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EUROPEAN PATENT APPLICATION

21 Application number: 82306608.9

51 Int. Cl.³: H 01 H 1/02

22 Date of filing: 10.12.82

30 Priority: 10.12.81 GB 8137209

43 Date of publication of application:
29.06.83 Bulletin 83/26

84 Designated Contracting States:
DE FR GB IT

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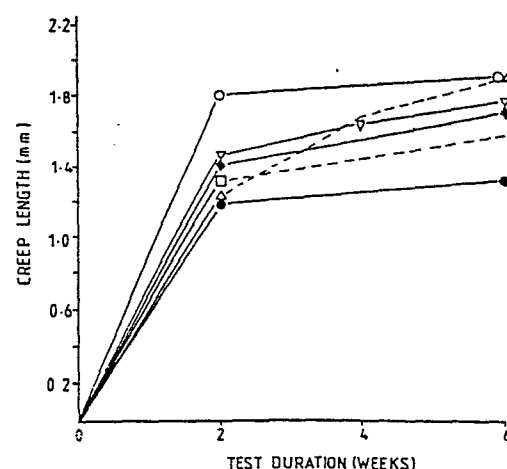
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54 Light duty corrosion resistant contacts.

57 Inlaid base metal or alloy bodies suitable for use as or from which may be fabricated, electrical contact elements in which the contact zones are constituted by the inlay or inlays or portions thereof, the inlay or inlays being formed from one or more cerrosive resistant alloys consisting of, apart from impurities, gold, silver and one or more platinum group metals with, optionally minor proportions of one or more of copper nickel, and indium. In addition to the expected intrinsic anti-corrosive properties whereby low contact resistance can be maintained, the alloys referred to surprisingly also exhibit a tendency to inhibit 'edge creep' from the boundary between the base metal or alloy and the inlay, an effect which has been the most prolific cause of failure with conventional inlaid contacts.

Fig.1.



○ 75 Au/25Ag
 □ 71 Au/26Ag/3NE
 △ 58 5 Au/24 5 Ag/17P
 ▽ 37.5 Au/29 5Ag/30Pd/3Cn
 ◆ 37 Au/33Ag/30 Pd
 ● 32 Au/34Ag/34Pd

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LIGHT DUTY CORROSION RESISTANT CONTACTS

This invention relates to metal or alloy bodies comprising one or more corrosion resistant inlays. The invention is particularly concerned with bodies of this type from which corrosion resistant electrical contact elements may be fabricated, and with electrical contact elements fabricated from such bodies.

By "electrical contact element" both here and throughout the remainder of this specification is meant an electrically conductive body which carries at least one layer of electrically conductive material and/or which embodies at least one region of such material, the or each layer and/or region constituting an electrical contact zone. Generally, such an electrically conductive body is formed from a sheet of lamina of metal or alloy by pressing or stamping. The said sheet or lamina may be inlaid with the metal or alloy which will constitute the electrical contact zone(s). In addition, or alternatively, the surface of the sheet or lamina or one or more regions thereof may be coated with contact zone metal or alloy.

By "electrical contact zone" both here and throughout the remainder of this specification is meant a part of the said electrically conductive body which is mechanically adapted to make contact with and thereby establish electrical connection with a similar zone of another electrical contact element or with some other electrically conductive body of suitable configuration.

By "corrosion resistant electrical contact elements" both here and throughout the remainder of this specification is meant electrical contact elements as herein defined in

which at least the electrical contact zones are corrosion resistant.

In the following, and where the context permits, electrical contact elements are sometimes referred to as
5 "contact elements" and even, on occasions, simply as "contacts". Similarly, electrical contact zones are sometimes referred to as "contact zones" and also, on occasions, simply as "contacts".

The electrically conductive body referred to in the
10 above definition of an electrical contact element is frequently in the form of a resilient, elongate arm, and, in one fairly common form of electrical contact element, the arm is of phosphor bronze with, towards the end, a contact zone comprising a layer of electrically con-
15 ductive, corrosion resistant metal or alloy applied to the material of the arm. Often the arm is slightly deformed at the contact zone end so that the effective part of the contact zone is a portion of a hemispherical or part spherical hollow bulge in the arm. In yet another configuration,
20 the contact zone end of the arm is deformed into a hollow semi-cylindrical or part cylindrical shape so that the effective part of the contact zone lies on the outer curved surface of the cylindrical or part cylindrical portion.

