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Factory Standard for the Determination of Technical Data

Area of application:

Simulation Chambers, Incubators and Storage Cabinets for Scientific and Industrial Applications

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1. Area of application

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

Standard test values are indicated in the according product data sheets.

The present version 05-2010 replaces the previous version 11-2006.

2. Definitions

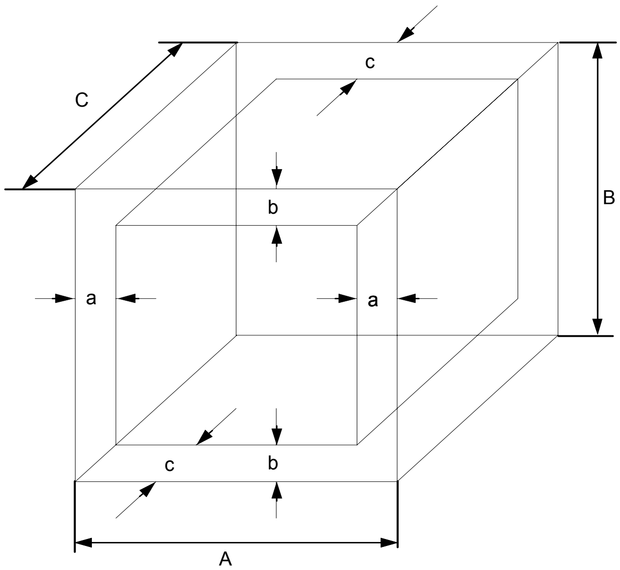
2.1 Useable volume

The useable volume is the part of the inner chamber, in which compliance with the published technical data is guaranteed.

It results from reducing the inner chamber diameter by at least 10% in all directions.

- Distance to the ceiling and bottom: each with at least 10% of the inner chamber height
- Distance to the side panels: each with at least 10% of the inner chamber width
- Distance to the rear panel and the door: each with at least 10% of the inner chamber depth

Falling below these values is permissible if the chamber does not provide shelf positions allowing for positioning of sensors or specimens on shelves within a minimum of 15 mm / *0.6 in* within the boundaries of the useable space defined by these values.



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

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

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

Figure 1: Definition of useable volume

For photometric values a special definition of the useable volume is given (see chap. 13).

2.2 Steady-state condition

2.2.1 Definition

The steady-state condition is the operating state during which the values of all controlled parameters (temperature, humidity, CO_2 concentration, O_2 concentration) permanently do not vary by more than the maximum uniformity (variation) of all controlled parameters specified for the respective chamber at any point within the useable space.

2.2.2 Empirical times to reach steady-state condition

Temperature with chambers with forced convection at least:	1 h
Temperature with chambers with natural convection at least:	4 h
Temperature with vacuum drying ovens at least:	12 h

Humidity with constant climatic chambers:	1 h
Humidity with growth chambers:	1h
Humidity with climatic test chambers:	1 h
Humidity (not controlled) with CO_2-incubators:	15 h

CO_2 with CO_2-incubators:	0.5 h (from ambient value up to 5 vol.-%)
O_2 with CO_2-incubators:	1.5 h (from ambient value up to 80 vol.-%)

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

2.3 Ambient temperature

2.3.1 Definition

Homogenous temperature around the test object in a distance of 2-3 meters / *6.6-9.8 feet*. Measuring location: half-way up the height of the test object above the ground, with refrigerated chambers in front of the suction grid of the condenser fan. All measurements of this factory standard relate to an ambient temperature of 25 °C +/- 0.5 °C without draft in the test area.

Deviating ambient conditions generally produce inferior performance data, since the chambers are designed to perform best at an ambient temperature of 25 °C / *77 °F*.

2.3.2 Ambient temperature to determine technical catalogue data

25 °C / *77 °F*

2.3.3 Ambient temperature influence on the chambers

Temperature uniformity (variation) and temperature recovery times change, depending on the temperature difference between the useable volume and ambient temperature.

Temperature uniformity (variation) also depends on the chamber type, due to the production process.

The combination of both effects result in a specific temperature uniformity (variation) for each set-point temperature. Within the ambient temperature range specified for the chambers, temperature uniformity may deviate from the respective catalogue value by max. +/- 20%. For this reason, temperature uniformity (variation) at ambient temperatures other than 25°C / *77 °F* must be determined individually.

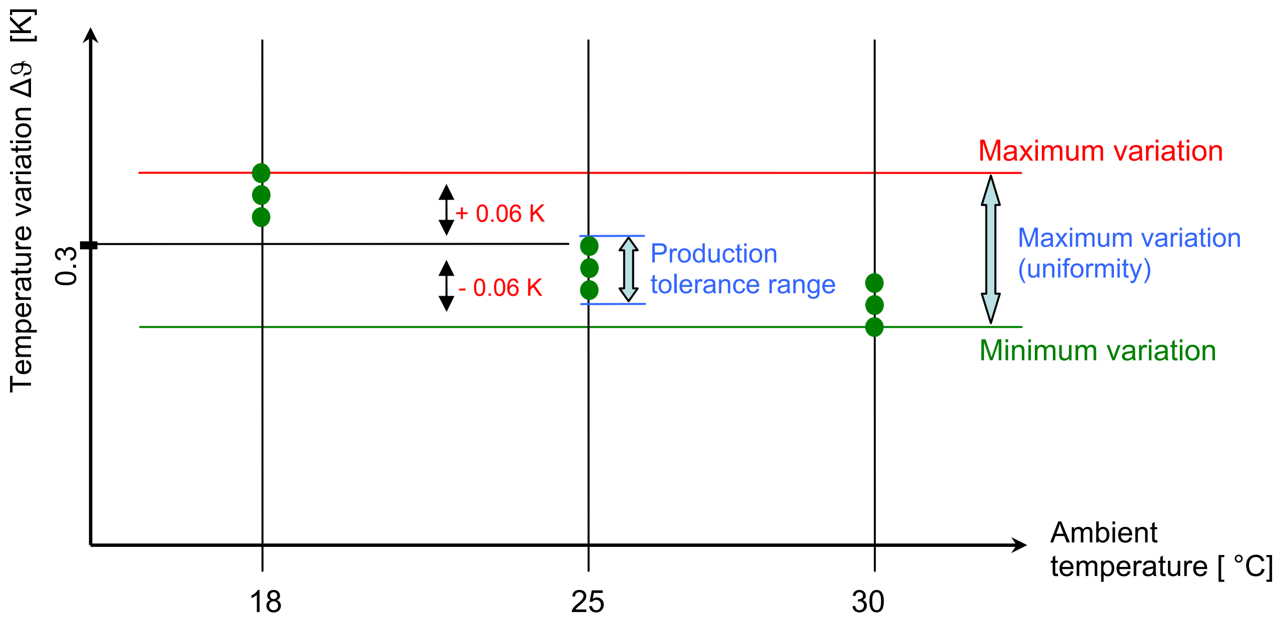


Figure 2: Influence of the ambient temperature (example: CO_2-incubator with set-point temperature 37 °C)

2.4 Conditions of measurement

The following conditions are valid for all measurements unless specified otherwise in the individual sections.

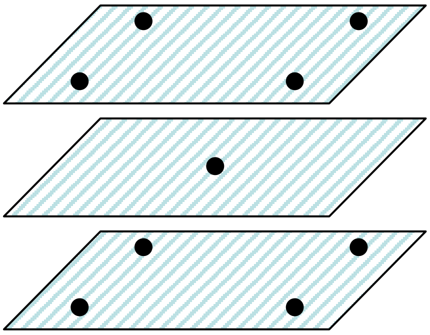
- Chambers with forced convection: 100% fan speed
- Non-loaded state
- Chambers with exhaust duct: Air flap closed
- Data acquisition in steady-state condition (definition see chap. 2.2.1)
- Standard shelves, standard quantity

3. Temperature uniformity (variation) and fluctuation

3.1 Arrangement of measuring points in the inner chamber

Depending on the chamber model and size, sensor arrangement shall be as follows:

9-point measurement



To be applied to the following models:

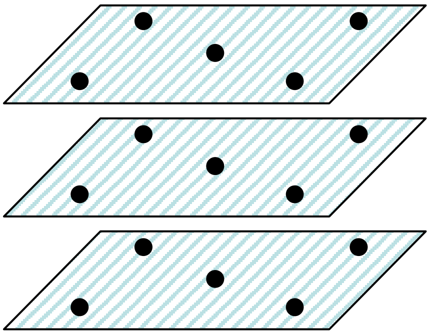
Vacuum drying ovens size 23l:
VD (E2.x), VDL (E2.x), VDL EX (E2.x)

