International Standard ISO 5187

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Welding and allied processes — Assemblies made with soft solders and brazing filler metals — Mechanical test methods

Soudage et techniques connexes — Assemblages exécutés avec des produits d'apport de brasage tendre et de brasage fort — Méthodes d'essai mécanique

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 5187 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*.

It cancels and replaces ISO 3683-1978 the scope of which was more limited.

Welding and allied processes — Assemblies made with soft solders and brazing filler metals — Mechanical test methods

0 Introduction

A joint is not a homogeneous body but a heterogenous assembly formed from different materials having different physical and chemical properties. In the simplest case, it consists of filler metal and the base metal. Diffusion phenomena occur at the contact surfaces giving rise to, in the interface, a series of new alloys different from one another and different from both the joining material and the base metal.

In the study of the strength of such heterogeneous joints, the simplified hypotheses of the theory of elasticity — valid for a homogeneous metallic body or stresses due to external forces transmitted uniformly from an element of surface or volume to neighbouring elements — are no longer applicable.

Hence, the notion of "joining material strength" needs to be limited strictly to metal solidified after melting. Conversely, the strength of an assembly is a function of the intrinsic strength of the filler metal and a series of external factors. It follows that tests designed to determine this strength need to be carried out according to precise conventions, taking into account, in addition to the characteristics of the joining material itself, a series of external factors, notably:

- composition and strength of base metal;
- shape of the specimen;
- geometry and state of the surface of the joint;
- flux used;
- brazing or soldering technique used (heat source, joining temperature, heating rate, etc.);
- time at joining temperature;
- joint clearance;
- number of tests;
- method used to interpret the results;
- nature and size of faults at the fracture surface.

To understand the strength of a joined assembly, this International Standard allows the determination of the following characteristics:

a) for brazing filler metal

   — the instantaneous tensile strength, cold, at ambient temperature or hot,

   — the instantaneous shear strength, cold, at ambient temperature or hot,

   — the creep strength at elevated temperatures;

b) for soft solder

   — the instantaneous shear strength, cold, at ambient temperature or hot,

   — the creep strength, cold, at ambient temperature or hot;

for a given brazing filler metal, flux and base metal.

So that the tests are reproducible and comparable, it is important to use tensile and shear specimens of a well-defined type and have recourse to a precise operating method. This International Standard meets this objective.

1 Scope and field of application

This International Standard defines the principles and the technique of the tests designed to determine the conventional mechanical characteristics of assemblies produced with soft solders and brazing filler metals; it also specifies a method of interpreting the results obtained.

This International Standard is applicable to joining materials and their fluxes which are used for soldering and brazing of ferrous and non-ferrous metals and alloys.

2 Test methods

2.1 Types of assemblies

2.1.1 Conventional shear strength

For the determination of the conventional shear strength, an assembly of two fitted pieces is used with predetermined joint clearance so that the brazed joint is subject to a shear stress when a tensile force is applied to the specimen.

Two specimens are proposed (see figures 1 and 2), the operator having a choice between the two. The type of specimen chosen shall be noted in the test report.

2.1.2 Conventional tensile strength

For the determination of the conventional tensile strength, an assembly made end-to-end on two bars with a predetermined joint clearance at the extremities is used.

Figure 3 gives the dimensions of the tensile specimen.

2.2 Choice of base metal and joint clearance

In order to obtain fracture at the joint, the base metal shall be chosen, as far as possible, so that the fracture load of the brazed assembly is lower than the load corresponding to the elastic limit of the base metal.

In practice, if data is required for a specific application, the parent metal for the specimens shall be the metal used for the components in the case being considered. Similarly, the joint clearance in the specimens shall be that used in the application.

The base metal and the joint clearance shall be indicated in the test report.

2.3 Preparation of the surfaces

Before the brazing operation, the surfaces to be brazed need to be clean and clear of oxides, grease, oil, paint, etc. A process and a cleaning agent suited to the requirements of the base metal shall be used.

Similarly, the specimens shall possess, at the joints, a surface condition corresponding to a roughness, R_a, between 1,6 and 3,2 µm if they are copper or copper alloys and a roughness between 1,6 and 6,3 µm if they are in non-alloyed steel.

If the tests are designed for a particular case, the surface condition shall be that corresponding to the case under consideration.

The cleaning product and process as well as the surface condition at the joints shall be indicated in the test report.

2.4 Application of joining material and flux

The component parts of the specimen are assembled in a vertical position, and the joining material, in an appropriate form (wire, powder, etc.), is placed at one side of the joint, in sufficient quantity to fill the joint after melting.

If it is necessary to use a flux, a tested flux suitable for the filler material and the base metal shall be used; the use of the flux shall conform to the manufacturer's instructions.

The characteristics of the flux shall be detailed in the test report.

2.5 Heating conditions

A support designed to hold the specimen vertically, in the position indicated in figures 1, 2 and 3, can be used. In order to avoid any load on the joint during cooling, this support shall not obstruct the contraction and expansion of the specimen assembly.

In the case of heating with an oxy-acetylene flame, the apparatus shown in figure 4 can be used. This consists of a base plate (1) on which is mounted a specimen support (2), a clamping system (3) and a pivoting support (4) for the blow-pipe shown schematically at reference point (5).

Other jigging arrangements can be used to suit the chosen heating method.

