

Supplemental Material for

A low-cost environmental chamber to simulate warm climatic conditions

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11 Pages:

13 Supplemental Figures

2 Supplemental Tables

Contents:

Supplemental Material 1: Bill of materials and construction manual

Supplemental Material 2: Homogeneity mapping experiments

Supplemental Material 3: Comparison with commercial devices

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Supplemental Material 1: Bill of materials and construction manual

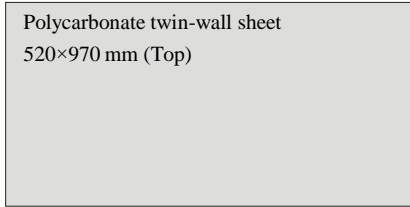
Bill of materials

Supplemental Table S1.1. Bill of materials, prices and suppliers.

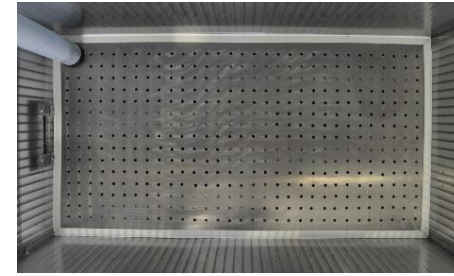
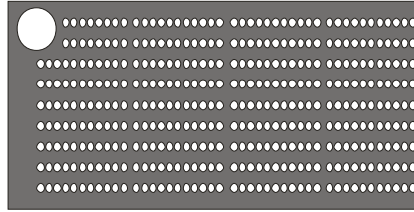
Name	Function	Number	Unit price [€]	Total price [€]	Supplier	Link
Chamber framework						
Heavy-duty shelf	Chamber framework	1	64.95	64.95	Simonrack	https://www.bauhaus.info/steckregale/simonrack-metall-schwerlastregal-maderclick-
PC twin-wall sheet (2500 x 980 x 16 mm)	Climate chamber wall	4	37.55	150.20	Bauhaus	https://www.bauhaus.info/hohlkammerplatten/hohlkammerplatte-makrolon/p/20456115
PVC sheet (1000 x 495 x 5 mm)	Controlling board platform & access port	2	17.00	34.00	alt-intech PVC Platte	https://www.amazon.de/gp/product/B0097961KS/ref=oh_au_detailpage_o01_s00?ie=UTF8
Transparent acrylic glass panel	Access doorway	1	11.80	11.80	Bauhaus	https://www.bauhaus.info/aluplatten-kunststoffplatten/hobbyglas-
Window/door sealant	Sealant for access doorway	1	11.99	11.99	TESA	https://www.amazon.de/gp/product/B0060V9FP4/ref=oh_au_detailpage_o08_s00?ie=UTF8&
Foam rubber sealing roll (10 m x 3 mm)	Sealant for door/access ports	1	5.99	5.99	CTA Dichtungen	https://www.amazon.de/gp/product/B017LXOFMC/ref=oh_au_detailpage_o09_s00?ie=UTF8
Cable glands (M16/M20/M25, 8 pieces)	Ports for cables/pipes	1	15.99	15.99	INIBUD	https://www.amazon.de/gp/product/B01LWCT6J6/ref=oh_au_detailpage_o03_s00?ie=UTF8
Air circulation unit						
Pressure reducing valve	Reducing dry air pressure (10 bar to 0.5 bar)	1	55.69	55.69	Riegler	https://www.contorion.de/drucklufttechnik/riegler-druckregler-0-5-10-bar-3-8-zoll-
PVC pipe (1 m, Ø 100 mm)	Air circulation	2	4.59	9.18	Awenta	https://www.amazon.de/gp/product/B01HBMKWSY/ref=oh_au_detailpage_o08_s00?ie=UTF8
Inline fan (Ø 100 mm)	Air circulation	1	18.09	18.09	Vents	https://www.amazon.de/gp/product/B0081CWM6E/ref=oh_au_detailpage_o00_s00?ie=UTF8
PVC elbow pipe (90°, Ø 100 mm)	Air circulation	1	4.06	4.06	Awenta	https://www.amazon.de/gp/product/B012ZJH56U/ref=oh_au_detailpage_o03_s00?ie=UTF8
Tube fan (Ø 100 mm)	Air circulation	1	3.09	3.09	Awenta	https://www.amazon.de/gp/product/B0146F2M28/ref=oh_au_detailpage_o05_s00?ie=UTF8
Connector flap for ventilation pipes	Connector flap for ventilation pipes	1	2.56	2.56	Lüftungssysteme Awenta	https://www.amazon.de/gp/product/B012ZZ8K5E/ref=oh_au_detailpage_o02_s00?ie=UTF8
Ventilation tube cap	Ventilation tube cap	1	1.90	1.90	MKK	https://www.amazon.de/gp/offer-
PVC non-return flap	Non-return flap	1	2.64	2.64	Awenta	https://www.amazon.de/gp/product/B01HD89KXE/ref=oh_au_detailpage_o08_s00?ie=UTF8
PVC air circulation pipe holder	Pipe holder	3	2.51	7.53	Awenta	https://www.amazon.de/gp/product/B01HEOAXW4/ref=oh_au_detailpage_o08_s00?ie=UTF8
Cable plug	Cable plug	4	3.49	13.96	Kopp	https://www.amazon.de/gp/product/B005LD2IWE/ref=oh_au_detailpage_o08_s00?ie=UTF8
Aluminum sheet (1000 x 495 x 6 mm)	Bottom stabilization/air diffuser sheet	1	72.66	72.66	HLS tactical	https://www.amazon.de/gp/product/B0732XY789/ref=oh_au_detailpage_o00_s00?ie=UTF8
Flat plastic strip with rubber lip	Sealant for bottom plate	1	11.30	11.30	ROLLA	https://www.amazon.de/gp/product/B06XNWS44Y/ref=oh_au_detailpage_o06_s00?ie=UTF8
Pipe connector with male thread & grommet	Pipe connection	2	7.99	15.98	REKUBIK	https://www.rekubik.de/bewasserung/fitings/tankdurchfuehrung/tankdurchfuehrung-quick-
Heating unit						
Digital thermostat (dual relay)	Thermostat	1	47.99	47.99	INKBIRD	https://www.amazon.de/Inkbird-Programmierbare-Temperaturregler-Schaltsteckdose-
Infrared heating lamp (150 W)	Heating	2	8.69	17.38	Philips	https://www.amazon.de/gp/product/B003EROVVU/ref=oh_au_detailpage_o04_s00?ie=UTF8
Infrared heating lamp (300 W)	Heating	2	9.43	18.86	Sylvania	https://www.amazon.de/gp/product/B004YJ3HIA/ref=oh_au_detailpage_o05_s00?ie=UTF8&
Ceramic hanging lamp socket	Infrared lamp holder	2	5.99	11.98	TerraBasic	https://www.amazon.de/gp/product/B003YNYW8O/ref=oh_au_detailpage_o00_s00?ie=UTF8
Cable connector (water-proof)	Cable connectors for heating unit	2	10.99	21.98	LEBRIGHT	https://www.amazon.de/LEBRIGHT-Wasserdicht-Anschlussdose-Kabelstecker-
Cooling unit						
Peltier element (12 V, 60 W)	Cooling device	8	3.99	31.92	HALJIA	https://www.amazon.de/TEC1-12706-K%C3%BChl%C3%B6per-Thermoelektrische-
Aluminum heat sink (4 x 4 x 2 cm)	Heat exchanger	8	1.39	11.12	Ebay seller: heimwerker666	https://www.ebay.de/itm/Aluminium-Ku%hler-Heatsink-Heizkorper-Chip-fur-Power-IC-
PC fan (Ø 6 cm)	Distribution of cold air from heat exchanger	2	7.99	15.98	Noiseblocker	https://www.amazon.de/Noiseblocker-XR2-BlackSilentFan-Series-
Water-cooling block (16 x 4 cm)	Cooling of Peltier elements	2	9.39	18.78	Kokiya	https://www.banggood.com/162x41x12mm-Water-Cooling-Heatsink-Block-Waterblock-
Submersible water pump (12 V, 10 L/min)	Circulation of water through water block liquid cooler	1	13.99	13.99	COMET	https://www.amazon.de/Comet-Campingbedarf-Tauchpumpe-Elegant-
PC power supply (400 W, modified)	Power supply for Peltier element	1	41.49	41.49	Be quiet	https://www.alternate.de/html/product/1418647?campaign=843171301&adgroup=457293968
Humidifier unit						
Digital humidity regulator (dual relay)	Air humidity controller	1	44.99	44.99	INKBIRD	https://www.amazon.de/gp/product/B017UAMZ0K/ref=oh_au_detailpage_o02_s01?ie=UTF8
Ultrasonic humidifier	Humidifier	1	9.99	9.99	MagiDeal	https://www.amazon.de/Sharplace-Ultraschall-Hersteller-Maschine-
Air pump	Circulation of humid air from humidifier	1	12.99	12.99	POMISTY	https://www.amazon.de/Pomisty-Multifunktion-Luftmatratzen-Schlauchboote-Camping-
Plastic container (rectangular, 3.9 L)	Humidifier box	1	7.99	7.99	Lock & Lock	https://www.amazon.de/gp/product/B000KHXRA8/ref=oh_au_detailpage_o03_s00?ie=UTF8
Pipe connector with male thread & grommet	Pipe connection	2	4.77	9.54	sourcemap	https://www.amazon.de/gp/product/B019QJ24EK/ref=oh_au_detailpage_o03_s00?ie=UTF8
Dry air injector						
Pressure reducing valve	Reducing dry air pressure (10 bar to 0.5 bar)	1	55.69	55.69	Riegler	https://www.contorion.de/drucklufttechnik/riegler-druckregler-0-5-10-bar-3-8-zoll-
Solenoid valve (G1/4 inch, NC)	Control of dry air flow	2	34.90	69.80	Magnetventile-shop	https://www.magnetventile-shop.de/magnetventile-2/magnetventile-messing/magnetventil-
Cable plug	Cable plug for solenoid valve	2	7.29	14.58	Kopp	https://www.amazon.de/gp/product/B000VDAISK/ref=oh_au_detailpage_o02_s01?ie=UTF8
Hose connector (T-shape, Ø 10 mm)	Connector for dry air hose	1	1.99	1.99	arbeitsbedarf24	https://www.amazon.de/gp/product/B01K4ROE4Q/ref=oh_au_detailpage_o03_s00?ie=UTF8
Miscellaneous						
Cable (10 m, 1.5 mm²)	Cable (e.g. for infrared lamps, solenoid valves, etc.)	1	16.99	16.99	Kopp	https://www.amazon.de/gp/product/B0029M8WZW/ref=oh_au_detailpage_o02_s00?ie=UTF8
PVC hose (reinforced, Ø 10 mm)	Hose (e.g. for dry air, humidified air, etc.)	1	17.99	17.99	Fittingstore	https://www.amazon.de/gp/product/B01E01ALMG/ref=oh_au_detailpage_o01_s00?ie=UTF8

