

Platinum Alloy Permanent Magnets

PROPERTIES AND APPLICATIONS OF PLATINAX II

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Platinax II is the latest development in magnetic alloys of the cobalt-platinum system, and is one of the most powerful permanent magnet materials known. Because it can be machined, rolled or drawn without difficulty, this alloy lends itself to the manufacture of magnets of complex shape or very small size that would be impracticable in conventional alloys

Certain alloys in the cobalt-platinum system have, for many years, been known to possess strong ferromagnetic properties. In 1936 Jellinghaus (1) reported that the 50 atomic per cent alloy had an unusually high coercive force after heat treatment. In more recent investigations, carried out by J. B. Newkirk and R. Smoluchowski (2, 3) at the Carnegie Institute of Technology and by A. H. Geisler and D. L. Martin (4, 5) at the Schenectady research laboratories of the General Electric Company, it was shown that alloys in the neighbourhood of 50 atomic per cent are subject to ordering on cooling below 825°C and that after a heat treatment which introduced partial ordering these alloys had pronounced magnetic properties.

The exact magnetic properties of the cobalt-platinum alloys can be varied appreciably by slight adjustments in the composition and by variations in their heat treatment. Investigations in this field carried out in the Johnson Matthey Research Laboratories have resulted in the production of an improved alloy—Platinax II—of outstanding magnetic properties combined with good workability.

In the annealed condition this alloy can therefore be machined without difficulty and can be rolled or drawn to virtually any size. The manufacture in this material of powerful magnets of complicated shape or very small size is practicable, this representing a significant advantage over base metal magnetic

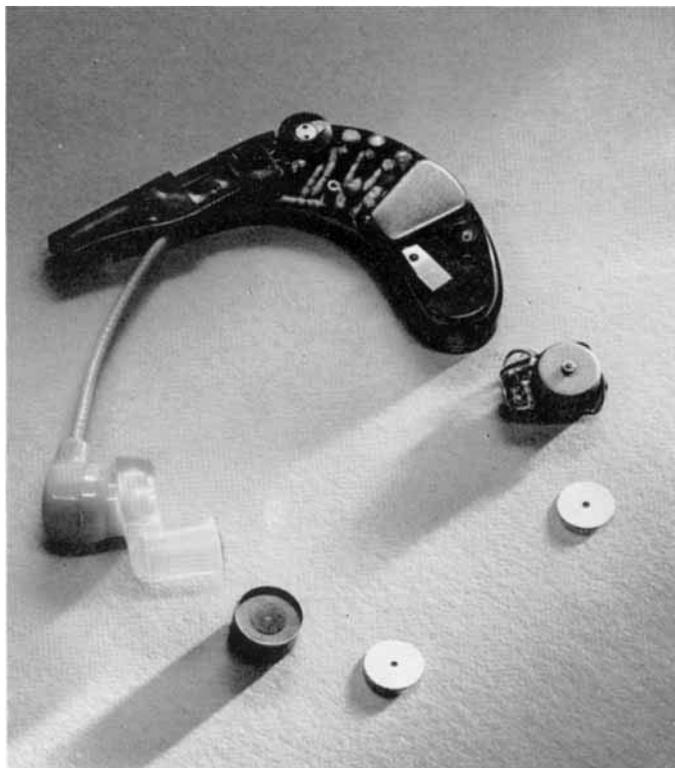
alloys, most of which are brittle and cannot be worked by methods other than grinding. Thus the high intrinsic cost of the alloy can be accepted where miniaturisation or similar demands for a powerful magnet of very small dimensions make it necessary to design a permanent magnet consisting, for example, of a small piece of wire, a thin disc or a small part produced from rod or strip.

Obviously where Platinax II is to be used to replace a conventional magnet material it is essential that full advantage is taken of its properties, and the most economical size and shape must be chosen to provide a given flux density in a particular circuit. As will be seen, a number of applications have arisen in which appreciable economic advantages are gained from its unique magnetic properties.

