Gemini 550S Evaluation Report

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AN EVALUATION REPORT OF THE GEMINI 550S (SERIAL NUMBER 550/1) METAL BLOCK BATH MANUFACTURED BY ISOTHERMAL TECHNOLOGY LTD.

INTRODUCTION

The Gemini 550S is the latest version of Isotech's most popular metal block bath. It works over the temperature range 35° C to 550° C.

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 metal block bath can be presented in many formats some of which will give an optimistic or indeed a pessimistic view of how the product operates.

For the first time to our knowledge in 1996 a discussion document was written by Germany's Laboratory Accreditation body DKD with the view of standardising the test and certification of metal block baths.

We have used this document as the basis of the evaluation that follows.

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

The Gemini 550S Metal Block Bath Serial Number 550/1 was fully evaluated in two ways.

Firstly it was evaluated using the guidelines of DKD-R5-4 (Draft) document for the calibration of temperature "block calibrators".

In document DKD-R5-4 (Draft) Annex 2 a table appears in which an uncertainty is introduced entitled, "Heat Conduction from the Thermometer to be Measured". The uncertainty of this component is quoted as 0.25% of (Tmeas-Tenv).

At higher temperatures this component becomes the largest source of error and has no relevance to the metal block bath itself, nor is it within the control of the manufacturer of the block bath.

For this reason we have calculated the bath uncertainties with and without this influence.

The largest total uncertainties using DKD-R5-4 (Draft) were found to be 0.6° C at 550° C without the measured thermometer error and 1.6° C with the measured thermometer immersion error,

Secondly it has been evaluated using "good practice and procedures".

The second evaluation takes an sprt and an industrial resistance thermometer both with UKAS calibrations. Using procedures which are normal in a good quality laboratory, the errors fall below 0.1° C over the whole temperature range.

It therefore seems that 3 uncertainties can be ascribed to a metal block bath.

A. That, using "good practice and procedures" with the Gemini 550S gives less than 0.1° C uncertainties.

B. That, worst case, ignoring the uncertainties of the thermometer to be measured, gives uncertainties of 0.2° C at 35° C, 0.2° C at 275° C and 0.6° C at 550° C.

C. That, worst case, including an arbitrary test thermometer with heat loss uncertainties of 0.25% (Tmeas-Tenv) gives uncertainties of 0.2° C at 35° C, 0.7° C at 250° C and 1.6° C at 550° C.

Having carefully considered the work performed in this evaluation of the Gemini 550S metal block bath we can summarise the uncertainties as follows:

A shows the capabilities of the Gemini 550S when used to Isotech's recommendations.

B provides a useful evaluation of the profile and stability of the metal block bath. It shows its limitations but not its capabilities.

C Shows how the errors of the measured thermometer mask the true performance of the bath at the higher temperatures. The thermometer to be measured is a separate item, whose stem conduction should be evaluated in the traditional way of withdrawing the thermometer in 1cm steps.

METHOD OF USE

ERROR VARIATIONS WITH OPERATING PRACTICE

	OPERATING TEMPERATURE		
	35° C	**275°C**	**550° C**

A. Good practice and procedures as stated by Isotech	0.1° C	0.1° C	0.1° C
B. Worst case ignoring stem conduction from the thermometer to be calibrated.	0.2° C	0.2° C	0.6° C
C. Worst case including stem conduction from thermometer to be calibrated.	0.2° C	0.7° C	1.6° C

Whenever possible this report follows the recommendations of the Guideline of the Deutscher Kalibriererdienst (DKD, German Calibration Service) for the calibration of temperature block calibrators. DKD-R5-4-(DRAFT) In particular section 2.2 Measurements to Ascertain Calibration Capability.

Summary of Performance.

