Pegasus 1200S Evaluation Report

An Evaluation Report of the Pegasus 1200S (Serial Number 1200S/1) Metal Block Bath manufactured by Isothermal Technology Ltd

INTRODUCTION

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 Pegasus 1200S Metal Block Bath Serial Number 1200S/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). Where Tmeas is the block's temperature and Tenv is the ambient room temperature.

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 2.3° C at 1100° C without the measured thermometer error and 3.9° C with the measured thermometer immersion error,

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

The second evaluation uses type R thermocouples with NAMAS calibrations. Using procedures which are normal in a good quality laboratory, the errors fall below 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 Pegasus 1200S gives typically 1° C uncertainties.

B. That, worst case, ignoring the uncertainties of the thermometer to be measured, gives uncertainties of 1.9° C at 150° C, 2.1° C at 660° C and 2.3° C at 1100° C.

C. That, worst case, including an arbitrary test thermometer with heat loss uncertainties of 0.25% (Tmeas-Tenv) gives uncertainties of 2.0° C at 150° C, 2.8° C at 660° C and 3.9° C at 1100° C.

Having carefully considered the work performed in this evaluation of the Pegasus 1200S metal block bath we can summarise the uncertainties as follows:

"A" shows the capabilities of the Pegasus 1200S 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		
	150° C	**660° C**	**1100° C**
A. Good practice and procedures as stated by Isotech	1° C	1° C	1° C
B. Worst case ignoring stem conduction from the thermometer to be calibrated.	1.9° C	2.1° C	2.3° C
C. Worst case including stem conduction from thermometer to be calibrated.	2.0° C	2.8° C	3.9° C

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 ° C	**STABILITY ±° C**	**RADIAL HOMOGENEITY**	**AXIAL HOMOGENEITY**	**LOADING EFFECT**
150	0.1	0	0.3	0
660	0.2	0.1	1.5	0
1100	0.2	0.2	2.3	0

HEAT UP TIME

100 to 1200° C, 20 minutes.

COOL DOWN TIME AT 23° C AMBIENT

1200° C to 800° C 50 minutes.

1200° C to 200° C 180 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 150° C two standard type R thermocouple probes were placed in an 8mm hole. One probe was raised in 1cm steps and the temperature difference between it and the static probe at the bottom of a pocket was recorded. Alumina powder was placed in the pocket.

The Pegasus is designed and suitable for the calibration of thermocouples using a relatively short insert. It has an homogenous zone of 30mm and it is this zone that has been surveyed.

We specify the homogenous zone to be the lower 30mm of the pocket

AXIAL TEMPERATURE HOMOGENEITY: 150° C

DISTANCE FROM BOTTOM OF INSERT POCKET, CM	**DIFFERENCE, μ V**
0	0
1	2
2	3
3	3

At 150° C the Maximum Variation over 30mm Zone was 0.3° C

(This includes the measurement error)

AXIAL TEMPERATURE HOMOGENEITY: 660° C

DISTANCE FROM BOTTOM OF INSERT POCKET, CM	**TEMPERATURE DIFFERENCE, μ V**
0	-2
1	8

2 3	6 -10

At 660° C the Maximum Variation over 30mm Zone was 1.5° C

(This includes the measurement error)

AXIAL TEMPERATURE HOMOGENEITY: 1100° C

DISTANCE FROM BOTTOM OF INSERT POCKET, CM POCKET E	**TEMPERATURE DIFFERENCE, μ V**
0 1 2 3	-1 16 14 -14

At 1100° C the Maximum Variation over 30mm Zone was 2.3° 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 standard type R thermocouples (R2107, R2108) were placed in two 8mm holes (A + D]. Measurements were recorded.

RADIAL TEMPERATURE HOMOGENEITY, 150° C

PROBE	**TEMPERATURE**	**Delta t**
R2107	Pocket A 152.06° C	0° C

R2108	Pocket D 152.06° C	

Radial Temperature Homogeneity 150°C = 0°C

RADIAL TEMPERATURE HOMOGENEITY, 660° C

PROBE	**TEMPERATURE**	**Delta t**
R2107 R2108	Pocket A 652.75° C Pocket D 652.83° C	0.1° C

Radial Temperature Homogeneity 660° C = 0.1° C

RADIAL TEMPERATURE HOMOGENEITY, 1100° C

PROBE	**TEMPERATIRE**	**Delta t**
R2107 R2108	Pocket A 1093.78° C Pocket D 1093.56° C	0.2° C

Radial Temperature Homogeneity 1100° C = 0.2° 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 935-14-14 is connected to the built in indicator of the site model. Two standard type R thermocouples were used to measure the actual temprature. A solid metal rod 300mm long and 8mm diameter is placed in the remaining pocket.

