2. The resistance to a feeble external magnetizing force is directly as the hardness, or molecular rigidity.

The author has proved this to be the case with sixty different varieties of iron and steel furnished direct from the manufacturers. And he has found that each variety of iron or steel has fixed points, beyond which annealing cannot soften, nor tempering harden ; consequently, if all varieties were equally and perfectly annealed, each variety would have iss own magnetic capacity, or its specific degree of value, by means of which we could at once determine its place and quality.

If in place of several varieties we take a single specimen, say hard-drawn Swedish iron wire, and note its magnetic capacity, we find that its value rises rapidly with each partial annealing, until an ultimate softness is obtained, being the limit of its molecular freedom. We are thus ennabled to study the best methods of annealing, and to find at once the degree of softness in an unknown specimen.

Similarly, when we temper annealed iron and steel, we find that we can follow out each degree of temper up to ultimate molecular rigidity ; and we may thus appreciate, in an unknown specimen of unknown temper, the degree of its hardness.

We have thus in each piece of iron or steel a limit of softness and hardness. In soft Swedish iron, tempering hardens it but 25 per cent. on the scale adopted ; whilst mechanical compression, such as hammering, hardens it 50 per cent. In cast steel, tempering hardens it 400 per cent., whilst mechanical compression gives but 50 per cent. Between cast steel and Swedish iron, we find a long series of mild steel, hard iron, &c., varying in their proportionate degrees between the two extremes just mentioned.

The theory which the author has advanced, of molecular freedom as in soft iron, and molecular rigidity as in cast steel, fully explains all the changes which we are enabled to perceive and measure ; but it is not absolutely necessary to accept the theory, in order to appreciate the results. For, leaving theoretical considerations aside, we have one proved fact : namely that the magnetic power or capacity of a piece of iron, under the influence of an external limited magnetising power, depends upon its softness ; and that the retention of magnetism, when the external power is withdrawn, depends upon its hardness. The same degree of temper or annealing, upon the same iron or steel, gives invariably the same readings ; but the slightest change—say from a straw-coloured temper to a blue—gives very wide differences.

DESCRIPTION OF APPARATUS.

The instrument which the author has constructed and used n these experiments, and which he has named a "Magnetic Balance," consists of a delicate magnetic needle N, Fig. 1, page 164, suspended by a silk fibre ; it is 5 centimetres in length(2 in.), and its pointer rests near an index having a single fine black mark for its zero. The movement of the needle on either side of zero is limited to 5 millimetres (0.2 in.) by means of ivory stops or projections. When the north end of the needle and its zero index are north, the needle rests parallel with its index ; but the slightest external influence such as a piece of iron 1 millimetre in diameter (0.04 ins.) placed at 10 centimetres distance (4 ins.) deflects the needle to the right or left, according to the polarity of ts magnetism, and with a force proportionate to its magnetic power. If we place on the opposite side of the needle, and at the same distance, a wire possessing absolute the same polarity, of similar name and force, the two balance each other and the needle returns to zero ; and if we know the magnetic value required to balance the first piece of iron we know the magnet value of both.

The iron I, which may be in the form of wires, rods, bars, plates, or any shape or size desired, is placed a fixed distance, preferaably 10 or more centimetres (4 ins.) resting against a fixed brass stop C. The centre line of the iron should be in line with the centre on which the needle turns, and it should be placed at right angles to the needles, lying horizontally east and west, so as to be free from the directing influence of the earth's magnetism.

The compensator, placed upon the opposite side of the needle, and at a distance of 30 centimetres (12 ins.), consists of a powerful steel bar-magnet, 3 centimetres wide, 1 centimetre thick, and 15 centimetres long (1·18 × 0.4 × 5·31 ins.), This turns upon its axis A, carrying with it the pointer P to indicate its degree of angular displacement on the graduated circle. Generally this bar-magnet is parallel with the needle, the pointer of the compensator and the needle being both at zero ; but when we wish to measure the amount of magnetism in the piece of iron I, the bar-magnet is made to pass through an angular displacement necessary to make it balance this force, and its index reading on the graduated circle is taken as the comparative value. The north pole of the compensator should be opposite the north pole of the needle, in order to render it almost estatic and consequently exceedingly sensitive.

In order to magnetise the iron I, if required, by an electric current, a coil of insulated copper wire F is placed near C, the iron I then becoming the core of an electro-magnet. Now as this coil, independently of its iron core, acts upon the needle, its action must be balanced by an opposing coil G, on the opposite side of the needle. The position and power of the second coil G can be minutely adjusted by means of the lever H, which allows of finding a position where the two coils completely neutralise each other. If we introduce iron in the coil on either side, the balance is destroyed, and we have solely the magnetic influence of the iron core, the value of which we find by an equal opposing magnetism brought into play by the rotating magnetic compensator A

A reversing key J serves to change the direction of the current, and thus any difference between north and south polarity in the iron core I can be observed. One Daniell cell is all that is required as a battery ; but great care must be taken that its electromotive force is a constant, otherwise all variations in the battery would be read as variations in the quality of the iron itself ; and we need in addition a series of resistance coils R from 10 to 100 ohms, in order to reduce the current sufficiently for bringing into range the whole series, from soft Swedish iron to cast steel. Separate and finer determination can then be made, by an extremely weak force for soft iron, and by full or increased battery power for tempered steel. A series of different sized coils to replace that at F is necessary, whenever we vary greatly the diameter of the iron core. The first size, with an internal core opening of one centimetre (0·4 in.), will test bars and rods of wire from one centimetre diameter down to the finest needle ; but for larger bars, plates, etc., coils must be used which allows free passage for the iron into the core opening. Great care and some practice are necessary in the use of the instrument, so as to ensure that the iron is placed in a neutral field ; but when we have really obtained the nécessary conditions, we can take several readings in a single minute, with an invariable result for the same kind of iron.

All irons and steels have some traces of remaining magnetism ; it is therefore necessary that a double reading (north and south) snould be taken by means of reversed currents. In this case the quadrant of the compensator scale is divided into 360° on each side of zero ; and the total value of north and south polarity added together is that given in the following tablef of magnetic capacity.

Several methods of observation can be employed with the magnetic balanse, the usual one being that already described ; but there are many others, such as magnetising all specimens to the same value and noting the amount of current required. We may also observe the remaining magnetism after the cessation of the current ; the influence of a weak current after the passage of a strong one, etc, Nany of these methods give interesting facts, particularly useful to those making researches upon the cause os magnetism.

By means of this instrument the author has tested sixty brands of iron and steel, mostly in the form of wires. A wire 1 millimetre diameter and 10 centimetres long (0·04 in. and 4 ins.) was the standard size used, as we can mora readilp temper small wires than large rods. In all comparative experiments between iron of different grades, we must have one standard form to which all the rest must be similar in form and size. Thus we could not compare a square or flat bar with a piece of wire ; but if all pieces have the same form, then any difference observed between them must be due to their comparative softnnss, from which we can deduce the quality and place of each in the range from soft iron to cast steel.

INFLUENCE OF ANNEALING UPON THE MOLECULAR STRUCTURE OF IRON AND STEEL.

The magnetic balance shows that annealing not only produces softness in iron, and consequent molecular freedom, but entirely frees it from all strains previously introduced by drawing or hammering. Thus a bar of iron drawn or hammered has a peculiar structure, say a fibrous one, which gives a