High-Speed Tool Steel.

NEARLY a quarter of a century has elapsed since a revolution in metal-machining practice was caused by the invention of the so-called high-speed cutting tools by Messrs. Taylor and White, of the Bethlehem Steel Company, U.S.A. This discovery was not an isolated one but was simply the last of a series of connected discoveries leading to this particular result. To a large extent it was empirical and in advance of the metallurgical theories of the time. It gave rise to various researches designed to explain the remarkable properties of these steels. Most of these have thrown some light on the properties in question, but none of them can be said to have provided a complete explanation of all the phenomena observed. The paper, therefore, by Messrs. Marcus A. Grossmann and Edgar C. Bain "On the Nature of High Speed Steel," presented at the autumn meeting of the Iron and Steel Institute, is to be welcomed in that it constitutes a further attempt to place on a scientific foundation a comprehensive theory of the mode of action of these steels.

The paper gives an account of the physical phenomena occurring from the time of casting the homogeneous melt to the production of the hardened tools. The authors emphasise the point that high-speed steel, far from being an alloy having wholly unique properties, merely possesses to an unusually marked degree certain of the tendencies which may already be discerned in other steels and alloys. They have availed themselves of the results of many of the methods of investigation applicable to metals, and the more recently developed conceptions of crystal structure and hardness constitute the foundation upon which the views offered have been built. They consider high-speed tool steel essentially as a binary alloy, of which one constituent is a solid solution of chromium in iron and the other the complex carbide containing tungsten, chromium, vanadium, and carbon. In the unhardened condition the finished bar is regarded as containing on an average 30 per cent. of carbide, but this is not evenly distributed. Rather more than half of it is in the form of fine particles which have been precipitated from solid solution, and, owing to "coring" in the original dendrites, it is never completely removed. There is a concentration gradient from the centres to the edges of the crystals. The remainder of the carbide is in comparatively coarse particles, which represent the plates of carbide in the original eutectic. These are still present in fairly pronounced streaks throughout the piece.

When this aggregate is heated to the hardening temperature (about 1300° C), the solubility of the carbide in the γ iron increases rapidly as the temperature rises, so that at the highest temperature nearly half the total carbide can be dissolved in the matrix. Owing, however, to the sluggishness of diffusion of the alloying elements, especially the tungsten, the amount dissolved never reaches the theoretical figure, and the austenite formed is far from homogeneous. In addition, small regional concentration gradients are set up round the larger carbide particles, the solution of which is never complete. Incidentally, the particles of excess carbide exercise a very useful function in preventing grain growth at this high temperature, which would otherwise be so rapid as to render the steel useless on account of brittleness.

After being suitably heated, the steel is now quenched, and in this process a portion of the austenite is transformed into martensite, so that freshly quenched high-speed steel shows under a microscope grains consisting of a mixture of austenite and martensite, and distributed through them the excess carbide particles. A light etching reveals the austenite grains and the excess carbide particles, but suitable further etching shows the martensite quite clearly. The relative proportions of martensite and preserved austenite undoubtedly vary from place to place. The regions lower in carbide contain more martensite, while those richer in carbide contain more austenite.

A piece of freshly quenched steel is thus to be conceived as containing regions of austenite-martensite mixtures of widely varying stability. On heating at comparatively low temperatures, softening is considered to take place in the martensitic areas, and this low-alloy martensite resembles carbon steel martensite. The decomposition of this can be traced both in changes of hardness and of shrinkage. On heating to 600° C. the phenomenon of secondary hardness is observed, due to the conversion of the austenite regions to martensite or troostite. This reaction takes place throughout the tool. The total effective hardening may be considered, therefore, as representing the algebraical sum of hardening effect of the transformation of the various austenites and the softening of the various martensites.

The authors do well to emphasise the point that "secondary hardness" is by no means restricted to high-speed steel and that it is not the same as "red hardness." The retention of austenite on quenching is characteristic of many alloy steels on heating to sufficiently high temperatures. When this is reheated at low temperatures, secondary hardening sets in owing to the formation of minute crystals of α iron and the precipitation of fine carbide particles. Indeed, it is likely that if the tungsten of high-speed steel were omitted altogether, the remaining elements alone would be sufficient to cause the retention of the austenite and the appearance of secondary hardening. The special usefulness of high-speed steel, however, is due to the extent to which it exhibits the property of red hardness, and it is here that tungsten plays its rôle. The large, heavy, immobile atoms of this metal act by supporting the structure at these slightly elevated temperatures and prevent the diffusion and agglomeration of the carbide particles, which would otherwise take place with consequent softening.

H. C. H. C.

Isotopes and Spectra.

THE question of the spectroscopic evidence of the existence of isotopes, which has already been brought forward in our correspondence columns (see NATURE, March 29, May 31, August 16) is dealt with at length in two papers published in the *Japanese Journal of Physics*, vol. ii., Nos. 6-10,—the first by Nagaoka, Sugiura, and Mishima, on "The Fine Structure of Mercury Lines and the Isotopes," and the second by Nagaoka and Sugiura, on "Spectroscopic Evidence of Isotopy."