TEMPERATURE ° C	**STABILITY ±° C**	**RADIAL HOMOGENEITY**	**AXIAL HOMOGENEITY**	**LOADING EFFECT**
35	0.05	0.0005	0.013	0
275	0.05	0.001	0.06	0
550	0.05	0.035	1.00	0

HEAT UP TIME

50 to 550° C, 60 minutes.

COOL DOWN TIME AT 23° C AMBIENT

550° C to 330° C 85 minutes.

550° C to 135° C 345 minutes.

(Faster times can be achieved with the fast cool down accessory)

From DKD-R5-4-(DRAFT)

2.2.1 Axial Temperature Homogeneity: *The axial temperature distribution is to be measured at three different temperatures representative of the field of application and covering the extreme temperatures that may occur. One of several suitable thermometers (e.g. a differential thermocouple) are to be used, and the sensor length must not exceed 5mm. At least six different measurements per bore are to be carried out in the calibration zone and adjoining parts of the bore, the recommended distance between measurement points being about 1cm. If there are several symmetrically arranged bores of equal diameter, the measurement must be carried* *out in only one representative bore.*

TEST METHOD

For 50° C two 935-14-61 probes (designed for small stem conduction) were placed in each hole A and E One probe was raised in 1cm steps (Pocket A) and the temperature difference between it and the static probe at the bottom of pocket E was recorded. Alumina powder was placed in the pocket.

We specify the homogenous zone to be the lower 40mm of the pocket

AXIAL TEMPERATURE HOMOGENEITY: 35° C

DISTANCE FROM BOTTOM OF INSERT POCKET, CM POCKET E	**TEMPERATURE DIFFERENCE Δ T=TA-TE ° C**
0	0.0105
1	0.0165
2	0.0165
3	0.0055
4	0.0035
5	-0.0005
6	-0.0165

At 35° C the Maximum Variation over 40mm Zone was 0.013° C

(This includes the measurement error)

AXIAL TEMPERATURE HOMOGENEITY: 275° C

Using a differential type N thermocouple, the lower section is 7.5mm diameter, over all length

300mm. The two "positive" conductors connected to Fluke 45 DVM serial number 45/1.

DISTANCE FROM BOTTOM OF INSERT POCKET, CM POCKET E	**TEMPERATURE DIFFERENCE Δ T=TA-TE uV (35uV/° C)**
0	0
1	0
2	-2
3	-2
4	0
5	5
6	7

At 275° C the Maximum Variation over 40mm Zone was 0.06° C

(This includes the measurement error)

AXIAL TEMPERATURE HOMOGENEITY: 550° C

Using a differential type N thermocouple in hole E the two junctions are formed with MI type N thermocouples. The two "positive" conductors connected to Fluke 45 DVM serial number 45/1.

DISTANCE FROM BOTTOM OF INSERT POCKET, CM POCKET E	**TEMPERATURE DIFFERENCE Δ T = TA-TEμ V (39μ V/° C)**
0	0
1	21
2	33
3	37
4	39
5	32

6	-18

At 550° C the Maximum Variation over 40mm Zone was 1.00° C

(This includes the measurement error)

From DKD-R5-4-(DRAFT)

2.2.2 Radial Temperature Homogeneity: *The temperature differences between the zones in the individual bores provided for the measurements are measured with one or several suitable thermometers at three different temperatures respresentative of the field of application and covering the extreme temperatures which may occur. The conditions stated under points 2.1.9 and 2.1.10 must be complied with. If there is only one bore, no measurement is to be carried out.*

TEST METHOD

Two 935-14-17 thermometers were placed in two 8mm holes (A + E]. 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.