Construction manual

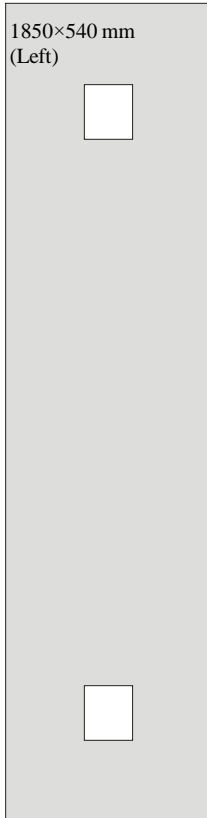
Polycarbonate twin-wall sheet
520×970 mm (Top)



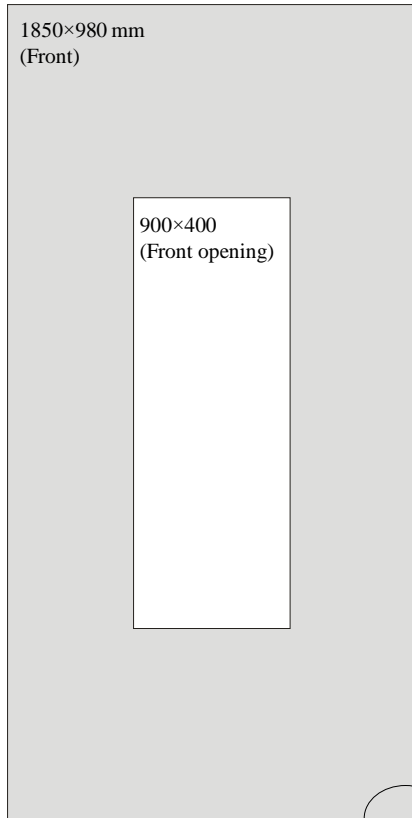
Perforated aluminum sheet 520×970 mm



1850×540 mm
(Left)

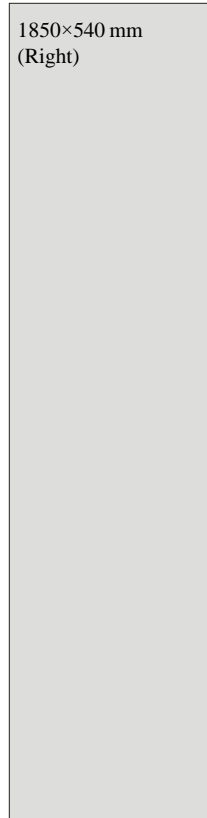


1850×980 mm
(Front)

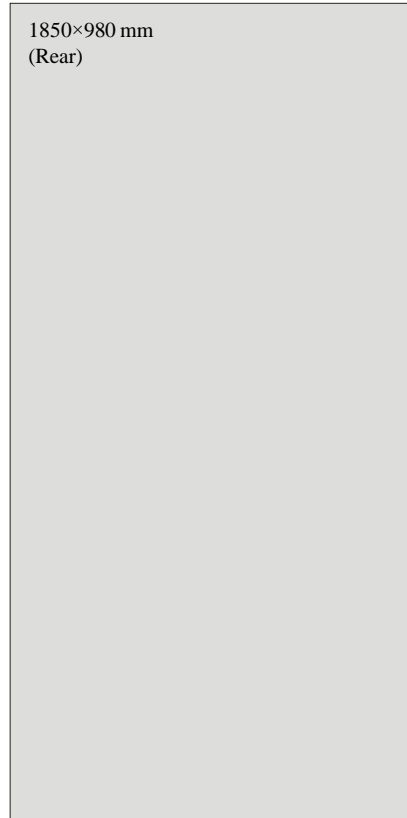


900×400
(Front opening)