The assembly is raised to the joining temperature by means of the selected heating method (torch, induction, furnace, etc.). If it is not heated uniformly over the complete length (for example, torch heating, induction heating), it is essential to ensure that the uniform joining temperature is reached over a distance of 10 mm either side of the joint.

Suggestion

If heating is carried out by torch or induction, the specimen heating cycle should be such that the melting temperature of the joining material is reached in 40 to 60 s, the heating cycle being prolonged for 5 s after this temperature has been reached. With the exception of particular specifications, the specimens need to be maintained at the brazing temperature for a period of 10 to 30 s.

All the operating conditions shall be entered in the test report.

NOTE — If the specimens have to be made in order to obtain fundamental information, the heating conditions are left to the initiative of the test controller.

2.6 Number of specimens

2.6.1 Five specimens are necessary to determine the strength at ambient temperature or cold.

2.6.2 Five to ten specimens are necessary to plot a curve of strength at high temperature or under creep.

2.7 Specimen machining

After joining, the tensile and shear specimens are machined according to figures 1, 2 and 3 in such a way that the strength properties of the joint will not be influenced.

2.8 Execution of shear and traction tests

All tests are carried out in jigs on a machine possessing (preferably) adjustable clamps in order to avoid parasitic bending stresses in the specimens. The shear tests on the specimens shown in figures 1 and 2 are carried out with the mounting arrangements shown in figures 5 and 6.

The joint strength expressed in megapascals (MPa) is obtained by dividing the fracture load expressed in newtons by the surface area of the brazed joint[1] expressed in square millimetres. The results of the fracture examination shall be noted in the test report.

For the instantaneous shear and tensile tests at cold, at ambient temperature (between 18 and 24 °C) or at hot temperature, imposing of the load needs to be carried out with the test machine regulated [rate of displacement expressed in micrometres per second (µm/s) or regulation of force expressed in newtons per second (N/s)] so as to be compatible with the characteristics of the filler metal submitted to the tests.

1) If faults have appeared in the fractured surface, the surface shall be analysed and the presence of faults indicated in the test report.

The instantaneous hot shear or tensile specimens shall be put under load on a tensile machine equipped with a furnace. The specimen temperature shall be stabilized for 1 h before imposing the load and furnace temperature regulation shall be within ± 1 %.

For creep test specimens, a creep/fracture machine shall be used. The temperature shall be stabilized for 2 h before imposing the load and furnace temperature regulation shall be within ± 1 %. If creep is carried out at ambient temperature, the latter requirement is a question of judgment.

The fracture surface needs to be examined and the results of the examination shall be noted in the test report.

3 Expression of results

3.1 Interpretation of instantaneous shear and tensile tests at ambient temperature

To facilitate the application of the instantaneous shear test results at ambient temperature, it is possible to use a statistical interpretation by calculating the mean and standard deviation of the test results.

This mean, $\bar{x}$, and standard deviation, s, are determined as follows:

$$\bar{x} = \frac{\Sigma x_i}{n}$$

$$s = \sqrt{\frac{\Sigma (x_i - \bar{x})^2}{n-1}}$$

Since the results are for a given joining material, the mean value can be fixed to tend to a minimum M_0.

This procedure can be explained as follows:

— the ratios between the variability due to the test method and the variability due to the joining material itself are not known;

— to fix a range of "minimum tolerances" demands several preliminary tests for all the types of existing joining materials;

— the number of tests required to evaluate the "minimum tolerances" is generally higher than that required for the evaluation of means.

Under these conditions and considering the results of n tests, one fixes as a rule to accept a joining material of a given classification when it is characterized by a minimum mean M_0 such that:

— the probability of accepting a joining material for which the mean strength is less than M_0 is at most equal to a small number β (customer's risk).

— a joining material giving a large theoretical proportion P of results higher than M_0 is accepted in a large number of cases $(1 - \alpha)$, α being the manufacturer's risk.

These conditions shall be respected whatever the unknown standard deviation characterizing the behaviour of the joining material during the test.

Each joining material is considered to fulfil the fixed condition concerning M_0, if the mean $\bar{x}$ of the results x_i of n tests satisfies the condition:

$$\bar{x} - ks > M_0$$

If one fixes the risk $\alpha - \beta = 0{,}10$ for $P = 10\ \%$, one finds by referring to existing variable sampling tables that:

for $n = 5$
$k = 0{,}68$

Under these conditions, $\bar{x}$ being the mean of five tests, one should have

$$\bar{x} - 0{,}68\, s > M_0$$

The calculation k and n is based on the fact that in a first approximation, the results follow a normal law. The uncertain variable

$$t = \frac{\bar{x} - M_0}{s/\sqrt{n}}$$

follows Student's law (if the mean is M_0) or a decentred Student's law of 1,281 6 $\sqrt{n}$ (when $P = 10\ \%$), and k and n values are determined by the two conditions:

$$Pr\,(t > k\sqrt{n}) = \alpha = 0{,}10 \text{ (} t \text{ centred)}$$
$$Pr\,(t > k\sqrt{n}) = \beta = 0{,}10 \text{ (} t \text{ decentred)}$$

The envisaged risk seems reasonable for the fixed test conditions because it implies a small number of tests which, from an economic viewpoint, is far from negligible.

3.2 Hot instantaneous shear test

The hot instantaneous shear tests permit the plotting of the curve for fracture stress, in megapascals, as a function of temperature, in degrees Celsius.

