# NATIONAL BUREAU OF STANDARDS REPORT

6660

Progress Report

on

REVISION OF AMERICAN DENTAL ASSOCIATION

SPECIFICATION NO. 4 FOR DENTAL INLAY CASTING WAX

by

John W. Stanford
Keith V. Weigel
George C. Paffenbarger


U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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This work is a part of the dental research program conducted at the National Bureau of Standards in cooperation with the Council on Dental Research of the American Dental Association, the Army Dental Corps, the Dental Sciences Division of the School of Aviation Medicine, USAF, the Navy Dental Corps, and the Veterans Administration.




U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

# REVISION OF AMERICAN DENTAL ASSOCIATION SPECIFICATION NO. 4 FOR DENTAL INLAY CASTING WAX

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## Abstract

To provide a basis for revision of American Dental Association Specification No. 4 for Dental Inlay Casting Wax, data were obtained on the nonvolatile residue, flow at various temperatures and thermal expansion of nine waxes. The values determined for residue of the waxes ranged between 0.00 and 0.08 percent. The proposed maximum is 0.10 percent. The values determined for flow at 37°C for Type I waxes (those intended for direct technics) ranged between 0.3 and 0.4 percent. The proposed maximum is 1.0 percent. Flow at 40°C for Type I waxes ranged between 1.4 and 15.4 percent with a maximum of 20 percent proposed. Flow at 45°C for Type I waxes ranged between 74.5 and 77.2 percent with a minimum of 70 and a maximum of 90 percent proposed. Flow at 30°C for Type II waxes (those intended for indirect technics) ranged between 0.2 and 0.4 percent with a maximum of 1.0 percent proposed. Flow at 40°C for Type II waxes ranged between 54.1 and 77.4 percent with a minimum of 50 percent proposed, and flow at 45°C ranged between 79.0 and 85.2 percent with a minimum of 70 and a maximum of 90 percent proposed. Linear thermal expansion of the Type I waxes between 25 and 30°C ranged between 0.13

and 0.16 percent with a maximum of 0.2 percent proposed. From 25 to 37°C the expansion was between 0.34 and 0.50 percent with a maximum of 0.6 percent proposed. Annealing of test specimens at 37°C before testing is recommended.

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## 1. INTRODUCTION

Since 1941 when the American Dental Association specification for inlay casting wax was first revised [1], there has been a growing demand for a specification covering the softer wax used in indirect technics. This, the second revision, was occasioned by this demand and by refinements in the test procedures for determining flow, residue upon volatilization and linear thermal expansion of the wax.

The revised specification was prepared by a subcommittee of the Specifications Committee of the Dental Materials Group of the International Association for Dental Research. Members of the subcommittee were:

George C. Paffenbarger, Chairman
John W. Stanford, Secretary
W. H. Crawford
Frank J. Demsko
J. R. Reasonberg
William F. Talbot

The procedure [2] followed in the revision was established by the Council on Dental Research of the American Dental Association in April 1956.

Data on which the second revision is based were obtained from a recent survey of the certified inlay casting waxes appearing on the List of Certified Dental Materials [3] and on tests conducted on four brands of softer waxes; that is, waxes having greater flow at temperatures near 37°C (98.6°F) than do the certified waxes.

## 2. EXPERIMENTAL PROCEDURES AND RESULTS

### 2.1 Procedure

The first revision [1] of A.D.A. Specification No. 4 for Dental Inlay Casting Wax required the testing for flow at four temperatures; that is, at 37.5°C (99.5°F), 38.0°C (100.4°F), 42.0°C (107.6°F), and 43.0°C (109.4°F). During the testing of the waxes four additional testing temperatures were utilized. They were 30.0°C (86.0°F), 37.0°C (98.6°F), 40.0°C (104.0°F), and 45.0°C (113.0°F). The purpose of this was to determine the flow characteristics of the hard (Type I) and soft (Type II) waxes at sufficient points to be able to distinguish them on the basis of flow. The procedure used to prepare and test the flow specimens followed as closely as possible the methods outlined for flow requirements in the second revision of American Dental Association Specification No. 3 for Dental Impression Compound [4].

The testing procedure for determining residue upon volatilization of the wax had not been outlined previously. In order that different testing laboratories can compare data it was deemed necessary that a specified maximum residue and a procedure

for determining such residue should be included in the proposed revision. The procedure involves volatilization of a known weight of wax at 500°C (932°F) and is outlined in paragraph 4.3.3 of the revised specification.

Detailed methods of preparation and procedures for testing linear thermal expansion specimens of the waxes are also included in this revision. In addition, maximum values for linear expansion from 25.0°C (77.0°F) to 30.0°C (86.0°F) and from 25.0°C (77.0°F) to 37.0°C (98.6°F) are specified for the direct technic (Type I) inlay wax. During testing of the certified waxes (Type I) the result for linear thermal expansion obtained during the initial heating cycle did not agree with values obtained on repeated runs upon the same specimen. The tests were conducted in duplicate upon specimens stored at 20-25°C (68.0-77.0°F) prior to testing. Since 37°C (98.6°F) was the highest temperature at which the expansion was determined, two additional specimens of each wax were stored at that temperature for 24 hours prior to testing. Linear thermal expansion measurements were made during four cycles of heating and cooling for each specimen.

## 2.2 Discussion of Results

Table 1 contains the data obtained in testing the flow properties of the waxes. Duplicate specimens were tested at each temperature. The data show that three testing temperatures instead of the four required in the first revision of the specification can be used to characterize flow properties of the waxes.

