BINDER
Best conditions for your success

Factory Standard for the determination of technical data

Area of application

Simulation Chambers for the Scientific and Industrial Laboratory

BINDER GmbH

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1. Area of application

This factory standard defines the measurement methods, default test values and general conditions to determine and verify technical data that are intended for publication. It is applicable for BINDER GmbH and its branches worldwide.

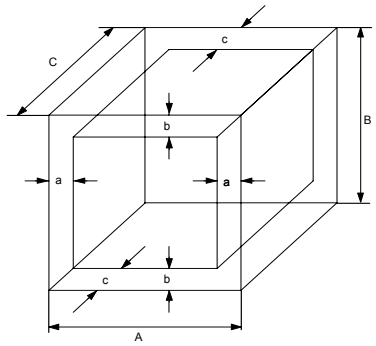
2. Definitions

2.1 Useable space

The useable space is the part of the inner chamber in which compliance with the published technical data is guaranteed.
The useable space is the space that results from reducing the inner chamber diameter by min. 10% from all sides.

- Distance to roof and floor by at least 10 % of the inner chamber height
- Distance to the side panels by at least 10 % of the inner chamber width
- Distance to the rear panel and the door by at least 10% of the inner chamber depth

Values below these values are permissible, if the chamber is not equipped with slots to allow for positioning of sensors or specimens on racks within a minimum of 15 mm within the boundaries of the useable space defined by these values.



A, B, C= internal dimensions (W, H, D)
a, b, c = wall spacing

a = 0.1*A
b = 0.1*B
c = 0.1*C

V_{USE} = (A - 2 * a) * (B - 2 * b) * (C - 2 * c)

2.2 Steady-state condition

Definition:

The steady-state condition is the operating state at which the values of all controlled parameters (e. g. temperature, humidity, CO_2 concentration, O_2 concentration) do not vary more than the maximum specified variations of all controlled parameters within a given time at any point within the useable space for the respective chamber.

Empirical times to reach the steady-state condition

- Temperature for chambers with forced convection: at least 1 hour
  Temperature for chambers with natural convection: at least 4 hours
  Temperature for vacuum drying ovens: at least 12 hours

- Humidity of constant climatic chambers: 1 hour
  Humidity of growth chamber: 1 hour
  Humidity of climatic test chamber: 1 hour
  Humidity of CB incubators (not controlled): 15 hours

- CO_2 of CO_2-incubators: 0.5 hours (from ambient air to 5% by vol. CO_2)
- O_2 of CO_2-incubators: 1.5 hours (from ambient air to 80% by vol. CO_2)

If the chamber controls several parameters, the time to reach the steady-state condition will be the longest empirical time value.

2.3 Environmental temperature

Definition:
A homogenous temperature for a radius of 2 – 3 meters (6.6 – 9.8 feet) around the test specimen when measured at the average height of the test specimen above the ground. All measurements of this factory standard relate to an ambient temperature of 25 °C +/- 0.5 °C (77.0 ºF +/- 0.9 °F), for air free of draft in the test space.
Different environmental conditions generally produce inferior performance data, since the equipment was designed to perform best at an ambient temperature of 25 °C (77.0 ºF).

Specified environmental temperature range for test equipment:

Heated units 18°C to 40°C, CB 18°C to 30°C (64.4 ºF to 104.0 ºF, CB 64.4 ºF to 86.0 ºF)
Refrigerated units 18°C to 32°C (64.4 ºF to 89.6 ºF)

Environmental temperature to verify technical data from the catalogue

25 °C (77.0 °F) or 20 °C (68.0 °F) for KB, KBW, KBF, KBWF, KBF(ICH)

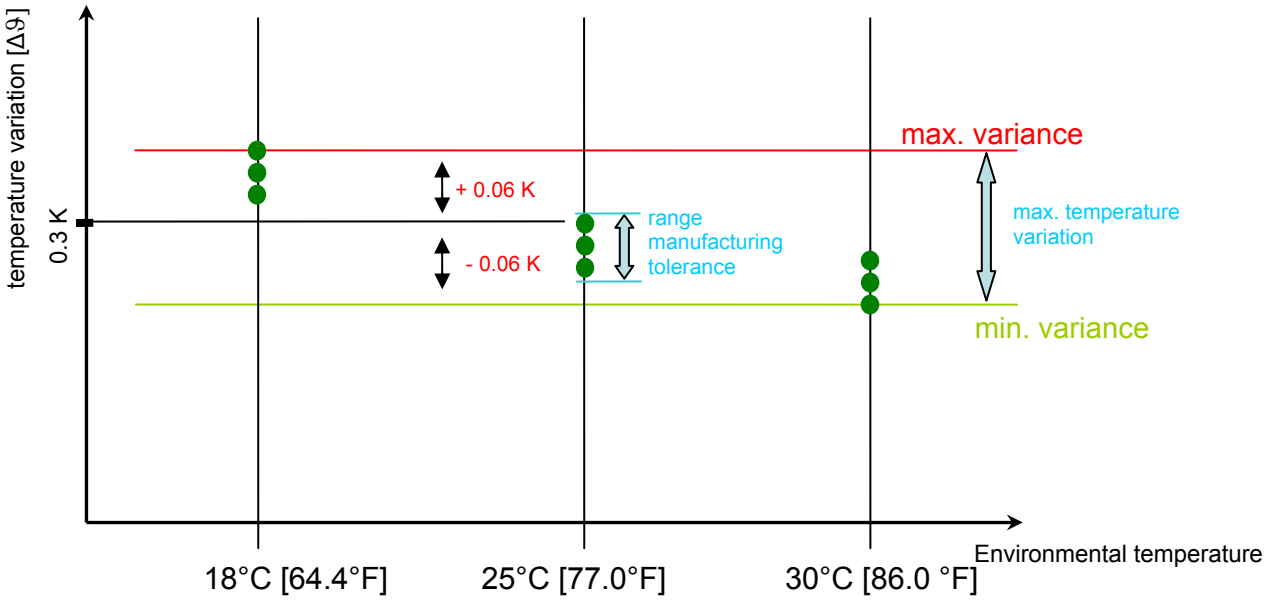
How the environmental temperature affects test equipment operation

The temperature variation and the temperature recovery times vary in accordance with the temperature difference between usable space and the environmental temperature.

Temperature variation can occur by conditional production, depending on the specific model.

The combination of those two effects can produce specific temperature variations at each set point temperature, e. g., the temperature variation can vary by max. +/- 20% from the respective catalogue value of a specified environmental temperature range for the equipment. For this reason, the temperature variation has to be determined individually for specific equipment at temperatures other than 25°C (77.0 ºF).

