EUR 4637 e

COMMISSION OF THE EUROPEAN COMMUNITIES

# LABORATORY GUIDE FOR THE SELECTION OF BRAZING MATERIALS

by

C. CAPPELLETTI

1971

Joint Nuclear Research Centre
Ispra Establishment - Italy

Materials Department
Direct Conversion

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The attention is being drawn on the difference of behaviour of refractory metals submitted to brazure at low temperature (⩽ 1 300 °C) and at high temperature (⩾ 1 300 °C). In the first case wetting will be obtained by adding small amounts of metal, which alloys easely with the base metal (mainly Ni). In the other case instead the compatibility between the brazing metal and the base metal plays its own important role. In order to avoid a too vigorous attack of the base metal, a judicious choice of the geometry of the parts to be joined and of the right brazing procedure is necessary.

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**ABSTRACT**

Orientating experiments were carried out on the wetting of various metals by different brazing alloys.

The attention is being drawn on the difference of behaviour of refractory metals submitted to brazure at low temperature ($\leqslant$ 1 300 °C) and at high temperature ($\geqslant$ 1 300 °C). In the first case wetting will be obtained by adding small amounts of metal, which alloys easely with the base metal (mainly Ni). In the other case instead the compatibility between the brazing metal and the base metal plays its own important role. In order to avoid a too vigorous attack of the base metal, a judicious choice of the geometry of the parts to be joined and of the right brazing procedure is necessary.

**KEYWORDS**

BRAZING
METALS
HEAT RESISTING METALS
WETTABILITY
WETTING AGENTS
HIGH TEMPERATURE
NICKEL
ALLOYS
GEOMETRY

# LABORATORY GUIDE FOR THE SELECTION OF BRAZING MATERIALS *)

The purpose of the present study is to provide the laboratory technician with a practical guide which can give him rapid help in the first selection of brazing materials for joining metals to metals and, in some cases, also to ceramics.

Besides the principal commercially known brazing alloys also a number of new alloys has been tested, which are little known but nevertheless interesting.

As base materials those refractory metals have been used which occur most frequently in high temperature technology (Nb, Nb-1Zr, Ta, Mo, W etc.), but also more conventional materials have been included in the study (as e.g. Fe, Ni, FeNi, Kovar, Cu).

Due to the orientative character of this work, the principal criterion used for the evaluation of the different brazing combinations is the surface wetting. It is characterized by a number. In cases where a reaction between brazing alloy and base material was apparent, a letter has been added to this number (see code on the following page). The applicability of combinations marked by "a" or "b" depends on factors such as geometry, thickness of the materials and brazing conditions. With other words, the appearence of "a" or "b" not necessarily excludes the use of the respective combination; it may well be usable under special conditions or with special precautions (e.g. flash brazing).

When no figure appears indicating the degree of wettability but only letter a or b, it should be understood that there has been alloys formation between the base metal and the brazing alloy. In some cases the sample was entirely damaged.

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*) Manuscript received on December 15, 1970

The tests were made by putting the brazing alloy on a piece of plain metal sheet and then heating up under vacuum between about $10^{-5}$ and $10^{-6}$ Torr (furnace with Mo or Ta resistance heater). The preparation of the samples included degreasing and some outgasing of the base metals (for Nb, Ta, Re, Ir generally 10 minutes at 1700°C in a vacuum of some $10^{-6}$ Torr). The tests were evaluated by visible inspection. The results are compiled in table 1 and 2 using the following code.

1 : very good wetting (wetting angle zero, good spreading) (photo 1)

2 : good wetting (wetting angle nearly zero) (photo 2)

3 : sufficient wetting (wetting angle well above zero, but smaller than about 45°) (photo 3)

4 : poor wetting (large wetting angle, roughly between 45° and 90°) (photo 4)

5 : no wetting (wetting angle larger than 90°) (photo 5)

a : attack of base metal (photo 6)
b : strong attack (formation of holes in base metal) (photo 7)
c : halo formation (photo 8).

REFERENCES

[1] W.H. Kohl, Handbook of materials and techniques for vacuum tubes, Reinholds Publishing Co. (1967), p. 360.

[2] C.M. Cappelletti, C.A. Busse and E.D. Dörre, Metal-to-ceramic seals for thermionic converters, Proc. Second Int. Conf. Thermionic Electrical Power Generation, Stresa (1968), EUR 4210 f.e., pp. 613-632.

