CALISTO 2250 S
EVALUATION REPORT
ISSUE 01

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Calisto 2250S Evaluation Report

Product Data Issue Date: 23 Jan 1999

An evaluation report of the Calisto 2250S (Serial Number 2250/1) metal block bath manufactured by Isothermal Technology Ltd.

Introduction

The Calisto 2250S is part of the ISOCAL-6 family of products. It can be used as a dry-block, liquid bath, ITS-90 fixed point device, black body and surface probe calibrator.

At Isotech it is our earnest desire to present for our customers consideration as much useful information as possible and to this end we have spent a substantial amount of time evaluating our products.
The results of the evaluation of a bath can be presented in many formats some of which will give an optimistic or indeed a pessimistic view of how the product operates. This evaluation report is based on the DKD-R5-4 document. The evaluation based on the DKD document presents almost the worse case error that may occur within the bath. With some care and proper procedures it is possible to improve considerably upon these uncertainties. We have therefore presented a second evaluation based on the best practice as an Appendix to the evaluation.

Summary of Performance

Metal Block Mode, Option 1, Site Model

TEMPERATURE °C	STABILITY ± ° C	RADIAL HOMOGENEITY	AXIAL HOMOGENEITY	UNCERTAINTY*
30 125 250	0.02 0.02 0.03	0.001 0.002 0.018	0.004 0.21 0.25	0.15 0.31 0.33

Liquid Mode, Option 2, Site Model

TEMPERATURE °C	STABILITY ± ° C	RADIAL HOMOGENEITY	AXIAL HOMOGENEITY	UNCERTAINTY*
30 125 250	0.02 0.02 0.04	0.001 0.014 0.011	0.008 0.013 0.015	0.15 0.16 0.20

* Uncertainty is calculated, for the spread k = 2, which is the combined uncertainty x 2
and equivalent to a confidence level of approximately 95% (2 Sigma)

ITS-90 Fixed Point Mode, Option 6

Fixed Point	UNCERTAINTY
Gallium, 29.7646°C Indium, 156.5985°C	0.001°C 0.001°C

Best Accuracy, Comparison Mode

Two sensors of different construction and diameter, good practice, using stirred oil, option 2, and external high accuracy temperature indicator such as Isotech TTI 2

ISOCND Oil

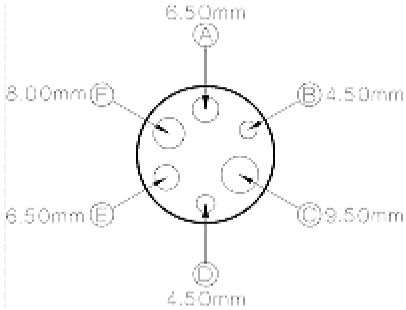
909/1144	53HT 1193	Difference
	30.232°C 124.827°C 249.729°C	-0.001°C -0.002°C 0.01

Metal Insert

909/1144 8mm Hole	**53HT 1193** 6.5mm Hole	**Difference**
30.243°C 125.160.°C 250.176°C	30.253°C 125.120°C 250.127°C	-0.01°C 0.04°C 0.049

Evaluation with Metal Insert

AXIAL TEMPERATURE HOMOGENEITY



Axial Temperature Homogeneity: The axial temperature distribution is measured at three different temperatures representative of the field of application and covering the extreme temperatures that may occur. A suitable thermometer is used, the sensor length not exceeding 5mm. At least six different measurements per bore are carried out in the calibration zone and adjoining parts of the bore, the distance between measurement points being 1cm.

TEST METHOD

Two 935-14-61 [3] (designed for small stem conduction) were placed in each of the 4.5mm holes. One probe was raised in 1cm steps (Pocket B) and the temperature difference between it and the static probe at the bottom of pocket D was recorded.