RADIAL TEMPERATURE HOMOGENEITY, 35° C

PROBE	**POCKET A**	**POCKET E**
TA-C TA-F	35.070° C 35.114° C	35.075° C 35.110° C

Δ t = ½ [(t$A_{TA\text{-}C}$ - t$E_{TA\text{-}C}$) + [(t$A_{TA\text{-}F}$- t$E_{TA\text{-}F}$)]

Radial Temperature Homogeneity 35°C = 0.0005°C

RADIAL TEMPERATURE HOMOGENEITY, 275° C

PROBE	**POCKET A**	**POCKET E**
TA-C TA-F	276.067° C 276.091° C	276.065° C 276.095° C

Δ t = ½ [(t$A_{TA\text{-}C}$ - t$E_{TA\text{-}C}$) + [(t$A_{TA\text{-}F}$- t$E_{TA\text{-}F}$)]

Radial Temperature Homogeneity 275° C = 0.001° C

RADIAL TEMPERATURE HOMOGENEITY, 550° C

PROBE	**POCKET A**	**POCKET E**
TA-C TA-F	550.120° C 550.026° C	550.110° C 550.106° C

Δ t = ½ [(t$A_{TA\text{-}C}$ - t$E_{TA\text{-}C}$) + [(t$A_{TA\text{-}F}$- t$E_{TA\text{-}F}$)]

Radial Temperature Homogeneity 550° C = 0.035° C

From DKD-R5-4-(DRAFT)

2.2.3 Influence upon radial temperature homogeneity due to different loading: *A suitable thermometer is placed into the bore located next to the largest bore, with due regard to points 2.1.9 and 2.1.10. The change in temperature is measured which results when a solid metal rod is introduced into the largest bore, in compliance with point 2.1.9, 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. If there is only one bore, no measurement is to be carried out.*

TEST METHOD

Isothermal Technology recommends an external probe is used to determine the insert temperature. For this test the recommended probe model 935-14-72 is connected to the built in indicator of the site model. A second thermometer is introduced to measure the insert temperature independently - 909 and TTI 2/2 record the temperature measured in pocket A, Probe 935-14-72-550/1 is placed in pocket G. A solid metal rod 360mm long and 19mm diameter is placed in pocket H.

Insert Temperature, 35° C

	NO ROD	**ROD ADDED**	**CHANGE DUE TO LOADING**
909/885 +TTI 2 935-14-72+Site Indicator (In Built)	35.25° C 35.1° C	35.23° C 35.1° C	0.02° C As Actual Insert T

The Gemini's separate PRT and in built indicator detected the temperature change due to loading hence

No additional error due to loading at 35° C

Insert Temperature, 275° C

	NO ROD	ROD ADDED	CHANGE DUE TO LOADING
909/885 + TTI 2 935-14-72+Site Indicator (In Built)	275.189° C 275.1° C	275.235° C 275.1° C	0.046° C As Actual Insert T

The Gemini's separate PRT and in built indicator detected the temperature change due to loading hence

No additional error due to loading at 250° C

Insert Temperature, 550° C

	NO ROD	ROD ADDED	CHANGE DUE TO LOADING
935-14-72-ZZ+TTI 2 935-14-72+Site Indicator (In Built)	549.961° C 550.0° C	550.034° C 550.0° C	0.073° C As Actual Insert T

The Gemini's separate PRT and in built indicator detected the temperature change due to loading hence

No additional error due to loading at 550° C

STABILITY WITH TIME

From DKD-R5-4-(DRAFT)

2.1.4 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 50° C, 30 minute period, ±0.05° C

Stability at 250° C, 30 minute period, ±0.05° C

Stability at 550° C, 30 minute period, ±0.05° C

TEST METHOD

A s.p.r.t serial number 909/887 was placed in hole A. The probe was connected to a TTI 2 precision temperature indicator [5] and the variation in temperature was recorded for a 30 minute period at three different temperatures. The ambient temperature was within 23° C ± 3° C.

HEAT UP TIME

35° C to 550° C 35 Min.

Cool Down

550 to 275° C 85 Min

550 to 65° C 345 Min

PROBE AGEING

A s.p.r.t. (909/887) was placed in a Jupiter along with the reference probe (935-14-17-550/1). The Jupiter 650 was set to the maximum operating temperature of 650° C and the difference between the two probes was recorded at two periods ten hours apart. The probe changed in value by 0.008° C, 8 mK.