Magnetic Properties of Platinax II

The optimum magnetic properties of Platinax II are obtained by a two-stage heat treatment process (6) that brings about partial ordering of the atomic structure. The first stage is carried out at 950 to 1000°C, approximately three hours being required to disorder the structure. The parts are then transferred to a salt bath maintained at 660°C, where they are kept at this temperature for a further fifteen to forty-five minutes. A protective atmosphere must be used to prevent oxidation while the parts are in the furnace, and transfer to the salt bath must be made sufficiently

Platinax II magnets in the form of thin discs are used in both the microphone and the earpiece of a hearing aid made by Fortiphone Ltd. The component parts of these two units are shown here, the magnet discs being in the right foreground. By using these magnets it was possible to reduce considerably the size and weight of both the microphone and the earpiece.

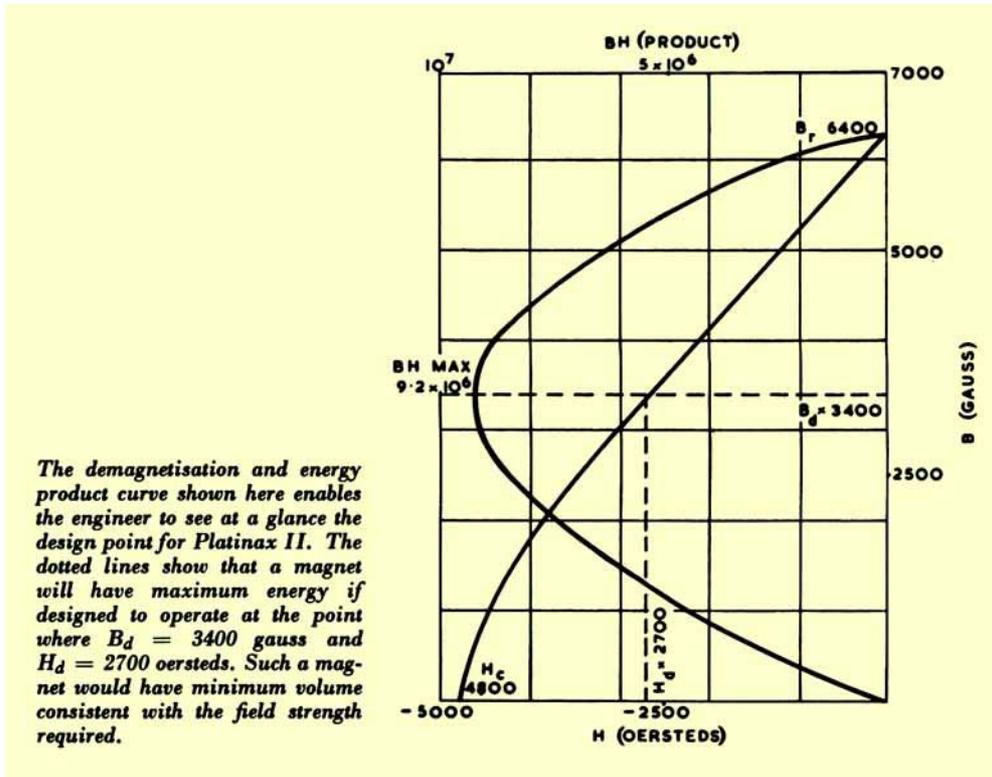


quickly to prevent the temperature of the parts falling below 660°C. It is convenient to wrap small parts in nickel foil with alumina powder to prevent sticking; a wire can then be attached to the foil to facilitate handling. The time required at 660°C is dependent on the amount of previous working the material has received, and there may be slight differences from batch to batch. The time required to give optimum magnetic properties can be found by heat treating a series of samples, to cover the range from fifteen to forty-five minutes, at 660°C. Magnetic tests can then be made and by plotting demagnetisation curves for each sample, and then BH_{\max} against time, the best conditions can be determined for the batch.