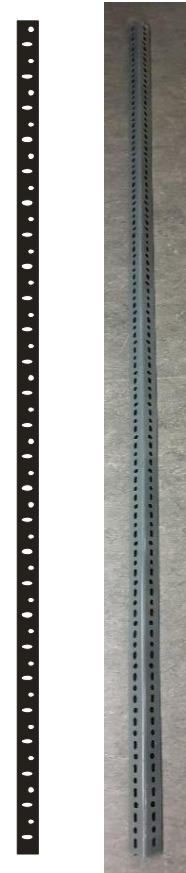
1850×540 mm
(Right)



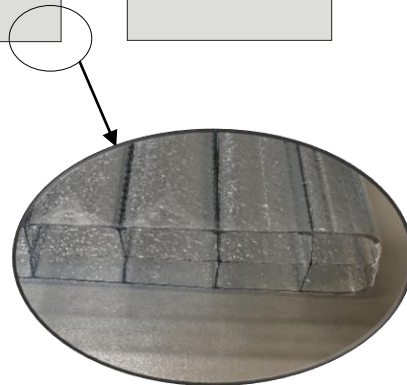
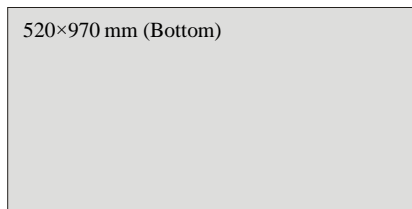
1850×980 mm
(Rear)



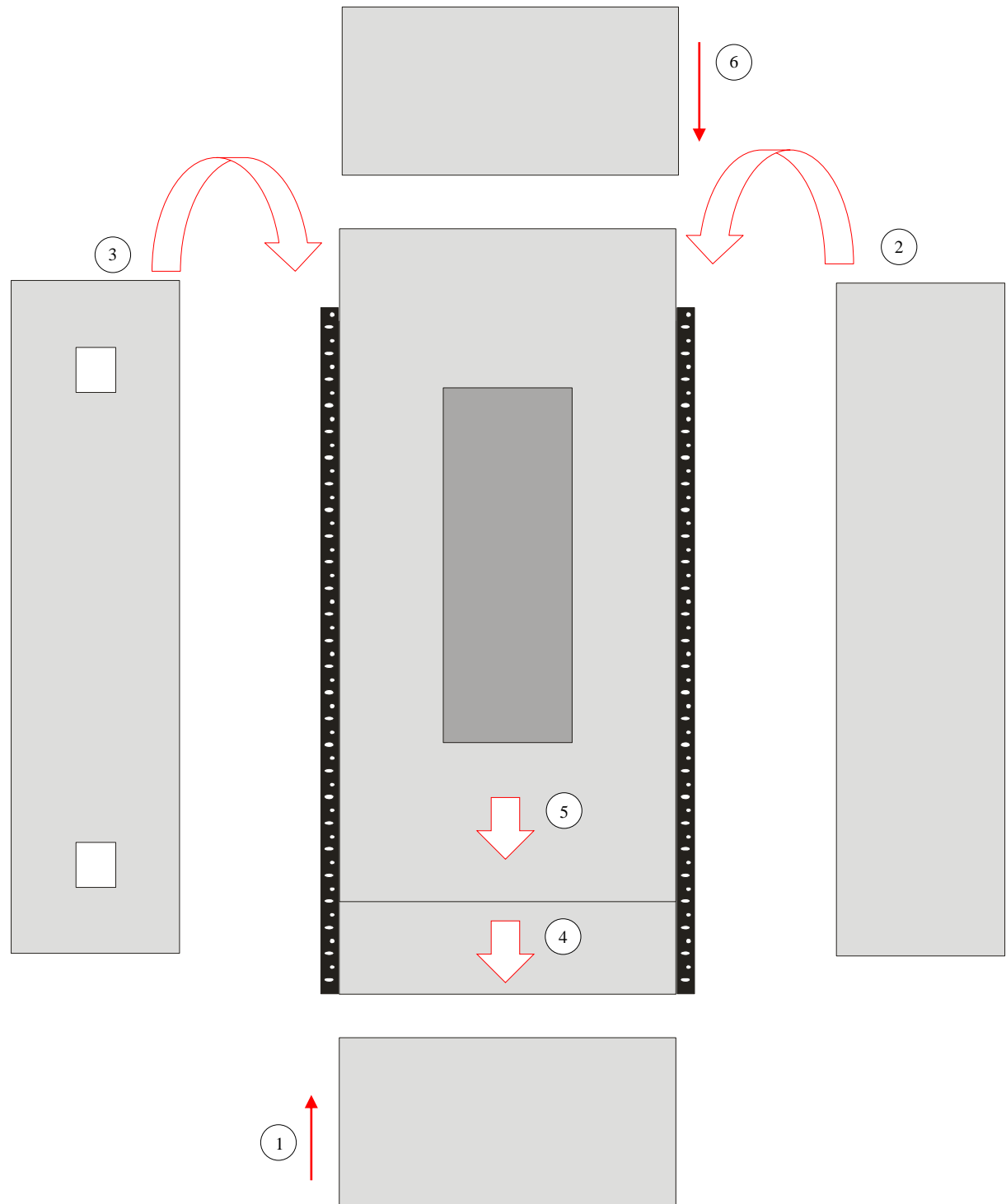
4 Heavy-duty shelf frames 2000 mm



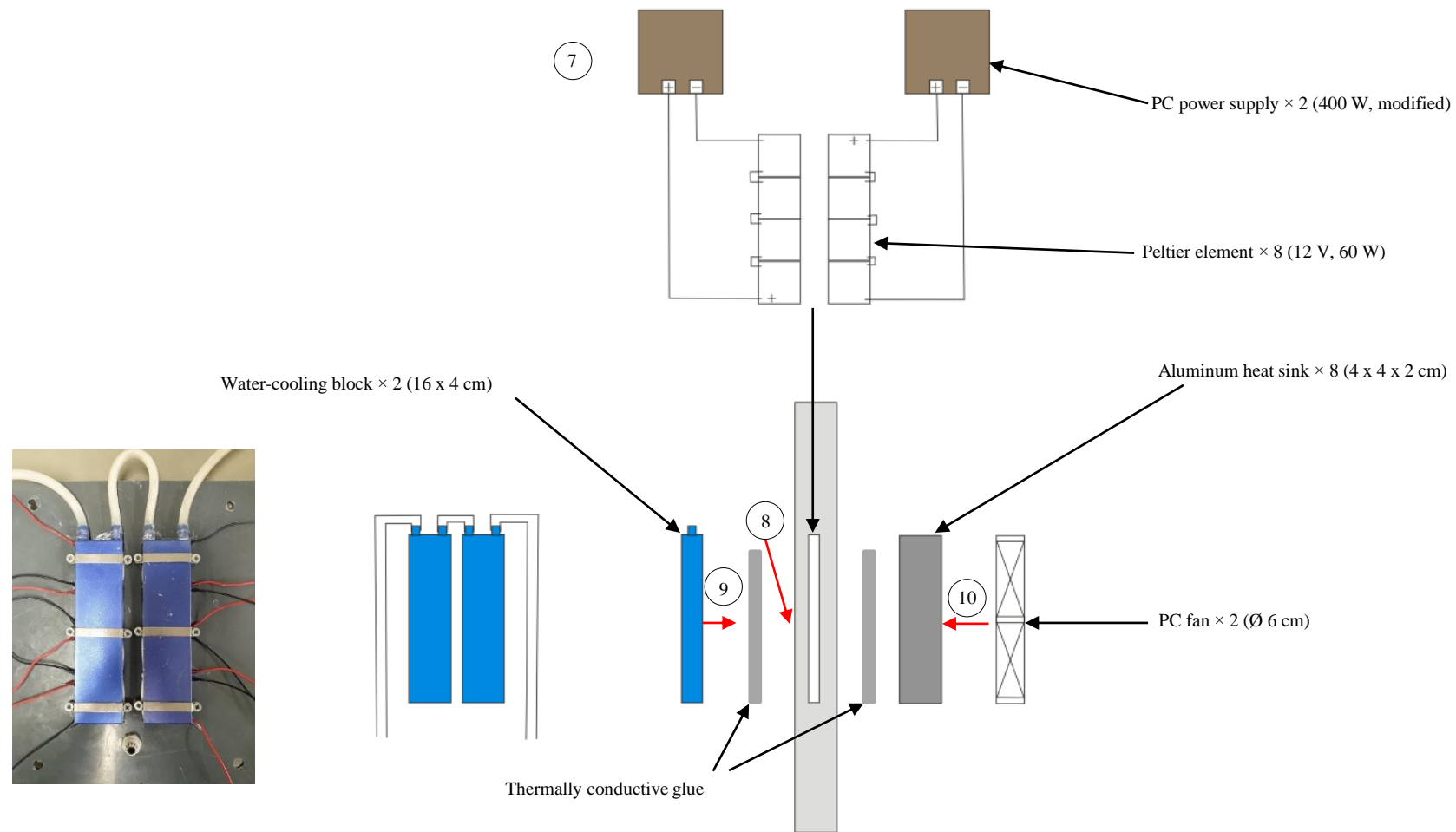
520×970 mm (Bottom)