AXIAL TEMPERATURE HOMOGENEITY: 30°C

DISTANCE FROM BOTTOM OF INSERT POCKET, CM	TEMPERATURE DIFFERENCE D T=TD-TB °C
0	0.000
1	0.000
2	0.002
3	0.001
4	0.001
5	-0.001
6	-0.002
(0 Repeat)	0.000

At 30°C the Maximum Variation over 50mm Zone was 0.004° C
(This includes the measurement error and stem conduction)

AXIAL TEMPERATURE HOMOGENEITY: 125°C

DISTANCE FROM BOTTOM OF INSERT POCKET, CM POCKET D	TEMPERATURE DIFFERENCE D T=TD-TB °C
0	0.000
1	0.005
2	0.034
3	0.017
4	0.035
5	0.21
6	0.548
(0 Repeat)	0.004

At 125°C the Maximum Variation over 50mm Zone was 0.21°C
(This includes the measurement error and stem conduction)

AXIAL TEMPERATURE HOMOGENEITY: 250°C

DISTANCE FROM BOTTOM OF INSERT POCKET, CM POCKET D	TEMPERATURE DIFFERENCE D T=TD-TB °C
0	0.000
1	0.092
2	0.168
3	0.237
4	0.295
5	0.275
6	-0.214
(0 Repeat)	0.001

At 250° C the Maximum Variation over 50mm Zone was 0.23° C
(This includes the measurement error and stem conduction)

RADIAL TEMPERATURE HOMOGENEITY

Radial Temperature Homogeneity: The temperature differences between the zones in the individual bores provided for the measurements are measured with a suitable thermometers at three different temperatures representative of the field of application and covering the extreme temperatures which may occur.
TEST METHOD
Two 935-14-61 [3] thermometers (designed for small stem conduction) were placed in each of the 4.5mm holes. Measurements were recorded and then the probes were moved between the two pockets and repeat measurements made. The temperature, Δ t, was calculated to remove the small offsets between the two probes.

$\Delta t = ¼[(t_{AAB} - t_{AAD}) + (t_{ZZB} - t_{ZZD})]$

Temperature, °C	Δ t
30	0.001°C
125	0.002°C
250	0.018°C

Loading Effects

Influence upon radial temperature homogeneity due to different loading: A suitable thermometer is placed into the bore located next to the largest bore. The change in temperature is measured which results when a solid metal rod is introduced into the largest bore which protrudes from the bore by at least 200mm. The measurement is to be carried out at three different temperatures representative of the field of application and covering the extreme temperatures that may occur.

TEST METHOD
Isothermal Technology recommends an external probe is used to determine the insert temperature. For this test the recommended probe model 935-14-81, is connected to the built in indicator of the site model. A second thermometer is introduced to measure the insert temperature independently. A metal rod 340mm long and 9mm diameter is placed in pocket C.

Insert Temperature, 30°C

	No Rod	Δ t	Rod Added	Δ t	Change
909/1144+TTI 2	30.031°C		30.001°C		
935-14-81+Site Indicator (In Built)	29.9°C	0.131	29.9°C	0.11	0.021

Although the block temperature is influenced by loading the Calisto's separate PRT and in built indicator compensates such that errors due to loading are eliminated.

Insert Temperature, 125°C

	No Rod	Δ t	Rod Added	Δ t	Change
909/1144+TTI 2	124.969 °C		124.698°C		
935-14-81+Site Indicator (In Built)	124.9°C	0.069	124.7°C	-0.002	0.067

Although the block temperature is influenced by loading the Calisto's separate PRT and in built indicator compensates such that errors due to loading are eliminated.

Insert Temperature, 250°C

	No Rod	Δ t	Rod Added	Δ t	Change
909/1144+TTI 2	250.357 °C		249.926°C		
935-14-81+Site Indicator (In Built)	250.2°C	0.157	249.8°C	-0.126	0.031

