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Soft soldered joints — Determination of shear strength

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FOREWORD

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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.

International Standard ISO 3683 was developed by Technical Committee ISO/TC 44, *Welding*, and was circulated to the member bodies in November 1976.

It has been approved by the member bodies of the following countries :

Austria	Israel	South Africa, Rep. of
Belgium	Italy	Spain
Bulgaria	Japan	Sweden
Canada	Korea, Rep. of	Switzerland
Finland	Mexico	Turkey
France	Netherlands	U.S.A.
Germany	Poland	Yugoslavia
India	Romania	

The member body of the following country expressed disapproval of the document on technical grounds :

United Kingdom

Soft soldered joints — Determination of shear strength

0 INTRODUCTION

A soft soldered joint is not a homogeneous body but a heterogeneous assembly of different metals having different physical and chemical properties. At its simplest, it consists of the filler metal and the parent metal. However, in most applications, diffusion phenomena may take place at the joint interface so that a series of new alloys, which differ from one another as well as from the filler metal and from the parent metal, form in the bonding zone.

In a study of the strength of such heterogeneous joints, the simplified assumptions of the elastic theory, valid for a homogeneous metallic body, where the stresses due to external forces are uniformly transmitted from a surface element or a volume element to the adjoining elements, are no longer applicable.

It follows that the concept of the "strength of a filler metal" must be strictly limited to the metal solidified after fusion. The strength of a soft soldered joint being, however, dependent on the intrinsic strength of the filler metal and on a number of external factors, it is obvious that tests made in order to determine this strength must be carried out in accordance with precisely defined conditions, due consideration being given both to the characteristics of the filler metal and to the external factors. These factors are :

- composition and strength of the parent metal,
- shape of test specimen,
- geometry and surface condition of the joint,
- soft soldering flux used,
- soft soldering technique used (heat source, soft soldering temperature, heating speed, etc.),
- number of tests,
- method used to interpret results,
- nature and importance of the defects on the fracture surface.

These problems are being investigated by the IIW[1] with a view to establishing a method for characterizing a filler metal. The representative characteristics selected to this effect are the instantaneous shear strength either at ambient temperature or in the hot condition, and the creep shear strength, either at ambient temperature or in the hot condition.

The results obtained may be used for filler metal classification or in order to provide knowledge of the strength of a soft soldered joint.

It should be noted that other tests must take into consideration the nature of the filler metal, the metals to be joined and the type of joint.

1 SCOPE

This International Standard specifies methods of determining the shear strength of joints made by soft soldering and describes a method of interpreting the results.

2 FIELD OF APPLICATION

It concerns the filler materials intended for soldering ferrous and non-ferrous materials and alloys and the assemblies obtained thereby.

3 TEST METHODS

3.1 Type of joint

For the determination of the conventional shear strength, an assembly of two jointed parts is used with a fit such that the soft soldered joint will be shear stressed when a tensile stress is applied to the test piece. Two test pieces are proposed (see figures 1 and 2). The user can select either.

1) International Institute of Welding.

3.2 Selection of the parent metal

For the classification of filler metals, usual grade carbon steel with a minimum tensile strength of 360 N/mm^2* should be used as a parent metal, the fits to be adopted being specified in figures 1 and 2.

In practice, if strength data are wanted, the metal used for the parts may have to be used as the test piece parent metal. Similarly, the fits of the test piece shall be those of the parts.

3.3 Preparation of the surface

If the parent metal is mild steel, the joint surfaces shall be degreased with ethylene perchloride, then immersed in hydrochloric acid (10 % by volume, ρ 1,4 g/cm^3) before soft soldering. After these operations, the parts shall be rinsed in distilled water.

3.4 Operating conditions

3.4.1 The soft soldering fixture to be used for flame-heating the test piece is illustrated in figure 3. It consists essentially of a base plate (1) on which a test-piece support (2), a clamping device (3) and a swivelling support (4) are fitted. The burner is also secured to the fixture.

3.4.2 The filler metal is placed on one side of the joint, in the form of either powder or wire, in sufficient quantity to fill the joint after melting. An appropriate soft soldering flux should be used.

3.4.3 The circular burner (reference 5, figure 3) should include nine orifices, six of the corresponding flames being directed towards the soldering area and the three other flames being directed towards the test piece body.