25 Two contact elements of the type just described are often joined together to form an opposed contact pair and electrical connection is established between them and, for example, a metal tongue by sliding the tongue between the contacts so that each arm is displaced slightly with the
30 result that each contact bears against the tongue. In an alternative arrangement, the two arms are formed from a single piece of metal or alloy. In this case, the two arms with their associated contact zones may together be

taken as constituting a single electrical contact element.

The configuration just described is, of course, only one of many possible arrangements that may be employed, but common to all of them, in almost every case, is the need
5 for at least those contact zones which actually make contact with each other or with some other body so as to complete an electrical circuit, to be relatively corrosion resistant so that surface films having a high electrical resistance will not be formed on them in service. In
10 general, the contact zones also need to be resistant to mechanical wear.

The actual degree of corrosion resistance, on the one hand, and resistance to mechanical wear, on the other, which contact zones may be required to exhibit, will depend
15 upon such factors as the atmosphere in which the contacts operate, the contact pressure, the frequency of make and break and the nature of the contact action, that is, whether the contacts concerned make sliding or butting contact.

20 Clearly some atmospheres such as those containing small quantities of hydrogen sulphide, chlorine and possibly sulphur dioxide and oxides of nitrogen, for example, will tend to cause corrosion. On the other hand, a high contact pressure will tend to break through the resulting surface
25 film or films on the contacts so that corrosion resistance becomes of less importance in these circumstances. The effect is enhanced if sliding instead of butting contacts are used since the act of sliding two surfaces together tends to clean them. A disadvantage of high contact
30 pressure, on the other hand, is that this tends to increase mechanical wear as does a high frequency of operation.

Other factors which influence the design of contacts

are the voltage at make and break as well as the current to be carried and interrupted. In general, the present invention is especially concerned with light duty contacts or, more particularly, with contact elements for use in
5 such applications as light duty, high reliability "professional" connectors of the type that are employed in computers and similar equipment, although the invention is, of course, by no means so limited.

Typically, such contacts carry currents of less than 1
10 amp and under these conditions the effects of corrosion can be very marked indeed. It is therefore important to make light duty contacts of the type just referred to as corrosion resistant as is economically practicable. At the same time, such contacts are often required to remain in
15 service for long periods, sometimes for as long as 30 years. It is therefore equally important that they should also be made as wear resistant as possible.

Among contacts subject to stringent corrosion resistance and mechanical wear requirements are those for use,
20 inter alia, in edge connectors for printed circuit boards and in pushbutton and keyboard switches.

Contacts of the above type or, more specifically, the contact zone of contact elements for use in equipment of the above type, have often, in the past, been made
25 corrosion resistant by applying to them a layer of about 5 microns thick of a gold alloy such as a 98% gold/cobalt alloy.

The increasing price of gold has led to pressure to reduce the thickness of the gold alloy layer and, for
30 some applications, layers 2.5 microns thick have been used. Such reduction in thickness have, however, led to the contacts concerned being more susceptible to wear and to consequent reductions in their service lives. This has,

in turn, led to a search for alternative ways of rendering contacts corrosion resistant at an acceptable cost without, at the same time, reducing their lives below acceptable limits.

5 German Patent specification 1089491 proposes alloys containing 5 - 65% palladium, 15-55% silver and 15-70% gold for use as contact material in low current electrical contacts. These alloys are said to be highly resistant to surface corrosion in sulphur containing atmospheres and
10 upon exposure to atmospheric components and chemicals present in equipment in which switchings installations are located whereby low contact resistance can be maintained.

