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Specification for

Secondary reference thermometers

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Co-operating organizations

The following were represented on the committee which, under the authority of the Laboratory Apparatus Industry Standards Committee, prepared this British Standard:

Agricultural Research Council
Association of Scientific, Technical and Managerial Staffs
Association for Science Education
British Laboratory Ware Association*
British Lampblown Scientific Glassware Manufacturers' Association*
British Pharmacopoeia Commission
Chemical Industries Association*
Chemical Society
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Department of Trade and Industry (Laboratory of the Government Chemist)*
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Glass Manufacturers' Federation
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Society of Glass Technology*
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The organizations marked with an asterisk in the above list, together with the following, were directly represented on the Committee entrusted with the preparation of this British Standard.

British Medical Association
British Standards Institution (Test Centre)
Meteorological Office
Ministry of Defence (Army Department)
Royal College of Nursing and National Council of Nurses of the UK

This British Standard, having been prepared under the direction of Laboratory Apparatus Industry Standards Committee was published under the authority of the Executive Board on 31 December 1976

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Contents

Foreword

This British Standard was first published in 1952 to meet the increasing use of liquid-in-glass thermometers as secondary reference (SR) thermometers for the absolute measurement of temperature in terms of the International Practical Temperature Scale. These thermometers were adopted as means of calibrating other thermometers[1)], both by the standardizing laboratories of various testing institutions and by manufacturers and users of thermometers. A comprehensive series of thermometers was listed, based upon those developed initially at the National Physical Laboratory (NPL).

Between 1952 and 1963 five amendments were issued, and the present revision was undertaken to incorporate further changes. These are an up-to-date list of approved thermometric glasses, a modification to the requirement for the means of identifying the bulb glass, and a new table in Appendix D giving the uncertainty of verification tests carried out at the NPL.

For convenience of reference to individual thermometers a designation mark has been allotted to each, consisting of the letters SR (for Secondary Reference) followed by a serial number and an indication of the maximum working temperature (e.g. SR6/51C).

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 9 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

[1)] When comparing other thermometers with the secondary reference thermometers, at least two SR thermometers should be used in the testing apparatus. The agreement between these two thermometers then gives a guide to the efficiency of the stirring of the medium.

1 Scope

This British Standard specifies a comprehensive series of secondary reference (SR) thermometers for calibrating other thermometers in laboratory and industrial use.

2 Type

Two types of thermometer are specified as follows.

a) All thermometers, except SR1/30C, shall be of the mercury-in-glass, solid-stem type, filled with inert gas at a pressure sufficient to raise the boiling point of the mercury so that reproducible readings can be obtained at the maximum temperature shown on the scale.

b) Thermometer SR1/30C shall be of the spirit-in-glass, solid-stem type, the spirit being pure toluene or pure ethanol (ethyl alcohol) coloured with a permanent dye which does not stain the glass.

3 Temperature scale

The temperature scale to which this specification refers is the Celsius scale as defined in the current definition of the International Practical Temperature Scale adopted by the General Conference of Weights and Measures (CGPM).

4 Material

Both bulb and stem of the thermometer shall be made of the same approved thermometric glass suitable for the range of temperature covered (see Appendix A). The stem shall have an enamel back.

NOTE It is permissible to join a normal glass bulb from one manufacturer to a normal glass stem from a different manufacturer.

5 Construction

The construction of a typical secondary reference thermometer is illustrated in Figure 1.

5.1 General. Each thermometer shall comply in all respects with the relevant details given in Table 1. The shapes of the bulb and the expansion and contraction chambers shall be such as not to entrap mercury or gas.

5.2 Stem and bulb. Both bulb and stem shall be cylindrical. The stem diameter shall be not less than 5.5 mm and not greater than 7.5 mm. The bulb diameter shall not exceed the stem diameter. The bulb shall be concentric with the stem.

5.3 Expansion volume. To minimize the effect of being accidentally overheated, and in the exceptional case of a thermometer whose temperature range is below ambient being stored at ambient temperature, an expansion volume shall be provided at the top of the capillary tube. This volume should preferably consist of an expansion chamber, and there shall be at least 10 mm of unchanged capillary tube between the highest scale line and the commencement of the widening of the capillary tube. Such a chamber shall be pear-shaped with the hemisphere at the top. In the case of gas filling, the expansion volume may take the form of at least 30 mm of unchanged capillary tube above the highest scale line.