3.4.4 If oxy-acetylene is used as the heating flame, the blowpipe will be supplied with purified acetylene and with oxygen having a minimum purity of 98 %. The flames should be adjusted normally. In any case, the nature of the flames should be specified in the test report.

3.4.5 The joint area is uniformly heated to the soft soldering temperature using the annular heating nozzle. Flames should be adjusted so that the filler metal melts within 20 to 40 s following the start of the heating operation. Once the filler metal is melted, heating is continued for a period of about 10 % of the heating cycle time, then stopped.

After solidification of the filler metal, the test piece is removed from the soft soldering fixture, then cooled in air to ambient temperature.

3.4.6 After soft soldering, test pieces are machined in accordance with figure 1 or 2.

3.4.7 To determine the instantaneous cold shearing strength, five test pieces are required.

To plot a curve of the instantaneous hot shearing strength, five to ten test pieces are required.

To plot a shear-creep curve for a given temperature, five to ten test pieces are required.

4 EXECUTION OF SHEAR TESTS

4.1 All shear tests are carried out with fixtures (figures 4 and 5) and machines eliminating any parasitic bending effects in the test pieces.

4.2 The instantaneous cold shear test pieces should be loaded at a rate of about 1,9 N/s and at an ambient temperature of 18 to 24 °C.

The instantaneous hot shear test pieces can be loaded on a standard tensile test machine fitted with an oven. Prior to loading, the test piece temperature should be allowed to stabilize for 1 h and the oven temperature should be controlled within ± 3 °C minimum.

For shear test pieces intended for creep tests, a creep-to-failure testing machine should be used. Prior to loading, the temperature should be allowed to stabilize for 4 h and the oven temperature should be controlled within ± 1 °C at least. If the creep test is carried out in cold conditions, the ambient temperature will be considered.

4.3 The shear strength in newtons per square millimetre (N/mm^2), is obtained by dividing the failure stress expressed in newtons by the brazed joint area expressed in square millimetres. The result of the fracture face examination shall be noted in the test report.

5 RESULTS

5.1 Interpretation of the instantaneous cold shear tests

To facilitate the analysis of the instantaneous cold shear strength data, a statistical interpretation can be used by calculating the mean of test results and the standard deviation of these results.

The mean of test results and the standard deviation are determined by :

– mean $\bar{x} = \dfrac{\Sigma x_i}{n}$

– standard deviation $s = \sqrt{\dfrac{\Sigma (x_i - \bar{x})^2}{n-1}}$

For the approval of a given filler metal, one may consider the value to be reached as a minimal mean M_0.

* 1 N/mm^2 = 1 MPa

This concept is justified as follows :

— the relationship between the variation due to the test method and that due to the filler metal itself is not known;

— setting up of a range of "minimum tolerances" would require numerous preliminary tests for every existing type of filler metal;

— the number of tests required to verify the "minimum tolerances" generally exceeds the number of tests necessitated to check the mean values.

Therefore, and taking as a basis the mean value of the results of n tests, a rule has been selected for the acceptance of a soft soldering filler metal in a given class, characterized by a minimum mean M_0, such that :

— the probability of accepting a filler metal having a mean strength lower than M_0 does not exceed a small value, β (customer's risk);

— a filler metal providing a high theoretical proportion P of results higher than M_0 is accepted in a large number of cases, $1 - \alpha$ (α being the producer's risk).

These conditions shall be observed whatever may be the unknown standard deviation which characterizes the filler metal behaviour within the test.

Any soft soldering filler metal is considered to fulfil the required condition concerning M_0 if the mean $\bar{x}$ of the results x_i of n tests meets the following condition :

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

Assuming a risk $\alpha = \beta = 0{,}10$ and $P = 10\ \%$ the existing tables for sampling by variables[1] show that :

for $n = 5$

$k = 0{,}68$

In these conditions, x being the mean of five tests, the above-mentioned condition becomes :

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

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

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

follows then a law of Student (case where the average is M_0) or an eccentric law of Student (eccentricity $1{,}281\,6\sqrt{n}$; case where $P = 10\ \%$); k and n are then determined by the two conditions :

$$\text{Prob}\ \{t > k\sqrt{n}\} = \alpha = 0{,}10\ (t \text{ centric})$$

$$\text{Prob}\ \{t > k\sqrt{n}\} = \beta = 0{,}10\ (t \text{ eccentric})$$

The risk taken seems reasonable for the test conditions given. It required only a small number of tests, an advantage which, from the economic point of view, is far from negligible.

