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Jupiter 650S Evaluation Report

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An evaluation report of the Jupiter 650S (Serial Number 650/1) metal block bath manufactured by Isothermal Technology Ltd.

Introduction

The Jupiter 650S is the latest version of Isotech's most popular metal block bath. It works over the temperature range 40℃ to 650℃.

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 Jupiter 650S Metal Block Bath Serial Number 650/1 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 0.5℃ at 650℃ without the measured thermometer error and 1.8℃ with the m easured 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 NAMAS calibrations. Using procedures which are normal in a good quality laboratory, the errors fall below 0.1℃ over the whole temperature range.

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

- A. That, using "good practise and procedures" with the Jupiter 650S gives less than 0.1° C uncertainties.
- B. That, worst case, ignoring the uncertainties of the thermometer to be measured, gives uncertainties of 0.16℃ at 50℃, 0.23℃ at 250°C a nd 0.5℃ at 650℃.
- C. That, worst case, including an arbitrary test thermometer with heat loss uncertainties of 0.25% (Tmeas-Tenv) gives uncertainties of 0.18℃ at 50℃, 0.7℃ at 250℃ and 1.88℃ at 650℃.

Having carefully considered the work performed in this evaluation of the Jupiter 650S metal block bath we can summarise the uncertainties as follows:

- "A" shows the capabilities of the Jupiter 650S 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		
	50℃	**250℃**	**650℃**
A. Good practise 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.	0.16°C	0.23°C	0.5°C
C. Worst case including stem conduction from thermometer to be calibrated.	0.18℃	0.7℃	1.88℃

AN EVALUATION REPORT OF THE JUPITER 650S (SERIAL NUMBER 650/1) METAL

BLOCK BATH MANUFACTURED BY ISOTHERMAL TECHNOLOGY LTD

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 ℃	STABILITY ± °C	RADIAL HOMOGENEITY	AXIAL HOMOGENEITY	LOADING EFFECT
50	0.02	0.004	0.031	0
250	0.02	0.021	0.29	0
650	0.03	0.081	0.79	0

HEAT UP TIME

50 to 650℃, 20 minutes.

COOL DOWN TIME AT 23°C AMBIENT

650℃ to 330°C, 22 minutes.

650℃ to 135°C in 60 minutes.

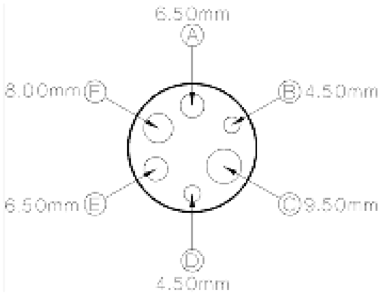
(Faster times can be achieved with the fast cool down accessory)

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℃ 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: 50°C

DISTANCE FROM BOTTOM OF INSERT POCKET, CM	**TEMPERATURE DIFFERENCE D T=TD-TB ℃**
0	0.000
1	-0.007
2	-0.011
3	-0.013
4	-0.008
5	-0.009
6	0.031
(0 Repeat	0.002)

At 50°C the Maximum Variation over 50mm Zone was 0 .013°C

(This includes the measurement error)

AXIAL TEMPERATURE HOMOGENEITY: 250°C

Using a differential type N thermocouple, the lower 55mm is 4.0mm 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 D	TEMPERATURE DIFFERENCE D T=TD-TB °C
0	0.00
1	0.12
2	0.21
3	0.26
4	0.29
5	0.24
6	0.12
(0 Repeat	0.06)

At 250°C the Maximum Variation over 50mm Zone was 0.29°C

(This includes the measurement error)

AXIAL TEMPERATURE HOMOGENEITY: 650°C

Using a differential type N thermocouple, the two junctions are formed with MI type N thermocouples. The lower 55mm is 4.0mm 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 D	TEMPERATURE DIFFERENCE D T=TD-TB °C
0	0.00
1	0.28
2	0.44
3	0.64
4	0.79
5	0.28
6	-0.54
(0 Repeat	0.08)

At 650°C the Maximum Variation over 50mm Zone was 0.79°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

For 50℃ and 250℃ 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, D t, was calculated to remove the small offsets between the two probes.

