

NATIONAL STANDARD METHOD

GUIDANCE NOTE

TRACEABILITY AND USE OF THERMOMETERS IN UKAS ACCREDITED LABORATORIES

QSOP 10

Issued by Standards Unit, Evaluations and Standards Laboratory
Centre for Infections

Association of Medical Microbiologists
Association of Medical Microbiologists



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AMENDMENT PROCEDURE

Controlled document reference	QSOP 10
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Each National Standard Method has an individual record of amendments. The current amendments are listed on this page. The amendment history is available from standards@hpa.org.uk.

On issue of revised or new pages each controlled document should be updated by the copyholder in the laboratory.

Amendment Number/ Date	Issue no. Discarded	Insert Issue no.	Page	Section(s) involved	Amendment
5/ 14.08.07	3.2	4	All	Title	Liquid-glass removed from title
			8	Acknowledgements and Contacts	Revised and expanded
			17	References	References updated and transferred to Reference Manager software

TRACEABILITY AND USE OF THERMOMETERS IN UKAS ACCREDITED LABORATORIES

1 INTRODUCTION

This Guidance Note explains the UKAS requirements²⁻⁵ for the traceability of liquid-in-glass thermometers. Traceability in this context is defined as the ability to relate a measurement to the appropriate International Practical Temperature Scale (IPTS) through an unbroken chain of comparisons.

Some information on reading thermometers is given and errors which may arise are described. An example of the calculation of the uncertainty of measurement for working liquid-in-glass thermometers is illustrated.

2 CALIBRATION 130

Calibration of reference thermometers should be carried out every five years by a UKAS accredited calibration laboratory. A valid calibration certificate should be held for the reference thermometer.

The calibration certificate should be current and bear the UKAS logo or the identity of the national standards laboratory or logo of an accreditation body recognised by UKAS.

The certificate should also provide the required uncertainty of measurement suitable for the procedure that the reference thermometer is being used for.

In-house calibrations and checks should be carried out according to a documented procedure. The results and the estimate for the uncertainty of measurement should be recorded and retained.

NOTE: a thermometer should be calibrated at either a minimum of five evenly spaced temperatures or at intervals of 100 smallest scale divisions, covering 80% of the scale range.

3 REFERENCE THERMOMETERS

These should be of BS 593 specification and have a valid calibration certificate.

Re-calibration should be carried out at least once every 5 years. Some laboratories replace these instead or re-calibrating them due to the time and cost implications.

A check should be carried out at least once a year against the ice point or, exceptionally, some other appropriate reference point. This may be carried out in-house or by a UKAS accredited calibration laboratory. An example of a procedure for checking against the ice point is given in Appendix 1.

Reference thermometers should be kept secure in a suitable environment separate from working thermometers.

As a minimum it is recommended that laboratories hold one reference thermometer of the range 0°C to 60°C with 0.2°C divisions and one of the range 40°C to 70°C with 0.1°C divisions.

4 WORKING THERMOMETERS

Where the accuracy of temperature measurement has a significant bearing on the test result and is required to be controlled better than $\pm 0.1^{\circ}\text{C}$ laboratories may use a working thermometer with a valid UKAS or NPL certificate or calibrate the working thermometer in-house against a reference thermometer held by the laboratory⁴. Such a working thermometer should be of the appropriate range for the temperature measurements it is intended to control.

A check should be carried out at least once a year against the ice point or, exceptionally, some other appropriate reference point such as the temperature that the thermometer is being used to monitor (eg 37°C). In the latter case, where the working thermometer is held in liquid (eg in a waterbath) the reference thermometer should also be placed in the liquid. When calibrating against reference points the reference thermometer and the working thermometer should be placed in close proximity to optimise the accuracy of calibration.

NOTE: if a thermometer is used to monitor a particular temperature (eg 37°C) the calibration check should be made within five smallest scale divisions of that temperature.

Re-calibration should be carried out after 5 years or sooner if the annual checks at the reference point reveal a significant change (eg $> 0.1^{\circ}\text{C}$) has occurred.