An alternative method which has met with some success, has been to replace gold alloy coatings by thin gold alloy
15 inlays, often no more than 0.000125 inch thick. Inlays have the advantages firstly, that they can easily be confined to the area or areas where they are needed, which is not necessarily true of electroplated coatings, especially when the contacts are small and the electroplating is done
20 after the fabrication of the contacts, and secondly, that they lend themselves to the use of a relatively wide range of corrosion resistant alloys. By comparison, comparatively few such alloys can be effectively electroplated on to a contact element or on to the sheet or lamina of conductive
25 metal or alloy from which the contact element is formed.

Alloys which have been used for inlays include a 75 Au/25 Ag alloy. This alloy, however, is still rather expensive in view of its relatively high gold content. Further, inlays of this alloy in base metal bodies such as those
30 made from phosphor bronze and other copper containing alloys, for example, are prone to an effect known as "edge creep". This is a corrosion effect in which a thin layer or film of corrosion products creeps over the surface of the precious

metal inlay from the boundary between the material of the inlay and that of the inlaid body. This seems to be a self-stabilising process in that the developing film of corrosion products tends progressively to inhibit the
5 passage of further corrosion products from the boundary and thus progressively to slow down the development of the film until its development comes practically to a stop. Since, in spite of this, the film will often grow to a width of 2 mm and more, its growth can seriously interfere with the per-
10 formance of contacts in which the contact zones are small in extent and are provided by precious metal inlays in, for example, phosphor bronze supports. The edge creep effect is, in fact, one of the most prolific causes of contact failures.

15 Edge creep, i.e. the corrosion effect arising as a result of the intimate juxtaposition of the inlay and the base metal or alloy body and at the boundary thereof, is unrelated to the more usual atmospheric corrosion affecting the contact resistance of a contact surface. Indeed, metals
20 or alloys which exhibit good intrinsic anti-corrosive properties are often unsuitable or unsatisfactory for use as inlays in that they are prone to edge creep. One prime example of this is pure gold which has excellent intrinsic anti-corrosive properties.

25 One object of the present invention is to provide inlaid bodies from which contact elements comprising inlaid contact zones may be fabricated, the resulting contact elements being less expensive than known contact elements in which the contact zones are provided by inlaid alloys
30 having a relatively high gold content (such as 75 Au/25 Ag) and having contact zones which are less prone to edge creep effects and at least as resistant to mechanical wear and surface corrosion as the contact zones of known contact

elements.

To our surprise, we have found that these conditions can be satisfied by the use, for inlays, of gold/silver/platinum group metal(pgm) alloys in which the pgm may be
5 any one or more of the platinum group metals platinum, palladium, rhodium, iridium, osmium, ruthenium, but which is preferably palladium.

According to one aspect of this invention, we propose an inlaid base metal or base metal alloy body from which
10 may be fabricated electrical contact elements (as herein defined) in which the contact zones (as herein defined) are constituted by the inlay or inlays or portions thereof, the said inlay or inlays being formed from one or more alloys consisting of, apart from impurities, gold, silver
15 and one or more platinum group metals, with, optionally minor proportions of one or more of the metals copper, nickel and indium and of any platinum group metals which are not otherwise present.

Preferably:

- 20 (a) the inlays are formed from one or more alloys consisting of 25-40 wt.% gold, 30-40 wt.% silver, balance, apart from impurities, palladium;
- (b) the body consists of phosphor bronze or copper-nickel or copper-chromium, or copper-beryllium alloy;
- 25 (c) the inlaid bodies are formed by diffusion bonding suitably shaped alloy bodies into pre-formed recesses in the base metal or alloy bodies with the surfaces of the recesses coated with a layer of nickel and then cold rolling the composites to
30 around 60% reduction.

According to another aspect of the present invention we propose a method of manufacturing an inlaid base metal or base metal alloy body according to the said one aspect of this invention comprising bonding one or more suitably
5 shaped inlay alloy bodies into preformed recesses in the base metal alloy body and cold rolling the composites, preferably to achieve a reduction in the region of 60%.

Further, the surfaces of the recess or recesses may be coated with nickel prior to insertion of the inlay bodies.

10 The invention also includes electrical contact elements fabricated from one or more inlaid bodies of the type just referred to.