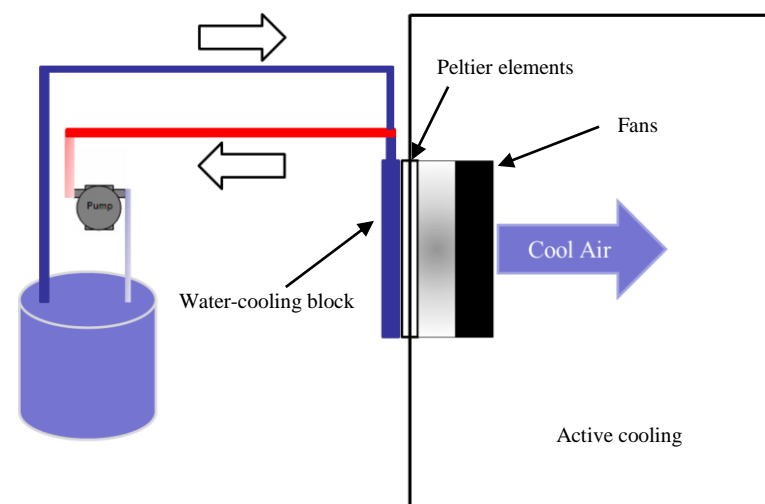
Supplemental Figure S1.1. Cutting templates

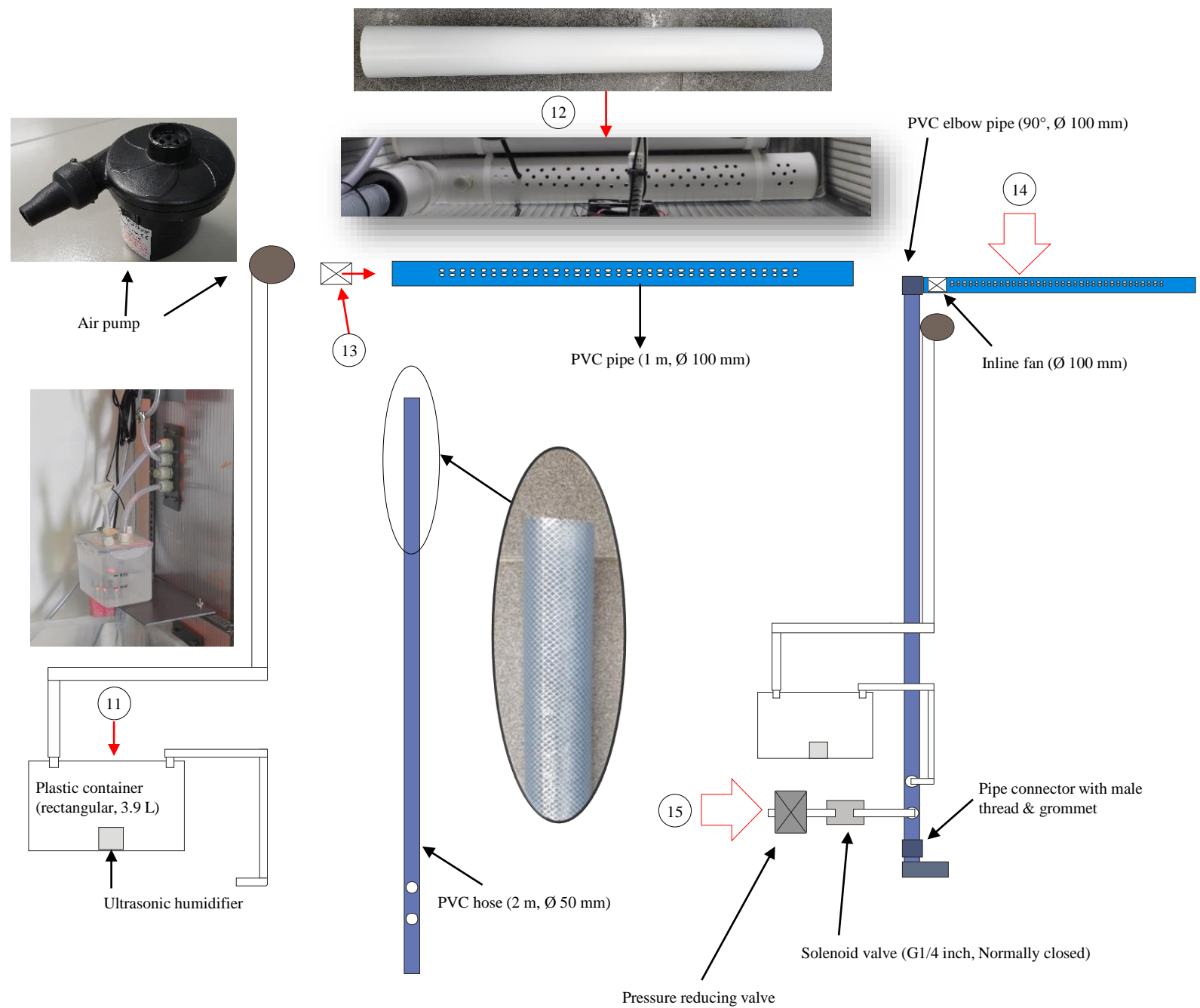


Supplemental Figure S1.2. Assembly of the heavy-duty shelf, sliding in the climate chamber walls (1 to 6) and application of the sealing materials

