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2015-03-05
M112237/01 MSG/JRE

# Consumer vacuum breast-pumps

## Determination of the sound power level of the noise emission according to ISO 3741

## Test report No. M112237/01

| | |
|---|---|
| Client: | Ardo medical AG<br>Gewerbestraße 19<br>6314 Unterägeri<br>Switzerland |
| Consultant: | M. Eng. Philipp Meistring |
| Date of report (revised version): | 05th March 2015 |
| Delivery date of the test objects: | 16th May 2014 / 26th January 2015 |
| Date of measurements: | 23rd May 2014 / 17th February 2015 |
| Total number of pages: | 43 pages in total, thereof<br>6 pages of text,<br>16 pages of Appendix A,<br>11 pages of Appendix B,<br>6 pages of Appendix C and<br>4 pages of Appendix D. |



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## Table of contents

# 1 Situation and task

On behalf of Ardo medical AG, 6314 Unterägeri, Switzerland, the sound power level of the noise radiated by consumer vacuum breast-pumps was to be determined by measurements in the reverberation room acc. to DIN EN ISO 3741 [2]. The tests were to be carried out for nine pumps (two single pumps, two double pumps and five pumps with single and double mode).

In the present test report, the execution of the tests and the test results will be described. The revised version of 05th March 2015 includes an additional test series that was executed in February 2015.

# 2 References

[1] DIN EN ISO 3740: Acoustics – Determination of sound power levels of noise sources – Guidelines for the use of basic standards. 2001-03

[2] DIN EN ISO 3741: Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Precision methods for reverberation test rooms. 2011-01

[3] DIN EN ISO 3382-2: Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation time in ordinary rooms. 2008-09

# 3 Test objects and operating conditions

Several different types of consumer vacuum breast-pumps of various manufacturers were examined. The test objects were prescribed and delivered to the test laboratory by the client. According to the information of the client, the test objects were purchased in the usual commercial way:

- in May 2014 (pumps of the test series of 23rd May 2014 resp.
- in January 2015 (pump of the test series of 17th February 2015.

The pumps can be classified in single and double pumps according to their operating modes or their number of simultaneously operable suction bottles. In several pumps both operating modes are alternatively available. Other operating parameters can be set according to the respective pump, i. e. vacuum performance, cycle frequency and pump mode (stimulation mode / suction mode). For the tests, all pumps were operated in suction mode, each at its maximum vacuum performance. As far as possible, all pumps were set to the same cycle frequency, i. e. 45 $min^{-1}$…56 $min^{-1}$. For the power supply during the test, the mains adapter delivered with each pump was used.

The operating conditions for the tests were also prescribed by the client or defined by the test laboratory in accordance with the client before the tests. The operating conditions determined for the tests (full load & cycle frequency 45 $min^{-1}$…56 $min^{-1}$) reflect the actual use in practice according to the client.

Table 1 gives an overview of the pumps tested. In the test certificates in Appendix A, the operating conditions during measurements are indicated. Appendix B shows photos of the pumps tested.

The arrangement of the test objects in the reverberation room was set up by employees of the test laboratory.

For the tests, the breast-pumps were connected to the suction bottles and funnels. In order to create the necessary vacuum, the suction funnels of the bottles were sealed by means of an artificial breast. The artificial breast was fixed to the suction funnel by an adhesive tape.

For the reverberation room test, the complete breast-pump setup was placed directly onto the reflecting reverberation room floor according to DIN EN ISO 3741 [2]. For all tests the same position on the reverberation room floor was used. In order to avoid contact noise between specimen and reverberation room floor, a pad of closed-cell polyurethane foam was laid underneath. One pump was fixed in the provided backpack and could be operated from the front pocket. Correspondingly, the test was carried out with intended operation inside the backpack. Comparatively the measurement was executed with open and with closed front pocket of the backpack. The suction bottles were placed next to the backpack.

For all tests, the operating state of the pumps was controlled before and after the test in terms of noise caused by the setup (rattling noise of the pump as a result of hoses lying loose on the pump or noise of the mounting base, or similar; air sucked in due to improperly positioned or slipped off artificial breast, etc.). Therefore, an influence by corresponding sounds on the measurements used for the determination of the sound pressure levels can be excluded.

Appendix B shows photos of the test arrangement.

## 4 Execution of the tests

The tests were carried out on 23rd May 2014 between 18:00 h und 23:00 h as well as on 17th February 2015 between 14:00 h and 16:00 h in the reverberation room of Müller-BBM GmbH, Planegg.

The climatic conditions during the tests are described in the test certificates in Appendix A.

The test method and the test equipment used are documented in Appendix D.

## 5 Evaluation

The evaluation of the measurement results was effected in third-octave bands (100 Hz … 10000 Hz) according to the specifications in DIN EN ISO 3741 [2]. The detailed procedure is described in Appendix D. From the sound pressure levels in octave bands the sound pressure levels in octaves (125 Hz … 8000 Hz) as well as the A-weighted sound power levels $L_{WA}$ were calculated.

## 6 Test results

The determined sound power levels in one third-octave bands are contained in the result tables in Appendix C. In the result sheets in Appendix A, the sound power levels summarized in octave bands as well as the A-weighted sound power levels $L_{WA}$ are listed.

Table 1 shows the comparison between the A-weighted sound power levels $L_{WA}$ determined for all pumps tested.

Table 1. Overview of examined pumps and test results: A-weighted sound power levels $L_{WA}$.

| Test No. / test certificate Appendix A, Page | Manufacturer / type | Serial No. | Mode tested | Cycle frequency [$min^{-1}$] | $L_{WA}$ [dB] |
|---|---|---|---|---|---|
| 1 | Ardo / Calypso | 14621129 | single | 52 | 46.0 |
| 2 | Medela / Freestyle™ | F20134300130 | single | 50 | 57.8 |
| 3 | Medela / Swing™ | G20140302318 | single | 47 | 55.1 |
| 4 | Philips / AVENT SCF 332 | 0238978 | single | 45 | 55.1 |
| 5 | Lansinoh® / Affinity Pro™ | SN0172 | single | 50 | 55.6 |
| 6 | Ameda / Purely Yours™ (bgl. Ameda / Lactaline) | 24502082 | single | 48 | 55.1 |
| 7 | Ardo / Calypso Double Plus | 14621129 | double | 52 | 46.4 |
| 8 | Medela / Freestyle | F20134300130 | double | 50 | 58.0 |
| 9 | Lansinoh® / Affinity Pro™ | SN0172 | double | 50 | 56.6 |
| 10 | Ameda / Purely Yours™ (bgl. Ameda / Lactaline) | 24502082 | double | 48 | 54.9 |
| 11 | Medela / Swing Maxi™ | M20140500034 | double | 46 | 49.6 |
| 12 | Philips / AVENT SCF 334 | 0045539 | double | 45 | 56.6 |
| 13 | Medela / Pump In Style® Advanced | P1402851050 | single/ backpack open | 56 | 51.8 |
| 14 | Medela / Pump In Style® Advanced | P1402851050 | single/ backpack closed | 56 | 48.9 |

| Test No. / test certificate Appendix A, Page | Manufacturer / type | Serial No. | Mode tested | Cycle frequency [$min^{-1}$] | $L_{WA}$ [dB] |
|---|---|---|---|---|---|
| 15 | Medela / Pump In Style® Advanced | P1402851050 | double/ backpack open | 56 | 52.9 |
| 16 | Medela / Pump In Style® Advanced | P1402851050 | double / backpack closed | 56 | 50.0 |

The requirements of DIN ISO 3741 [2] in terms of background noise criteria acc. to sections 5.4.1.1 and 5.4.1.2 could not be complied with in all frequency bands. If applicable, the respective sound levels in the test certificates and in the result tables in Appendix C are marked accordingly.

However, the relative criterion for the determination of the A-weighted sound power level acc. to sect. 5.4.1.3 of DIN ISO 3741 [2] is met in all tests carried out. It may therefore be assumed that the A-weighted sound power level of the background noise criteria calculated from the data of all frequency bands complies with the standard.

## 7 Remarks

The test results exclusively relate to the investigated subjects and conditions described.

M. Eng. Philipp Meistring



DAkkS Deutsche Akkreditierungsstelle D-PL-14119-07-00

Durch die DAkkS Deutsche Akkreditierungsstelle GmbH
nach DIN EN ISO/IEC 17025 akkreditiertes Prüflaboratorium.
Die Akkreditierung gilt für die in der Urkunde aufgeführten Prüfverfahren.

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Single pump type Ardo Calypso

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: single pump
- Manufacturer / type: Ardo/ Calypso
- Serial No.: 14621129
- Type of pump: piston pump
- Cycle: variable in 8 steps
- Vakuum performance: variable in 8 steps

Operating conditions during test:

- Vakuum performance: full load (step 8, maximum power)
- Cycle: 52/min (step 7)

Test set-up:

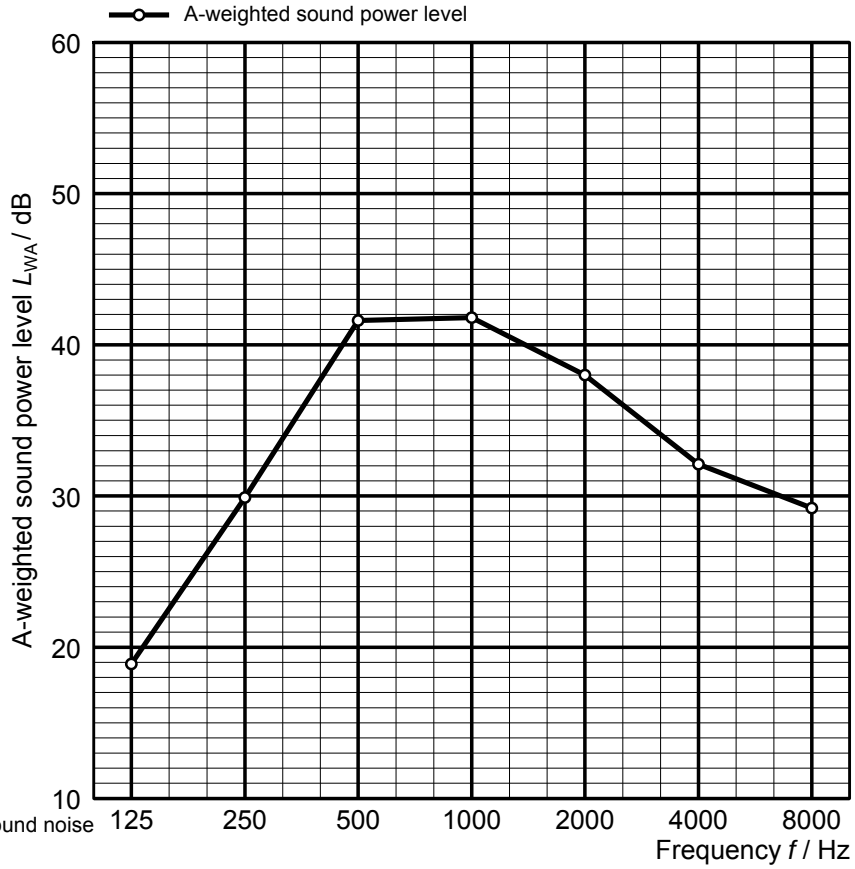
- Generation of vacuum via suction bottle with artificial breast
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.5 °C
r. h. = 48.5 %
*B* = 94.8 kPa

| Frequency octave [Hz] | $L_{WA}$ 1/3 octave [dB] |
|---|---|
| 125 | • 18.9 |
| 250 | • 29.9 |
| 500 | 41.6 |
| 1000 | 41.8 |
| 2000 | 38.0 |
| 4000 | • 32.1 |
| 8000 | • 29.2 |

• minimum value, dominated by background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 46.0 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Single pump type Medela Freestyle™

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: single pump
- Manufacturer / type: Medela / Freestyle™
- Serial No.: F20134300130
- Type of pump: membrane pump
- Cycle: not variable
- Vacuum performance: variable in 9 steps

Operating conditions during test:

- Vacuum performance: full load (step 9, maximum power), suction mode
- Cycle: 50/min

Test set-up:

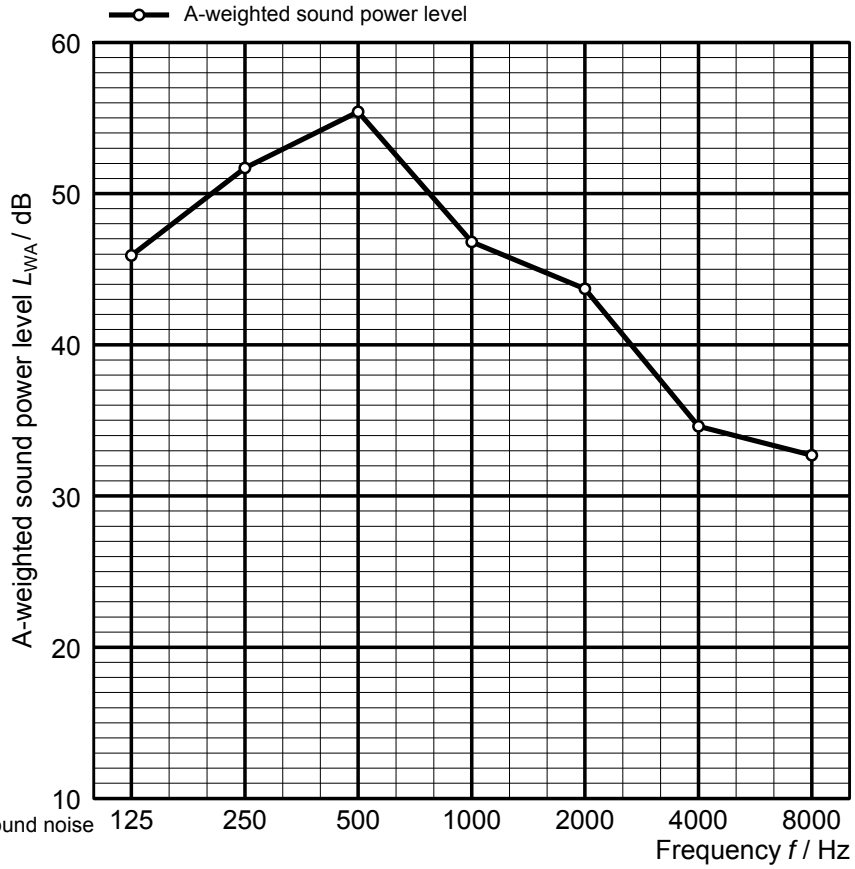
- Generation of vacuum via suction bottle with artificial breast
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.5 °C
r. h. = 48.6 %
*B* = 94.8 kPa

| Frequency octave [Hz] | | $L_{WA}$ 1/3 octave [dB] |
|---|---|---|
| 125 | ○ | 45.9 |
| 250 | | 51.7 |
| 500 | | 55.4 |
| 1000 | | 46.8 |
| 2000 | | 43.7 |
| 4000 | ○ | 34.6 |
| 8000 | • | 32.7 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 57.8 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Single pump type Medela Swing™

