

High Temperature Behaviour of Iridium-Rhodium Alloys

OXIDATION RESISTANCE AND COMPATIBILITY

Within the increasingly exotic context of space research we have grown quite accustomed to consider seriously the detailed design of components which might have a useful life of a few minutes only. It is refreshing, therefore, to hear of rocket units that are intended for continuous operation at 2000°C for periods up to thirty days.

"Poodle" is the name of a low thrust rocket engine being developed under the joint auspices of the A.E.C. Division of Isotopes Development and of the Nuclear Propulsion Office of the United States Government. The work is being carried out by T.R.W. Systems, Redondo Beach, California, and two progress reports by J. L. Blumenthal, J. R. Ogren and R. C. Ham, have recently been released (1).

The rocket uses a low viscosity gas as a propellant, and polonium as a radioactive

heat source. In the prototype scheme described heat energy from the polonium source is transferred to hydrogen which, when heated to 2000°C, is rapidly accelerated and discharged at a rate of one pound per hour to produce a thrust of 0.25 lb. Continuous operating periods of the order of thirty days are intended and the polonium heat source capsule must retain its integrity under these extreme conditions even though subjected to a high internal pressure of helium.

The first metallurgical problem concerned the selection of a refractory metal alloy for the heat source with acceptable creep properties at 2000°C. Several tantalum and tungsten base alloys were selected and evaluated. The most promising appeared to be a 25 per cent rhenium-tungsten alloy and a tantalum base alloy, T-222, which contained 9.5 per cent tungsten and 2.5 per cent of hafnium.

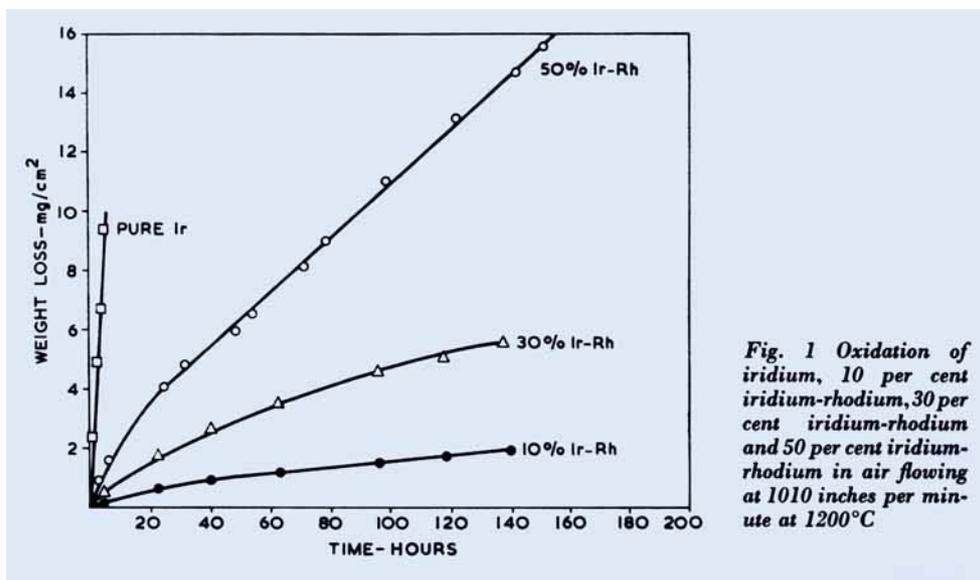


Fig. 1 Oxidation of iridium, 10 per cent iridium-rhodium, 30 per cent iridium-rhodium and 50 per cent iridium-rhodium in air flowing at 1010 inches per minute at 1200°C

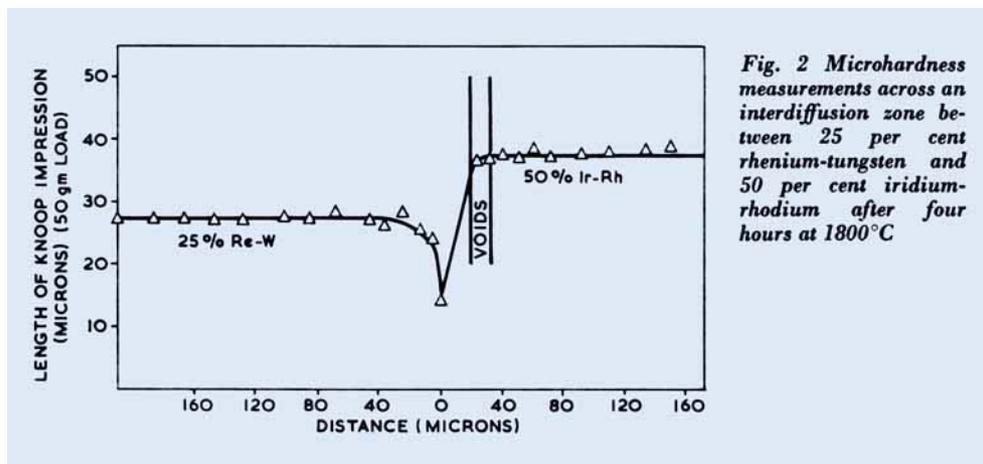


Fig. 2 Microhardness measurements across an interdiffusion zone between 25 per cent rhenium-tungsten and 50 per cent iridium-rhodium after four hours at 1800°C

Noble metal protective coatings are obviously required to protect these alloys against oxidation and these two reports present in detail the results of experiments on the high temperature oxidation characteristics of iridium-rhodium alloys and on the compatibility of these materials with the base metal capsule alloys at high temperatures.

