ter. While this is a great loss to the museum, it is but fitting that such an important expedition into Canadian territory should be controlled by Canada.

I quote the following letters by the Prime Minister of Canada and the president of the American Museum:

New York City, February 12th, 1913.

Dear Mr. Stefánsson:

The offer of the Canadian Government, through the telegram of the Hon. William J. Roche, Minister of the Interior, on Monday, February 10th, to cover the entire expenses of an expedition to the Arctic, places the plans you have made with us and with the National Geographic Society in a new light.

It would appear that this offers an opportunity of conducting your explorations under the direction of a strong Government which, through patriotic as well as scientific motives, will take every possible step to insure success.

We feel bound, under these circumstances, to relinquish the claim which our prolonged preliminary negotiations and understanding may have given us upon your expedition. We desire you to conduct your negotiations, therefore, with the Canadian government, with entire freedom.

It is, however, with the greatest reluctance that, through our desire to do what seems best for the general interests of science, we sever a connection established in 1908 with yourself and Dr. Anderson, which has been animated throughout by warm personal regard and which has been attended by the achievement of such notable scientific results. We desire especially to make record of our appreciation of the heroic and self-sacrificing efforts which you and Dr. Anderson made in carrying out the project of the first Stefánsson-Anderson expedition.

In case you enter upon this proposed service of the Canadian government, I am sure that the entire scientific staff of the American Museum will unite with me in the expression of our heartiest goodwill and of our desire that you may successfully accomplish all the

objects that you have in mind in the way of further exploration.

In view of our past friendly co-operation with the Canadian survey, we trust that continued co-operation with this museum, especially in certain lines of anthropology and zoology, may be arranged for in connection with your expedition.

Believe me, with the highest regard,

Faithfully yours,

Signed.

HENRY FAIRFIELD OSBORN.

President of the American Museum of Natural History.

PRIME MINISTER'S OFFICE, CANADA

Ottawa, Ontario, February 21st, 1913.

Dear Sir:

Mr. Stefánsson has shown me your letter of the 12th instant stating that you are willing to forego your claims to a share in his exploration of the northern waters of Canada, and to cancel the arrangements which you had so generously made to contribute toward the expenses of this undertaking, and I wish to thank you for your courtesy in withdrawing in favor of this government.

We are most appreciative of the valuable results obtained by Mr. Stefánsson's explorations in the northern part of the American continent, which have given valuable information as to this comparatively unknown portion of the Dominion of Canada, and have to thank you for the part you took in assisting Mr. Stefánsson in that work. The government of Canada feels, however, with regard to the present exploration, that it would be more suitable if the expenses are borne by the government more immediately interested, and if the expedition sails under the flag of the country which is to be explored. The government is, however, desirous that the line of investigation begun by Mr. Stefánsson and the members of your association should be continued and would be glad of the scientific co-operation of your members so as to obtain the best results from this expedition.

Signed.

Yours very truly,

R. L. BORDEN.

It is Mr. Stefánsson's present intention to carry out in detail the plan as formerly developed in the interests of this museum and the National Geographic Society. Its chief aim will be geographical and anthropological exploration. As planned, the expedition will have two main bases, the northern one on Prince Patrick Island and the southern on the mainland of North America near Coronation Gulf. Mr. Stefánsson will give personal attention to geographical exploration and the study of the Eskimo, Dr. Anderson will conduct the biological investigations. It is expected that a staff of at least six scientists will accompany Mr. Stefánsson, Dr. Anderson being one of that number.

In general, the plan is to spend three or four years in an intensive study of the archaeology and ethnology of the Eskimo, together with the zoology and geology of the whole region from Alaska to Coronation Gulf.

Also, to map the unexplored coast of Victoria and Prince Patrick islands and by off-shore journeys to the north and east determine by means of soundings the extent of the continental shelf and discover new lands, if such there be. It is intended that the expedition shall be a scientific one and devote its energies to the investigation of this unknown region.