After heat treatment the alloy is magnetically isotropic, that is it can be magnetised to the same degree in any direction. This is of particular advantage when small parts are to be stamped from foil or when cylindrical parts are to be cross magnetised.

Table I
Typical Properties of Platinax II

Remanence (B_r), gauss	6,400
Coercive force (H_c), oersteds ..	4,800
Energy product (BH_{\max}), gauss oersteds	9.2×10^3
Flux at BH_{\max} (B_d), gauss ..	3,400
Demagnetising force at BH_{\max} (H_d), oersteds	2,700
Force required for full magnetisation, oersteds	$\geq 20,000$
Curie temperature, °C	≈ 500
Resistivity Annealed, $\mu\Omega$ -cm ..	42.4
Heat treated, $\mu\Omega$ -cm ..	30.2
Hardness V.P.N. Annealed ..	200-210
Heat treated ..	305-315
Coefficient of linear expansion (0-100°C), per °C	9.3×10^{-6}
Specific gravity	15.5



A correctly heat treated piece of Platinax II when fully magnetised will have a remanence (B_r) of 6,400 gauss, a coercive force (H_c) of 4,800 oersteds and an energy product (BH_{max}) of 9.2 mega gauss oersteds. A typical demagnetisation and energy product curve is shown here for a magnet that has been given a thermal treatment to yield the maximum value for $B \times H$.

The hysteresis loop of a magnetic material shows graphically the relation between flux density and magnetising force. The area of a complete loop is a measure of the energy expended in taking the magnetic material through a complete magnetic cycle to its saturation point in both directions. The whole loop is of importance when considering soft magnetic materials, but in the case of permanent magnet materials, such as Platinax II, it is the second quadrant, or demagnetisation curve, that is of interest to designers. Two characteristics of particular importance are the remanence B_r when the magnetising

field is returned from a value sufficient to saturate the magnet back to zero, and the coercivity, which is a measure of the opposing field required to reduce the field of a previously saturated magnet to zero.

The energy product, or $B \times H$ curve, enables the optimum working point of a magnetic material to be seen at a glance. It is shown by the dotted lines and indicates the design values $B_d = 3,400$ gauss and $H_d = 2,700$ oersteds. A magnet designed to work at this point will have the smallest volume consistent with the field strength required.

Magnetising Procedure

A field strength of at least 20,000 oersteds is required to develop the maximum magnetic properties in Platinax II. This is because the very high coercive force of this alloy acts as a resistance to magnetising, just as this same property makes the alloy, once magnetised, very difficult to demagnetise.

Magnetising cylindrical or rectangular

shaped pieces can be achieved by placing them between the poles of an electro-magnet, but the length of magnets which can be made by this method is limited on account of the high field strength required across the gap.

Larger magnets can be made by placing them in the core of a coil consisting of a few turns of heavy section copper wire through which a current of several thousand amperes can be passed for a very short time. Such heavy currents can be obtained either by discharging a bank of capacitors through the coil or by using similar equipment to that used for spot welding, enabling a heavy current to be passed for one half cycle of the AC mains supply; these methods are generally referred to as "pulse magnetising". This technique can also be used to make horseshoe and ring magnets, where instead of using a coil, a single straight copper bar is passed through the centre of the part to be magnetised. The gap between the magnet poles should be closed with a piece of soft iron or Permendur during magnetising to reduce the reluctance of the gap.

Slope of Recoil Loop

In most applications magnets are subjected to variable or cyclic demagnetising conditions, i.e., the value of $-H$ is not constant. Under such conditions the value for remanence no longer corresponds with that shown on the major demagnetisation curve but with a value on a minor or recoil loop. Typical values for the slope of the recoil loop at three points in the demagnetisation curve are given in Table II.