Normal operating temperatures in rarefied atmospheres were expected to be in the region of 2000°C, and conditions of severe oxidation would be restricted to the post-impact period when temperatures in the range 1200 to 1400°C would be encountered.

The only noble metal materials satisfying the high temperature requirements were 10 per cent Ir-Rh, 30 per cent Ir-Rh, 50 per cent Ir-Rh and pure iridium. Preliminary tests soon showed, however, that the weight losses of iridium due to oxidation even at 1200°C were too high for this metal to be seriously considered. Attention was therefore concentrated upon the three alloys.

Weight Losses due to High Temperature Oxidation

The rate of oxidation of the noble metal alloys was assessed by weight loss tests on sheet specimens 0.010 inch thick suspended in hot mullite tubes through which a current of air was passed. Under identical test conditions the rate of weight loss increased with

iridium content. The relationship was not directly proportional to the iridium content, however, and in general the rate of loss of weight was rather lower than the percentage of iridium in the alloy would have indicated. These results suggested that oxidation rates were controlled largely by the rate at which iridium could diffuse from the centre of the test sample to its surface.

A good illustration of this effect is shown in Fig. 1, taken from the second report. These graphs, obtained at 1200°C, show that the oxidation curve of pure iridium is linear with respect to time. The oxidation rates of the alloys, however, decrease with increasing time. The tendency for the oxidation-time curves to level out was even more apparent at lower temperatures and with higher rates of air flow.

In such conditions diffusion rates are low and iridium evaporation rates are high. The logical conclusion is that strong iridium concentration gradients develop between the interior and exterior of the specimens which, after a short period of evaporation, develop a surface very deficient in iridium.

This hypothesis was confirmed by the metallographic structures which showed considerable interior cavitation in all the iridium alloys after a short period of oxidation, but no cavitation in pure iridium. Surface attack on the iridium alloys appeared to be con-

centrated at the grain boundaries and it is very probable that most of the iridium migration was concentrated in these regions.

Diffusion Between Base and Noble Metals

Diffusion studies showed that in general the tantalum base alloy was not compatible with the noble metals, which reacted strongly with it to form liquid phases at temperatures ranging from 1750°C for pure rhodium to 1975°C for pure iridium. The best results were obtained with couples of rhenium-tungsten and the noble metals. In general, the rate of interdiffusion which occurred at any temperature decreased with increasing quantity of iridium in the noble metal alloy.

The best combination of oxidation resistance and diffusion compatibility was displayed by the 30 and 50 per cent iridium-rhodium alloys. Fig. 2 illustrates a microhardness curve obtained by scanning the interdiffusion zone of a test couple annealed for four hours at 1800°C. The diffusion affected zone extends for 60 microns and a line of porosity has developed on the noble metal side of the interface.

Attempts to minimise diffusion effects by the use of a refractory barrier layer were largely unsuccessful, although a plasma-sprayed layer of yttria-stabilised zirconia sandwiched between 25 per cent rhenium-tungsten and 50 per cent iridium-rhodium retained its integrity for four hours. The oxide layer was of no value in contact with

the tantalum base alloy and since none of the tests was carried out for periods longer than four hours, the true efficiency of the barrier layer was not established.

Although the results presented in these reports provide much food for thought, they also leave many questions unanswered. It has been established that iridium-rhodium alloys are reasonably compatible with rhenium-tungsten alloys for short periods in vacuum at temperatures up to 2000°C. The degree of oxidation protection conferred by such alloys has not, however, been investigated. After exposure to flowing air at 1200°C for 145 hours, the 50 per cent iridium-rhodium alloy displayed considerable internal cavitation even at a distance 0.005 inch below the original specimen surface, and in view of the severe grain boundary attack at this temperature it seems most unlikely that this alloy would completely prevent access of oxygen to the surface of a refractory transition metal for any length of time.

Confirmatory tests of this sort have no doubt been included in the continuing "Poodle" research programme and we shall look forward, therefore, to reading the results of this work in due course.

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Reference

- 1 Radioisotope Propulsion Technology Program (Poodle), Quarterly Progress Reports for the period October 1st - December 31st, 1965 and January 1st - March 31st, 1966, Contract AT(04-3)-517 for United States Atomic Energy Commission.

Tungsten-Platinum Alloy Strain Gauges

Earlier studies on dynamic strain gauges for use at high temperatures have shown the advantages of a tungsten-platinum alloy in terms of stability, low temperature coefficient of resistance and high gauge factor, and this alloy—normally containing 8 per cent tungsten—has found considerable use in gauges of the wire type. An interesting further development in this field is the provision of foil type gauges in the same alloy. The illustration shows a typical precision die-cut foil gauge (magnified approximately five times) from a range produced by Dentronics Inc. of Hackensack, New Jersey, from tungsten-platinum alloy foil made by Sigmund Cohn of New York. Gauges of this type are stable at temperatures up to 800°C.