Figure 7 shows an example of a curve obtained from three temperature tests.

3.3 Creep shear tests

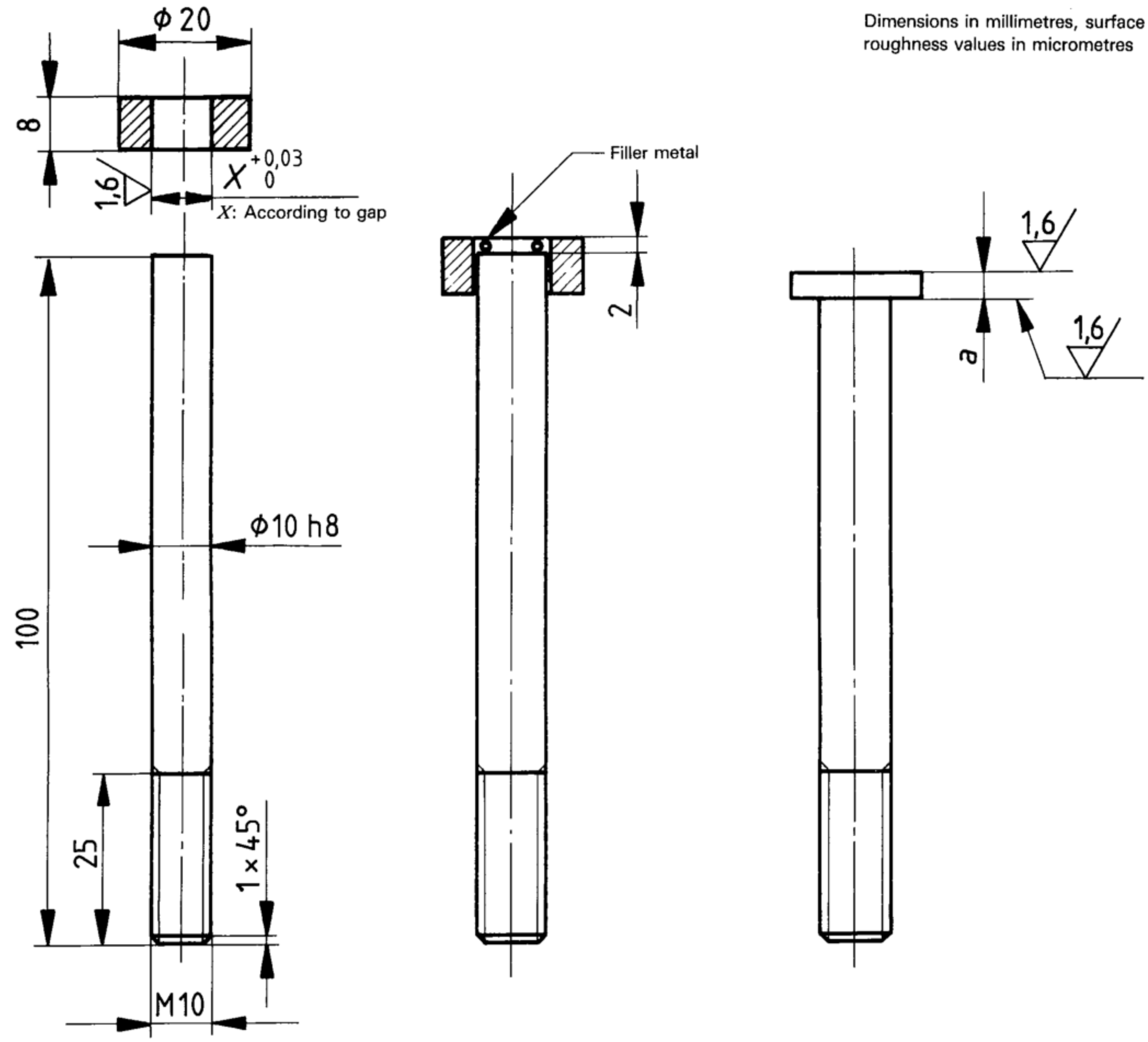
With one or several temperatures, the objective of these tests is to plot one or several curves:

Fracture stress, in megapascals = f (time to fracture, in hours)

The stresses need to be chosen in such a way as to obtain fracture times between 0,1 and 10^3 h. For special cases, it will be possible to research stresses giving fracture times of 10^5 or 10^6 h.

Figure 8 gives a method for presenting the results.