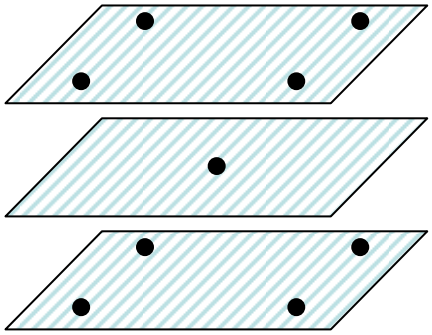
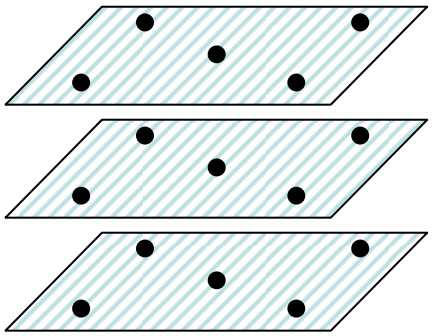
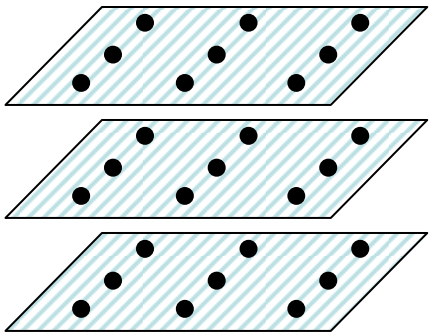
Example: CO_2 incubator at set point temperature 37°C (98.6°F)



3. Temperature variation and fluctuation

3.1 Arrangement of measuring points in the inner chamber

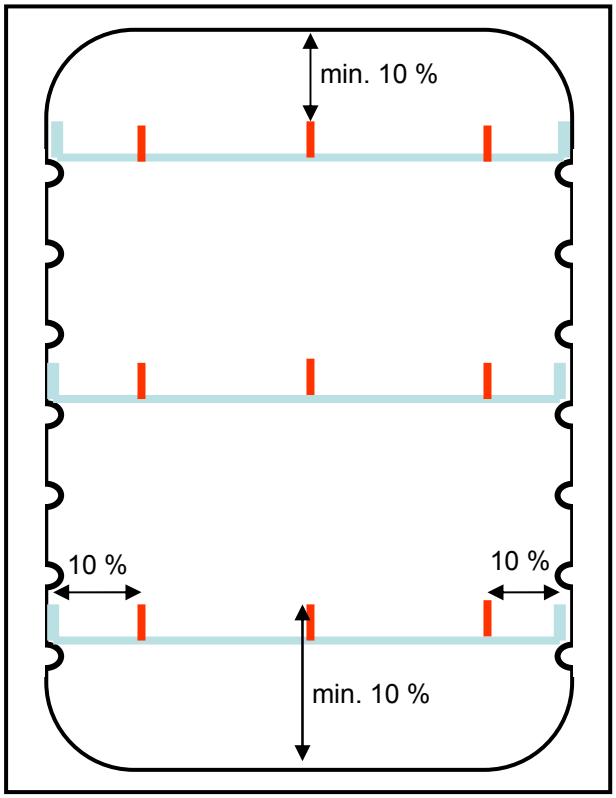
Depending on the chamber model and size, sensors are arranged as follows:

9 point measurement 	**To be used for the following models:** Vacuum drying ovens < 25 liter volume VD 23, VDL 23 Climatic chambers acc. to IEC 60068-3-5: MK, MKF, MKT, MKTF Optional 9-point spatial temperature measurement for BD, BF, KB, KBW Options: Spatial humidity-, CO_2 - or O_2 - mapping
15 point measurement 	**To be used for the following models:** Vacuum drying ovens > 25 liter volume VD 53, VD 115, VDL 53, VDL 115 BD 23, ED 23, FD 23, KB 23, E 28, B 28
27 point measurement 	**To be used for the following models:** BD, BF , BFD, BFED, ED, FD, FED, FP, M, FDL, MDL, KB, KBF, KBW, KBWF, KBF (ICH), CB

3.2 Guidelines for spatial temperature measurements

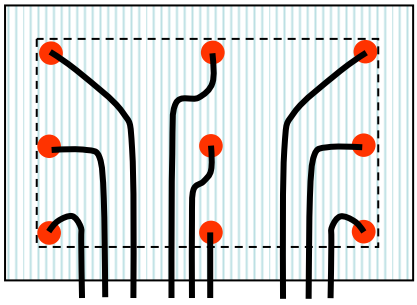
When measuring spatial temperatures, the following guidelines must be complied with:

- Adjust the temperature controller prior to spatial measurements in order to prevent any deviation from the set point during spatial measurements in the center of the usable space.
- Use type J thermocouples for the determination of time-based temperature deviations (= temperature fluctuation).
- For determination of spatial temperature deviations (= temperature variation), use Pt 100 sensors Class A or B (DIN EN 60751).
- Distribute sensors uniformly within the useable space (for definition of useable space, see chap. 2.1)
- Position the upper and lower rack, leaving a space of at least 10% of the height measurement of the inner chamber between the sensor heads and the inner chamber roof and floor
- The middle rack must be placed into the middle slot of the inner chamber. If no middle slot is available take the next possible slot below.
- Sensor heads must be positioned 15 mm above the racks

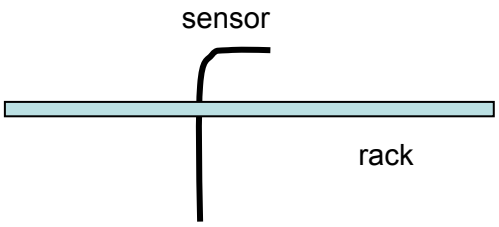


Note on procedure for adjustment of temperature controllers:
Adjustment of temperature controllers are exclusively done with Pt 100 sensors Class A or B (DIN EN 60751), in the center of the usable space.