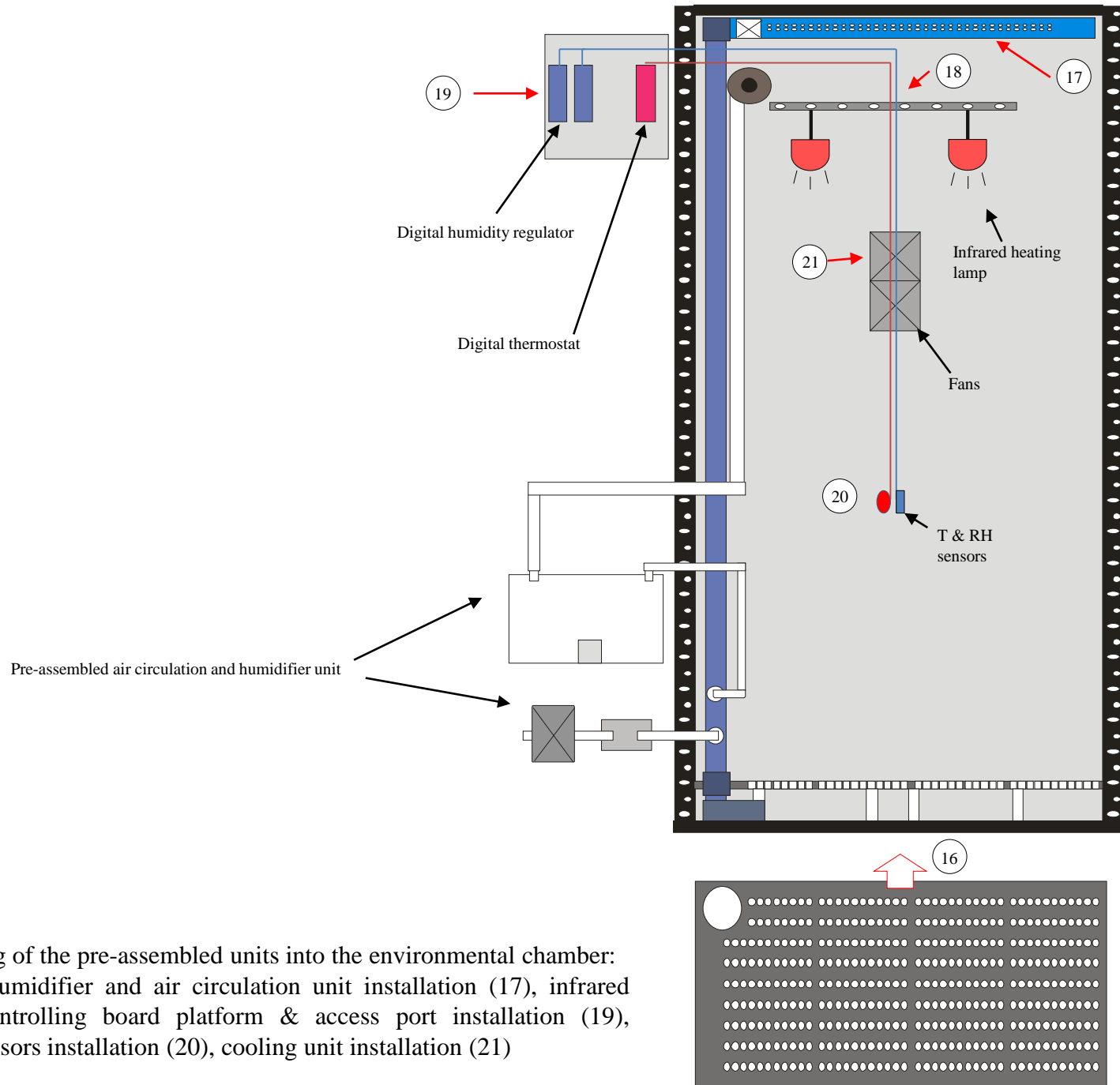


Supplemental Figure S1.3. Cooling unit assembly: The wiring of the Peltier elements (7), application of the thermally conductive glue on the Peltier elements (8), mounting of the water-cooling blocks (9), mounting of the aluminum heat sinks and fans (10).

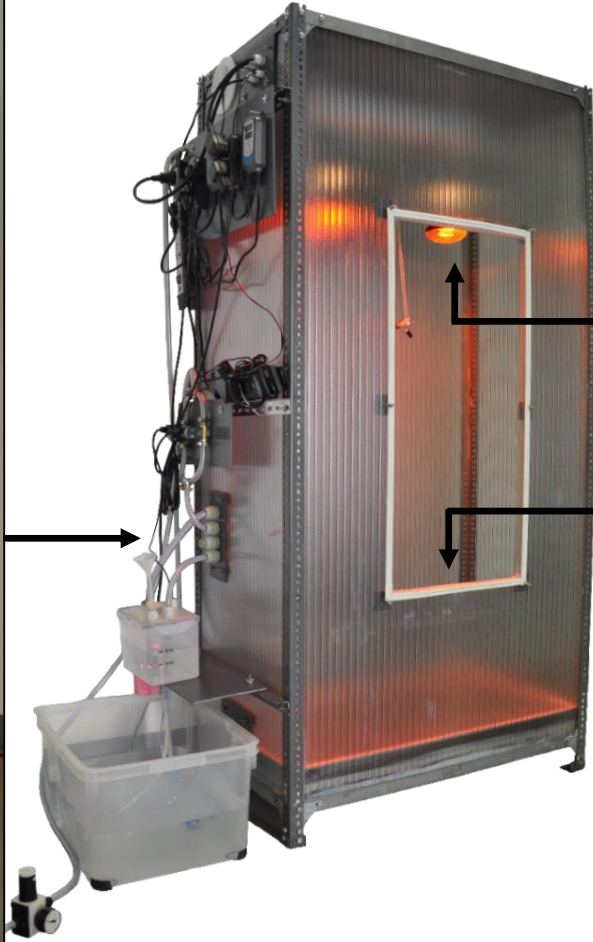
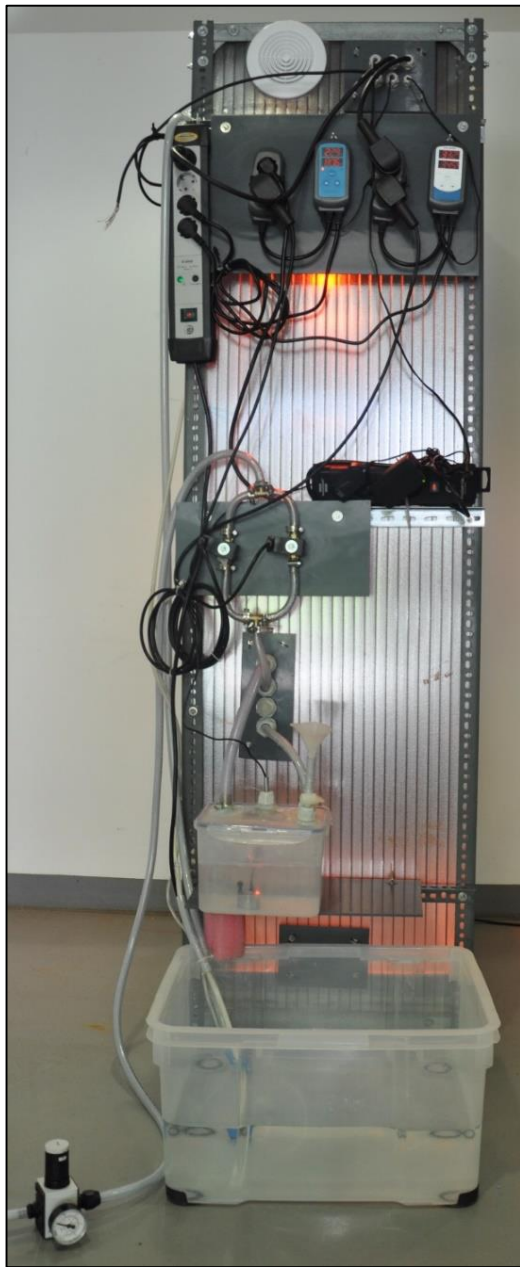




Supplemental Figure S1.4. Air circulation and humidifier assembly: Construction of the moistening unit (11), perforation of the PVC pipe (12), installation of the inline fan (Ø 100 mm) (13), connection of PVC pipes with elbows and pipe connectors (14), installation of pressure reducing and solenoid valves (15).