NOTE A thermometer should not be heated above its maximum working temperature because it may be subject to damage which may not be visible and recalibration may be necessary.

5.4 Contraction chamber. The design of the contraction chamber shall be such that the mercury does not recede into the main bulb at the ice point (0 °C).

5.5 Bore. The shape of the bore shall be such as to reduce sticking of the mercury to a minimum. No enlargement of the bore shall be within 10 mm of any part of the scale.

5.6 Top finish. Each thermometer shall be plain finished or with a glass ring or button, as required by the purchaser. The outside diameter of the ring or button, when provided, shall not exceed that of the stem. Thermometer SR12A/505C shall have a plain finish.

6 Annealing

Stress in the glass shall be reduced to a level sufficient to minimize the possibility of fracture due to mechanical or thermal shock (see Appendix B).

7 Stabilization

Each thermometer shall be stabilized by suitable heat treatment before it is graduated, and this process shall be such that the finished thermometer meets the requirements of clause **8**.

8 Accuracy

8.1 Instrument error. When tested in accordance with the procedure given in Appendix C, the maximum error at any point shall be within the limits given in Table 1.

8.2 Interval error. When tested in accordance with the procedure given in Appendix C, the maximum error in an interval shall be within the limits given in Table 1.

8.3 Change in indication at a point. The change in indication at the fiducial points described in appendices **C.2** and **C.3** shall not exceed half a scale interval.

9 Scale lines and figuring

The scale lines shall be clearly and durably etched and of uniform thickness not exceeding the values given in Table 1. The lines shall lie in planes at right angles to the axis of the thermometer, and their left hand ends shall lie on an imaginary line parallel with the axis of the thermometer. When the thermometer is held vertically and viewed from the front in such a way that the enamel back forms a suitable background to the scale lines and figuring, the long lines and medium lines (where appropriate) shall extend to the right, but the shortest lines shall not extend across the bore.

When the thermometer is held in a vertical position and viewed from the front, the figures may be either horizontal or vertical, provided that all are clearly visible, and shall be placed so that each would be intersected by the line to which it refers if the line were extended.

Each thermometer shall be graduated to read correctly under conditions of total immersion, i.e. for use with the entire liquid column immersed in the medium so that the top of the liquid column is in the same plane as the surface of the medium.

Figure 2 illustrates the scale lines and figuring specified for SR thermometers.

10 Inscriptions

Each thermometer shall be permanently and legibly marked with the following information.

a) The official symbol: "°C". An abbreviation of the name Celsius, e.g. "C" is also permitted.

b) The inscription "Total immersion" (or suitable abbreviation).

c) For mercury-filled thermometers, an inscription to indicate the gas filling employed, e.g. "Nitrogen filled" (or suitable abbreviation).

d) An identification number.

e) The maker's and/or vendor's name or readily identifiable mark.

f) The designation mark allotted to the thermometer, e.g. "SR5/100C".

g) The number of this British Standard, i.e. BS 1900.

h) The identification of the glass, e.g. by coloured stripe or stripes on the bulb or an approved abbreviation on the stem (see Appendix A).

