

High Temperature Strain Gauges

ADVANTAGES OF PLATINUM METAL ALLOYS

Electrical resistance strain gauges provide in principle a simple, cheap and sensitive method for measuring and recording small deformations at the surface of almost any structure or engineering component. They usually comprise a grid formed from a length of fine wire and cemented to the surface under study.

In the early years of their development, around 1941, strain gauges were used extensively for measuring strain in aircraft and similar structures at room temperatures, but in recent years the need to study strains in turbo-jet and similar engine components under operating conditions has stimulated the development of gauges capable of measuring steady strains at up to 300°C for periods of 50 to 150 hours and alternating strains at temperatures of 300° to 1000°C for shorter periods—all in oxidising surroundings.

When properly fabricated and installed, a strain gauge instantly and faithfully responds to any extension of the surface to which it is attached, registering the movement by a change in its electrical resistance. It is obviously of prime importance that the basic electrical resistivity of the alloy of which the gauge wire is made shall be stable, unaffected by structural and other changes during the heating cycle, and that the wire shall not be eroded by oxidation during service.

A recent paper by R. Bertodo, Chief Research Engineer of Ruston & Hornsby Limited, Lincoln (presented at a conference in Cambridge on "Recent Developments on the Theory of Electrical Resistance Strain Gauges", organised by the Institute of Physics and the Physical Society), describes the development of platinum metal alloys for this

purpose and lists the main requirements as:

- (1) Metallurgical stability, as in a single phase alloy, and resistance to oxidation, as in a platinum metal alloy;
- (2) Relatively constant temperature coefficient of resistance and a resistivity of more than 40 ohm/cm;
- (3) A moderate change of strain sensitivity with temperature (this is affected by the degree of mismatch between the materials of the alloy wire and the basic material in their expansion characteristics);
- (4) Adequate mechanical strength.

Hitherto, the wire material that has proved most satisfactory at temperatures up to 300°C is the 9.5 : 90.5 tungsten-platinum alloy developed by the author (*Platinum Metals Rev.*, 1964, 8, (4), 128).

At higher temperatures, however, oxidation and associated resistance drift severely limit its application, and in the present paper the author describes an extensive investigation for an improved alloy. The choice of alloying constituent was based more on conclusions drawn from the periodic table than



A typical assembly of eight strain gauges fitted to a turbo-jet engine

on knowledge of phase relationships, but it was implicitly accepted that a platinum metal was needed as a major constituent in order to resist oxidation.

The paper summarises the results of tests on the strain sensitivity, electrical resistivity, temperature coefficient of resistivity, and ultimate tensile strength of the systems of alloys of palladium with silver, ruthenium, osmium and molybdenum, and of platinum with gold, osmium and tungsten. Tests were also made on some alloys in the ternary systems palladium - rhodium - ruthenium, platinum - osmium - iridium, palladium - ruthenium - molybdenum and platinum - osmium - tungsten, as well as on some base metal systems.

From an electrical point of view, the molybdenum-palladium alloys were selected as having the most favourable properties, but their resistance to oxidation was found to be inadequate.

To improve oxidation resistance, platinum was substituted for part of the palladium; and the final conclusion was reached that of all the alloys tested the most suitable for use at high temperatures was the 45:45:10 platinum-palladium-molybdenum alloy. This has a temperature coefficient of resistance of 100 microhms per ohm per degree C, and a strain sensitivity at room temperature of 4.0. No prediction, however, is attempted of an upper safe temperature for its steady use.

J. C. C.

Selective Diffusion of Hydrogen Allotropes through Palladium

The isotopes of hydrogen diffuse through palladium at different rates, and several processes which utilise this effect for the concentration of deuterium have been established on an industrial scale. Some corresponding effects involving the ortho and para allotropes of hydrogen have recently been reported by L. Fitoussi of CEN Saclay (*Compte Rend. Acad. Sci.* 1968, **266**, (C), 164) and, in view of the considerable differences in diffusion rates observed, the experimental findings deserve careful consideration.

The tests were made on a palladium membrane of unspecified thickness which was maintained at 175°C and subjected to an upstream hydrogen pressure of 30 Torr. The downstream side of the membrane was continuously evacuated. Diffusion rates measured with ordinary hydrogen (25 per cent para-hydrogen) increased initially to a peak value of 1.3 arbitrary units and subsequently decreased slowly to a steady state value of 1 arbitrary unit. Rapid evacuation of the upstream side of the membrane followed by admission of fresh hydrogen momentarily increased the diffusion rate to 1.3 units after which a gradual return to steady state conditions was observed.

These findings were interpreted as an indication that diffusion was being inhibited by the development of an adsorbed layer of

ortho hydrogen on the upstream surface of the palladium membrane. When the proportion of para hydrogen in the feed gas was gradually raised from 25 to 50 per cent the diffusion rate increased by a factor of 6.5.

If para hydrogen diffuses so much faster than ortho hydrogen it is difficult to understand why the output of laboratory and commercial diffusion units run from gas cylinders should remain constant over long periods of time. Such units are of course run at temperatures and pressures much higher than those reported in this paper. The effectiveness of the hydrogen/deuterium separation processes can of course easily be correlated with the α to β phase changes in the palladium and it is possible therefore that in his selection of experimental conditions L. Fitoussi may have hit upon temperatures and pressures particularly favourable to selective allotropic diffusion.

It seems very significant, however, that the 50 per cent para hydrogen mixture which provided high diffusion rates was continuously circulated over the membrane surface. The ordinary unenriched hydrogen which diffused very slowly was not circulated, nor was any bleed-off provided in the vicinity of the membrane. Such stagnant conditions are well known to inhibit rapid diffusion.

A. S. D.