5.2 Instantaneous hot shear tests

The purpose of the instantaneous hot shear tests is to plot the curve of ultimate strength, in newtons per square millimetre, versus temperature, in degrees Celsius.

Figure 6 illustrates a typical curve obtained with three tests for each temperature.

5.3 Creep shear tests

For one or several levels of temperature, the tests are intended for plotting the curve (or curves) :

ultimate strength, in newtons per square millimetre, versus time to failure, in hours.

The ultimate strength values will be selected to obtain a time to failure ranging from 0,1 to 10^3 h; for special cases the strength values could be determined for times to failure of 10^5 or 10^6 h.

Figure 7 illustrates a typical presentation of results.

1) U.S.A. Military Standard 414. Columbia University, *Tables of the Statistical Research Group.* Bowker and Goods, *Sampling inspection by variables.*

Dimensions in millimetres

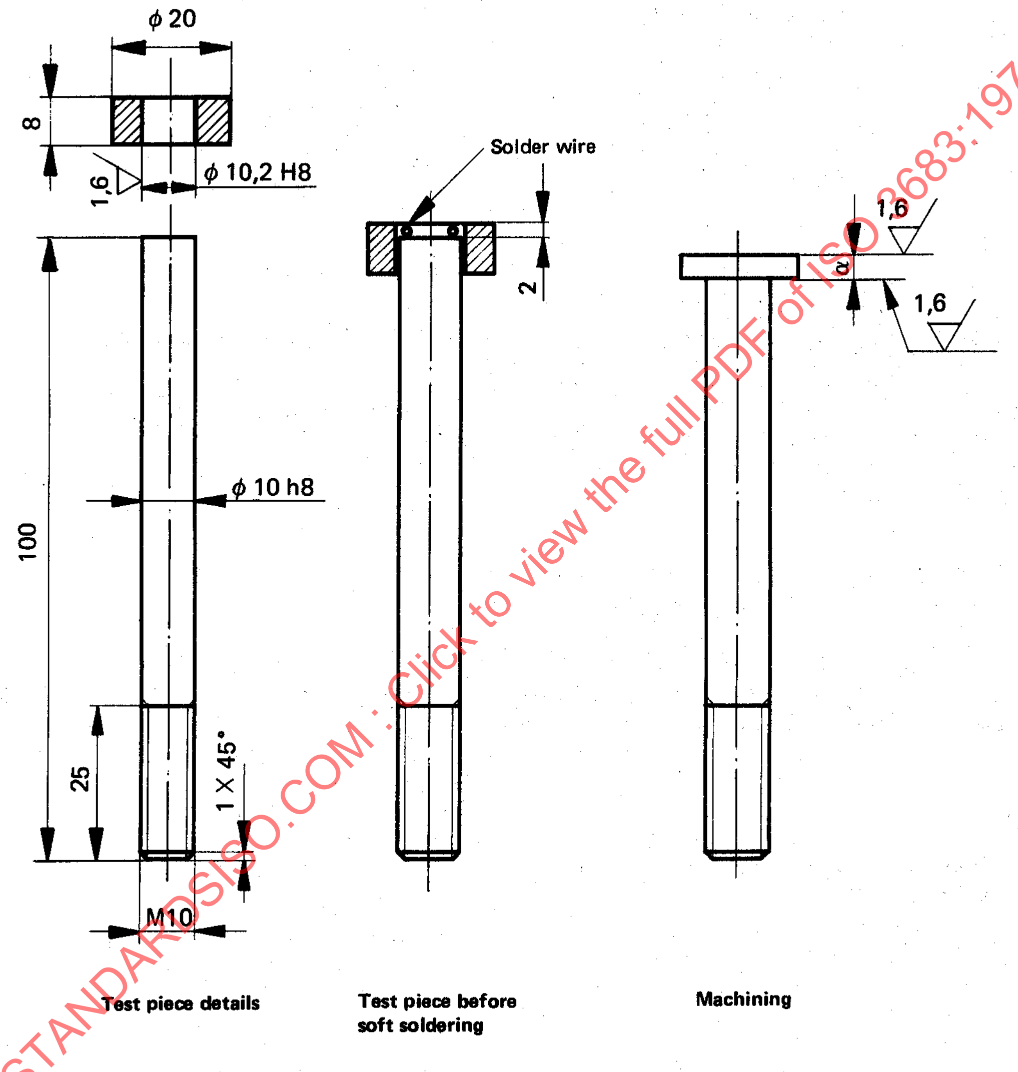

FIGURE 1 — Type I shearing test piece dimensions