NOTE: a change of about 0.04°C in the first year may be due to normal changes in the bulb volume. This correction factor should be taken account of when making temperature measurements with the thermometer⁴.

For new working thermometers reference point checks should be carried out at intervals not exceeding 6 months in the first year.

Where the accuracy of temperature measurement does not have a significant bearing on the test result (ie when temperature control does not need to be better than $\pm 0.1^{\circ}\text{C}$) laboratories may use a BS 593 thermometer.

5 CALCULATION OF THE UNCERTAINTY OF MEASUREMENT FOR WORKING THERMOMETERS

Tolerances should be set and should take into account the uncertainty of measurement for critical temperature monitoring. This can be calculated in a number of ways depending on whether or not a reference thermometer is used directly in the waterbath or incubator in question. Illustrative examples are given in the tables below.

Table 1: When a calibrated reference thermometer is used directly in a waterbath or incubator

Reference thermometer uncertainty of measurement (expanded uncertainty – see Appendix 2)	$\pm 0.05^{\circ}\text{C}$
Test tolerance	$44^{\circ}\text{C} \pm 0.25^{\circ}\text{C}$
Acceptable range for test	43.75°C to 44.25°C
New working tolerance for test	$44^{\circ}\text{C} \pm (0.25 - 0.05)$ $= 44^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$
New acceptable range for test	43.8°C to 44.2°C

NOTE: this calculation may be performed using the Excel programme “uofm3.xls.”
www.hpa-standardmethods.org.uk/documents/qsop/pdf/uofm3.xls

Table 2: When a thermometer that is not a calibrated reference thermometer is used in a waterbath or incubator

Working thermometer uncertainty of measurement(expanded uncertainty - see Appendix 3)	$\pm 0.12^{\circ}\text{C}$
Test tolerance	$44^{\circ}\text{C} \pm 0.25^{\circ}\text{C}$
Acceptable range for test	43.75°C to 44.25°C
New working tolerance for test (see Appendix 4)	$44^{\circ}\text{C} \pm (0.25 - 0.12)$ $= 44^{\circ}\text{C} \pm 0.13^{\circ}\text{C}$ $\cong 44^{\circ}\text{C} \pm 0.1^{\circ}\text{C}$
New acceptable range for test	43.9°C to 44.1°C

NOTE: this calculation may be performed using the Excel programme www.hpa-standardmethods.org.uk/documents/qsop/pdf/uofm3.xls

Further information on calculating uncertainty of measurement may be found in M3003⁵.

6 RESOLUTION OF READING (LIQUID-IN-GLASS THERMOMETERS ONLY)

When reading a thermometer an uncertainty needs to be taken account of when the meniscus falls between two intervals on the scale (see Appendix 5).

If the meniscus falls between two intervals and is above the target temperature the reading should be made up to the nearest interval.

If the meniscus falls between two intervals and is below the target temperature the reading should be made DOWN to the nearest interval.

NOTE: most thermometers are used vertically unless otherwise specified. If a thermometer is held horizontally instead of vertically the internal pressure increases which results in a higher reading.

7 PARALLAX (LIQUID-IN-GLASS THERMOMETERS ONLY)

Errors due to parallax arise if the meniscus is not viewed with the eye normal to the stem (see Appendix 6). The size of the error depends on the angle between the normal and the incorrect line of sight, separation of the capillary and the graduation lines.

If necessary, errors may be reduced by using an optical aid, such as a lens held almost in contact with the thermometer.

8 IMMERSION (LIQUID-IN-GLASS THERMOMETERS ONLY)

The condition of immersion (usually engraved on the stem) should be observed. There are three forms of immersion – total, partial and complete.

Total immersion – the bulb and the liquid column are immersed so that only 1mm of the column protrudes to enable temperature readings to be made. This form of immersion gives the most accurate temperature readings.

Partial immersion – the thermometer is immersed to a specified depth (usually engraved on the stem). This form of immersion produces uncertainties in temperature readings usually twice that of total immersion.

Complete immersion – the entire body of the thermometer is immersed which causes the internal gas pressure to be affected by the temperature of the medium.

