greater mechanical strength in one direction than another. This bar, if thoroughly annealed at high temperatures, becomes homogeneous in all directions, and has no longer even traces of its previous strains, provided that there has been no actual separation into a distinct series of fibres.

TABLE I.

Influence of annealing upon Swedish Iron, sample G.

—	Approximate Temperature. Cent.	Approximate Temperature. Fahr.	Degrees of softness indicated upon the Magnetic Balance.
Wire hard-drawn as furnished by makers ..	—	—	230o
Annealed at black heat	500o	950o	255o
" dull red	700o	1300o	329o
" bright red	1000o	1800o	438o
" " yellow	1100o	2000o	507o
" " yellow white	1300o	2300o	525o

From Table I. we see that a regular increase of softness occurs as the temperature at which Swedish is annealed increases, the maximum being at a point under that of fusion.

Some difficulty was experienced in annealing all wires to the same standard. The method employed at first was to place the wires in an iron tube heated to the desired temperature; but the temperature of the tube was extremely variable, and it was also found that an interchange of carbon takes place between the tube and the wires. Steel wires rapidly lose their carbon, and thus become softer at each successive annealing; whilst the purest iron absorbs carbon, until it contains exactly the same proportions as the tube itself. It is well known that iron wires at red heat, placed in a porcelain tube through which a current of carburetted hydrogen is passing, will absorb sufficient carbon to become hard steel.

Experiments regarding the time required for perfect annealing showed that, whilst hard steel required several hours, soft iron might be cooled in a few minutes without losing its degree of softness; consequently, knowing the great value of high temperature, the author adopted the following method. The tube was heated to a white heat or otherwise, the iron wires to be annealed were introduced quickly, and the instant they had the same temperature, they were withdrawn and simply allowed to cool in the air. The wire employed being 1 millimetre diameter (0.04 in.), the whole operation was complete in two minutes. This is not suggested as the best practical method of annealing, although in the case of these wires it produced the best result; but the experiments show that, whatever method is employed, the heating should be as rapid as possible to a high degree of temperature, and the wire should cool in a completely neutral medium or atmosphere.

The facts regarding annealing, as pointed out by the measurement of the magnetic capacity of iron wires, have no doubt been in a great measure perceived by ordinary mechanical methods. The results of the author's researches may be thus formulated :—

1. The highest degree of softness in any variety of iron or steel is that obtained by a rapid heating to the highest temperature less than fusion, followed by cooling in a medium incapable of changing its chemical composition.

2. The time required for gradual cooling varies directly as the amount of carbon in alloy. Thus absolutely pure iron would not be hardened by rapid cooling, as in tempering; whilst steel might require several hours or days for cooling, in order to soften it, even in the case of pieces only 1 milimetre diameter (0·04 in.) Slow cooling has no injurious effect upon iron, when cooled in a neutral field: consequently, where time is no object, slow cooling may be employed in every case.

A wire or piece of iron thoroughly annealed must not be bent, stretched, hammered, or filed; the hardening effect of a bend is most remarkable, and the mere cleaning of the surface with sand-paper hardens that surface by several degrees on the scale.

The following Table II. shows the effect of annealing upon a series of wires, kindly furnished expressly for these experiments by Messrs. Frederick Smith & Co,, of Halifax

TABLE II.

Mark.	Description of Iron or Steel.	Magnetic Capacity: Bright as sent. Degrees on Scale.	Magnetic Capacity: Annealed. Degrees on Scale.
G	Best Swedish charcoal iron, 1st var.	230	525
F	" " 2nd "	236	510
T	" " 3rd "	275	5s3
S	Swedish Siemens-Martin iron . .	165	430
H	Puddled iron, best best	212	340
Y1	Bessemer steel, soft	150	291
Y	Bessemer steel, hard	115	162
Z	Crucible fine cast steel	50	84

From the above Table it will be seen that annealing had a great effect on the iron wires, doubling their magnetic capacity, and that Swedish iron stands far in advance of puddled iron; consequently, for the cores of electro-magnets in Telegraph instruments—as in fact for all electro-magnets—Swedish iron is the most suitable; and the magnetic balance may find a field of practical utility in measuring each core before it is used in an electro-magnet, and may also aid by its measurements in finding the best methods of annealing.

TEMPERING.

The influence of tempering upon the magnetic retentivety, or molecular rigidity, has been shown in every piece of iron or steel yet examined. Swedish iron hardens but 10 to 20 per cent by tempering, while steel hardens 300 per cent; the molecular rigidity of tempered steel being 18 times greater than that of soft iron. The influence of different methods of tempering on crucible steel is shown in Table III., ranging from its ultimate molecular rigidity to its ultimate softness when annealed.

TABLE III.

Tempering of Crucible Fine Cast Steel, mark R.	Plate 2. Fig. 5.	Magnetic Capacity.
Bright yellow heat, cooled completely in cold water...	*a*	28
Yellow red " "	*b*	32
Bright yellow, let down in cold water to straw colour.	*c*	33
" " " blue	*d*	43
Bright yellow, cooled completely in oil...........	*e*	51
Bright yellow, let down in water to white...........	*f*	58
Red heat, cooled completely in water..........	*g*	66
" " " oil........	*h*	72
Annealed..............................	*j*	84

We may therefore represent graphically a diagram which shall include all methods of tempering; and another diagram which shall include all varieties of iron, from the softest iron to the hardest steel, intermediate qualities of hard iron and mild steel finding their place between the two extremes. The first diagram is shown in Fig. 5, Page 164, in which the figures represented by lines (lettered as in Table III.) erected from points on a horizontal scale, to meet a diagonal line drawn at 45°. Thus the height of each line shows the magnetic value, and their distance apart shows the way in which they gradually approach the maximum. The second diagram is shown in Fig. 6, page 000, where the lines are lettered as in Tables IV. and V.

The numerous specimens of wire tested have been forwarded direct from the manufacturers, at the request of the author's friend, Mr. W. H. Preece, F.R.S., Electrician to the General Post Office. The chemical analyses of most of these wires have not beem furnished; but Messrs. Frederick Smith & Co., of Halifax, not only supplied a beautiful series of wires, but had them specially analysed by Mr. Henry S. Bell, of Sheffield, in order that the results should be as exact as it was in their power to make them. The author therefore neglects in this paper all other samples except those of Messrs. Frederick Smith & Co.: they all stand between, or are included by, the two extremes of Swedish iron and cast steel.

Table IV. on page 165 gives the complete results of the mechanical, chemical, and physical tests upon these wires. The tensile strength and electric conductivity are as furnished by Messrs. Frederick Smith & Co.; the chemical analyses are as given by Mr. Henry S. Bell; and the magnetic capacities of