- Position sensors on the measuring plane parallel to the temperature gradient (see figures below)

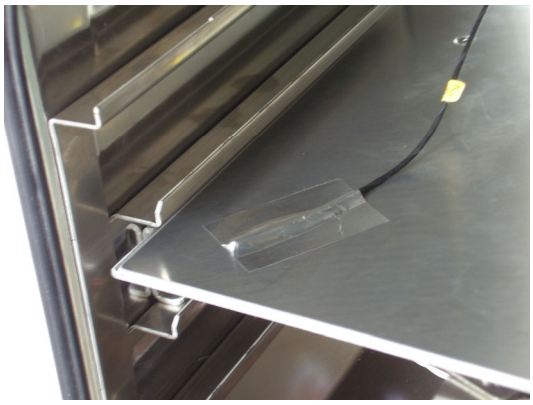


Top view of rack with alignment of sensors

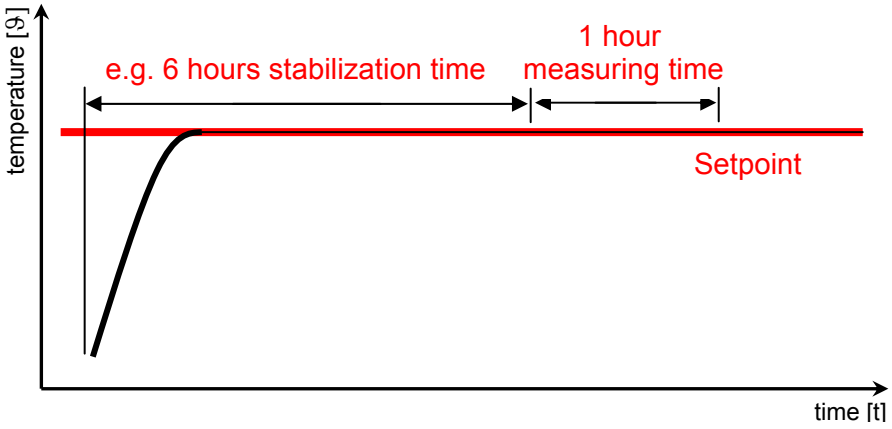


Side view of rack with alignment of sensors

- For vacuum drying ovens: pressure < 20 mbar, sensors are bonded to the expansion racks



- Measuring time: 1 hour, 360 measurements/hour



- 100 % fan speed (for forced convection units)
- Closed air flap (if fitted)
- Ambient temperature
  internal data 18 °C (64.4 °F), 25 °C (77.0 °F), 32 °C (89.6 °F) (with CB 30 °C (86.0 °F) instead of 32 °C) (89.6 ºF)
  catalog data at 25 °C (77.0 °F) or 20 °C (68.0 °F) with KB, KBW, KBF, KBWF, KBF(ICH)
- Recording of measuring data in steady-state condition (definition of steady-state condition see chap. 2.2)
- KBF / MKF: temperature mapping at 60 % RH
- CB: temperature mapping at 5 Vol.-% CO_2 with filled Permadry™ dish

3.3 Set points for spatial temperature measurements

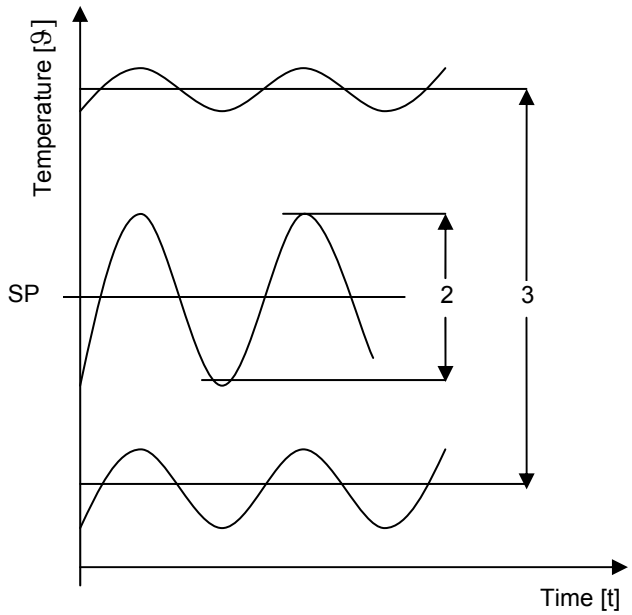
Model series	Test values (set points)
ED, FD, FED, FP, M, FDL, MDL	70 °C (158.0 °F), 150 °C (302.0 °F), 250 °C (482.0 °F)
VD, VDL	100 °C (212.0 °F), 200 °C (392.0 °F), 250 °C (482.0 °F) (250 °C (482.0 °F) only with option of increased VD temperature range)
BD, BF	37 °C (98.6°F)
BFD, BFED	37 °C (98.6 °F), 60 °C (140.0 °F)
CB	37 °C (98.6 °F) (at maximum humidity and 5 Vol.-% CO_2)
KB	5 °C (41.0 °F), 25 °C (77.0 °F), 40 °C (104.0 °F)
KBW, KBWF	15 °C (59.0 °F), 25 °C (77.0 °F) (with and without light)
KBF(ICH)	25 °C (77.0 °F) (at 60 % RH) (with and without light) 40 °C (104.0 °F) (at 75 % RH) (with and without light)
KBF	25 °C (77.0 °F) (at 60 % RH) 40 °C (104.0 °F) (at 75 % RH)
MK	-20 °C (-4.0 °F), 100 °C (212.0 °F)
MKF	25 °C (77.0 °F), 55 °C (131.0 °F) (at 60 % RH)
MKT	-50 °C (-58.0 °F), 100 °C (212.0 °F)

3.4 Evaluation of temperature variation and temperature fluctuation

Temperature variation = difference between the average values of those measuring points (3) with maximum difference.

Temperature fluctuation = maximum variance of the central measuring point (2), symmetrical in relation to the average value.

Unit of results: ± [K] (half of determined values)



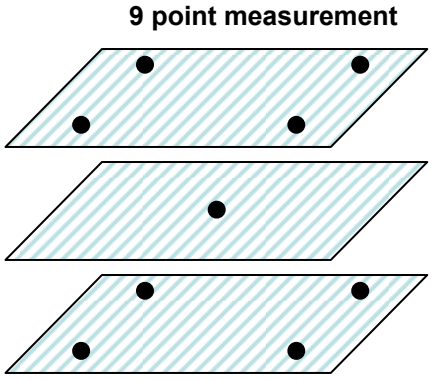
Temperature curves of 3 measuring points

4. Variation and fluctuation of CO_2 and O_2 concentration

This chapter is only applicable for CO_2-incubators.

4.1 Arrangement of the sensors in the inner chamber

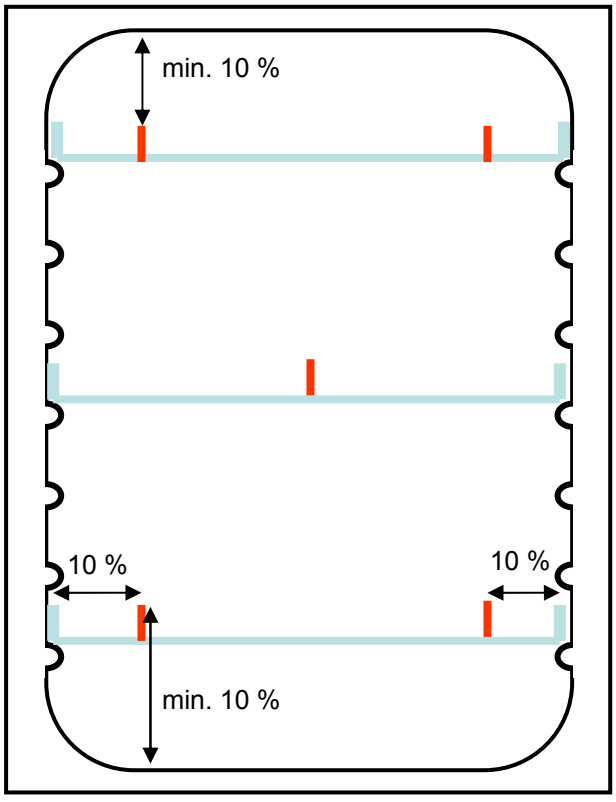
The sensors are arranged as follows:



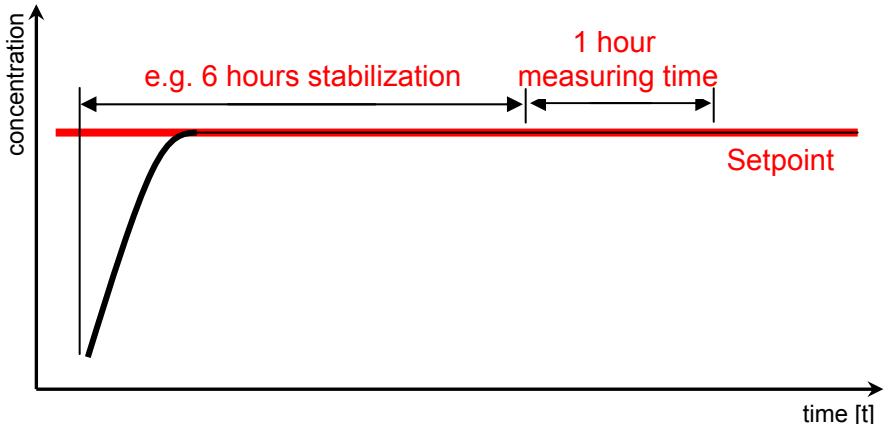
4.2 Instructions for spatial CO_2 and O_2 concentration measurements

For spatial measuring of CO_2 and O_2 concentrations, the following instructions must be complied with:

- Place the 9 sensors within the useable space (definition of useable space see chap. 2.1)
- Measuring points of the sensors must be located 35 mm to 40 mm above the racks, sensors must be put through a suitably prepared rack from below.
- Position the upper and lower rack, leaving a space of at least 10% of the height measurement of the inner chamber between the sensor heads and the inner chamber roof and floor.
- Place the middle rack into the middle slot of the inner chamber. If no middle slot is available take the next possible slot below.



- Measuring time: 1 hour, 360 measurements/hour



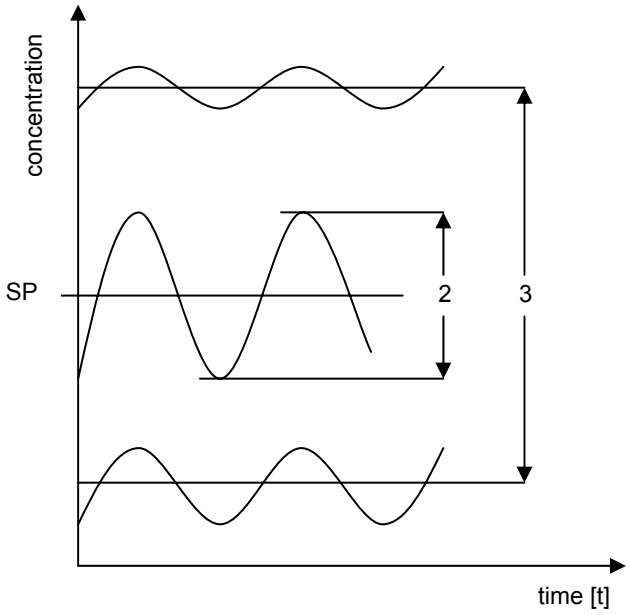
- Gas supply pressure = 2.0 bar (29.0 psi)
- Purity of the gases at least 99,8 %
- Ambient temperature 25 °C (77.0 °F)
- Record measuring data in steady-state condition (for definition of steady-state condition see chap. 2.2)
- Measure gas concentration at a temperature of 37 °C (98.6 °F) and with a filled Permadry™ dish at maximum attainable humidity.

4.3 Evaluation of variation and fluctuation of CO_2 and O_2 concentration

Variation of gas concentration = difference between the average values of those measuring points (3) with the maximum difference.

Fluctuation of gas concentration = maximum variance of the central measuring point (2)

Unit of results: ± [vol.-%] (half of determined values)



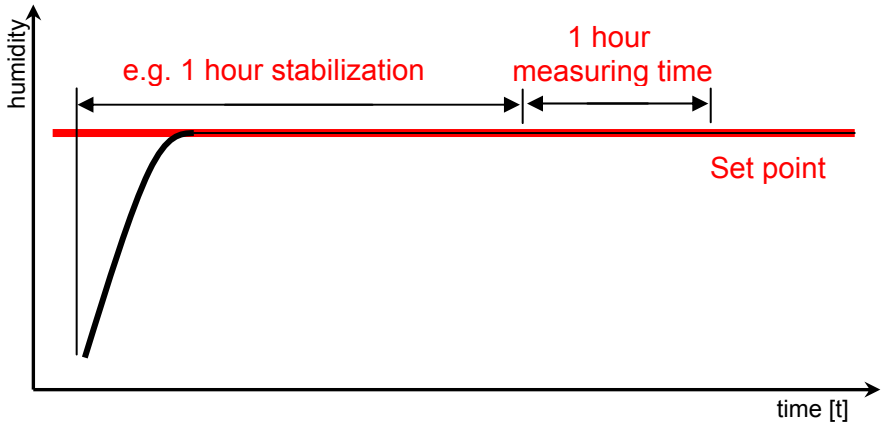
Gas concentrations of 3 measuring points

5. Humidity fluctuation

This chapter is only applicable for chambers with controlled humidity.

5.1 Instructions for measuring humidity fluctuation

- Humidity set point 60 % RH at 25 °C (77.0 °F) temperature set point
- Locate sensor in the center, 15 to 40 mm above the rack in the middle slot.
  If no middle slot is available take the next possible slot below.
- Measuring time: 1 hour, 360 readings/hour



- Ambient temperature 25 °C (77.0 °F)
- Record measuring data in steady-state condition (for definition of steady-state condition, see chap. 2.2)
- Unit of results: ± [% RH] (half of determined values)

6. Energy consumption

6.1 Definition of energy consumption

Power consumption of the unit in a steady-state condition at a specified set point of 25 °C (77.0 °F) ambient temperature, (or 20 °C (68.0 °F) for KB, KBW, KBF, KBF(ICH), KBWF).

