

# INTERNATIONAL STANDARD

# ISO 7490

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## Dental gypsum-bonded casting investments for gold alloys

*Revêtements à couler à liant-plâtre dentaire pour les alliages d'or*

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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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 7490 was prepared by Technical Committee ISO/TC 106, *Dentistry*.

Annexes A and B of this International Standard are for information only.

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# Dental gypsum-bonded casting investments for gold alloys

## 1 Scope

This International Standard establishes a classification of, and specifies requirements for, gypsum-bonded casting investments together with the test methods to be used to determine compliance with these requirements.

It applies to gypsum-bonded investments suitable for casting dental gold alloy which have liquidus temperatures not higher than 1 080 °C.

## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1561:1975, *Dental inlay casting wax*.

ISO 1562:1984, *Dental casting gold alloys*.

ISO 3310-1:1982, *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth*.

ISO 7500-1:1986, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tensile testing machines*.

## 3 Classification

For the purposes of this International Standard, gypsum-bonded investments are classified as follows:

**Type 1:** Thermal expansion type, for casting inlays and crowns

**Type 2:** Hygroscopic expansion type, for casting inlays and crowns

**Type 3:** For casting complete and partial denture bases

In its classification, a particular material need not be restricted to only one type.

## 4 Requirements

### 4.1 Material

The investment shall be supplied as a powder consisting essentially of a mixture of calcium sulfate hemihydrate and silica. The investment powder may also contain modifying agents. However, it shall not contain extraneous material, and shall be dry, uniform and free from lumps. If the instructions recommend the use of a mould liner (see clause 8), the recommended lining material shall be available from the manufacturer.

### 4.2 Particle size

The particle size distribution shall be such that, when the powder is tested as described in 7.2.2,

not more than 1 % (*m/m*) is retained on a 300 µm test sieve,

not more than 5 % (*m/m*) on a 150 µm test sieve, and

not more than 15 % (*m/m*) on a 75 µm test sieve.

### 4.3 Unset investment

When added to water in the proportions specified by the manufacturer, and mixed as directed in 6.3, the investment shall readily form a uniform paste.

The fluidity of types 1 and 2 investments shall be such that, when tested in accordance with 7.3.1, 2 min after the first contact of powder and water, the slump shall be not more than 40 mm high measured at its highest point.

The fluidity of type 3 investments shall be such that, when tested in accordance with 7.3.2, 2 min after the first contact of powder and water, the average diameter of the slump shall be not less than 60 mm.

### 4.4 Rate of setting

#### 4.4.1 Working time

##### 4.4.1.1 Low-speed mixing<sup>1)</sup>

When the test described in 7.3.1.2 (types 1 and 2) or 7.3.2.2 (type 3) is repeated 5 min after the first contact of powder and

1) This requirement applies to mixes prepared by hand mixing (see 6.3.1) or in mechanical devices with a rotational frequency of less than 700 r/min.

water, the mix shall still comply with the fluidity requirements specified in 4.3. No spatulation or vibration of the mix shall be permitted other than that specified in 7.3.1 (types 1 and 2) or 7.3.2 (type 3).

**4.4.1.2 High-speed mixing, types 1 and 2<sup>1)</sup>**

When the test described in 7.3.1.2 is repeated 3 min after the first contact of powder and water, the mix shall still comply with the fluidity requirements specified in 4.3. No spatulation or vibration of the mix shall be permitted other than that specified in 7.3.1.

**4.4.2 Setting time**

When the mixed investment is tested in accordance with 7.4, the Vicat initial set shall not vary by more than 20 % from the setting time stated by the manufacturer (see clause 8).

**4.5 Compressive strength**

The set investment, when tested in accordance with 7.5, shall comply with the requirements set out in table 1.

**Table 1 – Compressive strength**

| Type | Minimum compressive strength, MPa <sup>*)</sup> , at room temperature |
|------|---|
| 1    | 2,3   |
| 2    | 2,3   |
| 3    | 5,6   |

\*) 1 MPa = 10<sup>6</sup> N/m<sup>2</sup>

**4.6 Expansion**

The investment, when tested in accordance with 7.6, shall have a total linear expansion (setting and thermal combined) which complies with the requirements set out in table 2. None of the thermal expansion curves produced according to 7.6.4.4 shall vary by more than ± 0,1 % expansion over the recommended casting range (see clause 8), and at least one of these curves shall agree, within 0,1 % expansion, over the recommended casting range, with the thermal expansion curve provided by the manufacturer (see clause 8).

**Table 2 – Total expansion**

| Type | Minimum linear expansion, % |
|------|-----------------------------|
| 1    | 1,5                         |
| 2    | 1,5                         |
| 3    | 1,3                         |

**4.7 Behaviour during casting**

The investment mould, when tested in accordance with 7.7.1 (types 1 and 2) or 7.7.2 (type 3), shall not emit offensive fumes

when heated, shall not contaminate alloy cast into it, and shall not cause pitting, fins, rough surfaces or voids in the casting.

**5 Sampling**

The method of procurement and the amount of investment powder needed for testing shall be the subject of agreement between the interested parties. Powder from broken or damaged containers shall not be used for testing. If the powder is supplied in bulk, rather than in individual units, it shall be thoroughly mixed before testing and then stored in a moisture-proof container.

If a mould liner is recommended and is not supplied with the investment, an adequate amount of the recommended lining material shall be procured from the investment manufacturer.

**6 Test conditions and preparation of test specimens**

**6.1 Test conditions**

All mixing and testing of the investment shall be carried out in a room free from draughts and under atmospheric conditions of 23 °C ± 2 °C and (50 ± 5) % relative humidity.

**6.2 Materials and apparatus**

All apparatus and instruments used in mixing and testing shall be clean, dry and free from particles of gypsum. Before mixing and testing are begun, materials and apparatus shall be brought to ambient temperature. Irrespective of specimen size, all mixes shall be made with at least 100 g of powder.

**6.3 Method of mixing**

Carry out the mixing according to the manufacturer's instructions (see clause 8).

**6.3.1 Hand mixing**

**6.3.1.1 Apparatus**

**6.3.1.1.1 Clean scratch-free flexible mixing bowl**, of at least 300 ml capacity.

**6.3.1.1.2 Rigid spatula**, with a blade at least 20 mm wide.

**6.3.1.1.3 Electric dental vibrator**.

**6.3.1.2 Procedure**

Using the mixing bowl (6.3.1.1.1) and spatula (6.3.1.1.2), mix at least 100 g of powder with distilled water in the recommended proportions (see clause 8) according to the procedure described below.

1) This requirement applies only to mixes prepared in mechanical devices with a rotational frequency of 1 400 r/min or higher. These devices include provision for vacuum investing as well as mixing, and are suitable only for use with small casting rings (types 1 and 2 investments only).