9 ACKNOWLEDGEMENTS AND CONTACTS

This National Standard Method has been developed, reviewed and revised by the National Standard Methods Working Group (http://www.hpa-standardmethods.org.uk/working_groups.asp). The contributions of many individuals in clinical bacteriology laboratories and specialist organisations who have provided information and comment during the development of this document, and final editing by the Medical Editor are acknowledged.

The National Standard Methods are issued by Standards Unit, Evaluations and Standards Laboratory, Centre for Infections, Health Protection Agency London.

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APPENDIX 1: ICE POINT CHECK

- 1 Fill a container with finely crushed ice.
- 2 Add sufficient distilled or deionised water to produce a dense slurry.
- 3 Mix the ice and water carefully using a suitable stirrer to obtain a consolidated ice-water mixture. The surface of the mixture should take on a grey rather than white appearance. There should be sufficient water present so that manual compression of the ice at the surface causes a corresponding swell of water without a tendency for the ice to float.
- 4 Place the reference thermometer in the ice/water mix. Gently lift it and lower it again to ease any pressure build-up.

NOTE: The bulb has a thin wall to improve the speed of response to temperature changes. It is also fragile. If pressure is applied the bulb volume is reduced which causes the liquid column to rise⁴.

- 5 Leave for 1 minute for the reading on the thermometer to stabilise.
- 6 Tap the thermometer gently to minimise any sticking of the meniscus.
- 7 Record the reading on the appropriate record sheet.
- 8 The reference thermometer should give a reading of 0°C. If there is a difference of $\pm 0.1^\circ\text{C}$ or more the thermometer should be recalibrated.

APPENDIX 2: CALCULATION OF THE UNCERTAINTY OF MEASUREMENT FOR A CALIBRATED REFERENCE THERMOMETER USED DIRECTLY IN A WATERBATH OR INCUBATOR

Thermometer	Input quantity	Source of uncertainty	Value ±	Probability distribution	Divisor	Standard uncertainty (u) ± °C	u ²
Reference thermometer	x ₁	Uncertainty of reference thermometer (from calibration certificate)	0.03	Normal	2	0.0150	0.0002
	x ₂	Correction factor (from calibration certificate)	0.03	Rectangular	$\sqrt{3}$	0.0173	0.0003
	x ₃	Drift since last calibration or ice point	0	Rectangular	$\sqrt{3}$	0	0
	x ₄	Resolution of reading	0	Rectangular	$\sqrt{3}$	0	0
	x ₅	Immersion differences (non-uniformity of bath)	0	Rectangular	$\sqrt{3}$	0	0
	x ₆	Emergent column temp correction	0	Normal	2	0	0
	x ₇	Repeatability	0	Normal	1	0	0
	u_c (T)	Combined standard uncertainty		Normal		0.0229	
	U	Expanded uncertainty		Normal (k=2)		0.0458	

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$$\begin{aligned}
 u_c(T) &= \sqrt{u_1^2 + u_2^2 + u_3^2 + u_4^2 + u_5^2 + u_6^2 + u_7^2} \\
 &= \sqrt{0.0002 + 0.0003} \\
 &= \sqrt{0.0005} \\
 &= 0.0229
 \end{aligned}$$

$$\begin{aligned}
 U &= u_c(T) \times 2 \\
 &= 0.0229 \times 2 \\
 &= 0.0458
 \end{aligned}$$

Result

Uncertainty of measurement of thermometer = ± 0.05 °C

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor of $k=2$, providing a level of confidence of 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements

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APPENDIX 3: CALCULATION OF THE UNCERTAINTY OF MEASUREMENT FOR A THERMOMETER THAT IS NOT A CALIBRATED REFERENCE THERMOMETER USED IN A WATERBATH OR INCUBATOR