Dimensions in millimetres, surface roughness values in micrometres



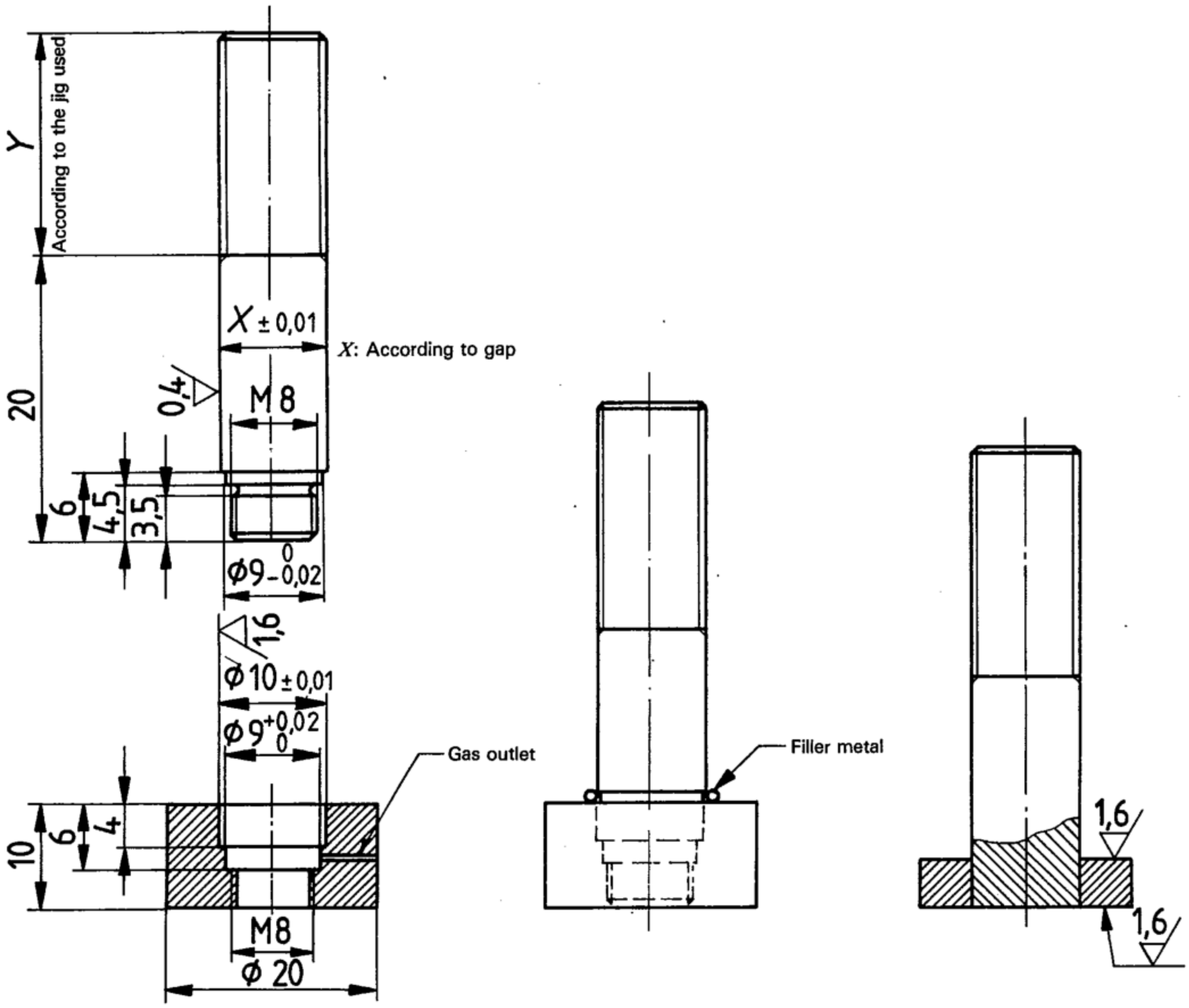
Test piece details

Test piece before brazing

Test piece after machining

Figure 1 — Type I shearing test piece dimensions