Table 1 — Details of British Standard secondary reference thermometers

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Designation mark	**Type (see clause 2)**	**Range**	**Overall length**	**Length of main scale**	**Length of bulb (see Figure 1)**	**Minimum distance from bottom of bulb to first graduation of main scale**	**Minimum distance from top of thermometer to top of main scale**	**Maximum thickness of graduation lines**	**Graduation at each**	**Long and medium lines at each**	**Partially figured at each**	**Fully figured at each**	**Maximum error at any point**	**Maximum permitted interval error in an interval[a]**
		°C	mm	mm	mm	mm	mm	mm	°C	°C	°C	°C	°C	°C
SR1/30C	B	– 80 to + 30	395 to 405	220 to 250	20 to 30	50	90	0.10	0.5	1 and 5	—	10	1.0	1.0/20
SR2/2C	A	– 40 to + 2	445 to 455	290 to 320	15 to 20	60	50	0.10	0.1	0.5	1	10	0.3	0.3/5
SR3/20C	A	– 20 to + 20	395 to 405	290 to 320	10 or 15	40	30	0.10	0.1	0.5 and 1	—	2	0.2	0.2/5
SR4/1C	A	– 11 to + 1	475 to 485	320 to 350	15 to 50	90	30	0.10	0.02	0.1 and 0.5	—	1	0.1	0.1/2
SR4/11C	A	– 1 to + 11	475 to 485	320 to 350	15 to 50	90	30	0.10	0.02	0.1 and 0.5	—	1	0.1	0.1/2
SR5/20C	A	– 0.5 to + 0.5 and 9.5 to 20.5	475 to 485	230 to 260	15 to 50	120	45	0.05	0.02	0.1 and 0.5	—	1	0.1	0.1/2
SR5/30C	A	– 0.5 to + 0.5 and 19.5 to 30.5	475 to 485	230 to 260	15 to 50	120	45	0.05	0.02	0.1 and 0.5	—	1	0.1	0.1/2
SR5/40C	A	– 0.5 to + 0.5 and 29.5 to 40.5	475 to 485	230 to 260	15 to 50	120	45	0.05	0.02	0.1 and 0.5	—	1	0.1	0.1/2
SR5/50C	A	– 0.5 to + 0.5 and 39.5 to 50.5	475 to 485	230 to 260	15 to 50	120	45	0.05	0.02	0.1 and 0.5	—	1	0.1	0.1/2
SR5/60C	A	– 0.5 to + 0.5 and 49.5 to 60.5	475 to 485	230 to 260	15 to 50	120	45	0.05	0.02	0.1 and 0.5	—	1	0.1	0.1/2
SR5/70C	A	– 0.5 to + 0.5 and 59.5 to 70.5	475 to 485	230 to 260	15 to 50	120	45	0.05	0.02	0.1 and 0.5	—	1	0.15	0.15/2
SR5/80C	A	– 0.5 to + 0.5 and 69.5 to 80.5	475 to 485	230 to 260	15 to 50	120	45	0.05	0.02	0.1 and 0.5	—	1	0.15	0.15/2
SR5/90C	A	– 0.5 to + 0.5 and 79.5 to 90.5	475 to 485	230 to 260	15 to 50	120	45	0.05	0.02	0.1 and 0.5	—	1	0.15	0.15/2
SR5/100C	A	– 0.5 to + 0.5 and 89.5 to 100.5	475 to 485	230 to 260	15 to 50	120	45	0.05	0.02	0.1 and 0.5	—	1	0.15	0.15/2
SR6/18C	A	– 1 to + 18	475 to 485	290 to 315	20 to 40	80	35	0.10	0.05	0.1	0.5	1	0.1	0.1/3
SR6/34C	A	– 0.5 to + 0.5 and 16 to 34	475 to 485	280 to 305	20 to 40	130	35	0.10	0.05	0.1	0.5	1	0.1	0.1/3
SR6/51C	A	– 0.5 to + 0.5 and 33 to 51	475 to 485	280 to 305	20 to 40	130	35	0.10	0.05	0.1	0.5	1	0.1	0.1/3
SR6/68C	A	– 0.5 to + 0.5 and 50 to 68	475 to 485	280 to 305	20 to 40	130	35	0.10	0.05	0.1	0.5	1	0.15	0.15/3
SR6/85C	A	– 0.5 to + 0.5 and 67 to 85	475 to 485	280 to 305	20 to 40	130	35	0.10	0.05	0.1	0.5	1	0.15	0.15/3
SR6/102C	A	– 0.5 to + 0.5 and 84 to 102	475 to 485	280 to 305	20 to 40	130	35	0.10	0.05	0.1	0.5	1	0.15	0.15/3
SR7/51C	A	– 1 to + 51 and 99 to 101	495 to 505	310 to 340	15 to 30	80	75	0.05	0.1	0.5	1	10	0.2	0.2/10
SR7/101C	A	– 1 to + 1 and 49 to 101	495 to 505	310 to 340	15 to 30	110	45	0.05	0.1	0.5	1	10	0.2	0.2/10
SR8/151C	A	– 1 to + 1 and 99 to 151	530 to 540	310 to 340	15 to 30	110	80	0.10	0.1	0.5	1	10	0.2	0.2/10
SR8/201C	A	– 1 to + 1 and 149 to 201	530 to 540	310 to 340	15 to 30	110	80	0.10	0.1	0.5	1	10	0.3	0.3/10
SR8/251C	A	– 1 to + 1 and 199 to 251	530 to 540	310 to 340	15 to 30	110	80	0.10	0.1	0.5	1	10	0.5	0.5/10
SR9/202C	A	– 2 to + 2 and 98 to 202	530 to 540	310 to 340	20 to 25	110	80	0.10	0.2	1	2	10	0.4	0.4/20
SR10/302C	A	98 to 102 and 198 to 302	530 to 540	310 to 340	20 to 25	110	80	0.10	0.2	1	2	10	1.0	1.0/20
SR11/452C	A	98 to 102 and 198 to 452	570 to 590	350 to 380	15 to 30	110	80	0.10	0.5	1 and 5	10	100	1.5	1.5/25
SR12A/505C	A	95 to 505	570 to 590	380 to 420	10 to 30	70	80	0.10	1	5	10	100	2.0	2.0/50