Measure the mass of the powder and the mass or volume of the distilled water with an accuracy of  $\pm 1\%$ .

Pour the water into the mixing bowl. Begin timing from the moment at which investment powder and water first make contact. Shake or sift the investment into the water over a period of 15 s, in such a way that entrapment of air is minimized.

During the next 15 s, jar or vibrate the bowl. In this period ensure that the powder is completely wetted, using limited movements of the spatula if necessary, but avoiding any stirring movements.

Then spatulate the powder and water for 30 s, using a circular stirring motion at a rate of approximately 3 r/s. Minimize the incorporation of air into the mix. During spatulation subject the bowl to appropriate vibration by means of an electric dental vibrator (6.3.1.1.3). Complete the mixing procedure in  $60\text{ s} \pm 2\text{ s}$ .

Transfer the mixed investment immediately to the moulds or testing apparatus.

### 6.3.2 Mechanical mixing

#### 6.3.2.1 Apparatus

**Mechanical mixing apparatus** complying with the details specified by the investment manufacturer [see item d) in clause 8].

#### 6.3.2.2 Procedure

Using the mechanical mixing apparatus (6.3.2.1), mix at least 100 g of powder with distilled water in the recommended proportion, for the time recommended by the investment manufacturer [see item d) in clause 8].

Transfer the mixed investment immediately to the moulds or testing apparatus.

## 7 Test methods

### 7.1 Visual inspection

Visual inspection shall be used in determining compliance with requirements of 4.1 and clauses 9 and 10.

### 7.2 Particle size distribution

#### 7.2.1 Apparatus

**7.2.1.1 Test sieves**, round, of diameter 200 mm and of the following nominal aperture sizes: 300  $\mu\text{m}$ , 150  $\mu\text{m}$ , and 75  $\mu\text{m}$ , complying with the requirements of ISO 3310-1.

**7.2.1.2 Oven or drying cabinet**, maintained at  $40\text{ }^\circ\text{C} \pm 2\text{ }^\circ\text{C}$ .

#### 7.2.2 Procedure

Add 25 g of investment powder to 100 ml of 2-propanol (isopropyl alcohol 95 %) in a 250 ml conical flask. Stopper the flask and shake for 2 min. Transfer the suspension to the 300  $\mu\text{m}$  sieve (7.2.1.1) nested on the 150  $\mu\text{m}$  sieve which is in turn nested on the 75  $\mu\text{m}$  sieve, and wash with 2-propanol until the washings are clear. When the washings from the 300  $\mu\text{m}$  and the 150  $\mu\text{m}$  sieves are clear, the sieves may be separated to facilitate washing the residues on the 75  $\mu\text{m}$  sieve.

Dry the residues on the sieves at  $40\text{ }^\circ\text{C} \pm 2\text{ }^\circ\text{C}$ . Remove and weigh the residues, and report the mass of each residue as a percentage of the mass of the original sample.

**CAUTION** — When using 2-propanol keep away from flame, provide good ventilation and avoid excessive inhalation of vapour.

### 7.3 Fluidity of the unset mix

#### 7.3.1 Types 1 and 2 investments

##### 7.3.1.1 Apparatus

**7.3.1.1.1 Mould**, as shown in figure 1.

**7.3.1.1.2 Flat smooth glass or glazed plate**, at least 80 mm square.

**7.3.1.1.3 Electric dental vibrator**.

##### 7.3.1.2 Procedure

Make a mix of investment, following the appropriate method described in 6.3 and timing the test from the moment of first contact between powder and water. Stand the mould (7.3.1.1.1) in the centre of the plate (7.3.1.1.2) and fill it with the mix, applying sufficient vibration to the plate so that the mould fills rapidly. The vibration shall cease not later than 110 s from the start of mixing.

Place the plate and the filled mould on a vibration-free surface. After  $2\text{ min} \pm 1\text{ s}$  from the start of mixing, lift the mould vertically away from the plate at a rate of approximately 10 mm/s and allow the mix to slump on the plate.

When the investment has set sufficiently, measure the height of the slump at its highest point.

If in the first test the investment fails to meet the requirement specified in 4.3, repeat the test two more times and report the average of the three results as the height of the slump.

#### 7.3.2 Type 3 investments

##### 7.3.2.1 Apparatus

**7.3.2.1.1 Electric vibrator with a substantially flat platform**, to which is screwed or bolted a flat smooth glass or

glazed plate at least 150 mm square. The vibrator shall operate on a 50 Hz or 60 Hz supply and shall be adjusted so that its platform vibrates with a peak-to-peak displacement of 0,2 mm.

**7.3.2.1.2 Cylindrical mould**, with an inside diameter of  $25 \text{ mm} \pm 0,5 \text{ mm}$  and a height of  $35 \text{ mm} \pm 0,5 \text{ mm}$ .

**7.3.2.2 Procedure**

Make a mix of investment, following the appropriate method described in 6.3 and timing the test from the moment of first contact between powder and water. Place the mould (7.3.2.1.2) in the centre of the plate, and fill it with the mix, applying sufficient vibration to the plate so that the mould fills

rapidly. The vibration shall cease not later than 110 s from the start of mixing.

After  $2 \text{ min} \pm 1 \text{ s}$  from the start of mixing, switch on the vibrator (7.3.2.1.1) and simultaneously lift the mould vertically away from the plate. Continue the vibration for an additional period of  $15 \text{ s} \pm 1 \text{ s}$ .

When the investment has set sufficiently, measure the largest and smallest diameters of the slump and record the average of the two as the slump diameter.

If in the first test the investment fails to meet the requirement specified in 4.3, repeat the test two more times and report the average of the three results as the slump diameter.

Dimensions in millimetres;  
surface roughness value in micrometres

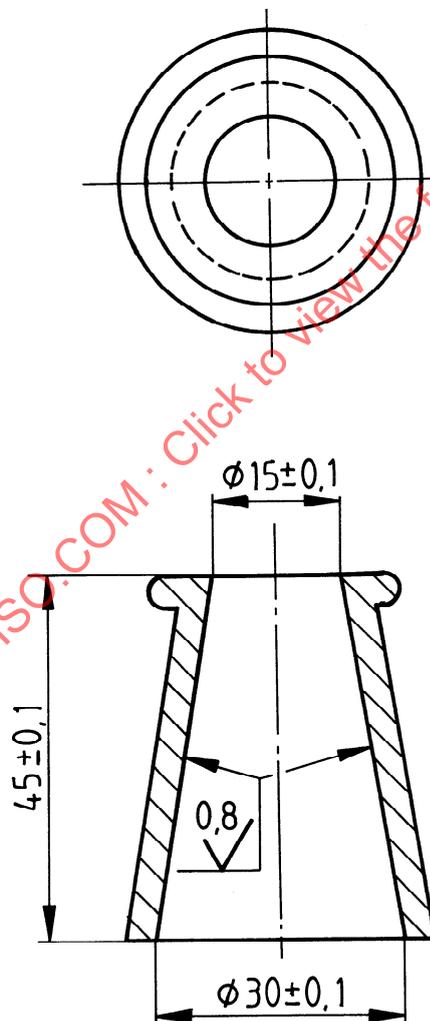


Figure 1 — Slump test apparatus in brass or stainless steel

**7.4 Setting time**

**7.4.1 Apparatus**

**7.4.1.1 Vicat apparatus**, consisting of a frame supporting a rod which is free to move up and down; an initial set needle, at least 35 mm long, of uniform circular cross-section, 1 mm ± 0,05 mm in diameter shall be attached to the lower end of the rod. The total mass of the rod and initial set needle shall be 300 g ± 1 g. A pointer attached to the rod shall move over a scale, graduated in millimetres, indicating the depth of penetration of the needle into the specimen.