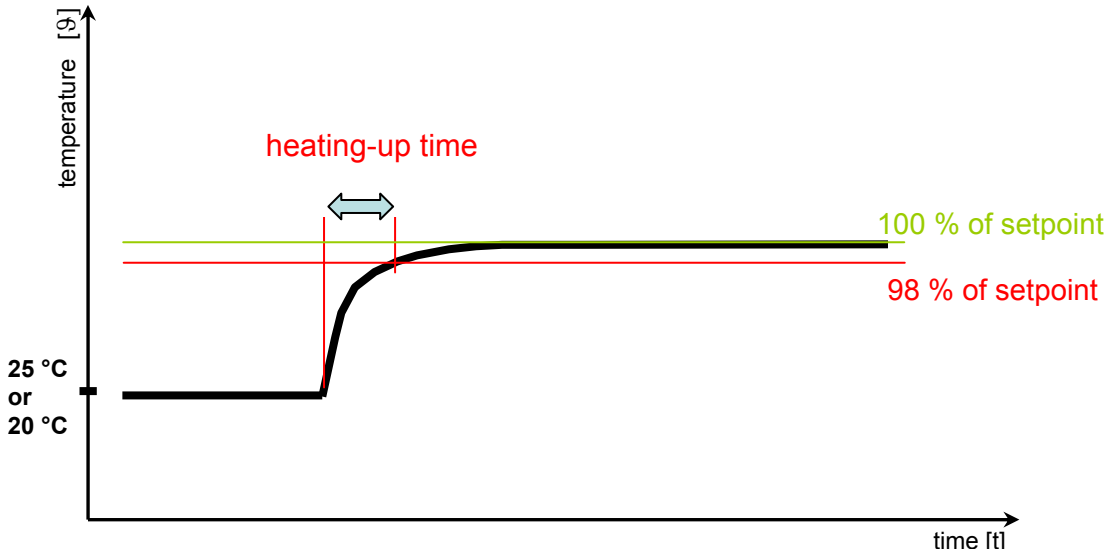
6.2 Instructions for measuring energy consumption

- Connect the power supply system via a wattmeter (for single-phase units) or via three wattmeters (for 3-phase units) or one 3-phase wattmeter (for 3-phase chambers)
- 100 % fan speed (for forced ventilation units)
- Air flap closed (if fitted)
- Ambient temperature 25 °C (77.0 °F)
- Record measuring data in a steady-state condition (for definition, see chap. 2.2)
- Measuring time at least 1 hour with power/energy meter. Measuring unit = kWh
- Calculation: supplied energy [kWh] / measuring time [h]
- Unit of results: Watt [W]

7. Heating-up and cooling-down time

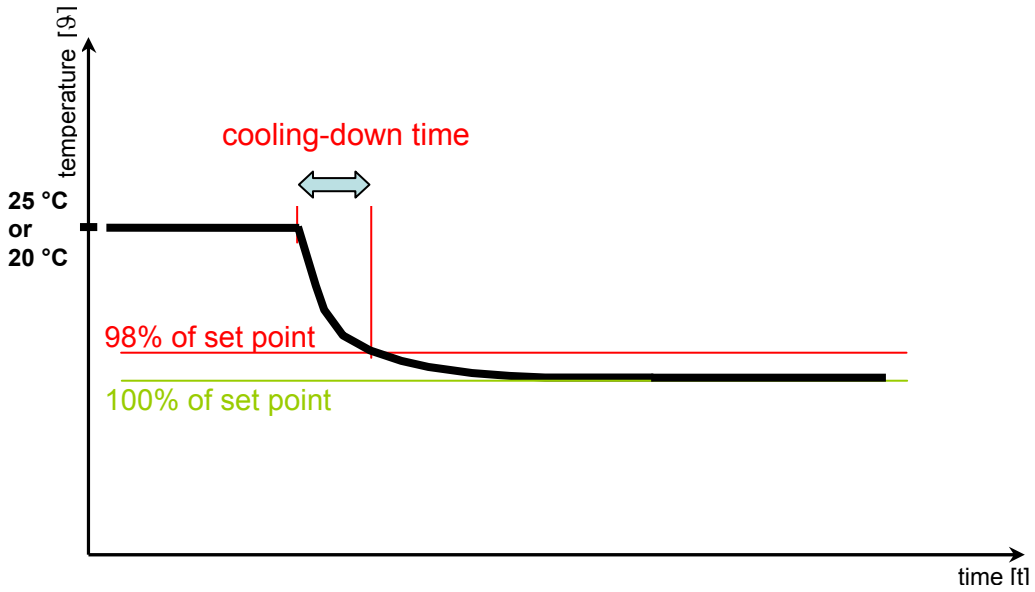
7.1 Definition of heating-up time

Time to heat-up an empty unit from 25 °C (77.0 °F) to 98 % of a specified set point (20 °C (68.0 °F) for KB, KBW, KBF, KBF(ICH), KBWF) to be defined at 25 °C (77.0 °F) ambient temperature, (20 °C (68.0 °F) for KB, KBW, KBF, KBF(ICH), KBWF).



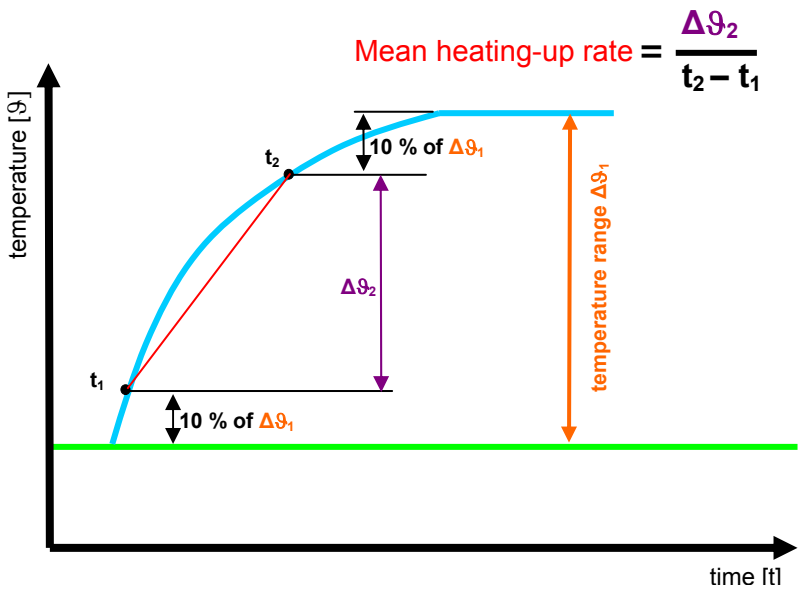
7.2 Definition of cooling-down time

Definition: Time to cool down an empty unit from 25 °C (77.0 °F) (20 °C (68.0 °F) for KB, KBW, KBF, KBF(ICH), KBWF) to 98 % of a specified set point temperature to be defined at 25 °C (77.0 °F) at ambient temperature, (20 °C (68.0 °F) for KB, KBW, KBF, KBF(ICH), KBWF).