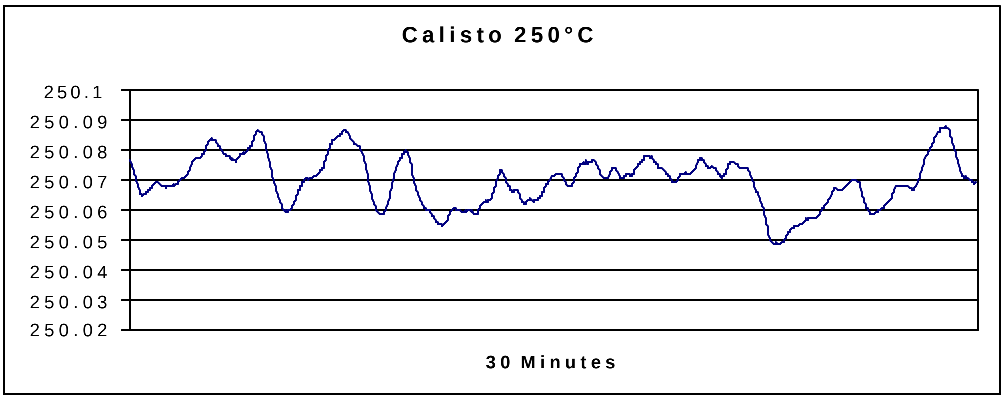
Although the block temperature is influenced by loading the Calisto's separate PRT and in built indicator compensates such that errors due to loading are eliminated.

Stability with Time

Stability with time: The variation of temperature with time in the zones in the individual bores provided for measurements must be sufficiently small. The temperature variations are considered to be sufficiently small when the greatest temperature difference occurring within 30 minutes is smaller than or, equal to, half the uncertainty of the measurement stated.

Stability at 30° C, 30 minute period, ± 0.02° C
Stability at 125° C, 30 minute period, ± 0.02° C
Stability at 250° C, 30 minute period, ± 0.03° C

TEST METHOD
A 935-14-61 thermometer was placed into one of the 4.5mm holes. The probe was connected to a TTI 2 precision temperature indicator [5] and the variation in temperature was recorded for a 30-minute period. The ambient temperature was within 23°C ± 3°C.



PROBE AGEING
An s.p.r.t. (909/1144) was placed in the insert along with the reference probe, both probes connected to a precision temperature indicator model TTI 2. The Calisto was set to the maximum operating temperature of 250° C and the difference between the two probes was recorded at two periods ten hours apart. The difference in value was 0.002°C, 2 mK.

HYSTERESIS (REPEATABILITY)
The Calisto was set to 30°C and the actual temperature along with the value for the in-built temperature indicator was recorded, then the temperature was raised to 250°C for two hours. The temperature was then reset to 30°C and repeat measurements made. The difference was within the resolution of the indicator: - 0.1°C

HEAT UP TIME - Insert
30°C to 250°C - 22 minutes.

COOL DOWN TIME - Insert

250°C to 50°C – 24 minute Ambient 22°C

Evaluation with Stirred Oil Tank

AXIAL TEMPERATURE HOMOGENEITY

Axial Temperature Homogeneity: The axial temperature distribution is measured at three different temperatures representative of the field of application and covering the extreme temperatures that may occur. A suitable thermometer is used, the sensor length not exceeding 5mm. At least six different measurements are carried out in the calibration zone and adjoining parts, the distance between measurement points being 1cm.

TEST METHOD

Two 935-14-61 [3] (designed for small stem conduction) were placed in a holder such that the two probes were spaced 10mm apart. The probes were arranged to be 15mm from the base of the stirred oil tank. The mid point between the probes was over the centre of the oil tank. One probe was raised in 1cm steps and the temperature difference between it and the static probe was recorded.

AXIAL TEMPERATURE HOMOGENEITY: 30°C – ISODC202

dL, CM	TEMPERATURE DIFFERENCE D T=TD-TB °C
0	0.000
1	0.001
2	-0.001
3	0.000
4	-0.003
5	-0.003
6	-0.007
(0 Repeat)	0.000

At 30°C the Maximum Variation over 60mm Zone was 0.008° C
(This includes the measurement error and stem conduction)

AXIAL TEMPERATURE HOMOGENEITY: 125°C – ISO-CND Oil

dL, CM	TEMPERATURE DIFFERENCE D T=TD-TB °C
0	0.000
1	0.001
2	0.004
3	0.005
4	0.008
5	0.011
6	0.009

(0 Repeat)	-0.002

At 125°C the Maximum Variation over 60mm Zone was 0.013° C
(This includes the measurement error and stem conduction)
AXIAL TEMPERATURE HOMOGENEITY: 250°C – ISO-CND Oil

dL, CM	TEMPERATURE DIFFERENCE D T=TD-TB °C
0	0.000
1	0.007
2	0.010
3	0.011
4	0.013
5	0.007
6	0.005
(0 Repeat)	-0.002

At 250°C the Maximum Variation over 60mm Zone was 0.015° C
(This includes the measurement error and stem conduction)

RADIAL TEMPERATURE HOMOGENEITY

Radial Temperature Homogeneity: The radial temperature differences are measured with a suitable thermometers at three different temperatures representative of the field of application and covering the extreme temperatures which may occur.

