Applications

Note 243 | December 2011

The Mastercycler® nexus combines high energy efficiency with very low noise generation

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Abstract

In the comparative tests presented herein, measurements of power consumption and operating noise were performed for the Mastercycler nexus and competitors' thermal cyclers. The values obtained characterize the Mastercycler nexus to be a thermal cycler which stands out among its competitors by virtue of its high energy efficiency and very low noise generation.

Introduction

The development of workflow in modern laboratories has led to increased usage of devices or even complete automation of entire processes. One reason underlying this development is the increased sample throughput made possible by the availability of powerful instruments. Further, since reproducibility of laboratory results can generally be improved while simultaneously reducing the error rate, workflow is subject to a higher degree of standardization. This, in particular, is required more and more frequently in guidelines of accredited and certified laboratories.
A further positive aspect can be derived from the fact that monotonous and tiring routine steps no longer need to be performed manually. However, the increasing number of laboratory instruments imposes other stressors on the user, e.g. increased operational noise and waste heat generated by the instruments. Whereas heat generation may be neglected as physical stress in an air conditioned laboratory, increasing noise generation is a significant stress factor [1].

Apart from noise pollution, the use of more laboratory instruments leads to increased power consumption in the laboratory. Often the instruments are continually in use, or they are kept in standby mode over long periods of time. For this and other reasons listed below, power consumption of laboratory instruments is subject to increasing scrutiny [2]:
- Environmental protection – conservation of resources through the use of energy efficient instruments,
- rising cost of energy,
- increased demands on the electro-technical infrastructure in the laboratory.

Lately, these aspects have influenced purchasing decisions more prominently and therefore, factors such as power consumption and noise generation are gaining increasing significance. This Application Note will demonstrate that alongside optimization of PCR performance and ease of operation, the consideration of these parameters was paramount during the development of the Mastercycler nexus.

Methods

1) Determination of power consumption

Within the scope of this investigation the power consumption of the PCR thermal cycler Mastercycler nexus (MC nexus) and seven further competitors (V, C, T, A, S, P, R) was measured under a variety of conditions which reflect the use of the instruments during routine applications:

1) Idle state: thermal cycler switched on, temperature control of block and lid switched off, duration of measurement: 5 min
2.1) Thermal cycler turned off (power switch off, instrument cable plugged into outlet)
2.2) Thermal cycler in standby mode (if available), duration of measurement: 5 min
3) Continuous temperature control of the block at 4 °C (lid temperature control turned off), duration of measurement: 5 min
4) Performance of a typical PCR program:

95 °C	95 °C	60 °C	72 °C	72 °C	10 °C
2 min	15 s	15 s	30 s	1 min	10 min
		30 x			

The measuring device LMG95 (PC driver software: LMG-Control 2.35; ZES Zimmer Electronic Systems GmbH) was used to determine power consumption. All measurements were performed using an inserted 96 well PCR plate. To this end, the plate positions of columns 1, 3, 5, 8, 10, 12 were filled with 30 µL H_2O each, thus filling 48 of the 96 well positions.

2) Noise generation: Determination of the sound power level

The sound power level was determined in A-weighted decibel [dB(A)] for the Mastercycler nexus and six competing instruments (V, C, T, A, S, P) in accordance with DIN EN ISO 3744, using the measuring instrument Norsonic 118. The measurements were taken at the following three operational states:

1) Idle state: Thermal cycler switched on, temperature control of block and lid turned off.
2) Continuous temperature control of the block at 4 °C.
3) Performance of a standard 3-step PCR protocol:

95 °C	60 °C	72 °C
15 s	15 s	30 s

Results and Discussion

1) Measurements of power consumption

The measurements performed in idle state revealed that six of the seven competing instruments showed continuous power consumption, which were between two-fold and nearly four-fold higher than the power consumption determined for the Mastercycler nexus (Figure 1). Whereas one competing cycler (R) displayed slightly lower power consumption (8 W), this instrument is not equipped with a standby function. This mode is available on the Mastercycler nexus and a change into standby (6 W) when not using the instrument is energetically more favorable than the idle state on thermal cycler R (Figure 1, Table 1).

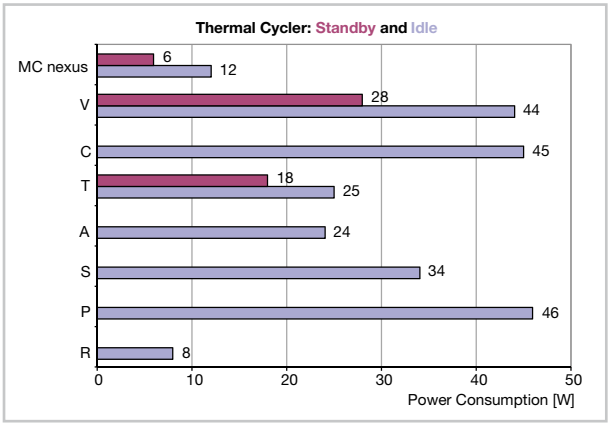

Figure 1: Power consumption of the thermal cyclers in standby and idle state. Standby function was only available on Mastercycler nexus, V and T.

