XIX. On the choice of steel, and the methods of hardening and tempering it

Mr. S. Varley

To cite this article: Mr. S. Varley (1798) XIX. On the choice of steel, and the methods of hardening and tempering it, Philosophical Magazine Series 1, 2:5, 92-97, DOI: [10.1080/14786449808676887](https://doi.org/10.1080/14786449808676887)

To link to this article: <http://dx.doi.org/10.1080/14786449808676887>

Published online: 18 May 2009.

Submit your article to this journal [↗](#)

Article views: 5

View related articles [↗](#)

equal, the velocity with which the hydrogen gaz enters the balloon, will not experience the least change. When the first gazometer is entirely empty, the cock Z 1 is shut, and the first gazometer is filled; and the cock Z 1 is not opened till a little before the second gazometer is totally emptied. The second gazometer is then to be filled again, and in this manner the combustion of hydrogen gaz may be continued by these gazometers to any length of time without interruption. To introduce the oxygen gaz without interruption into the balloon by means of two gazometers, it will be sufficient that the two cocks, which form a communication between the gazometers and the balloon, be immediately fixed in the covering of the latter.

Both halves of the apparatus being similar, the letters of reference are only marked on that part which is given in outline upon the plate.

XIX. *On the Choice of Steel, and the Methods of hardening and tempering it.* By Mr. S. VARLEY. Communicated by the Author.

IT seldom happens that theory and practice are united in the same individual: the man of science often labours under a great disadvantage (notwithstanding his excellent theories) for want of the experience of the practitioner, and the practical man seldom has a theory to guide him. He knows from experience that certain things or operations will produce a particular effect, but can give no reason why. His application to business has not allowed him time to search into causes, nor to reason upon effects; and it would be difficult to persuade this useful class of men how much theoretical knowledge might be gained by applying their leisure hours to study, and how much pleasure might be derived from thus uniting theory with practice, which so mutually assist each other.

I was

I was led to these reflections by reading Mr. Collier's paper on iron and steel (inserted in the first number of your excellent Magazine), in which he gives some methods of hardening and tempering steel; and concludes by saying, that the springs for penknives are covered over with oil before they are exposed to the fire to be tempered, but gives no reason for that application. I shall therefore endeavour to supply that defect, and add some other observations on the management of steel, conceiving that any useful hint on a subject so universally applicable to the manufactories of this country will be of general benefit. It is a subject of the first importance to the practical mechanic: take this useful substance away, and he would be utterly incapable of proceeding one step forward, and would soon be convinced that steel is of more value than gold itself.

For ordinary purposes, the method noticed by Mr. Collier will answer very well, both for hardening and tempering; but in many cases it is necessary that the steel should be of the best quality, and be both hardened and tempered in such a manner as to preserve the greatest hardness possible without brittleness; and steel is of more or less value in proportion as it possesses this property in a greater or less degree.

Steel, when soft, can be wrought into almost any form as well as iron, welding excepted, of which the better sorts, particularly cast steel, are incapable. It can be forged, filed, turned in a lathe, drawn into wire, rolled into large plates, &c. &c. and, when by these means brought into the desired form, it can then be made so hard as to be capable of cutting the hardest substances (the precious stones excepted), while at the same time it is almost proof against being itself worn by friction: but in this state it is brittle, like all other hard substances, and for many purposes must have this brittleness lessened, and this is what is termed by workmen, tempering, and consists in giving it certain degrees of heat according to the temper desired, which may be produced in any degree until the whole effect of hardening is destroyed, and the steel

is

is reduced to its soft state. On each of these operations I shall offer a few remarks, proved by long experience; and, first, on the choice of steel for such purposes as require the best that can be procured for making cutting instruments, such as gravers, punches, turning tools, chisels, &c. &c. to be employed in turning or cutting tempered steel, and substances that are too hard to be cut by tools made of ordinary steel: for these purposes cast steel is undoubtedly the best; but even this sort differs in quality.

The general mode of choosing such as is most suitable for the above purposes is to break a bar, and observe its fracture, and to select the closest grained; but this mode is not always certain, owing to the difference made in the fracture by the steel being hammered under a greater or less degree of heat, steel being much improved by being hammered under a low heat, and even when cold; and when overheated, being quite spoiled for the above purpose. It is owing to this circumstance that the best sorts of cast steel are incapable of being welded as above mentioned. Another method is, to harden with as low a heat as possible a piece of steel, and then to break it, and observe its fracture: but this is not wholly to be depended upon; for some steel breaks with a very close grain, and yet is not of a good quality. But the surest method is to have one end of a bar drawn out into a small rod under a low heat, an obscure red for instance, or but little above; then heat it as before, and suddenly plunge it into pure cold water: if it proves hard, and requires a great force to break it, it is good, let its fracture be what it may*; and I have always found that the specimens that hardened with the lowest heat, and when in that state required the greatest force to break them, proved the best steel. Having thus selected steel fit for the required use,