For the Type I wax used in direct technics, 37.0°C (98.6°F), 40.0°C (104.0°F) and 45.0°C (113.0°F) were chosen as testing temperatures whereas 30.0°C (86.0°F), 40.0°C (104.0°F) and 45.0°C (113.0°F) were chosen for the Type II wax. The results in Table 1 show that the Type I waxes have less than 1 percent flow at 37.0°C (98.6°F) and that the Type II waxes have less than 1 percent flow at 30.0°C (86.0°F). Flow of the Type II waxes was determined at lower temperatures than 37.0°C (98.6°F) since this type of wax is used at room temperatures. Since there were no differences in the results at 25.0°C (77.0°F) and 30.0°C (86.0°F), the 30.0°C (86.0°F) testing temperature was chosen. The 40.0°C (104.0°F) point was chosen to differentiate between the Type I and Type II waxes. The hard (Type I) waxes have less than 20 percent flow and the soft (Type II) waxes have more than 50 percent flow at this temperature. The same maximum and minimum flow requirements were set at the 45.0°C (113.0°F) temperature for both types of waxes to insure that the waxes had sufficient flow at elevated temperatures yet did not melt at or below this temperature. Typical flow curves for the two types of wax are shown in Figure 1.

The results for residue after volatilization of the waxes at 500°C (932°F) are given in Table 2. All of the waxes tested had less than 0.10 percent residue after ignition. A maximum of 0.10 percent residue was used in the specification revision. Due to the apparent successful use of the certified waxes in clinical

practice there does not appear to be any significant harm in 0.10 percent residue during burnout of the wax pattern.

Table 3 contains the results of linear thermal expansion determined on two specimens of each wax stored at 20.0 to 25.0°C (68.0 to 77.0°F) before measurement. Linear thermal expansion values were determined between 25.0 and 30.0°C (77.0 and 86.0°F) and between 25.0 and 37.0°C (77.0 and 98.6°F). The specimens were allowed to cool in the water bath to 25.0°C (77.0°F) and then the test repeated three times. The values for the expansions between 25.0°C (77.0°F) and 37.0°C (98.6°F) determined during the repeated runs were significantly greater than those between these temperatures for the first runs on specimens stored at 20.0 to 25.0°C (68.0 to 77.0°F) (Table 3, Columns c and d). However, the values for the three repeated runs agreed within experimental limits. The results for the two specimens of each wax stored at 37.0°C (98.6°F) for 24 hours prior to testing are shown also in Table 3. The values obtained by the initial and repeated runs agreed very well. Table 3 shows also that the value from 25.0 to 37.0°C (77.0 to 98.6°F) of the initial or the average of the second, third and fourth runs (Columns c and d) agreed within experimental limits with the average value of the second, third and fourth determinations (Column d) on the specimens annealed at 20.0 to 25.0°C (68.0 to 77.0°F). The data in Table 3 show that the annealing temperature of 37.0°C (98.6°F) apparently releases some of the strains induced into the specimens during preparation. The 37.0°C (98.6°F) annealing temperature has thus

## REFERENCES

1. Beall, J. R. Revision of American Dental Association specification no. 4 for inlay casting wax. J.A.D.A. 27:1140 July 1940.
2. Paffenbarger, G. C.; Stanford, J. W., and Sweeney, W. T. 1960-1961 American Dental Association specifications for dental materials. American Dental Association, Chicago, Ill., January 1960.
3. List of certified dental materials revised to May 1, 1959. J.A.D.A. 59:130 July 1959.
4. Stanford, J. W.; Paffenbarger, G. C. and Sweeney, W. T. A revision of American Dental Association specification no. 3 for dental impression compound. J.A.D.A. 51:56 July 1955.

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1. Beall, J. R. Revision of American Dental Association specification no. 4 for inlay casting wax. J.A.D.A. 27:1140 July 1940.
2. Paffenbarger, G. C.; Stanford, J. W., and Sweeney, W. T. 1960-1961 American Dental Association specifications for dental materials. American Dental Association, Chicago, Ill., January 1960.
3. List of certified dental materials revised to May 1, 1959. J.A.D.A. 59:130 July 1959.
4. Stanford, J. W.; Paffenbarger, G. C. and Sweeney, W. T. A revision of American Dental Association specification no. 3 for dental impression compound. J.A.D.A. 51:56 July 1955.

TABLE 1

Flow of Inlay Casting Waxes

| Type I | 25°C | 30°C | 37°C | 37.5°C | 38°C | 40°C | 42°C | 43°C | 45°C |
|---|---|---|---|---|---|---|---|---|---|
| Brand | % | % | % | % | % | % | % | % | % |
| A | - | - | 0.3 | 0.4 | 1.2 | 15.4 | 65.4 | 70.4 | 77.2 |
| B | - | - | 0.4 | 0.5 | 0.7 | 2.0 | 32.2 | 58.1 | 76.5 |
| C | - | - | 0.4 | 0.5 | 0.4 | 1.4 | 23.6 | 55.0 | 75.1 |
| D | - | - | 0.4 | 0.8 | 1.2 | 2.1 | 51.0 | 62.2 | 75.3 |
| E | - | - | 0.3 | 0.4 | 1.0 | 2.3 | 31.8 | 56.0 | 74.5 |
| Type II | | | | | | | | | |
| Brand | | | | | | | | | |
| F | 0.2 | 0.2 | 12.0 | - | 51.2 | 77.4 | 81.8 | 83.3 | 85.2 |
| G | 0.2 | 0.2 | 2.1 | - | 8.0 | 55.2 | 72.0 | 79.0 | 80.1 |
| H | 0.2 | 0.2 | 2.2 | - | 8.1 | 54.1 | 71.8 | 77.7 | 79.0 |
| I | 0.3 | 0.4 | 5.4 | - | 49.5 | 66.2 | 72.3 | 76.5 | 83.1 |