Supplemental Figure S1.5. Mounting of the pre-assembled units into the environmental chamber: Aluminum sheet installation (16), humidifier and air circulation unit installation (17), infrared heating lamps installation (18), controlling board platform & access port installation (19), temperature and relative humidity sensors installation (20), cooling unit installation (21)



Supplemental Figure S1.6. Detailed photographs

Supplemental Material 2: Homogeneity mapping experiments

To detect deviations from the target temperature, USB temperature data loggers (EasyLog1, Lascar Electronics) were used. Eight loggers were tested against each other for a bias error in a preliminary experiment (pre-test 1).

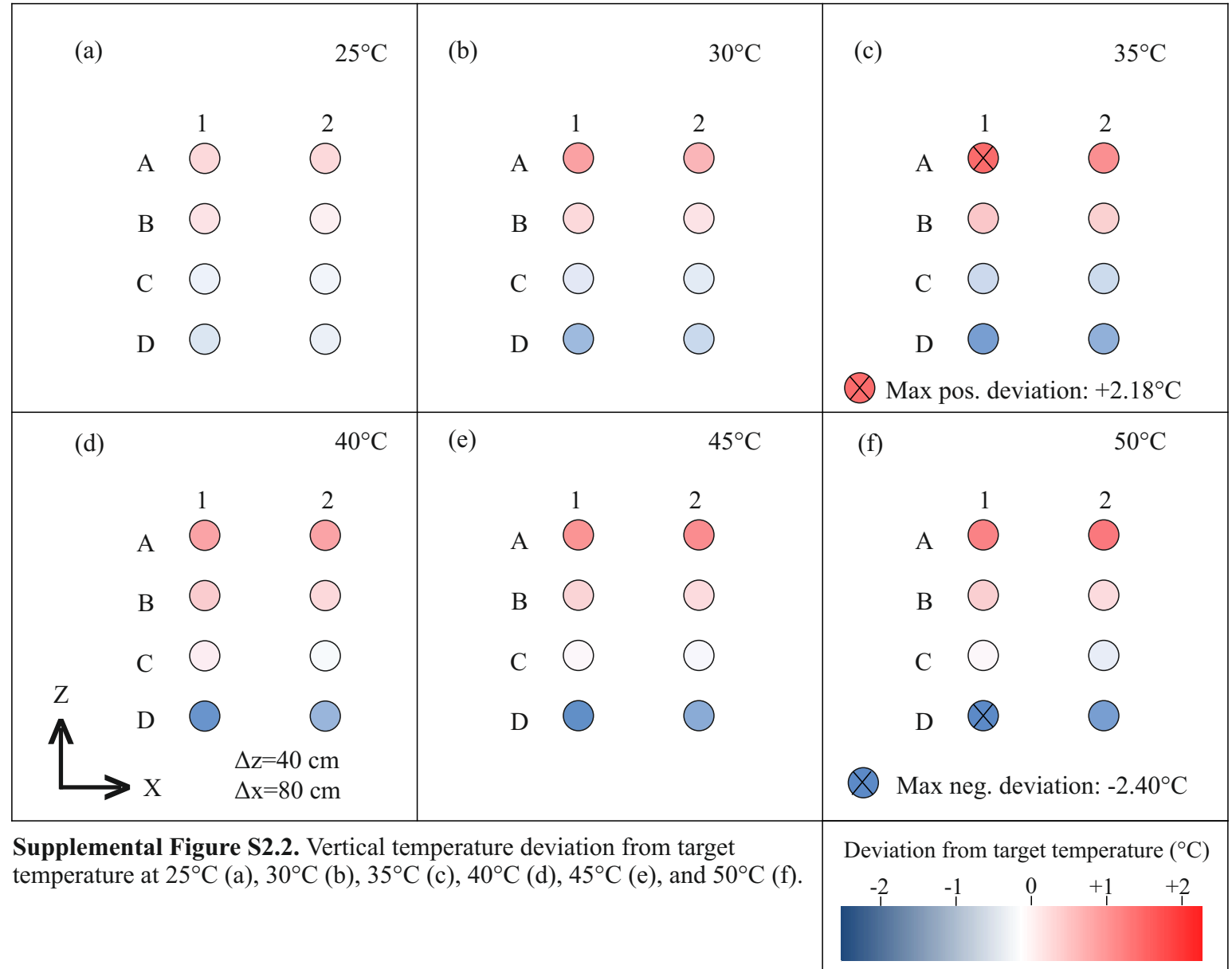
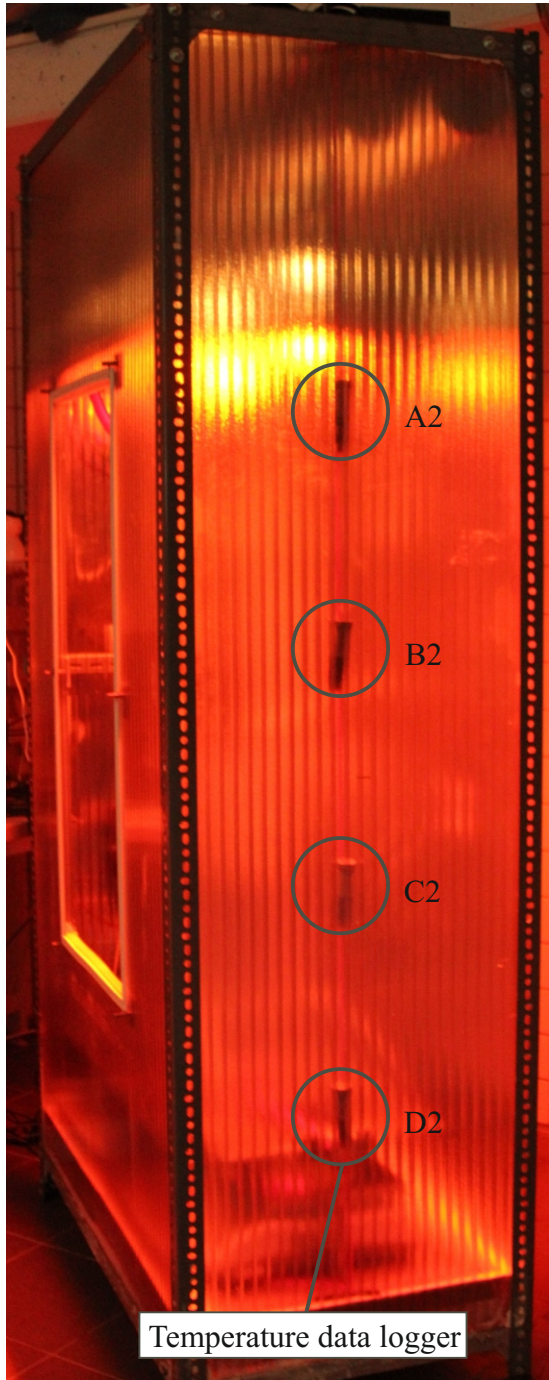
They were set to 1-minute measurement intervals and placed in an insulated box at a constant temperature for 24 hours. The average temperatures recorded by the individual loggers differed slightly and maximum negative and positive deviations accounted for -0.20°C and $+0.22^{\circ}\text{C}$, respectively. The encountered offsets were used to correct logger results in subsequent experiments (bias-correction).

