Heated Modules – Thermal Performance Report

Abstract

The goal of this Application Note is to demonstrate the heating capabilities of the HM02 Heated Module in combination with the Ther-Mix & Flexi-Therm instruments. The results demonstrate that the Heated Modules set a new industry standard for thermal performance.

Introduction

The Vitl Ther-Mix and Flexi-Therm instruments are the next generation of highly accurate sample heating devices. Often laboratories are forced to work with instruments which display temperatures which are several degrees different from the temperature of the sample.

The Vitl Heated Module range, (used as adapters on the Ther-Mix and Flexi-Therm base units) is engineered to mitigate this problem, so that that the temperature on the instrument display accurately reflects the temperature of the sample.

Test Aims

To use the data collated to provide performance figures for the Heated Modules: this includes temperature accuracy, inter-module homogeneity, and intra-sample repeatability.

Equipment Used

- 5 x 965 HM02 Vitl Heated Modules
- T965-10: Flexi-Therm test jig
- PC with PicoPlayer software
- Picologger [1]
- 6 x Thermocouples
- 3mm Hex Screwdriver
- 6 x 1.5ml Microcentrifuge tubes half filled with 100% Glycerol liquid

(NB: All equipment used was calibrated)

Test Description

- The Heater Module lid heaters were set to -AUTO- in the the Flexi-Therm software which sets the lid temperature exactly 5°C higher than the block temperature.
- Tests were carried out on each module from ambient room temperature (20-24°C) to 37.0°C and logged for 30 minutes, and again from 37.0°C to 99.9°C and logged for 30 minutes.

Test Method

Testing setup

The T965-10: Calibrated Flexi-Therm test jig was connected to the PC using the USB connection cable.

The Picologger was connected to the PC using the USB cable provided.

The thermocouples were labelled 1-6, and were connected to the respective ports in the Picologger. These thermocouples did not change ports throughout the entirety of the testing carried out (e.g. thermocouple 1 was always connected to port 1 etc).

This set up can be seen in Fig. 1 below.

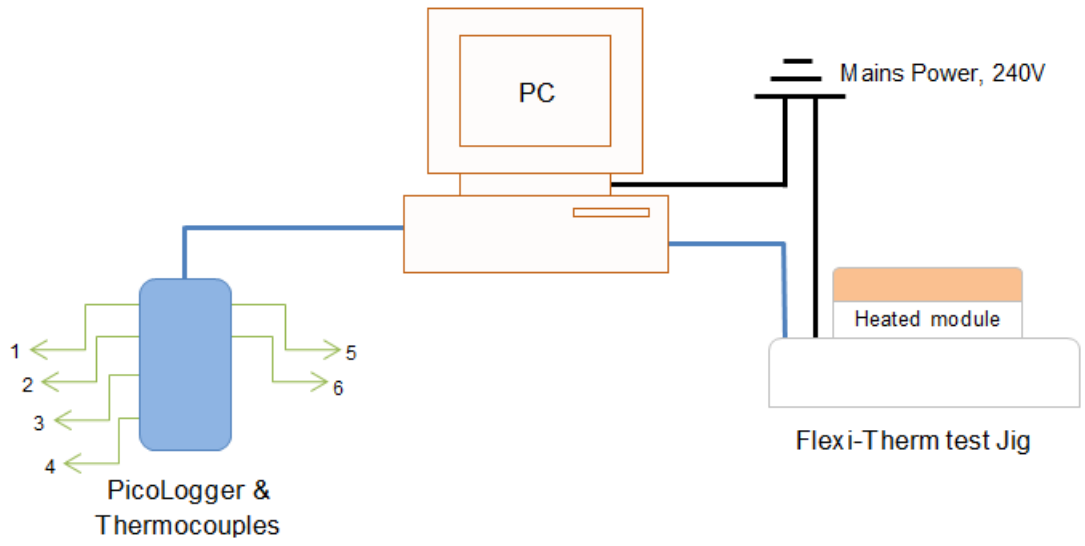

Figure 1: Schematic diagram showing the setup used during testing

Thermocouple channels

Thermocouple channels 1-6 were used as follows:

Thermocouples 1-6 were immersed in 100% Glycerol, within 1.5ml microcentrifuge tubes as shown in Fig. 2. These tubes were then placed into the HM02 Heated Module in the positions shown in Fig. 3. These positions were chosen to represent a good range of locations within the Heated Module to monitor heat distribution throughout.