Climatic chambers acc. to IEC 60068-3-5:
MK (E2), MK (E3.x), MKF (E3.x), MKT (E3.x), MKFT, KMF (E5.x)

Option 9-point spatial measurement of temperature:
BD (E2), BF (E1), KB (E3.x), KBW (E3.x), KB (E5.x), KBW (E5.x),

Options spatial measurement of humidity, CO_2 or O_2

15-point measurement



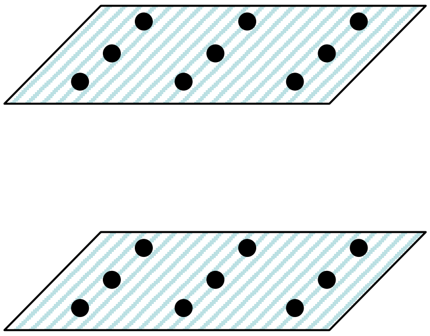
To be applied to the following models:

Vacuum drying ovens sizes 53l, 115l:
VD (E2.x), VDL (E2.x), VDL EX (E2.x)

Size 23l:
BD (E2), ED (E2), FD (E2), KB (E3.x)

Size 28l, B, E

18-point measurement



To be applied to the following models:

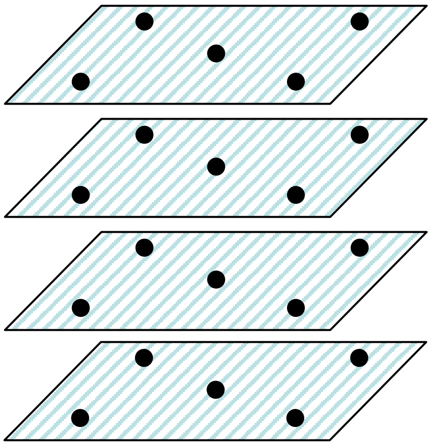
Chambers with 2 light cassettes, size 240l: KBW (E3.x), KBW (E5.x), KBF-ICH (E5.x), KBF P (E5.x), KBF-LQC (E5.x), KBWF (E5.x)

Measuring conditions:

With light switched on (after at least 1h).

Arrangement of measuring points: measurement level by 12 cm / *4.7 in* below each light cassette.

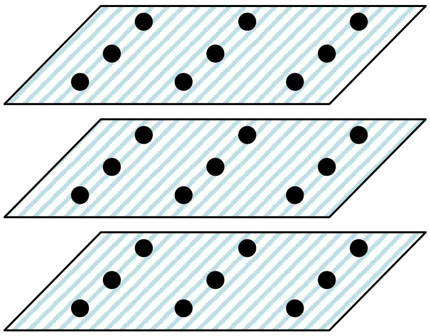
20-point measurement



To be applied to the following models:

Freezers with 4 inner doors, sizes 300l, 500l, 700l: F / UF V

27-point measurement



To be applied to the following models:

BD (E2), BF (E1), BFD (E1), BFED (E1), ED (E2), FD (E2), FED (E2), FP (E1.x), M (E2), FDL (E2), MDL (E2), C150, CB (E2), CB (E3), KB (E3.x), KBF (E2), KBF (E5.x)

Chambers with illumination in the chamber doors, sizes 240l, 720l:
KBF-ICH (E2), KBF-LQC (E2), KBWF (E2)

Chambers with 3 light cassettes, sizes 400l, 720l: KBW (E3.x), KBW (E5.x), KBF-ICH (E5.x), KBF P (E5.x), KBF-LQC (E5.x)

Chambers with light cassettes for data acquisition with removed light cassettes: KBW (E3.x), KBW (E5.x), KBF-ICH (E5.x), KBF P (E5.x), KBF-LQC (E5.x)

Measuring conditions:

With light switched on (after at least 1h).

Arrangement of measuring points: measurement level by 12 cm / *4.7 in* below each light cassette

3.2 Test instructions for spatial measurements of temperature

- Adjust the temperature controller prior to spatial measurements of temperature in order to prevent any deviation from the set-point in the center of the usable space during the measurement.
- Use type J thermocouples to determine the time-based temperature deviation (fluctuation)
- Use Pt 100 sensors class A or B (DIN EN 60751) to determine temperature uniformity (variation).
- Arrange the sensors evenly distributed within the useable volume (definition of useable volume see chap. 2.1).
- Place the top and bottom shelves in a way that the sensor tips keep a distance of at least 10 % of the inner chamber height to the ceiling and bottom.
- Place the middle shelf in central position. If no central position is available, use the next one below.
- Place the sensor heads 15 mm / *0.6 in* above the shelf.

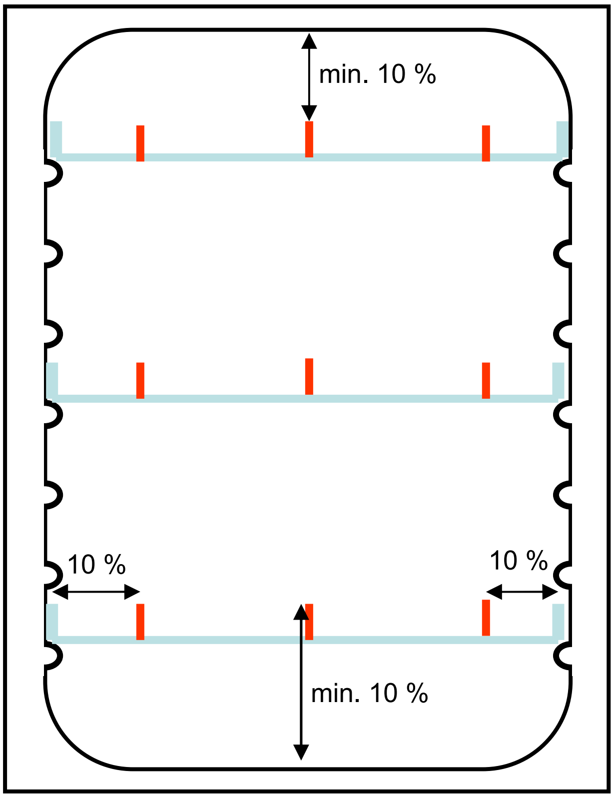


Figure 3: Arrangement of shelves for spatial measurements of temperature

Note on differentiating this procedure from the adjustment of temperature controllers:

Adjustments of temperature controllers shall be performed exclusively with Pt 100 sensors class A or B (DIN EN 60751) in the center of the usable volume

- Arrange the sensors on the measuring plane parallel to the temperature gradient.

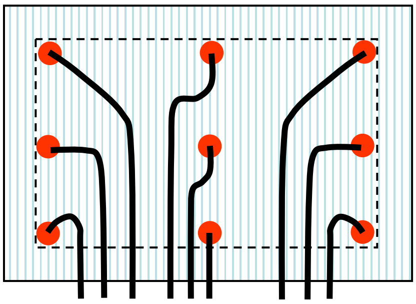


Figure 4: Shelf with sensor orientation, top view

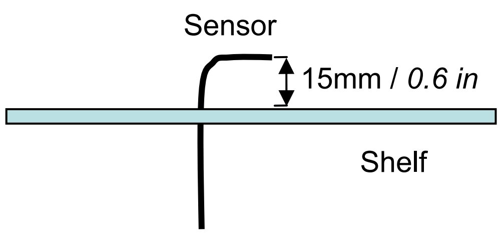


Figure 5: Shelf with sensor orientation, lateral view

- Vacuum drying ovens: pressure <20 mbar, sensors glued on three aluminum expansion racks with aluminum tape