TEST METHOD
Two 935-14-61 [3] (designed for small stem conduction) were placed in a holder such that the two probes were spaced 10mm apart. The probes were arranged to be 15mm from the base of the stirred oil tank. The mid point between the probes was over the centre of the oil tank. After measurements were recorded the probes were swapped between positions and then repeat measurements were made.

The temperature, Δ t, was calculated to remove the small offsets between the two probes.

$\Delta t = \frac{1}{4}[(t_{AAB} - t_{AAD}) + (t_{ZZB} - t_{ZZD})]$

Temperature, °C	Δ t
30 ISODC202	0.001°C
125 ISOCND Oil	0.014°C
250 ISCCND Oil	0.011°C

Loading Effects

Influence upon radial temperature homogeneity due to different loading: A suitable thermometer is placed into the liquid. The change in temperature is measured which results when a solid metal rod is introduced which protrudes from the liquid by at least 200mm. The measurement is to be carried out at three different temperatures representative of the field of application and covering the extreme temperatures that may occur.

TEST METHOD
Isothermal Technology recommends an external probe is used to determine the liquid temperature. For this test the recommended probe model 935-14-81, is connected to the built in indicator of the site model. A second thermometer is introduced to measure the insert temperature independently. A metal rod 340mm long and 9mm diameter is later placed in the liquid.

Liquid Temperature, 30°C

	No Rod	Δ t	Rod Added	Δ t	Change
909/1144+TTI 2	30.056 °C		29.999°C		
935-14-81+Site Indicator (In Built)	29.9°C	0.156	29.8°C	0.199	-0.043

Although the block temperature is influenced by loading the Calisto's separate PRT and in built indicator compensates such that there is,

No additional error due to loading at 30° C

Liquid Temperature, 125°C ISOCND Oil

	No Rod	Δ t	Rod Added	Δ t	Change
909/1144+TTI 2	124.927°C		125.563°C		
935-14-81+Site Indicator (In Built)	125.0°C	-0.073	124.6°C	-0.037	0.036

Although the block temperature is influenced by loading the Calisto's separate PRT and in built indicator compensates such that there is,

No additional error due to loading at 125° C

Liquid Temperature, 250°C ISOCND Oil

	No Rod	Δ t	Rod Added	Δ t	Change
909/1144+TTI 2	250.030°C		248.892°C		
935-14-81+Site	250.1°C	-0.07	248.9°C	-0.008	0.062

Indicator (In Built)					

Although the block temperature is influenced by loading the Calisto's separate PRT and in built indicator compensates such to within 0.1°C, the resolution of the indicator.

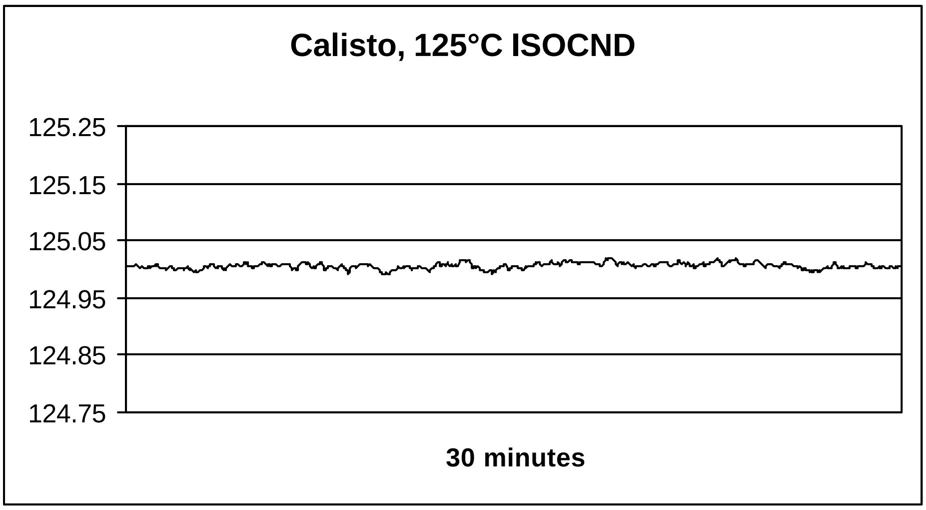
Additional error due to loading at 250°C within resolution of indicator, 0.1