To map out vertical temperature deviations at different target temperatures, eight temperature data loggers (with 1-minute measurement intervals) were placed inside the climate chamber (two arrays; levels: 40, 70, 100, and 130 cm; Supplemental Fig. S2.1). Tests were conducted for six different temperatures, namely 25, 30, 35, 40, 45, and 50°C (24 hours each; Supplemental Fig S2.2).

To investigate lateral homogeneity, more sensors were needed, requiring an additional preliminary experiment (pre-test 2). Here, 21 loggers were set to 1-minute measurement intervals and placed in an insulated box at a constant temperature for 24 hours. The average temperatures recorded by the individual loggers again differed slightly and maximum negative and positive deviations accounted for -0.15°C and $+0.27^{\circ}\text{C}$, respectively. The encountered offsets were used to correct logger results in subsequent experiments (bias-correction).

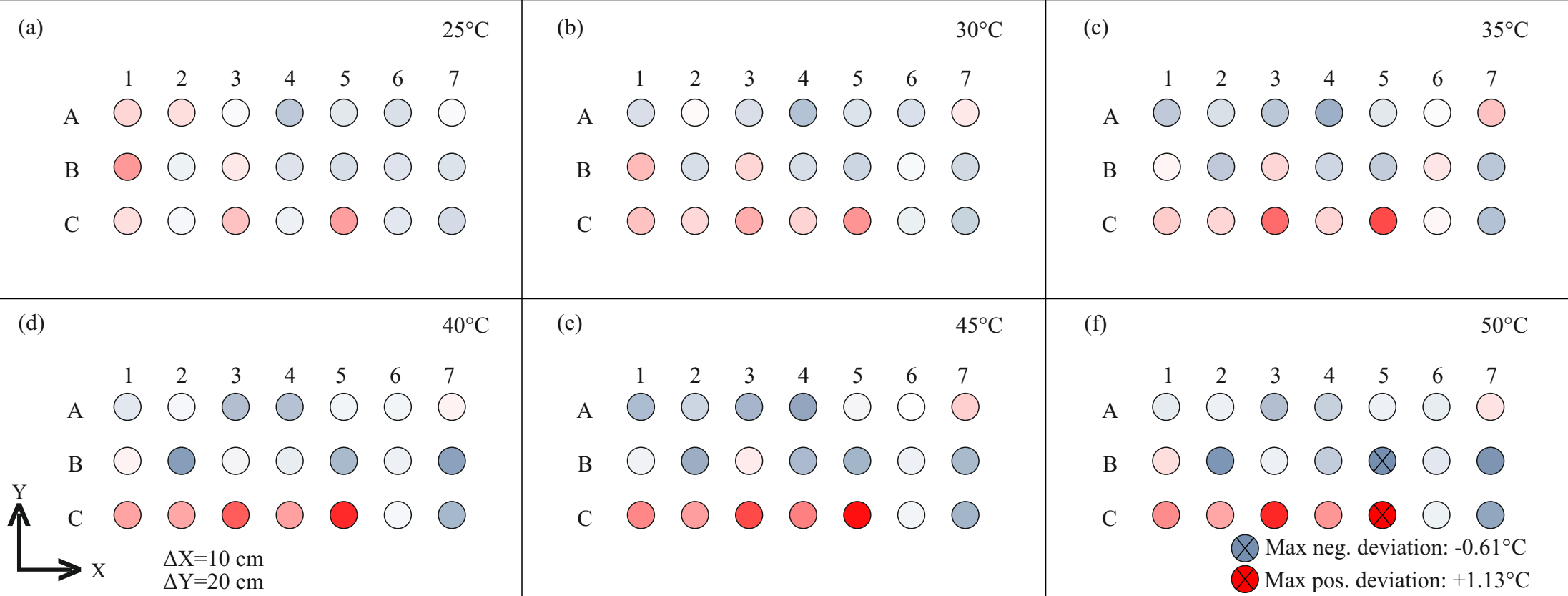
To map out horizontal temperature deviations at different target temperatures, the 21 temperature data loggers (with 1-minute measurement intervals) were placed inside the climate chamber (3 by 7 grid 80 cm above the perforated aluminum sheet; Supplemental Fig. S2.3). Tests were conducted for six different temperatures, namely 25, 30, 35, 40, 45, and 50°C (24 hours each; Supplemental Fig. S2.4).

Vertical temperature deviation from target temperature

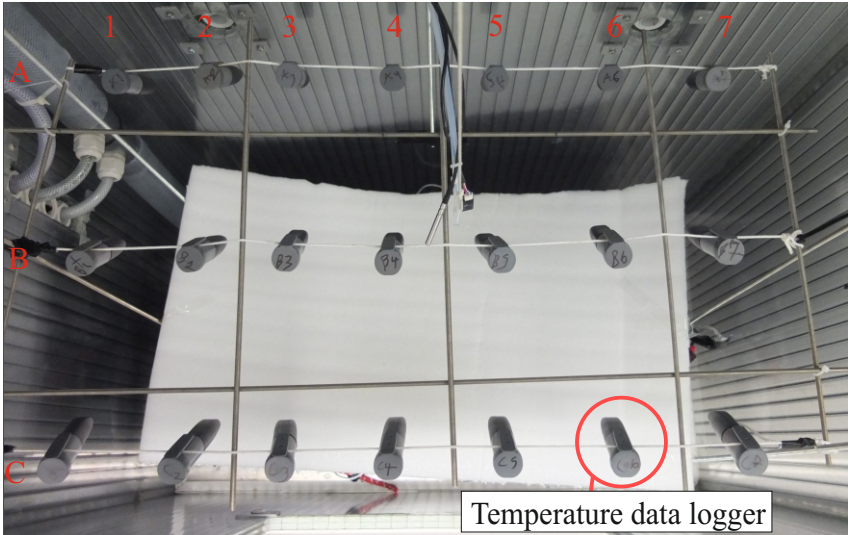


Supplemental Figure S2.1. Vertical distribution of temperature data loggers.

