its independent drive is decided upon, there is no unanimity of opinion as to how it shall be arranged. Some prefer the variable speed motor with a controller, some the smaller constant-speed motor with mechanical speed control, and some a combination of the two.

One designer uses belts, another gearing, and a third the silent chain; in fact, most builders advertise all three, leaving the burden of choice upon the buyer. Perhaps the general consensus of opinion is in favor of the constant-speed motor, as it is smaller and cheaper and can be run at a high speed.

On large machines, where a considerable range of speeds is economical, a combination of the two systems is desirable, using perhaps four to six speeds on the controller and multiplying these by the usual gearing. Some large lathes and boring mills have as many as 72 speeds obtained in this way.

It is evident to the unprejudiced observer, as he studies the various arrangements of motor drives shown in catalogues, that the machine tool builder and the electrician have not "got together" on this problem, and that in most instances the machine has not been adapted to the motor or the motor to the machine. There is some excuse for this in the fact that most manufacturers of machine tools build certain standard machines, which are to be sold to the trade and are to be driven, some in the old and some in the new way, and must consequently be adapted to either set of conditions.

The rapidly increasing use of electricity as a motive power will change all this, and every year more machines will be built for electric drives alone. We shall then see machine tools in which the motors will be an integral part of the design and the present loose and temporary relations will be replaced by a definite and permanent connection.

The Structure of High-Speed Steels.

THE ENGINEER, LONDON.

Although high-speed steels have sprung into popularity with surprising suddenness; although much has been written about their use and something about their manufacture, little has been heard as to the causes which give them their astonishing properties. We turn, therefore, with no small amount of interest to two papers which appear in the current "Bulletin de la Société d'Encouragement pour l'Industrie Nationale," one by Le Chatelier and the other by Osmond, which promise us some light on this subject. These gentlemen hold such an exalted position in the field of scientific metallurgy that we must give close attention to whatever they have to tell us.

It is, then, disappointing to find that the explanations they offer are only tentative, and, in Osmond's case, not even based on actual commercial high-speed steel, which he has not examined, but only on specimens of chrome and tungsten steels, which he assumes to possess the same nature. We are far from saying that he is not right in this assumption, since we can ask for no more capable judge of such matters; but it is impossible, when we remember the remarkable effect that minute quantities of certain ingredients have on alloys, not to regret that the examinations on which his theory is founded are not based on actual samples of such metals as are used daily in manufacturing works. However, leaving that to one side, the explanation Osmond has to offer is simple and up to a certain point convincing. No new theory he tells us is required, only a slight addition to that of the hardening of ordinary carbon steel. "To render the general theory of carbon steels immediately applicable, it is sufficient to take account of the fact that the separation of carbide during cooling and its corresponding solution during heating are rendered difficult by the presence of chromium, tungsten, or other substances." Hence the changes in the constitution take place slowly, and we need not adopt such a sudden method of arresting them at any particular stage as when we plunge ordinary carbon steel into water. It is sufficient to cool the tungsten steel slowly to obtain the same end. Put in another way, whereas we must use powder and shot to stop the hare, we may roll a ball fast enough to strike the tortoise. If such an explanation as this on further examination should be proved to hold good, it is entirely admirable for its simplicity. It, too, may be taken to explain the extraordinary fact that such steels cut well at temperatures which would soften ordinary tool steels. The reason the latter fail is that at the temperature reached the particular condition obtaining at the instant they were petrified by being suddenly chilled is destroyed; but with tungsten steels the brakes, so to speak, are hard on all the time. The change takes place slowly instead of rapidly, and, in place of the rapid softening at the edge which occurs with ordinary steel, a comparatively long period of subjection to the high temperature is necessary. This, combined with the fact that the changes do not occur until a fairly elevated temperature has been reached, gives us an explanation of why high-speed steels will cut at a dark red heat. Le Chatelier tells us that such steels will stand 500° to 600° C., "at least for a certain time," and that it requires the application of 700° for an hour to soften them completely. We may add to this that Osmond seems disposed to accept a suggestion of Le Chatelier's that the high temperature that must be reached to restore the qualities of tungsten steels is due to the fact that at this point "austenite transforms itself into martensite," and that hardening takes place instead of the softening to which one is habituated by ordinary carbon steels—a suggestive, if not a very satisfactory, explanation of their peculiar cutting properties.

Whilst Osmond has little or nothing to say about practical applications, Le Chatelier gives more attention to them than to questions of constitution. He urges, very rightly, a point which we believe has been thoroughly well grasped in this country, and which is testified to by the extraordinary success of British high-speed steels. It is, of course, the necessity for exactness, in manufacture—exactness in the apportionment of the ingredients and precision in the temperatures used in treatment, but he makes the curious reflection on the ease with which self-hardening steels are treated that it rather hinders progress, since that delicacy of manipulation, which he believes will some day be required when the highest duty is sought, is not now demanded. That is a point of view that will certainly not