The anthropological work is to be made a special feature, the main problem here being to determine the present and former limits of human occupation. During summer the surface will be searched for traces of former villages which when found will be carefully studied by excavation and otherwise to determine their relative ages and the cultural character of their occupants. Such archaeological work is now needed to estimate the period of occupation and the direction of Eskimo migration.

In the east, special attention will be given to the distribution of the peculiar hybrid Eskimo discovered on the last expedition. It is intended that a full census of the people be made, noting the somatic character of each to serve as a basis for the study of this peculiar biological problem.

The Hardness of Metals

Theoretical Basis of Metal Working

By Thos. A. Eastick

Fig. 1.—High Carbon Steel. Dark Area is Pearlite. Long White Crystallites are Cementite. Magnified 300 Diameters.

The valuable physical properties of metals upon which their use in engineering practice mainly depends are tensile strength, or resistance to a pulling or pushing force; elastic limit, or the ability of a metal to be forced out of shape and then recover its position, i. e., flexibility or "springiness;" and finally, toughness, a property somewhat hard to define, but which may be gaged, say, by the amount of pulling, bending or twist-

Fig. 2.—Pure copper. As Cast. Magnified 85 Diameters.

Fig. 3.—Pure Copper. Same as Fig. 2 After Hard-Drawing. Magnified 85 Diameters.

ing a metal will undergo before rupture occurs.

Hardness is a combination of all these properties, and to harden a metal implies that the tensile strength and elastic limit are increased.

A metal may exist in various degrees of hardness, and when in its hardest condition is very different from its soft state. A dead soft copper rod, for example, may show only a tensile strength of 30,000 pounds per square inch, but when it has been cold

Fig. 4.—Same as Fig. 3. After Annealing. Magnified 85 Diameters.

Fig. 5.—Steel Containing 0.80 per cent Carbon. Pearlite Entirely. Magnified 400 Diameters.

Fig. 6.—Low Carbon Steel. Small White Specks are Pearlite. Dark is Ferrite. Magnified 200 Diameters.

drawn through steel dies till it is only half its former diameter it will show a tensile strength of 50,000 pounds per square inch, while the elastic limit is greatly increased and its electrical conductivity is reduced.

Metals and alloys become hard when cold-worked, i. e., hammered, rolled or drawn, and within certain limits, the severer the mechanical operation, the harder the metal will become. If, however, the working is too severe, the metal will of course rupture.

Before describing hardness and methods of hardening further, let us examine what is known as the stress-strain diagram obtained by testing a metal in a testing machine.

A testing machine, as is well known, is a machine for subjecting a given specimen to a strain, which may be read off in pounds on a beam. It consists mainly of a pair of jaws in which the sample is fixed, a beam on which is a sliding weight, and a screw gear operated by power by which a constant pull is obtained. One jaw is connected with the beam and the other with the screw gear.

When the machine is first started the beam is jerked up, showing that the specimen is under considerable tension, the weight on the beam is then quickly moved along the beam until a balance is obtained, the weight required to obtain this balance is usually taken as the "yield point" (on small machines this is sometimes taken as the breaking strain), because a few seconds after this balance is obtained the specimen suddenly elongates, the beam drops showing that the specimen is no longer under tension, the specimen rapidly "necks out" and then breaks.

The changes undergone by the specimen under test may be shown graphically by plotting the tension in pounds per square inch against the elongation expressed as percentage, as in the first diagram.

By this diagram it will be seen that the metal elongates very little under increasing loads until it reaches the elastic limit when it "gives" and then rapidly elongates until the yield point is reached, at this point the metal, slowly at first, and then rapidly "necks out" to the breaking load.

To return to the consideration of hardness; in order to harden a metal we must overcome its elastic limit, otherwise cold working will have no effect.