Apart from the Mastercycler nexus only two of the seven competing thermal cyclers were equipped with a standby function. The energy consumed by the Mastercycler nexus in standby mode was three-fold to almost five-fold lower than the energy consumed by these two competitors (Table 1).

The Mastercycler nexus and the instruments V, T and R did not consume energy when the power was turned off. However, for two competing cyclers (C, P), a considerable power consumption was registered even when the power switch was turned off (Table 1). Thus, instrument C consumes approximately 79 kWh annually, even if it is never switched on. Since the Mastercycler nexus requires an energy amount of 0.154 kWh for a complete typical PCR run (Figure 3), a total of 513 runs could be carried out with 79 kWh.

Table 1: Power consumption of the thermal cyclers when power was turned off and in standby mode.
Two competing cyclers show considerable power consumption, even when turned off.

Thermal Cycler	Power Consumption [W]	
	Power Switch Off	Standby
MC nexus	0	6
V	0	28
C	9	no Standby → Idle: 45
T	0	18
A	< 0.1	no Standby → Idle: 24
S	< 0.1	no Standby → Idle: 34
P	8	no Standby → Idle: 46
R	0	no Standby → Idle: 8

During constant control of block temperature at 4 °C, the Mastercycler nexus and the cycler R consumed the least energy (Figure 2). The values of the other cyclers were at least two-fold higher. Under these conditions 18-fold higher power consumption was measured for cycler P compared to the Mastercycler nexus. For example, if a user performs an overnight PCR run and programs the cycler P in such a way that the samples are kept at 4 °C at the end of the run, the energy consumed would equal 7.24 kWh for a period of 10 h – for temperature control at 4 °C alone. In comparison the Mastercycler nexus would consume only 0.4 kWh.

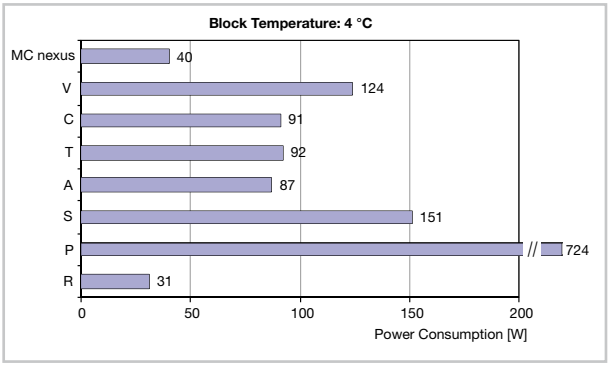

Figure 2: Power consumption of the thermal cyclers at constant temperature control of the block at 4 °C (lid temperature control switched off).

During a complete PCR run, the Mastercycler nexus displayed the lowest power consumption of all cyclers: 0.154 kWh (Figure 3). While this value was slightly higher for cycler R, the power consumption determined for 5 other thermal cyclers was 32 – 63 % higher. With a value three-fold higher, thermal cycler P consumed by far the most energy.

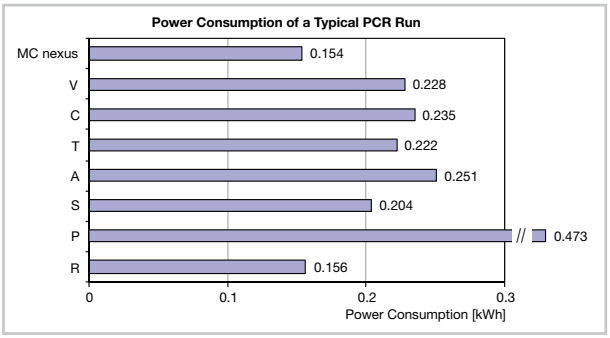

Figure 3: Power consumption of the thermal cyclers in kilowatt hours [kWh] during the run of a typical PCR program.

The maximum values for power consumption measured during the PCR run (Table 2) exceeded the respective manufacturer's claims of maximum values (data not shown) for three competing instruments (A, P, R). For the thermal cycler with the highest discrepancy, the value was 36 % higher than the information provided by the manufacturer.

Table 2: Maximum power consumption of the thermal cyclers during the run of a standard PCR program.
Three competing cyclers showed maximum values which exceeded those provided by the respective manufacturer (see text).

Thermal Cycler	Max. Power Consumpt. [W]
MC nexus	510
V	652
C	623
T	511
A	619
S	362
P	1337
R	655

2) Noise generation: Measurements of the sound power level

During all three conditions of operation, the Mastercycler nexus was the only thermal cycler tested which yielded a sound power level below 40 dB(A) (Figure 4). Furthermore, the intensity of the operational noise varied only slightly between the different conditions. All competing cyclers produced above 50 dB(A) during at least two operating conditions, and four of the six competing cyclers reached 60 dB(A) during at least one series of measurements. During continuous temperature control of the block at 4 °C, the highest value (72.3 dB(A)) was measured for thermal cycler P. In contrast the respective value obtained for the Mastercycler nexus was 39.1 dB(A).