TABLE 2

Residue After Volatilization of
Inlay Casting Waxes

Type I

| Brand | Residue % |
|---|---|
| A | 0.08 |
| B | 0.00 |
| C | 0.00 |
| D | 0.00 |
| E | 0.03 |

Type II

| Brand | |
|---|---|
| F | 0.00 |
| G | 0.00 |
| H | 0.00 |
| I | 0.00 |

TABLE 3

Linear Thermal Expansion of Inlay Casting Waxes

| Brand | Specimens Stored at °C | Temperature Range 25.0 to 30.0°C Run a | Run b | 25.0 to 37.0°C Run c | Run d |
|---|---|---|---|---|---|
| | | 1 | 2, 3, 4 | 1 | 2, 3, 4 |
| | | % | % | % | % |
| A | 20-25 | 0.14 | 0.15±0.01 | 0.39 | 0.47±0.01 |
| | 37 | 0.15 | 0.16±0.01 | 0.48 | 0.50±0.02 |
| B | 20-25 | 0.12 | 0.13±0.01 | 0.30 | 0.34±0.02 |
| | 37 | 0.13 | 0.13±0.01 | 0.33 | 0.34±0.02 |
| C | 20-25 | 0.14 | 0.14±0.01 | 0.40 | 0.45±0.01 |
| | 37 | 0.14 | 0.14±0.00 | 0.44 | 0.44±0.01 |
| D | 20-25 | 0.07 | 0.13±0.01 | 0.24 | 0.45±0.01 |
| | 37 | 0.14 | 0.15±0.02 | 0.46 | 0.47±0.01 |
| E | 20-25 | 0.13 | 0.13±0.00 | 0.26 | 0.35±0.01 |
| | 37 | 0.14 | 0.14±0.00 | 0.41 | 0.41±0.00 |

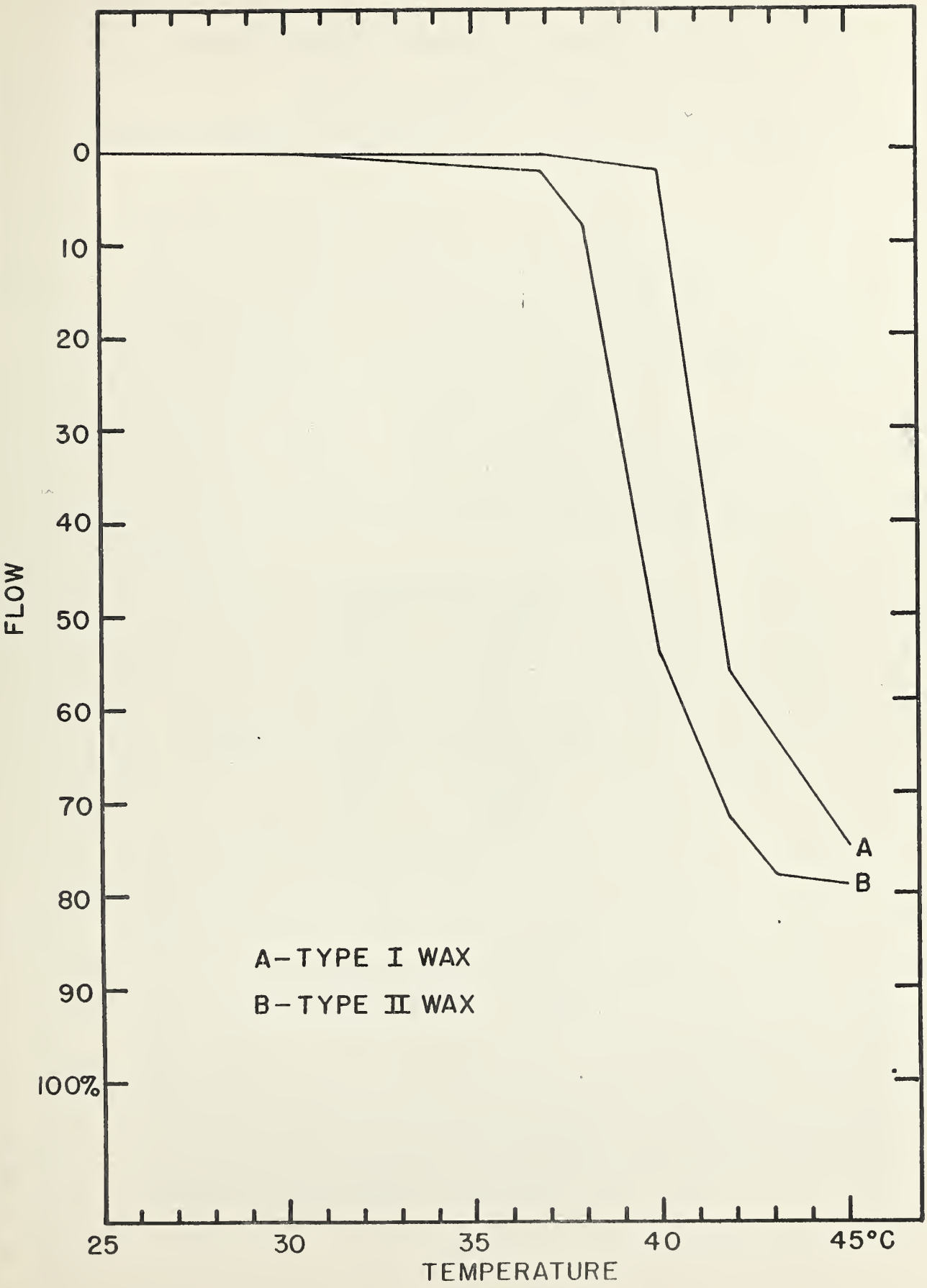


FIGURE 1

TYPICAL FLOW CURVES OF INLAY CASTING WAX

# American Dental Association Specification No. 4

## for Dental Inlay Casting Wax

(Second revision, Approved _____, Effective_____)

1. SCOPE AND CLASSIFICATION

1.1 Scope. This specification is for inlay casting wax used in making patterns in the production of inlays and crowns. The wax consists essentially of natural waxes, resins and hydrocarbons of the paraffin series.