Dimensions in millimetres, surface roughness values in micrometres



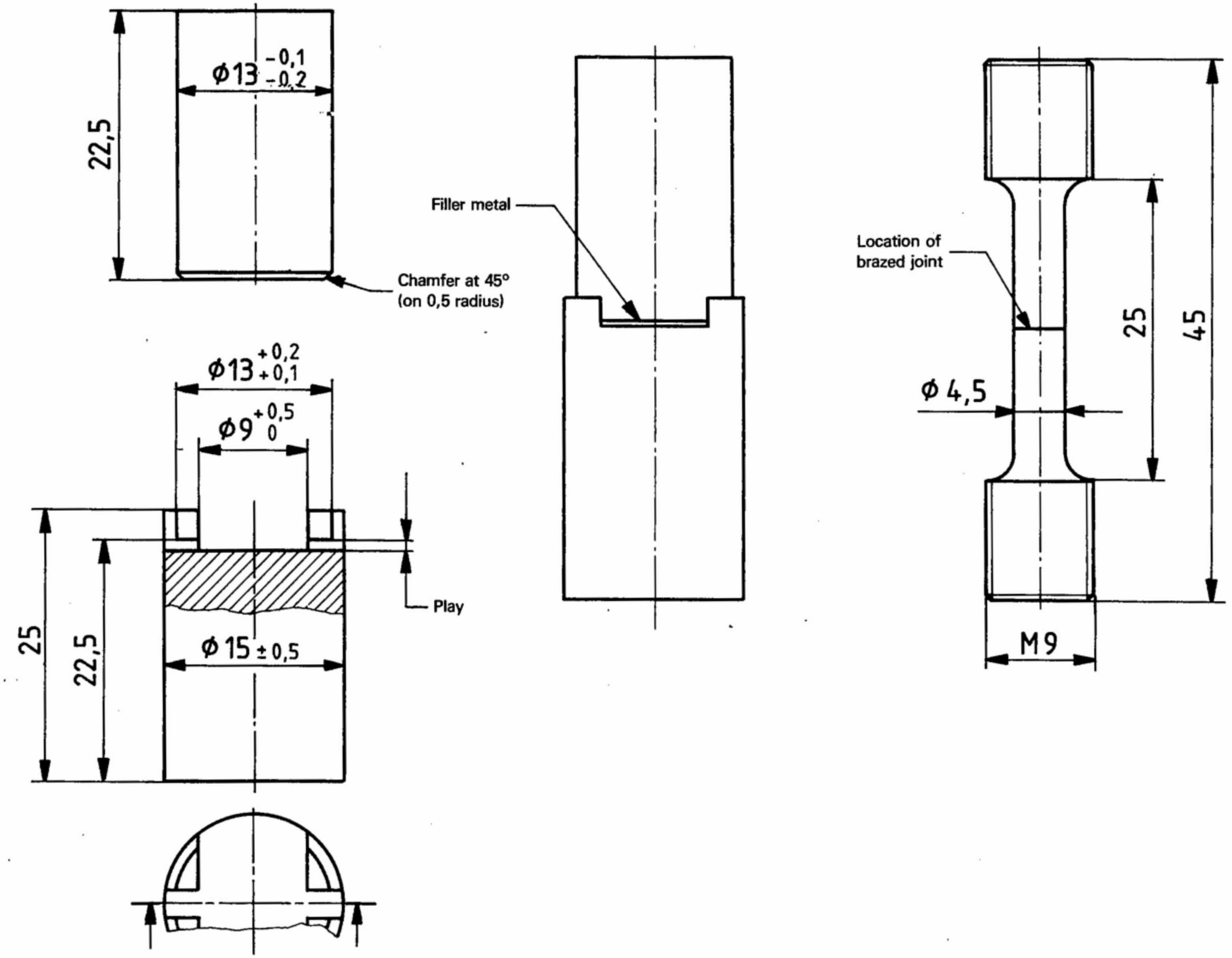
Test piece details

Test piece before brazing or soldering

Test piece after machining

Figure 2 — Type II shearing test piece dimensions

Dimensions in millimetres



Test piece details