Stability with Time

Stability with time: The variation of temperature with time must be sufficiently small. The temperature variations are considered to be sufficiently small when the greatest temperature difference occurring within 30 minutes is smaller than or, equal to, half the uncertainty of the measurement stated.

Stability at 30° C, 30 minute period, ± 0.02° C ISODC202 Oil
Stability at 75° C, 30 minute period, ± 0.02°C Water
Stability at 125° C, 30 minute period, ± 0.02°C ISOCND Oil
Stability at 250° C, 30 minute period, ± 0.04°C ISOCND Oil

TEST METHOD
A 935-14-61 thermometer was placed in the centre of the liquid with the tip 15mm above the tank base. The probe was connected to a TTI 2 precision temperature indicator [5] and the variation in temperature was recorded for a 30-minute period. The ambient temperature was within 23°C ± 3°C.



PROBE AGEING and HYSTERESIS (REPEATABILITY) values are taken from work done with the metal insert, see earlier.

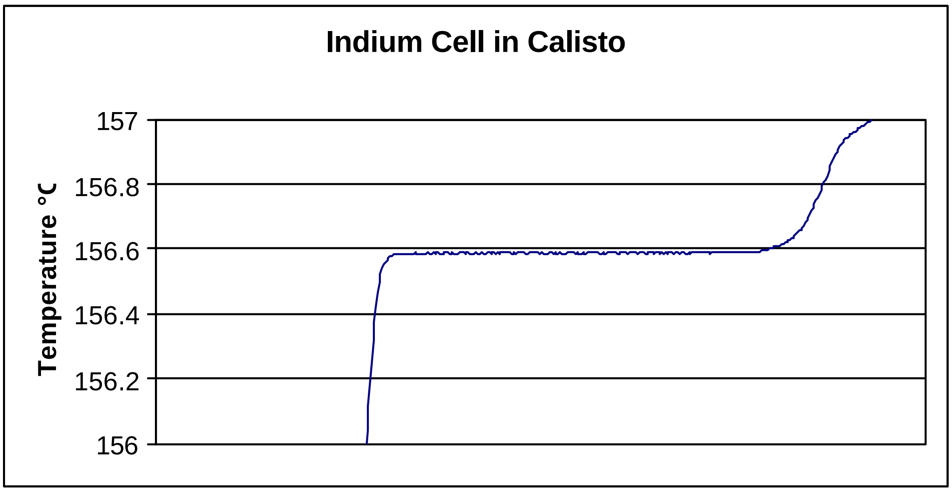
Use with Fixed Points

Isocal Fixed Point Cells

Fixed Point Cells provide fixed point calibration. The International Temperature Scale, ITS-90, specifies for the range -38 to 962°C values for the melting, freezing or triple points of a metal (or water for the water triple point, 0.01°C).
The freezing point of a metal can be defined with great accuracy. The accuracy comes not from the precision of electronic or other artificial means but from the purity of a metal and the physics of latent heat.
Using a fixed point cell with the Calsisto is simple. The cell is placed into the well and thermometers to be calibrated are then placed in turn into the cell. As the cell changes state, from a solid to a liquid the temperature remains constant and known - a fundamental constant of nature.
IsoCal-6 Fixed Point Cells are built with the same materials and techniques as the larger cells that Isotech manufactures for Primary Standards Laboratories but the smaller size of the cells make them more affordable and practical for the industrial laboratory. For the industrial laboratory IsoCal-6 cells provide fixed point reference standards, useful for checking the labs reference thermometers.