The effect on the crystalline structure on a metal produced by hardening it, is very striking. Fig. 2 is a photograph showing the appearance of a piece of copper as it is cast, under the microscope, Fig. 3, shows the same copper after having been drawn into wire. It will be noticed that the large grain structure has been entirely destroyed and the metal after drawing appears as an amorphous mass.

In the rolling and drawing of metals and alloys this hardening up is a very important item. In drawing copper wire, for instance, after the first few draws the metal becomes too hard to draw further, and it is then annealed.

The effect of annealing on metals is to cause recrystallization. The molecules of the highly strained metal, when heated, rearrange themselves in a crystalline condition, and the metal loses its hardness and becomes more ductile and tougher.

The sample of hard-drawn copper wire in Fig. 3 was annealed by heating it in a furnace at a temperature of 800 deg. Cent. for 15 minutes. A section was cut off and examined under the microscope. Fig. 4 shows its appearance. It will be noticed that the particles of the metal have arranged themselves in well formed and defined crystals.

Annealing, or the formation of crystals in a metal is effected by heating the metal to a certain temperature, which depends on the melting point. Thus copper which melts at 1,087 deg. Cent. may be softened rapidly by heating to 800 deg. Cent. Hard zinc, on the other hand, which melts at about 430 deg. Cent. may be softened by immersing in boiling water for some time. The higher the temperature the more rapidly the recrystallization proceeds and the consequent softening.

The dynamical theory of the hardening of metals by cold-working is somewhat complicated, but an idea may be obtained by a consideration of the following:

First. The smaller the crystal grains of a metal are, the harder and stronger will that metal be.

Second. Under the influence of working, the metal assumes a semi-fluid condition and then instantaneously becomes solid again upon the release of the pressure of the rolls or hammer, as the case may be.

Third. The sudden return of the metal from a semi-fluid to a solid form, naturally induces an exceedingly fine crystal structure. This structure is so fine as to be invisible under the microscope.

The explanation of the second item above is that under the sudden application of great pressure of the rolls the metal momentarily becomes liquid and then instantly solidifies. The structure shown in Fig. 3, therefore, consists of exceedingly minute crystals too

small to be seen under the microscope. Upon heating, however, these crystals coalesce to form larger ones.

This theory is the one generally held by metallurgists and was first enunciated by Dr. Beilby of London.

In dealing with iron and steel we find that there is another type of hardness, very different from what we have considered so far.

As is very well known, if we take a piece of steel and heat it red hot and then plunge it into water, it becomes intensely hard, so hard, in fact, that unless it be "tempered" it will break and fly into pieces like glass when bent. The phenomena of hardening by quenching steel will now be dealt with.

Steel consists of iron containing from 0.15 per cent to 2 per cent carbon. With less carbon than 0.15 per cent the metal is known as wrought iron, "ingot iron" and various other trade names. With more than 2 per cent carbon the metal approaches the composition of cast iron or pig iron.

Carbon forms with iron a chemical compound of the formula Fe_3C , and it is in this condition that it exists in steel. Upon examining different samples of steel containing various percentages of carbon we find that three different constituents may be distinguished. These constituents, on account of their resemblance to mineral or rock sections, have been given mineralogical names; they are ferrite, pearlite and cementite.

Ferrite is chemically pure iron, absolutely free from carbon. It is soft and possesses little strength. Wrought iron, "ingot iron," and very mild steel consist almost entirely of ferrite.

Cementite is the compound of carbon and iron mentioned above, having the formula Fe_3C . It is an intensely hard substance and may be observed in high carbon steel, tool steel, etc.

Pearlite, as its name implies, is a "pearly" looking constituent which consists of a very intimate mixture of ferrite and cementite. This mixture is known as an "eutectoid," it has a composition similar to a chemical

compound, but yet is merely a very intimate mechanical mixture. It is called an eutectoid on account of its similarity to an eutectic; details concerning eutectics, etc., may be found in a previous article in the SCIENTIFIC AMERICAN SUPPLEMENT, May 4th, 1912, p. 276.