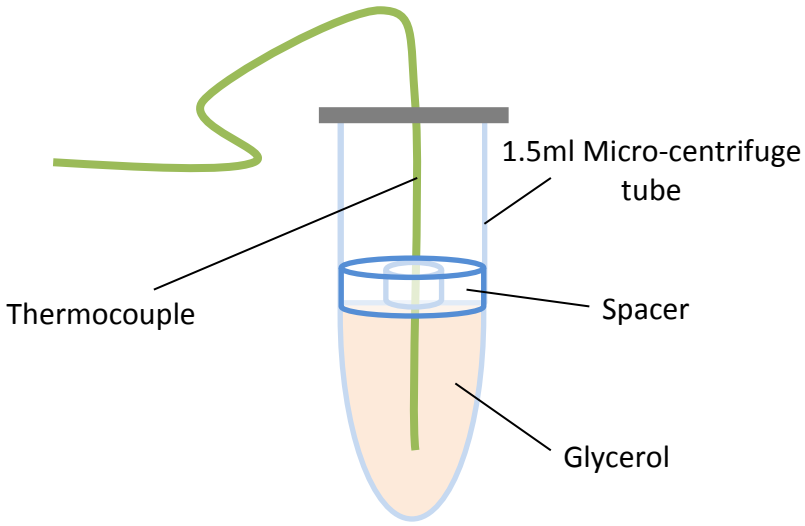

Figure 2: Diagram showing the thermocouples in 1.5ml tubes with glycerol

1					
	2				6
		3		5	
			4		

Figure 3: Details of the positions of each thermocouple within and around the Heated Module

Test Procedure

- Thermocouples were placed in the Heated Module as described in Fig. 3.
- PicoLog Recorder software was opened and set with the following parameters:
  - Channels 1-6 in use
  - 30 Minute recordings
  - Sample every 15 seconds
  - Data saved to file
- The Heated Module was heated from Ambient to 37.0°C and results were logged from the Picologger over the course of 30 minutes at 15 second intervals.
- After 30 minutes, the Heated Module was heated from 37.0°C to 99.9°C and results were logged from the Picologger for another 30 minutes at 15 second intervals.
- The Heated Module was removed and thermocouples were left to cool to room temperature
- Thermocouples were given a minimum of 30 minutes to cool from 99.9°C to ambient between module testing.
- Next Heated Module was introduced and the procedure was repeated

Test Results

The results were collected using PicoPlayer and collated in an EXCEL spreadsheet. Each result was individually adjusted according to the calibration graphs determined for each thermocouple [2].

Once the results had been adjusted, a mean average was taken across all six thermocouples to provide an average temperature of the sample within the Heated Module for each time-stamp. The data from the averages was then adjusted so that each unit aligned with the same temperature at the same time by shifting the data along the time axis.

The average block temperature curves for each module were plotted onto graphs for each ambient to 37.0°C (Fig. 4) and for 37.0°C to 99.9°C (Fig. 5)

Results

Table 1 shows the time taken to reach stable temperature [3] and the maximum and minimum temperatures achieved. Finally, it details the deviation in temperature of the sample within the Heated Module from the temperature input on the unit.