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: single pump
- Manufacturer / type: Medela / Swing™
- Serial No.: G20140302318
- Type of pump: membrane pump
- Cycle: frequency not variable
- Vacuum performance: variable in 11 steps

Operating conditions during test:

- Vacuum performance: full load (step 11, maximum power), suction mode
- Cycle: 47/min

Test set-up:

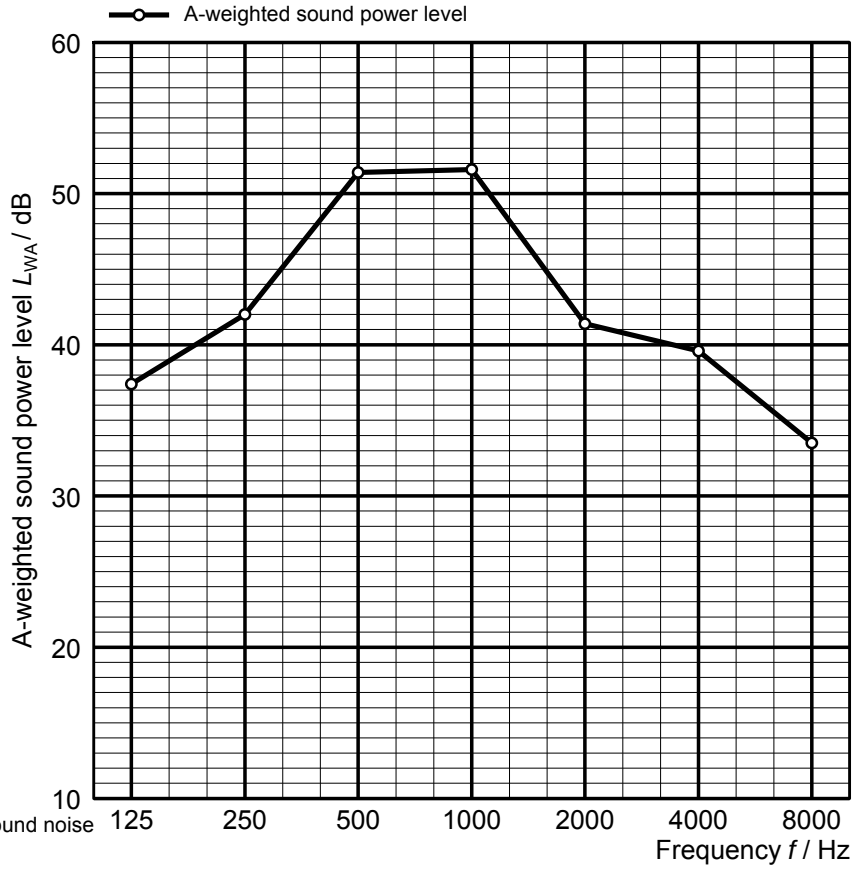
- Generation of vacuum via suction bottle with artificial breast
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.5 °C
r. h. = 49.5 %
*B* = 94.8 kPa

| Frequency octave [Hz] | | $L_{WA}$ 1/3 octave [dB] |
|---|---|---|
| 125 | • | 37.4 |
| 250 | | 42.0 |
| 500 | | 51.4 |
| 1000 | | 51.6 |
| 2000 | | 41.4 |
| 4000 | ○ | 39.6 |
| 8000 | ○ | 33.5 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 55.1 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Single pump type Philips AVENT

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: single pump
- Manufacturer / type: Philips / AVENT SCF 332
- Serial No.: 0238978
- Type of pump: membrane pump
- Cycle: frequency not variable
- Vacuum performance: variable in 3 steps

Operating conditions during test:

- Vacuum performance: full load (step 3, maximum power), suction mode
- Cycle: 45/min

Test set-up:

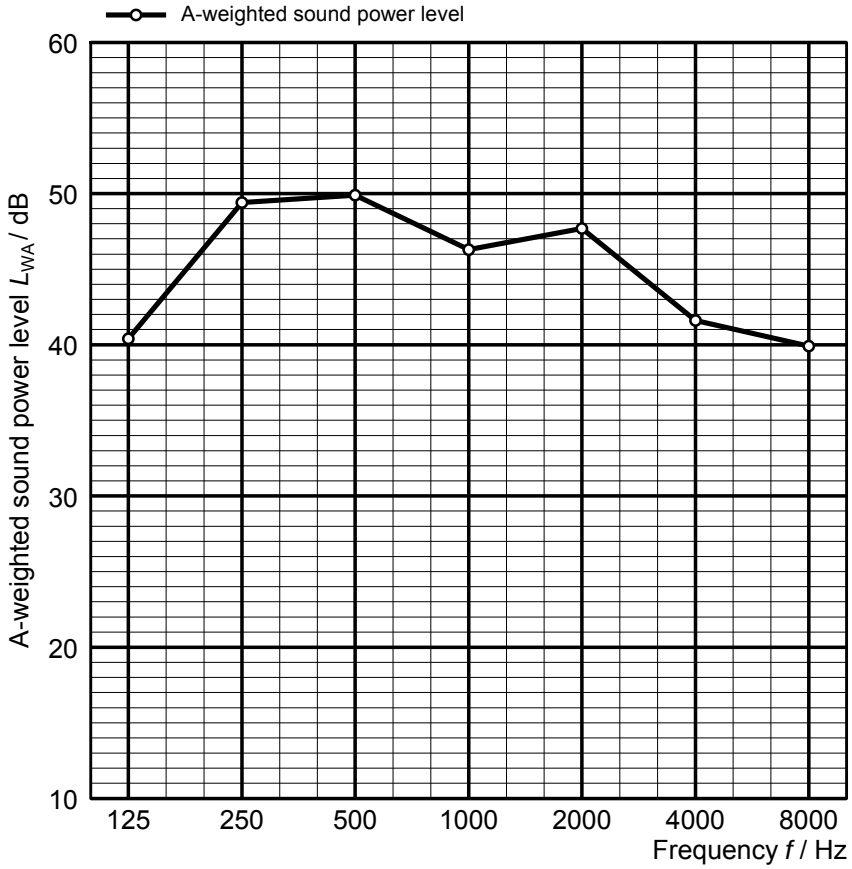
- Generation of vacuum via suction bottle with artificial breast
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.5 °C
r. h. = 50.0 %
*B* = 94.8 kPa

| Frequency octave [Hz] | $L_{WA}$ 1/3 octave [dB] |
|---|---|
| 125 | ◦ 40.4 |
| 250 | 49.4 |
| 500 | 49.9 |
| 1000 | 46.3 |
| 2000 | 47.7 |
| 4000 | ◦ 41.6 |
| 8000 | ◦ 39.9 |

◦ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 55.1 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Single pump type Lansinoh® Affinity Pro™

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: single pump
- Manufacturer / type: Lansinoh® / Affinity Pro™
- Serial No.: SN0172
- Type of pump: membrane pump
- Cycle: variable in 3 steps
- Vacuum performance: variable in 8 steps

Operating conditions during test:

- Vacuum performance: full load (step 8, maximum power), suction mode
- Cycle: 50/min (step 2)

Test set-up:

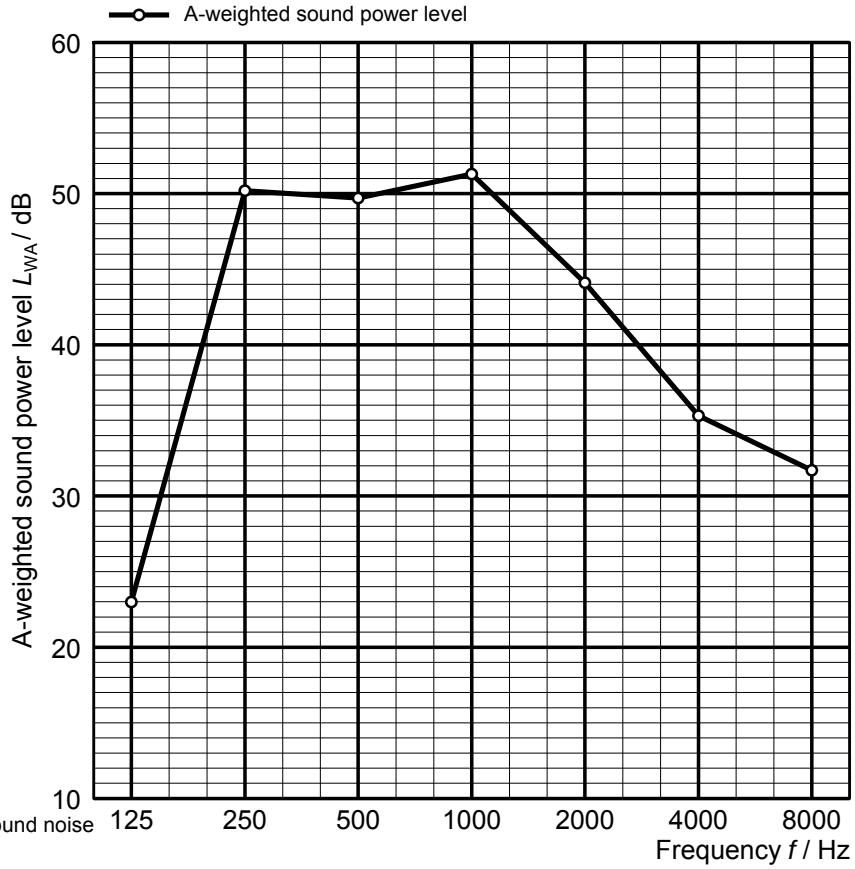
- Generation of vacuum via suction bottle with artificial breast
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.4 °C
r. h. = 50.6 %
*B* = 94.8 kPa

| Frequency octave [Hz] | $L_{WA}$ 1/3 octave [dB] |
|---|---|
| 125 | • 23.0 |
| 250 | ○ 50.2 |
| 500 | 49.7 |
| 1000 | 51.3 |
| 2000 | 44.1 |
| 4000 | ○ 35.3 |
| 8000 | • 31.7 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 55.6 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Single pump type Ameda Purely Yours™

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: single pump
- Manufacturer / type: Ameda / Purely Yours™ (same construction as Ameda / Lactaline)
- Serial No.: 24502082
- Type of pump: membrane pump
- Cycle: variable (infinitely variable adjustment wheel, stepping not registered)
- Vacuum performance: variable (infinitely variable adjustment wheel, stepping not registered)

Operating conditions during test:

- Vacuum performance: full load (maximum power)
- Cycle: 48/min

Test set-up:

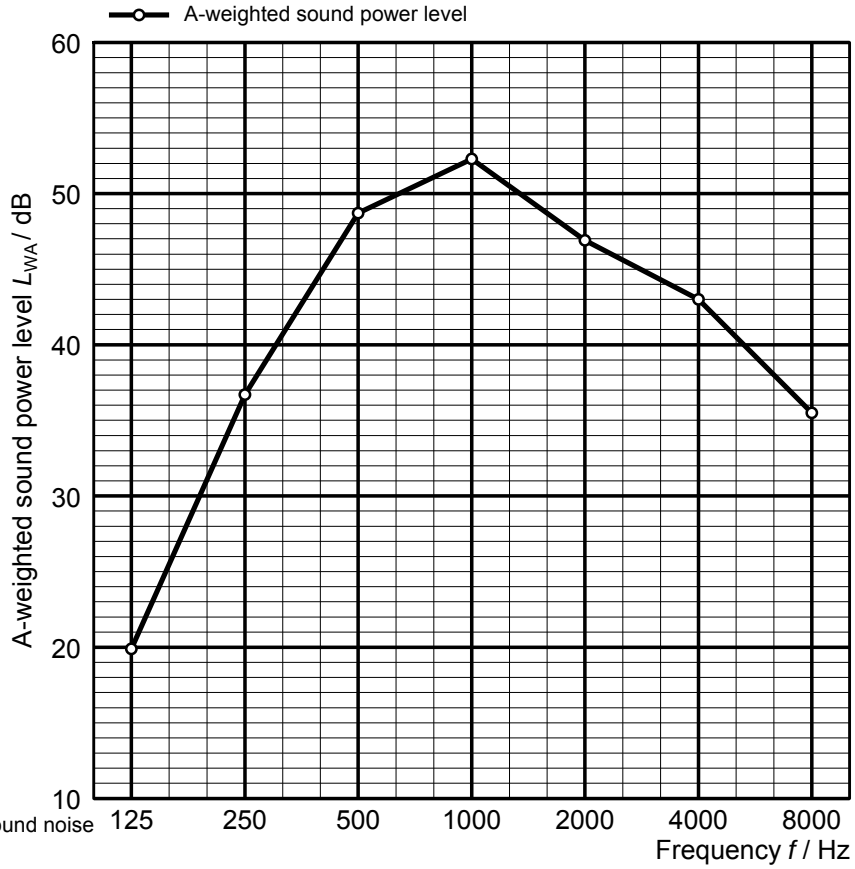
- Generation of vacuum via suction bottle with artificial breast
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.5 °C
r. h. = 50.3 %
*B* = 94.8 kPa

| Frequency octave [Hz] | $L_{WA}$ 1/3 octave [dB] |
|---|---|
| 125 | • 19.9 |
| 250 | • 36.7 |
| 500 | 48.7 |
| 1000 | 52.3 |
| 2000 | 46.9 |
| 4000 | 43.0 |
| 8000 | ○ 35.5 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 55.1 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Double pump type Ardo Calypso Double Plus

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: double pump
- Manufacturer / type: Ardo / Calypso Double Plus
- Serial No.: 14621129
- Type of pump: piston pump
- Cycle: variable in 8 steps
- Vacuum performance: variable in 8 steps

Operating conditions during test:

- Vacuum performance: full load (step 8, maximum power)
- Cycle: 52/min (step 7)

Test set-up:

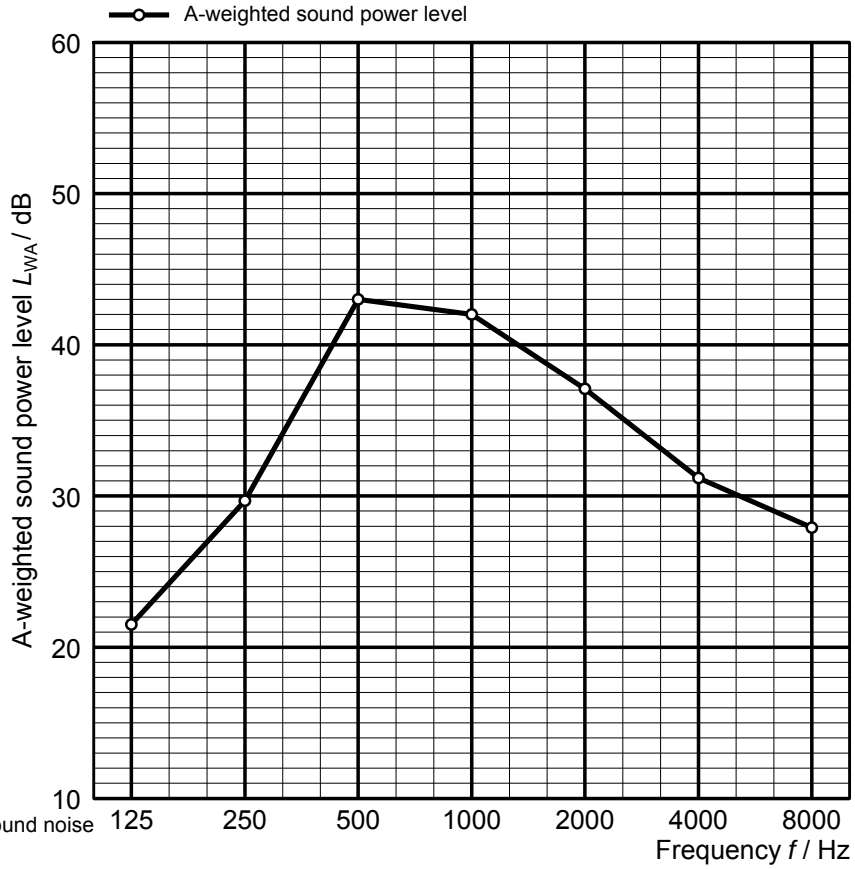
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.5 °C
r. h. = 48.5 %
*B* = 94.8 kPa

| Frequency octave [Hz] | $L_{WA}$ 1/3 octave [dB] |
|---|---|
| 125 | • 21.5 |
| 250 | • 29.7 |
| 500 | 43.0 |
| 1000 | 42.0 |
| 2000 | 37.1 |
| 4000 | • 31.2 |
| 8000 | • 27.9 |

• minimum value, dominated by background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 46.4 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Double pump type Medela Freestyle™

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: double pump
- Manufacturer / type: Medela / Freestyle™
- Serial No.: F20134300130
- Type of pump: membrane pump
- Cycle: not variable
- Vacuum performance: variable in 9 steps

Operating conditions during test:

- Vacuum performance: full load (step 9, maximum power), suction mode
- Cycle: 50/min

Test set-up:

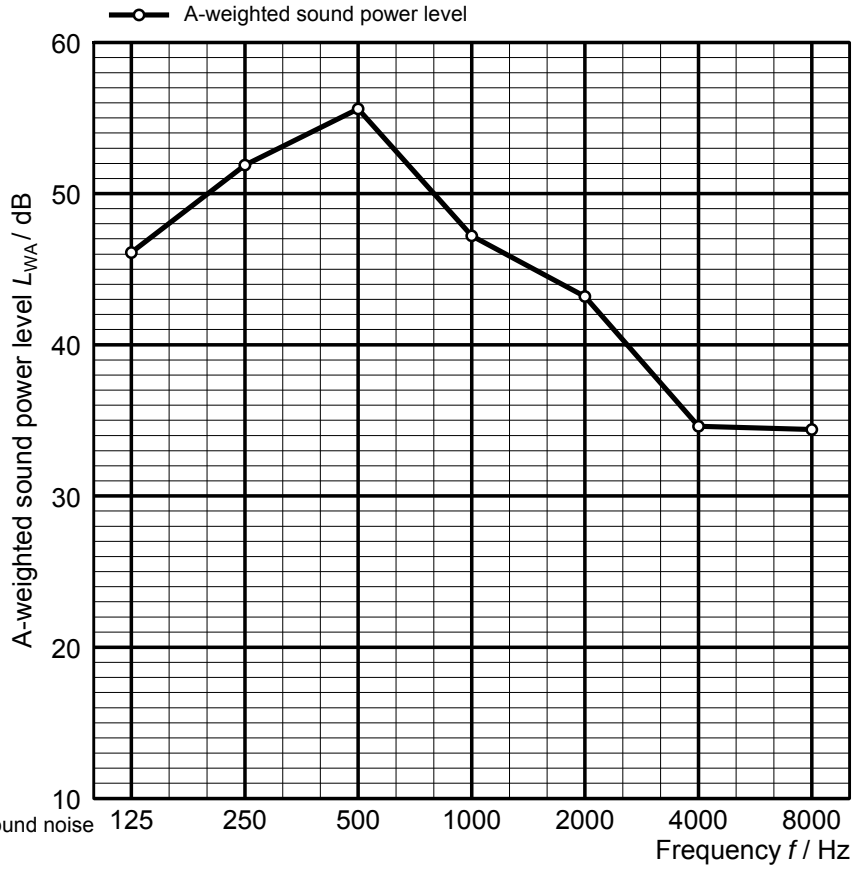
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.4 °C
r. h. = 50.6 %
*B* = 94.8 kPa

| Frequency octave [Hz] | | $L_{WA}$ 1/3 octave [dB] |
|---|---|---|
| 125 | | 46.1 |
| 250 | | 51.9 |
| 500 | | 55.6 |
| 1000 | | 47.2 |
| 2000 | | 43.2 |
| 4000 | ○ | 34.6 |
| 8000 | • | 34.4 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 58.0 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Double pump type Lansinoh® Affinity Pro™

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: double pump
- Manufacturer / type: Lansinoh® / Affinity Pro™
- Serial No.: SN0172
- Type of pump: membrane pump
- Cycle: variable in 3 steps
- Vacuum performance: variable in 8 steps

Operating conditions during test:

- Vacuum performance: full load (step 8, maximum power), suction mode
- Zyklus: 50/min (step 2)

Test set-up:

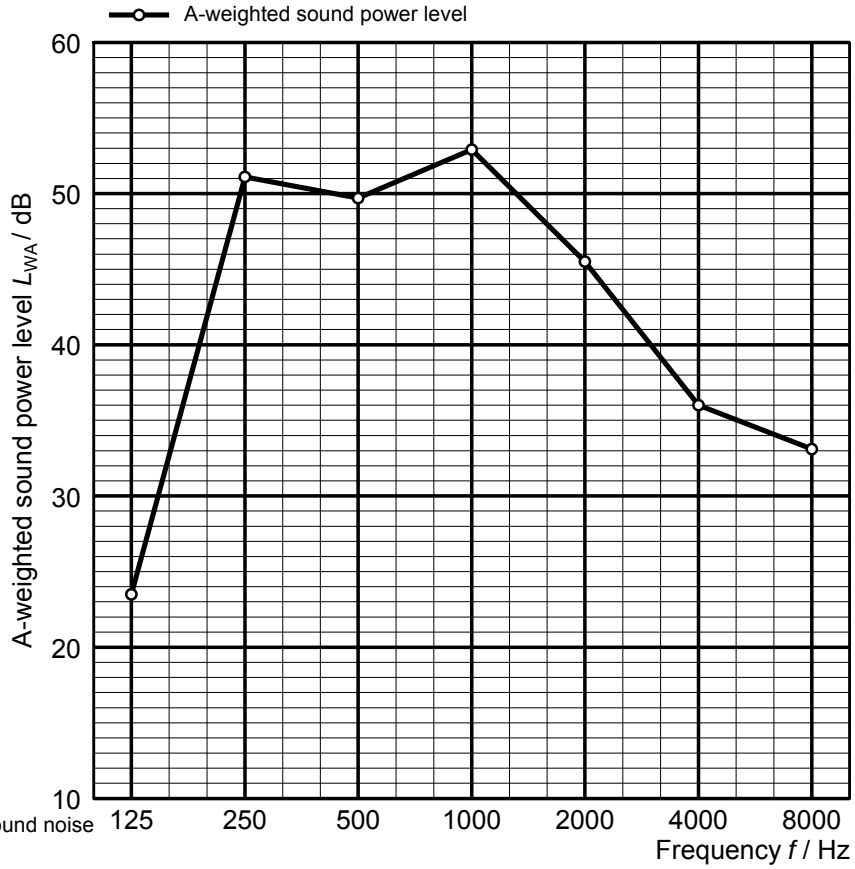
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.5 °C
r. h. = 50.3 %
*B* = 94.8 kPa

| Frequency octave [Hz] | $L_{WA}$ 1/3 octave [dB] |
|---|---|
| 125 | • 23.5 |
| 250 | ○ 51.1 |
| 500 | 49.7 |
| 1000 | 52.9 |
| 2000 | 45.5 |
| 4000 | ○ 36.0 |
| 8000 | ○ 33.1 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 56.6 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Double pump type Ameda Purely Yours™

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: double pump
- Manufacturer / type: Ameda / Purely Yours™ (same construction as Ameda Lactaline)
- Serial No.: 24502082
- Type of pump: membrane pump
- Cycle: variable (infinitely variable adjustment wheel, stepping not registered)
- Vacuum performance: variable (infinitely variable adjustment wheel, stepping not registered)

Operating conditions during test:

- Vacuum performance: full load (maximum power)
- Cycle: 48/min

Test set-up:

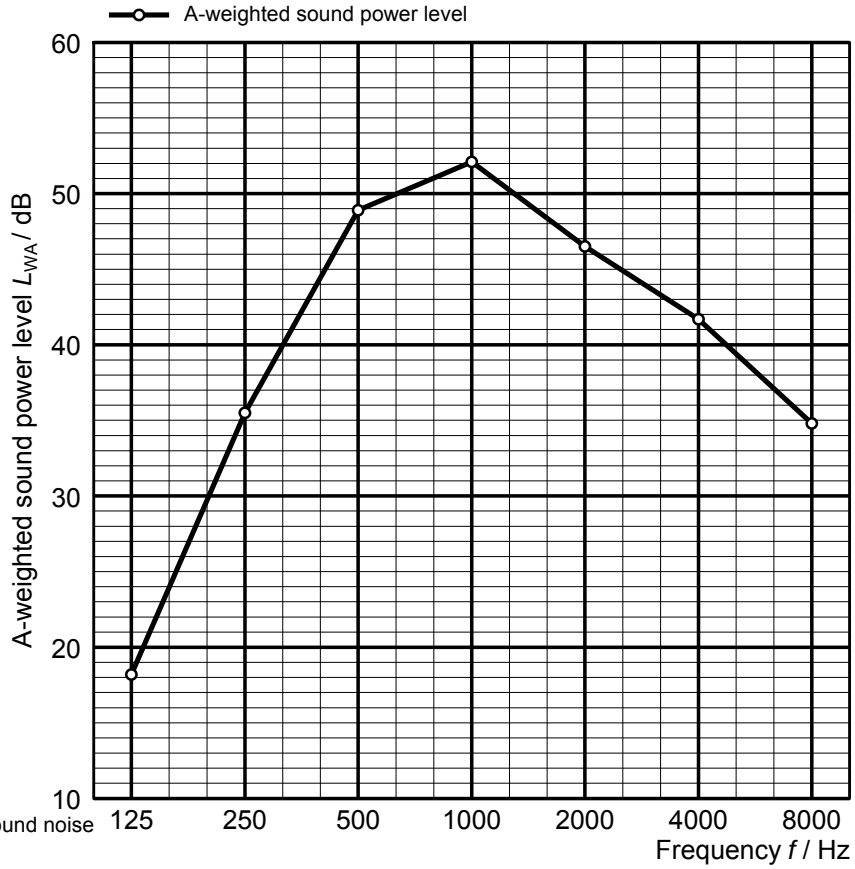
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.5 °C
r. h. = 50.3 %
*B* = 94.8 kPa

| Frequency octave [Hz] | $L_{WA}$ 1/3 octave [dB] |
|---|---|
| 125 | • 18.2 |
| 250 | • 35.5 |
| 500 | 48.9 |
| 1000 | 52.1 |
| 2000 | 46.5 |
| 4000 | 41.7 |
| 8000 | ○ 34.8 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 54.9 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Double pump type Medela Swing Maxi™

Description of the test object::

- Type of product: consumer vacuum breast-pump
- Mode: double pump
- Manufacturer / type: Medela / Swing Maxi™
- Serial No.: M20140500034
- Type of pump: membrane pump
- Cycle: frequency not variable
- Vacuum performance: variable in 9 steps

Operating conditions during test:

- Vacuum performance: full load (step 9, maximum power), suction mode
- Cycle: 46/min

Test set-up:

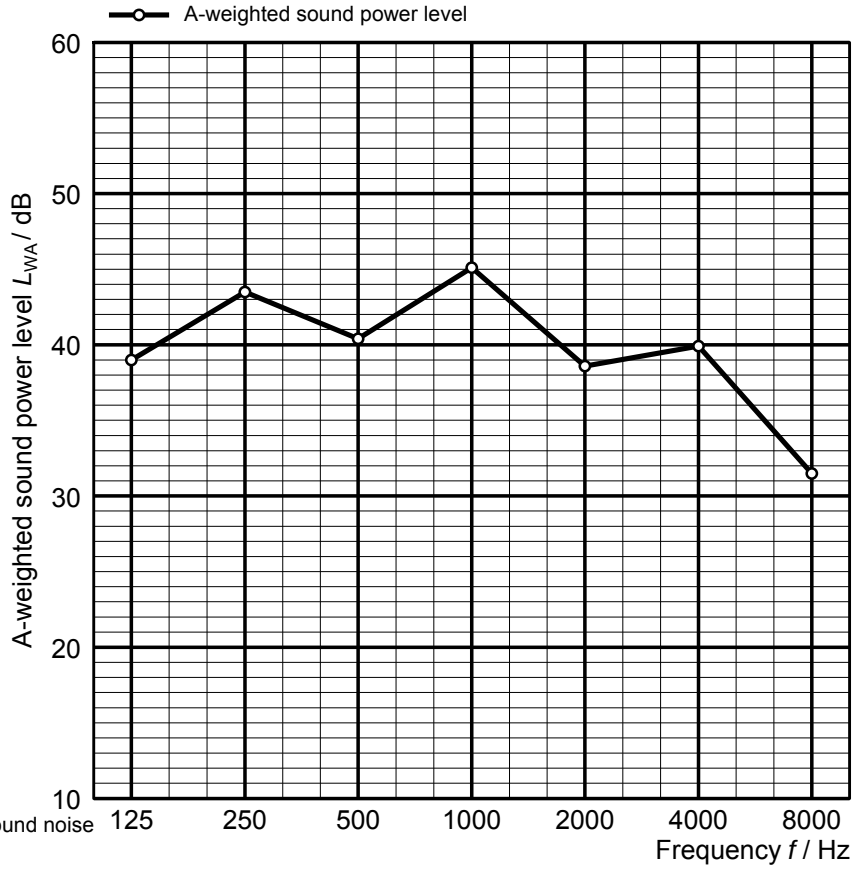
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.5 °C
r. h. = 50.3 %
*B* = 94.8 kPa

| Frequency octave [Hz] | | $L_{WA}$ 1/3 octave [dB] |
|---|---|---|
| 125 | • | 39.0 |
| 250 | | 43.5 |
| 500 | | 40.4 |
| 1000 | | 45.1 |
| 2000 | | 38.6 |
| 4000 | ○ | 39.9 |
| 8000 | • | 31.5 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 49.6 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Double pump type Philips AVENT