Table II Slope of Recoil Loops		
Starting Point of Recoil Loop H, oersteds B, gauss		Slope of Recoil Loop (Reversible Permeability) $\mu_r = \frac{\delta B}{\delta H}$
-2,000	4,000	1.13
-3,000	2,800	1.14
-3,600	1,900	1.16

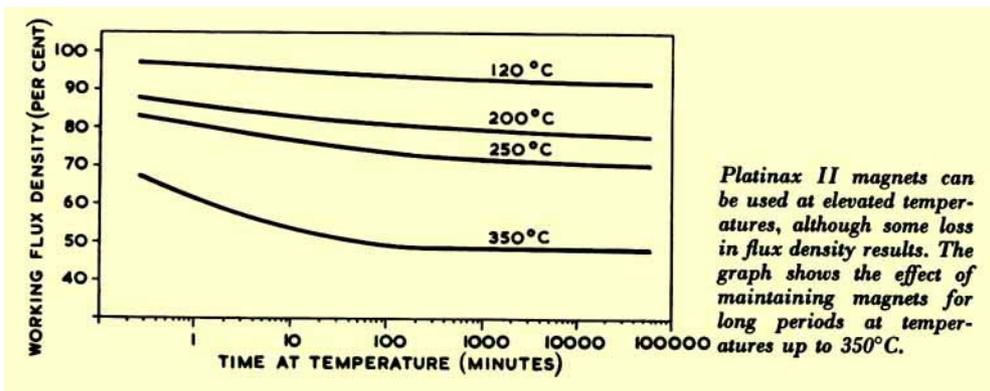
Effect of Temperature Cycling

During normal service it is possible for magnets to be subjected to repeated changes in temperature. This may be due to changes in ambient temperature as, for example, would be met in the case of aircraft instruments and control gear. A series of tests has been carried out on Platinax II magnets made from both cast and worked material to find the effect of temperature cycling between -40°C and $+70^{\circ}\text{C}$. The values for remanence and coercivity were first determined at room temperature, the samples were then cooled to -40°C , allowed to reach room temperature again, then raised to $+70^{\circ}\text{C}$ and finally allowed to cool to room temperature. This treatment caused a small drop in both remanence and coercivity, but further cycling of the same samples between -40°C and $+70^{\circ}\text{C}$ caused no further change. Magnets required for use over a known temperature range can, therefore, be stabilised by a single cycle between the two extreme temperatures.

Properties at Elevated Temperature

Platinax II magnets can be used at elevated temperatures, although some loss in flux density results. The upper graph on page 84 shows the losses that occur when magnets are maintained at temperatures up to 350°C for periods up to 1,000 hours (7). The major loss in flux occurs during the first few minutes at temperature. This is illustrated more clearly in the lower graph, where the loss of flux in the first five minutes is shown. Thereafter, with longer heating times, the rate of loss of flux slows down appreciably. Table III gives the percentage loss in working flux after five minutes, two hours and 1,000 hours at different temperatures.

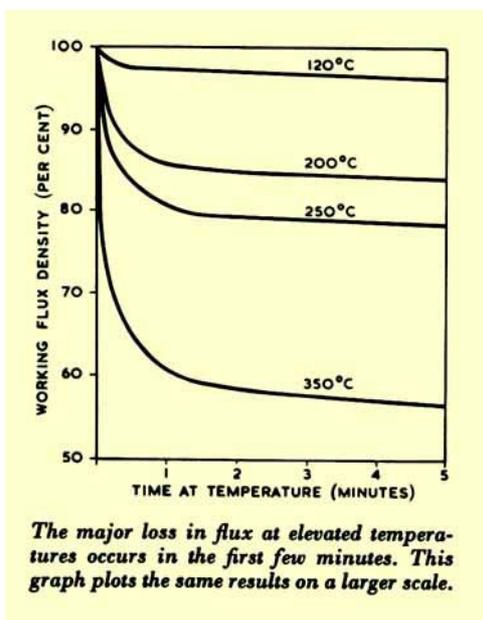
At temperatures up to 250°C no damage is done to the inherent magnetic properties and magnets can be remagnetised to almost their original strength, the small drop in energy product (BH_{max}) resulting from a loss in coercive force (H_c). At 350°C , however, there is some permanent damage to inherent