Dimensions in millimetres

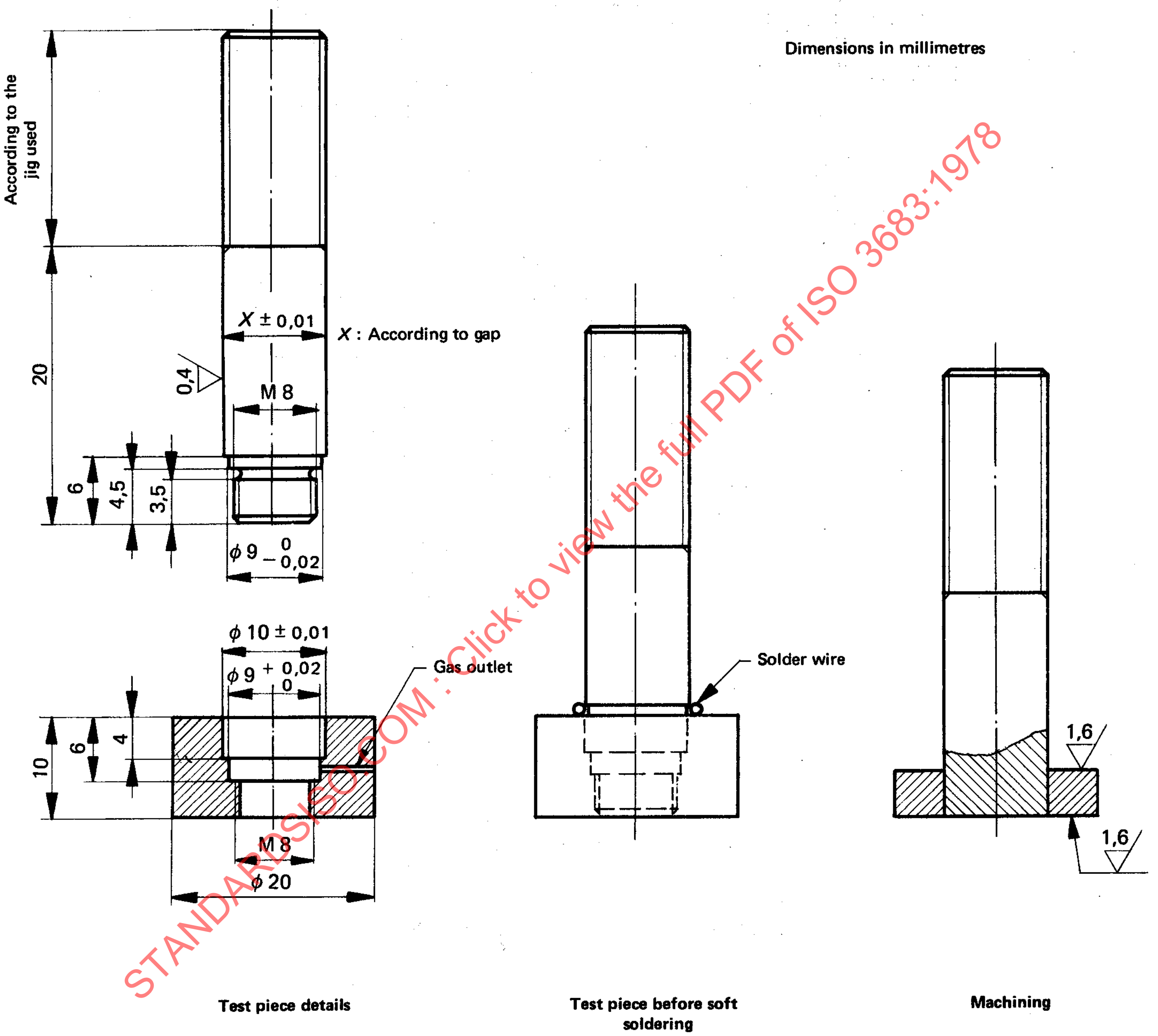

FIGURE 2 — Type II shearing test piece dimensions

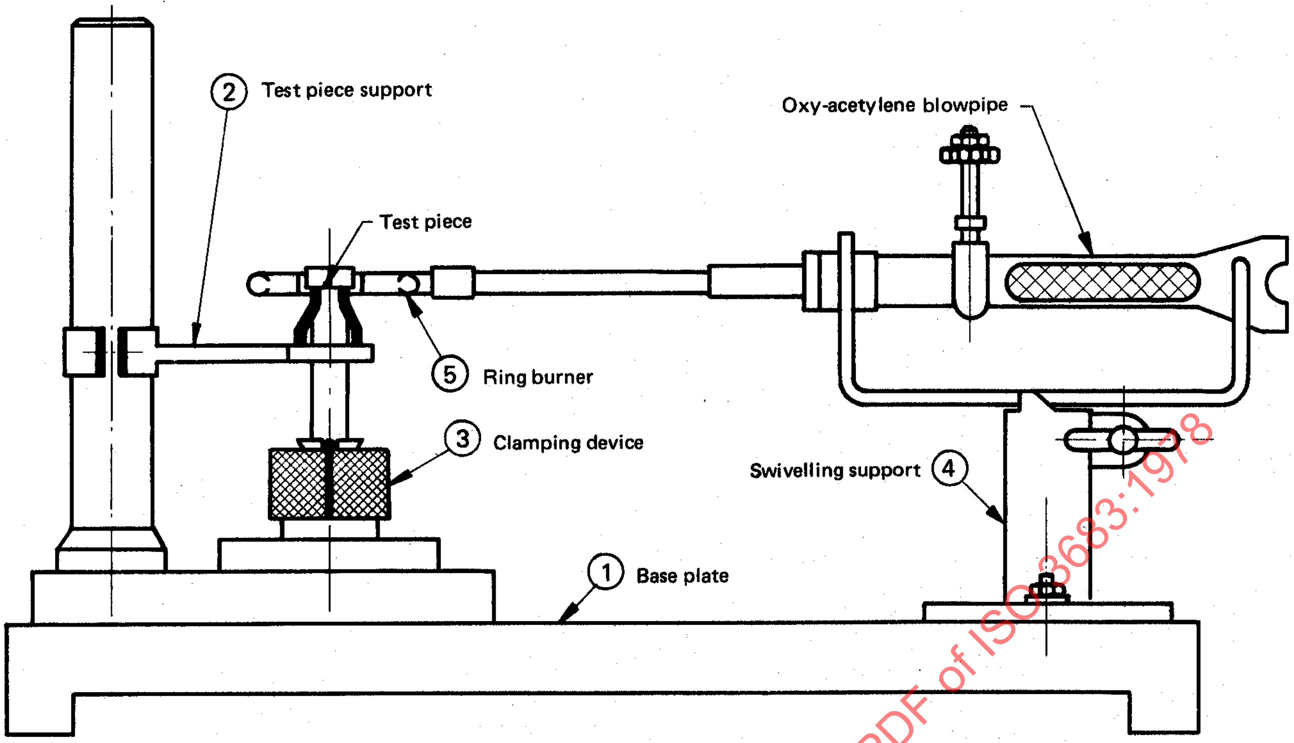

FIGURE 3 — **Example of soft soldering test piece fixture**

Dimensions in millimetres

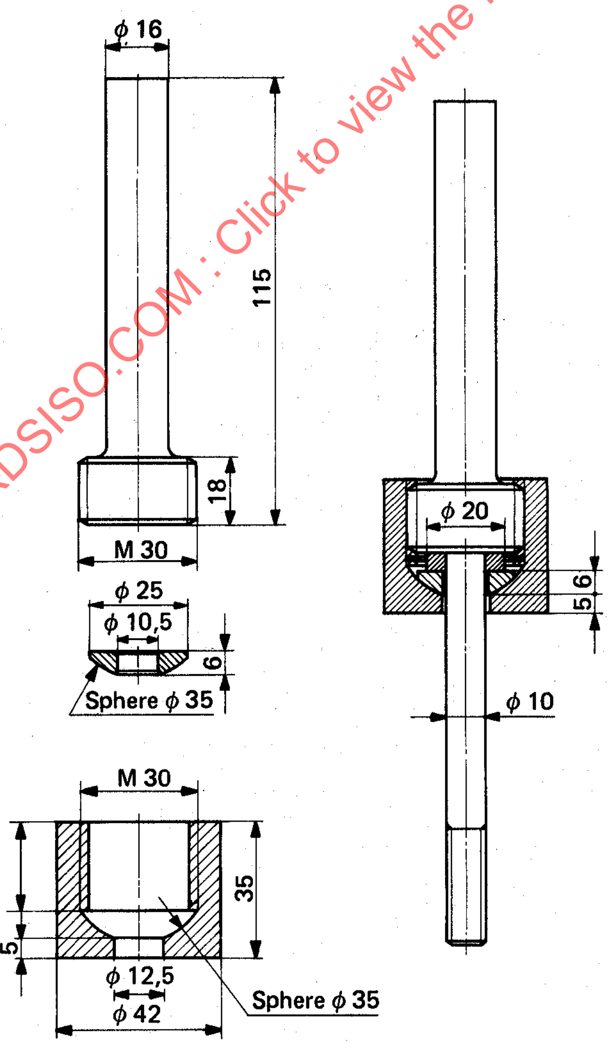

FIGURE 4 — **Fixture for tensile loading, Type I test pieces**