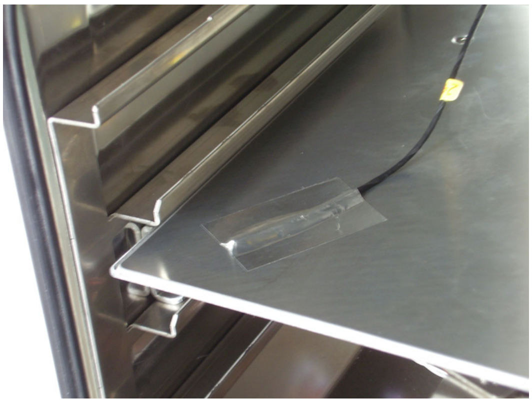


Figure 6: Sensor for temperature measurement in vacuum drying ovens

- Measuring time 1 hour, 360 measured values/hour

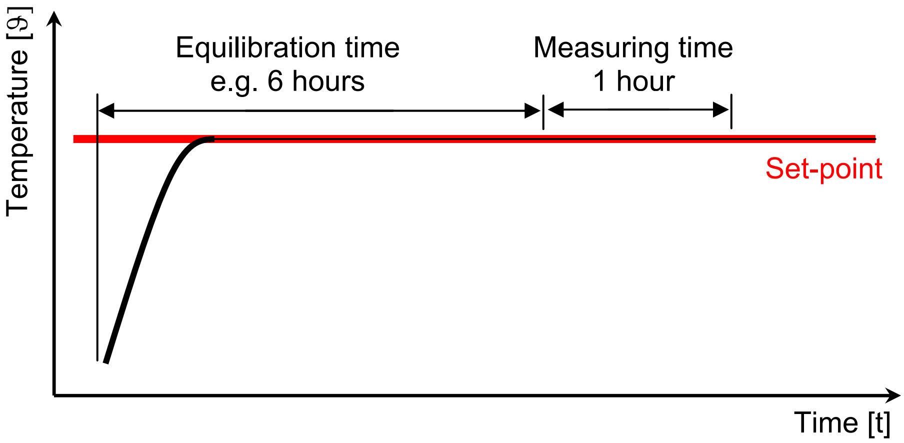


Figure 7: Time course of temperature measurement in vacuum drying ovens

- Pt100 temperature sensor attached on standard shelves.

3.3 Evaluation of temperature uniformity (variation) and fluctuation

Temperature uniformity (variation) results from half the difference between the mean values of the measuring points (3) with the maximum deviation:

$$\text{Temperature uniformity (variation) in +/- [K]} = \frac{(\text{Mean value } T_{max} - \text{Mean value } T_{min})}{2}$$

Temperature fluctuation results from half of the maximal variance of the central measuring point (2) symmetrically around the mean value:

$$\text{Temperature fluctuation in +/- [K]} = \frac{\text{Mean deviation } (T_{Center})}{2}$$

Definitions based on DIN 12880:2007.

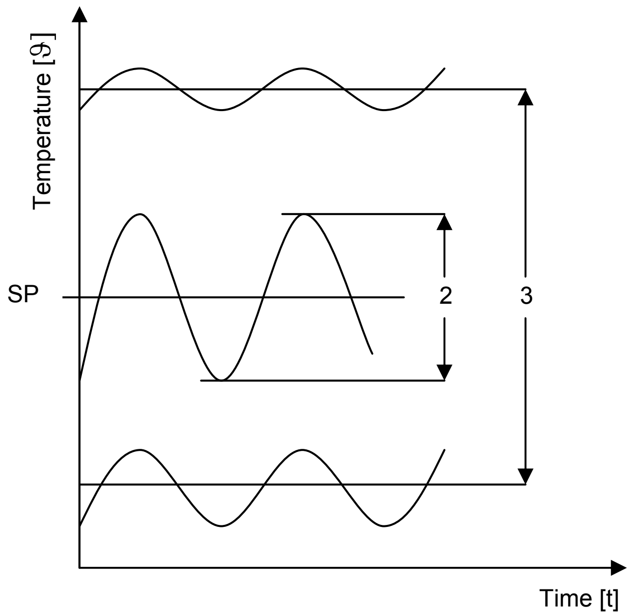


Figure 8: Temperature pattern at three measuring points

4. CO_2 and O_2 uniformity (variation) and fluctuation

This chapter applies only to CO_2-incubators.

4.1 Arrangement of the measuring in the inner chamber

Arrangement of the measuring points as follows:

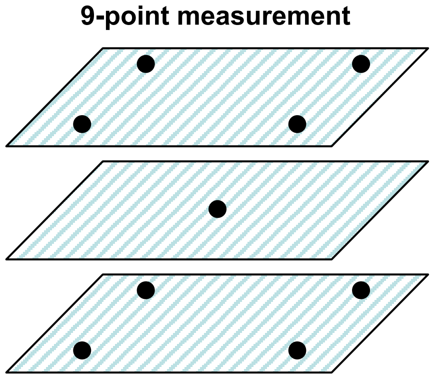


Figure 9: Arrangement of the measuring points for spatial and temporal measurements of CO_2 and O_2

4.2 Test instructions for spatial measurements of CO_2 and O_2

For spatial measurements of CO_2 and O_2 the following test instructions shall be observed:

- Arrange the 9 sensors within the useable volume (definition of useable volume see chap. 2.1).
- The sensors shall be passed from below through an appropriately prepared shelf. Place the sensor heads 35-40 mm / *1.4-1.6 in* above the shelf.
- Place the top and bottom shelves in a way that the sensor tips keep a distance of at least 10 % of the inner chamber height to the ceiling and bottom.
- Place the middle shelf in central position. If no central position is available, use the next one below.

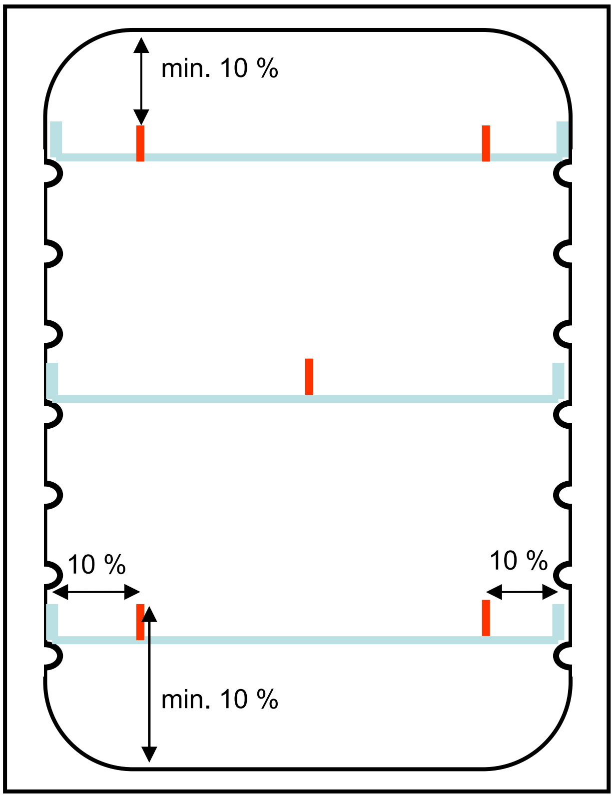


Figure 10: Arrangement of the shelves for spatial and temporal measurements of CO_2 and O_2

- Measuring time 1 hour, 360 measured values/hour

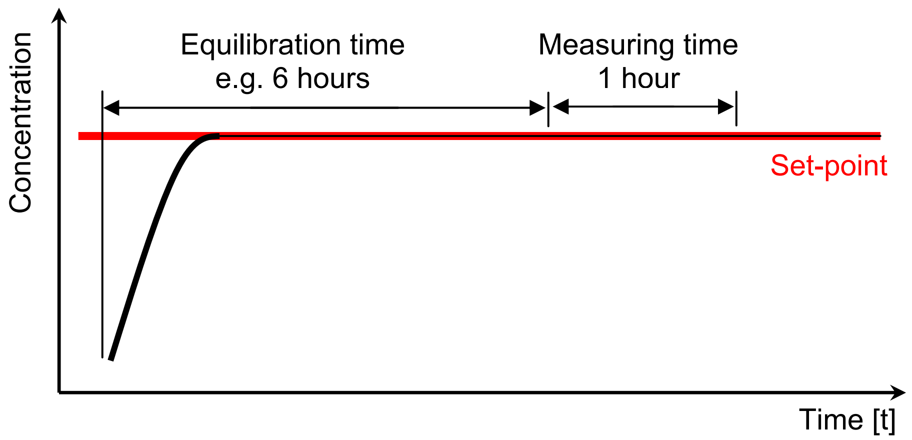


Figure 11: Time course of spatial measurements of CO_2 and O_2

4.3 Evaluation of CO_2 and O_2 uniformity (variation) and fluctuation

Gas concentration uniformity (variation) results from half the difference between the mean values of the measuring points (3) with the maximum deviation.