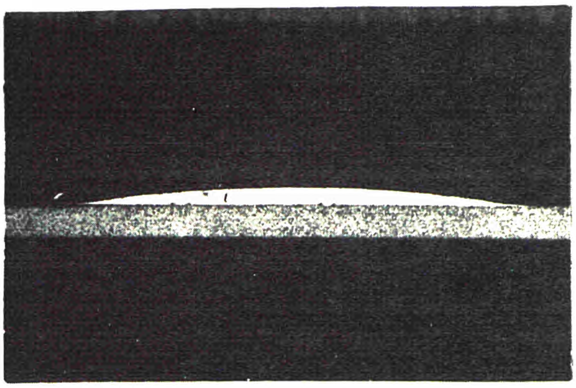

Photo 1: very good wetting

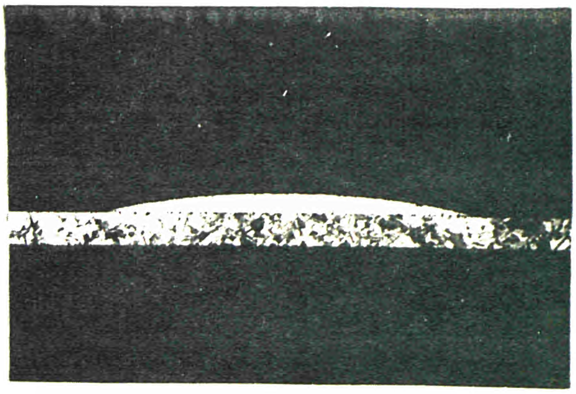

Photo 2: good wetting

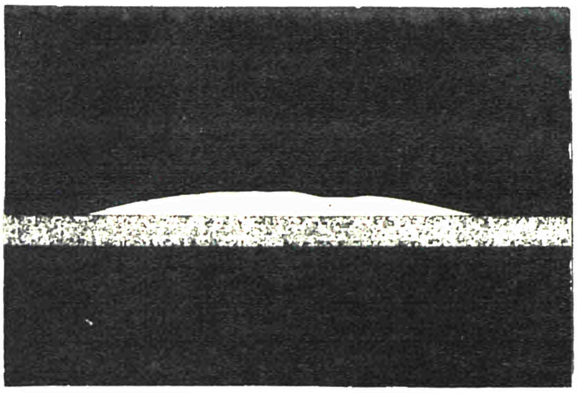

Photo 3: sufficient wetting

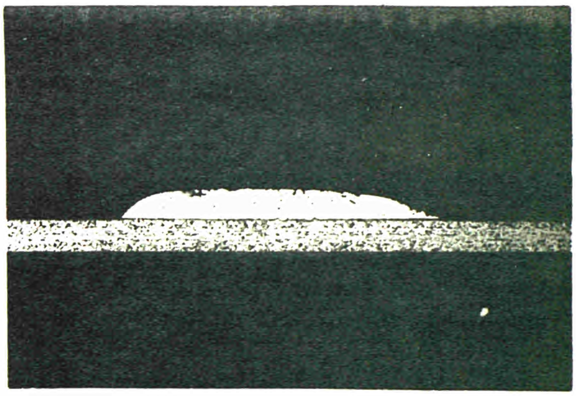

Photo 4: poor wetting

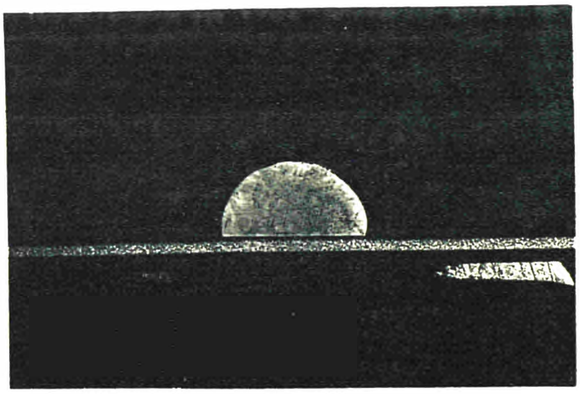

Photo 5: no wetting

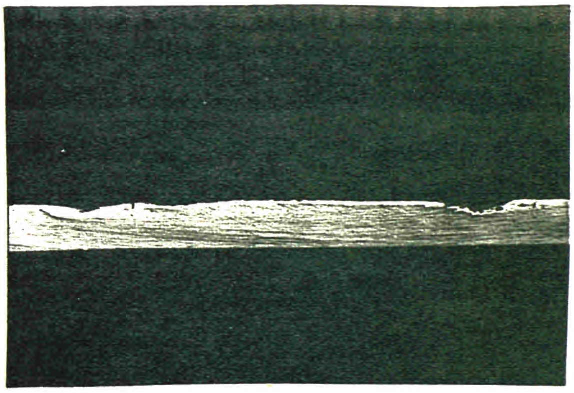

Photo 6: attack of base metal

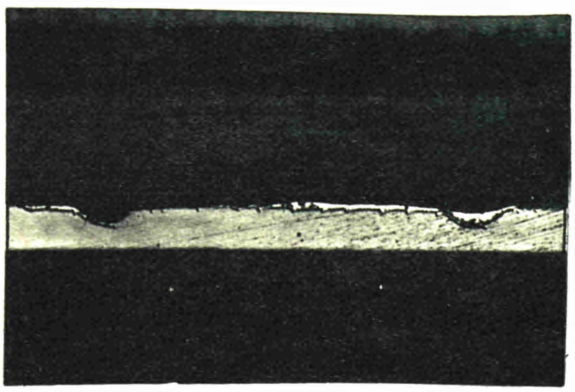

Photo 7: strong attack

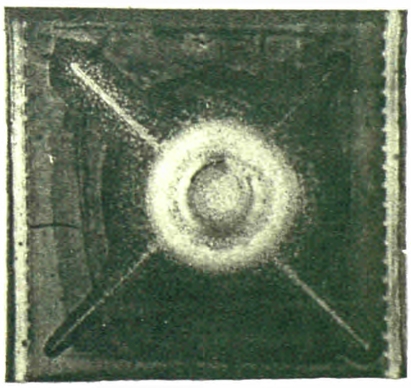

Photo 8: halo formation

## Comments on the tables

### Table 1

Upper part: The different brazing alloys which have been tested are not arranged in the order of their melting points, but according to the value of the experimentally obtained "brazing temperature". In fact, it is this value which is most interesting for the realisation of the joint.

On the row - "brazing process": Two values of time and temperature are indicated (e.g. for Ag-28Cu: 10' at 760°C + 3' at 810°C). The first indication refers to a step of stabilization of temperature in the piece to be brazed, the second one to the proper brazing step. The given values are those which have been used in the present experiments. Of course these values can vary considerably with the geometry of the pieces, their mass and the brazing furnace. This pause before the real brazing is very important for pieces of complicated form and with brazings on the inside, where a large temperature difference between one point and another can cause a flow of brazing material to undesired spots.

On the row - "suppliers": The suppliers of the materials used in the present experiments are indicated. For a larger compilation of suppliers of other markets the reader is referred to table 12.1 in reference [1].