Dimensions in millimetres

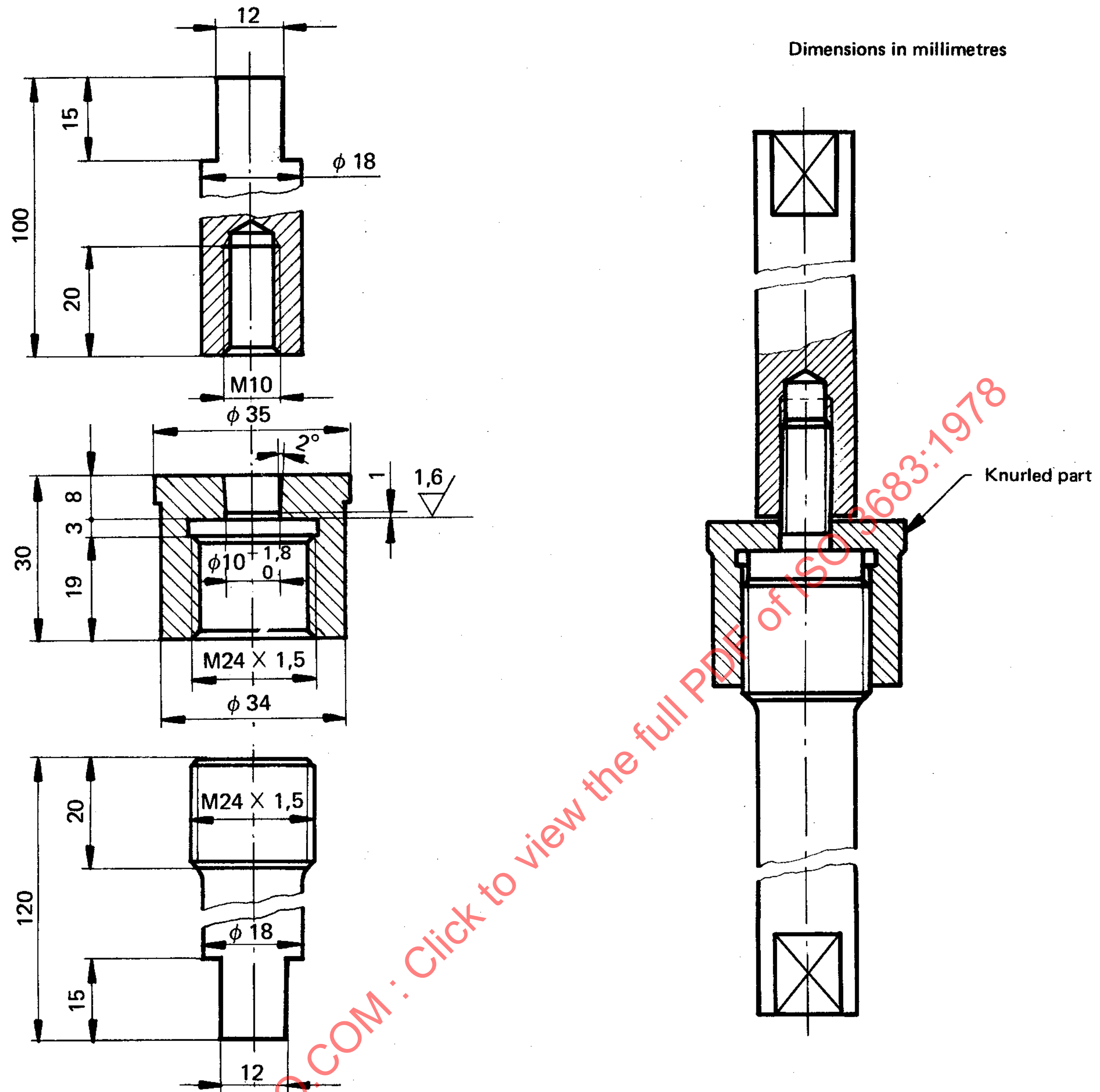

FIGURE 5 — Fixture for tensile loading, Type II test pieces

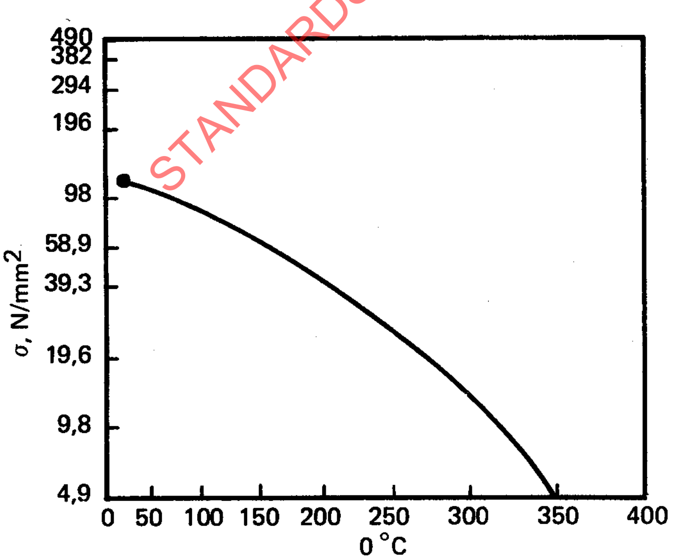

FIGURE 6 — Typical curve of instantaneous hot shearing strength

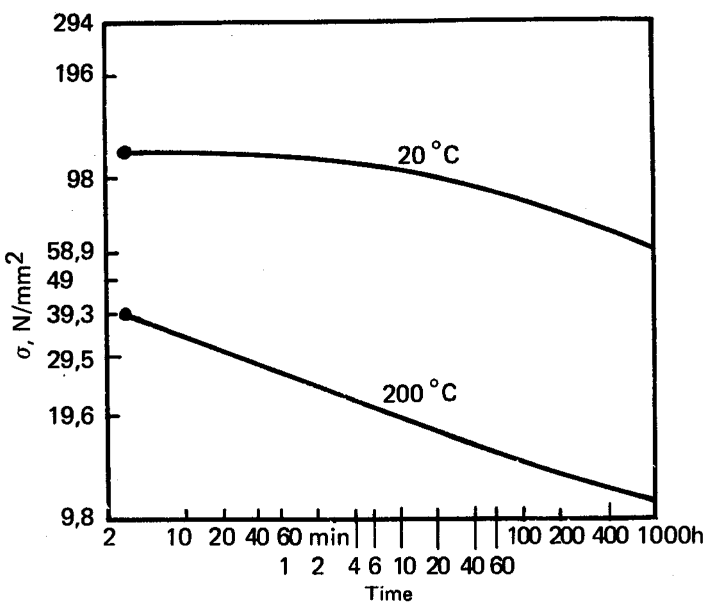

FIGURE 7 — Typical creep shearing strength curves