Test piece before brazing

Test piece after machining

Figure 3 — Tensile test piece dimensions

Dimensions in millimetres

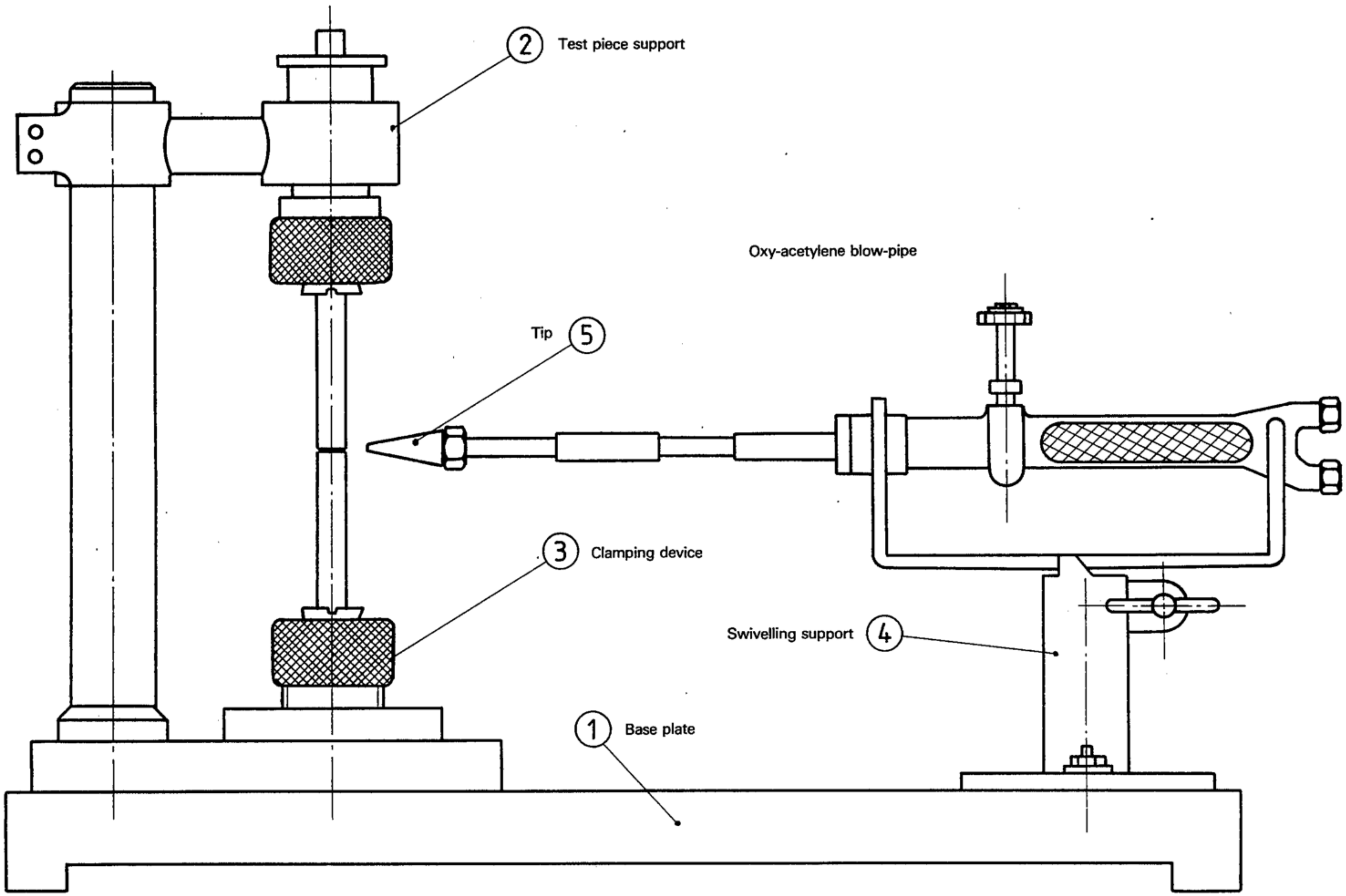


Figure 4 — Test piece brazing or soldering fixture

Dimensions in millimetres