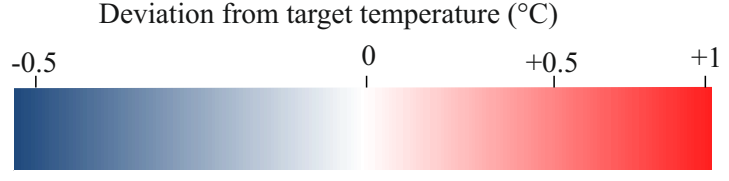
Horizontal temperature deviation from target temperature



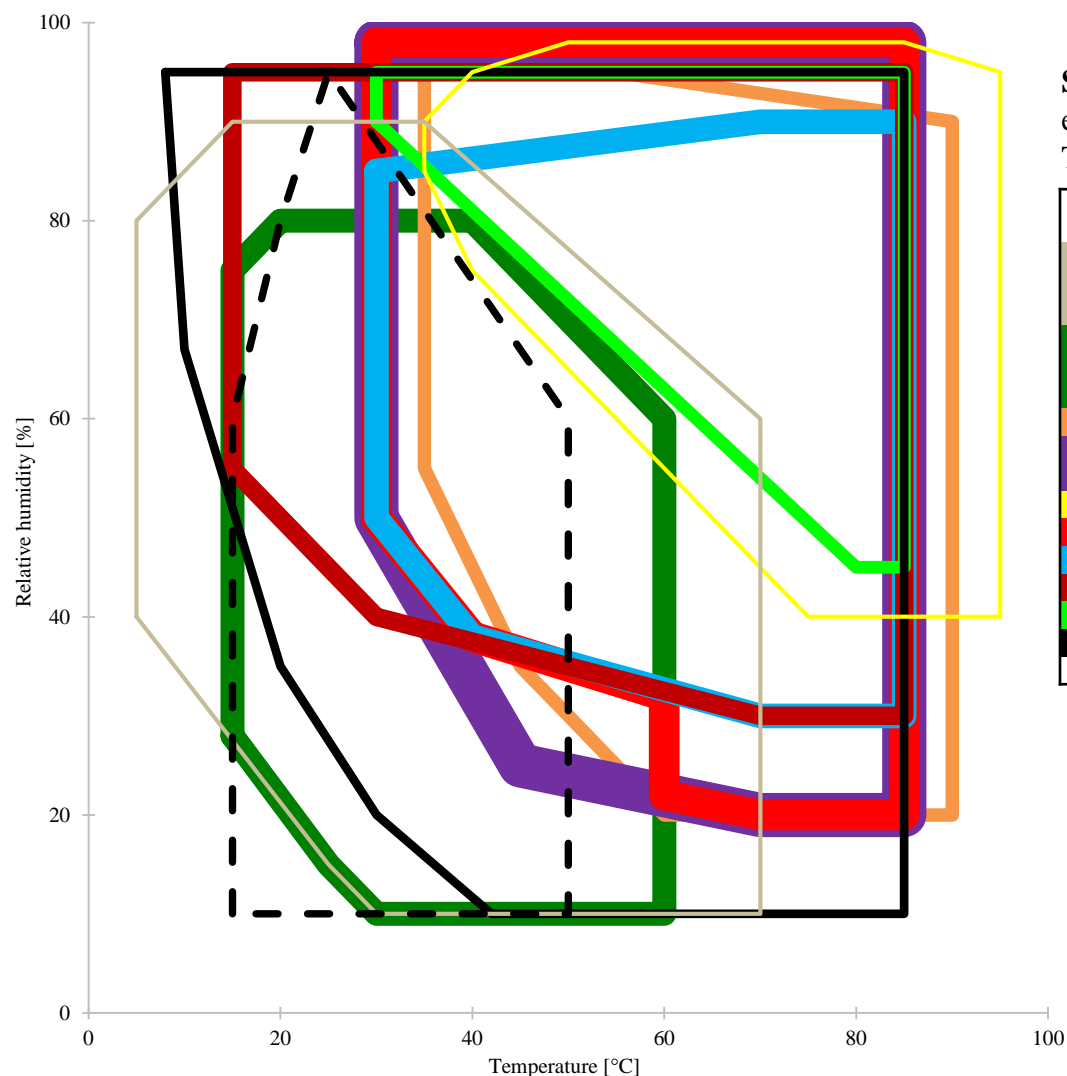
Supplemental Figure S2.4. Horizontal temperature deviation from target temperature at 25°C (a), 30°C (b), 35°C (c), 40°C (d), 45°C (e), and 50°C (f).



Supplemental Figure S2.3. Horizontal distribution of temperature data loggers.



Supplemental Material 3: Comparison with commercial devices



Supplemental Table S3.1. Temperature and humidity control ranges for commercial environmental chambers and the DIY environmental chamber presented in this study. The color code applies to Figure S1.1.

Color Code	Brand	Model	Temperature range [°C]	Humidity range [%]	Inner dimensions w x h x d [mm]	Reference
	Memmert	HPP110	+5 to +70	10 to 90	560 x 480 x 400	Memmert GmbH, (2019)
	Memmert	HPP260 (A)	+5 to +70	10 to 90	640 x 800 x 500	Memmert GmbH, (2019)
	Memmert	HPP750	+5 to +70	10 to 90	1040 x 1200 x 600	Memmert GmbH, (2019)
	Memmert	HPP260 (B)	+15 to +60	10 to 80	640 x 800 x 500	Memmert GmbH, (2019)
	Memmert	HPP1400	+15 to +60	10 to 80	1250 x 1450 x 750	Memmert GmbH, (2019)
	Memmert	HPP2200	+15 to +60	10 to 80	1972 x 1450 x 750	Memmert GmbH, (2019)
	Memmert	HCP105	+35 to +90	20 to 95	800 x 1030 x 800	Memmert GmbH, (2019)
	ESPEC	Platinus PSL-4J	+30 to +85	20 to 98	1000 x 1000 x 800	ESPEC CORP, (2019a)
	ESPEC	Platinus PR-4J	+30 to +85	20 to 98	1000 x 1000 x 800	ESPEC CORP, (2019a)
	ESPEC	Platinus PHP-4J	+35 to +95	40 to 98	1000 x 980 x 800	ESPEC CORP, (2019a)
	ESPEC	Platinus PDL-4J	+30 to +85	20 to 98	1000 x 1000 x 800	ESPEC CORP, (2019a)
	ESPEC	Platinus PCR-3J	+30 to +85	30 to 90	600 x 650 x 800	ESPEC CORP, (2019a)
	ESPEC	Bench top SH-642	+15 to +85	30 to 95	400 x 400 x 400	ESPEC CORP, (2019b)
	ESPEC	Bench top LH-114	+30 to +85	45 to 95	500×600×390	ESPEC CORP, (2019b)
	Russells	G-64-5-5	+8 to +85	10 to 95	1220 x 1220 x 1220	Russells, (2019)
- -		DIY environmental chamber	+15 to 50	10 to 95	970 x 1790 x 520	This study

Supplemental Figure S3.1. Temperature and relative humidity control ranges that can be simulated, for selected commercially available devices and for the DIY environmental chamber presented in this study.

All commercial environmental chambers were tested at an ambient temperature of 23°C and the DIY environmental chamber was at an ambient temperature between 21 and 22°C.

References (Supplemental Material)

ESPEC CORP. 2019a. Platinous J Series Brings New Value to the World of Test Equipment. Available at:

https://espec.com/images/uploads/files/e_platinum.pdf

ESPEC CORP. 2019b. Bench-Top Type Temperature and Humidity Chamber. Available at: <https://www.espec.co.jp/english/inquiry/catalog/sh.pdf>

Memmert GmbH. 2019. Climate chambers. Schwabach. Available at: <https://www.memmert.com/fileadmin/products/documents/categories/BR-Climate-Chambers-english-USA.pdf>

Russells. 2019. Russells G - 64 specifications. Michigan. Available at: <https://www.russells-tech.com/g-64-elite-test-chambers.htm>