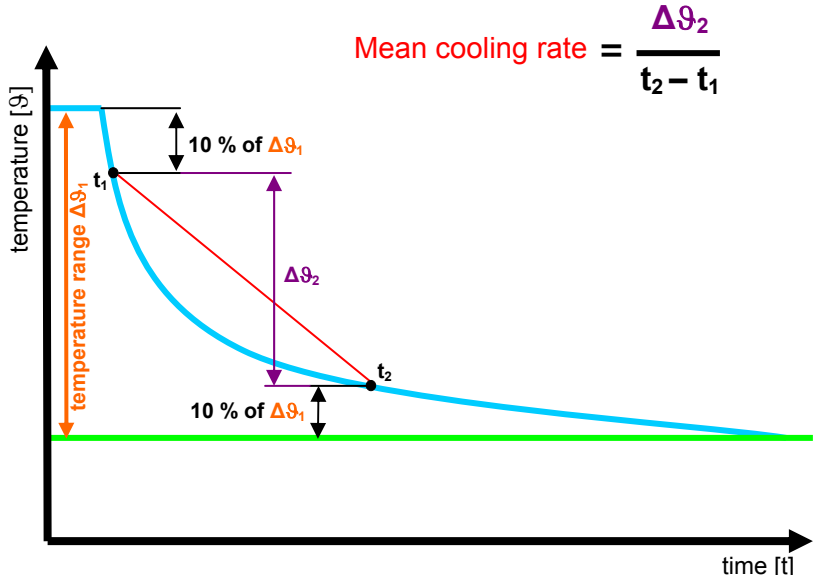
7.3 Definition of mean heating-up rate

Calculated heating-up speed that is reached between 10 % of the full temperature range of the unit above the minimum temperature of the unit, and 10 % of the full temperature range of the unit below the maximum temperature of the unit.



7.4 Definition of mean cooling rate

Calculated cooling-down speed that is reached between 10 % of the full temperature range of the unit below the maximum temperature of the unit, and 10 % of the full temperature range of the unit above the minimum temperature of the unit.



7.5 Instructions for measuring heating-up and cooling-down times, chap. 7.1 – 7.4

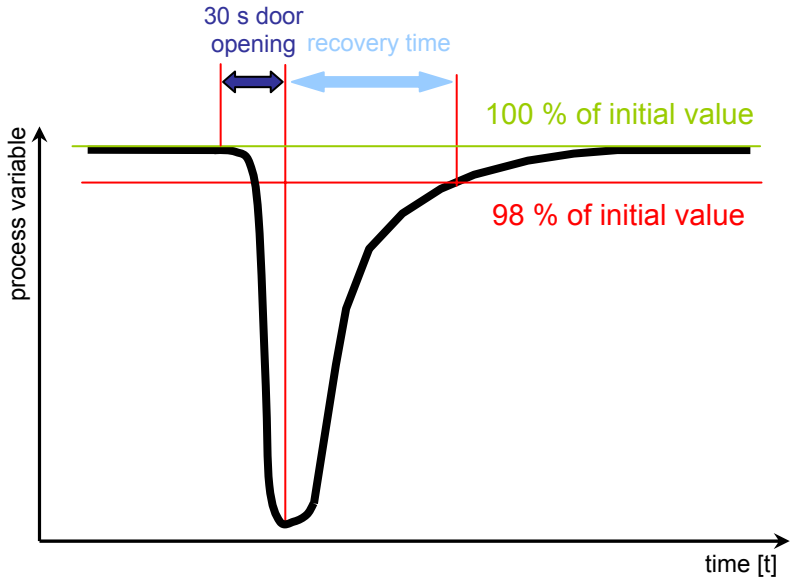
- Measuring point: Center of useable space
- Using type J thermocouples
- Ambient temperature: 25 °C (77.0 °F), or 20 °C (68.0 °F) for KB, KBW, KBF, KBWF, KBF(ICH)
- Starting conditions for set point step-change: steady-state condition (for definition, see chap. 2.2)
- 100 % fan speed (for forced ventilation units)
- Air flap closed (if fitted)
- Unit of results: minutes

8. Recovery time (T, RH, CO_2, O_2)

This chapter applies to chambers with controlled process parameters, such as: temperature, humidity, CO_2 concentration, O_2 concentration.

8.1 Definition of recovery time

Time needed for recovery to 98 % (Celsius temperature scale) of the initial value, 30 seconds after opening the door by 90 degrees. The door should be opened quickly.



8.2 Instructions for measuring recovery times

- Measuring point: Center of useable space
- Using type J thermocouples
- Ambient temperature: 25 °C (77.0 °F), or 20 °C (68.0 °F) for KB, KBW, KBF, KBWF, KBF(ICH)
- Gas supply pressure (CO_2, O_2, N_2 = 2.0 bar (29.0 psi)) with CO_2 incubators
- Purity of the gases at least 99,8 % with CO_2 incubators
- Ambient humidity (only relevant if the recovery time of humidity is measured): 60 % RH
- Starting conditions for door OPEN: steady-state condition (for definition, see chap. 2.2)
- 100 % fan speed (for forced ventilation units)
- Air flap closed (if fitted)
- Unit of results: minutes

Note for CO_2 incubators:
Lower gas supply pressures result in increased recovery times.

8.3 Test values of recovery times

Model series	Temperature test values	Additional test values
ED, FD, FED, FP, M, FDL, MDL	70 °C (158.0 °F), 150 °C (302.0 °F), 250 °C (482.0 °F)	
BD, BF,	37 °C (98.6 °F)	
BFD, BFED	37 °C (98.6 °F), 60 °C (140.0 °F)	
CB	37 °C (98.6 °F) (at maximum humidity and 5 Vol.-% CO_2)	5 Vol.-% CO_2, 5% O_2
KB	5 °C (41.0 °F), 40 °C (104.0 °F)	
KBW, KBWF	15 °C (59.0 °F), 25 °C (77.0 °F) (with and without light)	
KBF(ICH)	25 °C (77.0 °F) (at 60 % RH) (with and without light) 40 °C (104.0 °F) (at 75 % RH) (with and without light)	75 % RH (at 40 °C (104.0 °F))
KBF	25 °C (77.0 °F) (at 60 % RH) 40 °C (104.0 °F) (at 75% RH)	75 % RH (at 40 °C (104.0 °F))
MK	-20 °C (-4.0 °F), 100 °C (212.0 °F)	
MKF	-20 °C (-4.0 °F), 100 °C (212.0 °F)	90 % RH (at 40 °C (104.0 °F))
MKT	-50 °C (-58.0 °F), 100 °C (212.0 °F)	

9. Power consumption and rated power

The measuring is performed in two steps:

1st step: Determine the operating mode that has the biggest power consumption;
i.e. 100 % heating rate or 100 % cooling rate, or a combined operating mode of heating and cooling (if provided). Adjust all other consumers (lights, fans, etc.) to 100 % ON. For multi-phase chambers, determine the phase with the highest current flow.
The maximum current is measured in Amp [A].