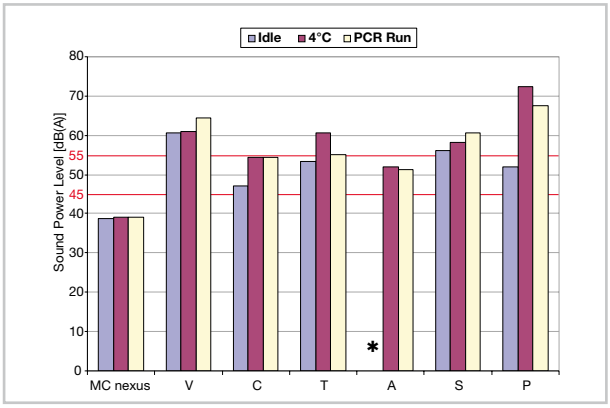

Figure 4: Sound power levels of the thermal cyclers during three operational states. Recommended maximum values according to ISO 11690-1 (see text).
(* The fan is switched off in idle state of A. Thus, a relevant differentiation of the operating noise to the surrounding sound level (ca. 32 dB(A)) was not possible.)

According to the recommendation of ISO 11690-1 the noise immission and/or noise exposure should not exceed the following maximum values [3]:

- In industrial workplaces : < 80 dB(A),
- For routine office work: < 55 dB(A),
- For meeting rooms or tasks involving concentration: < 45 dB(A).

Only the Mastercycler nexus undercuts the 45 dB(A) maximum value for all tested operational states.

In the human sound perception, an increase of the sound power level by 10 dB(A) means a doubling of the loudness [4,5]. Thus, a user perceives the maximal detected sound power level difference of 33.2 dB(A) as a 10-fold higher loudness on cycler P in comparison to the Mastercycler nexus (Figure 5). Most of the other measured sound power levels led to two- to five-fold higher loudness perceptions on the competitors' thermal cyclers.

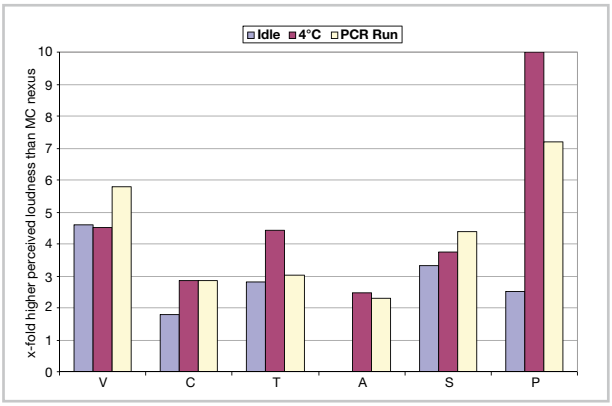

Figure 5: Loudness perceptions in comparison to the Mastercycler nexus - deduced from the detected differences in the sound power levels (see Fig. 4).

Conclusion

During development of the Mastercycler nexus, the increasing importance of energy efficiency, as well as noise generation, of laboratory instruments were taken into consideration. The measurement results for power consumption presented here, as well as the operational noise data, characterize the Mastercycler nexus as a cycler which features high energy efficiency and a very low operational noise.

References

[1] World Health Organization. Additional laboratory hazards – Noise. In: Laboratory biosafety manual. 3rd ed. Geneva: WHO Library Cataloguing-in-Publication Data; 2004; 111.

[2] Borchardt, J.K. Achieving Laboratory Energy Efficiency. *Lab Manager* 2009; 4 (3): 16-19.

[3] ISO 11690-1:1996. Acoustics - Recommended practice for the design of low-noise workplaces containing machinery - Part 1: Noise control strategies.

[4] Moore BCJ. Cochlear hearing loss: physiological, psychological and technical issues. 2nd ed. John Wiley & Sons Ltd.; 2007

[5] Stevens SS. On the psychophysical law. *Psychological Review* 1957; 64 (3): 153–181.

Ordering information

Product	Description	Order no. International	Order no. North America
Mastercycler® nexus gradient	230 V / 50 - 60 Hz,	6331 000.017	-
	120 V / 50 - 60 Hz, with US-plug	-	6331000025
Mastercycler® nexus	230 V / 50 - 60 Hz,	6333 000.014	-
	120 V / 50 - 60 Hz, with US-plug	-	6333000022
Mastercycler® nexus eco*	230 V / 50 - 60 Hz,	6332 000.010	-
	120 V / 50 - 60 Hz, with US-plug	-	6332000029
CAN_BUS connection cable	50 cm	5341 612.006	950014008
CAN_BUS connection cable	150 cm	5341 611.000	950014016
Selftest USB key		6320 071.001	950030040
Temperature Verification System – Single-channel		0055 000.298	950008059
Temperature Verification System – Multi-channel		6328 000.006	on request

* A Mastercycler nexus gradient or Mastercycler nexus is needed to run a Mastercycler nexus eco. Up to 2 Mastercycler nexus eco can be controlled by one Mastercycler nexus gradient or Mastercycler nexus.

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