**7.4.1.2 Test specimen holder**, consisting of a cylindrical mould and a detachable base, with the dimensions shown in figure 2. When the specimen holder is assembled, the base shall make a watertight seal with the mould.

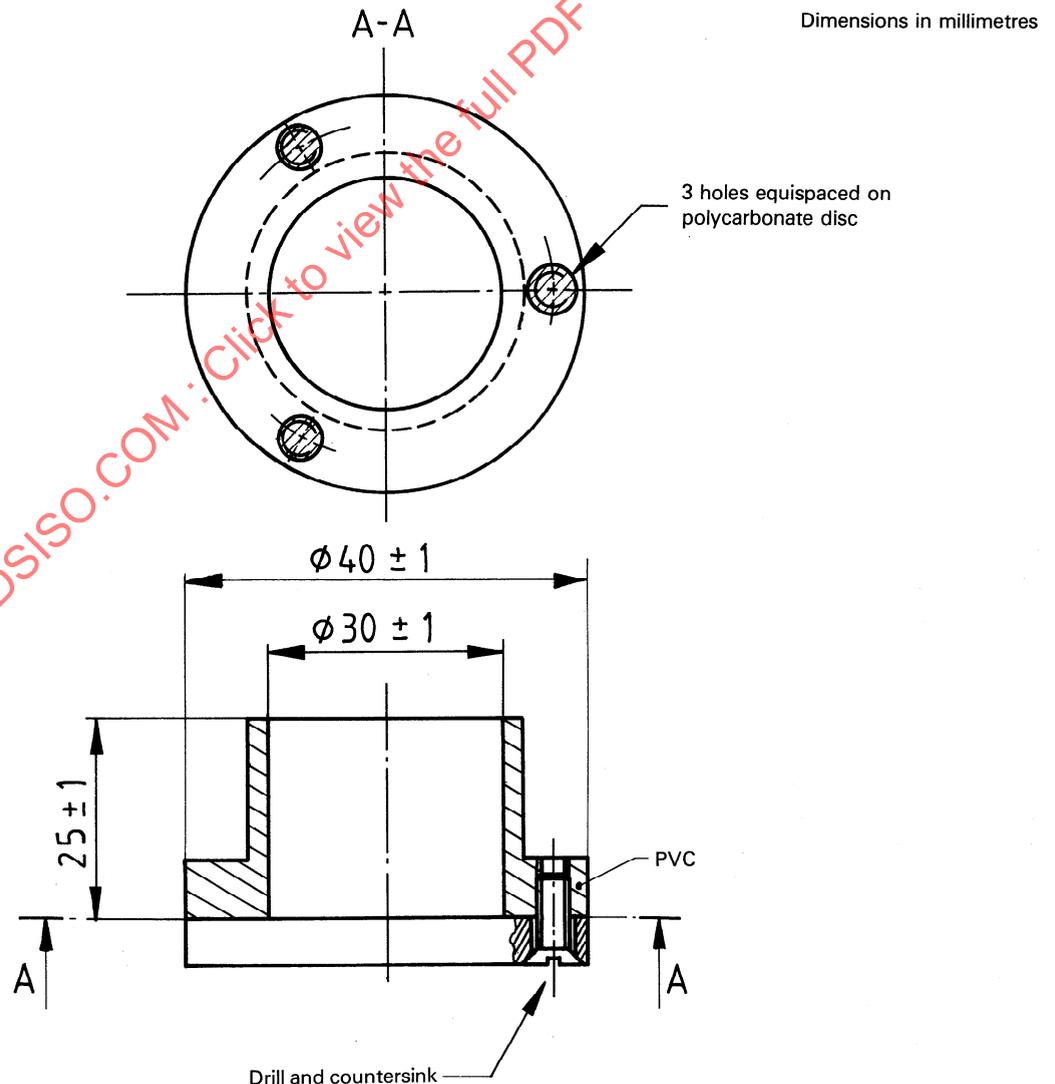
**7.4.1.3 Mould lining material**, as supplied by the manufacturer.

**7.4.1.4 Water bath** (for tests on type 2 investments), of area sufficient to accommodate the test specimen holder (7.4.1.2), with a depth of at least 35 mm and capable of being maintained at 23 °C ± 2 °C.

**7.4.2 Procedure: types 1 and 3**

Line the mould with a single piece of dry lining material (7.4.1.3). If the instructions (see clause 8) require wetting of the liner, immerse the lined mould in distilled water for 3 min, and then allow it to drain in air for 30 s. Attach the base. Do not allow any free water to collect in the bottom of the assembled specimen holder (7.4.1.2).

Make a mix of investment, following the appropriate method described in 6.3 and timing the test from the moment of first contact between powder and water. Overfill the specimen holder with the mix and level the surface. Place the test specimen on the platform of the Vicat apparatus (7.4.1.1).



**Figure 2 – Vicat test specimen holder**

When the glossy surface has completely disappeared from the mix, carefully lower the Vicat needle vertically until it touches the surface and release it gently, allowing it to sink into the mix under its own weight. Repeat this procedure at intervals of 30 s, wiping the needle clean after each penetration and moving the test specimen slightly so that the needle does not enter the same place twice. Avoid making any penetration of the specimen closer than 5 mm to the walls of the mould.

Record the setting time as the total time from the start of mixing to the time when the needle first fails to penetrate to within 5 mm of the base of the specimen holder.

Record the mean of three such tests, rounded to the nearest 1 min, as the net result. If the mean falls exactly on a half minute, round it to the preceding whole minute.

### 7.4.3 Procedure: type 2

Follow the procedure outlined in 7.4.2, but perform the tests on test specimens placed in the water bath (7.4.1.4) on the platform of the Vicat apparatus. After the test specimen has been positioned in the empty bath, carefully pour distilled water at 23 °C ± 2 °C into the bath until the level is at least 5 mm above the top of the test specimen. If the probable setting time of the material is unknown, start penetration tests 5 min after beginning the mix.