$$\text{Gas concentration uniformity (variation) in +/- vol.-\%} = \frac{(\text{Mean value } C_{max} - \text{Mean value } C_{min})}{2}$$

Gas concentration fluctuation results from half of the maximal variance of the central measuring point (2) symmetrically around the mean value:

$$\text{Gas concentration fluctuation in +/- vol.-\%} = \frac{\text{Mean deviation } (C_{Center})}{2}$$

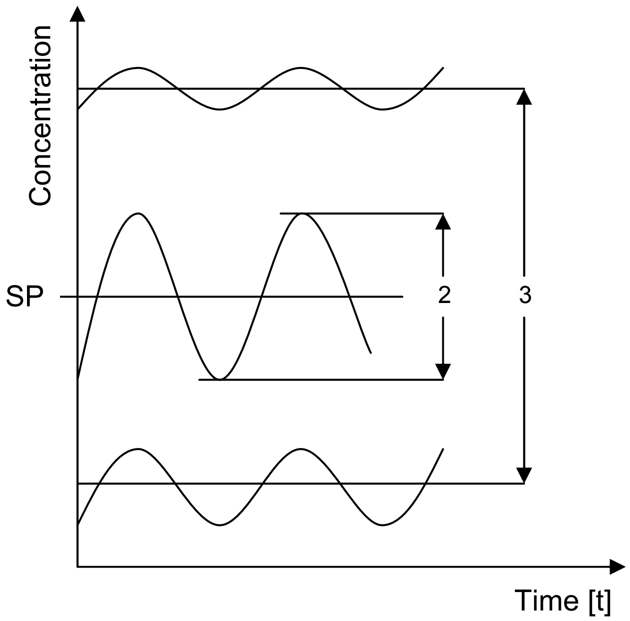


Figure 12: Gas concentrations at three measuring points

5. Humidity uniformity (variation) and fluctuation

This chapter applies only to chambers with controlled humidity.

5.1 Test instructions for temporal measurement of humidity

- Sensor in central position 15-40 mm / *0.6-1.6 in* above the central shelf
- Measuring time 1 hour, 360 measured values/hour

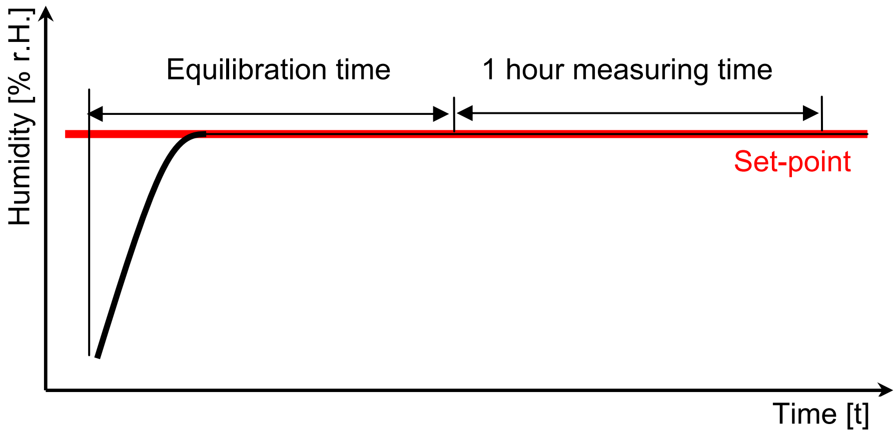


Figure 13: Time course of humidity measurement

5.2 Evaluation of humidity fluctuation

Humidity fluctuation results from half of the maximal variance of the central measuring point (2) symmetrically around the mean value:

$$\text{Humidity fluctuation in +/- [\% r.H.]} = \frac{\text{Mean deviation } (F_{Center})}{2}$$

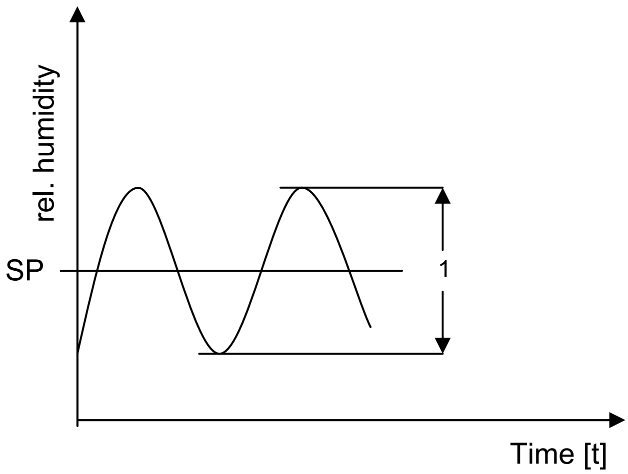


Figure 14: Temporal humidity course

5.3 Test instructions for spatial measurement of humidity

- 9-point measurement with measuring points distributed as shown in chap. 3
- Sensor distance 15-40 mm / *0.6-1.6 in*
- Humidity equilibrated

5.4 Result

Humidity uniformity (variation) in +/- % r.H. around the humidity set-point, in each case for a defined temperature set-point.

6. Energy consumption

6.1 Definition of energy consumption

Energy consumption is the power consumption of the chamber per time unit at a defined set-point in steady-state condition.

6.2 Test instructions to measure the energy consumption

Figure 15: Measurement of energy consumption

- Connect the power supply by one power measuring device / wattmeter (with single-phase chambers) resp. by three wattmeters or one three-phase wattmeter (with three-phase chambers)
- Duration of measurement at least 1 hour with a power and energy meter. Unit kWh
- Calculation: energy supplied [kWh] / measurement duration [h]
- Unit of the resulting value: [Wh/h] with a defined constant operating state

7. Heating and cooling capacity

7.1 Definition of heating-up time

Time to heat up an empty chamber with standard shelves with active heating, starting in steady-state condition at its equilibrated minimum temperature, to a set-point temperature entered to the chamber's temperature controller. It refers to the period until the temperature measured in the center of the useable volume reaches the defined limit deviation of the set-point.

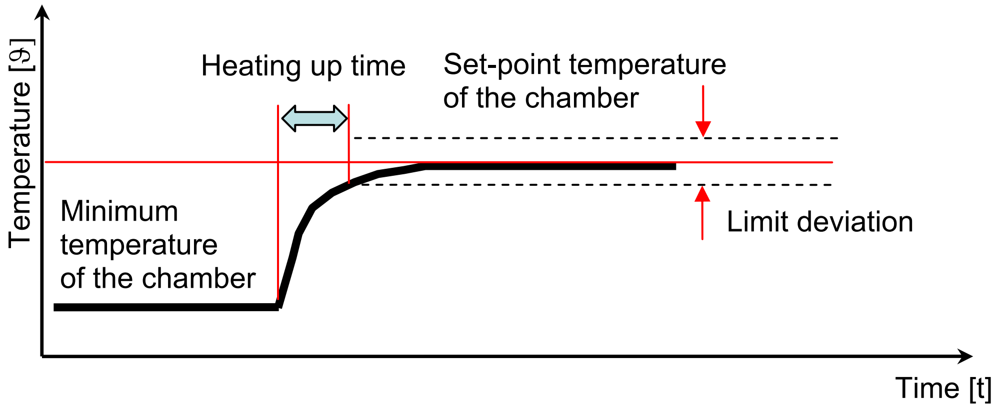


Figure 16: Definition of heating-up time

7.2 Definition of cooling-down time

This chapter applies only to chambers with active refrigeration.

Definition: Time to cool down an empty chamber with standard shelves with active refrigeration, starting in steady-state condition at its equilibrated maximum temperature, to the minimum temperature entered to the chamber's temperature controller. It refers to the period until the temperature measured in the center of the useable volume reaches the defined limit deviation of the set-point.

