Platinum Alloy Permanent Magnets

HIGH ENERGY AND COERCIVE FORCE VALUES OF COBALT-PLATINUM

For many years it has been known that some alloys in the cobalt-platinum system have surprisingly pronounced ferromagnetic properties, but until recently it has not been generally appreciated that those alloys in the system containing approximately equal numbers of atoms of each element (23.3 per cent by weight of cobalt) can provide a more powerful permanent magnet than any other material known.

In spite of all the intensive work of the past thirty years or so in developing improved permanent magnets, no material has been found—either in the Alnico range, among any of the ferrites, or even in the latest discovery of compressed powdered manganese bismuthide—which is as much as half as powerful as a suitably heat-treated cobalt-platinum permanent magnet.

The table on page 85 compares the values of coercive force and the amounts of energy that can be stored per cubic centimetre, $BH_{(max)}$, in a cobalt-platinum permanent magnet with corresponding values for some of the better known permanent magnet materials. From these typical values the extraordinary combination of properties obtainable with a cobalt-platinum alloy is clearly to be seen.

One reason for the relative neglect of the cobalt-platinum magnet alloys may have been the belief—plausible enough at first sight—that their use in industry could never be economically justified. However, as so often happens, instances have arisen in which the advantages to be gained from the unique magnetic properties of the alloy far outweigh the intrinsic cost.

A recent example of the value of cobalt-platinum permanent magnet alloy is to be found in the Hamilton electric wrist watch, introduced last January. Here the need was for the smallest possible permanent magnet motor to drive the balance wheel and for this the highest energy magnetic material had to be selected, it being essential also that the magnet should resist demagnetisation. The need has been met by using the 23:77 weight ratio cobalt-platinum magnet alloy to make cylindrical slugs 0.090 inch in diameter,

Platinum Alloy Magnets in the First Electric Watch

The revolutionary design of electric wrist watch, introduced in January by the Hamilton Watch Company of Lancaster, Pennsylvania, after ten years of research and development employs a permanent magnet motor, using the balance wheel as the rotor element. This necessitated the use of a permanent magnet material of highest energy content and—to resist demagnetisation—the highest coercive force. The 23 per cent cobalt-platinum alloy was selected, first for its unique magnetic properties and secondly on account of its ductility.

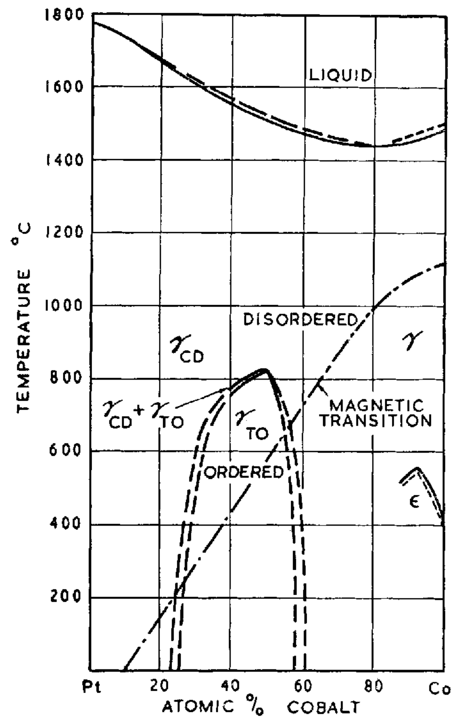
0.083 inch high, weighing only 134 milligrams each. These are heat treated, stacked in alignment, and magnetised. The new watch is said to run without attention for a year, energised by a miniature dry cell, and to keep time to an accuracy of 99.995 per cent.