Table 1 : results gathered from thermal testing

Mode		Ambient to 37.0°C					37.0°C to 99.9°C				
Unit Serial No:		**103**	**104**	**107**	**108**	**116**	**103**	**104**	**107**	**108**	**116**
Stable after (mins)[3]		10.25					21.50				
Temperature Range (once stable) (°C)	**Min**	37.07	37.06	37.04	37.06	37.07	99.95	99.98	99.95	99.94	99.97
	Max	37.09	37.10	37.06	37.09	37.10	99.99	100.01	99.99	99.97	100.00
	Difference	0.02	0.04	0.02	0.03	0.03	0.04	0.03	0.04	0.03	0.03
Deviation from target (°C)		0.09	0.10	0.06	0.09	0.10	0.09	0.11	0.09	0.07	0.10

Heating from ambient to 37.0°C

Graphs showing the temperature of the glycerol in the Heated Modules are shown in Fig.4. A "zoomed-in" view is provided between points 22-24 minutes [5], where the temperature was stable [3]. These give a more detailed insight into the small variation in temperature during these stable periods. Fig.4 shows there is less than a 0.05°C variation in temperature, at "stable temperature".

Table 2 further summarises the data in Table 1 for direct consideration. It can be seen that there a maximum of only 0.10°C difference in the actual temperatures of the sample within the Heated Module, compared to those set and displayed on the Flexi-Therm.