## 7.5 Compressive strength

### 7.5.1 Apparatus

**7.5.1.1 Sectional mould**, open at both ends, to produce one or more cylindrical specimens, each having a diameter of 20 mm ± 0,05 mm and a length of 40 mm ± 0,05 mm.

**7.5.1.2 Two flat glass plates**, large enough to close the ends of the mould.

### 7.5.1.3 Electric dental vibrator.

**7.5.1.4 Compression testing machine**, complying with the machine class 1 requirements specified in ISO 7500-1 up to a force of 20 kN.

### 7.5.2 Preparation of test specimens

Lightly oil or grease the mould (7.5.1.1), or spray with a suitable mould-release agent. Place the assembled mould on one of the glass plates (7.5.1.2). Make a mix of investment, following the appropriate method described in 6.3. Slightly overfill the mould with investment, applying suitable vibration.

As soon as the glossy surface has completely disappeared from the mix, apply the second glass plate (7.5.1.2) to the top of the mould and press it down until the surface of the mould is uniformly visible through the glass. When the specimen is strong enough to handle, remove it from the mould and store

it at 23 °C ± 2 °C and not less than 95 % relative humidity. Prepare ten specimens from at least two mixes of investment.

### 7.5.3 Procedure: compressive strength at room temperature

Test five specimens, made from at least two mixes of investment. Start testing the specimens 2 h after making the last mix.

Position each specimen between the loading platens of the testing machine (7.5.1.4) so that the specimen will be loaded axially. Use no packing between specimen and platens.

Apply a compressive force increasing continuously at a rate of 5 kN/min ± 2 kN/min until fracture occurs.

For each specimen record the load at fracture and calculate the compressive strength,  $k$ , in megapascals<sup>1)</sup>, using the following formula:

$$k = \frac{4F}{\pi d^2}$$

where

$F$  is the applied load at fracture, in newtons;

$d$  is the diameter of the specimen, in millimetres (= 20 mm).

For all five results, calculate the mean,  $\bar{x}$ , and the standard deviation,  $\sigma$ ; calculate the coefficient of variation, expressed as a percentage, using the following formula:

$$100 \frac{\sigma}{\bar{x}}$$

If the coefficient of variation is less than or equal to 15 %, report the mean; if the coefficient of variation is greater than 15 %, carry out a further five tests and report the mean of all ten results.

NOTE — If the testing machine is of the type in which cross-head speed rather than loading rate is controlled, it will be necessary to undertake preliminary trials to determine a cross-head speed which gives a loading rate within the limits specified in 7.5.3. These trials shall be made with a specimen in position, which shall subsequently be discarded without further testing. A suitable starting point is a cross-head speed of 0,5 mm/min.

## 7.6 Expansion

### 7.6.1 Test specimen

Both setting and thermal expansion shall be measured on the same specimen, which shall be 50 mm ± 1 mm in length and of uniform cross-section; the cross-section may be circular, square or an equilateral triangle. The cross-sectional area shall be within the range from 78 mm<sup>2</sup> to 275 mm<sup>2</sup>. The total measuring pressure exerted on the specimen during setting or heating shall not exceed 2,4 kPa<sup>2)</sup>. During setting, all sides of the specimen shall be in contact with the lining material supplied with the investment. If the manufacturer's instructions recommend wetting the liner, this shall be done as described in 7.6.4.

1) 1 MPa = 10<sup>6</sup> N/m<sup>2</sup>

2) 1 kPa = 10<sup>3</sup> N/m<sup>2</sup>

## 7.6.2 Test conditions

Types 1 and 3 investments shall be allowed to set under conditions of  $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$  and not less than 95 % relative humidity. Type 2 investments shall be immersed in distilled water at  $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$  for the duration of setting.

In all cases, one end of the specimen shall set against a heat-resistant alloy plate, 1 mm thick, of the same cross-section as the specimen, which will form part of the specimen during the thermal expansion test and which will distribute the measuring force of the thermal expansion apparatus uniformly over the cross-sectional area of the specimen.

During heating, the sides of the specimen should not contact the thermal expansion apparatus; the heat-resistant alloy plate is used to transfer specimen expansions to the moving parts of the measuring apparatus. Frictional forces in the measuring system should be confined to the actual measuring device itself; it is important that these frictional forces be as small as possible. The temperature of the specimen shall be measured by a sheathed thermocouple the hot junction of which is inserted to a depth of 15 mm in an axial recess drilled in the base of the specimen.

## 7.6.3 Apparatus

### 7.6.3.1 Setting expansion apparatus

Any apparatus can be used which complies with the general requirements set out in 7.6.1 and 7.6.2 and which can be adjusted to apply a measuring force of  $0,5\text{ N} \pm 0,1\text{ N}$  to the specimen over a range of movement of 1 mm, and which produces a specimen that can be used for the subsequent measurement of thermal expansion. The equipment shall be capable of measuring the specimen expansion with an accuracy of  $\pm 5\text{ }\mu\text{m}$ . A suitable form of apparatus is described in annex A and illustrated in figures A.1, A.2 and A.3.

### 7.6.3.2 Thermal expansion apparatus

Any form of thermal expansion apparatus may be used which will accept a specimen of the dimensions specified in 7.6.1 and which complies with the other requirements specified in 7.6.1 and 7.6.2. The equipment shall be capable of measuring the specimen expansion with an accuracy of  $\pm 5\text{ }\mu\text{m}$ . A suitable form of apparatus is described in annex B and illustrated in figure B.1.

## 7.6.4 Procedure

### 7.6.4.1 General

The instructions specified in 7.6.4.2 to 7.6.4.5 apply specifically to the use of the setting expansion and thermal expansion apparatus described in annex A and annex B, respectively; they may have to be modified if some other form of apparatus is used.

### 7.6.4.2 Preparation of lining material and apparatus

If the manufacturer's instructions require wetting of the mould lining material, this shall be done as described below.

Place a suitably sized piece of rubber sponge<sup>1)</sup> in a container, and add distilled water until the sponge is immersed to half its height. Lay each piece of lining material on the wet sponge until its upper surface is completely wetted.

If the manufacturer's instructions do not specify wetting, use dry lining material.

Line the side walls of the trough with two pieces of lining material and place the triangular plate vertically against the fixed end wall of the trough so that its spigot projects into the mould space, and its edges rest on the liners.

### 7.6.4.3 Procedure for determining setting expansion

Make a mix of investment, following the appropriate method described in 6.3 and timing the test from the moment of first contact between powder and water. Pour or vibrate the mix into the trough up to the top edges of the two liners and the triangular plate. Then gently place the third piece of lining material on the upper surface of the specimen.