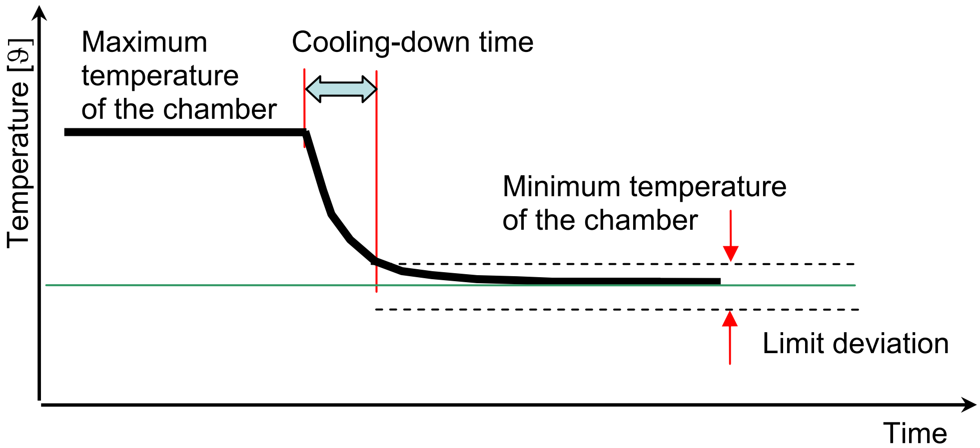


Figure 17: Definition of cooling-down time

7.3 Definition of the limit deviation

Selected temperature set-point	Limit deviation
above +25 °C	+/- 2 % of the set-point
+25 °C up to -25 °C	+/- 0.5K
below -25 °C	+/- 2 % of the set-point

Table 1: Limit deviation

7.4 Definition of the mean heating rate

Calculated heating rate, which is reached between 10 % (referring to °C scale) of the chamber's total temperature range above the chamber's minimum temperature and 10 % (referring to °C scale) of the total temperature range below the chamber's maximum temperature. Determination according to IEC 60068-3-5.

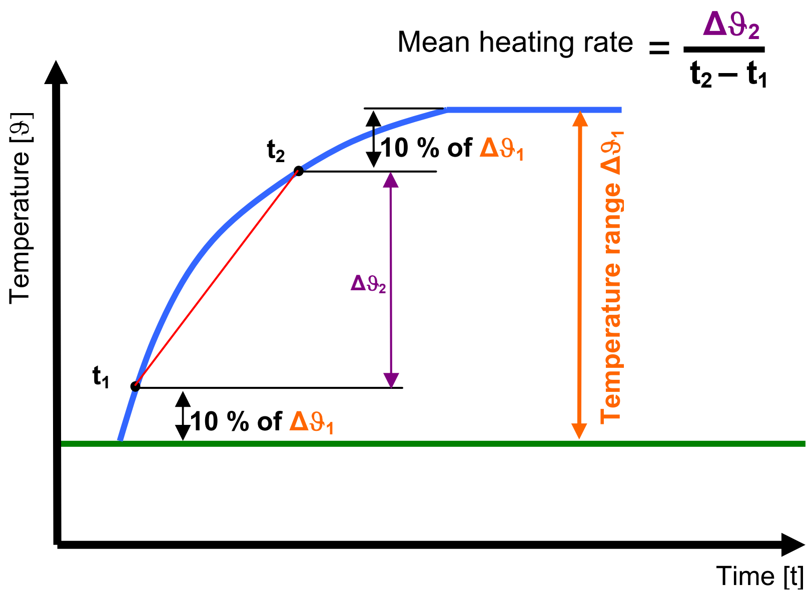


Figure 18: Definition of the mean heating rate according to IEC 60068-3-5

7.5 Definition of the mean cooling rate

Calculated cooling rate, which is reached between 10 % (referring to °C scale) of the chamber's total temperature range below the chamber's maximum temperature and 10 % (referring to °C scale) of the total temperature range above the chamber's minimum temperature. Determination according to IEC 60068-3-5.

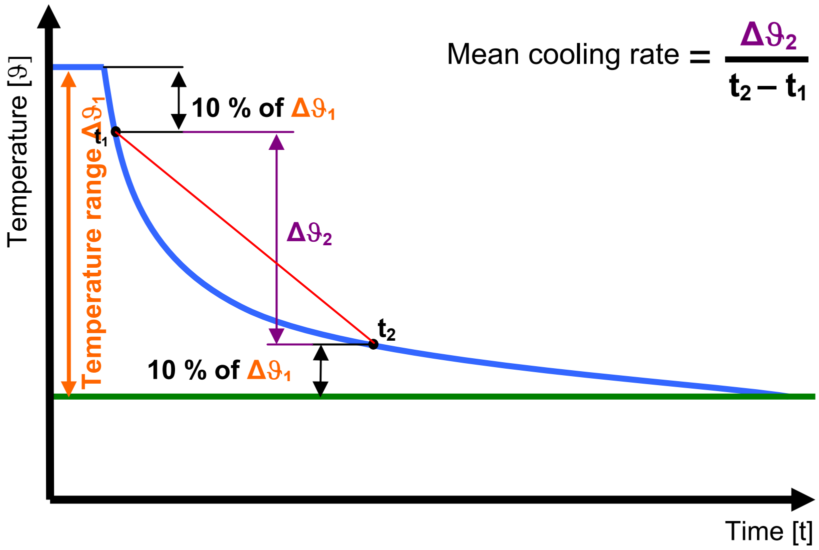


Figure 19: Mean cooling rate according to IEC 60068-3-5

7.6 Test instructions to determine the heating and cooling capacity

- Position of shelves / Measuring location: center of useable volume
- Start conditions: steady-state condition for at least one hour
- Humidity control switched off
- Illumination switched off, light cassettes removed
- All chamber parts are fitted to the chamber; flaps, if existing, are closed.
- Unit of the resulting values: minutes

8. Recovery times of temperature, humidity, CO_2, O_2

This chapter applies to following controlled process parameters: temperature, relative humidity, CO_2 concentration, O_2 concentration.

8.1 Definition of recovery times

Period of time until the actual value measured in the center of the useable volume remains permanently within the limit deviations of chap. 7.1 after opening the door by 90 degrees for 30 seconds and closing it. The door shall be opened and closed quickly.

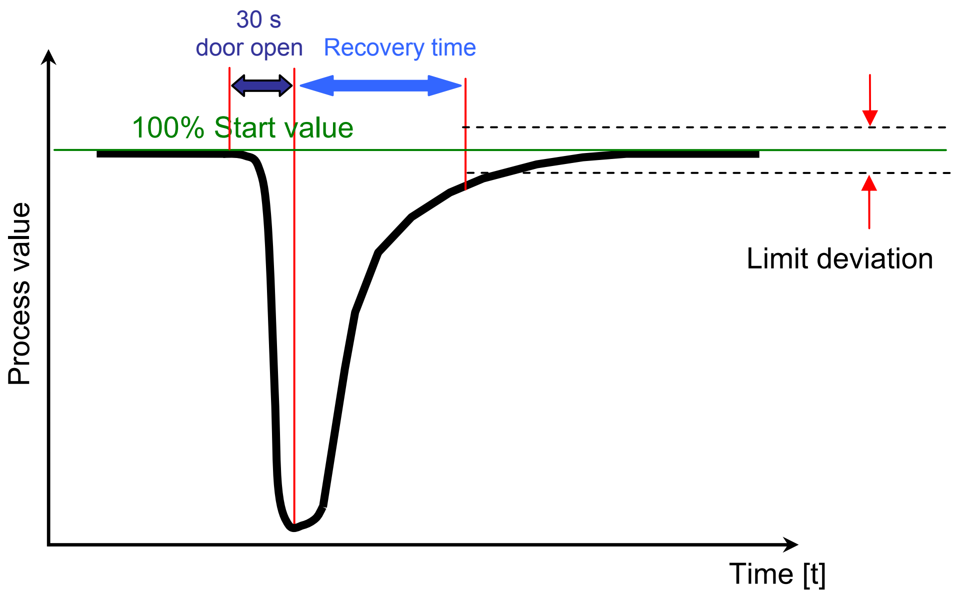


Figure 20: Definition of recovery times (based on DIN 12880:2007)

