#1 "Mechanical Testing" modification

OTS: 60-41,356

JPRS: 4039

15 September 1960

Precious metals misc.



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- USSR -



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205 EAST 42nd STREET, SUITE 300
NEW YORK 17, N. Y.

JPRS: 4039

CSO: 1029/c-S

# INVESTIGATION OF THE HEAT RESISTANCE OF ALLOYS OF PLATINUM WITH RHODIUM, IRIDIUM, RUTHENIUM, CHROMIUM, AND ALUMINUM BY THE BEND-TEST METHOD

-USSR-

[Following is a translation of the article "Issledovaniye zharoprochnosti splavov platiny s rodiyem, iridiyem, ruteniyem, khromom i alyumineyem metodom isgiba" (English version above) by I. I. Kornilov and R. S. Polyakova in Doklady instituta metallurgii imeni A. A. Baykov (Reports of the Institute of Metallurgy imeni A. A. Baykov), No. 5, Production Metallurgy, Physical Metallurgy and Physicochemical Methods of Research, Moscow, 1960, pages 139-144.]

Much theoretic and experimental material has been accumulated on the study of the heat resistance of metal alloys depending upon chemical composition and temperature. In work (1) A. A. Bochvar has shown that the weakening temperature for pure metals corresponds to the temperature of recrystallization, i.e., 013-0.4 of the absolute melting temperature. In case of the formation of solid solutions of a metal with other elements there is a distortion of the spatial lattice, resulting in an increase in the strength and a diminution in the plasticity of the alloy. Hence, for metal alloys, unlike pure metals, the weakening temperature is 0.5-0.6 of the absolute melting temperature (2). It has recently been shown that in complexly alloyed (multi-component) solid solutions of metals the hardened state is maintained up to 0.7-0.8 of the absolute melting temperature of the alloys (3).

Thus, one of the decisive factors in the raising of the heat resistance is the multi-component alloying of solid solutions of metals. This contention has found confirmation in many examples from the study of the heat resistance of metal systems depending upon the chemical composition, structure and temperature (4-8). For example, pure metals — iron and nickel — weaken sharply at temperatures of 700-900°, whereas alloys having them as bases are fairly strong at those temperatures. It has been demonstrated from the example of nickel and its alloys (3, 7, 8) that by complicating the chemical composition, the temperature limits of their hardened state grow considerably in spite of the reduction of the melting point of the alloys. Thse contentions may be true also for alloys based on other refractory metals.

The literature contains many works devoted to the study of the heat resistance of alloys based on iron, nickel, chromium and other metals, but there are almost no works on the heat resistance of alloys based on metals of the platinum group, although this question is of great interest.

The metals of the platinum group are located in group VIII of the periodic system and belong to the refractory ones. Table 1 gives the melting points and certain properties of these metals.

Table 1

| Metal | Melting Point °C | Type of crystal lattice | Density, g/cu mm | Brinell hardness | Elasticity module E, kg/ cu mm |
|---|---|---|---|---|---|
| Platinum | 1773 | Face-centered | 21,44 | 31 | 15 000 |
| Palladium | 1555 | " | 12,25 | 31,7 | 11 480 |
| Rhodium | 1966 | α-simple cubic<br>β-face-centered | 12,4 | 54,9 | 28 000 |
| Ruthenium | 2450 | Hexagonal | 12,2 | 220 | 42 000 |
| Iridium | 2454 | Face-centered | 22,5 | 163 | 52 500 |
| Osmium | 2500 | Hexagonal | 20,0 | - | 56 700 |

The metals of the platinum group, being analogous to iron and nickel, are inclined to form continuous and limited solid solutions. With such metals as iron, cobalt, nickel, rhodium, palladium, iridium and copper, platinum forms continuous solid solutions. However, small additions of non-platinic metals considerably lower the corrosion resistance of platinum and the other metals of the platinum group. Vines (9) has investigated the effect of alloying elements on the hardness of platinum and has shown that the latter grows sharply as a result of adding such metals as nickel, osmium, ruthenium, silver, copper and iridium. Allen (10) has investigated the strength of pure metals at high temperatures by the compression method. The author determined the tension causing 1% deformation in 24 hours at 1000° and constructed a diagram showing the dependence of the tensions upon the atomic number for the elements of the transitional groups of the three long periods of the periodic system. The work shows that platinum and palladium are very plastic: at 1000° a tension of 0.16 kg/sq mm deformed both metals by 1% in 24 hours. Rhodium showed greater strength: it required 4.7 kg/sq mm to deform it 1% in 24 hours at 1000°. Iridium proved to be the most resistant of the platinum metals: it has the same resistance as tungsten.