For types 1 and 3 investments, place the lid in position on the dry bath. For type 2 investments, pour sufficient distilled water at  $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$  into the bath to cover the top surface of the specimen to a depth of at least 5 mm.

Zero the recording apparatus or take an initial reading. Determine the expansion of the specimen to the nearest 0,01 mm over a period of 2 h; express the setting expansion as a percentage of the original length of the specimen, excluding the thickness of the end-plate (i.e. gauge length = 50 mm).

### 7.6.4.4 Procedure for determining thermal expansion

After a period of 2 h, drain the water bath, free the set specimen from the trough and carefully remove the liners from its sides. The end of the specimen furthest from the triangular plate will become the base of the specimen during the thermal expansion test. Drill a hole in the centre of the base, at least 5 mm in diameter and 20 mm deep. Then position the specimen vertically in the bottom of the dilatometer so that it fits over the specimen thermocouple and stands free of the sides of the outer tube.

Position the inner tube of the dilatometer so that its pointed end rests in the recess in the centre of the triangular plate. Place the heat shield over the upper end of the outer tube so that the inner tube passes through its central hole without coming into contact with it, and then position the expansion-measuring device so that it locates the inner tube in a vertical position. Turn on the water cooling to the dilatometer head, and the exhaust system; zero the measuring system or take an initial reading.

1) An office sponge or moistener is suitable.

Raise the furnace temperature at a rate of about 5 °C/min.

If the investment does not contain cristobalite (see note below), maintain this rate for the whole of the heating cycle. If it does contain cristobalite, slow the heating rate to approximately 1 °C/min over the temperature range from 200 °C to 300 °C. In both cases raise the furnace temperature to the mid-point of the manufacturer's recommended casting range (see clause 8), and maintain at that temperature for the recommended time.

NOTE — To perform this test, it is necessary to know whether the investment contains cristobalite as a refractory filler. If this fact is not apparent from the name of the material, it can be established by examining the thermal expansion curve supplied by the manufacturer (see clause 8). If the investment contains cristobalite, it will show a well defined isothermal expansion at about 250 °C.

During heating, if an X-Y recorder is being used, make a continuous graph of thermal expansion; otherwise, make readings of expansion and temperature at intervals of 30 °C, and plot a thermal expansion curve.

At the end of the heating cycle, determine the final expansion to the nearest 0,01 mm; express the thermal expansion as a percentage of the original length of the unset specimen, excluding the thickness of the end-plate (i.e. gauge length = 50 mm).

#### 7.6.4.5 Expression of results

Add the values for setting and thermal expansion and round the sum to the nearest 0,1 % total expansion. Carry out three such measurements, and report the average of the three results as the total expansion of the investment.

Check each thermal expansion curve to ensure that the percentage thermal expansion does not vary by more than  $\pm 0,1$  % over the recommended casting range and that the thermal expansion curve provided by the manufacturer (see clause 8) does not deviate, within the casting range, by more than 0,1 % from at least one of the thermal expansion curves produced during these tests.

## 7.7 Behaviour during casting

### 7.7.1 Types 1 and 2 investments

#### 7.7.1.1 Apparatus

##### 7.7.1.1.1 Inlay casting ring and matching sprue base.

##### 7.7.1.1.2 Centrifugal casting machine.

7.7.1.1.3 Electric burn-out furnace, fitted with a pyrometer accurate to  $\pm 10$  °C at 700 °C.

7.7.1.1.4 Dental casting gold alloy type II, complying with ISO 1562.

7.7.1.1.5 Typical mesio-occluso-distal inlay pattern, made from wax complying with ISO 1561, with a sprue former at least 2,5 mm in diameter attached to the centre of its occlusal surface.

#### 7.7.1.2 Procedure

Mount the sprue former (7.7.1.1.5) on the sprue base in such a way that the pattern will be situated in the central axis of the casting ring (7.7.1.1.1), with its highest part 8 mm  $\pm$  2 mm from the open end of the ring.

Line the ring with a single piece of dry lining material supplied by the manufacturer; this should be 6 mm narrower than the height of the ring and long enough to overlap slightly where its ends meet in the ring. Position the liner so that it is short of both ends of the casting ring. If the instructions require wetting of the liner, immerse the lined ring in distilled water for 3 min, and then allow it to drain in air. Attach the casting ring to the sprue base.

The disposition of the sprued pattern and liner within the casting ring is shown in figure 3.

Make a mix of investment, following the appropriate method described in 6.3, and invest the wax pattern following the manufacturer's instructions [see item k) in clause 8].

At the time recommended by the manufacturer, remove the sprue base and sprue former, and place the mould in the furnace (7.7.1.1.3), with the sprue facing downwards, in such a position that some part of the mould is within 10 mm of the hot junction of the furnace thermocouple.

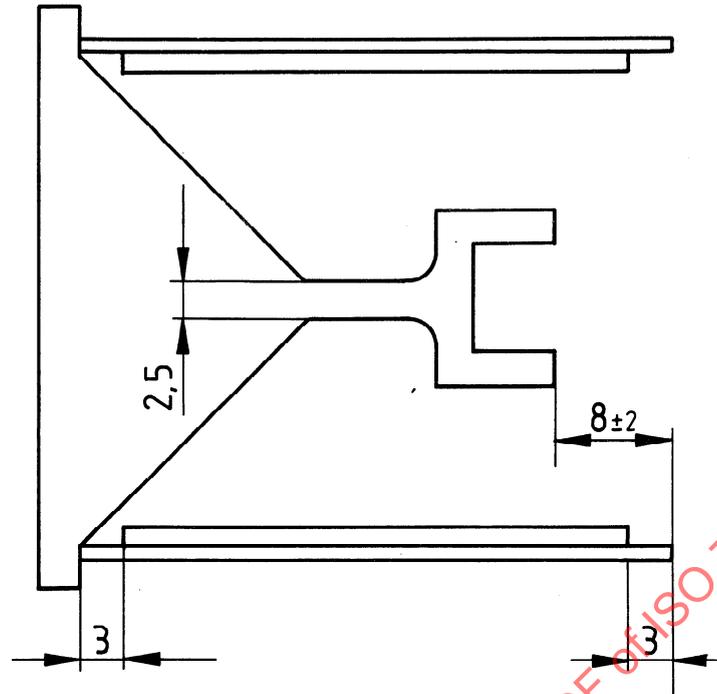


Figure 3 — Arrangement of mesio-occluso-distal inlay pattern and liner in casting ring

Heat the mould to the mid-point of the recommended casting temperature range (see clause 8), following the manufacturer's instructions for timing of the burn-out procedure. During heating, note any evolution of offensive fumes attributable to the investment. If it is uncertain whether such fumes are attributable to the investment or the wax, repeat this part of the test using a casting ring filled with investment only.