Description of the test object:

- Type of product: consumer vacuum breast-pump
- Mode: double pump
- Manufacturer / type: Philips / AVENT SCF 334
- Serial No.: 0045539
- Type of pump: membrane pump
- Cycle: frequency not variable
- Vacuum performance: variable in 3 steps

Operating conditions during test:

- Vacuum performance: full load (step 3, maximum power), suction mode
- Cycle: 45/min

Test set-up:

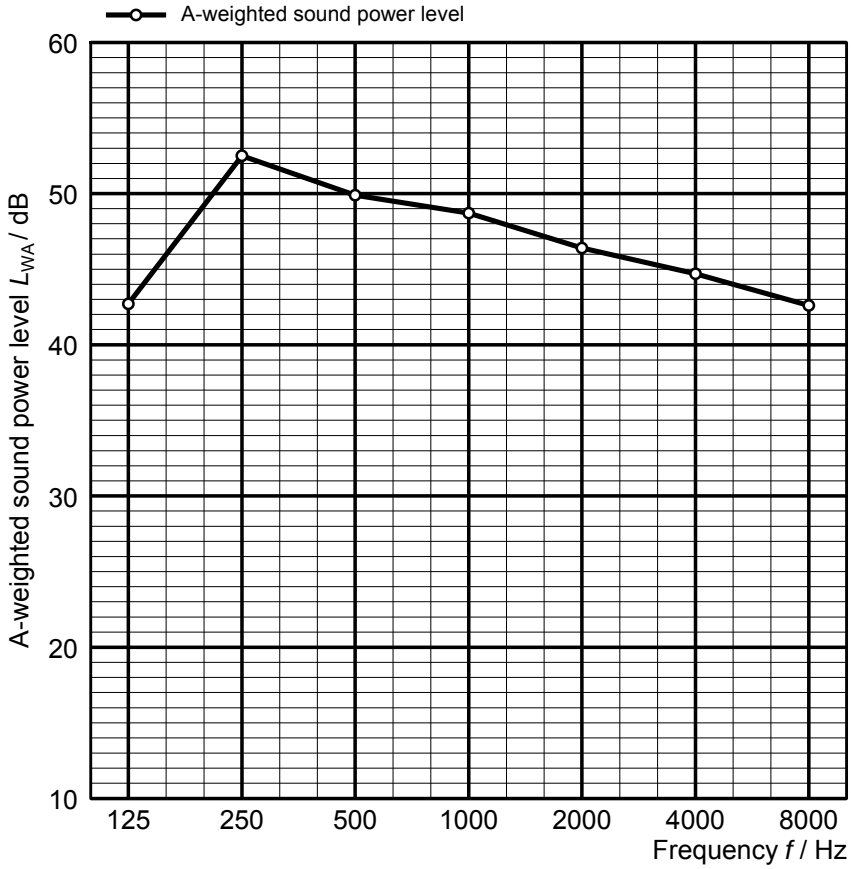
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2014-05-23

θ = 22.6 °C
r. h. = 50.1 %
*B* = 94.8 kPa

| Frequency octave [Hz] | $L_{WA}$ 1/3 octave [dB] |
|---|---|
| 125 | ◦ 42.7 |
| 250 | 52.5 |
| 500 | 49.9 |
| 1000 | 48.7 |
| 2000 | 46.4 |
| 4000 | 44.7 |
| 8000 | ◦ 42.6 |

◦ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 56.6 dB**

# Sound power levels of noise sources ISO 3741
## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Single pump type Medela Pump In Style® Advanced
Front pocket of backpack open

Description of the test object:

- Type of product: comsumer vacuum brest-pump
- Mode: single pump
- Manufacturer / type: Medela / Pump In Style® Advanced
- Serial No.: P1402851050
- Type of pump: membrane pump
- Cycle: frequency not variable
- Vacuum performance: infinitely variable

Operating conditions during test:

- Vacuum performance: full load (maximum power), suction mode
- Cycle: 56/min

Test set-up:

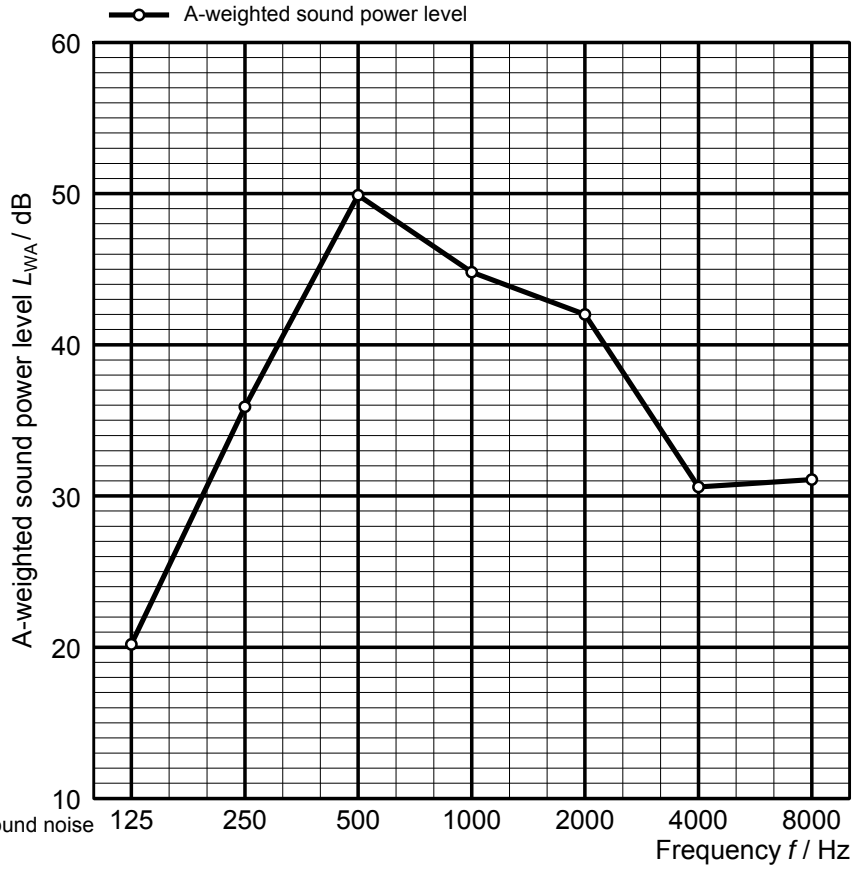
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Pump integrated in provided backpack, front pocket open
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2015-02-17

θ = 18.8 °C
r. h. = 28.3 %
*B* = 96.4 kPa

| Frequency octave [Hz] | | $L_{WA}$ 1/3 octave [dB] |
|---|---|---|
| 125 | • | 20.2 |
| 250 | ○ | 35.9 |
| 500 | | 49.9 |
| 1000 | | 44.8 |
| 2000 | | 42.0 |
| 4000 | ○ | 30.6 |
| 8000 | ○ | 31.1 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 51.8 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Single pump type Medela Pump In Style® Advanced
Front pocket of backpack closed

Description of the test object:

- Type of product: comsumer vacuum brest-pump
- Mode: single pump
- Manufacturer / type: Medela / Pump In Style® Advanced
- Serial No: P1402851050
- Type of pump: membrane pump
- Cycle: frequency not variable
- Vacuum performance: infinitely variable

Operating conditions during test:

- Vacuum performance: full load (maximum power), suction mode
- Cycle: 56/min

Test set-up:

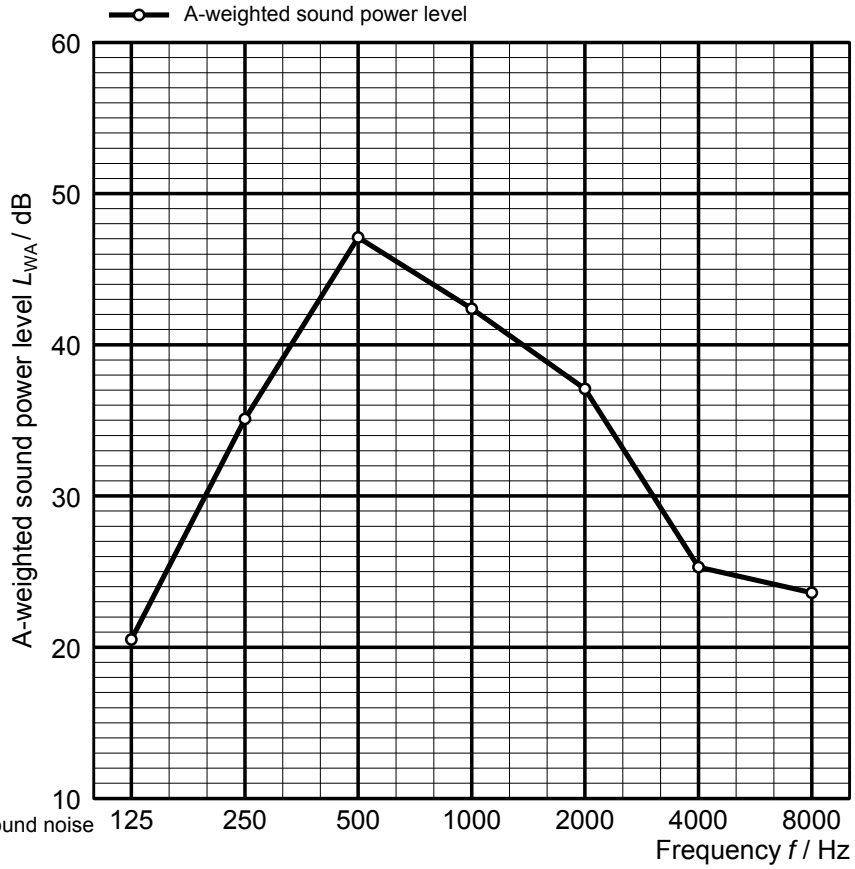
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Pump integrated in provided backpack, front pocket closed
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2015-02-17

θ = 18.8 °C
r. h. = 28.3 %
*B* = 96.4 kPa

| Frequency octave [Hz] | $L_{WA}$ 1/3 octave [dB] |
|---|---|
| 125 | • 20.5 |
| 250 | ○ 35.1 |
| 500 | 47.1 |
| 1000 | 42.4 |
| 2000 | 37.1 |
| 4000 | • 25.5 |
| 8000 | • 23.6 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 48.9 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Double pump type Medela Pump In Style® Advanced
Front pocket of backpack open

Description of the test object:

- Type of product: comsumer vacuum brest-pump
- Mode: double pump
- Manufacturer / type: Medela / Pump In Style® Advanced
- Serial No.: P1402851050
- Type of pump: membrane pump
- Cycle: frequency not variable
- Vacuum performance: infinitely variable

Operating conditions during test:

- Vacuum performance: full load (maximum power), suction mode
- Cycle: 56/min

Test set-up:

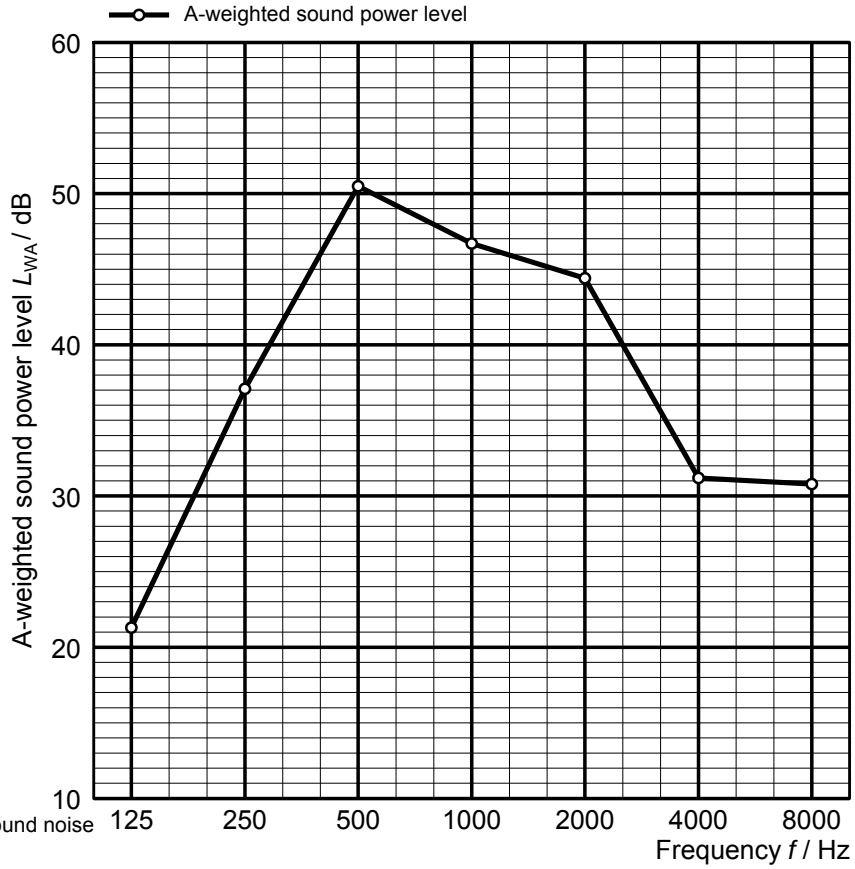
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Pump integrated in provided backpack, front pocket open
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2015-02-17

θ = 18.8 °C
r. h. = 28.3 %
*B* = 96.4 kPa

| Frequency octave [Hz] | | $L_{WA}$ 1/3 octave [dB] |
|---|---|---|
| 125 | • | 21.3 |
| 250 | ○ | 37.1 |
| 500 | | 50.5 |
| 1000 | | 46.7 |
| 2000 | | 44.4 |
| 4000 | ○ | 31.2 |
| 8000 | • | 30.8 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 52.9 dB**

# Sound power levels of noise sources ISO 3741

## Precision methods for reverberation rooms

**Client:** Ardo medical AG
Gewerbestraße 19, 6314 Unterägeri, Switzerland

**Noise source under test:** Double pump type Medela Pump In Style® Advanced
Front pocket of backpack closed

Description of the test object:

- Type of product: comsumer vacuum brest-pump
- Mode: double pump
- Manufacturer / type: Medela / Pump In Style®Advanced
- Serial No: P1402851050
- Type of pump: membrane pump
- Cycle: frequency not vari
- Vacuum performance: infinitely variable

Operating conditions during test:

- Vacuum performance: full load (maximum power), suction mode
- Cycle: 56/min

Test set-up:

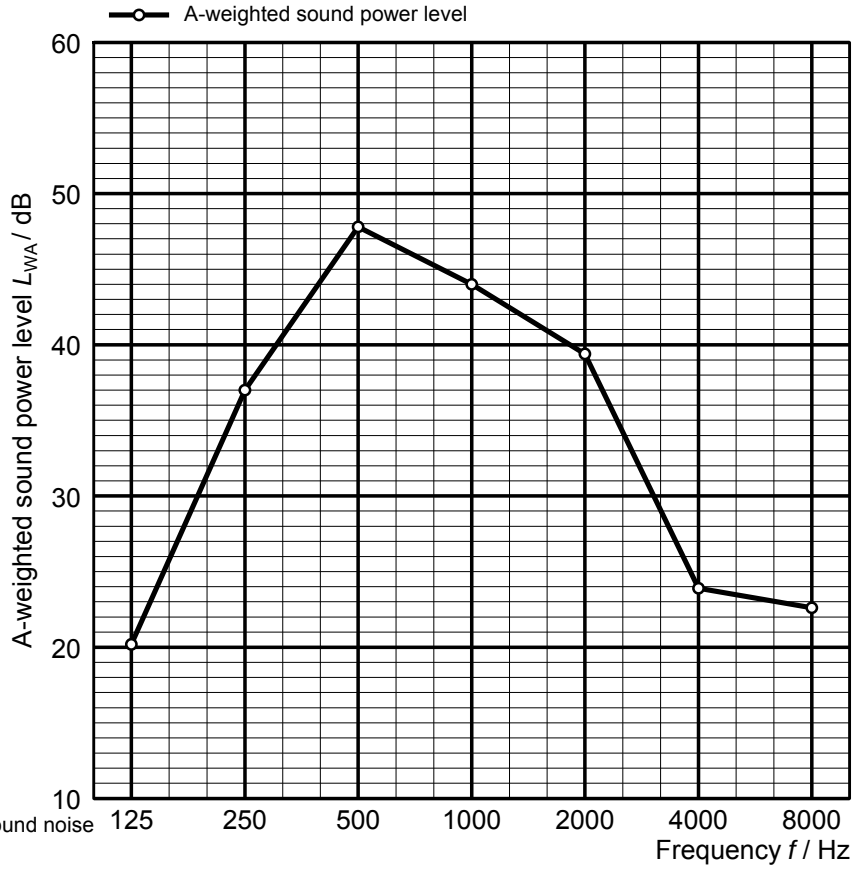
- Generation of vacuum via suction bottles with artificial breasts
- Suction bottle without additional soft inlays (only hard plastic shell)
- Pump integrated in provided backpack, front pocket closed
- Test set-up acc. to ISO 3741 on the reverberation room floor

Room: E
Volume: 199.60 m³
Surface of room: 216.00 m²
Date of test: 2015-02-17

θ = 18.8 °C
r. h. = 28.3 %
*B* = 96.4 kPa

| Frequency octave [Hz] | | $L_{WA}$ 1/3 octave [dB] |
|---|---|---|
| 125 | • | 20.2 |
| 250 | ○ | 37.0 |
| 500 | | 47.8 |
| 1000 | | 44.0 |
| 2000 | | 39.4 |
| 4000 | • | 24.3 |
| 8000 | • | 22.7 |

• minimum value, dominated by background noise
○ value corrected for background noise




Rating according to ISO 3741:

**A-weighted sound power level $L_{WA}$ = 50.0 dB**

# Appendix B

## Pictures

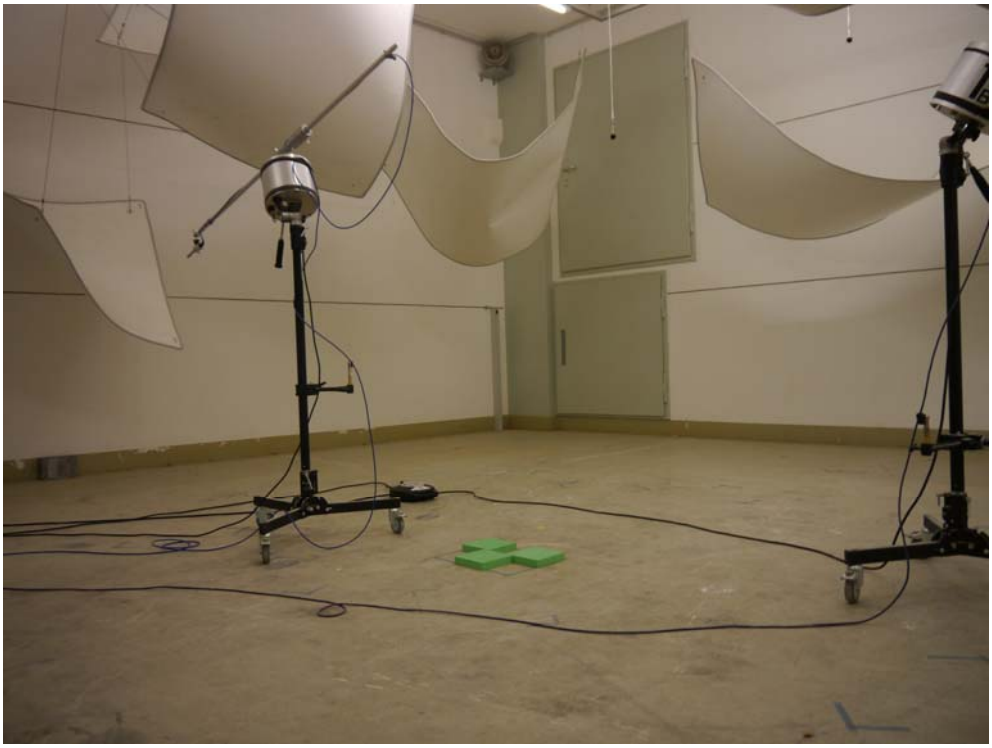


Figure B.1. Reverberation room and test position without test object.

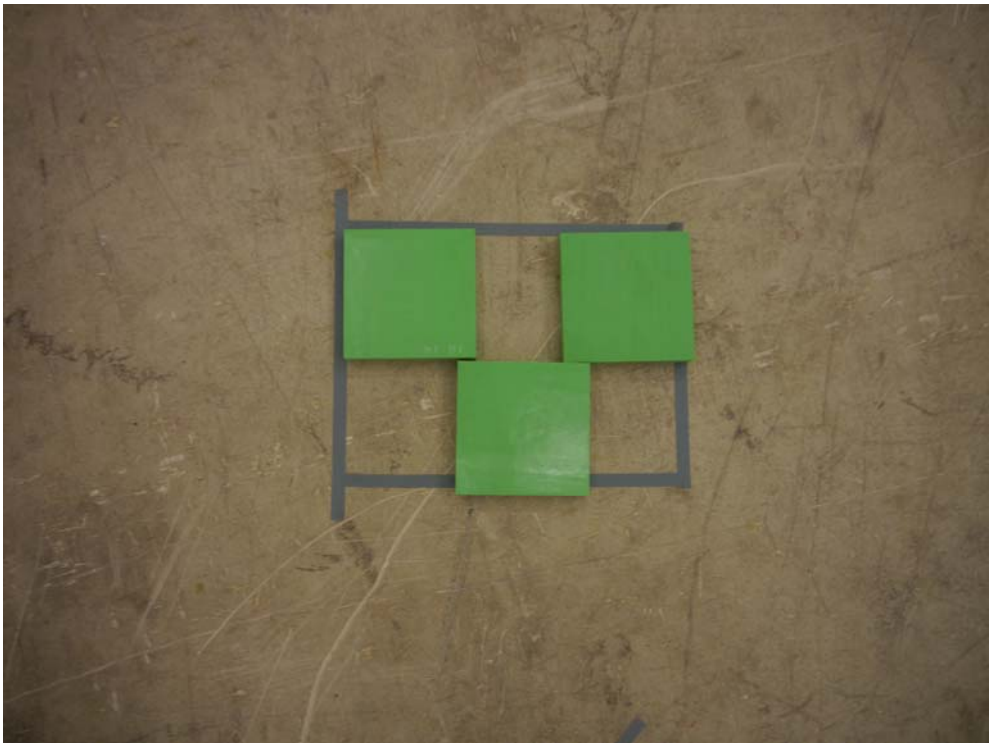


Figure B.2. Test position on the reverberation room floor without test object.

Figure B.3. Test arrangement on the reverberation room floor.

Figure B.4. Suction bottle with fixed artificial brest.

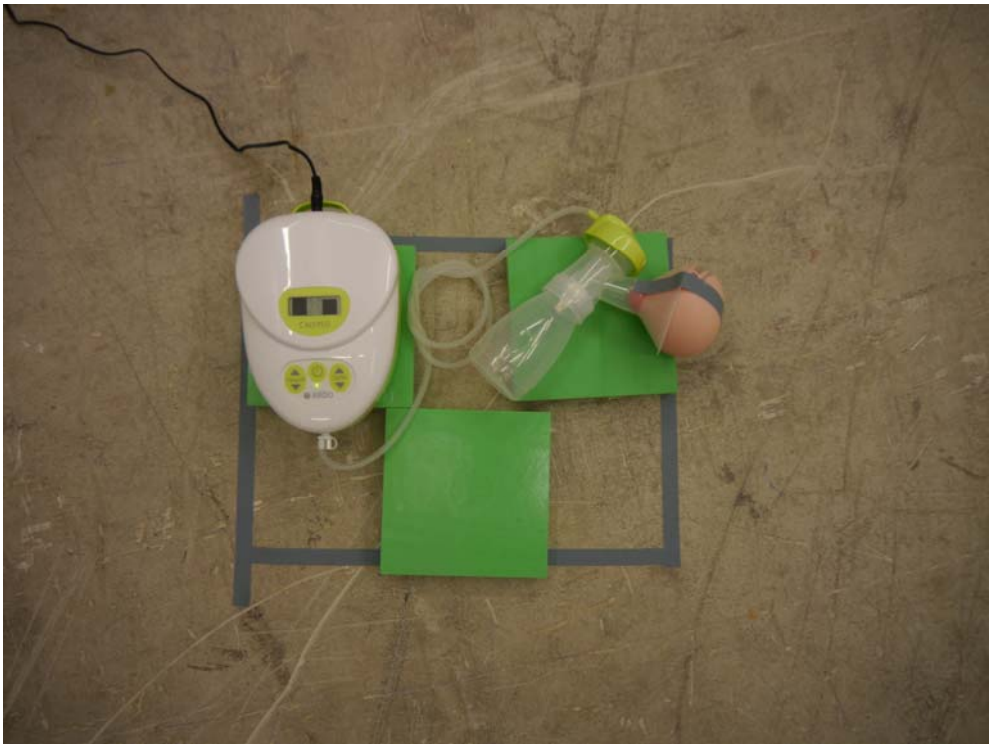


Figure B.5. Test No. 1: Ardo Calypso (single pump).

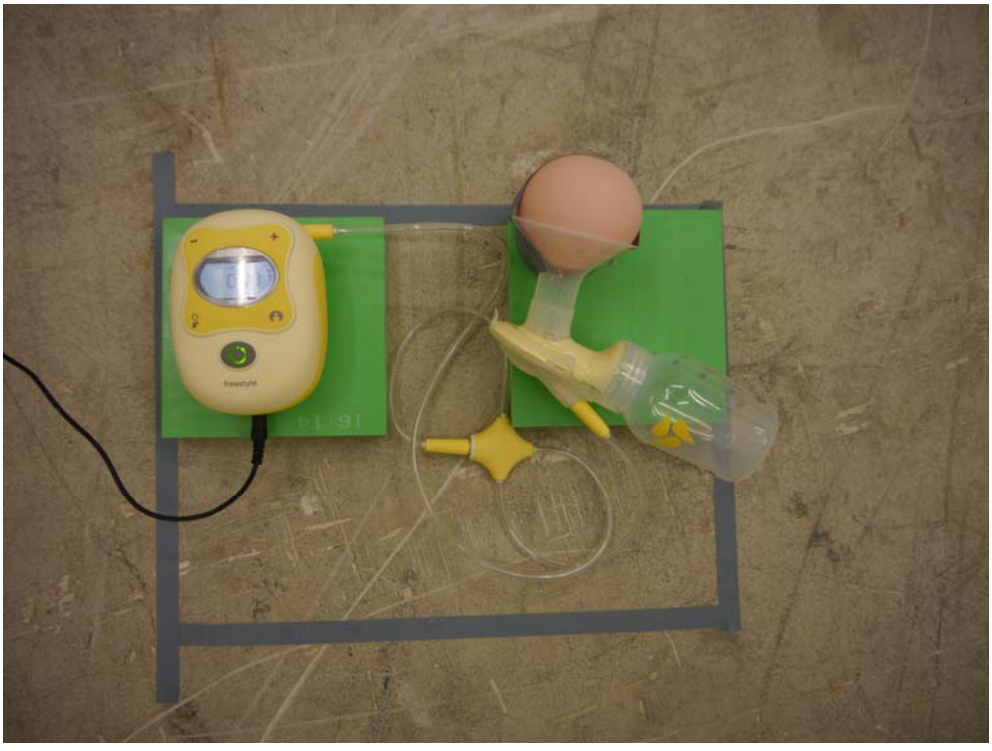


Figure B.6. Test No. 2: Medela Freestyle™ (single pump).

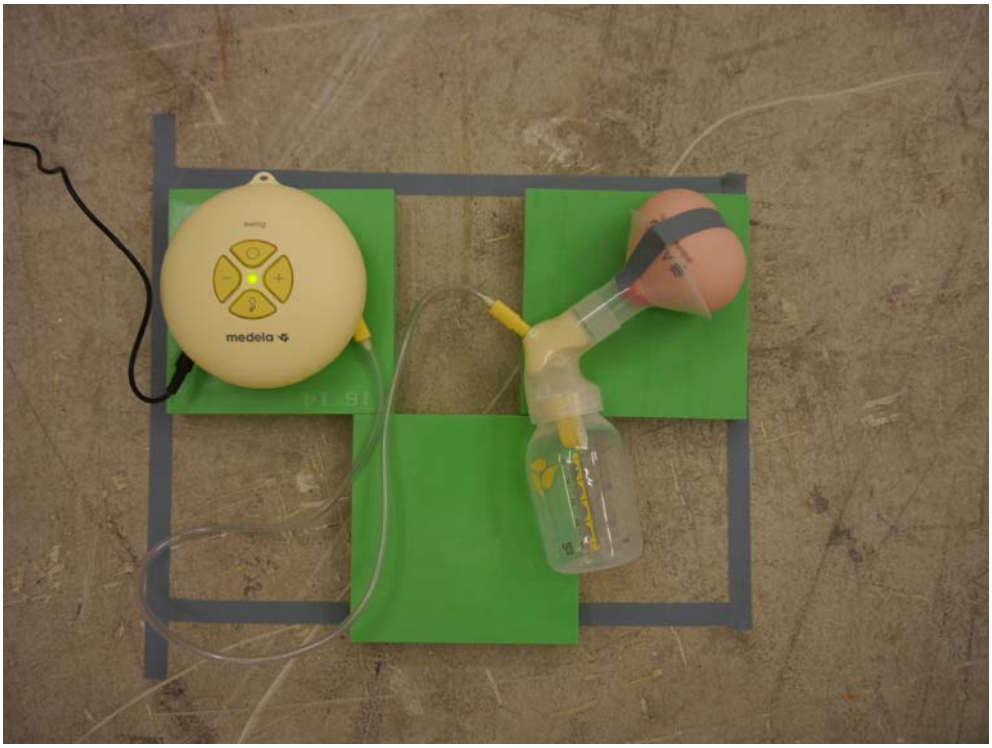



Figure B.7. Test No. 3: Medela Swing™ (single pump).