* This circumstance deserves particular attention, as workmen, in general, reject such steel as breaks with a coarse fracture, even though it be of such a quality as to require a great force to break it after being hardened.

and,

and, with the precautions already noticed, given it the proper form, it may be hardened; but the same method will not answer for all purposes. Some pieces, from their size and figure, are very difficult to be hardened; if they are large, they heat the water in immediate contact with them, and the heat is communicated to the rest of the water, so fast that it prevents the pieces from being cooled quick enough to produce the desired effect: this is in part prevented by continually moving the piece about in the water; but when too large to be hardened by this method, a stream of water must be employed; and for such pieces as the face of large anvils, a birch broom is used with advantage to break the bubbles that are formed by the continual disengagement of air, and which, if not swept away, would prevent that intimate contact and uniform succession of the stream necessary to produce the degree of hardness required. Other articles, from their length, are difficult, and almost impossible to be made hard without bending, or otherwise altering their figure: this circumstance occasions a great deal of trouble; and many a piece of work is spoiled, after a good deal of labour has been bestowed upon it. The method that has succeeded best with me is, either to enclose the piece or pieces intended to be hardened in an iron case or box, open at one end (for the more ready dropping the pieces into the water), and giving it a slow, yet regular heat; then to take the case out of the fire, and drop the pieces into the water in such manner as will allow them to come as little as possible in contact with the air. This method answers two good purposes at once, causing the heat to be more equally applied, and preventing the contact of the air, and of course any scaling; and when the work has been polished and well defended from the air, it comes out nearly as clean as it was before. When the greatest possible hardness is required, it may be obtained by using quicksilver instead of water; but this can only be employed for small articles. For some purposes steel is required to have a superior degree

of

of hardness given to its surface, such as in the case of files, &c. This is obtained by using a coarse powder made of leather slightly burned, hair or horn, either in raspings or in powder: this is mixed with a little common salt, and the files, when just red hot, are thrust into a heap of this powder, some of which adhering to their surface is carried into the fire with them, and gives them a case hardening: the salt fluxes upon their surface, and defends them from the air while passing from the fire into the trough of water, into which they are plunged to harden. The workmen say, the longer this water is used for this purpose the better.

We are now come to the last process called tempering, for one method of which see Mr. Collier's paper; but that method cannot be conveniently applied in all cases, and has several disadvantages, some of which I shall mention. First, each piece must be made bright that the change of colour may be better seen, and must be heated singly or nearly so; and pieces of irregular figure cannot be made to receive an equal degree of heat in all their parts, so that some will be softer than others. These circumstances would retard the manufactory of many articles very much, and prevent their being afforded at the present prices, such as the springs of gun locks, door locks, various articles in clock and watch work, &c. &c. The necessity of making them bright enough to mark the change of colour is obviated by smearing them with oil or tallow, which helps to apply the heat more uniformly, and marks the temper as well as by observing the colour, or nearly so; or by putting the things to be tempered into a proper vessel, and adding so much oil or tallow as will cover them, and then holding them over the fire or the flame of a lamp until a sufficient heat is given. By this means the most irregular pieces may be uniformly heated, and great numbers may be done at one time, and with great certainty: thus are clock and watch pinions, watch verges, balances, &c. tempered; sometimes many dozens at once; and no more time is necessary for the whole

whole than would be for one single article. The requisite temper may be known by the following circumstances: When such a heat is given that the tallow is first observed to smoke, it indicates the same temper as that called a straw colour: this will reduce the hardness but little; but if the heat is continued until the smoke becomes more abundant, and of a darker colour, it will be equal to a brown, and indicates a temper that may be wrought—that is, which may be turned or filed, but with difficulty, and only when a mild sort of steel is employed. If the tallow be heated so as to yield a black smoke, and still more abundant, this will denote a purple temper; and if the steel is good, it will now work more pleasantly, though still hard enough to wear well in machinery. The next degree may be known by the tallow taking fire if a lighted body is presented to it, but yet not so hot as to continue to burn when the light is withdrawn; this would equal a full blue colour. Increase the heat till the tallow continue to burn, being once lighted, and this will denote a pale blue; and if the whole of the tallow be allowed to burn away, or to burn dry, as the workmen call it, it gives what clock-makers mostly use for their work. Further tallow is useless; a small degree of heat more would just be seen in a dark place, or the lowest degree of a red heat: such is the temper given to the springs for coaches, &c. Thus I have given a reason why oil or tallow is made use of, and given you the parallel degrees of temper which by a dry heat are observed by the change of colour only. The method of hardening in quicksilver is of great use where a superior degree of hardness is required; and good steel so hardened, when the precautions before mentioned are duly attended to, will cut glass like a diamond, and turn or cut other steel at so high a temper as to differ but little from quite hard.—Perhaps at a future time I may give you a method by which this hardest of steel may also be worked with considerable ease, and the cases in which I have applied it to advantage.