Tests will now be described which we have carried out to determine the resistance of the inlaid portions of bodies
15 according to the invention - (a) to corrosion, (b) to the edge creep effect, and (c) to mechanical wear. The tests have also been carried out on similar bodies in which the inlaid portions are formed from the 75 Au/25 Ag alloy which is used to form the inlaid contact zones in certain
20 prior art electrical contact elements. As will be seen, the results of the tests clearly illustrate the effectiveness of our invention.

For each test, one or more inlaid phosphor bronze bodies were first prepared and subjected to accelerated
25 environmental tests for periods of 2-6 weeks in steps of 2 weeks. On completion of each test, or of one or more of the 2 weeks stages of each test, an indication of the resulting corrosion of the inlay surface was obtained by measuring the contact resistance of each inlay under controlled con-
30 ditions. The extent of the edge creep corrosion was then determined by direct measurement. Finally, the wear resistance of the alloys used for the inlays of selected bodies was estimated by a method which is described later.

Details of the test procedures are as follows. Alloys from which inlays were to be produced were induction melted and cold rolled to produce fine-grained homogeneous material from which test coupons were prepared. The surface of each alloy sample was highly polished to give maximum initial values of contact resistance of less than $5m\Omega$. Inlaid bodies were then produced by hot bonding the test alloy coupons into pre-grooved phosphor bronze strips and cold rolling the composites to around 60% reduction.

Accelerated corrosion tests were next carried out by exposing the inlaid bodies either to an atmosphere containing 100 ppb SO_2 , 20 ppb Cl_2 and 150 ppb NO_2 or to an atmosphere containing 100 ppb H_2S , 100 ppb SO_2 , 20 ppb Cl_2 and 150 ppb NO_2 . As will be appreciated, the second atmosphere is the first atmosphere with the addition of 100 ppb H_2S , the two atmospheres representing different levels of severity in corrosion tests. The exposures were carried out at temperatures and relative humidities of $30 \pm 1^\circ C$ and $75 \pm 3\%$ respectively and the inlaid bodies were exposed for one or more periods of 2 weeks up to a maximum of 6 weeks. Comparison of the depths of the corrosion films produced by these atmospheres on silver samples placed in them and on samples exposed to the air at a field site suggest that the rates of corrosion in these atmospheres are at least 100 times as large as the rate in the field. The "acceleration" factor is thus about 100.

The contact resistance of each inlay after the exposure of the inlaid body in the test chamber was determined at 100 equidistant points along the inlay by means of computer controlled contact resistance apparatus which automatically calculated and displayed the resistant values. For the purpose of carrying out the measurements, a polished,

hemispherical gold probe 1.5 mm in diameter was pressed onto each inlay with a force of 100 grams weight and a current of 10 mA was then passed between the probe and the inlay in each direction consecutively. The contact resistance was determined from the voltage drop between the probe and the inlay.

The wear resistances of two alloys which were used to form the inlays of bodies according to the invention and of the 75 Au/25 Ag alloy which is used to form the inlaid contact zones of certain prior art contact elements were determined by measuring the dimensions of the wear tracks produced by a rotating alloy disc rubbing against a flat sheet of the same material.

The results of the contact resistance tests and of the measurements of the extent of edge creep are presented in Tables 1 and 2, whilst the change in the extent of edge creep with time for various inlays is shown in Figures 1 and 2.

The contact resistance results were subject to considerable scatter so that comparison between any two readings can be misleading. It is clear, however, that open circuit (o/c) readings are indicative of a highly corroded sample whereas samples that consistently gave low contact resistances can be regarded as effectively corrosion resistant. All contact resistance data shown in the tables are the 50 percentile values so that at least 50 of the 100 contact resistance readings taken in each case will fall below the quoted value.

As will be seen, many of the Au/Ag/Pd alloys gave low contact resistances, this in spite of the fact that the test conditions were severe enough to give open circuit readings on two of the prior art 75 Au/25 Ag inlays and 500 m Ω contact resistance on another. The alloys containing

37.5% Au and 32% Au gave particularly good results.