1.2 Types and classes. Inlay casting wax covered by this specification shall be of the following types and classes as specified:

Type I. Direct technic wax

Class 1. Sticks

Class 2. Cones

Type II. Indirect technic wax

Class 1. Sticks

Class 2. Cones

2. APPLICABLE SPECIFICATIONS

2.1 Specification. There are no other specifications applicable to this specification. (Copies of American Dental Association specifications may be obtained free upon application to the Council on Dental Research, American Dental Association, 222 East Superior Street, Chicago 11, Illinois, or to the American Dental Association Research Division, National Bureau of Standards, Washington 25, D. C.)

3. REQUIREMENTS

3.1 Uniformity. The wax shall be uniform and free of foreign materials.

3.2 Size. Sizes shall be as specified by the purchaser.

3.3 Color. The color of the waxes shall be the color specified by the purchaser.

3.4 Softening. The wax shall soften without becoming flaky. It shall not show laminations when formed into a working mass.

3.5 Chipping. The wax shall not show appreciable chipping or flaking when trimmed to a fine margin at 20-25°C (68-77°F).

3.6 Residue. The melted wax when vaporized at 500°C (932°F) shall leave no solid residue in excess of 0.10 percent of the original weight of the specimen when tested as described in 4.3.3.

3.7 Flow

3.7.1 Type I wax

3.7.1.1 The flow at 37°C (98.6°F) shall be not more than 1.0 percent.

3.7.1.2 The flow at 40°C (104.0°F) shall be not more than 20 percent.

3.7.1.3 The flow at 45°C (113.0°F) shall be not less than 70 nor more than 90 percent.

3.7.2 Type II wax

3.7.2.1 The flow at 30°C (86.0°F) shall be not more than 1.0 percent.

3.7.2.2 The flow at 40°C (104.0°F) shall be not less than 50 percent.

3.7.2.3 The flow at 45°C (113.0°F) shall be not less than 70 nor more than 90 percent.

3.8 Linear thermal expansion, Type I wax

3.8.1 The linear thermal expansion from 25.0°C (77.0°F) to 30.0°C (86.0°F) shall be not more than 0.2 percent when tested as in 4.3.2.2.

3.8.2 The linear thermal expansion from 25.0°C (77.0°F) to 37.0°C (98.6°F) shall be not more than 0.6 percent when tested as in 4.3.2.2.

3.9 Manufacturer's instructions. Instructions, including method for softening, working temperature, and data showing the thermal expansion of the wax from 25.0°C (77.0°F) to 30.0°C (86.0°F) and to 37.0°C (98.6°F), shall be supplied with each package of wax. The thermal expansion data shall be required for the Type I wax only.

4. SAMPLING, INSPECTION AND TESTING PROCEDURES

4.1 Sampling. Five packages or approximately five ounces of wax shall be procured at retail by a member of the American Dental Association. This sample shall be forwarded in the original, unopened package or packages to the American Dental Association Research Division at the National Bureau of Standards, Washington 25, D. C.

4.2 Inspection. Visual inspection shall be used in determining compliance with the requirements stated in 3.1, 3.3, 3.4, 3.5, 3.9 and 5.

4.3 Physical tests.

4.3.1 Flow

4.3.1.1 Preparation of specimens. A quantity of wax shall be broken into pieces and placed in a metal pouring pan such as illustrated in Figure 4-1. The pan shall be placed on a surface which is 130 mm (5.1 in.) below a 250 watt infrared lamp. The wax, while being stirred, shall be allowed to reach a temperature of 75 ± 5°C (167 ± 9°F) and be maintained at this temperature until the sample is melted throughout. A thermometer shall be used to measure the temperature. The melted wax shall then be poured into a mold that has been lubricated with a silicone grease whose melting point is higher than 75 ± 5°C (167 ± 9°F). The mold, Figure 4-2, shall consist of a stainless steel plate 6.0 mm (0.236 in.) thick, having flat, parallel top and bottom surfaces, and containing four holes 10.0 mm (0.394 in.) in diameter. The axes of the holes shall be perpendicular to the surfaces of the plate. The sides of the holes shall be finished smooth. The mold shall be preheated to a temperature of 55 ± 5°C (131 ± 9°F) and placed on a smooth glass slab 152 mm long, 76 mm wide and 19 mm thick (6 x 3 x 0.75 in.) preheated to the same temperature. As the wax freezes and a shrinkage void appears, liquid wax shall be added. When the wax has lost its "mirror-like" surface, a smooth, flat tin-foil or aluminum-foil covered-glass plate, preheated to 55 ± 5°C (131 ± 9°F) shall be placed on the top of the mold. A load of 9000 g (20 lb) shall be applied to the top of the foil covered-glass plate for 30 minutes.

The weight and the glass plate shall then be removed and the excess wax trimmed away. This may be accomplished by drawing a metal scraper across the mold trimming the specimen flush with the surface. The mold shall be removed from the glass slab by gently tapping the side of the mold. The specimens of wax shall be removed from the mold by chilling in water at 10°C (50°F) and shall then be stored at 20-25°C (68-77°F) for 24 hours before testing.