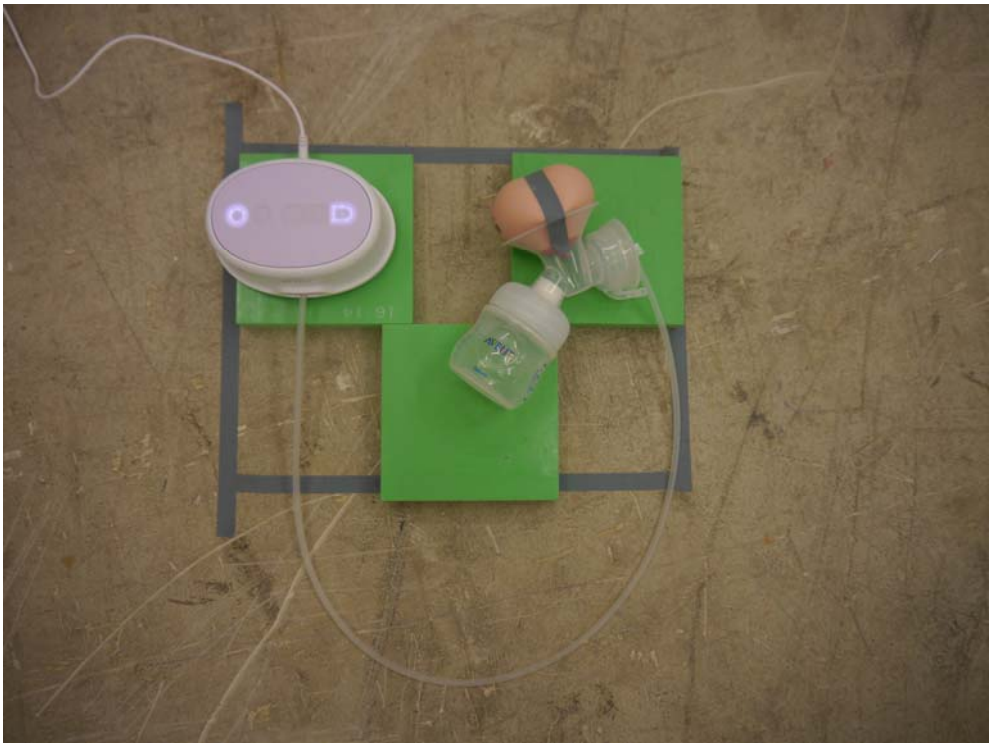


Figure B.8. Test No. 4: Philips AVENT (single pump).

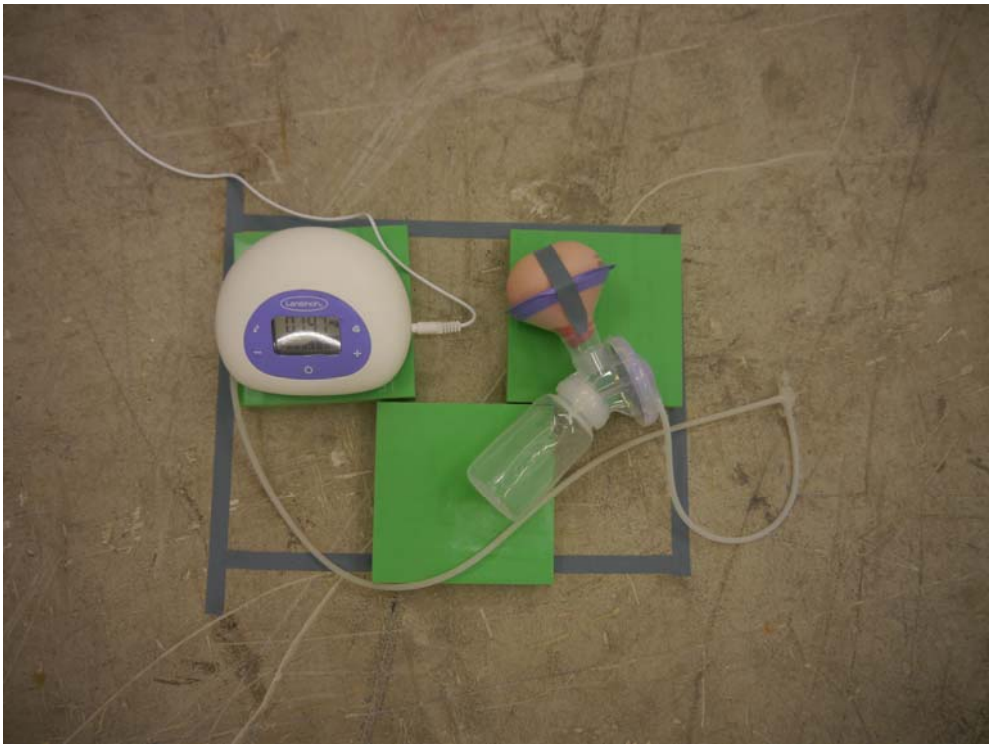


Figure B.9. Test No. 5: Lansinoh® Affinity Pro™ (single pump).

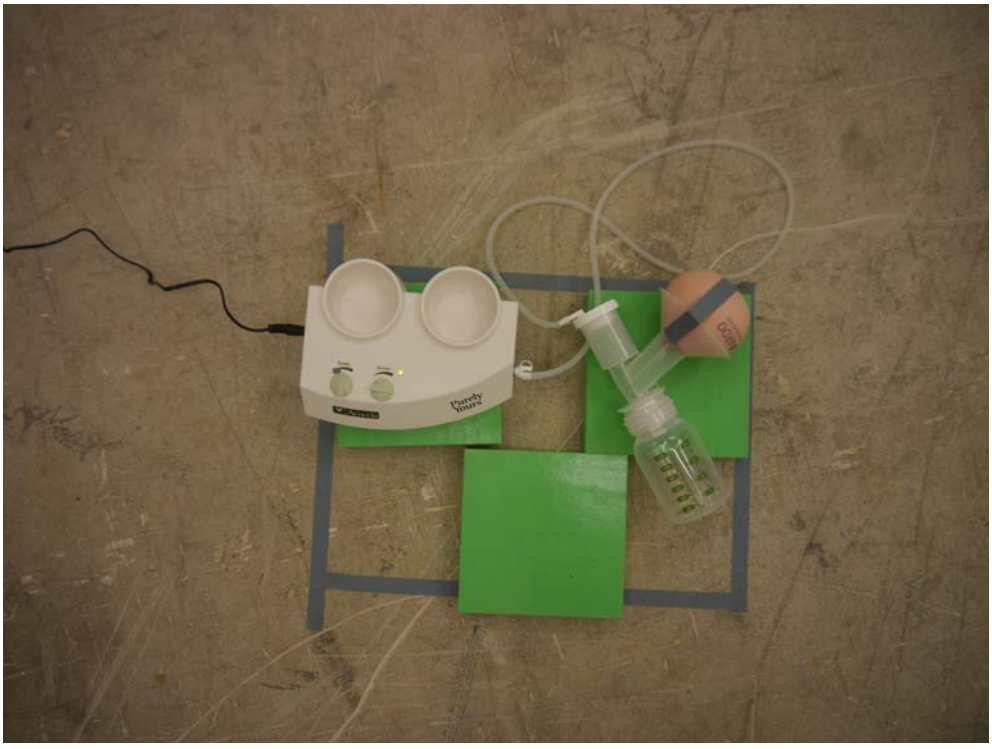


Figure B.10. Test No. 6: Ameda Purely Yours™ (single pump).

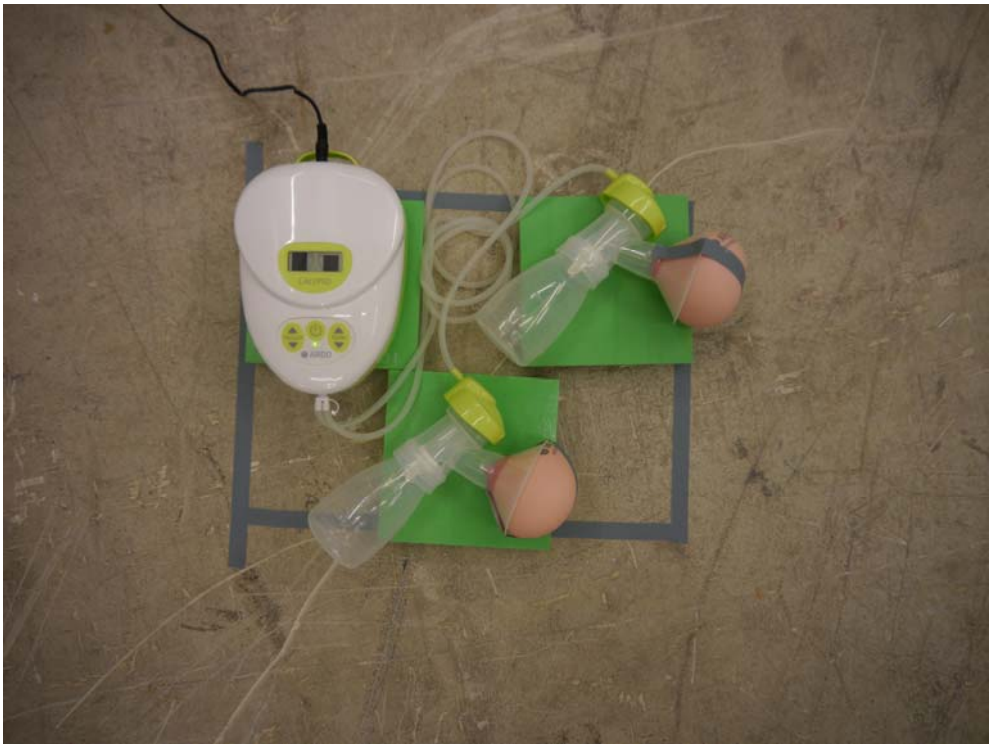


Figure B.11. Test No. 7: Ardo Calypso Double Plus (double pump).

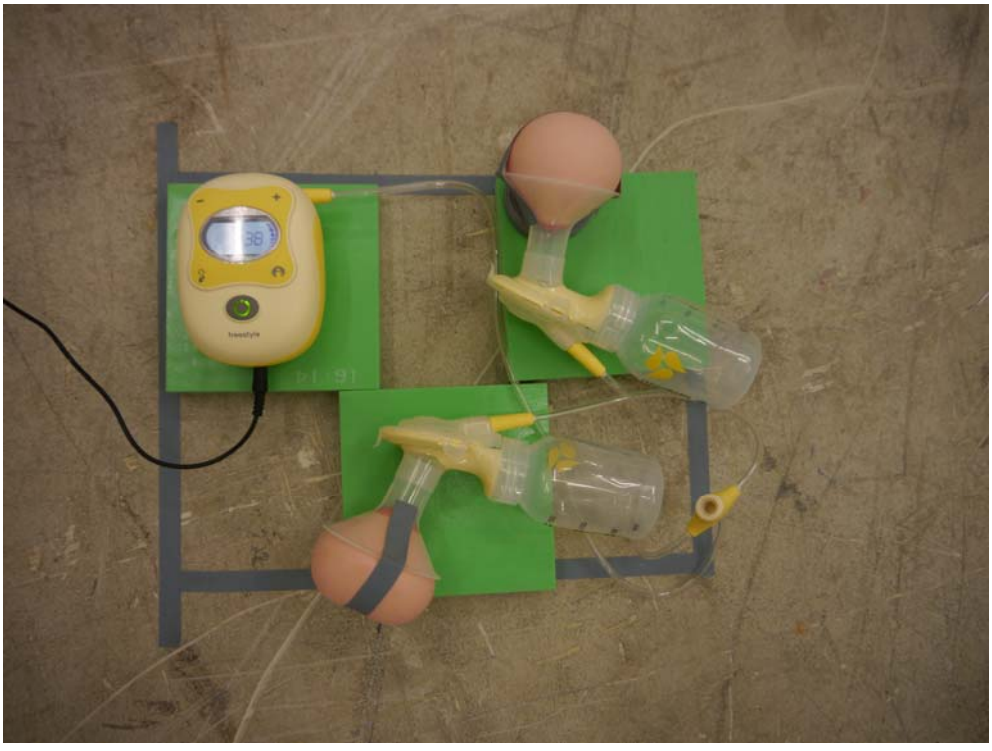


Figure B.12. Test No. 8: Medela Freestyle™ (double pump).

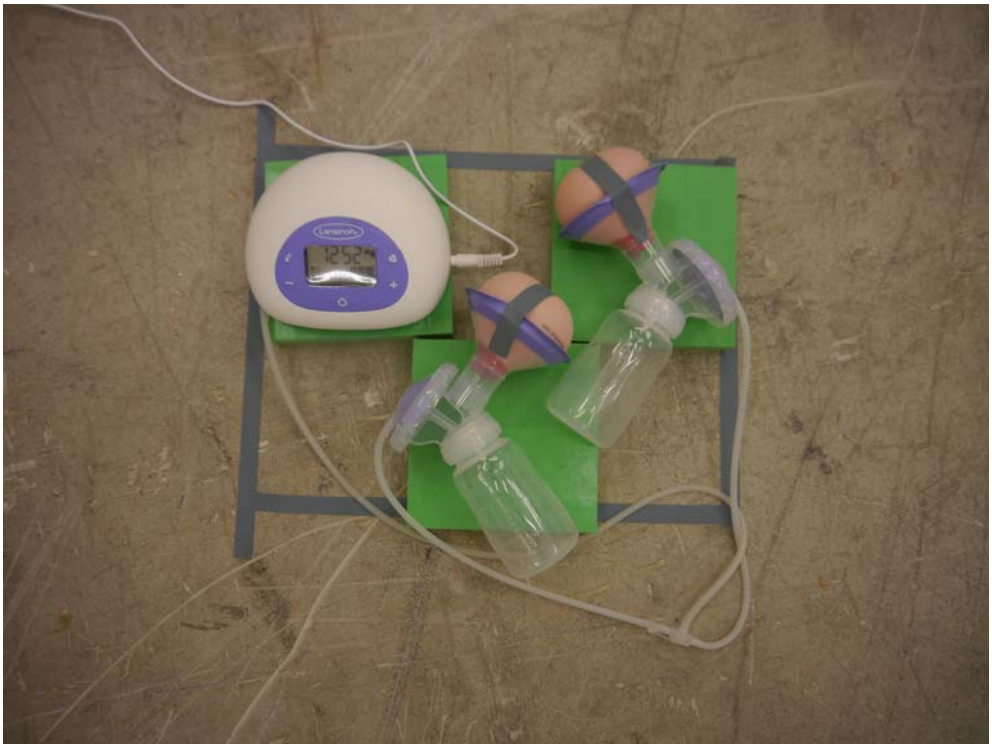


Figure B.13. Test No. 9: Lansinoh® Affinity Pro™ (double pump).

