THE INFLUENCE OF PROGRESSIVE COLD WORK ON PURE COPPER.

THE hardening effect of the various forms of cold work on metals and alloys has long been known and utilised in the arts, and in recent years various theories have been put forward to explain the phenomena observed. Few attempts, however, have been made to test whether any quantitative relationship exists between the amount of cold work done upon a metal and the magnitude of the change in its properties. A serious and well-planned attempt to obtain information of this kind has been made by Mr. Alkins, who presented a paper at the September meeting of the Institute of Metals on the change in the tensile strength of copper-wire as it is progressively hardened by cold-drawing in the ordinary way. Copper was chosen as the experimental material for the following reasons:—

(1) The wire used in the arts is of a high degree of purity, and seldom contains 1 part of impurity in 1000.

(2) It shows the hardening by plastic deformation very strikingly, inasmuch as its tensile strength may be doubled by cold-drawing without any indication that it is actually overdrawn.

(3) It has hitherto been accepted as a metal which does not possess any allotropic transformation between its freezing-point and 0° C. [Prof. Cohen, however, holds that there is evidence of an allotropic transformation at 71° C.]

In Mr. Alkins's experiments a billet of copper was cast and hot-rolled to a mean diameter of 0·553 in. in the ordinary way. The rolled billet was then annealed for four hours at about 600° C. in order to remove stresses completely, and was allowed to cool. After "pickling" in sulphuric acid to remove the scale it was cold-drawn by light drafts (twenty-five in all) down to 0·04 in. without any further annealing. From the billet after "pickling," and from the wire after each draft, a few feet were scrapped from the end, and three 2-ft. lengths cut for testing. The tensile strength of the wires was determined on a 5-ton Buckton machine. Five determinations were made on each sample of wire, and the readings were found to be concordant within 1 per cent. The mean of the five was taken as the actual breaking load. The results of the tests are shown in the accompanying graph, in which the co-ordinates are tensile strength in tons per sq. in. and sectional area in sq. in. It will be seen that the tensile strength is raised progressively from 15·49 tons in the original billet to 30·80 tons in the wire of the smallest sectional area. It will also be seen that the curve showing the variation of tenacity with sectional area consists of two rectilinear portions AB, CD, connected by a smooth curve BEC with a point of inflection at E. Mr. Alkins's analysis of the curve is as follows:—

The portion AB corresponds with the equation

$$T = 31{\cdot}6 - 67\,A,$$

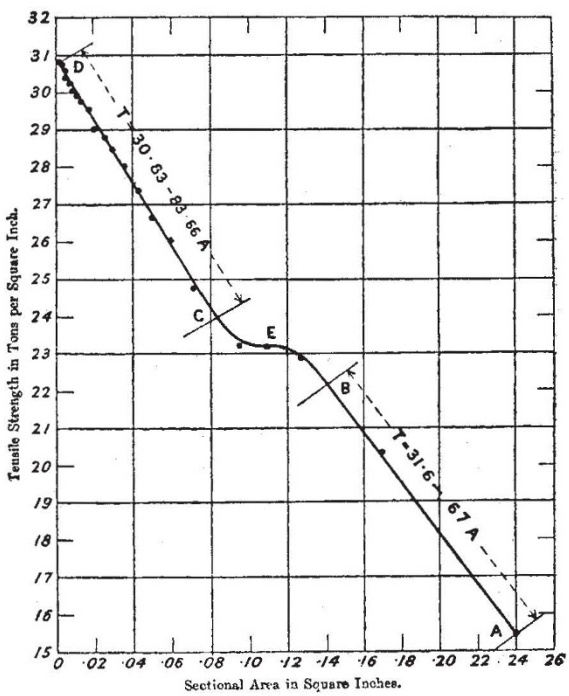
where T = tensile strength in tons per sq. in., and A = cross-sectional area in sq. in. The curved portion BEC agrees closely with the expression