4.3.1.2 Method of test. The initial length of the specimen shall be determined at 20-25°C (68-77°F) using a metric micrometer caliper. Four measurements shall be made around the circumference and one measurement shall be made in the center of the specimen. The measurements shall be averaged and recorded to the nearest 0.005 mm. The specimen and flow testing instrument shall be placed in a water bath and held at the testing temperature for twenty minutes prior to testing. The flow testing instrument, Figure 4-3, consists of the following: A, a weight; B, a shaft having low thermal conductivity; C, a brass platen. The total weight, in air, of these three components shall be 2000 g (4.41 lb). The weight, A, shall be separated a minimum distance of 76 mm (3 in.) from the brass platen by the non-conducting shaft. This shaft shall be of hard rubber or a similarly poor thermal conductor to reduce loss of heat from the specimen.

The diameter of the brass platen shall not be less than 51 mm (2 in.). The thickness shall not exceed 6.35 mm (0.25 in.). The temperature of the bath shall be controlled to within ± 0.1°C (± 0.2°F) of the required temperature. (A calibrated thermometer shall be used for determining the temperature.) Agitation shall be provided in the water bath by means of a mechanical stirrer. A thin sheet of waterproof cellophane shall be placed between the instrument and each end of the specimen. The bottom of the specimen shall be 51 mm (2 in.) below the surface of the water in the bath. A constant axial load of 2000 g (4.41 lb) shall then be applied to the specimen for ten minutes, after which the specimen shall be removed and cooled in air to 20-25°C (68-77°F). The cellophane shall be stripped off and the final length determined in the same manner as the original length. The flow, as evidenced by the change in length, shall be reported as percentage of the initial length. The value for flow at any temperature shall be the average value for two specimens and shall be reported to the nearest 0.1 percent.

4.3.2 Linear thermal expansion

4.3.2.1 Preparation of specimens. The wax shall be melted as described in 4.3.1.1, and shall be poured into a brass mold lubricated with a silicone grease whose melting point is higher than 75 ± 5°C (167 ± 9°F), Figure 4-4, and having an opening of 6.35 x 6.35 mm (0.25 x 0.25 in.) running the

length of the mold, until the mold is overfilled. Spacers, 19 mm (0.75 in.) in length, shall be placed in the opening at each end of the mold (Figure 4-4, C). The mold shall be preheated to 55 ± 5°C (131 ± 9°F). As the wax freezes and shrinkage occurs, liquid wax shall be added. When the wax has lost its "mirror-like" surface, a lubricated brass plate preheated to 55 ± 5°C (131 ± 9°F) shall be placed on top of the overfilled mold. A load of 9000 g (20 lb) shall be applied to the top of the brass plate for 30 minutes. The weight and brass plate shall then be removed and the excess wax trimmed away until the specimen is flush with the top of the mold. The size of the specimen thus prepared will be approximately 267 x 6.35 x 6.35 mm (10.5 x 0.25 x 0.25 in.) and is suitable for use with the micrometer microscope comparator (4.3.2.2). The specimen shall be removed from the mold and shall have embedded in its surface near each end, small metal pins having crossmarks which shall serve as reference marks for subsequent linear measurements. After the test specimen is prepared, it shall be stored at 37°C (98.6°F) for 24 hours before testing.

4.3.2.2 Method of test. The specimen shall be heated to three different temperatures and the distance between the reference marks shall be determined at each temperature. A micrometer microscope comparator or equipment of equal accuracy shall be used to make the measurements. The specimen shall be placed under a suitable holder with openings for viewing the reference marks as is shown in Figure 4-5. The openings shall be located 6.35 (0.25 in.)

from each end of the holder and shall be 9.52 x 12.7 mm (0.375 x 0.5 in.) in size. The holder shall be so constructed that the wax specimen shall ride against only two narrowed sections, having 7.94 x 7.94 mm (0.312 x 0.312 in.) openings (Figure 4-5, A), located 25.4 mm (1.0 in.) from each end, to enable alignment but a minimum of restraint to the expansion during heating. An initial measurement shall be made in water after 20 minutes at 25.0 ± 0.1°C (77.0 ± 0.2°F). The temperature shall then be raised in the water bath to 30.0 ± 0.1°C (86.0 ± 0.2°F). The specimen shall remain 20 minutes at that temperature before the distance between marks is determined. The same procedure shall be carried out at 37.0 ± 0.1°C (98.6 ± 0.2°F). A repeat test starting at 25.0 ± 0.1°C (77.0 ± 2°F) shall be made on the same specimen. Using the 25.0 ± 0.1°C (77.0 ± 0.2°F) temperature measurement as zero, the value for linear thermal expansion shall be the average value of the two determinations at each temperature and shall be reported to the nearest 0.05 percent.

4.3.3 Residue. Approximately one gram of wax shall be placed in a crucible previously conditioned to constant weight by repeated heatings to 500°C (932°F) and cooling to 20-25°C (68-77°F). The conditioned, tared and loaded crucible shall be transferred to a furnace at 20-25°C (68-77°F). The temperature of the furnace shall be

increased to 500°C (932°F) and maintained at this temperature for one hour. The crucible shall then be removed from the furnace, placed in a desiccator, and allowed to cool to 20-25°C (68-77°F) before weighing. The value for residue shall be the average value of two determinations and shall be reported to the nearest 0.02 percent.

5. PREPARATION FOR DELIVERY

5.1 Packaging. The material shall be packaged in accordance with accepted commercial practice.

5.2 Marking

5.2.1 Lot numbers. Each container shall be marked with a serial number or a combination of letters and numbers which refer to the manufacturer's records for the particular lot or batch of wax.

5.2.2 Date of manufacture. The date of manufacture (year and month) shall be given on the container either as a separate item or as part of the lot number (5.2.1).