Work (11) is devoted to an investigation of the hardness and elasticity module of the pure metals at high temperatures. The author investigated platinum, palladium, ruthenium and iridium when heated to 1100°, and showed that the hardness of iridium and rhodium declines linearly with increased temperature; the relation is a similar one for the elasticity module. However, platinum and palladium behave somewhat differently. With a temperature rise to 500-600° the hardness of platinum scarcely changes, and only above this temperature is a noticeable decline in the hardness and elasticity module observed.

The present work is devoted to the study of the heat resistance of platinum with alloying additions of rhodium, iridium, rutheniumm, chromium and aluminum. The test was made by the bend method in a furnace specially designed by V. S. Mikheyev in an atmosphere of air or in a vacuum at 1100-1200°.

A tube of heat-resistant alloy No. 2 with an inside diameter of 900 mm was placed in a Silit furnace. The samples in the form of rods 3 mm in diameter and 25 mm long were inserted from the two sides into fire-resistant magnesite brick and were weighted with weights of heat-resistant alloy EI 437. The little weights were computed according to the length and diameter of the sample. A window was arranged in the tube to observe the bending of the sample in the process of testing in air or in a vacuum (Fig. 1). The temperature in the tube was determined by a platinum-platinorhodium thermocouple and regulated by a thermoregulator.

The samples for the investigation of the resistance by the bending method were prepared in a high-frequency furnace. The molten metal was pumped into porcelain tubes 3 mm in diameter.

The measures of heat resistance adopted were the temperature at which the prescribed bend is reached (6 mm for low-resistance alloys), or the time when the bend is reached at 1150° (for high-resistance alloys). The test temperature was 1150°, and the bending tension 15 kg/sq mm.

The constant conditions of temperature and initial tension allowed the effect of the chosen elements on the heat resistance of pure platinum to be studied. Alloys of the dual systems platinum-rhodium, platinum-iridium, platinum-ruthenium, platinum-aluminum and platinum-chromium were examined.

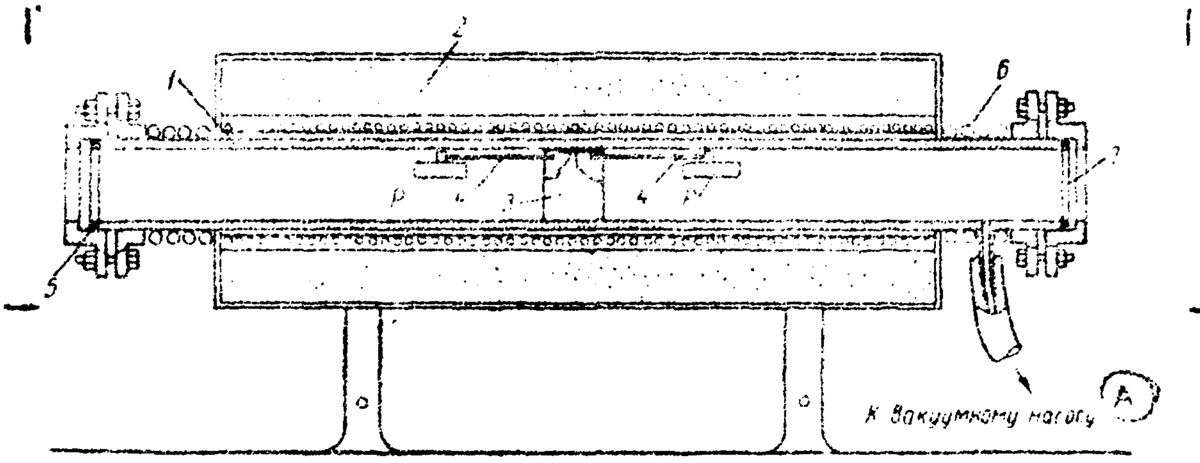


Figure 1. Bend-Test Furnace. Legend: 1. tube of alloy No. 2; 2. oven lining; 3. fire-resistant brick; 4. samples; 5. rubber gasket; 6. copper coil cooling inspection window; and 7. inspection window. (A) = To the vacuum pump.