Thermometer	Input quantity	Source of uncertainty	Value ±	Probability distribution	Divisor	Standard uncertainty (u) ± °C	u ²
Reference thermometer	x ₁	Uncertainty of reference thermometer (from calibration certificate)	0.03	Normal	2	0.0150	0.0002
	x ₂	Correction factor (from calibration certificate)	0.03	Rectangular	$\sqrt{3}$	0.0173	0.0003
	x ₃	Drift since last calibration or ice point	0	Rectangular	$\sqrt{3}$	0	0
	x ₄	Resolution of reading	0	Rectangular	$\sqrt{3}$	0	0
	x ₅	Immersion differences (non-uniformity of bath)	0	Rectangular	$\sqrt{3}$	0	0
	x ₆	Emergent column temp correction	0	Normal	2	0	0
	x ₇	Repeatability	0	Normal	1	0	0
Working thermometer	x ₈	Correction factor of working thermometer (obtained from comparison of working thermometer against reference thermometer)	0.1	Rectangular	$\sqrt{3}$	0.0577	0.0033
	x ₉	Drift since last calibration or ice point	0	Rectangular	$\sqrt{3}$	0	0
	x ₁₀	Resolution of reading	0	Rectangular	$\sqrt{3}$	0	0
	x ₁₁	Emergent column temp correction	0	Rectangular	$\sqrt{3}$	0	0
	x ₁₂	Repeatability	0	Normal	1	0	0
	u_c (T)	Combined standard uncertainty		Normal		0.0621	
	U	Expanded uncertainty		Normal (k=2)		0.1242	

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$u_c(T) = \sqrt{u_1^2 + u_2^2 + u_3^2 + u_4^2 + u_5^2 + u_6^2 + u_7^2 + u_8^2 + u_9^2 + u_{10}^2 + u_{11}^2 + u_{12}^2}$ $= \sqrt{0.0002 + 0.0003 + 0.0033}$ $= \sqrt{0.0038}$ $= 0.0621$ $U = u_c(T) \times 2$ $= 0.0621 \times 2$ $= 0.1242$	<p>Result <i>Uncertainty of measurement of thermometer = $\pm 0.12^\circ\text{C}$</i></p> <p><i>The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor of $k=2$, providing a level of confidence of 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements</i></p>
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NOTES (applicable to Appendices 2 and 3):

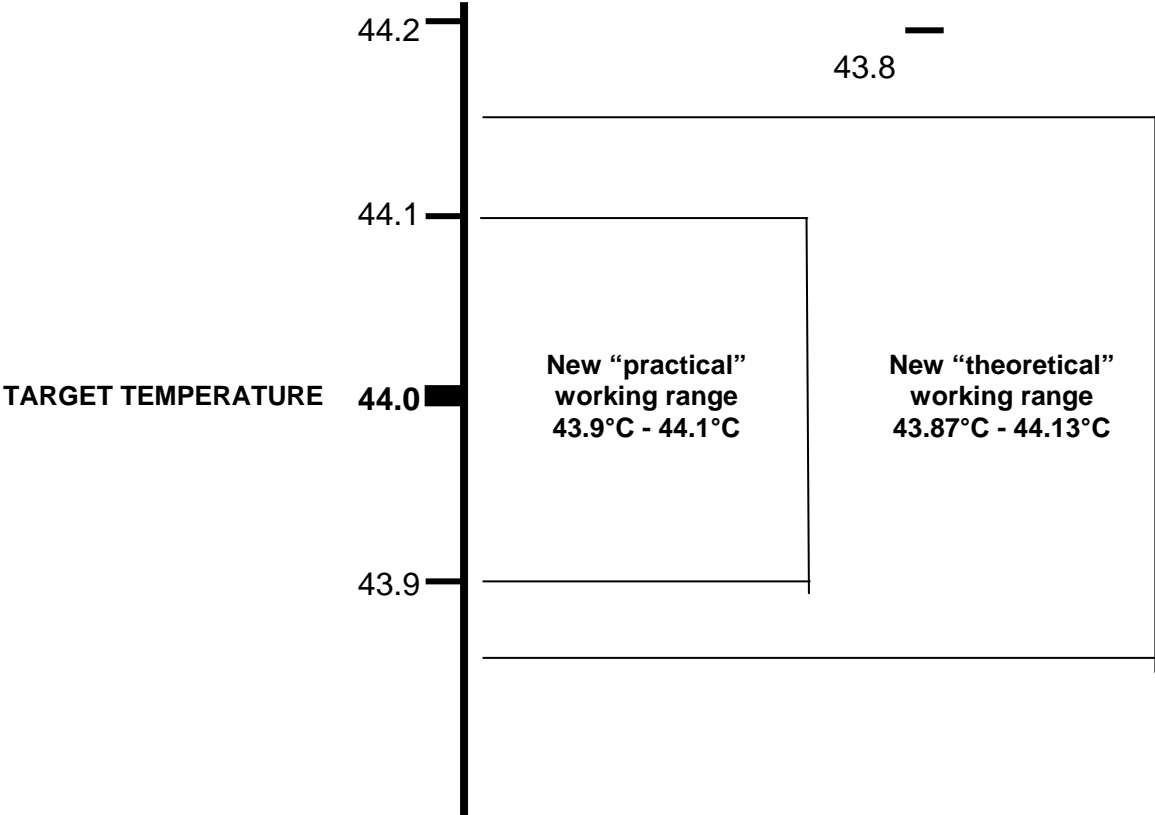
Correction factor (x_2 and x_8) – if this is not applied in the reading then it must be included in the uncertainty budget