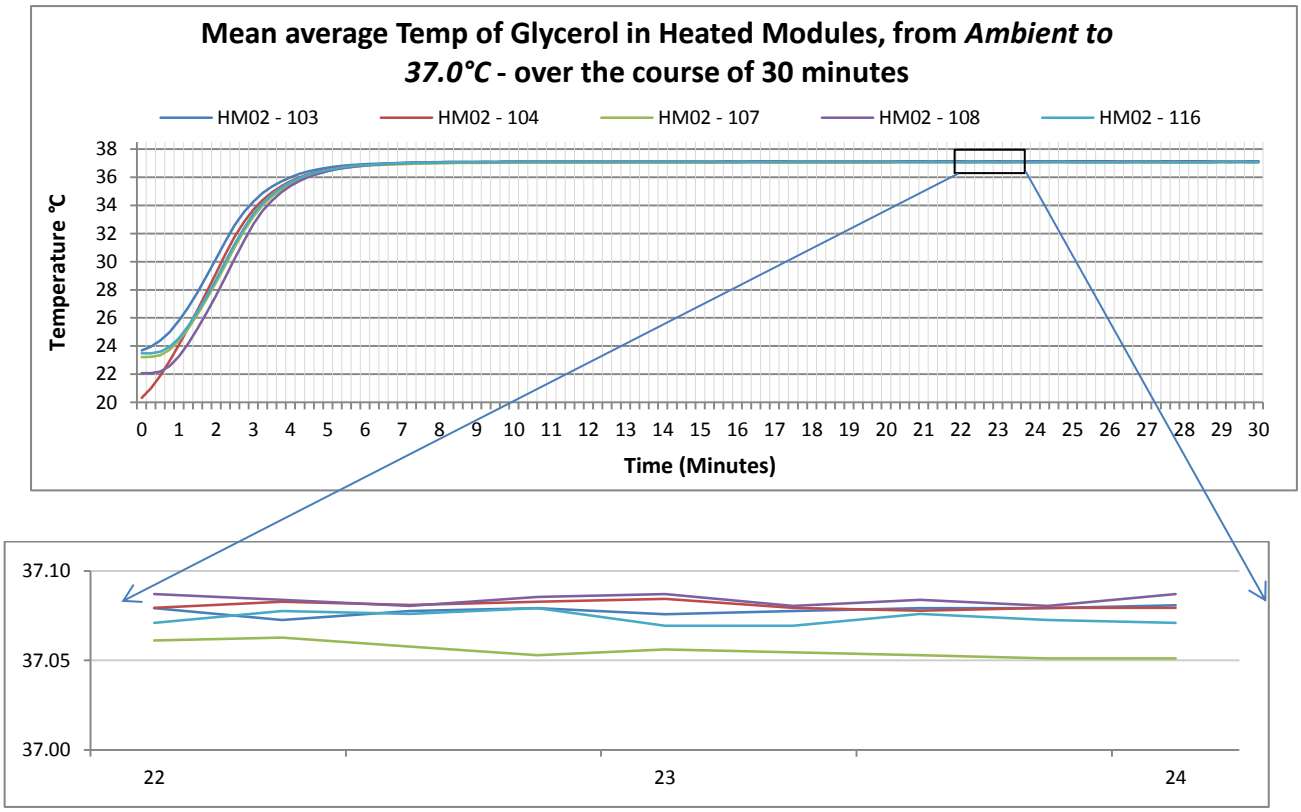

Figure. 4: Graphs showing the temperature of the glycerol as the Heated Modules were heated from ambient to 37°C.

Table 2: Summary of Heated Module temperature data when heating from ambient to 37°C

Max deviation from the target temperature (37.0°C)	0.10°C

Heating from 37.0°C to 99.9°C

Graphs showing the temperature of the glycerol in the blocks are shown in Fig.5. A "zoomed-in" view is again provided between points 22-24 minutes [5], where the temperature was stable. As can be seen in Fig.5, there is less than a 0.06°C variation in temperature, at "stable temperature".

Table 3 further summarises the data in Table 1 for direct consideration. It can be seen that there is only a 0.11°C difference in the actual temperatures compared to those set and displayed on the Flexi-Therm.