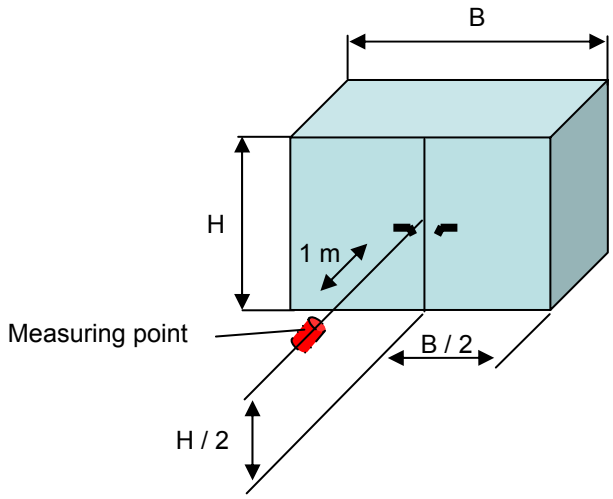
2nd step: Measure the active power with a wattmeter (use three single phase or one 3-phase wattmeter for multi-phase chambers) for the operating mode with the highest power consumption (with multi-phase chambers, measure the maximum power consumption of each phase, if these maximum values are reached simultaneously at one operating stage). With multi-phase chambers and using single-phase wattmeter, add the power consumption of all phases at a specific operating stage, as described above.

Result: Power consumption [A], rated power (active power) in Watt [W]

10. Noise level

Measurement set-up and measurement procedure

- Measure in an almost empty room with minimal furnishing
- Place the noise level measuring device in the center between the temperature chamber and the unit, leaving a space of 1 m between the two
- 100 % fan speed (for forced ventilation units)
- Air flap closed (if fitted)
- Refrigeration units: 100 % cooling rate
- Result:
  noise level in decibel [dB(A)]



11. Air change rate

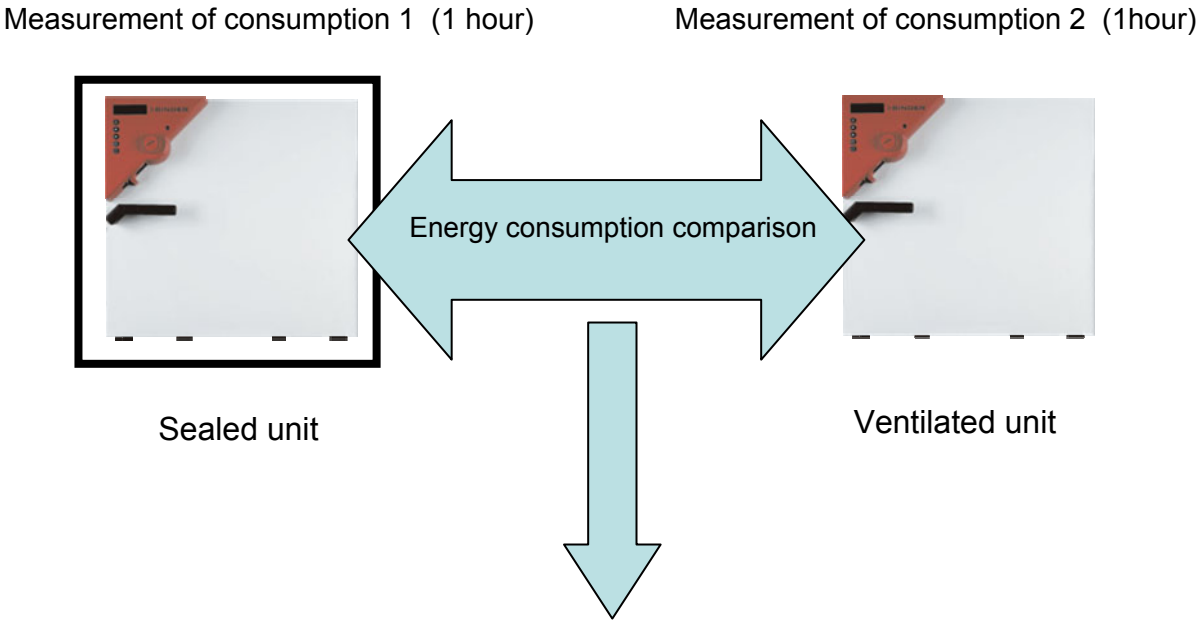
11.1 Definition of air change rate

Number of volume units of ambient air (according to the vapor volume of the chamber) at normal pressure, which are exchanged between the vapor volume of the chamber and its environment in one hour.

Note: The vapor volume is always greater than the inner chamber of the unit (see table in chap. 11.6).

11.2 Measuring principle according to ASTM D 5374

Determination of the different energy consumption values of a unit in the steady-state condition, with and without air exchange of its vapor volume with the environment. Calculate the air volume heated up by this energy difference.



11.3 Instructions for measuring air change rates

- Perform measurement only with drying covens / heating chambers (without vacuum drying chambers)
- Ambient temperature: 25 °C (77.0 °F) with maximum variance of 2 °C (3.6 ºF)
- Temperature set point: 150 °C (302 °F)
- Connect chamber to the power supply system via a wattmeter
- 100 % fan speed (for forced ventilation units)

11.4 Procedure for measuring the air change rate

Consumption measurement 1:

- Seal vapor volume completely to prevent any air exchange with the environment.
  Seal the exhaust pipe (if fitted) and the door gap.

  Additional measures for units with forced convection:
  Remove the inner chamber and seal the outer chamber, i.e. the seam of the outer chamber back wall and the holes around the motor housing, with sealing tape. Seal the fan motor shaft with the Teflon bushing. Reinstall the inner chamber parts.

  Additional measures for natural convection units:
  Seal the ventilation holes in the outer chamber back wall; these holes can be accessed after the back wall is removed.

- Operate the unit in steady-state condition (for definition, see chapter 2.1.2) until the desired set point is reached.
- Measure the temperature T1 inside in the center, and the ambient temperature T2 at a distance of about 2 m.
- Operate unit for one hour at a constant set point and constant ambient temperature (tolerance +/- 2 °C (+/- 3.6 ºF), and measure the energy consumption.