The edge creep results in the accompanying Figure show that most of the Au/Ag/Pd alloys tested as well as those with minor additions of copper, indium or nickel, offered
5 edge creep resistance superior to those of the prior art 75 Au/25 Ag alloy inlays.

Finally, wear resistance tests carried out on sample alloys containing 37 wt% Au/33 wt% Ag, 30 wt% Pd, 32 wt% Au/
34 wt% Pd and 75 wt% Au/25 wt% Ag showed the alloys to be
10 used for inlays according to the invention are more wear resistant than the prior art 75 Au/Ag alloy. The surface areas of the wear tracks formed on the alloys containing 37 wt% and 32 wt% Au were 1.2mm^2 and 1.5mm^2 respectively whereas the surface area of the wear track formed on the
15 75 Au/25 Ag alloy was 2.2mm^2 .

All wear resistance testing was carried out on alloys which had been 60% cold worked so that the results obtained can be considered to give a realistic assessment of the performance in service of contact elements containing inlays
20 of these alloys.

Electrical contact elements suitable for use in edge connectors and the like may be fabricated from the inlaid bodies of the type used for the foregoing tests by, for example, rolling the bodies down to the required thickness,
25 with intermediate anneals if necessary, and then stamping out from the resulting sheets either the contact elements per se or blanks from which the contact elements may be formed by one or more additional operations.

It will be appreciated that the invention is in no way
30 limited to bodies with corrosion resistant inlays from which contact elements of the type just described may be made. Indeed, inlaid bodies according to the invention may be

used to form articles other than contact elements for use in applications in which the corrosion resistance of the inlays is a desirable feature. Alternatively, the bodies may themselves be used unchanged in such applications.

TABLE 1
CORROSION DATA OF INLAY SAMPLES

ALLOY COMPOSITION				SAMPLE NO.	CONTACT RESISTANCE - 50% VALUES (m Ω)			EXTENT OF EDGE (mm) CHEEP (mm)		
Au	Ag	Pd	Ni		2 Weeks	4 Weeks	6 Weeks	2 Weeks	4 Weeks	6 Weeks
100	-	-	-	1	-	-	-	1.6	-	-
75	25	-	-	1	-	-	0/0	1.52	-	1.52
-	-	-	-	2	-	0/C	-	-	1.2	-
75	25	-	-	1	-	-	500	1.02	-	1.9
-	-	-	-	2	-	-	-	-	2.0	-
71	26	-	3	1	-	-	-	1.32	-	-
-	40	60	-	1	300	-	-	1.0	-	-
58.5	24.5	17	-	1	-	0/C	-	-	1.2	-
58.5	24.5	17	-	1	-	-	100	1.21	-	1.9
37.5	37.2	25.3	-	1	-	5	-	1.0	1.0	-
37.5	30	32.5	-	1	8	-	-	1.7	-	-
37.5	20	42.5	-	1	90	-	-	2.1	-	-
37.5	10	52.5	-	1	20	-	-	2.0	-	-

TABLE 1 (continued)
CORROSION DATA OF INLAY SAMPLES

ALLOY COMPOSITION				SAMPLE NO.	CONTACT RESISTANCE 50% VOLTAGE (ohm)				EXTENT OF EDGE (mm) CREEP (mm)			
Al	Ag	Pd	Hf		2 Weeks	4 Weeks	6 Weeks	10 Weeks	2 Weeks	4 Weeks	6 Weeks	10 Weeks
				1	-	90	-	-	-	0.8	-	-
37	33	30	-	2	-	400	-	-	-	1.7	-	-
				3	-	-	0/C	-	-	-	1.7	-
				4	20	-	-	-	1.9	-	-	-