$$T = 23{\cdot}2 - \sqrt[3]{A - 0{\cdot}107},$$

and the upper rectilinear branch CD corresponds with the equation

$$T = 30{\cdot}83 - 82{\cdot}66\,A.$$

According to these equations, then, from A to B the tensile strength increases at the rate of 67 tons per sq. in. for a reduction in area of 1 sq. in., while from C to D the rate of increase is 82·66 tons per sq. in. per sq. in. From B to E the rate diminishes to 0, and increases again from E to C. This curve shows no discontinuity, and at no stage is there a simultaneous diminution in sectional area and in the tensile strength. There is, however, one stage in the drawing at which a reduction of area of almost 10 per cent. (from 0·10927 to 0·095507 sq. in.) is unaccompanied by any change in the tensile strength. This corresponds with the point E, where the tenacity equals about 23·2 tons per sq. in. It appears, then, that over this particular range a reduction in area by cold work is not accompanied by any change in the tensile strength. Of this phenomenon the amorphous phase theory of plastic deformation does not appear to offer any explanation. Assuming, as Mr. Alkins does in the absence of quantitative data, that the amount of cold work actually performed on a metal during drawing is measured by the decrease in cross-sectional area, he is forced to the conclusion that two distinct changes occur in the hard drawing of copper, one of them along the branch AE and the other along the branch



ED. He states that he investigated several other physical properties of the metal as it was drawn down—for instance, density, elongation (both general and at fracture), and scleroscope hardness—and that all these were found to change in a similar way to the tensile strength. A full account of this and of further work is promised. Meantime, as a tentative explanation of the results recorded, he suggests that when copper is subjected to cold work by drawing through dies, the first change which occurs is allotropic in nature, and, after this is complete, a second change sets in which may be either allotropic or explicable on the lines of the amorphous theory.

Another set of experiments is quoted, in which wires were drawn down from the billet by heavy instead of light drafting, the reduction in area being accomplished in thirteen operations, as against twenty-five in the previous set. Here also the results yield a curve of the same type. It was found that over the range AE the values were identical with those obtained in the previous set of experiments, which

appears to show that the transformation occurring after this range is constant is independent of the manner in which the cold work is applied. Beyond E, however, the new curve does not coincide with ED, but rises more steeply, the tensile strength corresponding with the 0·040 in. diameter wire, being nearly 33 tons per sq. in. It would appear, then, that the change taking place along ED is different in type from that occurring along AE. It is stated that wires of such a diameter that they fall within the range AE are stable at the ordinary temperatures. At any rate, they do not change in a year's time. On the other hand, wires corresponding with the points on the branch ED are unstable at atmospheric temperatures, their tensile strength being gradually diminished. Finally, Mr. Alkins records that, if fully annealed wire of any diameter is taken and drawn down, a stage is always reached, when its area has been reduced about 50 per cent., where, over a limited range, further drawing causes no corresponding alteration in the properties. He finds that the physical properties corresponding with this constant range are always the same—*e.g.* density = 8·889, tensile strength = 23·2 tons per sq. in., and so on. He concludes, therefore, that the point E corresponds with a definite physical state of the metal.

The facts thus brought forward by Mr. Alkins are of definite practical importance and distinct scientific interest. Considering the importance of the point E, it would have strengthened his case if he could have shown rather more observations in its immediate neighbourhood. This, of course, would have involved the preparation of a new set of rolls, by which very slight differences in area could be effected. Such work cannot, of course, be undertaken under war conditions. Further, he would have been well advised to determine the percentage of copper-cuprous oxide eutectic in his wire, which he did not do. This omission can, of course, be remedied, and until it is, and the influence of oxide specifically determined, no one can say how far his results are due to copper itself. If and when these omissions can be remedied, Mr. Alkins will improve a paper which already does him very great credit. H. C. H. CARPENTER.

THE RAT PEST.