Platinum-rhodium system. The system consists of continuous solid solutions. Work (15) has shown, however, that rhodium has two modifications: $\alpha$ and $\beta$. The first is stable up to 10[illegible]0° and cannot furnish continuous solid solutions with platinum because of the difference in their crystal structures. Apparently the system contains a small two-phase area adjoining the $\alpha$-solid solution of rhodium.

The mechanical properties of this system have been studied in (16). The Brinell hardness values and the tensile strength for alloys of platinum with rhodium in the roasted and cold-worked (50%) states are given in Table 2.

Table 2

| [illegible] | Brinell hardness, kg/ sq mm | | Tensile strength, kg/ sq mm | |
|---|---|---|---|---|
| | cold-worked | roasted | cold-worked | roasted |
| 0 | 97 | 42 | 2[illegible],3 | 1[illegible],6 |
| 3,5 | 12[illegible] | 60 | [illegible],0 | 17,[illegible] |
| 5 | 130 | 70 | 49,0 | 2[illegible],0 |
| 10 | 1[illegible]5 | 90 | 63,0 | 31,[illegible] |
| 20 | [illegible] | 120 | 91,0 | 49,0 |
| 40 | 290 | 150 | - | - |

To study heat resistance by the bend method we used alloys from the area of solid solutions of platinum with 10, 20, 30 and 40% Rh. The platinum alloys with this rhodium content proved to have a low heat resistance: in the process of the adopted heating regime they bent and reached the prescribed bend at various temperatures. The results of the investigation are shown in Table 3.

Table 3

| Content, by weight, | | Temperature at which 6-mm bend was reached, °C |
|---|---|---|
| Rh | Pt | |
| 0 | 100 | 20 |
| 10 | 90 | 800 |
| 20 | 80 | 850 |
| 30 | 70 | 900 |
| 40 | 60 | 1000 |

Table 4

| Content, weight % | | Temperature at which 6-mm bend was reached, °C |
|---|---|---|
| Ir | Pt | |
| 0 | 100 | 20 |
| 10 | 90 | 900 |
| 20 | 80 | 1000 |
| 30 | 70 | 1050 |
| 40 | 60 | 1100 |

It follows from Table 3 that all alloys containing up to 40% RH are plastic: they bent before a temperature of 1150° was reached. Rhodium, however, partially hardens platinum. This may be seen from Table 3. An especially sharp temperature rise is observed with a 10% Rh content. Consequently, the latter considerably raises the heat resistance of platinum.

Platinum-iridium system. According to (12-17) this system forms continuous solid solutions. However, investigation (8) establishes the decomposition of the solid solution into two phases, the solubility limits at 700° being confined to a content of 7-99% Ir.

As the iridium content is increased, the plasticity of the alloys drops sharply. Thus, an alloy containing 35% Ir is hard to work.

To investigate heat resistance by the bend method at 1150° and $\sigma$ = 15 kg/sq mm, we used alloys containing 10, 20, 30 and 40% Ir. The alloys of this system also turned out to be plastic, bent in the heating process and reached a 6-mm bend at different temperatures. The compositions of the alloys and the results of their tests are given in Table. 4.

As may be seen, the samples of alloys bent under loading in the heating process. It may be noted that the alloys gradually become stronger with an increase in the iridium content, which is confirmed by the rise of the bending temperature from room for pure platinum to 1100° for an alloy containing 40% Ir.