TABLE 2

CORROSION DATA OF INLAY SAMPLES

ALLOY COMPOSITION						SAMPLE NO.	CONTACT DISTANCE 50% VALUES (mm)			EXTENT OF EDGE CREEP (mm)		
Au	Ag	Pd	Cu	Ni	Other		2 Wks.	4 Wks.	6 Wks.	2 Wks.	4 Wks.	6 Wks.
32	34	34				1	-	-	40	-	-	1.3
						2	-	-	-	-	1.3	-
						3	-	20	-	-	1.5	-
						4	30	-	-	1.8	-	-
25	58	17				1	-	0/0	-	-	0.8	-
25	40	35				2	-	0/0	-	-	1.0	-
						1	-	200	-	0.8	1.2	-
						2	-	200	-	0.7	1.4	-
25	35	40				1	30	-	300	1.2	1.4	1.4
						2	-	0/0	-	1.0	1.3	-
						3	-	0/0	-	0.8	1.2	-
						1	30	-	50	0.91	1.3	1.4
37	30	30		3		2	-	0/0	-	0.7	1.5	-
						3	-	200	-	0.9	1.4	-

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TABLE 2 (continued)

CORROSION DATA OF INLAY SAMPLES

ALLOY COMPOSITION					SAMPLE NO.	CONTACT RESISTANCE 50% VALUES (ma)				EXTENT OF EDGE CREEP (10 ³ hrs)		
						2 Wks.	4 Wks.	6 Wks.		2 Wks.	4 Wks.	6 Wks.
Au	Ag	Pd	Cu	Ni	Other							
37	30	30	3			70	-	200		1.36	1.6	1.7
						40	-	70		0.91	1.0	1.3
37	30	30			3 In	-	300	-		1.1	1.1	-
						-	60	-		1.3	1.3	-
37	30	30			2.8In, 0.1Rh, 0.1Ir	60	-	20		1.06	1.2	1.3
32	31	34			2.8In, 0.1Rh, 0.1Ir	20	-	80		1.06	1.2	1.2

CLAIMS:

1. An inlaid base metal or base metal alloy body from which may be fabricated electrical contact elements in which the contact zones are constituted by the inlay or
5 inlays or portions thereof, the said inlay or inlays being formed from one or more alloys consisting of, apart from impurities, gold, silver and one or more platinum group metals, with, optionally, minor proportions of one or more of the metals copper, nickel and indium and of any
10 platinum group metals which are not otherwise present.
2. A body according to claim 1, wherein the inlay or inlays are formed from one or more alloys containing 32 -
58.5 wt% Au, 10 - 58 wt% Ag optionally from a trace to 3 wt% of Cu, Ni or In, the balance, apart from impurities
15 being palladium and optionally minor proportions of Rh and/or Ir.
3. A body according to claim 1 or claim 2, wherein the inlay or inlays are formed from one or more alloys containing of 25 - 40 wt% Au, 30 - 40 wt% Ag.
- 20 4. A body according to any one of claims 1 to 3, wherein the said balance, apart from impurities, is palladium.