HYSTERESIS (REPEATABILITY)

The Gemini was set to 110° C and the actual temperature along with the value for the in-built

temperature indicator was recorded, then the temperature was raised to 550° C for two hours. The temperature was then reset to 110° C and repeat measurements made.

	FROM COLD	**AFTER 550° C**
Actual	110.052	109.883
External	110.1	109.8

Change in actual temperature and hence the hysteresis 0.169° C, change in external indicated value 0.1° C, NOTE: Resolution of indicator is 0.1° C

CALCULATION OF THE UNCERTAINTY, DKD METHOD

CALIBRATION TEMPERATURE, 35° C

Ambient Temperature 23° C. Using 909/885 with TTI 2 and in built "external" indicator of Gemini 550 with reference probe 935-14-17-550/1.

SOURCE OF UCT	**DETERMINATION** **OF UCT**	**PROBABILITY** **DISTRIBUTION**	**UNCERTAINTY** **° C**	**DIVISOR**	**ui(t),** **° C**
Standard Thermometer including measurement with standard thermometer	UKAS Schedule	Normal	0.05	2	0.025
Axial Temperature distribution	This evaluation report	Rectangular	0.013	√ 12	0.0038
Radial Temperature distribution	This evaluation report	Rectangular	0.0005	√ 3	0.0003
Loading of block	This evaluation report	Rectangular	0	√ 3	0
Stability with time	This evaluation report	Rectangular	0.05	√ 12	0.014
Ageing of reference thermometer	This evaluation report	Rectangular	0.04	√ 3	0.023
Repeatability (Hysteresis)	This evaluation report	Rectangular	0.1*	√ 3	0.058
Heat Conduction from thermometer	0.25% of (Tmeas-Tenv)	Rectangular	0.03	√ 3	0.017
Combined Uct		k=1	0.083		

Expanded Uct		k=2	0.166		

*Hysteresis figure is resolution of in built indicator.

CALIBRATION TEMPERATURE 275° C

Ambient Temperature 23° C. Using 909/885 with TTI 2 and in built "external" indicator of Gemini 550 with reference probe 935-14-17-550/1.

SOURCE OF UCT	**DETERMINATION OF UCT**	**PROBABILITY DISTRIBUTION**	**UNCERTAINTY ° C**	**DIVISOR**	**ui(t), ° C**
Standard Thermometer including measurement with standard thermometer	UKAS Schedule	Normal	0.05	2	0.025
Axial Temperature distribution	This evaluation report	Rectangular	0.06	√ 12	0.017
Radial Temperature distribution	This evaluation report	Rectangular	0.001	√ 3	0.00058
Loading of block	This evaluation report	Rectangular	0	√ 3	0
Stability with time	This evaluation report	Rectangular	0.05	√ 12	0.014
Ageing of reference thermometer	This evaluation report	Rectangular	0.04	√ 3	0.023
Repeatability (Hysteresis)	This evaluation report	Rectangular	0.1*	√ 3	0.058
Heat Conduction from thermometer	0.25% of (Tmeas-Tenv)	Rectangular	0.63	√ 3	0.36

Combined Uct		k=1	0.37		
Expanded Uct		k=2	0.74		

*Hysteresis figure is resolution of in built indicator.

CALIBRATION TEMPERATURE, 550° C

Ambient Temperature 23° C. Using 909/885 with TTI 2 and in built "external" indicator of Gemini 550 with reference probe 935-14-17-550/1.