Indium Cell

Indium has a phase transition of 156.5985°C. For convenience the cells are used with the melting point. For a short and well-defined melting point plateau the cell is placed centrally into the Calisto's well. The temperature is set for 158.4, a metal ring is placed over the cell re-entrant tube and insulation is added both below and above this ring. Oil may optionally be used inside the cell for improved heat transfer to the thermometer being calibrated. Typically one hour after switch on a 2 hour plateau will be achieved, see chart.

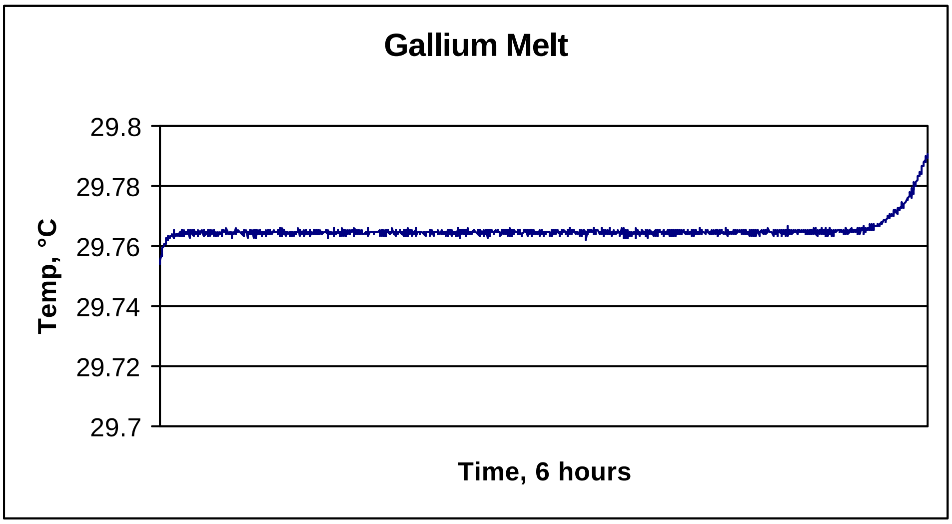


Two Hour Plateau starts 1 hour from switch on – longer plateaux are achieved by lowering the Calisto temperature but for industrial probes a shorter "sharper" plateau is generally preferred.

Gallium Cell

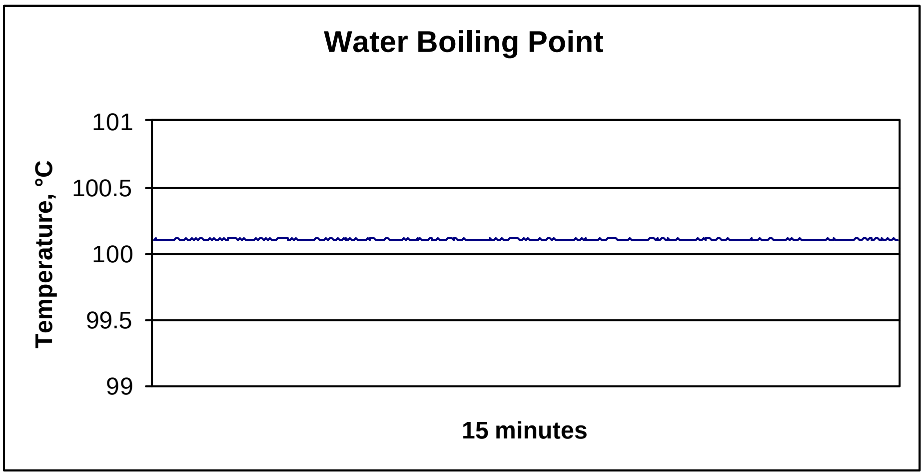
Gallium has a melting point of 29.7646°C. for a well defined melting point plateau the cell is placed centrally into the Calisto's well and the top is insulated as for the Indium cell. The temperature is set for 1.6°C above the melting point. Water is used inside the cell for improved heat transfer to the thermometer being calibrated.