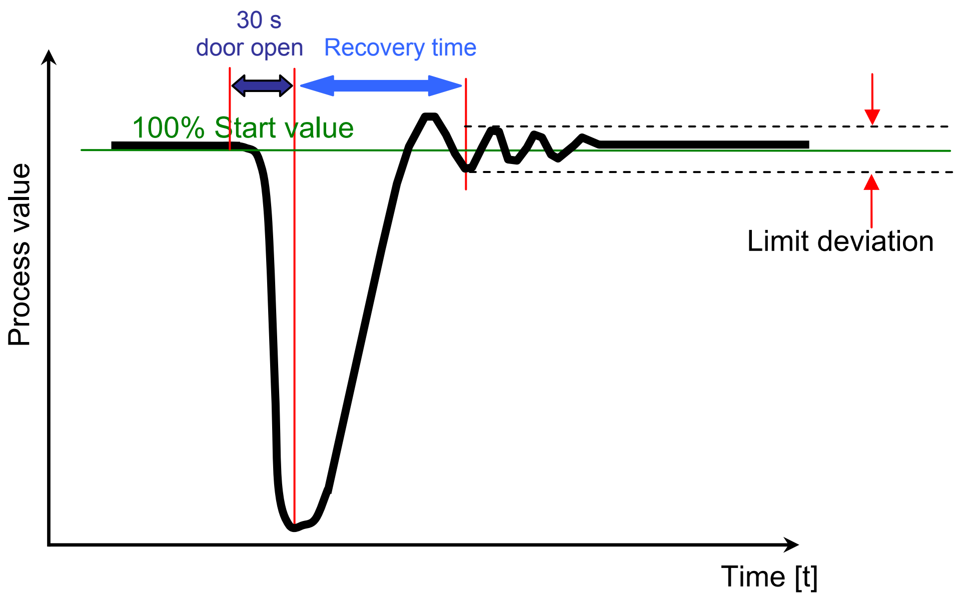


Figure 21: Definition of recovery times with higher performance (based on DIN 12880:2007)

Selected temperature set-point	Limit deviation
above +25 °C	+/- 2 % of the set-point
+25 °C up to -25 °C	+/- 0.5K
below -25 °C	+/- 2 % of the set-point

Table 2: Limit deviation of temperature

Limit deviation with CO_2-incubators	Limit deviation with climatic chambers
+/- 2 % of the set-point	Value of humidity fluctuation (determination see chap. 5.1)

Table 3: Limit deviation of humidity

Selected gas concentration set-point	Limit deviation of CO_2	Limit deviation of O_2
above 10 vol.-%	+/- 2 % of the set-point	+/- 2 % of the set-point
below 10 vol.-%	+/- 0.2 vol.-% CO_2	+/- 0.2 vol.-% O_2

Table 4: Limit deviation of gases

8.2 Test instructions to measure the recovery times

- Measuring location: center of useable volume
- Ambient humidity (applies only to recovery time of humidity) 50 % r.H. +/- 15% r.H.
- Unit of the resulting value: minutes
- Note on CO_2-incubators: Lower gas supply pressure values result in longer recovery times.

9. Maximum current consumption and nominal power

9.1 Determination of the maximum current consumption

9.1.1 Principle of measurement

Determination of the operating state with the largest current consumption, i.e., 100 % heating regulation ratio or 100 % cooling regulation ratio or combined operating of heating and refrigeration (if existing). All other loads (illumination, fan etc.) 100 % ON. With multi-phase chambers, that phase shall be evaluated through which most current flows.

Measurement of the maximum current in Ampere [A].

9.1.2 Result

Maximum current consumption in Ampere [A]

9.2 Determination of the nominal power

9.2.1 Principle of measurement

Measurement of the effective power using a power measuring device / wattmeter (with multi-phase chambers, use three single-phase wattmeters or one three-phase wattmeter) at the operating state with the largest current consumption (with multi-phase chambers: the maximum current consumption of each individual phase, provided that those maximum values are reached simultaneously at one moment of operation). With multi-phase chambers and when using a single-phase wattmeter, the power consumptions of all phases at one moment of operation determined as described above shall be added.

9.2.2 Result

Nominal power (effective power) in Watt [W].

10. Noise level

10.1 Measurement setup and test instruction

- Measurement shall be performed in an almost empty room with minimal extraneous noise
- 3 cycles with a measurement duration of one minute and at least 30 measured values per cycle
- Distance between the sound level meter and the temperature chamber: 1 m centered in front of the chamber

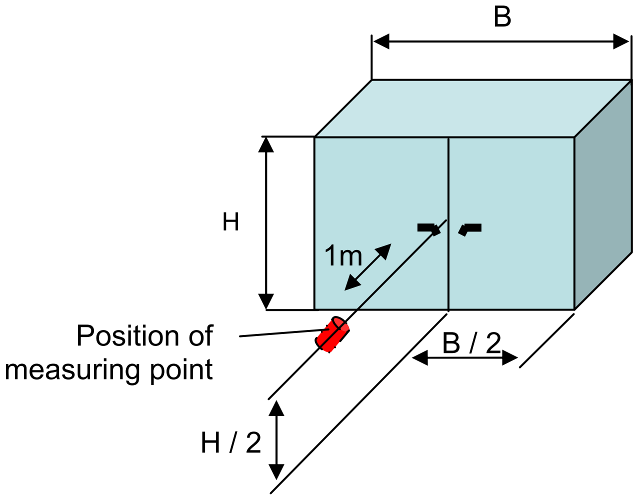


Figure 22: Noise level measurement

10.2 Result

Mean value of the sound pressure level in Decibel [dB(A)] of the 3 measurement cycles

11. Air exchange

11.1 Definition of air exchange rate

Number of ambient air volume units (according to the chamber's steam space) under normal pressure, which are exchanged between the chamber's steam space and its environment during one hour.

Note: The steam space is always greater than the inner chamber of the unit. The dimensions of the outer chamber are decisive.

11.2 Principle to determine the air exchange rate according to ASTM D 5374

The average power shall be determined, which is required to maintain the chamber at 100 °C and at its maximum temperature. With each of these temperature values, 2 measurements shall be performed: one measurement with air exchange with the ambiance (air flap open), one measurement without air exchange (sealed chamber). Then the air exchange rate shall be calculated from the difference in power of these measurements, depending on the ambient temperature and density and on the air volume, which is heated by this difference in power.

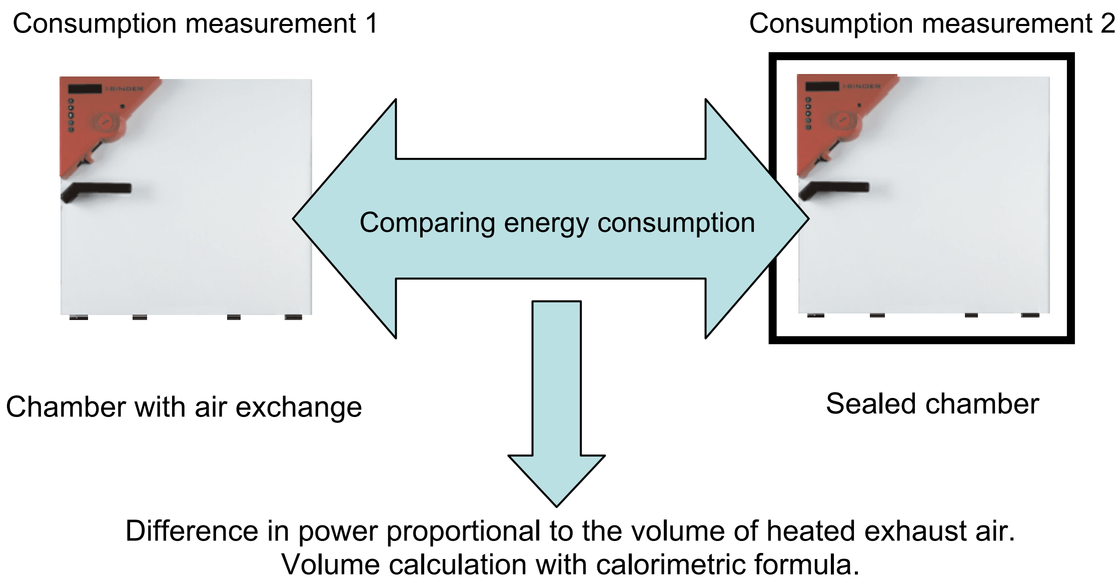


Figure 23: Measurement principle according to ASTM D 5374

11.3 Test instructions to measure the air exchange rate

- Measurement only for heating/drying ovens (no vacuum drying ovens)
- Connect the chamber to the power supply via a power measuring device / wattmeter (measurement in W/h)
- Temperature in the center of the useable volume T1 as on the controller display
- Measure the ambient temperature T2 in a distance of 2 m / *79 in* to 3 m / *118 in*
- Operate the chamber for approx. 1 hour with a constant set-point and measure the energy consumption
- Perform a measurement with air exchange and another measurement without air exchange at 100 °C
- Perform a measurement with air exchange and another measurement without air exchange at the chamber's nominal temperature
- The ambient temperature must remain constant during the four measurements. Maximum deviation 2 °C

11.3.1 Preparing the chamber for a measurement with air exchange

- Open the air flap (if existing)

11.3.2 Preparing the chamber for a measurement without air exchange

- Completely seal the steam space, so that air exchange with the ambiance becomes impossible. Close the exhaust duct (if existing), seal the door gap.
- Additional measures for chambers with forced convection:

  Remove the inner chamber and seal the outer chamber, i.e. the seam of the outer chamber's rear panel and the holes in the area of the fan motor housing, with sealing tape. Seal the fan motor shaft with the Teflon bush. Reinstall the inner chamber parts.
- Additional measures for chambers with natural convection:

  Seal the ventilation gaps in the outer chamber's rear panel. Those gaps are accessible when removing the rear housing panel.