After the mould has been heat-soaked at the casting temperature for the recommended time, transfer the mould to the casting machine (7.7.1.1.2) and complete the casting. After the casting has been recovered from the mould, inspect it for defects attributable to the investment.

Report the results.

## 7.7.2 Type 3 investment

### 7.7.2.1 Apparatus

#### 7.7.2.1.1 Denture casting ring.

**7.7.2.1.2 Electric burn-out furnace**, fitted with a pyrometer accurate to  $\pm 10$  °C at 700 °C.

**7.7.2.1.3 Dental casting gold alloy, type IV**, complying with ISO 1562.

**7.7.2.1.4 Dental casting machine**, large enough to accept a denture casting ring (7.7.2.1.1).

**7.7.2.1.5 Cast**, made from the investment to be tested, bearing a wax pattern for an upper partial denture base with bilateral saddles. The pattern should include retention grids on the saddle areas, clasps on the abutment teeth, and the connector shall be in the form of a palatal plate at least 15 mm wide in the mid-line of the cast and not more than 0,5 mm thick. The

pattern shall be sprued with multiple wax sprues in a manner consistent with accepted dental practice and suitable for the particular type of casting machine to be used.

### 7.7.2.2 Procedure

Line the ring (7.7.2.1.1) with a single piece of dry lining material supplied by the manufacturer; this should be 6 mm narrower than the height of the ring and long enough to overlap slightly where its ends meet in the ring. Position the liner so that it is short of both ends of the casting ring. If the instructions require wetting of the liner, immerse the lined ring in distilled water for 3 min, and then allow it to drain in air.

Make a mix of investment, following the appropriate method described in 6.3, and invest the cast (7.7.2.1.5) and wax pattern in the ring following the manufacturer's instructions.

At the time recommended by the manufacturer, place the mould in the furnace (7.7.2.1.2), with the sprues facing downwards, in such a position that some part of the mould is within 10 mm of the hot junction of the furnace thermocouple.

Heat the mould to the mid-point of the recommended casting temperature range (see clause 8), following the manufacturer's instructions for timing of the burn-out procedure. During heating, note any evolution of offensive fumes attributable to the investment. If it is uncertain whether such fumes are attributable to the investment or the wax, repeat this part of the test using a casting ring filled with investment only.

After the mould has been heat-soaked at the casting temperature for the recommended time, transfer the mould to the casting machine (7.7.2.1.4) and complete the casting. After the casting has been recovered from the mould, inspect it for defects attributable to the investment.

Report the results and specify the type of casting machine and the method of sprueing used.

## 8 Information to be supplied by manufacturer

Instructions shall accompany each package of the investment powder, and shall include the following information:

- a) the classification of the investment (see clause 3);
- b) the maximum alloy liquidus temperature for which the investment is recommended;
- c) the recommended water/powder ratio of mixing expressed as a single value only;
- d) details of the recommended method of mixing: if mechanical mixing is specified, details shall include the size of the mixing vessel, the rate of rotation of the paddle, and the time of mixing;
- e) if a mould liner is recommended, a statement indicating whether it is to be used wet or dry;
- f) the setting time determined in accordance with 7.4;
- g) the setting expansion determined in accordance with 7.6.4.3;
- h) a typical thermal expansion curve determined as described in 7.6.4.4;
- i) details of the recommended burn-out procedure: these details shall include the minimum time to elapse before heating can begin, the rate or rates of heating, a casting temperature range of at least 100 °C over which the percentage thermal expansion does not vary by more than  $\pm 0,1\%$  and the length of time the mould shall be held at the casting temperature before the casting is made;
- j) recommended storage conditions, including a statement that gypsum-bonded investments will deteriorate if exposed to the atmosphere, especially if the humidity is high;
- k) details of the recommended investing procedure.

## 9 Packaging

### 9.1 Packaging

The material shall be supplied in strong moisture-proof containers. If the powder is supplied in bulk, rather than in individual units, the container shall be capable of being effectively resealed.

### 9.2 Mould lining

If the instructions recommended the use of a mould liner (see clause 8), the recommended lining material shall be available from the manufacturer.

## 10 Marking

Each container shall be marked clearly with at least the following information:

- a) name and/or trade-mark of the manufacturer;
- b) classification (see clause 3) — in its classification, a particular material need not be restricted to only one type;
- c) net mass of the contents;
- d) lot identification which refers to the manufacturer's records for the particular lot or batch from which the material came;
- e) date of manufacture (year and month), either as a separate item or as a recognizable part of the lot identification;
- f) recommended storage conditions, including a statement that gypsum-bonded investments will deteriorate if exposed to the atmosphere, especially if the humidity is high;
- g) date (year and month) beyond which the material should not be used without retesting, if it has been stored under recommended conditions.

## Annex A (informative)

### Apparatus for measuring setting expansion

A suitable form of apparatus is illustrated in figure A.1 and consists of the following equipment.

**A.1 Brass or stainless steel trough**, of V section, with one end closed, supported inside a small water-bath which has a closely fitting lid. The other end of the trough is fitted with a movable polytetrafluoroethylene (PTFE) partition which is rebated to fit into the end of the trough. When this is fully in place, the internal length of the closed trough shall be 51 mm.

The movable partition is carried on a horizontal stainless steel shaft, which passes through a flexible rubber diaphragm at one end of the water-bath. The shaft forms a hermetic seal at the rubber diaphragm; one method of achieving this is shown in figure A.2.

The shaft slides in a linear ball raceway, and has a controlled seating force applied to it by a cranked lever, rotating on miniature ball-bearings. The vertical arm of the crank bears on a collar on the shaft, and the horizontal arm carries a mass which can be positioned to apply the required seating force (see figure A.3).

The end of the shaft is reduced in section and carries a ferrite core which moves inside a linear transducer of the differential transformer type. The core is located so that it is free of the

bore of the transducer. The housing of the differential transformer and the shaft shall be of non-magnetic material.

A micrometer screw allows fine adjustment of the position of the transducer and is also used for calibration. The output of the transducer is linearly proportional to specimen expansion, and may be read by a suitable voltmeter. Alternatively, the transducer may be connected to a Y-t recorder to provide a continuous graph of setting expansion against time.

Instead of the transducer, a dial gauge may be used to measure specimen expansion. The measuring force of the dial gauge shall be adjusted to  $0,5 \text{ N} \pm 0,1 \text{ N}$  for the part of its travel used in the test. In this case no additional seating force is applied.

**A.2 Plate**, 1 mm thick, made of heat-resistant alloy in the shape of an equilateral triangle with sides of 25 mm. The plate should have a small spigot in the centre of one face, and a small conical depression in the centre of the other face.