Insert Temperature, 150° C

	NO ROD	ROD ADDED	CHANGE DUE TO LOADING
Actual Temperature	152.30° C	151.45° C	0.9° C
935-14-14+Site Indicator (In Built)	151° C	150° C	As Actual Insert T -1° C

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

No additional error due to loading at 150° C

Insert Temperature, 660° C

	NO ROD	ROD ADDED	CHANGE DUE TO LOADING
Actual Temperature	654.21° C	659.37° C	5.2° C
935-14-14+Site Indicator (In Built)	656° C	661° C	As Actual Insert T +5° C

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

No additional error due to loading at 660° C

Insert Temperature, 1100° C

	NO ROD	ROD ADDED	CHANGE DUE TO LOADING
Actual Temperature	1095.4° C	1097.82° C	2.4° C
935-14-14+Site	1096° C	1098° C	As Actual Insert T +2° C

Indicator (In Built)			

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

No additional error due to loading at 1100° 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 150° C C, 30 minute period, ±0.1°C

Stability at 660°CC, 30 minute period, ±0.2°C

Stability at 1100° C, 30 minute period, ±0.2°C

TEST METHOD

A type R thermocouple was placed in hole A 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

100° C to 1200° C 20 min

Cool Down

1200 to 800° C 50 min) Times can be substantially

1200 to 200° C 3 hours) reduced using cooling adaptor

PROBE AGEING

HYSTERESIS (REPEATABILITY)

The Pegasus was set to 220° C and the actual temperature along with the value for the in-built

temperature indicator was recorded, then the temperature was raised to 1100° C for two hours. The temperature was then reset to 220° C and repeat measurements made.

	FROM COLD	AFTER 1200° C
Actual	219.4	220.4
External	219	219/220

Change in actual temperature and hence the hysteresis 1° C, change in external indicated value switching between LSD, NOTE: Resolution of indicator is 1° C

CALCULATION OF THE UNCERTAINTY, DKD METHOD

CALIBRATION TEMPERATURE, 150° C

Ambient Temperature 23° C. Using Type R T/C with DVM and in built "external" indicator of Pegasus 1200S with reference probe 935-14-14.

SOURCE OF UCT	**DETERMINATION OF UCT**	**PROBABILITY DISTRIBUTION**	**UNCERTAINTY °C**	**DIVISOR**	**ui(t), °C**
Standard Thermometer including measurement with standard thermometer	NAMAS Schedule	Normal	1	2	0.5
Axial Temperature distribution	This evaluation report	Rectangular	0.3	/ 12	0.0866
Radial Temperature distribution	This evaluation report	Rectangular	0	/ 3	0
Loading of block	This evaluation report	Rectangular	0	/ 3	0
Stability with time	This evaluation report	Rectangular	0.1	/ 12	0.0289
Ageing of reference thermometer	This evaluation report	Rectangular	1	/ 3	0.5774
Repeatability (Hysteresis)	This evaluation report	Rectangular	1	/ 3	0.5774
Heat Conduction	0.25% of (Tmeas-Tenv)	Rectangular	0.318	/ 3	0.184

from thermometer					
Combined Uct		k=1	0.98		
Expanded Uct		k=2	1.96		

*Hysteresis figure is resolution of in built indicator.

CALIBRATION TEMPERATURE 660° C

Ambient Temperature 23° C. Using Type R T/C with DVM and in built "external" indicator of Pegasus 1200S with reference probe 935-14-14.