Consumption measurement 2:

- Remove all seals used for the consumption measurement 1.
- Open the air flap (if fitted).
- Operate the unit in steady-state condition (at the same temperature as consumption measurement 1) until the desired set point is reached.
- Measure the temperature T3 inside in the center, and the ambient temperature T4 at a distance of about 2 m.
- Operate unit for one hour at a constant set point and constant ambient temperature (tolerance +/- 2 °C (+/- 3.6 °F), and measure the energy consumption.

11.5 Calculation and result

- Calculate the difference in energy consumption ΔE between measurement 1 and measurement 2.
- Calculate the mean temperature gradient ΔT = (T1+T3)/2)-((T2+T4)/2)
- Read the vapor volume from table (chap. 11.6)

- Use all values with the units in [ ] in the formula below.

$$N = 3590 * \Delta E\,[W] / \text{vapor volume unit}\,[dm^3] * 0.9329\ g/dm^3 * \Delta T\,[K]$$

- Result: Air change rate N [X/h]

11.6 Table of vapor volumes of BINDER simulation chambers

Model	BFD/BFED 53	FDL/MDL 115
Volume (dm³)	81.1	155.9

Model	BD/ED 23	BD/ED 53	BD/ED 115
Volume (dm³)	31.8	71.7	145.5

Model	BD/ED 240	BD/ED 400	BD/ED 720
Volume (dm³)	288.2	467.7	821.5

Model	FP/BF/FD/M/FED 53	FP/BF/FD/M/FED 115	FP/BF/FD/M/FED 240
Volume (dm³)	79.0	157.9	308.4

Model	FP/BF/FD/M/FED 400	FP/BF/FD/M/FED 720
Volume (dm³)	500.2	869.2

12. Heat compensation

12.1 Definition of heat compensation

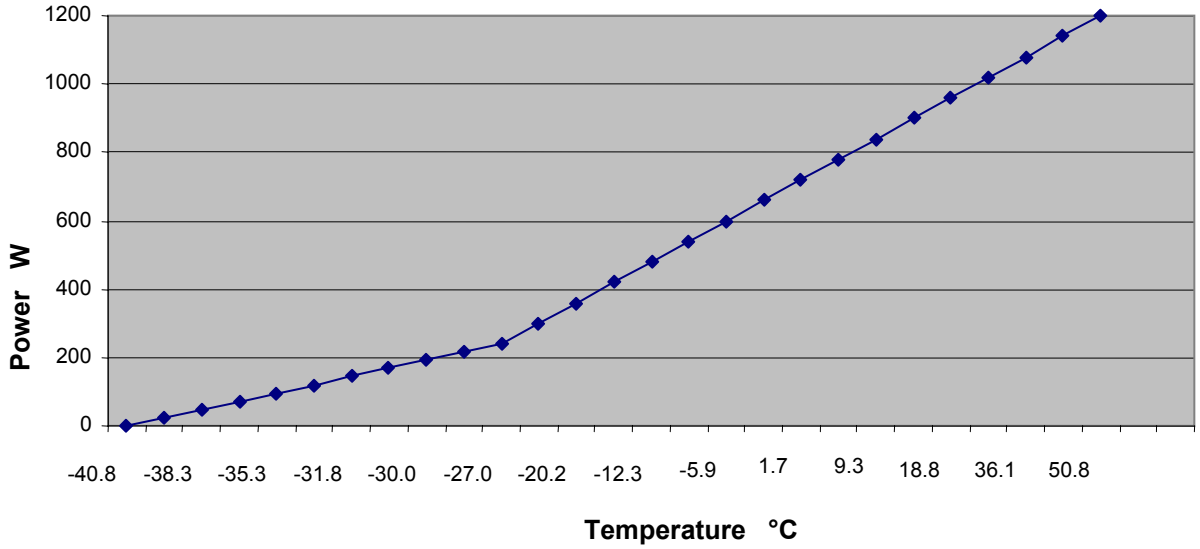
Maximum heat load supplied as electrical energy, so that a defined set point will not be exceeded through active refrigeration of the unit.

Note: Measurement of heat compensation is possible only with cooling chambers.

12.2 Measuring setup and measurement of heat compensation

- A heat load (heating element) is placed into the center of the usable space, and the heat output power is increased stepwise, using a regulating transformer.
- The unit is adjusted to the minimum available setpoint at 25 °C (77.0 °F) ambient temperature, or 20 °C (68 °F) for KB, KBW, KBF, KBWF, KBF(ICH).
- Upon reaching the steady-state operating condition (for definition, see chap. 2.1.2), read the minimum temperature achieved at every power stage.
- Evaluation: Heat load [W] relative to minimum achieved temperature

Example graph of results



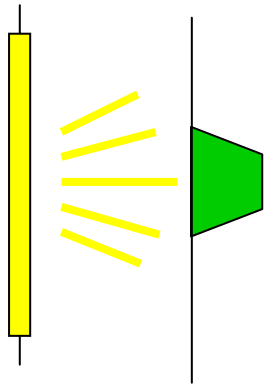
13. Light measurement

13.1 Photometric and radiometric measurement

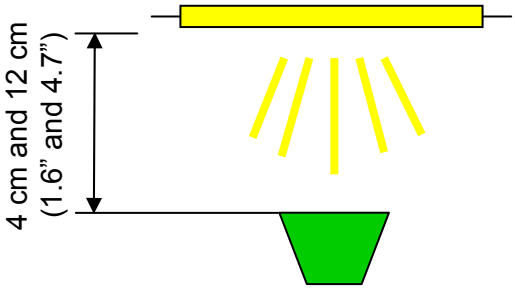
- Measure the maximum light intensity value
  - for KBW, at a distance of 4 cm and 12 cm (1.6” and 4.7”) from the bottom edge of the fluorescent tubes
  - for KBWF, KBF(ICH), directly on the inner surface of the inner glass door
- Use spherical sensors for measurement
- Measuring unit: LUX (Vλ- sensitivity), W/m^2 UVA, µE/sm^2 (quantum sensitivity)
- Orientation of sensors to the lighting device, as shown below

Measurement set-up for different chamber series:

KBF(ICH), KBWF



KBW



14. Normative reference and differentiation from other standards

This factory standard was developed based upon the following standards:

DIN 12880 Part 2 “Electrical laboratory equipment. Heating chambers. Testing”
ASTM D 5374 “Standard Test methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation”

Other ASTM and JTM standards also exist, which specifically define the determination of spatial temperature accuracy. Portions of these standards describe calculations relating to the setpoint and the mean value, using 9 measurement points. Given the same or inferior product quality, these calculations produced better results than those according to DIN 12880 Part 2 or this factory standard.
The missing reference to the setpoint of this factory standard or DIN 12880 Part 2 for spatial temperature measurements is compensated by the initial adjustment of the controller for the temperature measured in the center of the usable space (see chapter 3.2).