RADIAL TEMPERATURE HOMOGENEITY, 50°C

PROBE	POCKET B	POCKET D
935-14-61-AA 935-16-61-ZZ	49.707°C 49.765°C	49.680°C 49.785°C

D t = ½ [(t_{AAB} - t_{AAD}) + (t_{ZZB} - t_{ZZD})]

Radial Temperature Homogeneity 50°C = 0.0035°C

RADIAL TEMPERATURE HOMOGENEITY, 250°C

PROBE	POCKET B	POCKET D
935-14-61-AA 935-16-61-ZZ	249.624°C 249.684°C	249.622°C 249.644°C

D t = ½ [(t_{AAB} - t_{AAD}) + (t_{ZZB} - t_{ZZD})]

Radial Temperature Homogeneity 250°C = 0.021°C

RADIAL TEMPERATURE HOMOGENEITY, 650°C

PROBE	POCKET B	POCKET D
935-14-72-AA 935-16-72-ZZ	650.433°C 650.530°C	650.222°C 650.580°C

D t = ½ ½ [(t_{AAA} - t_{AAE}) + ($t_{ZZ\,A}$ - t_{ZZE})]

Radial Temperature Homogeneity 650°C = 0.081°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 [7], is connected to the built in indicator of the site model. A second thermometer is introduced to measure the insert temperature independently. For 50°C and 250℃ prob e 935-14-61-AA and TTI 2/2[5] record the temperature measured in pocket B, probe 935-14-72-650/1 is placed in pocket E. A metal rod 340mm long and 9mm diameter is placed in pocket C. For 650°C probe 935-14-61-AA was removed and replaced with the high temperature probe 935-14-72-AA to pocket A.

Insert Temperature, 50℃

	NO ROD	**ROD ADDED**	**CHANGE DUE TO LOADING**
935-14-61+TTI 2 935-14-72+Site Indicator (In Built)	49.773°C 49.8°C	49.735°C 49.7°C	0.038°C As Actual Insert T

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

No additional error due to loading at 50°C

Insert Temperature, 250℃

	NO ROD	**ROD ADDED**	**CHANGE DUE TO LOADING**
935-14-61-AA-TTI 2	249.801°C 249.8°C	249.607°C 249.6°C	0.194°C As Actual Insert T

935-14-72+Site Indicator (In Built)			

The Jupiter'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, 650°C

	NO ROD	ROD ADDED	CHANGE DUE TO LOADING
935-14-72-ZZ+TTI 2 935-14-72+Site Indicator (In Built)	649.913°C 649.8°C	649.546°C 649.4°C	0.367°C As Actual Insert T

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

No additional error due to loading at 650°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, ± 0.02°C

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

Stability at 650°C, 30 minute period, ± 0.03°C

TEST METHOD

For 50℃ and 250℃ a 935-14-61 serial number 935-14 -61-ZZ [3] 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 at two different temperatures. The ambient temperature was recorded with probe 935-14-61-AA, it was within 23℃ ± 3℃.

For 650℃ probe 909/25SD [7] thermometer was used (the thermometer used for the other tests has a maximum operating temperature of 250°C)

HEAT UP TIME

50℃ to 650℃ - 20 Minutes.

PROBE AGEING

An s.p.r.t. (909/887) was placed in the insert along with the reference probe (935-14-17-650/1). 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℃, 8 mK.

HYSTERESIS (REPEATABILITY)

The Jupiter was set to 250℃ and the actual tempera ture along with the value for the in-built

temperature indicator was recorded, then the temperature was raised to 650℃ for two hours. The temperature was then reset to 250℃ and repeat measurements made.