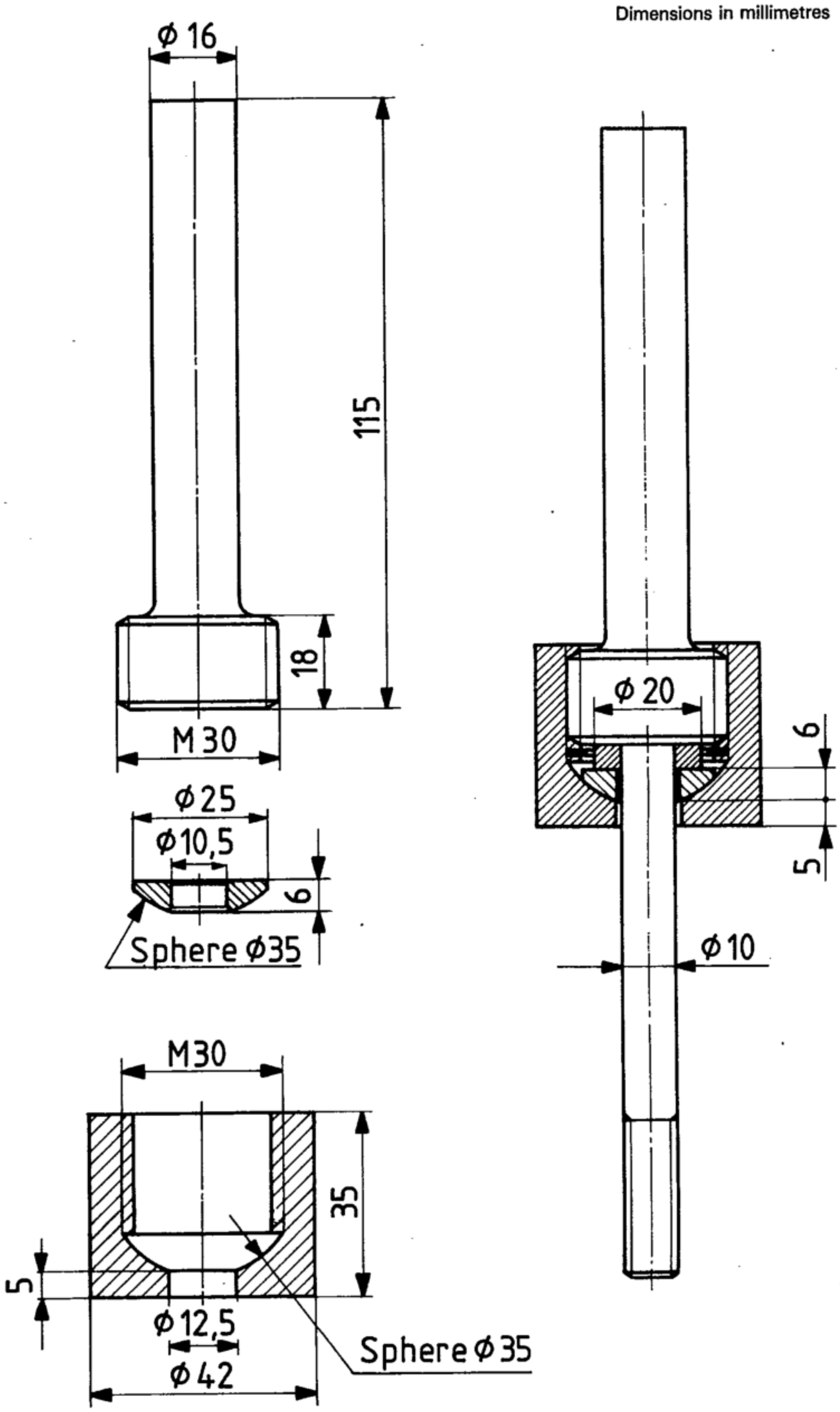


Figure 5 — Fixture for tensile loading, Type I test pieces

Dimensions in millimetres, surface roughness value in micrometres

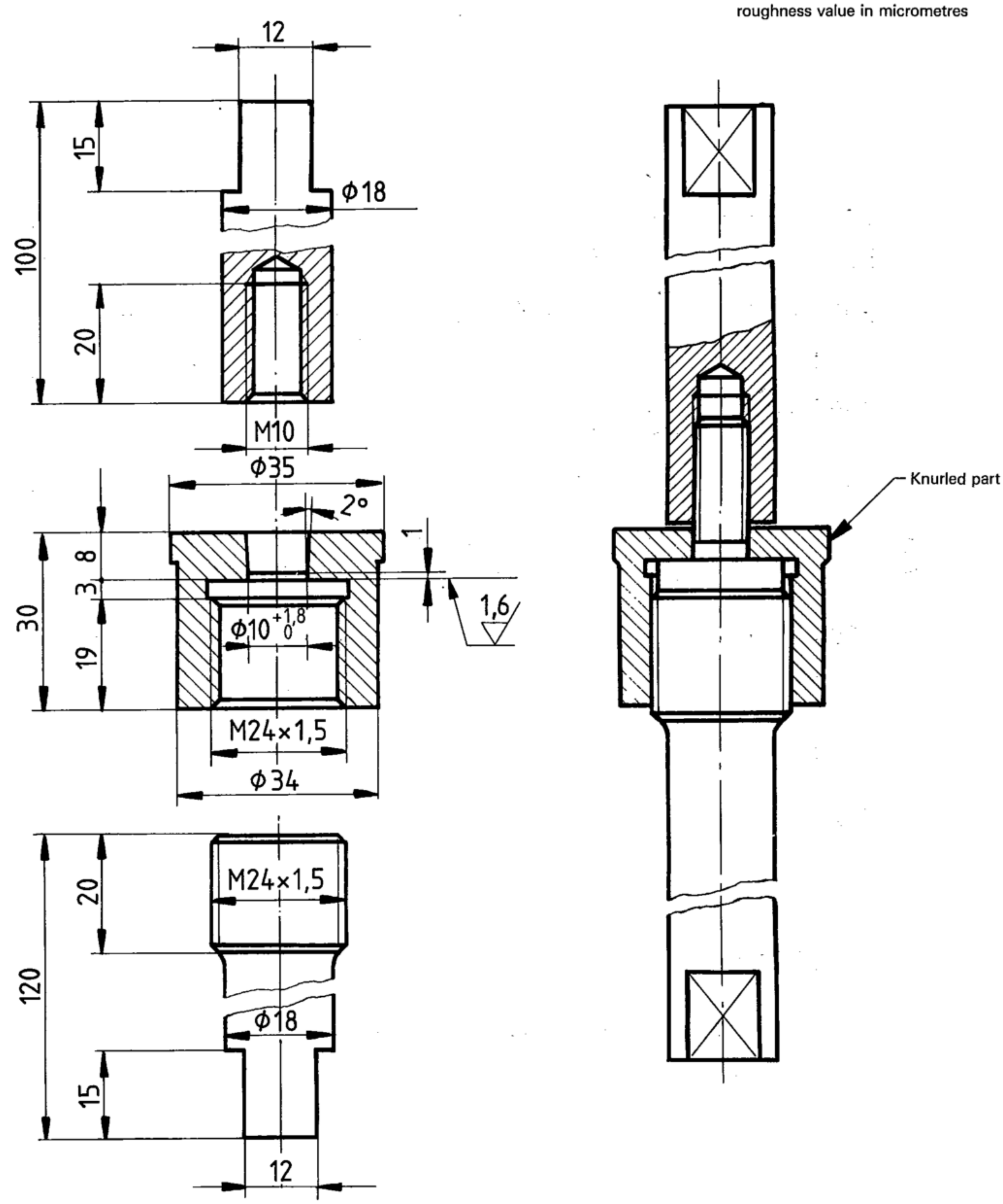
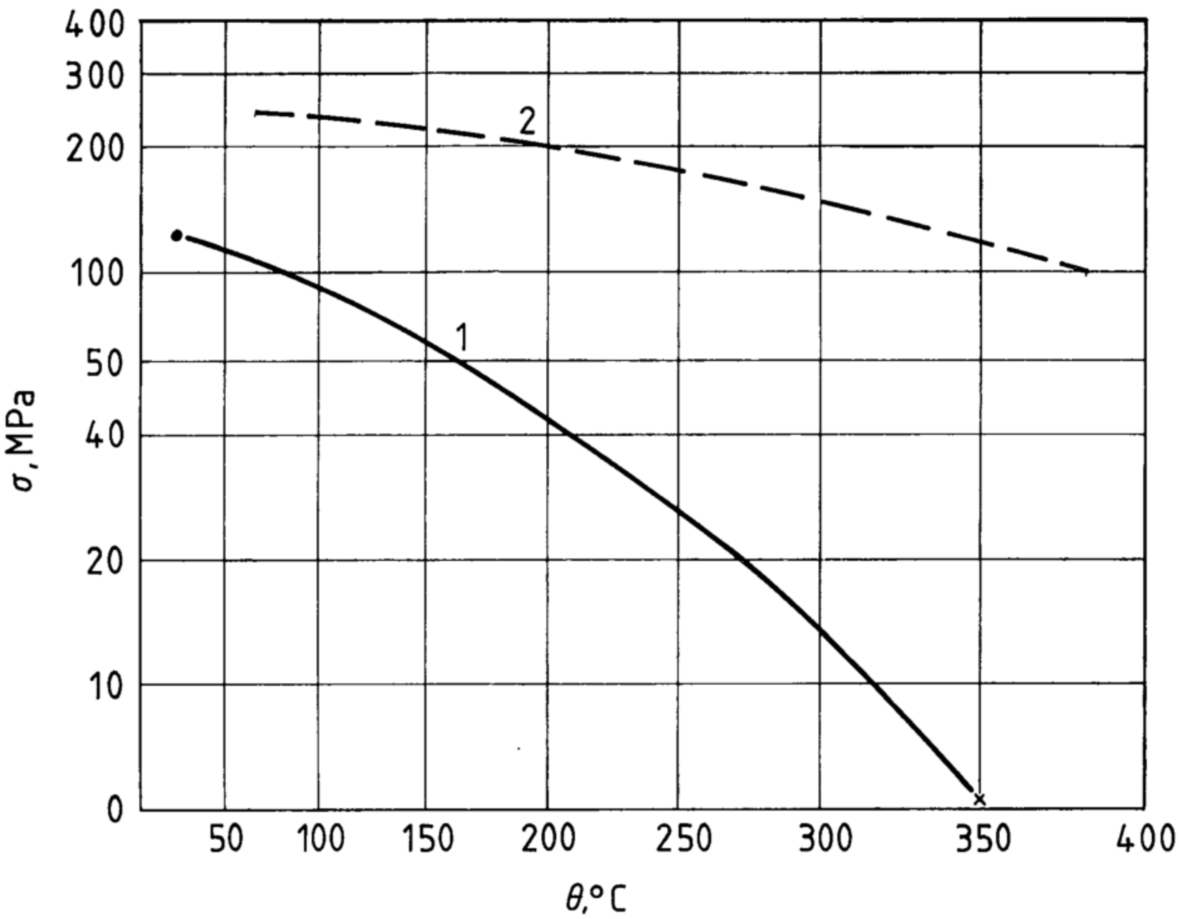
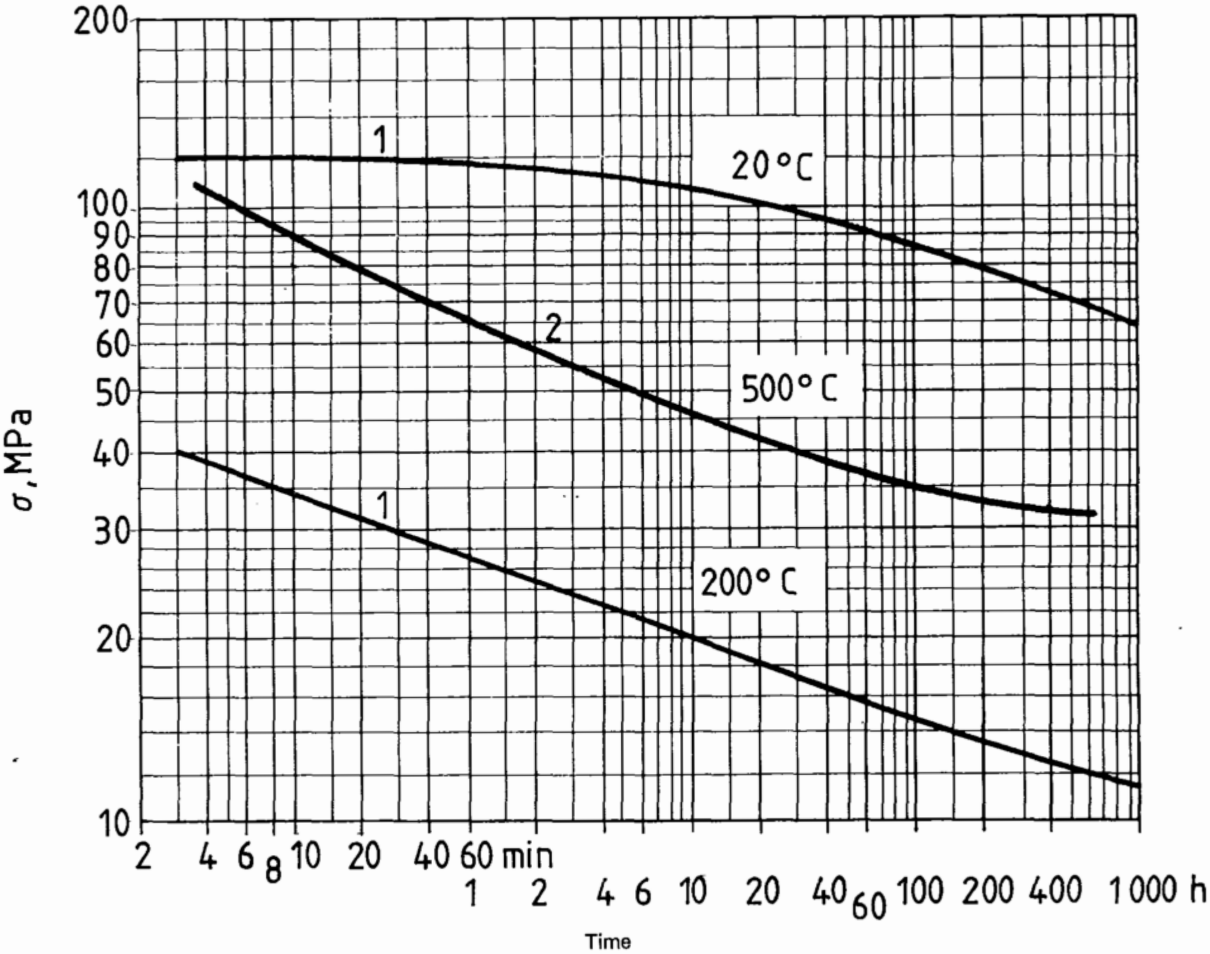


Figure 6 — Fixture for tensile loading, Type II test pieces



1 Soldering
2 Brazing

Figure 7 — Typical instantaneous hot shearing strength curves



1 Soldering: at 20 and 200 °C
2 Brazing: at 500 °C

Figure 8 — Typical creep shear strength curves