### Table 2

In this table the results are compiled of brazing tests on refractory metals Nb, Nb-1Zr, Ta, Mo, W.

In the column - "melting temperature": As mostly new brazing alloys are concerned, no indication of liquidus and solidus temperatures is given because these values were not precisely known and the reading from phase diagrams is often too inaccurate. The brazing temperature has been found experimentally.

In the column - "brazing process": Here the temperature of the stabilization step is not indicated. In general, it is around 90-95% of the brazing temperature in °C. The time depends on the geometry and the mass of the samples.

In some cases the brazing process is indicated, for example, as "1510°C to 1560°C in 3 minutes". This means that at the moment where the thermocouple of the furnace indicated 1510°C, the temperature controlling program disk was stopped. The temperature however continued to rise and reached after 3 minutes 1560°C. Evidently these data refer to a special type of furnace and therefore have only orientative value.

In some cases for the same brazing material the brazing process varies with the base material (see, e.g. Zr-22Nb). These are cases in which the brazing material tends to react with the base metal prior to fusion (diffusion?, reaction over the vapor phase?). Thus it can occur that the same brazing material at a certain temperature is already liquid on one material (in our example Nb), while it is not so on the other (Ta). To obtain fusion, a temperature increase of about 60°C was necessary in the quoted example.

In cases like this, even if the impression of melting on the base material is good, one has to proceed with care to the realisation of the brazing.