5.2.3 Net weight. The minimum net weight of the contents shall be indicated on all containers.

5.2.4 Type and class. The type and class (1.2) of wax shall be indicated on all containers.

6. NOTES

6.1 Intended use. The usual uses for the two types of waxes specified are: Type I, direct technic wax, the wax being suitable for making patterns in or out of the oral cavity

for the production of inlays and crowns; Type II, indirect technic wax, the wax being suitable for making patterns outside the oral cavity for the production of inlays and crowns.

6.2 Reference.. Reference to items 27 and 93 in the bibliography will assist the observer in the testing of inlay casting wax for compliance with this specification.

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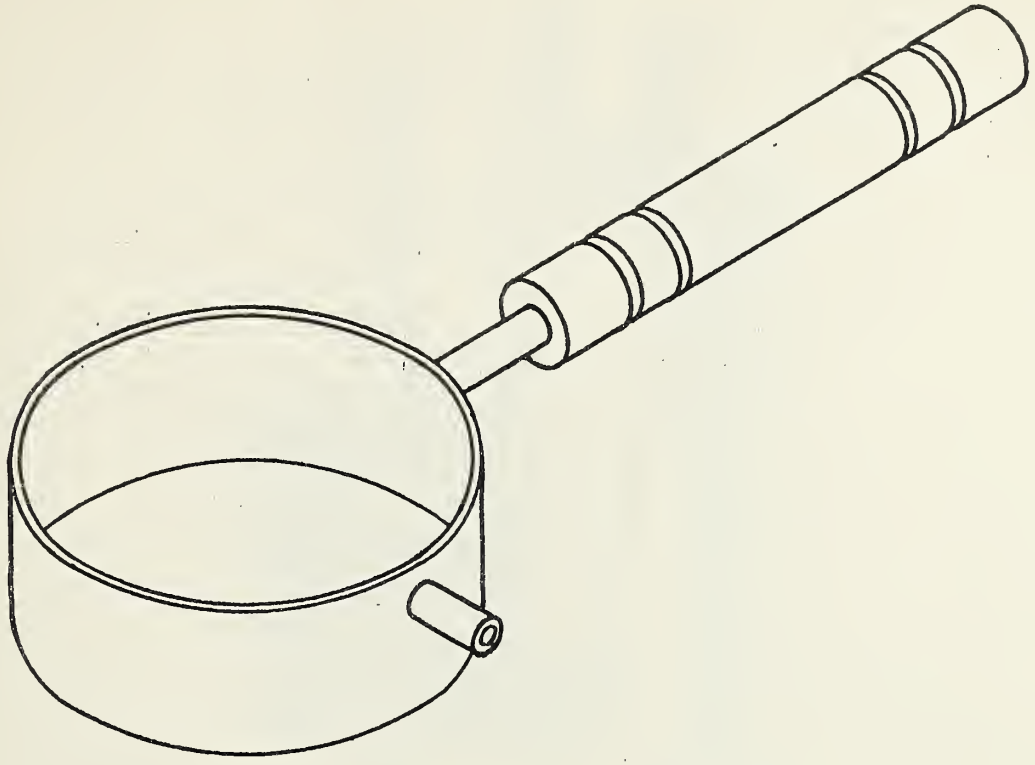