11.4 Measurement results

P1 Average power [W] when measured without air exchange, determined from the value displayed on the power measuring device [W/h] divided by the measurement duration [h]

P2 Average power [W] when measured with air exchange, determined from the value displayed on the power measuring device [W/h] divided by the measurement duration [h]

ΔP Difference in power [W] between the measurement without air exchange and the measurement with air exchange. $\Delta P = P1 - P2$.

T1 Temperature in the center of the useable volume

T2 Ambient temperature

ΔT Temperature difference [°C] between the temperature in the center of the useable volume and the ambient temperature. $\Delta T = T1 - T2$.

11.5 Calculating the air exchange rate from the measurement results

N = 3.59 ΔP / (V* ρ * ΔT)

N Average air exchange per hour [x/h]

ΔP Difference in power [W] between the measurement without air exchange and the measurement with air exchange (chap. 11.4).

V Volume of the chamber's steam space [m^3]

ρ Ambient air density [kg/m³] during the measurement

ΔT Temperature difference [°C] between the temperature in the center of the useable volume and the ambient temperature (chap. 11.4).

Examples:

ρ Air density at the BINDER site in Tuttlingen (0.65 km above sea level) at 25 °C = 1.099 kg/m^3

ρ Air density under normal conditions (1013hPa, 20 °C) = 1.205 kg/m^3

ρ Air density at sea level (1013hPa) at 25 °C = 1.184 kg/m^3

Density in kg/m^3 or g/dm^3		Temperature [°C]										
		0	5	10	15	20	25	30	35	40	45	50
Height above sea level [m]	0	1.292	1.269	1.246	1.225	1.204	1.184	1.164	1.145	1.127	1.109	1.092
	100	1.284	1.261	1.239	1.218	1.197	1.177	1.158	1.139	1.121	1.103	1.086
	200	1.276	1.253	1.232	1.210	1.190	1.17	1.151	1.133	1.115	1.098	1.081
	300	1.268	1.246	1.224	1.203	1.183	1.164	1.145	1.126	1.109	1.092	1.075
	400	1.260	1.238	1.217	1.196	1.176	1.157	1.138	1.120	1.103	1.086	1.069
	500	1.252	1.231	1.209	1.189	1.169	1.150	1.132	1.114	1.097	1.08	1.064
	600	1.245	1.223	1.202	1.182	1.163	1.144	1.126	1.108	1.091	1.074	1.058
	700	1.237	1.216	1.195	1.175	1.156	1.137	1.119	1.102	1.085	1.068	1.053
	800	1.229	1.208	1.188	1.168	1.149	1.131	1.113	1.096	1.079	1.063	1.047
	900	1.221	1.201	1.181	1.161	1.142	1.124	1.107	1.09	1.073	1.057	1.041
	1000	1.214	1.193	1.174	1.154	1.136	1.118	1.100	1.084	1.067	1.051	1.036
	1100	1.206	1.186	1.166	1.148	1.129	1.111	1.094	1.078	1.061	1.046	1.031
	1200	1.199	1.179	1.159	1.141	1.123	1.105	1.088	1.072	1.056	1.040	1.025
	1300	1.191	1.172	1.152	1.134	1.116	1.099	1.082	1.066	1.050	1.035	1.020
	1400	1.184	1.164	1.146	1.127	1.110	1.093	1.076	1.060	1.044	1.029	1.014
	1500	1.176	1.157	1.139	1.121	1.103	1.086	1.070	1.054	1.039	1.024	1.009
	1600	1.169	1.150	1.132	1.114	1.097	1.080	1.064	1.048	1.033	1.018	1.004
	1700	1.162	1.143	1.125	1.107	1.090	1.074	1.058	1.042	1.027	1.013	0.998
	1800	1.155	1.136	1.118	1.101	1.084	1.068	1.052	1.037	1.022	1.007	0.993
	1900	1.147	1.129	1.112	1.094	1.078	1.062	1.046	1.031	1.016	1.002	0.988
	2000	1.140	1.122	1.105	1.088	1.072	1.056	1.040	1.025	1.011	0.996	0.983

Table 5: Ambient air density

12. Heat compensation

This chapter applies only to chambers with active refrigeration.

12.1 Definition of heat compensation

Thermal input (heat load) introduced as electrical energy, at which a defined minimal achievable temperature is obtained in the center of the chamber's useable volume. It serves to determine the heat compensation graph.

Maximum thermal input (maximum heat load) introduced as electrical energy, at which the chamber is barely able to equilibrate a defined set-point in the interior using its active refrigeration. It serves to determine the maximum heat load when measured with humidity.

12.2 Heat compensation without humidity

12.2.1 Measurement setup and test instruction

- Set the chamber to its minimum temperature set-point as specified in the product data sheet.
- Introduce a heat load (heating element) in the center of the useable volume. Use a regulating transformer to progressively increase the thermal output.
- Chambers with controlled humidity: Switch off the humidity generation.
- Chambers with controlled gas concentration: Switch off the gas supply.
- Chambers with illumination: Remove the light cassettes.
- With each power stage, read the minimum temperature reached as soon as steady-state condition (definition see chap. 2.2.1) is reached.

12.2.2 Representation of the heat compensation graph

Heat compensation graph relative to the minimum temperature reached, represented in a chart from the lowest setting up to +40 °C:

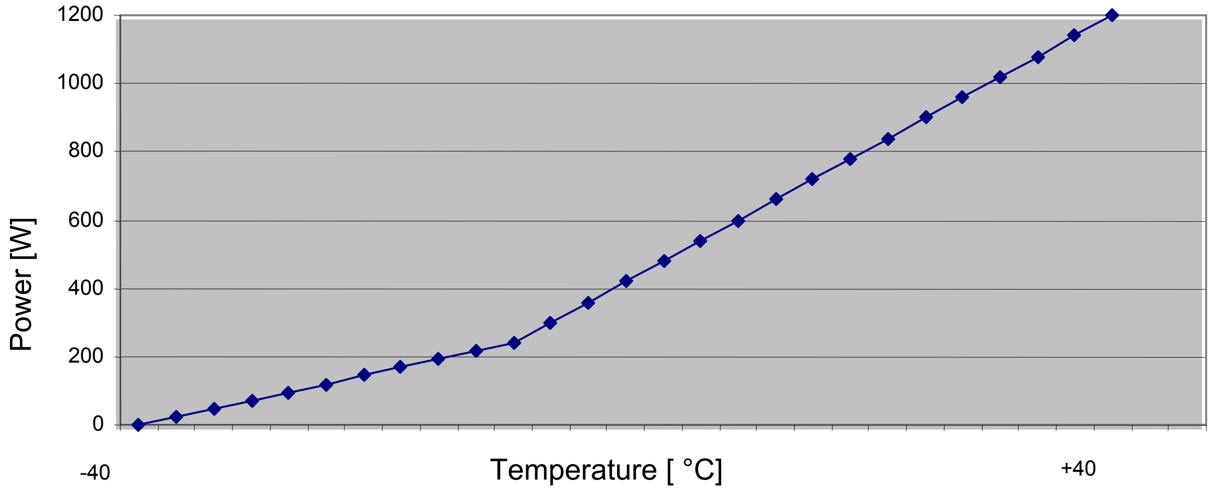


Figure 24: Graphic representation of results (example)

12.2.3 Reading defined heat compensation values

At a defined temperature, the corresponding value of the max. heat compensation [W] is read from the heat compensation graph.