Table 1: Brazing alloys between 700°C and 1300°C

| | Brazing material | | | |
|---|---|---|---|---|
| Component | Ag-Cu | Ag-Cu-Ni | Ag-Cu-Pd | Ag-Cu-Pd |
| % wt. | 72-28 | 71.15-28.1-0.75 | 64.8-26.6-5 | 58.5-31.5-10 |
| T. liquid °C | 779 | 795°C | 810 | 852 |
| T. solid °C | 779 | 780 | 807 | 824 |
| Brazing process | 10'760°C +3'810°C | 10'760°C +3'815°C | 10'790°C +5'830°C | 10'810°C +5'870°C |
| Alloy design. Supplier | Ag-Cu eutectic Do Du Co Pforzheim | Nicusil 3 Wesgo | SCP1 Do Du Co Pforzheim | SCP2 Engelhard |
| Nb | 5 | 4-5 | 3 | 3 |
| Ta | 5 | 3-4 | 3 | 3 |
| Mo | 5 | 4 | 3 | 5 |
| Re | 5 | 3 | 3 | 3 |
| Ir | 1 c | - | - | - |
| Cu | 1 | 1 a | 1 | 1 |
| Ni | 1 | 1 | 1 | 1 |
| Fe | 3 | 2 | 2 | 2 |
| SS304L | 5 | 2 | 3 | 3 |
| Vacon 10 Fe-28Ni-18Co | 3 c | 2 | 1 | 2 c |
| Vacodil 42 Fe-42Ni | - | 1-2 | 2 c | - |

Table 1: Continued

| | Brazing material | | | |
|---|---|---|---|---|
| Component | Ag-Cu-Pd | Ag-Pd-Cu | Au-Ni | Ag-Mn |
| % wt. | 65-20-15 | 54-25-21 | 82-18 | 85-15 |
| T. liquid °C | 900 | 950 | 950 | 971 |
| T. solid °C | 850 | 901 | 950 | 960 |
| Brazing process | 10'830°C +3'920°C | 10'880°C +3'970°C | 10'940°C +3'990°C | 10'960°C +3'990°C |
| Alloy design. Supplier | SCP3 Engelhard | SCP4 Engelhard | Degussa | -- Degussa |
| Nb | 3 | 2 | 2 | 4 |
| Ta | 3 | 3 | 3 | 4 |
| Mo | 3 | 2 | 3 | 3 |
| Re | 2 | 1 | 3 | 3 |
| Ir | - | - | 1 | 3 |
| Cu | 1 a | 1 | 3 | 1 b * |
| Ni | 1 | 2 | 3 | 3 |
| Fe | 1 | 1 c | 3 | - |
| SS304L | 2 | 2 | 3 | 3 |
| Vacon 10 Fe-28Ni-18Co | 2 | 2 | 3 | - |
| Vacondil 42 Fe-42Ni | 2 c | 2 c | - | - |

Table 1: continued

| | Brazing material | | | |
|---|---|---|---|---|
| Component | Cu-Pd-Ni-Mn | Cu-Ni | Ni-Mn-Pd | Cu-Ni |
| % wt. | 55-20-15-10 | 98-2 | 48-31-21 | 95-5 |
| T. liquid. °C | 1105 | 1095 | 1120 | 1120 |
| T. solid. °C | 1060 | 1085 | 1120 | 1090 |
| Brazing process | 10'1040°C +3'1125°C | 10'1070°C +3'1150°C | 10'1100°C +3'1150°C | 10'1070°C +3'1170°C |
| Alloy design. Supplier | CPNM2 Engelhard | Do Du Co Pforzheim | NMP1 Engelhard | --- Do Du Co Pforzheim |
| Nb | 3 | 3-4 | 3 | 3 c |
| Ta | 2 | 3 | 2 | 2 |
| Mo | 2 | 4 | 2 c | 1 |
| Re | 1 | 1 | 2 c | 1 |
| Ir | - | - | - | - |
| Cu | - | - | - | - |
| Ni | 2 | 3 | 2 c | 3 |
| Fe | 1 | 1 | 3 | 1 |
| SS304L | 1 c | 1 | 3 | 1 |
| Vacon 10 Fe-28Ni-18Co | 2 | 1 | 3-4 | 1 c |
| Vacodil 42 Fe-42Ni | 2 | 2 | - | - |