SOURCE OF UCT	**DETERMINATION OF UCT**	**PROBABILITY DISTRIBUTION**	**UNCERTAINTY ° C**	**DIVISOR**	**ui(t), ° C**
Standard Thermometer including measurement with standard thermometer	NAMAS Schedule	Normal	1	2	0.5
Axial Temperature distribution	This evaluation report	Rectangular	1.5	/ 12	0.4330
Radial Temperature distribution	This evaluation report	Rectangular	0.1	/ 3	0.0577
Loading of block	This evaluation report	Rectangular	0	/ 3	0
Stability with time	This evaluation report	Rectangular	0.2	/ 12	0.0577
Ageing of reference thermometer	This evaluation report	Rectangular	1	/ 3	0.5774
Repeatability	This evaluation	Rectangular	1	/ 3	0.5774

(Hysteresis)	report				
Heat Conduction from thermometer	0.25% of (Tmeas-Tenv)	Rectangular	1.593	/ 3	0.9197
Combined Uct		k=1	1.4		
Expanded Uct		k=2	2.8		

*Hysteresis figure is resolution of in built indicator.

CALIBRATION TEMPERATURE, 1100° C

Ambient Temperature 23° C. Using Type R T/C with DVM and in built "external" indicator of Pegasus 1200S with reference probe 935-14-14.

SOURCE OF UCT	**DETERMINATION OF UCT**	**PROBABILITY DISTRIBUTION**	**UNCERTAINTY ° C**	**DIVISOR**	**ui(t), ° C**
Standard Thermometer including measurement with standard thermometer	NAMAS Schedule	Normal	1	2	0.5
Axial Temperature distribution	This evaluation report	Rectangular	2.3	/ 12	0.6640
Radial Temperature distribution	This evaluation report	Rectangular	0.2	/ 3	0.1155
Loading of block	This evaluation report	Rectangular	0	/ 3	0
Stability with time	This evaluation report	Rectangular	0.2	/ 12	0.0577
Ageing of	This evaluation	Rectangular	1	/ 3	0.5774

reference thermometer	report				
Repeatability (Hysteresis)	This evaluation report	Rectangular	1	/ 3	0.5774
Heat Conduction from thermometer	0.25% of (Tmeas-Tenv)	Rectangular	2.693	/ 3	1.5648
Combined Uct		k=1	1.95		
Expanded Uct		k=2	3.9		

*Hysteresis figure is resolution of in build indicator

SUMMARY TABLE

Including the UCT ignoring heat conduction allowance for thermometer under test at k = 2

TEMPERATURE	**UCT OF BLOCK BATH**	**UCT *including a theoretical sensor withstem conduction 0.25% Tmeas-Tenv***
150° C 660° C 1100° C	1.9 2.1 2.3	2.0 2.8 3.9

PEGASUS 1200S - AUDIT CALIBRATION

Appendix 1 of Pegasus 1200S 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 NAMAS calibrated Pegasus 1200S, the audit probe was calibrated by comparison to the supplied external probe and in built indicator arrangement of the Pegasus 1200S. The audit probe has previously been calibrated in the NAMAS Laboratory. The results from the calibration in the Pegasus 1200S can then be compared to the NAMAS calibration.

The audit probe and the standard probes are all type R thermocouples calibrated by comparison with an uncertainty of 0.3° C not including the electrical measurement system.

As well as comparing the standard probe to the supplied reference probe of the Pegasus 1200S the audit probe was compared directly to the standards and shows the very best results that might be expected using the Pegasus as a comparison bath.

SET POINT	**ACTUAL TEMPERATURE MEAN OF TW0 STANDARD R T/C'S**	**TEMPERATURE MEASURED WITH THE PEGASUS 1200S**	**AUDIT PROBE 2312-90-080**
220	221.4	221	221.2
440	437.1	437	437.3
660	655.2	655	655.7
880	876.4	876	876.8
1600	1100.7	1100/1101	1101.0

CONSIDERING THE DIFFERENCES BETWEEN PROBES

	DIFFERENCE FROM ACTUAL TEMPERATURE	**DIFFERENCE FROM IN-BUILT STANDARD**	**UCT FROM DKD R5-4-DRAFT**
TEMPERATURE	**AUDIT PROBE**	**AUDIT PROBE**	
220° C	0.2	<1° C (Indicator resolution)	2.0 at 220
440° C	0.2	<1° C (Indicator resolution)	
660° C	0.5	<1° C (Indicator resolution)	2.8 at 660

880° C	0.4	<1° C (Indicator resolution)	
1100° C	0.3	<1° C (Indicator resolution)	3.9 at 1100

The audit calibration shows the largest error between the actual temperature and the audit probe was 0.5° C. The difference between the actual temperature and the Pegasus in built standard was less than the 1° C resolution of the indicator