**A.3 Three rectangular pieces**, each 51 mm × 26 mm, of the lining material recommended for use with the investment to be tested. When they are used as lining in the trough, their length shall completely occupy the distance between the fixed end wall of the trough and the inside surface of the movable partition, when the latter is completely seated in position.

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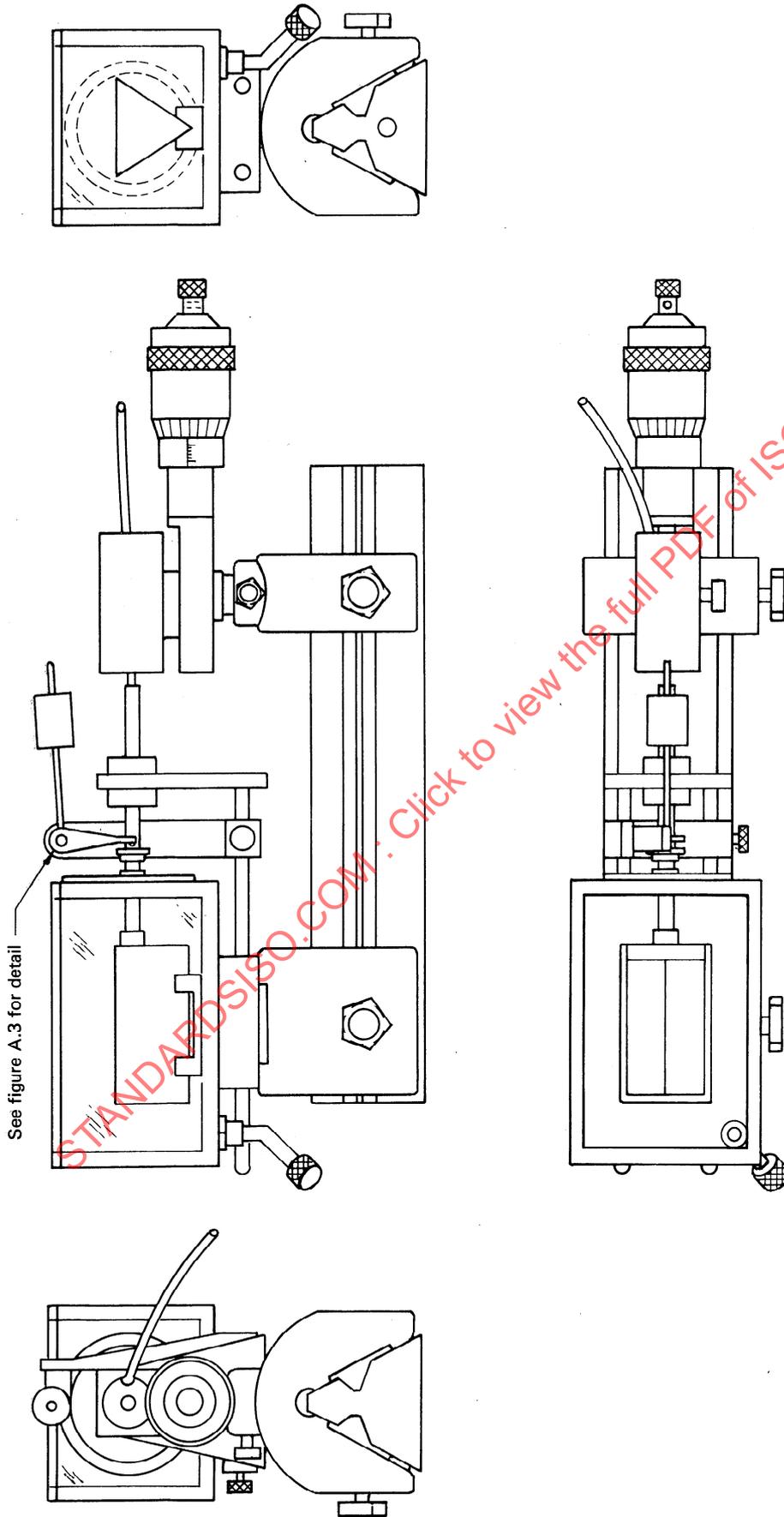