Table 1: continued

| | Brazing material | | | |
|---|---|---|---|---|
| Component | Ag-Pd | Cu-Au-Ni | Cu(OFHC) | Cu-Pd |
| % wt. | 90-10 | 62-35-3 | 100 | 82-18 |
| T. liquid. °C | 1065 | 1025 | 1083 | 1090 |
| T. solid. °C | 1002 | 980 | 1083 | 1080 |
| Brazing process | 10'1060°C +3'1120°C | 10'960°C +3'1050°C | 10'1060°C +3'1120°C | 10'1060°C +3'1120°C |
| Alloy design. Supplier | --- Degussa | --- Degussa | Do Du Co Pforzheim | Do Du co Pforzheim |
| Nb | 2 | 3 c | 4 | 3 |
| Ta | 2 c | 3 c | 4 | 3 |
| Mo | 3-4, a,c | 3 | 3-4 | 3 c |
| Re | 3-4 a | 3 | 3 | 1 |
| Ir | 3-4, a,c | 1 | 1 | - |
| Cu | - | 3 | - | - |
| Ni | 1 | 2 c | 3 | 3 |
| Fe | - | 1 | 1 | 2 c |
| SS304L | 2 | 2 c | 1 | 1 |
| Vacon 10 Fe-28Ni-18Co | - | 2 c | 3 | 3 |
| Vacodil 42 Fe-42Ni | - | - | - | - |

Table 1: Continued

| | Brazing material | | |
|---|---|---|---|
| Component | Pd-Co | Pd-Ni | Cu-Pt |
| % wt. | 65-35 | 60-40 | 60-40 |
| T. liquid. °C | 1120 | 1238 | 1250 |
| T. solid. °C | 1120 | 1238 | 1200 |
| Brazing process | 10'1210°C +3'1260°C | 10'1210°C +3'1260°C | 10'1180°C +3'1270°C |
| Alloy design. Supplier | --- Degussa | PN1 Engelhard | Couplat Wesgo |
| Nb | - b,c | - b | 2 c |
| Ta | 3-4 | 3 | 1 c |
| Mo | 3 | 3 | 1 |
| Re | 1 | 2 | 2 b |
| Ir | - | - | - |
| Cu | - | - | - |
| Ni | 3 | - | 3 |
| Fe | 3 | 3 | 1 c |
| SS304L | 1 | 3 | 2 c |
| Vacon 10 Fe-28Ni-18Co | 3 | 3 b | 2 |
| Vacodil 42 Fe-42Ni | - | - | 1 a,b |

Table 2: Brazing alloys between 1500°C and 1900°C

| Brazing alloy | Melting temperature | | Brazing process | Base Material | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | liq. | solid | °C | Nb | Nb1Zr | Ta | Mo | W | Re | Note |
| Pd | 1552 | 1552 | 10'1530<br>+3'1570 | 3-4 b | - | 3 c | 4 | 3 | 2 | |
| Pd-0.1Ni | - | - | 1510 to 1560 in 3 min. | - | 1 a,b | 3 c | 3 | 2-3 | - | |
| Pd-0.5Ni | - | - | 1510 to 1560 in 3 min. | - | 1 a | 2 c | 2-3 | 2 | - | |
| Pd-1Ni | - | - | 1510 to 1560 in 3 min. | - | 1 b | 2 c | 1 | 1 | - | |
| Pd-2Ni | - | - | 1510 to 1560 in 3 min. | - | 1 b | 1 c | 1 c | 1 c | - | |
| Pd-50Nb (alloy) | 1560 | 1560 | Argon 5'1620 | - | 2 | 3 | - | - | - | II |
| Pd-50Nb (clad wire) | - | - | 5'1620 | - | 2 | - | - | - | - | |
| Pt | 1769 | 1769 | 10'1730<br>+3'1800 | - b | - | 2 a | 3 | - | 1 | |
| Zr-22Nb | 1740 | 1740 | 3'1740<br>3'1800<br>3'1700 | 3<br><br>- | -<br>-<br>- | *<br>3<br>- | 2 a | -<br>-<br>- | -<br>-<br>1 | |
| V-30Nb-5Ti | - | - | 3'1780<br>+90'1830 | 3 | 3 | 3 | 3 | - | | I |

Note:
- * Not completely molten
- I Wetts graphite well
- II Strong adherence on unmetalized high purity alumina (Feldmühle E37, 99.7 $Al_2O_3$).

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Alfred Nobel

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