magnetic properties after 1,000 hours which is probably the result of increased ordering of the crystal structure. On remagnetising after the 1,000 hours treatment at this temperature the values obtained for remanence and coercive force are lower than the original values and there is, therefore, a permanent drop in the energy product. Table IV shows the initial and final values for B_r , H_c and BH_{max} for samples heated for 1,000 hours at temperatures up to 350°C. It can be seen that even after this latter treatment the magnets are still very powerful, having a $B_r = 6,230$ oersteds, $H_c = 4,600$ gauss and

$BH_{max} = 8.35 \times 10^6$ gauss oersteds. At temperatures above 350°C the losses would presumably increase more rapidly with

Temperature, °C	Time at Temperature		
	5 minutes	2 hours	1,000 hours
120	3	5.5	7.5
200	16	18.5	22.5
250	21.5	26	29
350	43.5	50.5	51



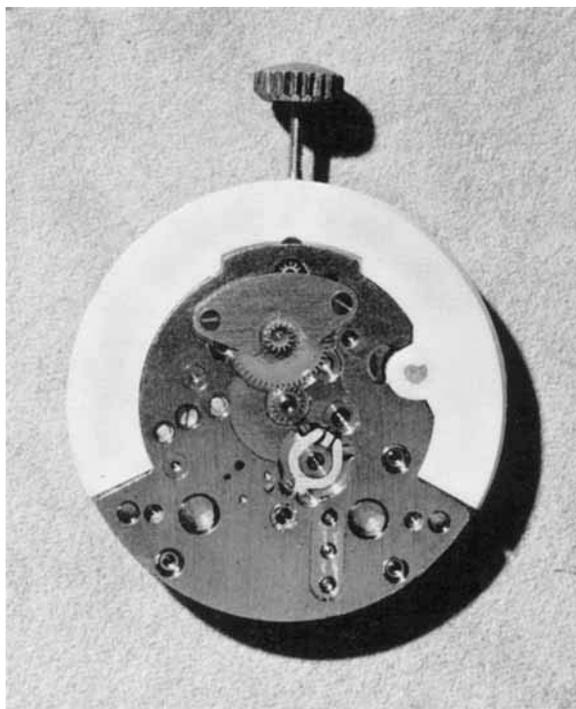
temperature as further ordering took place, until the transformation temperature of the alloy was reached at 825°C.

Since most of the loss in flux occurs in the early stages of heating, magnets required for use at elevated temperatures can be stabilised by a short heat treatment for about two hours at the highest temperature likely to be reached in service.

Corrosion Resistance

Platinax II magnets have a high resistance to corrosion. A polished surface will remain unchanged after months of exposure to normal atmospheric conditions, while the alloy is virtually unaffected by mineral acids and caustic alkalis at ordinary temperatures.

The movement of the first Swiss electric watch, developed by Ebauches S.A. of Neuchatel, incorporates a horseshoe magnet, made from Platinax II, secured to the bottom plate.



It will also withstand prolonged immersion in hot, strong sulphuric acid solutions without attack. It is therefore possible to use Platinax II magnets in pumping or metering devices where one set of magnets in the drive unit is in contact with a corrosive liquid.

Applications of Platinax II

The high intrinsic value of this material tends to restrict its use to applications where very small magnets are required, but it is in such cases that its very high energy product and coercive force can be fully utilised. Small, powerful magnets can be made for equipment in which miniaturisation is essential. Further, the very high values of coercive force that can be obtained enable magnets to be made very short in relation to their cross section. Under open circuit conditions a magnet with a length-to-diameter ratio of 1.2 to 1 would operate at the BH_{max} point of the curve.

