

and all the alloys tested expanded 16 to 18 × 10⁻³ inch per inch over the range 0 to 1500°C. The 30 per cent rhodium alloy expands somewhat less than its composition might

suggest. The proportional changes in length of the alloys tested over the temperature range 0 to 1500°C are summarised in the table on the preceding page.

References

- 1 H. Ebert *Phys. Zeit.*, 1938, **39**, 6
- 2 L. Holborn, K. Scheel and F. Henning Warmetabellen, Braunschweig, 1919, p. 54

High Temperature Brazing of Heat-resisting Materials

INVESTIGATION OF NICKEL-PALLADIUM ALLOYS

The many problems in the design and construction of gas turbines and other equipment operating at high temperatures include the need for brazing alloys capable of giving strong sound joints resistant to oxidation in service. The parent metals to be joined are the range of heat-resisting alloys, most of them based upon nickel-chromium compositions with additions of cobalt, iron, aluminium and titanium, and for many applications a number of nickel-base brazing alloys have been developed containing chromium, silicon, boron or phosphorus.

The major disadvantage of these nickel-base alloys is that the additions designed to promote flow and to reduce melting temperatures always tend to produce severe penetration or undercutting of the parent metal when used in conditions conducive to the achievement of ductile joints, and they must therefore be used with great caution—if at all—on thin sections.

For moderate strength combined with good wetting properties without appreciable diffusion, alloys based on palladium have for some time been accepted as useful brazing media in such assemblies as thin-wall tubular heat exchangers and sandwich panels, particularly as they are ductile alloys capable of being produced as thin foil and wire. One alloy of this type, 40 per cent nickel-palladium, the lowest melting in the Ni-Pd system, has been used successfully but its melting point of 1238°C is inconveniently high.

An investigation to develop a ductile brazing alloy of this type having a lower melting range together with good wettability has recently been reported by W. Feduska, of the Materials Engineering Department of Westinghouse Electric Corporation, and pre-

sented as a paper to the American Welding Society conference in Los Angeles (*Welding J.*, 1960, **39**, 292-s). As a basis for achieving a new low-melting solid-solution alloy free from embrittling intermetallic compounds, the nickel-palladium system was considered to be attractive, and the investigation was concentrated on additions of beryllium and silicon to this base alloy. The most promising composition was found to be the 40 per cent nickel-palladium alloy with additions of 0.5 per cent silicon and 0.25 per cent beryllium, this alloy having a melting range of 1115 to 1160°C and satisfactory ability to wet heat-resisting alloys containing aluminium and titanium. It was also found to cause little penetration or erosion of the parent metal during the brazing of thin-walled structures, to possess adequate shear strength up to 800°C and to show ductility at room temperature in brazed joints on various materials.

It is a little unfortunate, however, that the results given for shear strength of joints both at room and at elevated temperatures cannot be considered of very great value, as the tests were evidently conducted under conditions of rapid loading—conditions of considerably less interest to designers of high-temperature equipment than are creep studies.

The author also reports observing an apparent reduction in the flow temperature of the new brazing alloy when used on parent metals containing manganese, and infers this to be due to pick-up from the parent metal. No extension of the work into brazing alloys containing additions of manganese is, however, reported, nor is reference made to the known palladium-manganese-nickel brazing alloys that have been developed by other workers.

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