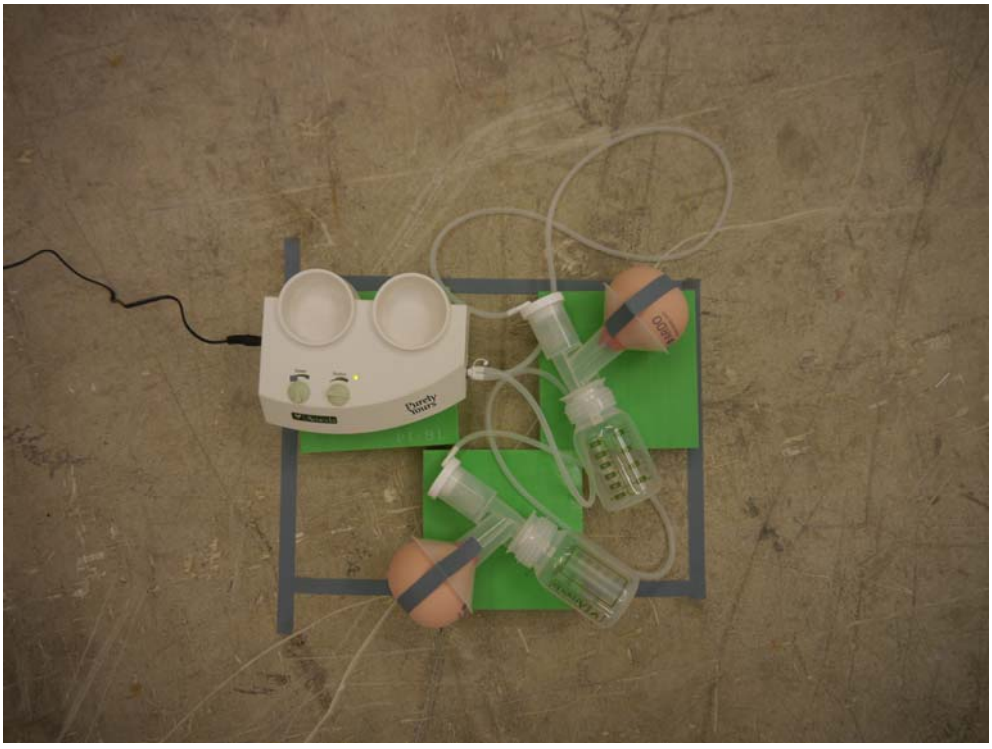


Figure B.14. Test No. 10: Ameda Purely Yours™ (double pump).

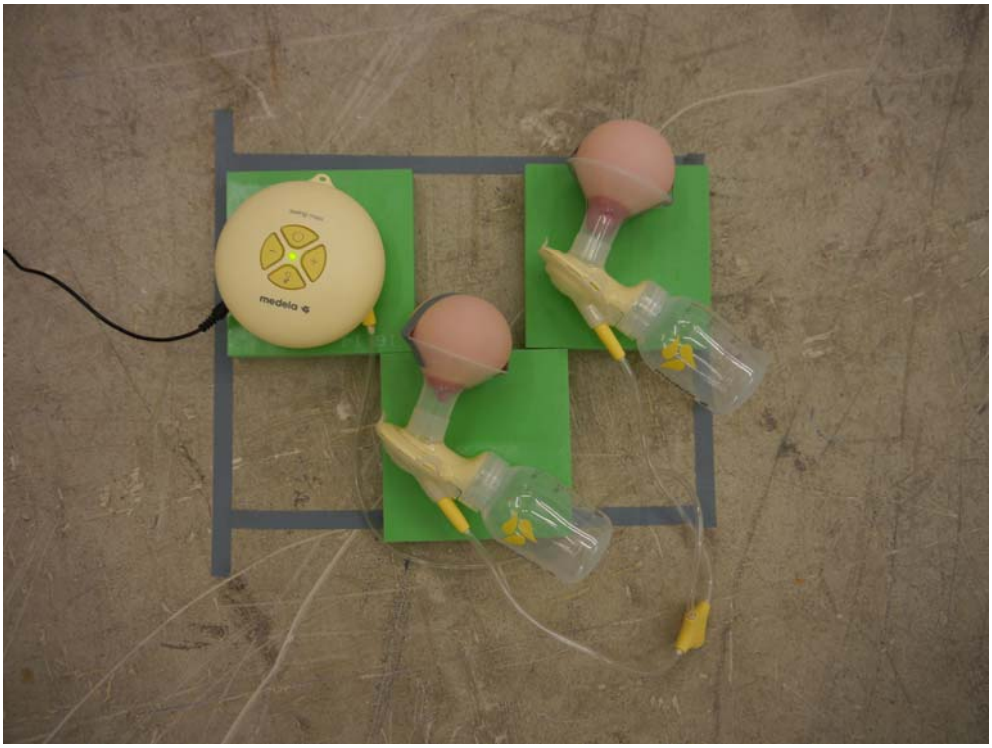



Figure B.15. Test No. 11: Medela Swing Maxi™ (double pump).

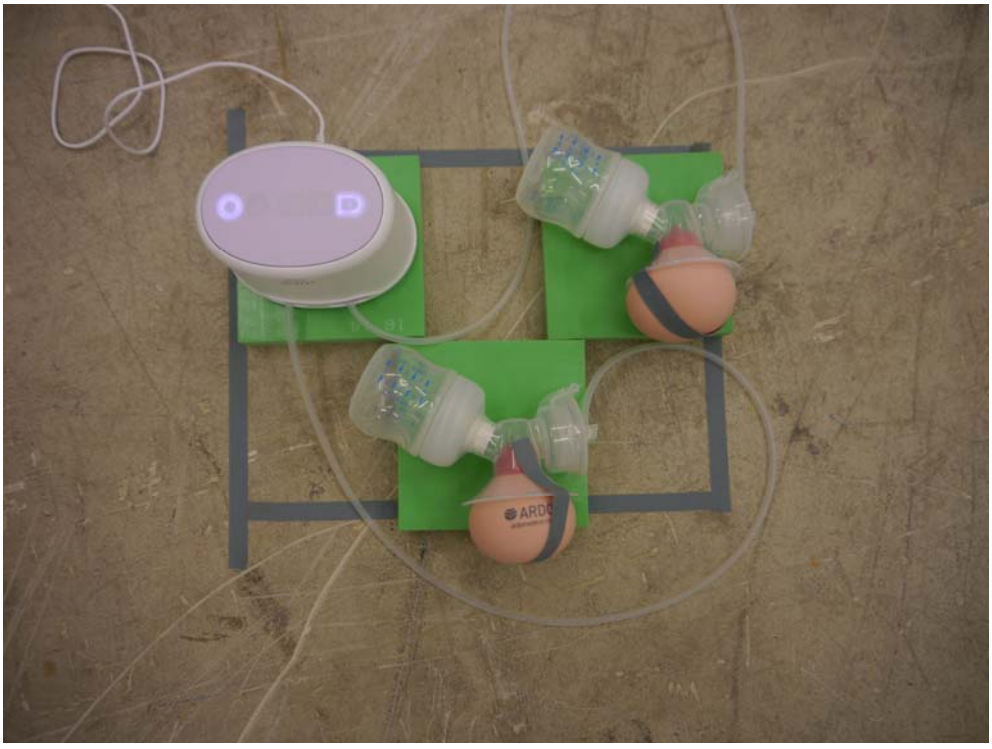


Figure B.16. Test No. 12: Philips AVENT (double pump).

Figure B.17. Test No. 13: Medela Pump In Style® Advanced (single pump, backpack open).

Figure B.18. Test No. 14: Medela Pump In Style® Advanced (single pump, backpack closed).

Figure B.19. Test No. 15: Medela Pump In Style® Advanced (double pump, backpack open).

Figure B.20. Test No. 16: Medela Pump In Style® Advanced (double pump, backpack closed).

## Result tables

The markings in the following tables signify:

Column “Corr.“: background noise correction

| | | |
|---|---|---|
| without | no influence of background noise | $\Delta L_p \geq 15$ dB; $K_{1i} = 0$ dB |
| * | Measurement value influenced by background noise: | |
| | 100 Hz…200 Hz und ≥ 6300 Hz: | 6 dB ≤ $\Delta L_p$ < 15 dB; $K_{1i}$ = 0.0…1.3 dB |
| | 250 Hz…5000 Hz: | 10 dB ≤ $\Delta L_p$ < 15 dB; $K_{1i}$ = 0.0…0.5 dB |
| ** | Measurement value determined by background noise (minimum value): | |
| | 100 Hz…200 Hz und ≥ 6300 Hz: | $\Delta L_p$ < 6 dB; $K_{1i}$ = 1.3 dB (= max.) |
| | 250 Hz…5000 Hz: | $\Delta L_p$ < 10 dB; $K_{1i}$ = 0.5 dB (= max.) |

Column “Crit.“: Compliance with relative criterion

| | |
|---|---|
| without | Relative criterion acc. to 5.4.1.1 and 5.4.1.2 of ISO 3741 [2] complied with |
| n. c. | Relative criterion acc. to 5.4.1.1 and 5.4.1.2 of ISO 3741 [2] not complied with. |

Table C.1. Tests Nos. 1 to 4 (test certificates Appendix A, pages 1 to 4): Determined sound power levels $L_W$ in third-octave bands in dB(A).

| Frequency | Test No. 1 | | | Test No. 2 | | | Test No. 3 | | | Test No. 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. |
| 100 | 15.7 | ** | | 38.0 | | | 20.2 | ** | | 29.9 | * | |
| 125 | 14.3 | ** | | 27.3 | * | | 22.9 | * | | 39.7 | | |
| 160 | 11.6 | ** | | 45.0 | | | 37.2 | | | 25.7 | * | |
| 200 | 16.6 | ** | | 44.9 | | | 31.7 | * | | 34.0 | * | |
| 250 | 21.0 | ** | | 48.3 | | | 39.1 | | | 47.8 | | |
| 315 | 29.2 | * | | 47.0 | | | 37.9 | | | 43.7 | | |
| 400 | 34.1 | | | 50.8 | | | 44.9 | | | 47.8 | | |
| 500 | 38.8 | | | 52.5 | | | 45.8 | | | 42.1 | | |
| 630 | 36.3 | | | 46.8 | | | 48.4 | | | 43.4 | | |
| 800 | 31.9 | * | | 44.3 | | | 48.5 | | | 39.8 | | |
| 1000 | 38.3 | | | 41.4 | | | 47.6 | | | 43.9 | | |
| 1250 | 38.4 | | | 38.7 | | | 41.7 | | | 39.6 | | |
| 1600 | 35.0 | | | 39.9 | | | 39.3 | | | 41.6 | | |
| 2000 | 33.2 | * | | 40.7 | | | 36.0 | | | 44.4 | | |
| 2500 | 29.6 | * | | 32.3 | * | | 31.5 | * | | 42.3 | | |
| 3150 | 30.1 | * | | 32.2 | * | | 34.6 | | | 38.8 | | |
| 4000 | 25.6 | ** | n. c. | 28.7 | * | | 36.3 | | | 36.8 | | |
| 5000 | 24.4 | ** | n. c. | 26.6 | ** | | 32.9 | * | | 33.5 | * | |
| 6300 | 25.5 | ** | n. c. | 29.2 | * | | 27.5 | * | | 34.8 | * | |
| 8000 | 24.0 | ** | n. c. | 27.8 | * | | 28.6 | * | | 35.6 | * | |
| 10000 | 23.8 | ** | | 26.3 | ** | | 30.0 | * | | 34.9 | * | |

Table C.2. Tests Nos.5 to 8 (test certificates Appendix A, pages 5 to 8): Determined sound power levels $L_W$ in third-octave bands in dB(A).

| Frequency | Test No. 5 | | | Test No. 6 | | | Test No. 7 | | | Test No. 8 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. |
| 100 | 16.5 | ** | | 15.4 | ** | | 18.4 | ** | | 42.2 | | |
| 125 | 14.0 | ** | | 11.7 | ** | | 16.3 | ** | | 29.5 | * | |
| 160 | 21.1 | * | | 16.9 | ** | | 14.6 | ** | | 43.7 | | |
| 200 | 28.8 | * | | 17.9 | ** | | 15.8 | ** | | 45.0 | | |
| 250 | 49.0 | | | 32.2 | * | | 19.8 | ** | | 48.2 | | |
| 315 | 43.7 | | | 34.6 | * | | 29.1 | * | | 47.5 | | |
| 400 | 35.5 | | | 43.7 | | | 32.9 | * | | 50.7 | | |
| 500 | 48.4 | | | 44.4 | | | 39.5 | | | 52.7 | | |
| 630 | 43.2 | | | 43.7 | | | 39.5 | | | 47.7 | | |
| 800 | 43.1 | | | 43.5 | | | 36.1 | | | 44.9 | | |
| 1000 | 43.4 | | | 47.2 | | | 38.0 | | | 41.7 | | |
| 1250 | 49.8 | | | 49.9 | | | 37.3 | | | 38.7 | | |
| 1600 | 43.5 | | | 45.2 | | | 34.2 | | | 40.2 | | |
| 2000 | 33.2 | * | | 40.9 | | | 31.9 | * | | 39.8 | | |
| 2500 | 32.3 | * | | 36.2 | | | 29.4 | * | | 31.1 | * | |
| 3150 | 32.7 | * | | 35.8 | | | 28.9 | * | | 31.5 | * | |
| 4000 | 29.8 | * | | 40.6 | | | 25.5 | ** | n. c. | 30.2 | * | |
| 5000 | 27.4 | ** | | 36.4 | * | | 23.9 | ** | | 26.7 | ** | |
| 6300 | 27.2 | * | | 30.1 | * | | 24.0 | ** | | 30.3 | * | |
| 8000 | 26.6 | ** | | 31.5 | * | | 22.3 | ** | | 30.4 | * | |
| 10000 | 26.8 | ** | | 30.5 | * | | 23.1 | ** | | 27.9 | ** | |

Table C.3. Test Nrs.9 to 12 (test certificates Appendix A, pages 9 to 12):
Determined sound power levels $L_W$ in third-octave bands in dB(A).

