THE STEEL HARDENING PROCESS.

By R. H. Cunningham, B.A.Sc.,
General Manager, Canadian Hoskins, Limited,
Walkerville, Ont.

ORIGINALLY the name "steel" was applied to various combinations of iron and carbon, there being also present, as impurities, small proportions of silicon and manganese. At the present time, however, the use of the name is extended to cover combinations of iron with tungsten, vanadium, nickel, chromium, molybdenum, titanium and some of the rarer elements. These latter combinations are quite generally known as the "alloy steels" to distinguish them from the "carbon steels," those in which the characteristic properties are dependent upon the presence in the steel of carbon alone. The alloy steels are divided into the "high speed" steels and the Mushet or "air-hardening" steels.

The specific properties that distinguish these different steels are due in part to their respective compositions, i.e., to the particular elements they may contain and the relative proportions in which these occur, and, in part, to their subsequent working and heat treatment.

Effect of Difference in Composition.—In general, any change in the composition of a steel results in some change in its properties. For example, the addition of a certain metallic element to a carbon steel causes, in the alloy steel thus formed, a change in position of the proper hardening temperature point. Tungsten or manganese added, tend to lower this point; boron and vanadium, to raise it. The amount of the change is practically proportional to the amount of the element added.

Further, adding a small proportion of carbon to iron produces steel, which has decidedly different properties than pure iron. Increasing the proportion of carbon in the steel thus formed, within certain limits, causes a variation in the degree in which these properties manifest themselves. For example, consider the property of tensile strength. In a 0.1 carbon steel (one in which there is present but 0.1% of carbon) the tensile strength is very nearly 25% greater than that of pure iron. Adding further carbon causes this to rise, at approximately the rate of a 2.5% increase in tensile strength for each 0.01% of carbon added.

Due alone to differences in proportion of carbon present, carbon steels are divided into three classes. The first of these embraces the "unsaturated" steels, those in which the carbon content is lower than 0.89%; the second, the "saturated" steels, in which the proportion of carbon is exactly 0.89%; and the third, the "super-saturated" steels, those in which the carbon content is higher than 0.89%.

Effect of Heat Treatment.—With a steel of a given composition, proper heat treatments may be applied which of themselves will alter in form or degree some of its specific properties, or practically eliminate one or more of them, or, perhaps, add certain new ones. Physical properties of size, shape and ductility are examples of the first. Of the second, heating a steel beyond its hardening temperature takes away its magnetism, making it "non-magnetic." And the third, the property of hardness—for practical purposes—may be added to a steel by the process of hardening. In connection with this it must be understood that strictly speaking, "hardness" is a relative term and that all steel has some hardness.

There are three general heat treatment operations so considered—forging, hardening and tempering. In all of these the object sought is to change in some manner the existing properties of the steel; in other words, to produce in it certain permanent conditions. Each of these operations, broadly speaking, consists of two parts, viz., raising and lowering the temperature of the piece. (In forging, of course, mechanical work is also done upon it.)

Obviously then, the controlling factor in all heat treatment is temperature. Whether the operation is forging, hardening or tempering, there is, for any certain steel and particular use thereof, a definite temperature point, at which to work the steel, that alone gives the best results. Insufficient temperatures, either through ignorance of what the correct point is, or through inability to tell when it exists, cause "burned" steel. This is a common failing, resulting in great loss. In degree, very slight variations, from the proper point, may do irreparable damage.

Due to temperature variation alone, steel may be had in any of three conditions: (1) in the "unhardened" or annealed state—when not heated to temperatures above 735° C. (1355° F.); (2) in the "hardened" state—by heating to temperatures between 735° C. (1355° F.) and 820° C. (1508° F.); (3) in a state softer than (2), though harder than (1), when heated to temperatures which exceed 820° C. (1508° F.).

The Hardening Process.—Hardening a carbon steel is the process of increasing its degree of hardness, this property being its power to resist penetration. It is the result of a change of internal structure which takes place in the steel when heated properly to a correct temperature. In the different carbon steels this change for practical purposes is effective only in those in which the proportion of carbon is between 0.2% and 2.0%.

When heated, ordinary carbon steels begin to soften at about 200° C. (392° F.) and continue to soften throughout a range of 170° C. At the point 370° C. (698° F.) practically all of the hardness has disappeared. "Red hardness" in a steel, is a property which enables it to remain hard at red heat. In a high-speed steel this property is of the first importance, 550° C. (1022° F.) being a minimum temperature at which softening may begin. This is some 350° C. above the point at which softening commences in ordinary carbon steels.

The process of hardening a steel is best carried out in a closed furnace. Of the many sources of energy capable of producing the required heat, electricity offers the most attractive advantages. The electric resistance furnace, as now built in such a variety of sizes of either muffle or tube chamber types, has one fundamental point of superiority over all coal, coke, gas or oil-heated furnaces. *It is entirely free from all products of combustion*, the heat being produced by electrical resistance. This is important. It does away with the chief cause of oxidation of the heated steel. Further, the temperature of the electric furnace can be easily and accurately regulated to, and maintained uniform at, any desired point. When electric power is generated for other purposes, the increased cost of this form of energy for operating furnaces is not sufficient to orgue against it. Even when current is purchased, the superior quality of work performed by this kind of furnace, frequently more than offsets the slightly higher cost of operation.

In the actual heating of a piece of steel, it is essential to good hardening that small projections or cutting edges are not heated more rapidly than is the body of