[a] Expressed in the form $\frac{\text{maximum permitted interval error}}{\text{interval}}$, the interval error being the algebraic difference between the errors at opposite ends of the interval, e.g. 0.2 °C/5 °C means that the change of error in any interval of 5 °C, does not exceed 0,2 °C.

Appendix A Thermometric glasses approved by The National Physical Laboratory (1974)

Glass	Identification stripe(s) or approved abbreviation	Normal maximum working temperature
		°C
Normal glass, made by Whitefriars Glass Ltd.	Single blue stripe	350
Normal glass, Dial, made by Plowden and Thompson Ltd.	Double blue stripe	350
Normal glass, Schott-N16, made by Jenaer Glaswerk Schott and Genossen, Mainz.	Single red stripe	350
Normal glass, 7560, made by Corning Glass Co.	CN	350
Corning borosilicate glass, made by Corning Glass Co.	CB	450
Thermometric glass, Schott-2954, made by Jenaer Glaswerk Schott and Genossen, Mainz.	Single black stripe	460
Borosilicate glass, made by Whitefriars Glass Ltd.	Single white stripe	460
Corning glass, 1720, made by Corning Glass Co.	C1720	600
Schott-Supremax R8409, made by Jenaer Glaswerk Schott and Genossen, Mainz.	SPX 8409	600

NOTE The maximum temperatures given in the last column of the table are a guide to normal practice. The performance of a thermometer depends greatly on the stabilizing heat treatment which it has been given during manufacture, and a well-made thermometer of "normal glass" may be quite satisfactory for many purposes at temperatures as high as 400 °C. On the other hand, for the best accuracy it may be preferred to use one of the borosilicate glasses for temperatures lower than 350 °C. In general the lower the maximum temperature of use in relation to the approved temperature of the glass the better will be the "stability of zero" of the thermometer.

Appendix B Annealing and stabilization

Each thermometer should be thoroughly annealed and stabilized before graduation so that the required accuracy is not impaired by lack of zero stability during subsequent use throughout its temperature range.

Annealing is a prolonged heating to a certain maximum temperature, governed by the melting point of the glass, and very slow cooling over a period of many hours.

Stabilization is the further prolonged heating at a temperature in excess of the maximum scale temperature of the thermometer, but lower than the annealing temperature.

Appendix C Procedure for testing secondary reference thermometers

The following sequence of tests are carried out:

C.1 A preliminary inspection is made of all requirements specified in clauses **5**, **9** and **10**. It is also examined for visible defects such as flaws in the bulb glass or stem, detached liquid in the expansion chamber, gas trapped in the bulb, or a divided liquid column. Where possible, the faults are rectified before calibration, although usually such faults will cause the thermometer to be discarded.

C.2 A conveniently low point on the scale is checked at least three times over the course of three days to establish whether or not the indication is reproducible.

C.3 The thermometer (except series SR 1, 2, 3, 4, and SR 6/18) is then tested at the highest scale temperature by comparison with a platinum resistance thermometer or a suitable previously calibrated secondary reference thermometer. The point selected in **C.2** is re-determined at intervals of 24 ± 6 h after exposure of the thermometer to the highest scale temperature, and allowing it to cool naturally in air. This cycle is repeated to establish whether or not the thermometer has been adequately annealed and is stable.

C.4 The point selected in **C.2** is re-determined and the scale is then tested at a number of points by comparison with a platinum resistance thermometer or a suitable previously calibrated secondary reference thermometer. Any fixed points (e.g. 0 °C and 100 °C) within the range are determined separately. Generally, the lowest readings are determined first and then the test proceeds throughout the range as the temperature is raised. The first point is again determined after a suitable period (according to range) which may be 24 ± 6 h after exposure to the highest temperature observed.

C.5 Spirit thermometers should be cooled at approximately 1 °C per minute.