Applications are thus to be found in miniature relays, in stereo and monaural pick-ups for record reproduction, where weight must be kept to a minimum, and in a variety of

magnetic clutches. Further possibilities are being studied in moving magnet loudspeakers, in flow meters based on electromagnetic induction, in small transducers for medical research and in applications where a high resistance to corrosion is necessary.

Platinax II magnets stamped from foil are used in both the microphone and the earpiece of a hearing aid made by Fortiphone Limited. For each application a disc 0.3125 inch in diameter and only 0.003 inch thick is used, magnetised through the thickness. The component parts of these two units and the com-

Table IV
Properties on Remagnetisation after 1,000 hours at Elevated Temperatures

Property	Initial value	Remagnetisation Value after 1,000 hours			
		120°C	200°C	250°C	350°C
Remanence (B_r), gauss	6,400	6,400	6,400	6,360	6,230
Coercive force (H_c), oersteds . .	4,800	4,770	4,650	4,620	4,600
Energy product (BH_{max})	9.2×10^5	8.9×10^5	8.8×10^5	8.6×10^5	8.4×10^5

plete hearing aid are shown on page 87. By using these magnets it was possible to reduce considerably the size and weight of both microphone and earpiece, the microphone measuring only 0.5 inch long by 0.45 inch maximum width by 0.296 inch in thickness. The earpiece measures only 0.43 by 0.43 by 0.59 inches. Both of these units have an excellent frequency response.

For some time now electric wrist watches incorporating cobalt-platinum alloy perma-

nent magnets have been available in the United States. Just recently the first electric watch of Swiss manufacture has appeared, the movement having been developed by Ebauches S.A. of Neuchatel and the watch produced by the Avia concern, Degoumois & Co S.A. In this movement a horseshoe-shaped magnet is used, blanked from Platinax II sheet and pulse-magnetised so that the poles are at the ends of the two limbs of the horseshoe.

References

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Ruthenium Complexes in Homogeneous Catalysis

HYDROGENATION OF OLEFINIC COMPOUNDS

Catalysed chemical reactions have grown enormously in importance during the past few decades, notably in the petroleum, petrochemical, heavy, fine and pharmaceutical chemical industries. At the present time almost all such reactions are heterogeneous gas or liquid phase processes in which the platinum group of metals play a well-known role as highly active and selective oxidation and hydrogenation catalysts, usually dispersed on a carrier or support. Interest has however focused during recent years on a number of homogeneous liquid phase catalysed reactions.

In such reactions, numerous workers are investigating whether the known catalytic properties of the platinum metals, together with their ability to form a very large range of complex co-ordination compounds, may lead to their future use on a large scale in this field. Among such investigations, it has recently been reported by J. Halpern, J. F. Harrod and B. R. James of the University of British Columbia (*J. Amer. Chem. Soc.*, 1961, **83**, (3), 753) that homogeneous hydrogenation of the olefin double bonds of maleic, fumaric and acrylic acids has been effected using chlororuthenate (II) complexes as catalysts. Experi-

ments conducted with maleic acid in HCl solutions and with Ru(II) generated by reduction of $(\text{NH}_4)_2\text{RuCl}_6$ with TiCl_3 , showed that hydrogenation proceeds at a conveniently measurable rate in the temperature range 70 to 90°C.

Homogeneous hydrogenation of olefinic double bonds necessitates activation in solution of both the olefinic compound and of the dissolved hydrogen by the catalyst. The latter should not itself be reduced in the process to a lower and possibly inactive valency state. Such catalyst-reduction has been responsible for the failure experienced by earlier workers when using Cu(II), Ag(I) and Hg(II) in the attempted hydrogenation of olefins. It is believed that hydrogenation using Ru(II) proceeds via the formation of a 1:1 Ru(II)-olefin complex which is capable of activating hydrogen and reacting with it to form a saturated compound with the liberation of Ru(II).

Although ethylene and propylene have also been found to form 1:1 complexes with Ru(II), homogeneous hydrogenation has not so far been observed under the conditions studied. It seems possible, however, that ruthenium complexes may find applications in this field.