Figure A.1 — Setting expansion apparatus fitted with linear transducer

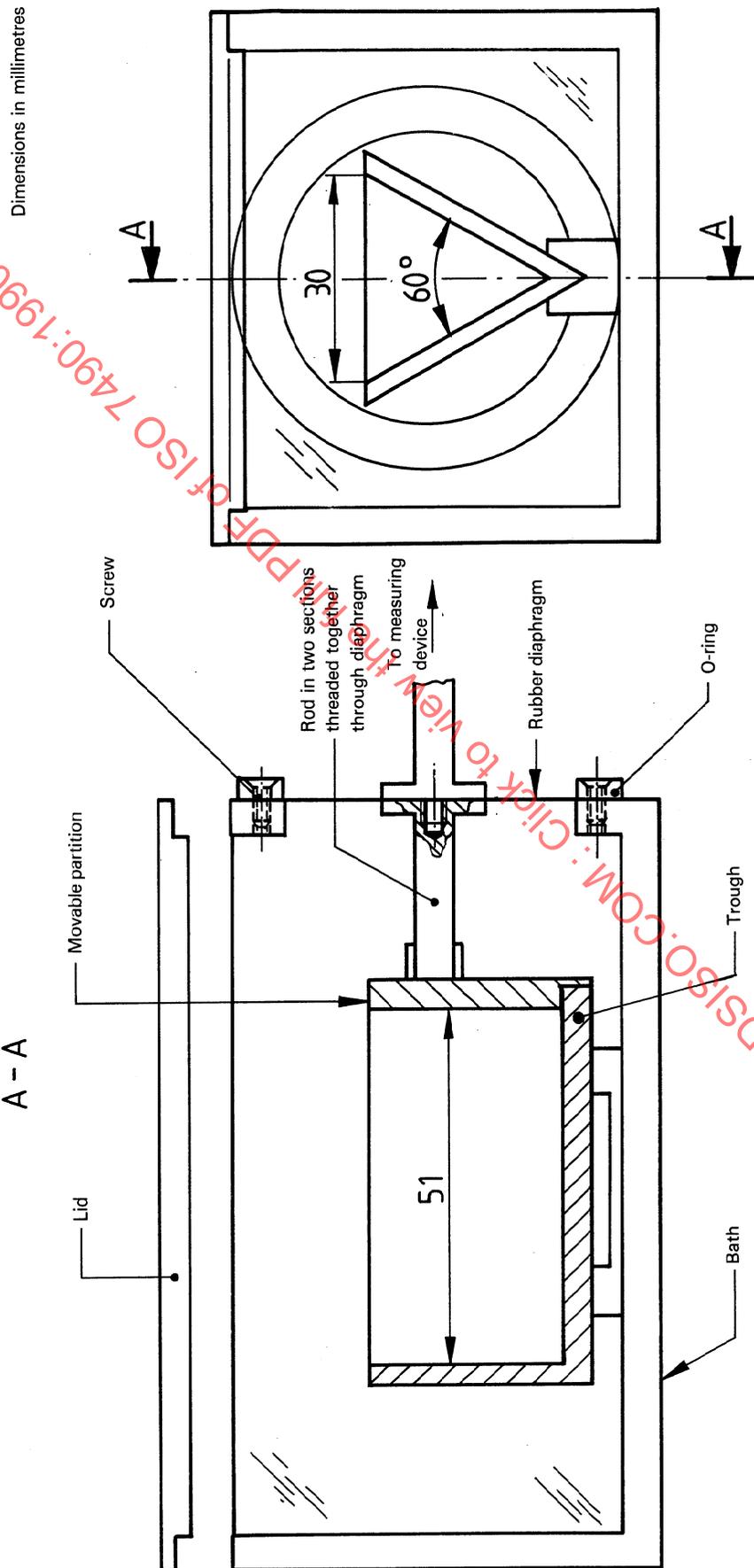


Figure A.2 — Specimen container for measuring setting expansion

ar transducer

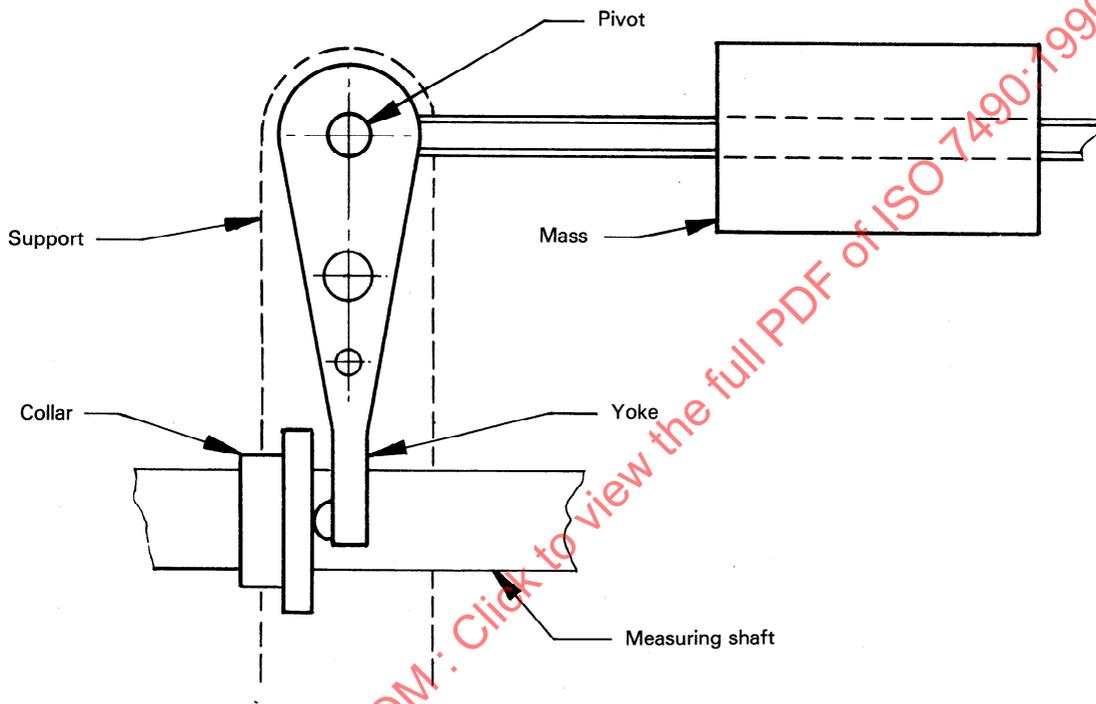


Figure A.3 — Detail illustrating how to apply controlled measuring force

## Annex B (informative)

### Apparatus for measuring thermal expansion

A suitable form of apparatus is illustrated in figure B.1, and consists of the following components.

**B.1 Vitreous silica dilatometer**, disposed vertically, the outer tube of which has an internal diameter large enough to accommodate the specimen produced during the setting expansion test. The inside surface of the base is ground flat and normal to the axis of the tube, and the base is perforated by an axial hole 5 mm in diameter. This outer tube is positioned in a vertical tube furnace so that its lower 50 mm is situated within the zone of maximum temperature of the furnace. It is supported on refractory spacers fitted within the lower part of the furnace and located by a clamp fitted to the top of the furnace.

The outer tube is provided with an exhaust system to remove water vapour and other gases which may be released from the specimen during heating. To provide adequate ventilation, four holes are cut in the side of the outer tube, at its junction with the base.

**B.2 Inner tube of the dilatometer** (the "push rod"), which moves relative to the outer tube as the specimen expands, made of small diameter vitreous silica tubing, with the lower end closed and ground to a point.

**B.3 Sheathed thermocouple**, approximately 3 mm in overall diameter, which is passed vertically through the axial hole in the base of the outer dilatometer tube so that it projects upwards from the base for a distance of 15 mm; this thermocouple indicates specimen temperature.

**B.4 Second thermocouple**, positioned between the dilatometer tube and the furnace wall, close to the latter, so that its hot junction is level with the centre of height of the specimen; this thermocouple is connected to the instrument used for controlling the furnace temperature.

**B.5 Instrument for measuring vertical movement of the inner tube of the dilatometer**, fixed to the top of the outer tube by a water-cooled clamp. The instrument shall be capable of measuring to an accuracy of 0,1 %. The instrument may take the form of a linear transducer, such as a differential transformer, with its ferrite core fixed to the top of the inner tube. Alternatively, if a dial gauge is used, it should be positioned so that its anvil contacts and locates the top of the inner tube, and its measuring force should be adjusted so that the total pressure on the specimen (arising from the mass of the inner tube and the measuring force of the dial gauge) does not exceed 2,4 kPa.

When the specimen is positioned in the base of the outer tube, and the equipment assembled, there should be no contact of either the specimen or the inner tube with the inside wall of the outer tube.

**B.6 Heat shield**, which can be located over the upper end of the outer dilatometer tube, with a central hole large enough to give a radial clearance of about 1 mm to the inner tube.

**B.7 Control unit**, capable of raising the furnace temperature from ambient to 700 °C at a constant rate of either 1 °C/min or 5 °C/min, and of maintaining the temperature at any setting between 400 °C and 700 °C, with an accuracy of  $\pm 5$  °C.

**B.8 Means of measuring the electromotive force (e.m.f.) of the specimen thermocouple**; if a linear transducer is to be used for measuring specimen expansion, it is convenient to connect its output and that of the specimen thermocouple to a suitably calibrated X-Y recorder so that a graph of thermal expansion is produced directly.