Appendix D Testing of British Standard thermometers

The National Physical Laboratory is prepared to accept thermometers for examination for compliance with this British Standard. Thermometers reported as complying with this British Standard may nevertheless be stated as having errors exceeding the requirements of clause **8** by amounts corresponding to the uncertainty of the test. (See Table 2.) Particulars of the fees charged can be obtained on application to the Director, National Physical Laboratory, Teddington, Middlesex TW11 0LW.

It is desirable that thermometers be re-tested at intervals not exceeding five years, or more frequently if determinations of the zero point or other suitable temperature indicate that re-testing is required. A change of one or two divisions does not necessarily indicate the need for a complete re-test as this may be due to a normal change in the volume of the bulb and can be allowed for by applying a correction equal to the zero change, throughout the scale. In the case of a thermometer with a contraction chamber between the zero and the main scale, the assumption that the described method of correction may be applied may not be valid in view of the possibility of a change in volume of the chamber. For this type of thermometer a complete re-test is preferred.

Table 2 — Uncertainty of test for British Standard secondary reference thermometers verified at the National Physical Laboratory

Designation mark	Range	Uncertainty of test
	°C	°C
SR1/30C	– 80 to + 30	± 0.2
SR2/2C	– 40 to + 2	± 0.05
SR3/20C	– 20 to + 20	± 0.02
SR4/1C	– 11 to + 1	± 0.01
SR4/11C	– 1 to + 11	± 0.005
SR5/20C	– 0.5 to + 0.5 and 9.5 to 20.5	± 0.005
SR5/30C	– 0.5 to + 0.5 and 19.5 to 30.5	± 0.005
SR5/40C	– 0.5 to + 0.5 and 29.5 to 40.5	± 0.005
SR5/50C	– 0.5 to + 0.5 and 39.5 to 50.5	± 0.005
SR5/60C	– 0.5 to + 0.5 and 49.5 to 60.5	± 0.01
SR5/70C	– 0.5 to + 0.5 and 59.5 to 70.5	± 0.01
SR5/80C	– 0.5 to + 0.5 and 69.5 to 80.5	± 0.01
SR5/90C	– 0.5 to + 0.5 and 79.5 to 90.5	± 0.01
SR5/100C	– 0.5 to + 0.5 and 89.5 and 100.5	± 0.01
SR6/18C	– 1 to + 18	± 0.01
SR6/34C	– 0.5 to + 0.5 and 16 to 34	± 0.01
SR6/51C	– 0.5 to + 0.5 and 33 to 51	± 0.01
SR6/68C	– 0.5 to + 0.5 and 50 to 68	± 0.02
SR6/85C	– 0.5 to + 0.5 and 67 to 85	± 0.02
SR6/102C	– 0.5 to + 0.5 and 84 to 102	± 0.02
SR7/51C	– 1 to + 51 and 99 to 101	± 0.02
SR7/101C	– 1 to + 1 and 49 to 101	± 0.02
SR8/151C	– 1 to + 1 and 99 to 151	± 0.05
SR8/201C	– 1 to + 1 and 149 to 201	± 0.05
SR8/251C	– 1 to + 1 and 199 to 251	± 0.1
SR9/202C	– 2 to + 2 and 98 to 202	± 0.05
SR10/302C	98 to 102 and 198 to 302	± 0.1
SR11/452C	98 to 102 and 198 to 452	± 0.2
SR12A/505C	95 to 505	± 0.5 overall when tested up to 450 °C ± 1 overall when tested up to 500 °C