SOURCE OF UCT	**DETERMINATION OF UCT**	**PROBABILITY DISTRIBUTION**	**UNCERTAINTY ° C**	**DIVISOR**	**ui(t), ° C**
Standard Thermometer including measurement with standard thermometer	UKAS Schedule	Normal	0.05	2	0.025
Axial Temperature distribution	This evaluation report	Rectangular	1.00	√ 12	0.29
Radial Temperature distribution	This evaluation report	Rectangular	0.035	√ 3	0.020
Loading of block	This evaluation report	Rectangular	0	√ 3	0
Stability with time	This evaluation report	Rectangular	0.05	√ 12	0.014
Ageing of reference thermometer	This evaluation report	Rectangular	0.04	√ 3	0.023
Repeatability (Hysteresis)	This evaluation report	Rectangular	0.1*	√ 3	0.058
Heat	0.25% of (Tmeas-	Rectangular	1.32	√ 3	0.76

Conduction from thermometer	Tenv)				
Combined Uct		k=1	0.82		
Expanded Uct		k=2	1.64		

*Hysteresis figure is resolution of in build indicator

SUMMARY TABLE

Including the UCT ignoring heat conduction allowance for thermometer under test.

TEMPERATURE	**UCT OF BLOCK BATH**	**UCT *including a theoretical sensor with stem conduction 0.25% Tmeas-Tenv***
35° C 275° C 550° C	0.2 0.2 0.6	0.2 0.7 1.6

GEMINI 550S - AUDIT CALIBRATION

Appendix 1 of Gemini 550S Evaluation Report

The evaluation report represents almost the worst uncertainties of use.

It is normal to recommend that the standard and test thermometer are immersed to a similar depth, which all but eliminates the axial homogeneity assuming the probes are similar. An additional recommendation is to exchange the standard and test thermometer to obtain 2 comparison results which all but eliminates radial inhomogeneity.

Thirdly, comparing the standard to the test thermometer calibration is made quickly or simultaneously then the absolute stability of the metal block bath is of little importance.

Here an audit probe was calibrated in the UKAS calibrated Gemini 550S, the audit probe was calibrated by comparison to the supplied external probe and in built indicator arrangement of the Gemini 550S. The audit probe has previously been calibrated in the UKAS Laboratory. The results from the calibration in the Gemini 550S can then be compared to the UKAS calibration.

The audit probe is an Isotech Model 935-14-95 thermometer which has a 100 ohm resistance element 25mm long. The thermometer is 6mm diameter, 450mm long and has a metal alloy sheath. The serial number is 51196[8]. The thermometer was calibrated in fixed point cells, gallium, tin, zinc and aluminium. The calibration uncertainty of the thermometer is better than ±0.05° C.

In addition a 25.5 ohm standard platinum resistance thermometer 909/885 was placed in pocket F. This allows the audit probes to be compared directly to the s.p.r.t. and shows the very best results that might be expected from using the Gemini as a comparison bath. The uncertainty of 909/885 and the TTI 2 indicator is ±0.05° C.

SET POINT	**ACTUAL TEMPERATURE** **909/885**	**TEMPERATURE MEASURED WITH THE Gemini 550S (CORRECTED, from CAL CERT)**	**AUDIT PRT** **51196**
110 220 330 440 550	110.052 220.195 330.209 439.945 549.428	110.1 220.2 330.2 440.0 549.4	110.016 220.153 330.163 439.887 549.349

CONSIDERING THE DIFFERENCES BETWEEN PROBES

	DIFFERENCE FROM **SPRT**	**DIFFERENCE FROM IN-BUILT STANDARD**	**UCT FROM DKD** **R5-4-DRAFT**
TEMPERATURE	**AUDIT PRT 51196**	**AUDIT PRT 51196**	
110° C 220° C 330° C	0.036 0.042 0.046	<0.1° C <0.1° C <0.1° C	0.2 at 35 0.7 at 275

440° C 550° C	0.058 0.079	0.1° C <0.1° C All less than indicator res.	1.6 at 550

The Audit calibration shows the largest error between the metal sheathed PRT 100 ohm thermometer and either the 25.5 ohm sprt or the in-built standard probe/indicator of the Gemini 550S was 0.1° C over the range of the bath, 35 to 550° C.