Platinum-ruthenium system. Works (19 and 20) are devoted to an investigation of the platinum-ruthenium system. The authors have established solubility up to 6% by weight of ruthenium in platinum. In this system one must expect discontinuity of the solid solutions, since the components possess different crystal-lattice structures. The mechanical properties of the alloys of platinum with ruthenium are studied in (16).

Ruthenium, like iridium, sharply raises the strength of platinum. An alloy containing 15% Ru becomes unworkable. An alloy with 5% Ru is similar in mechanical properties to an alloy of platinum with 10% Ir.

We have studied alloys with 10, 20, 30 and 40% Ru. The results are given in Table 5.

Table 5

| Content, % by weight | | Temperature at which 6-mm bend was reached at $\sigma$ = 15 kg/sq mm, °C |
|---|---|---|
| Ru | Pt | |
| 0 | 100 | 20 |
| 10 | 90 | 900 |
| 20 | 80 | 1150 after 30 minutes |
| 30 | 70 | 1150 after 3 hours |
| 40 | 60 | 1150 after 5 hours |

As may be seen, ruthenium considerably increases the strength of platinum. While an alloy containing 10% Ru bends at 900°, alloys containing 20% Ru or more stand a heating temperature up to 1150° for some time. As the ruthenium content is raised, the time taken to reach the 6-mm bend at 1150° grows, and is 5 hours for 40% Ru.

Platinum-aluminum system. Thus far the Pt-Al system has been investigated up to 70% by weight. As established in (20), aluminum does not dissolve platinum in the solid state at all. According to the data of (21), the solubility of aluminum in platinum is 6%.

Investigation of heat resistance by the bend method at 1150° and a tension of 15 kg/sq mm was made by us on alloys containing 2.5, 5 and 7.5% Al by weight, and having a platinum base and surrounded by eutectic. All the alloys of this sytem proved to be brittle and the samples broke under tension before reaching 1150°.

Hence, it does not appear possible to draw any conclusions about the effect of aluminum on the heat resistance of platinum.

Platinum-chromium system. Many works (22, 23, 24) have been devoted to the investigation of the platinum-chromium system. According to the data of (25) platinum and chromium are soluble in one another to a limited extent. Two compounds are formed in the system: one of them as a result of the decomposition of the solid solution; it belongs to the compounds of the Kurnakov type (26); the second ($Pt, Cr_3$) crystallizes at the maximum on the fusibility curve.

We have studied heat resistance in alloys with 10, 20 and 30% Cr by weight. The results are given in Table 6.

Table 6

| Content, % by weight | | Temperature at which 6-mm bend was reached at $\sigma$ = 15 kg/sq mm, °C |
|---|---|---|
| Cr | Pt | |
| 0 | 100 | 20 |
| 10 | 90 | 1150 after 60 hours |
| 20 | 80 | 1150, broke after 170 hours |
| 30 | 70 | 1150, broke after 25 hours |

Unlike the alloys of the preceding systems, all three compositions of alloys of platinum with chromium stood up to 1150° without bending under a tension of 15 kg/sq mm. The alloy with 10% Cr by weight did not bend at 1150° during 60 hours. The alloy containing 20% Cr by weight did not bend for more than 170 hours; that with 30% Cr broke after 25 hours because of great brittleness. It should be noted that the alloys become brittle as the chromium content is increased and are shattered without deformation (without bending).

## CONCLUSIONS

1. Rhodium strengthens pure platinum, but the alloys become very plastic when heated, and they bend at 900°.

2. The alloys of the platinum-iridium system are plastic, but their plasticity diminishes as the iridium content is increased; an alloy with 40% Ir has a 6-mm bend at 1100°.

3. The alloys of the platinum-ruthenium system have greater strength than the alloys of platinum with rhodium and iridium. An alloy with 40% Ru stands the assigned test conditions at 1150° up to 5 hours.

4. The alloys of the platinum-aluminum system with an Al content of up to 7.5% are brittle and break under a tension of 1? kg/sq mm before reaching 1150°.

5. The alloys of the platinum-chromium system have the highest heat-resistant properties. All the compositions of alloys stand heating up to 1150° without bending. However, an increase in chromium content results in brittleness.

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