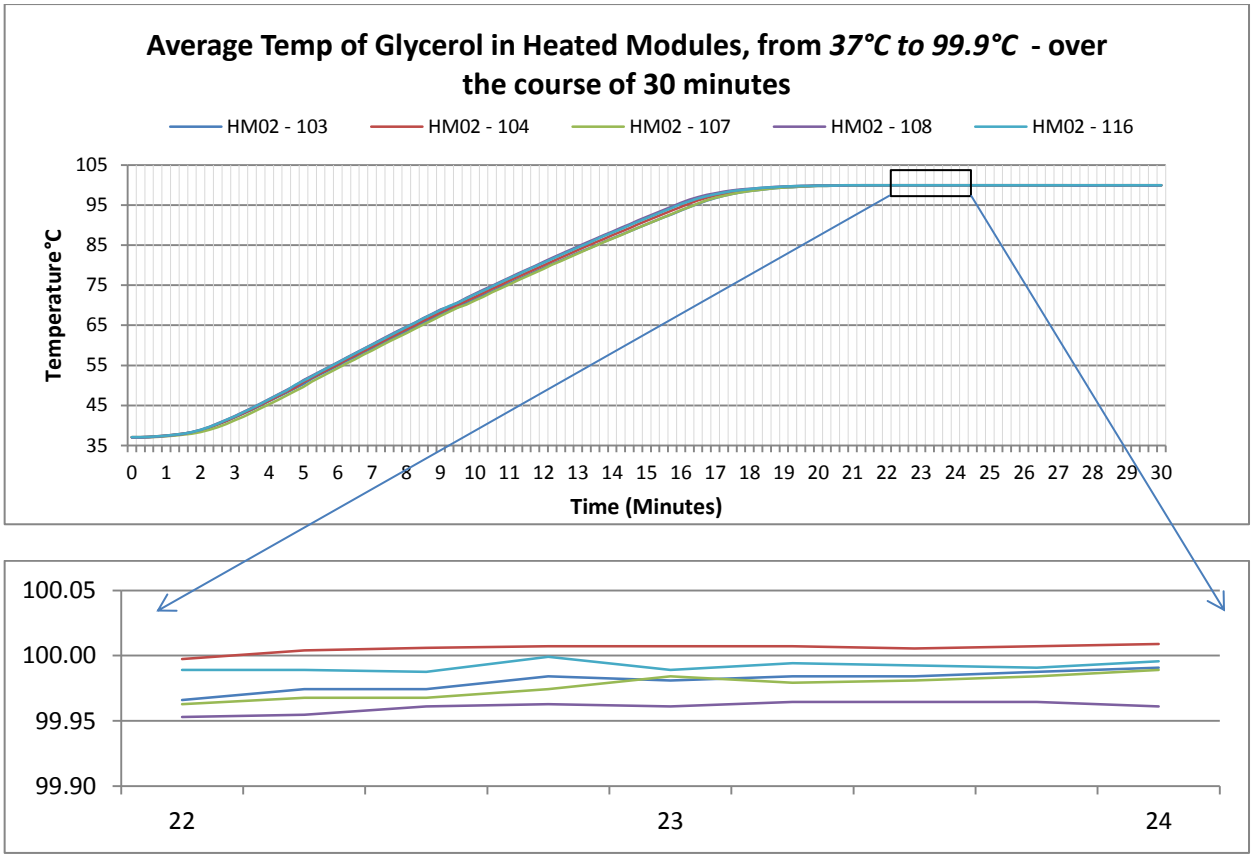

Figure 5: Graphs showing the temperature of the glycerol as the Heated Modules were heated from 37.0°C to 99.9°C.

Table 3: Summary of Heated Module temperature data when heating from 37.0°C to 99.9°C

Max deviation from the target temperature (99.9°C)	0.11°C

Summary

Accuracy

The final line in *Table 2* shows the deviation from expected temperature based on the feedback from the thermocouples. In all but one case, the accuracy of the readings falls below a ***0.10°C deviation***, even at the max temperature (table 3).

Module Homogeneity and Deviation

The modules showed ***less than 0.06°C variation*** between the 5 calibrated Modules, showing that the variation between different modules is negligible, and verifying the quality of the factory set calibration procedure.

There was also shown to be a negligible difference between readings taken in different locations throughout the Heated Module, showing ***good temperature homogeneity throughout***.

Appendix

[1] Used with PicoLog Software (Recorder and Player)

[2] Calibration equations used for thermocouples 1-6:

Thermocouple	Actual Temp (°C)	Thermocouple Reading (°C)	Setpoint Offset (°C)	Linear Interpolation
1	37	37.24	0.24	*y = 931/925x*
	50	50.59	0.59	*y = 267/260x - 983/1300*
	70	70.71	0.71	*y = 503/500x + 29/100*
	99.99	100.97	0.98	*y = 1513/1495x - 3971/29900*
2	36.95	37.25	0.3	*y = 745/739x*
	50.01	50.41	0.4	*y = 667/653x - 1607/3265*
	69.98	70.62	0.64	*y = 2003/1997x + 4291/9985*
	99.91	100.87	0.96	*y = 3025/2993x - 8096/74825*
3	37.04	37.31	0.27	*y = 3731/3704x*
	50.02	50.3	0.28	*y = 1299/1298x + 15671/64900*
	70	70.42	0.42	*y = 1006/999x - 3521/49950*
	99.94	100.72	0.78	*y = 505/499x - 10521/24950*
4	37.02	37.07	0.05	*y = 3707/3702x*
	49.99	50.23	0.24	*y = 1316/1297x - 63853/129700*
	70.01	70.42	0.41	*y = 2019/2002x - 7387/40040*
	99.94	100.72	0.78	*y = 3030/2993x - 34081/74825*
5	36.95	37.01	0.06	*y = 3701/3695x*
	50.06	50.15	0.09	*y = 657/655x - 173/3275*
	69.93	70.29	0.36	*y = 1007/994x - 315/568*
	99.91	100.56	0.65	*y = 3027/2998x - 94869/299800*
6	36.97	37.25	0.28	*y = 3725/3697x*
	50.03	50.44	0.41	*y = 1319/1306x - 11493/130600*
	69.96	70.64	0.68	*y = 2020/1993x - 13342/49825*
	99.91	100.55	0.64	*y = 3027/2998x - 94869/299800*

[3] Stable Temperature is defined as when the temperature deviates no more than 0.5 degrees from the average of the previous five results

[4] Arbitrarily chosen time during the “Stable” period

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