Steel containing about 0.80 per cent carbon consists of pure pearlite, and has the appearance under the microscope of Fig. 5. A steel containing less carbon than this consists of a conglomerate of ferrite and pearlite; the less carbon, the less pearlite is there. Fig. 6 shows the appearance of a low carbon steel or "mild" steel, as it is known. When the carbon exceeds 0.80 per cent cementite begins to appear in the form of a hard, white material which exists between the grains of pearlite. Fig. 1 shows the appearance of a piece of high carbon steel containing 1.20 per cent carbon.

In the previous article, referred to above, the use and construction of what are known as equilibrium diagrams, was described. These equilibrium diagrams are of great value in metallography and are obtained by co-ordinating the melting points and percentage composition of a series of alloys of two metals. Thus in the alloys of copper and silver, from 0 per cent copper to 100 per cent copper, the melting points of a number of experimental alloys from the ordinates while the composition, in per cent, of the alloys form the abscissæ. The second diagram shows this curve. From this curve we can tell the approximate constitution of any alloy at any temperature. Thus, all alloys above the line A E F are liquid. Those in the space A B E consist of a liquid eutectic of copper and silver, in which are floating solid crystals of silver. Alloys in the space E D C B consist of a solid groundwork of silver surrounded by a network of the eutectic of copper and silver. Those in the space E F G would consist of the liquid eutectic in which are floating crystals of solid copper, while those in the space E D H G consist of solid copper crystals surrounded by a network of solid eutectic. For example, a United States ten-cent piece, which is an alloy of copper and silver containing 90 per cent silver and 10 per cent copper, at an ordinary temperature, would correspond to a point in the space B E C D, and would therefore consist of crystals of silver surrounded by a eutectic of copper and silver.

To return to steel, an equilibrium diagram has gradually been constructed by the work and observation of many masters, after infinite trouble and pains. This diagram is without doubt the hardest to construct in metallography on account of the very high melting points of the material, the difficulty in obtaining samples of the desired composition and the extreme complexity of these alloys of carbon and iron; yet this diagram is perhaps more valuable, industrially, than any other. However, it has been done, and our last diagram is the most recently published.

It will be only necessary to consider the left side of (the long dotted line on) the diagram, because steel rarely contains more than 2 per cent carbon.

All the alloys above the line A D are liquid; this line is therefore the line of solidification. In the space A B I the metal will consist of crystals of austenite (a constituent of steel which will be described below), surrounded by a still liquid mass of pearlite. In the space A B F H the whole mass will solidify as a homogeneous solid solution. This solid solution is called austenite after Sir Roberts-Austen, the great metallurgist. After cooling below the line H F B this solid solution splits up into its constituents, ferrite and pearlite, provided that the percentage of carbon does not exceed 0.80 per cent or 0.90 per cent. Should the carbon exceed this, there exists, below the line B C a conglomerate of austenite and cementite; on cooling below the line F E the austenite changes into pearlite, leaving a conglomerate of pearlite and cementite. Thus steel, below a temperature of 600 deg. Cent., if it contains less than 0.90 per cent carbon, will consist of ferrite and pearlite, while if the carbon exceeds this percentage it will consist of cementine and pearlite.

The greater hardness of high carbon steel over mild steel is due, therefore, to the fact of its containing cementite, an intensely hard constituent.

The austenite is one of the hardest constituents of steel and is also very brittle. If the steel be gradually cooled this austenite changes completely into its constituents, but if the steel be cooled rapidly, as by plunging in water, the molecules have not sufficient time to arrange themselves, and thus the austenitic structure may be preserved to a certain degree. The more rapid the cooling the greater the consequent hardness due to the more complete preservation of the austenitic structure. By cooling at various rates we may obtain different degrees of hardness. For instance many steel articles are quenched from above the line H F B in oil, which does not cool them off as rapidly as water. Articles which require intense hardness, such as hack-saw blades, are quenched in cold water. They are then intensely hard, but brittle and partake of an austenitic structure.