The assumption is made that the mercury atom consists of a central mass with a proton quasi-elastically connected with it. Vibrations of this system are conceived to give rise to spectrum lines. Thus, several mercury lines are known to have large numbers of closely adjacent satellites. It is thought that these are due to coupled vibrations of the nucleus owing to the stimulus given by the principal line which seems to be excited by the change of electron configuration according to Bohr's scheme. A number of facts are adduced in support of the hypothesis. It is possible to calculate the intervals between the lines which would be produced by the vibrations of such a nucleus. Knowing the masses of the main core and the proton, and taking these from the observed values of Aston for the isotopes of mercury, the calculated intervals are shown to be in good agreement with the intervals between the satellites of mercury lines. The latter were carefully measured by the use of crossed Lummer-Gehrcke plates, and a discussion is introduced on the forms of the interference points so produced. It is concluded that the fine structure of mercury lines is due to the existence of several isotopes.

In the second paper the more general hypothesis is advanced that non-series lines in spectra are produced in an essentially different manner from the series lines. The latter are adequately accounted for by the movements of satellite electrons, according to Bohr's model, but the non-series lines are assumed to arise from the vibrations of pairs of atoms coupled in the manner described above for the mercury nucleus and its associated proton. When an element has two or more isotopes, two kinds of coupling are possible—symmetric and asymmetric—corresponding to pairs of atoms having the same and different masses respectively. A formula is given for calculating the wave-length intervals between lines arising from the coupled atoms, and these are shown to be in good agreement with intervals found in the spectra of elements the isotopes of which are known.

The lines having these intervals are accordingly looked upon as products of atomic vibrations and not of passages of an electron from orbit to orbit. Most of the lines so explained are spark lines. They are remarkably numerous in the spectra of the monatomic gases; thus, more than 90 per cent. of the 856 neon lines given by Paschen are assigned to atomic vibrations, and in argon a still greater proportion. An explanation of this is given. It is concluded that atomic vibrations give rise to spectra having constant frequency differences, and the suggestion is made that unknown isotopes may be detected from spectroscopic data.

Problems of Unemployment Insurance.

AT the recent Toronto meeting of the British Association, a paper by Prof. John R. Commons, of the University of Wisconsin, on "The Limits of Unemployment Insurance," was read to the Section of Economic Science and Statistics. In view of recent discussion in Great Britain of the relative merits and demerits of insurance by industry, insurance by firms, and the present State system, a short account of this paper may be of interest.

Prof. Commons is a well-known advocate of unemployment insurance in the United States. Conditions in the States are, of course, very different from those prevailing in Britain, and in particular there is a strong prejudice against a State insurance scheme. Prof. Commons in his paper emphasised the point that the principle of overhead charges (*i.e.* those manufacturing costs that go on whatever the number of units produced) applies to labour just as much as to capital, though this fact is not generally realised by industrial firms.

The modern manufacturer is faced with problems of business cycles, overhead costs, and organised labour that were unknown to his predecessors of the time when Adam Smith wrote, or perhaps more correctly it would be truer to say that nowadays these problems are greatly intensified. Business cycles are "a normal abnormality of the nineteenth and twentieth centuries."

The business cycle results in a lag both in time and amplitude in the daily wages received by labour, compared with the prices obtained for the product by the employers. Organised labour, however, tends to reduce this lag by boosting wages during the rise and holding them up during the slump. Consequently, such labour obtains a higher *daily* wage, while employed, on account of the business cycle than would otherwise be the case.

Two solutions of the problem are apparent, either (1) the curve of employment or (2) that of daily wages must be smoothed out. If attention be concentrated on the first solution rather than on the second, the community of interest rather than the antagonism of interest between capital and labour becomes clearer.

Statistics, however, point to a curious paradox, for large firms show greater fluctuations in their labour demands than the smaller. This is not what might have been expected, since the large firm has presumably a much larger item of overhead relative to the number of employees, which would at first sight seem to intensify the inducement to make greater efforts to stabilise production, thus reducing the overhead costs per unit of product. Apparently in practice the large firms take care of their capital overhead by means of high profits at the peak and large reserves for the trough of the business cycle, compelling their employees to take care of the labour overhead on a slumping market. If the employment cycle is to be smoothed out, the principle indicated from this analysis is that industry should take care of both kinds of overhead. The only way, however, to induce industry to take care of this labour overhead charge is "through the pocket book."

Prof. Commons arrives ultimately at three propositions:

(1) The larger establishments should each carry, so far as possible, its own risk by way of setting aside its own reserve, not merged with the reserves of other establishments in a common fund.

(2) Establishments having a small number of employees should be treated differently from those with a larger number. They might, for example, be organised in the form of a mutual insurance scheme.

(3) Employees should not ordinarily be required to contribute to the fund out of their wages.

"It will be seen," concludes Prof. Commons, "that only from the largest establishments and not from the smaller establishments, nor from the employees nor from the State, can any material progress be made towards prevention of unemployment."

University and Educational Intelligence.

BELFAST.—Applications are invited for two posts in the Queen's University, namely, the professorship in bio-chemistry and the lectureship in bacteriology. Terms of the appointments are obtainable from the secretary of the college.

BRISTOL.—Prof. Andrew Robertson, professor of mining and mechanical engineering in the Merchant Venturers Technical College, has been appointed principal of the College in succession to the late Dr. Wertheimer.

CAMBRIDGE.—T. R. B. Sanders, Trinity College, has been elected to a fellowship at Corpus Christi College. A. M. Binnie, Queens' College, has been awarded the John Winbolt Prize in engineering. The number of freshmen who have matriculated this term is 1498. The corresponding figure in 1913 was 1110.