A 6 Hour plateau started 40 minutes from switch on.



Two Hour Plateau starts 1 hour from switch on – longer plateaux are achieved by lowering the Calisto temperature but for industrial probes a shorter "sharper" plateau is generally preferred. Cell Ga267

Water Boiling Point



The boiling point of water is not a defining point of the temperature scale. The boiling point of water is 99.975°C (ITS-90). Variations in water purity and pressure will alter boiling point and for fixed point calibration the gallium and Indium Fixed points are strongly preferred for absolute calibration with the Calisto. However the ease of use and readily availability of water does allow for simple checking of probes at the boiling point of water.

In use the stirred oil tank is fitted and filled 2/3 full with water, at the boiling point water is added with carefully to the desired level. A loose fitting metal disk sits on top of the tank drilled to accept the probe or probes. The temperature stability is in the order of +/-0.006°C over a 15-minute period.

Uncertainty Calculations

1, With Metal Insert

Standard Insert, ambient 23+/-3°C.
909/1144, TTI2/2.

Set point =30°C

SOURCE OF UCT	DETERMINATION OF UCT	PROBABILITY DISTRIBUTION	UNCERTAINTY ° C	DIVISOR	ui(t), ° C
Standard Thermometer including measurement with standard thermometer	NAMAS Schedule	Normal	0.05	1	0.05
Axial Temperature distribution	This evaluation report	Rectangular	0.004	√ 3	0.0023
Radial Temperature distribution	This evaluation report	Rectangular	0.001	√ 3	0.00058
Loading of block	This evaluation report	Rectangular	0	√ 3	
Stability with time	This evaluation report	Rectangular	0.02	√ 3	0.0115
Ageing of reference thermometer	This evaluation report	Rectangular	0.002	√ 3	0.0012
Repeatability (Hysteresis)	This evaluation report	Rectangular	0.1*	√ 3	0.058
Combined Uct		k=1			0.08
Expanded Uct		k=2			0.15

* Resolution of indicator.

Standard Insert, ambient 23+/-3°C. 909/1144, TTI2/2.

Set point =125°C

SOURCE OF UCT	DETERMINATION OF UCT	PROBABILITY DISTRIBUTION	UNCERTAINTY ° C	DIVISOR	ui(t), ° C
Standard Thermometer including measurement with standard thermometer	NAMAS Schedule	Normal	0.05	1	0.05
Axial Temperature distribution	This evaluation report	Rectangular	0.21	√ 3	0.121
Radial Temperature distribution	This evaluation report	Rectangular	0.002	√ 3	0.0012
Loading of block	This evaluation report	Rectangular	0.1	√ 3	0.058
Stability with time	This evaluation report	Rectangular	0.02	√ 3	0.01155
Ageing of reference thermometer	This evaluation report	Rectangular	0.002	√ 3	0.0012
Repeatability (Hysteresis)	This evaluation report	Rectangular	0.1*	√ 3	0.058
Combined Uct		k=1			0.15
Expanded Uct		k=2			0.31

* Resolution of indicator

Standard Insert, ambient 23+/-3°C. 909/1144, TTI2/2.

Set point =250°C

SOURCE OF UCT	DETERMINATION OF UCT	PROBABILITY DISTRIBUTION	UNCERTAINTY ° C	DIVISOR	ui(t), ° C
Standard Thermometer including measurement with standard thermometer	NAMAS Schedule	Normal	0.05	1	0.05
Axial Temperature distribution	This evaluation report	Rectangular	0.25	√ 3	0.144
Radial Temperature distribution	This evaluation report	Rectangular	0.018	√ 3	0.0104
Loading of block	This evaluation report	Rectangular	0	√ 3	
Stability with time	This evaluation report	Rectangular	0.03	√ 3	0.0173
Ageing of reference thermometer	This evaluation report	Rectangular	0.002	√ 3	0.0012
Repeatability (Hysteresis)	This evaluation report	Rectangular	0.1*	√ 3	0.058
Combined Uct		k=1			0.16
Expanded Uct		k=2			0.33

* Resolution of indicator

2, With Stirred Liquid Tank

Oil Tank, ISODC202 Oil ambient 23+/-3°C.
909/1144, TTI2/2.