Resolution of reading (x_4 and x_{10}) – this is 0 if taken account of when reading the thermometer – see section 6 and Appendix 5. For digital thermometers the resolution of reading will need to be taken account of in the calculation (eg 0.1°C)

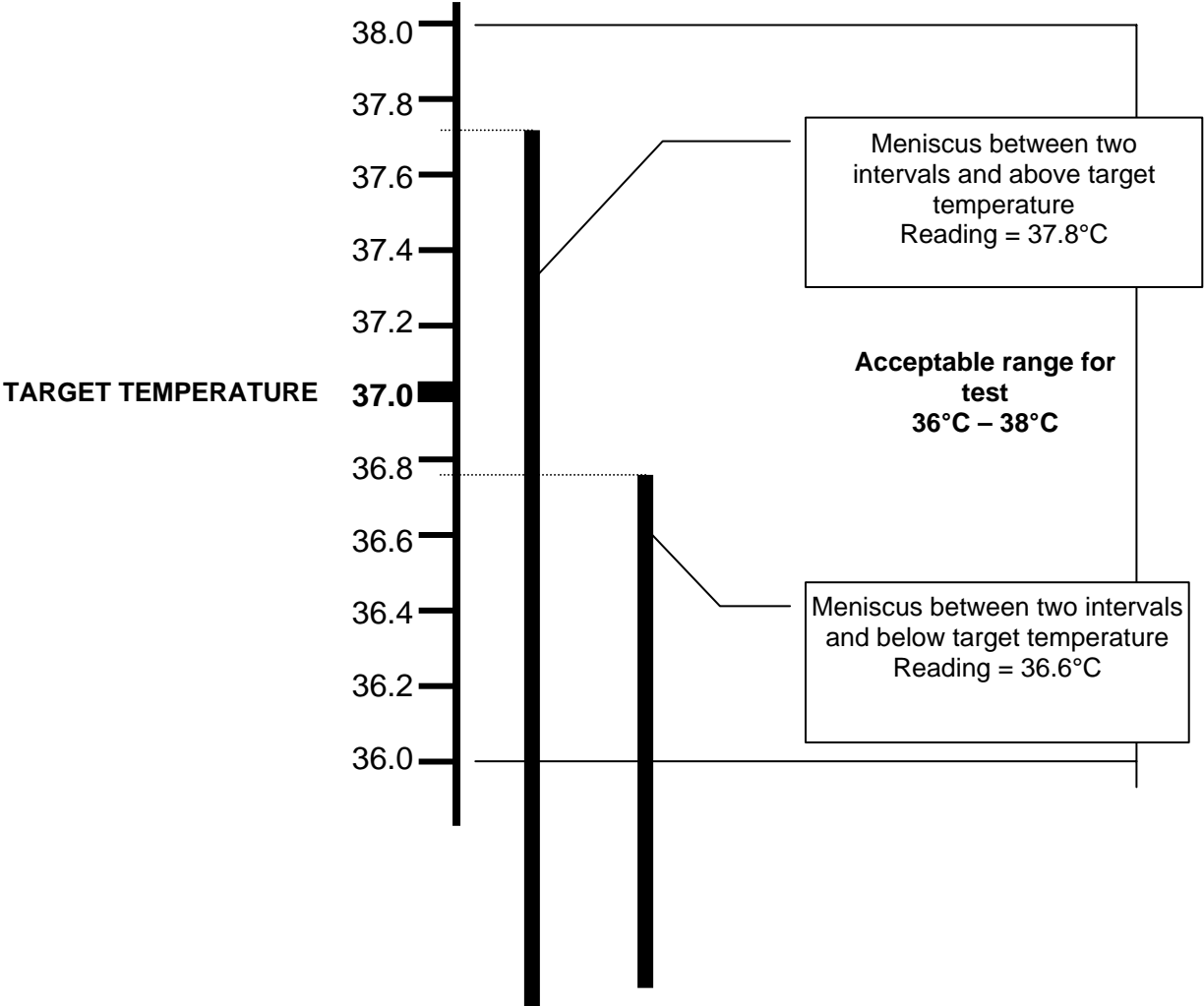
Emergent column temp correction (x_6 and x_{11}) – if a partial immersion thermometer is used a correction should be applied for any differences in the emergent column temperature, as measured, to that stated on its calibration certificate. If this correction is not made then the value must be included in the uncertainty budget