REFERRING to Prof. P. Chavigny's report on rats in the trenches (NATURE, September 19, p. 53), Mr. C. B. Moffat, Enniscorthy, points out that the descendants of a pair of rats must in three years far exceed the twenty millions stated. At the end of the first year there should be 50 offspring, 500 grand offspring, 1000 great-grand offspring, 1250 great-great-grand offspring—2800 in all. Half of this number, supposing females equal males, multiplied by 2800, gives 3,920,000 at the end of the second year. At the end of the third year the number should be far more than five thousand millions. It has to be borne in mind, however, that female rats probably reach their limit or menopause long before three years. The most secure data known to us are those of Helen Dean King (*Anat. Record*, vol. xi., 1916, pp. 269–87) on 76 females derived from a cross between the wild Norway rat and the domesticated white rat. The average number in a litter was 6·7 (Prof. Chavigny speaks of 10); the average total number of litters for a female was 7·7; there is a sharp decline in fertility after the female is a year old, and the menopause appears at eighteen months. The sex ratio for 3955 individuals was 106·1 males to 100 females. We do not know how Prof. Chavigny reached the figure twenty millions, but, as Mr. Moffat recognises, there are various biological considerations which make the computation not so simple as it seems at first.

Without doubt the most thorough and informative summary of the menace which faces us from the hordes of rats and mice in our midst has just been issued by the Trustees of the British Museum (Natural History), forming No. 8 of the Economic Series issued by that institution. The author, Mr. M. A. C. Hinton, one of the greatest living authorities on this subject, has marshalled his facts with extraordinary skill; so much so that he has contrived, within the space of some sixty pages, to pass in review, not only the life-history of these pests in a state of nature, their relation to public health, and their amazing destructiveness in the matter of our food supplies, but also the various preventive measures which afford us means of relief. On this head he has much to say in condemnation of the destruction of so-called "vermin," which, until now, has been so persistently and stupidly followed. Finally, he adds a most valuable chapter on the classification of the Muridæ, and a table showing the assumed rate of increase in the annual rat population, which, even while postulating a mortality which is purposely exaggerated, shows clearly enough that none but the most determined efforts can hope to lessen the seriousness of the situation, which has come about owing to the withdrawal of all labour hitherto devoted to the destruction of rats, either by the needs of the Army or by the allurement of the high wages paid for other kinds of work more or less directly arising out of the war. A number of well-chosen and beautifully executed illustrations, showing the dental and cranial characters by which our native species of Muridæ may be distinguished, add still further to the value of these pages. But the figures of the black and common rat and of the house-mouse, to say the least, leave much to be desired. This pamphlet should be carefully studied, not only by the agriculturist, the merchant, and those responsible for the preparation of food in restaurants, but also by the housekeeper; for it is only by the concerted efforts of us all that we can hope for success in this campaign, which is now to be commenced against a condition of affairs which is fraught with real peril.

THE RALEIGH TERCENTENARY.

THE tercentenary of Sir Walter Raleigh's death was celebrated on Sunday, October 27, by a special service at St. Margaret's Church, Westminster. The service was arranged by the Tercentenary Committee, of which the King is patron, Mr. Balfour one of the honorary presidents, and Prof. Gollancz hon. secretary. Two wreaths in memory of Sir Walter Raleigh were laid before the service at the foot of the Communion-table, where the body is said to have been buried. One was from the Tercentenary Committee; the other, of laurels, was from the Royal Geographical Society, and was inscribed: "To the memory of Sir Walter Raleigh on the tercentenary of his death." It was borne by Sir Thomas Holdich, K.C.M.G., and Mr. Arthur R. Hinks, secretary of the society. The address was delivered by the rector of St. Margaret's, Canon Carnegie. Memorial services were also held at the Temple Church and at Woolwich Parish Church. The work of Raleigh in exploration and colonisation was also commemorated on Tuesday by meetings at the Mansion House and elsewhere. At the Mansion House meeting Sir Charles Wakefield (hon. treasurer of the Tercentenary Committee) offered for the acceptance of the Lieutenant of the Tower a copy of Raleigh's "History of the World," which he hoped would find a place in the room where the history was written. He offered to the British Academy as the nucleus of a Raleigh Fund for History the sum of 500*l.* a year for at least the next