Set point =30°C

SOURCE OF UCT	DETERMINATION OF UCT	PROBABILITY DISTRIBUTION	UNCERTAINTY ° C	DIVISOR	ui(t), ° C
Standard Thermometer including measurement with standard thermometer	NAMAS Schedule	Normal	0.05	1	0.05
Axial Temperature distribution	This evaluation report	Rectangular	0.008	√ 3	0.0046
Radial Temperature distribution	This evaluation report	Rectangular	0.001	√ 3	0.00058
Loading of block	This evaluation report	Rectangular	0	√ 3	
Stability with time	This evaluation report	Rectangular	0.02	√ 3	0.0115
Ageing of reference thermometer	This evaluation report	Rectangular	0.002	√ 3	0.0012
Repeatability (Hysteresis)	This evaluation report	Rectangular	0.1*	√ 3	0.058
Combined Uct		k=1			0.08
Expanded Uct		k=2			0.15

* Resolution of indicator.

Oil Tank, ISOCND Oil ambient 23+/-3°C. 909/1144, TTI2/2.

Set point =125°C

SOURCE OF UCT	DETERMINATION OF UCT	PROBABILITY DISTRIBUTION	UNCERTAINTY ° C	DIVISOR	ui(t), ° C
Standard Thermometer including measurement with standard thermometer	NAMAS Schedule	Normal	0.05	1	0.05
Axial Temperature distribution	This evaluation report	Rectangular	0.013	√ 3	0.008
Radial Temperature distribution	This evaluation report	Rectangular	0.014	√ 3	0.0081
Loading of block	This evaluation report	Rectangular	0	√ 3	
Stability with time	This evaluation report	Rectangular	0.02	√ 3	0.0115
Ageing of reference thermometer	This evaluation report	Rectangular	0.002	√ 3	0.0012
Repeatability (Hysteresis)	This evaluation report	Rectangular	0.1*	√ 3	0.058
Combined Uct		k=1			0.08
Expanded Uct		k=2			0.16

* Resolution of indicator.

Oil Tank, ISOCND Oil ambient 23+/-3°C. 909/1144, TTI2/2.

Set point =250°C

SOURCE OF UCT	DETERMINATION OF UCT	PROBABILITY DISTRIBUTION	UNCERTAINTY ° C	DIVISOR	ui(t), ° C
Standard Thermometer including measurement with standard thermometer	NAMAS Schedule	Normal	0.05	1	0.05
Axial Temperature distribution	This evaluation report	Rectangular	0.015	√ 3	0.0087
Radial Temperature distribution	This evaluation report	Rectangular	0.011	√ 3	0.0064
Loading of block	This evaluation report	Rectangular	0.1	√ 3	0.058
Stability with time	This evaluation report	Rectangular	0.04	√ 3	0.0231
Ageing of reference thermometer	This evaluation report	Rectangular	0.002	√ 3	0.0012
Repeatability (Hysteresis)	This evaluation report	Rectangular	0.1*	√ 3	0.058
Combined Uct		k=1			0.10
Expanded Uct		k=2			0.20

* Resolution of indicator.

Appendix Best Practise

Best Accuracy, Comparison Mode

Using an external indicator, comparing two calibrated standards

Two thermometers, one a 25 ohm quartz glass sheathed standard platinum resistance thermometer and the second a metal sheathed Pt100 resistance thermometer are placed in the calibration area of the Calisto. The values of the probes are recorded from the TTI 2 Temperature Indicator.

909/1144 and 53HT 51193 (Metal Sheathed Pt100)

ISOCND Oil

909/1144	**53HT 1193**	**Difference**
30.231°C 124.825°C 249.739°C	30.232°C 124.827°C 249.729°C	-0.001°C -0.002°C 0.01

Metal Insert

909/1144 8mm Hole	**53HT 1193** 6.5mm Hole	**Difference**
30.243°C 125.160.°C 250.176°C	30.253°C 125.120°C 250.127°C	-0.01°C 0.04°C 0.049