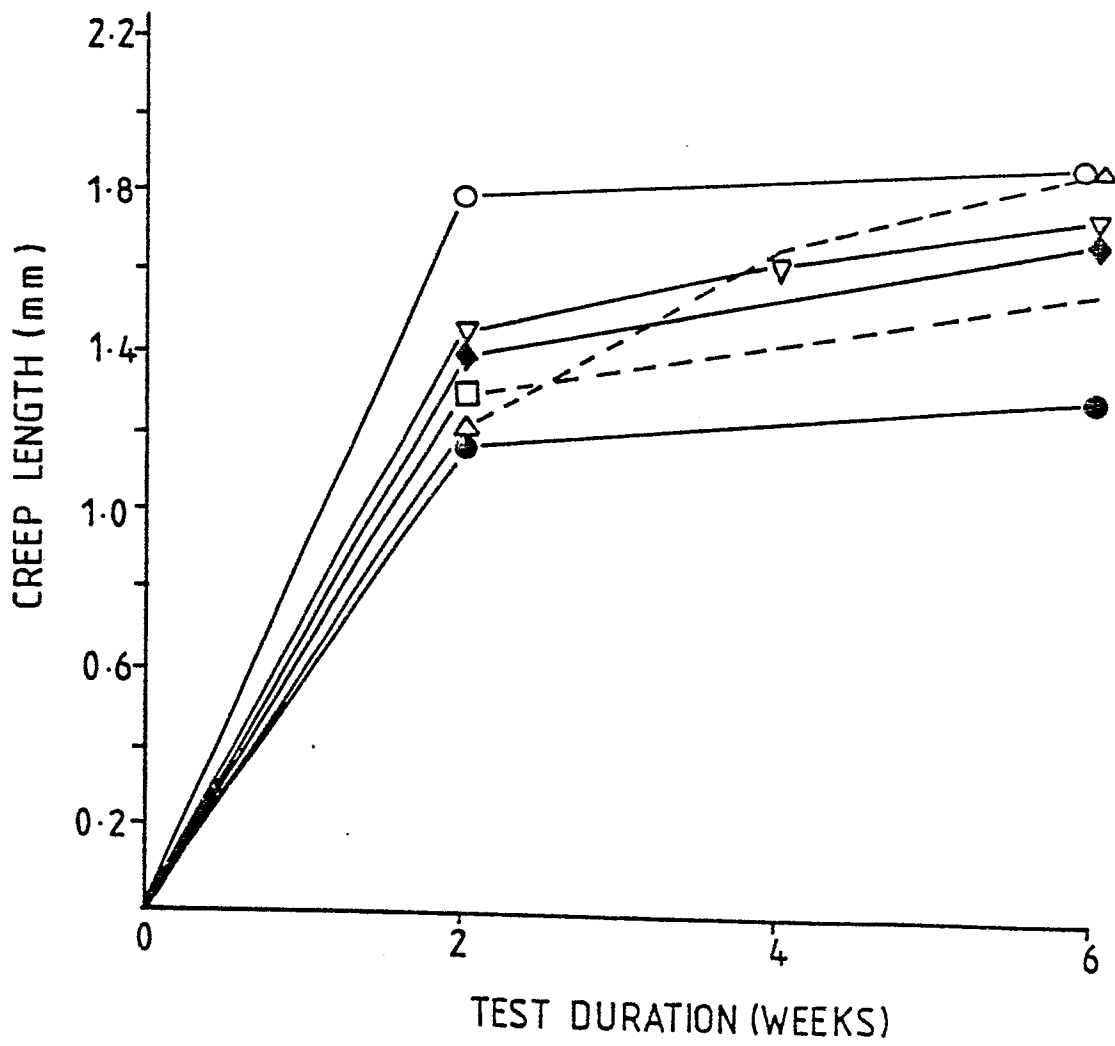
5. A body according to any one of claims 1 to 4,
wherein the inlay alloy contains 3 wt% Cu.
6. A body according to any one of claims 1 to 5,
wherein the inlay alloy contains 3 wt% In.
- 5 7. A body according to any one of claims 1 to 6,
wherein the inlay alloy contains 3 wt% Ni.
8. A body according to any one of claims 1 to 7,
wherein the base metal or base metal alloy body is formed
from a phospher bronze, copper-nickel, copper chromium or
10 copper-beryllium alloy, a layer of nickel being interposed
between the surfaces of the recess or recesses and the
associated inlays.
9. A body according to any one of claims 1 to 8,
wherein the inlay or inlays are diffusion bonded into a
15 recess or recesses in the base metal or alloy bodies.
10. A body according to claim 1, wherein the composi-
tion of the inlay alloy is one of the compositions set
forth in table 1 or table 2.
11. Electrical contact elements fabricated from one or
20 more inlaid bodies according to any one of the preceding
claims.

12. A method of manufacturing an inlaid base metal or base metal alloy body according to any one of the preceding claims 1 to 8, comprising bonding one or more suitably shaped inlay alloy bodies into pre-formed recesses in the
5 base metal or alloy body, and cold rolling the composites.

13. A method according to claim 12, wherein cold rolling is effected to achieve a reduction in the region of 60%.

14. A method according to claim 12 or claim 13, wherein the surfaces of the recesses are coated with nickel.

Fig.1.



- 75 Au/25Ag
- 71 Au/26Ag/3NE
- △ 58.5 Au/24.5 Ag/17P
- ▽ 37.5 Au/29.5Ag/30Pd/3Cu
- ◆ 37 Au/33Ag/30 Pd
- 32 Au/34Ag/34Pd

Fig.2.