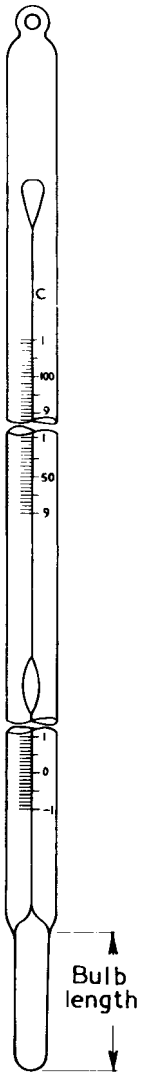

Figure 1 — Typical construction of a thermometer

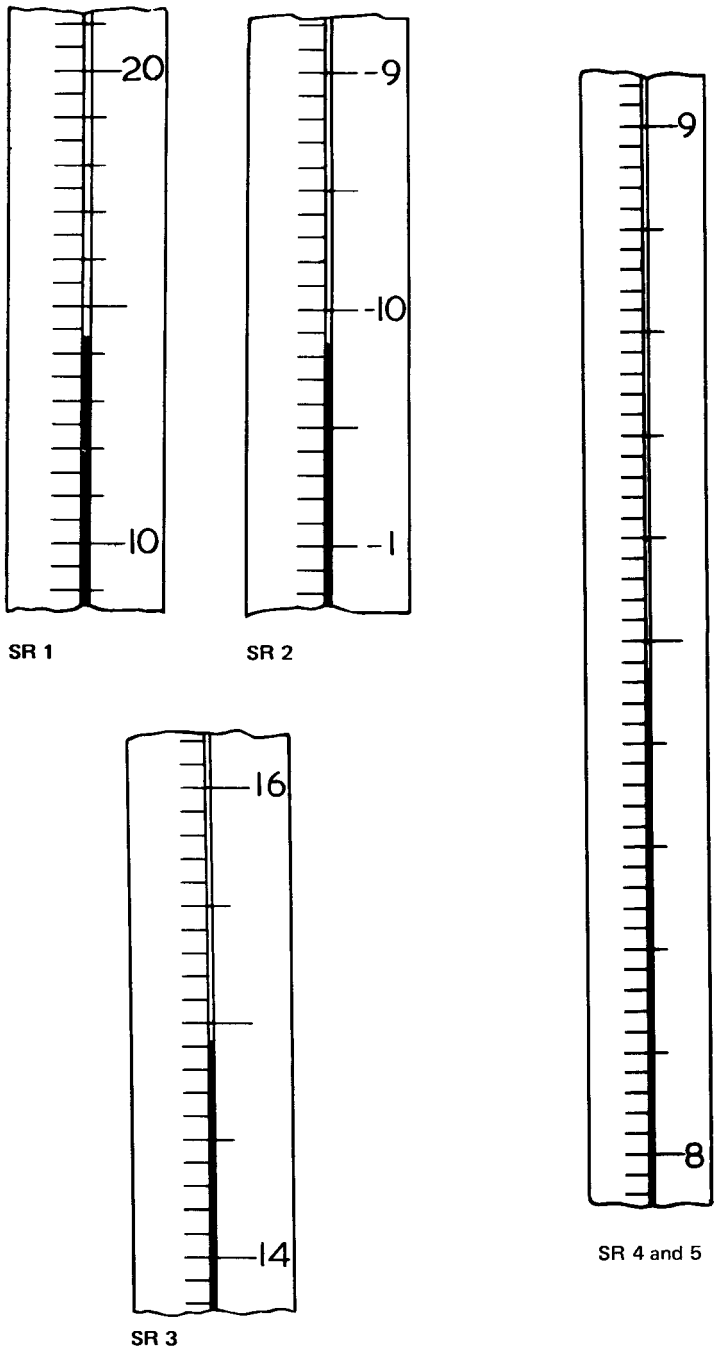

Figure 2 — Examples of graduation and figuring for secondary reference thermometers *(continued)*

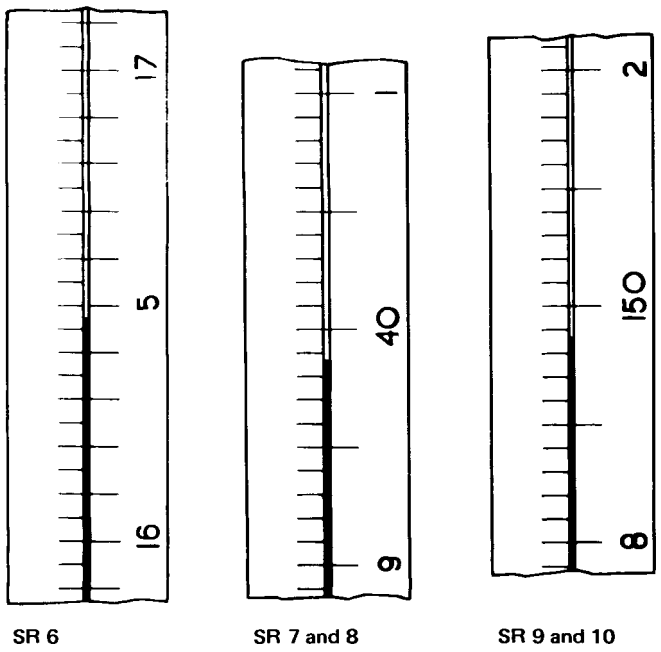

Figure 2 — Examples of graduation and figuring for secondary reference thermometers *(concluded)*

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