	FROM COLD	**AFTER 650°C**
Actual	249.922	249.900
External	249.9	249.9

Change in actual temperature and hence the hysteresis 0.022℃, change in external indicated value 0.0, NOTE: Resolution of indicator is 0.1°C

CALCULATION OF THE UNCERTAINTY, DKD METHOD

CALIBRATION TEMPERATURE, 50°C

Ambient Temperature 23℃. Using 909/885 with TTI 2 and in built "external" indicator of Jupiter 650 with reference probe 935-14-17-650/1.

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	/ 12	0.004
Radial Temperature distribution	This evaluation report	Rectangular	0.0035	/ 3	0.006
Loading of block	This evaluation report	Rectangular	0	/ 3	0
Stability with time	This evaluation report	Rectangular	0.04	/ 12	0.012
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	0.0675	/ 3	0.039
Combined Uct		k=1			0.09
Expanded Uct		k=2			0.18

*Hysteresis figure is resolution of in built indicator.

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CALIBRATION TEMPERATURE 250°C

Ambient Temperature 23℃. Using 909/885 with TTI 2 and in built "external" indicator of Jupiter 650 with reference probe 935-14-17-650/1.

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	0.29	/ 12	0.0837
Radial Temperature distribution	This evaluation report	Rectangular	0.021	/ 3	0.012
Loading of block	This evaluation report	Rectangular	0	/ 3	0
Stability with time	This evaluation report	Rectangular	0.04	/ 12	0.0115
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	0.57	/ 3	0.33
Combined Uct		k=1			0.35
Expanded Uct		k=2			0.70

*Hysteresis figure is resolution of in built indicator.

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CALIBRATION TEMPERATURE, 650°C

Ambient Temperature 23℃. Using 909/885 with TTI 2 and in built "external" indicator of Jupiter 650 with reference probe 935-14-17-650/1.

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	0.79	/ 12	0.228
Radial Temperature distribution	This evaluation report	Rectangular	0.081	/ 3	0.047
Loading of block	This evaluation report	Rectangular	0	/ 3	0
Stability with time	This evaluation report	Rectangular	0.06	/ 12	0.017
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	1.57	/ 3	0.905
Combined Uct		k=1			0.88
Expanded Uct		k=2			1.76

*Hysteresis figure is resolution of in built indicator.

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SUMMARY TABLE

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

TEMPERATURE	UCT OF BLOCK BATH	UCT *including atheoretical sensor withstem conduction 0.25% Tmeas-Tenv*
50°C	0.16	0.18
250°C	0.23	0.7
650°C	0.50	1.88

JUPITER 650S - AUDIT CALIBRATION

Appendix 1 of Jupiter 650S 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 from which errors due to radial inhomogeneity can be eliminated 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 NAMAS calibrated Jupiter 650S, the audit probe was calibrated by comparison to the supplied external probe and in built indicator arrangement of the Jupiter 650S. The audit probe has previously been calibrated in the NAMAS Laboratory. The results from the calibration in the Jupiter 650S can then be compared to the NAMAS 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℃.

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 Jupiter as a comparison bath. The uncertainty of 909/885 and the TTI 2 indicator is ± 0.05℃.

SET POINT	ACTUAL TEMPEPERATURE 909/885	TEMPERATURE MEASURED WITH THE JUPITER 650S (CORRECTED, SEE CALCERT)	AUDIT PRT 51196
130	129.761	129.8, correction=0	129.750
260	259.866	259.9 correction=0	259.887
390	389.856	389.9 correction=0	389.861
520	519.737	519.7correction=0.2	519.751
650	649.869	649.9 correction=0	649.888

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**	
130°C	0.011	<0.1℃	0.7 at 250
260°C	-0.021	<0.1℃	
390°C	-0.005	<0.1℃	
520℃	-0.014	<0.1℃	1.8 at 650
650°C	-0.019	<0.1℃ (All less than indicator resolution)	

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 Jupiter 650S was less than 0.1℃ over the range of the bath , 50 to 650℃.