FIGURE 4-1

Metal pouring pan

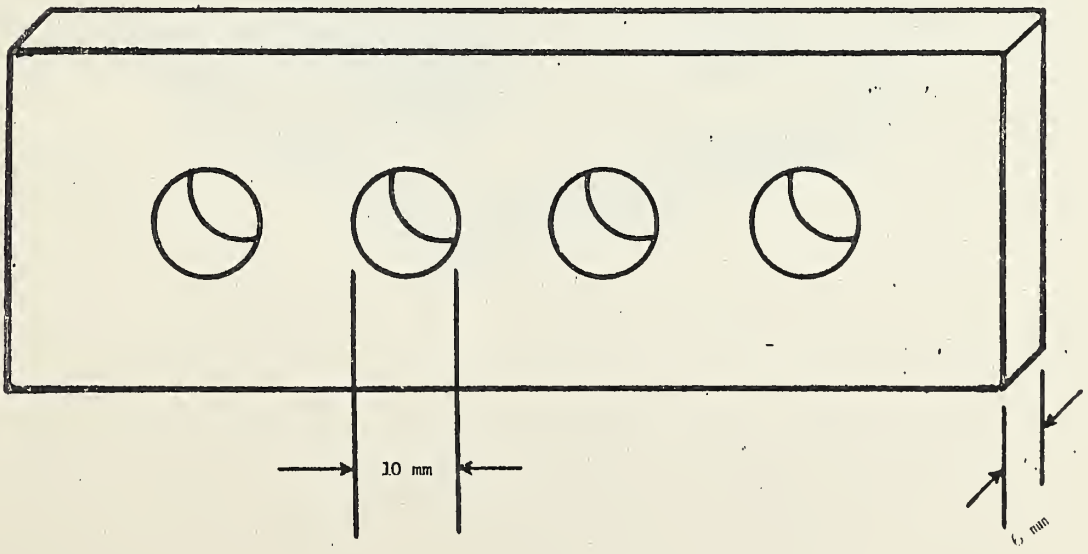


FIGURE 4-2

Mold for forming flow specimens

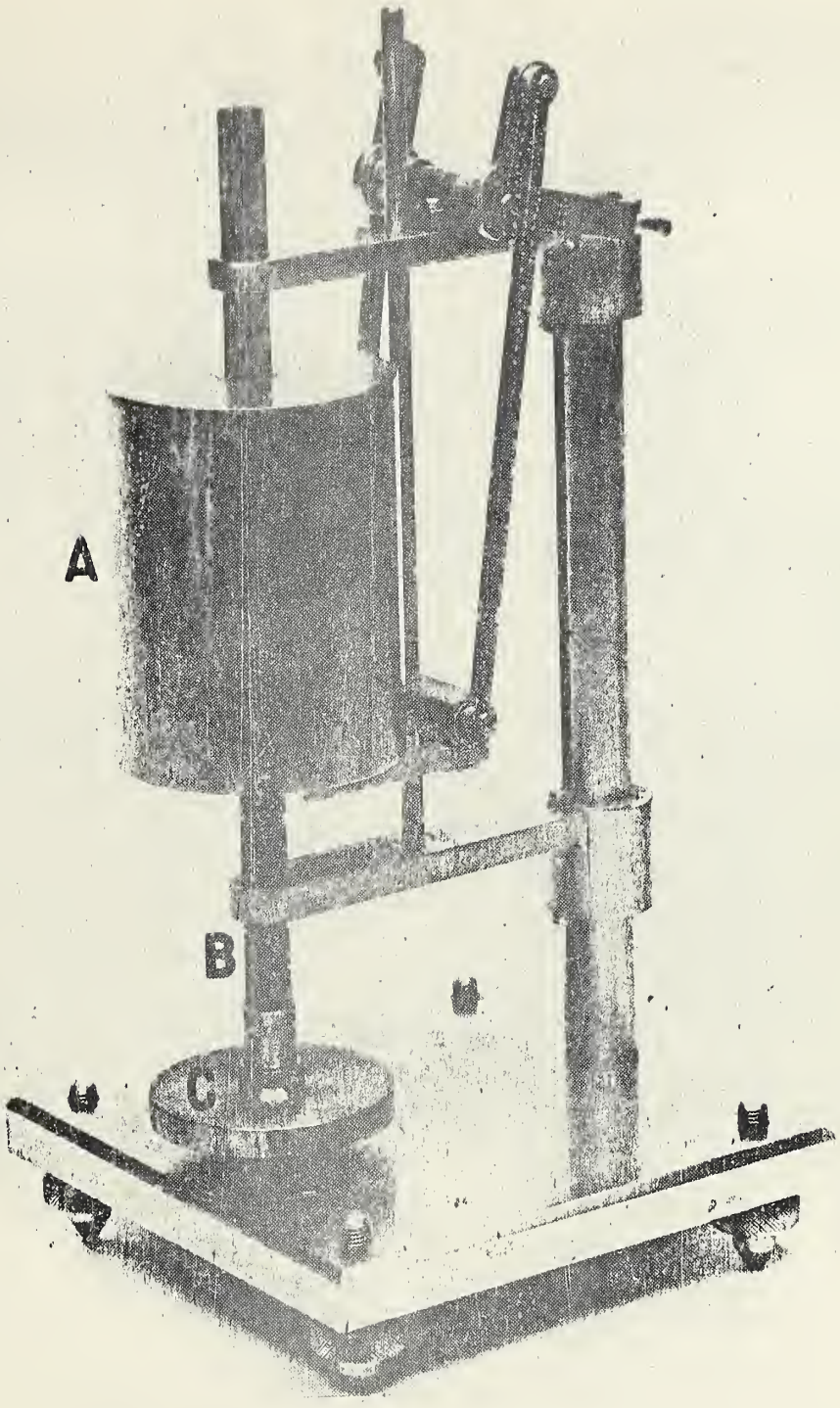


FIGURE 4-3

Flow testing instrument

A. Weight

B. Shaft

C. Brass platen

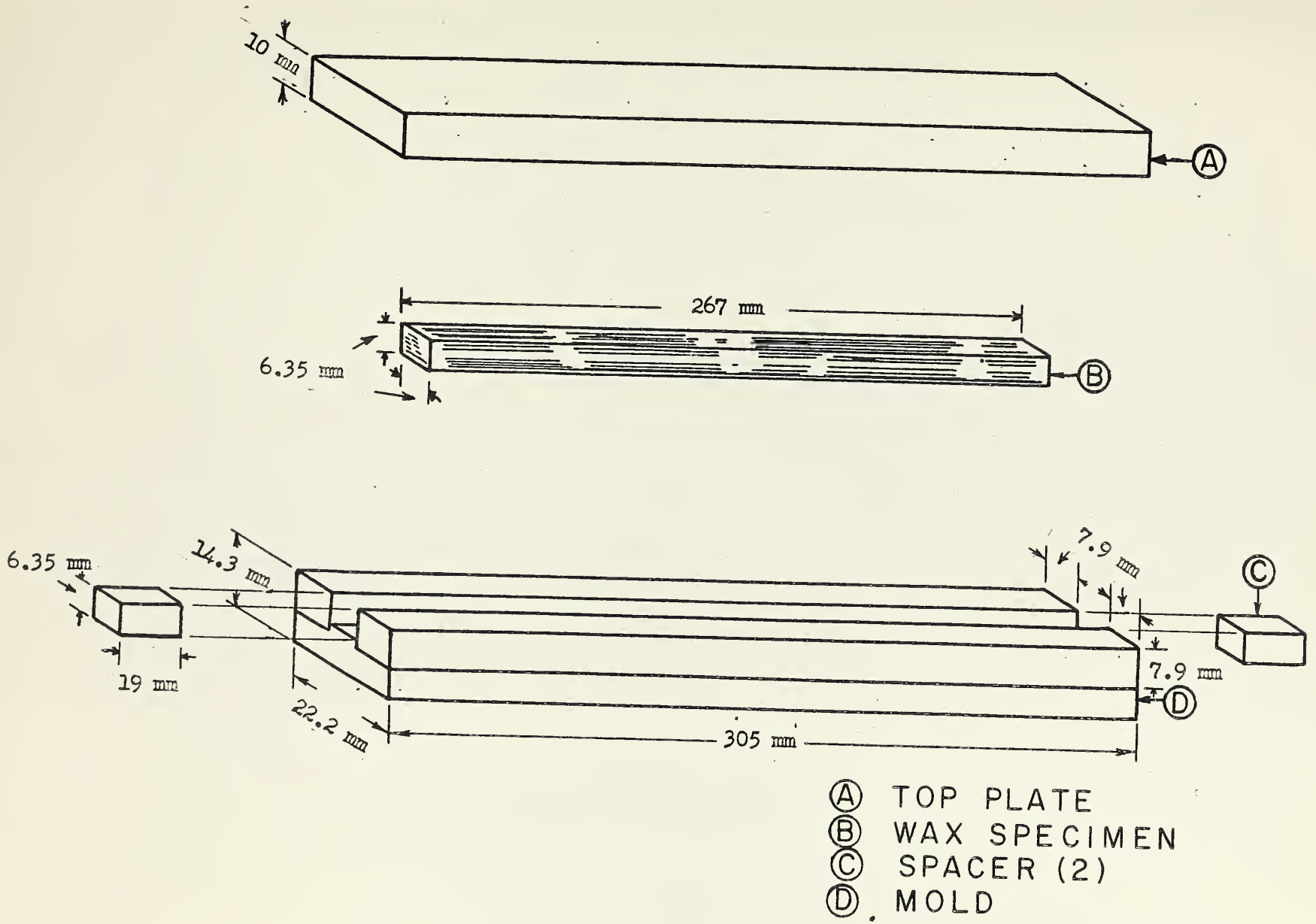


FIGURE 4-4

Mold for forming thermal expansion specimens

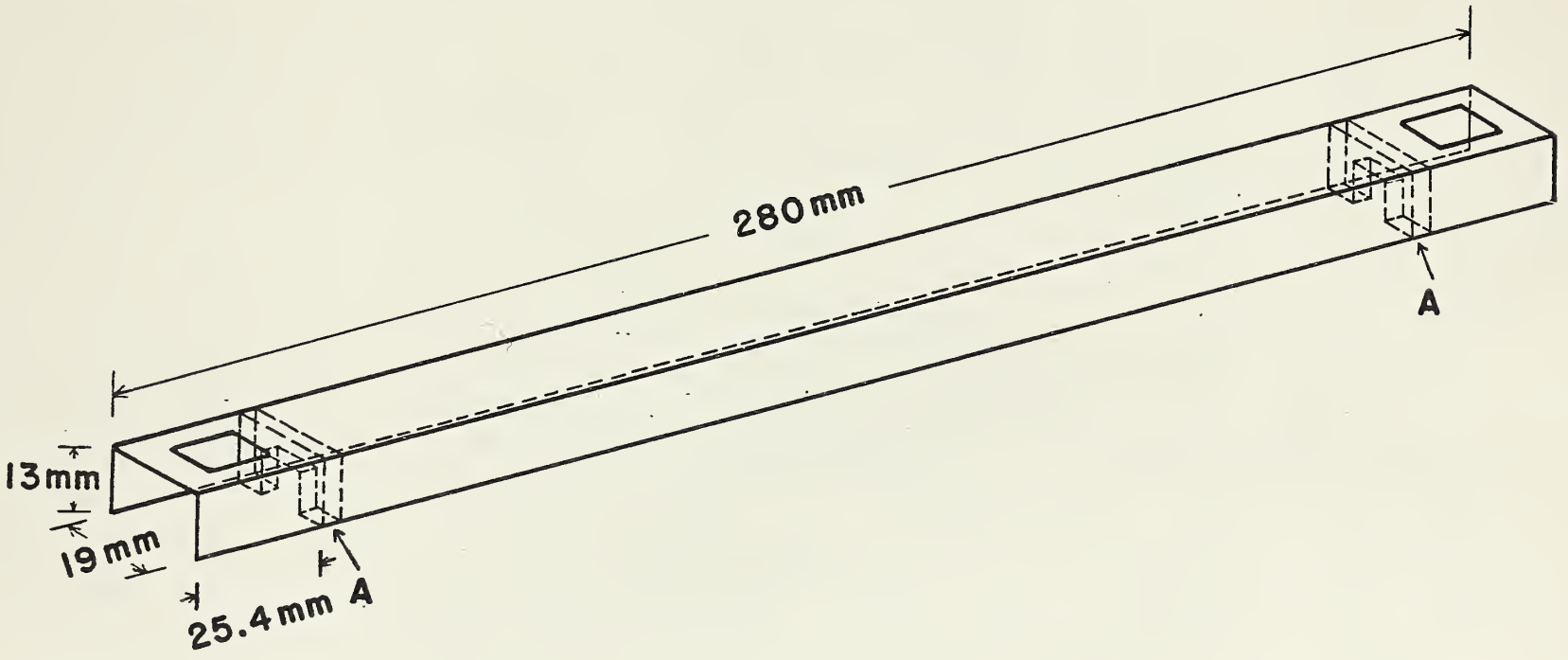


FIGURE 4-5

Holder for thermal expansion specimen

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

# THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

## WASHINGTON, D.C.

**Electricity and Electronics.** Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

**Optics and Metrology.** Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

**Heat.** Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research.

**Atomic and Radiation Physics.** Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

**Chemistry.** Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

**Mechanics.** Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

**Organic and Fibrous Materials.** Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

**Metallurgy.** Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

**Mineral Products.** Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

**Building Technology.** Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer. Concreting Materials.

**Applied Mathematics.** Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

**Data Processing Systems.** SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

## BOULDER, COLORADO

**Cryogenic Engineering.** Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

**Radio Propagation Physics.** Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

**Radio Propagation Engineering.** Data Reduction Instrumentation. Modulation Research. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation Obstacles Engineering. Radio-Meteorology. Lower Atmosphere Physics.

**Radio Standards.** High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

**Radio Communication and Systems.** Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.


NBS