Metallurgical Investigations

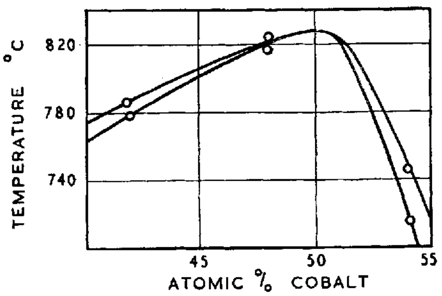
Although the general characteristics of cobalt-platinum alloys are well established, the reasons for their outstanding magnetic behaviour are less well understood. While the discovery that the 50:50 atomic per cent alloy had unusually high coercive force after heat treatment was reported by Jellinghaus (1) in 1936, the early investigations of the phase diagram by Nemilow (2) and by Gebhardt and Köster (3) did little to help on this point. The most valuable contribution so far made to our knowledge of the cobalt-platinum system has been by a team of investigators in America, J. B. Newkirk and R. Smoluchowski working at the Carnegie Institute of Technology and A. H. Geisler and D. L. Martin (4, 5, 6, 7) at the Schenectady research laboratories of the General Electric Company. They have established a revised equilibrium diagram, reproduced here, from which it is clear that the alloys in the neighbourhood of 50 atomic per cent are subject to ordering on cooling below 800°C. Metallurgically, the transformation is of particular interest, since it is the first one which has been definitely established to be a true phase transformation; there is a field in which discrete regions of ordered tetragonal lattice

Magnetic Properties of Cobalt-Platinum by Comparison with other Magnetic Materials

Material	BH(max) × 10^{-6}	Coercive force H_c oersted
Cobalt-platinum .. (48 at.% Co, cooled from 1000°C to 200°C in 10 minutes, reheated to 600°C for 5 hours)	9.0	4000
Alnico II	1.6	540
Alnico V .. .. **(Ticonal)**	5.0	575
Alnico VI	3.8	730
Alcomax IV ..	4.7	760
Barium Ferrite ..	3.0	1800
Bismanol	4.3	3400



Equilibrium diagram for the cobalt-platinum system (Newkirk, Smoluchowski, Geisler and Martin)



Detail of the boundaries of the two-phase field separating the ordered from the disordered phase (Newkirk, Smoluchowski, Geisler and Martin) and of disordered cubic lattice have been found to co-exist in equilibrium.

Ordering Transformation

On ordering, usually by reheating the alloy, after first cooling fairly rapidly from 1000°C, for some hours at about 600°C, the atoms in each face-centred crystal arrange themselves in parallel layers each of cobalt and platinum atoms alternatively, and the unit cell seems to expand about 1 per cent in one crystallographic direction and contract the same amount in the two other directions. The strain induced by this dimensional change in the relatively rigid alloy when it is ordered at about 600°C results in considerable mechanical hardening and puts it in a condition in which it is best able to retain induced magnetism. It is of interest that this material is the only permanent magnet material known so far to harden by an ordering mechanism: all the other known permanent magnet alloys are hardened by a precipitation reaction.

The exact magnetic characteristics of the cobalt-platinum alloys can be varied a good deal by adjusting the composition, which may be in the range from 40 to 60 atomic per cent of cobalt, and by varying the heat treatment. Some of the results obtained in this way have recently been described by D. L. Martin (8). It is found, for instance, that the alloys need to be aged longer to develop the maximum value of coercive force than to develop the maximum value of BH (max). The effect of cobalt content is not as clear cut as might be expected, but it is confirmed that alloys with 49 to 50 atomic per cent of cobalt have the highest coercive force and the highest BH (max).

Martin notes with some surprise that the magnetic properties depend not only on the time and temperature of ageing but also on the temperature at which the alloys are previously heated for disordering and the rate at which they are then cooled. It may be recalled, however, that in the copper-manganese-nickel system the hardness developed on ordering certain alloys is similarly affected by the previous disordering heat treatment. Here the effect is undoubtedly due to the variations in grain size produced by the various pre-treatments; the larger the grain size the greater the local strains set up when each crystal changes shape on ordering.

One final point may be emphasised. The cobalt-platinum alloys can all, by suitable techniques, be worked mechanically by forging, they can be rolled to bar, sheet or strip, and they can be drawn to wire. They represent the only outstanding permanent magnetic material of the many introduced during the last thirty years that is malleable and ductile before hardening. This alone may render them particularly suited to numerous special applications.

References

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