

"A steel is called 'hardened' when it has been suddenly cooled and thereby become as hard as possible. This is owing to the presence of carbon, for pure malleable iron is not affected by the operation, while both steel and cast iron are to a marked degree.

"The operation consists in forging the steel to a certain degree of temperature, and then plunging it into some fluid which abstracts the heat from the tool. The quicker it is done, and the greater the difference of temperature, the harder is the tool. Either water or oil is used; both volatilize at a temperature much below that of the immersed tools, so the hardening takes place in a vapor; oil generally produces the best effects. On the first plunge the metal is chilled and coated with soot, after which a slow process of cooling takes place."

#### TEMPERING.

"Tempering follows hardening, whereby the steel is subjected to a subsequent lower heat, which softens it, and removes its brittleness. When the hardened iron is slowly reheated, its surface gradually assumes phases of color, beginning with a light straw, passing through shades of yellow, brown, purple, blue and red. At a cherry-red heat, the original color before hardening, the effects of the chilling are practically removed.

"Tempering consists in carrying the second heat to one of the above mentioned colors, according to the amount of the brittleness to be annealed. This depends upon the use to which the article is to be put. A second stage of the operation finishes the job. The aforementioned reheat goes on a little way beyond the desired color. The tool is carefully plunged part way into the water or oil, till the disappearance of the steam indicates that it is cold, when another portion of the distance is further immersed for a moment. The tool is withdrawn, the scales rubbed off and the heat of the remaining portion draws to the edge, until it has assumed the proper tempering color. It is then thoroughly cooled. The idea that the steel is cooler at a blue, than at a yellow, in final drawing, is erroneous; for more of the heat is conducted from the red portion to the point, than it radiates to the air, and the first heat to the edge