Repeatability (x_7 and x_{12}) – a number of readings (n) should be taken (at least 3) and the standard deviation of these readings calculated. Then divide the Standard deviation by \sqrt{n}

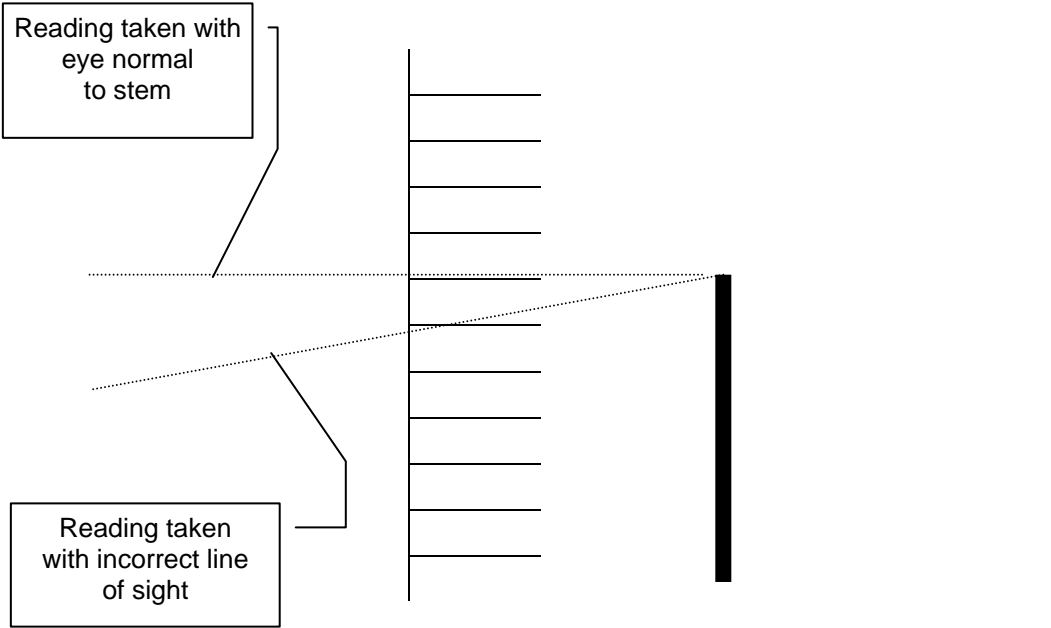
APPENDIX 4: SETTING WORKING TEMPERATURE RANGES



APPENDIX 5: TAKING ACCOUNT OF THE RESOLUTION OF READING



APPENDIX 6: ERROR ASSOCIATED WITH PARALLAX



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