| Frequency | Test No. 9 | | | Test No. 10 | | | Test No. 11 | | | Test No. 12 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. |
| 100 | 17.1 | ** | | 14.9 | ** | | 20.6 | ** | | 37.3 | * | |
| 125 | 14.6 | ** | | 10.8 | ** | | 30.0 | * | | 40.9 | | |
| 160 | 21.6 | * | | 13.8 | ** | | 38.3 | | | 27.0 | * | |
| 200 | 29.6 | * | | 18.1 | ** | | 37.4 | | | 37.7 | | |
| 250 | 50.0 | | | 28.0 | * | | 36.6 | | | 46.2 | | |
| 315 | 44.6 | | | 34.4 | * | | 40.8 | | | 51.1 | | |
| 400 | 34.4 | | | 44.7 | | | 36.2 | | | 48.6 | | |
| 500 | 48.0 | | | 44.4 | | | 33.6 | | | 41.3 | | |
| 630 | 44.3 | | | 43.3 | | | 36.6 | | | 40.5 | | |
| 800 | 44.2 | | | 45.2 | | | 39.1 | | | 42.1 | | |
| 1000 | 44.7 | | | 46.7 | | | 42.3 | | | 46.1 | | |
| 1250 | 51.5 | | | 49.3 | | | 38.8 | | | 42.4 | | |
| 1600 | 44.8 | | | 44.9 | | | 33.8 | | | 39.3 | | |
| 2000 | 33.4 | * | | 40.7 | | | 35.1 | | | 41.3 | | |
| 2500 | 35.4 | | | 34.7 | | | 31.8 | * | | 43.3 | | |
| 3150 | 33.8 | * | | 35.1 | | | 34.9 | | | 41.4 | | |
| 4000 | 30.2 | * | | 38.9 | | | 36.9 | | | 38.4 | | |
| 5000 | 27.7 | ** | | 35.5 | * | | 31.9 | * | | 39.5 | | |
| 6300 | 28.3 | * | | 29.0 | * | | 27.1 | * | | 40.2 | * | |
| 8000 | 27.8 | * | | 31.7 | * | | 27.2 | * | | 35.3 | * | |
| 10000 | 28.7 | * | | 29.1 | * | | 25.9 | ** | | 35.9 | * | |

Table C.4. Test Nrs. 13 to 16 (test certificates Appendix A, pages 13 to 16): Determined sound power levels $L_W$ in third-octave bands in dB(A).

| Frequency | Test No. 13 | | | Test No. 14 | | | Test No. 15 | | | Test No. 16 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. | $L_W$ | Corr. | Crit. |
| 100 | 13.3 | ** | | 12.3 | ** | | 14.0 | ** | | 12.5 | ** | |
| 125 | 14.5 | ** | | 14.6 | ** | | 14.8 | ** | | 14.1 | ** | |
| 160 | 17.5 | * | | 18.3 | * | | 19.0 | * | | 17.8 | * | |
| 200 | 23.8 | * | | 26.3 | * | | 23.3 | * | | 25.9 | * | |
| 250 | 30.6 | * | | 29.6 | * | | 32.4 | * | | 31.8 | * | |
| 315 | 34.0 | * | | 32.8 | * | | 35.0 | * | | 34.8 | * | |
| 400 | 42.2 | | | 39.4 | | | 43.2 | | | 40.3 | | |
| 500 | 46.8 | | | 43.8 | | | 47.2 | | | 44.6 | | |
| 630 | 45.3 | | | 42.6 | | | 45.9 | | | 43.1 | | |
| 800 | 38.6 | | | 36.8 | | | 41.9 | | | 39.3 | | |
| 1000 | 41.5 | | | 38.9 | | | 42.7 | | | 40.1 | | |
| 1250 | 39.5 | | | 36.7 | | | 40.9 | | | 38.0 | | |
| 1600 | 39.7 | | | 35.8 | | | 42.4 | | | 38.2 | | |
| 2000 | 36.3 | | | 29.8 | * | | 38.4 | | | 31.6 | * | |
| 2500 | 33.8 | | | 26.7 | * | | 35.3 | | | 28.4 | * | |
| 3150 | 27.0 | * | | 19.4 | ** | | 28.6 | * | | 21.5 | * | |
| 4000 | 24.8 | * | | 22.2 | ** | | 23.3 | * | | 17.9 | ** | |
| 5000 | 25.3 | * | | 20.2 | ** | | 25.7 | * | | 18.0 | ** | |
| 6300 | 24.4 | * | | 19.3 | ** | | 22.2 | ** | | 17.8 | ** | |
| 8000 | 25.1 | * | | 18.1 | ** | | 24.3 | * | | 17.5 | ** | |
| 10000 | 28.2 | * | | 18.9 | ** | | 28.9 | * | | 18.2 | ** | |

# Description of the test procedure for the determination of the sound power level

## 1 Measurand

The measurement of the sound power level was performed following the direct procedure according to DIN EN ISO 3741 [2]. The sound power level was determined in one third-octave bands. The calculation of the sound power level $L_W$ was calculated using the following equation:

$$L_W = \overline{L_{p(ST)}} + \left\{ 10\lg\frac{A}{A_0}dB + 4{,}34\frac{A}{S}dB + 10\lg\left(1+\frac{S\cdot c}{8\cdot V\cdot f}\right)dB + C_1 + C_2 - 6dB \right\}$$

With:

| | |
|---|---|
| $\overline{L_{p(ST)}}$ | mean value of the corrected time-averaged one third-octave band sound pressure levels of the sound sources to be examined in operation in the reverberation room in dB |
| $A$ | equivalent sound absorption area in the reverberation room in m² |
| $A_0$ | 1 m² |
| $S$ | total surface of the reverberation room in m² |
| $c$ | sound-propagation velocity at the air temperature prevailing in the reverberation room at the time of measurement in m/s |
| $V$ | volume of the reverberation room in m³ |
| $f$ | one third-octave band centre frequency in Hz |
| $C_1$ | correction to take account of the different reference parameters of the sound pressure and sound power levels in function of the characteristic acoustic impedance of the air in the reverberation room at the time of measurements in dB |
| $C_2$ | correction of the radiation impedance in dB |

Information regarding the measurement uncertainty of the measurement procedure is given in DIN EN ISO 3740 [1] and DIN EN ISO 3741 [2].

## 2 Description of the reverberation room

The reverberation room of Müller-BBM GmbH in Planegg complies with the requirements defined in DIN ISO 3741 [2].

The reverberation room has a volume of $V$ = 199.6 m$^3$ and a surface area of $S$ = 216 m$^2$. Thus it is possible according to section 5.2 of DIN ISO 3741 [2] to perform measurements starting from and including the one third-octave band of the centre frequency 100 Hz.

In order to increase diffusivity, six composite sheet metal boards dimensioned 1.2 m x 2.4 m and six composite sheet metal boards dimensioned 1.2 m x 1.2 m were suspended curved and irregularly

Figure D.1 shows drawings of the reverberation room.

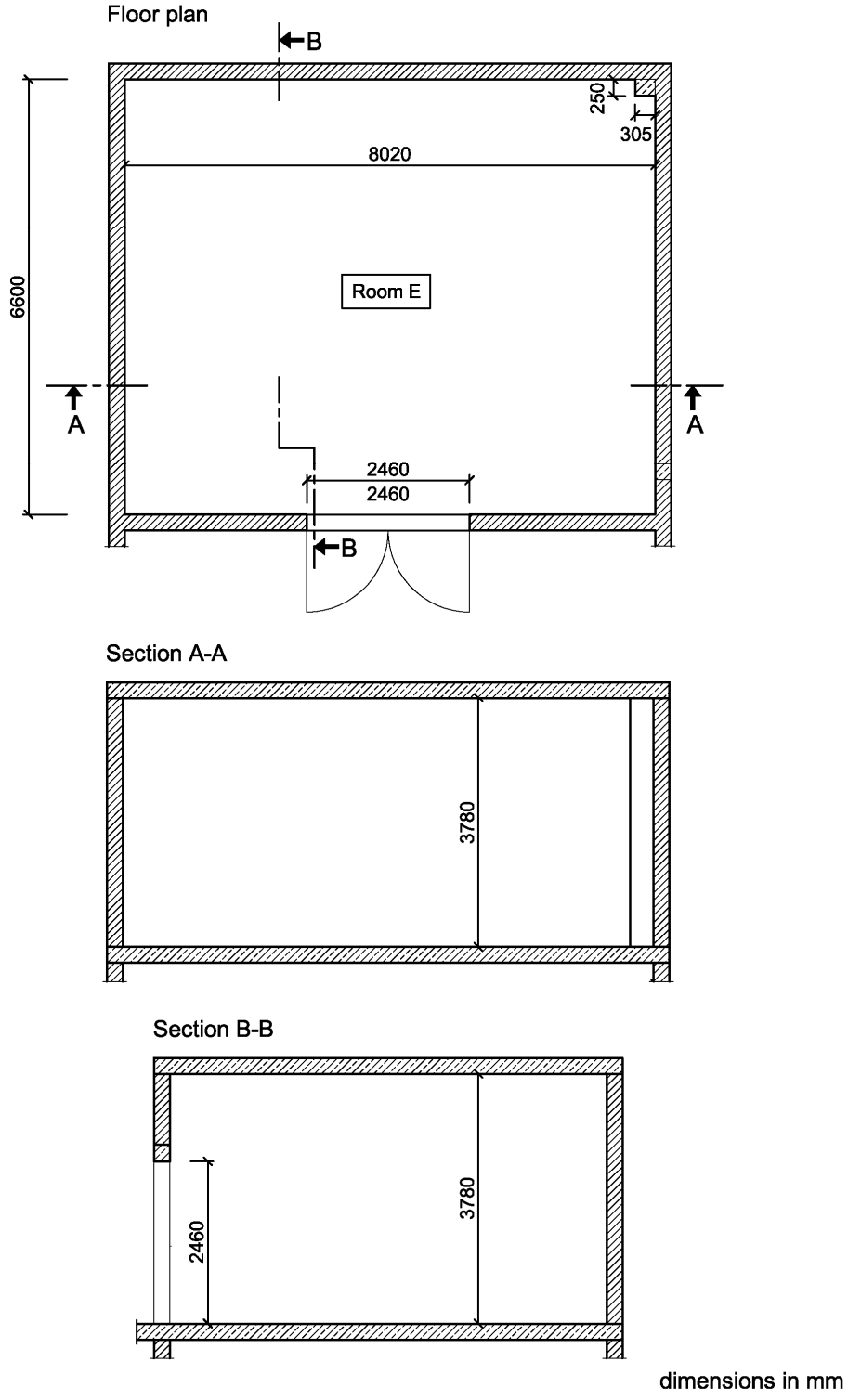



Figure D.1. Plan view and sections of the reverberation room.

## 3 Measurement of the sound pressure level

The measurement of the average sound pressure level $L'_{pi(ST)}$ was performed with $i$ = 2 single microphones by continuous scanning using moved microphones on circular paths. The path radius of the microphones was 1.0 m. The minimum distances between the microphone positions were as follows:

- 1.5 m between each microphone position and the test object;
- 1.0 m between each microphone position and the surfaces of the reverberation room;
- 0.5 m between each microphone position and the diffusors.

The path levels were inclined by at least 10° compared to all room surfaces.

The chosen measurement duration of 45 s corresponds to two complete circuits of the measurement paths.

The sound pressure level was registered in one third-octave bands (100 Hz…10000 Hz).

The test was performed for one source position at a time (position of the test object on the floor of the reverberation room).

The required minimum path length of the microphone paths and the necessary number of source positions were qualified acc. to section 8.4.2, DIN EN ISO 3741 [2].

## 4 Background noise correction

The time-averaged sound pressure level of the background noise was determined on the same microphone paths and with the same measurement duration as in the measurements with sound source.

The background noise correction $K_{1,i}$ was determined according to section 9.1 of DIN EN ISO 3741 [2]. In the result tables in Appendix C and in the test certificates in Appendix A, the results are marked if a correction due to background noise was done.

## 5 Absorption area in the reverberation room

The equivalent sound absorption area *A* of the reverberation room was determined by measuring the reverberation time *T* following the indirect procedure according to DIN EN ISO 3382-2 [3] using the following equation:

$$A = \frac{55{,}26}{c}\left(\frac{V}{T}\right)$$

With

| | |
|---|---|
| *A* | equivalent sound absorption area in the reverberation room in $m^2$ |
| *c* | sound-propagation velocity in m/s at the air temperature prevailing in the reverberation room at the time of measurement |
| *V* | volume of the reverberation room in $m^3$ |

The determination of the impulse responses was carried out following the indirect procedure in the reverberation room without test object. In terms of test signal, a sine-sweep with a pink spectrum was used. 24 independent loudspeaker-microphone combinations were registered. The evaluation of the reverberation time was carried out acc. to DIN EN ISO 3382-2 [3], whereby a linear regression was used to calculate the reverberation time *T* from the level of the inverse impulse response.

## 6 Test equipment

The calibration of the measurement instruments used was controlled by means of the pistonphone at the beginning of the measurements. At the end of measurement, the constancy of the calibration was checked and confirmed. Within the scope of our own quality assurance system, the equipment is additionally inspected and controlled in regular intervals.

In Table D.1 the test equipment used is listed.

Table D.1. Test equipment.

| Name | Manufacturer | Type | Serial-No. |
|---|---|---|---|
| **Reverberation time measurement** | | | |
| Sound card | RME | Multiface II | 22460388 |
| Amplifier | APart | Champ One | 09070394 |
| Dodecahedron | Müller-BBM | DOD130B | 265201 |
| Dodecahedron | Müller-BBM | DOD130B | 265202 |
| Dodecahedron | Müller-BBM | DOD130B | 265203 |
| Dodecahedron | Müller-BBM | DOD130B | 265204 |
| Microphone | Microtech | M360 | 1783 |
| Microphone | Microtech | M360 | 1785 |
| Microphone | Microtech | M360 | 1786 |
| Microphone | Microtech | M360 | 1787 |
| Microphone | Microtech | M360 | 1788 |
| Microphone | Microtech | M360 | 1789 |
| **Sound pressure level measurements** | | | |
| Measuring system | Norsonic | 121 | 26342 |
| Microphone swivel facility | Norsonic | 212 | 12986 |
| Microphone swivel facility | Norsonic | 212 | 12987 |
| Pre-amplifier microphone<br>with free-field microphone | Norsonic<br>Norsonic | 1201<br>1220 | 26145<br>25160 |
| Pre-amplifier microphone<br>with free-field microphone | Norsonic<br>Norsonic | 1201<br>1220 | 30588<br>26071 |
| Pistonphon | Brüel & Kjaer | 4228 | 1651956 |
| **Measurement of the climatic conditions** | | | |
| Hygro-/thermometer | Testo | Saveris H1E | 01554624 |
| Barometer | Lufft | Opus 10 | 030.0910.0003.9.<br>4.1.30 |
| **Software** | | | |
| Software for measurement and evaluation | Müller-BBM | Bau 4 | Version 1.7 |