12.3 Heat compensation with humidity

12.3.1 Measurement setup and test instruction

- Set the chamber to defined temperature and humidity set-points
- Introduce a heat load (heating element) in the center of the useable volume. Use a regulating transformer to progressively increase the thermal output
- The power at which the chamber is barely able to equilibrate the entered set-points using its active refrigeration, results in the maximum heat load

12.3.2 Measuring result

Maximum heat compensation (maximum heat load) [W] as a single value related to the selected temperature and humidity set-points

13. Light

This chapter applies only to chambers with illumination (fluorescent tubes). It serves to determine the light intensity, the distribution of light intensity over the projection surface (only with chambers with light cassettes), and the spectral distribution.

13.1 Photometrical and radiometrical measurements

Arrangement of the measuring points with chambers equipped with illumination in the chamber doors

- Determination of the maximum value directly at the surface of the inner glass door.

Arrangement of the measuring points with chambers equipped with light cassettes

- Individual measurement for each light cassette at 25 evenly distributed measuring points
- Distance of 12 cm / *4.7 in* between the center of the spherical radiation sensors and the bottom edge of the fluorescent tubes or the lamp protection glass, if existing
- Distances between the centers of the light sensors placed on the shelf to the shelf edges depending of the chamber size

  The distances from the border of the projection surface are 10% of the length or width of the projection surface. The projection surface is defined as the straight projection of the lower open cassette face onto the shelf.

13.1.1 Sensors

- Measurement with radiometers, which are equipped with spherical sensors, i.e. sensors the spatial sensitivity characteristics of which is to a great extent directionally independent. This serves to include reflections which can form in the inner chamber lined with stainless steel and therefore lead to results which correspond in optimal approximation to the photochemical effect in samples with spatial extension.
- It is possible to use a cosine adapted global radiation sensor (planar sensor) if the LUX cosine adapted – LUX spherical ratio at the respective measuring location is known and the measurement result is corrected accordingly
- Units: LUX (Vλ sensitivity), W/m^2 UVA (only for illumination with a UV proportion), W/m^2 global radiation
- Sensor position relative to the source of light shown as follows

13.1.2 Measuring arrangement according to the type of illumination

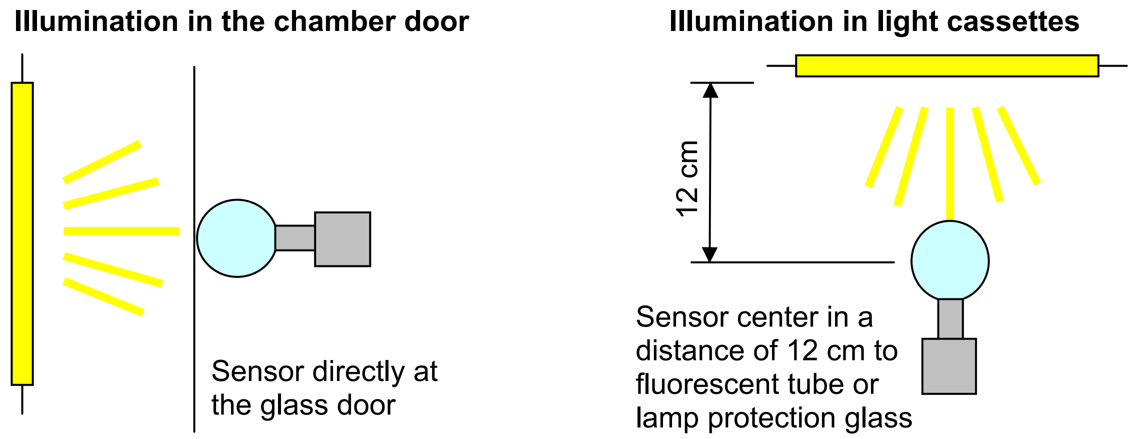


Figure 25: Sensor position relative to the source of light

13.1.3 Results

- Chambers with light cassettes:

  Mean value out of 25 evenly distributed measuring points and percent deviation from the maximum and minimum values in % of the mean value.

  The light qualification result, when referring to the functionality of the illumination, is positive if the mean value of 25 measured values reaches or exceeds a certain lamp-type specific percentage of the light cassette's nominal value given in the product data sheet and if the deviation from the maximum and minimum values is within the range specified in the product data sheet.
- Chambers with illumination in the chamber door:

  Maximum value directly at the surface of the inner glass door.

  Units of results: LUX, W/m² UVA, W/m² global radiation.

  The light qualification result, when referring to the functionality of the illumination, is positive if the obtained maximum value of radiation intensity reaches or exceeds a certain lamp-type specific percentage of the illumination unit's specified nominal value.

13.2 Quantitative measurement of the spectral distribution

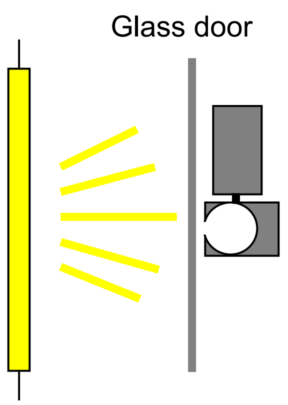
- A spectroradiometer calibrated for intensity with a specified wavelength range of at least 300 nm to 800 nm shall be used. Spectral resolution at least 1 nm.
- Entrance slit shaped as an integrating sphere in order to ensure the independence of direction as with radiometrical measurements (see chap. 13.1) also with the spectral measurement.
- Arrangement of the measuring points with chambers equipped with light cassettes:

  One individual measurement for each light cassette. For each one there shall be an individual measuring point in a distance of 12 cm / *4.7 in* between the entrance slit of the spectroradiometer array and the bottom edge of the fluorescent tubes or the lamp protection glass. The opening of the sensor (of the integrating sphere) shall face upwards.
- Arrangement of the measuring points with chambers equipped with illumination in the chamber doors:

  One individual measurement in the center of useable volume. The opening of the sensor (of the integrating sphere) shall face toward the glass door.

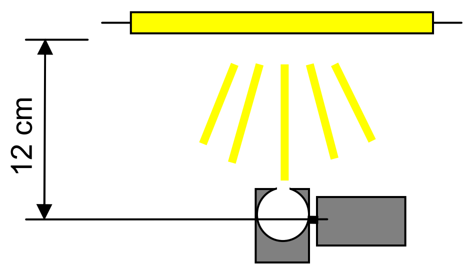
13.2.1 Measuring arrangement according to the type of illumination

Illumination in the chamber door



Spectroradiometer with fitted integrating sphere directly at the glass door at the measuring point of maximum intensity, see chap. 13.1

Illumination in light cassettes



Entrance slit of the spectroradiometer in a distance of 12 cm / *4.7 in* to the fluorescent tube or lamp protection glass

Figure 26: Spectroradiometer position relative to the source of light

13.2.2 Result

Quantitative spectral distribution in W/m² plotted over the wavelengths.

14. Gas consumption CO_2, O_2, and N_2

14.1 Definition

The quantity of gas, which a chamber with controlled gas concentration takes from the connected storage container (e.g., gas cylinder) in order to maintain a defined gas concentration set-point during undisturbed operation or after opening the door in a defined way and with a defined number of repetitions.

14.2 Test instruction

Depending on the chamber equipment with or without O_2 control, consumption measurements of the CO_2-incubator for one or three gas types shall be performed in independent measurement runs, each using the first **and** the second measurement method.

The following two measurement methods for all gas types shall be used in parallel:

First measurement method:

Measurement during one day following equilibration and with permanently closed chamber doors

Second measurement method:

Measurement over at least one day following equilibration and with opening the door 5 times by 90 degrees, each time for 30 seconds and with complete recovery of the gas concentration (100% of the set-points of temperature and gas concentration)

Measuring technique:

Measurement with a thermal flow meter during one day, beginning when the chamber is in equilibrated condition at the upper limit of the defined gas supply pressure (CO_2, O_2, N_2: 2.0 bar)

14.2.1 Measurement result

Unit of gas consumption: grams [g] and norm liters (i.e., gas volume in liters at STP: 0 °C and 1013 hPa) [L] per day.

15. Maximum load per shelf and maximum total load

15.1 Definitions

The **maximum load per shelf** is the permissible mass, which may be applied on the utility surface of the shelf as an evenly distributed area load. The utility surface is smaller than the total shelf surface and results from the definition of the useable volume of the respective chamber (see chap. 2.1).

The **maximum total load** is the permissible mass, which may be introduced into the chamber simultaneously by the total of the introduced loaded shelves

Note: The maximum load per shelf and the maximum total load only refer to the resistance of the shelf and chamber construction to weight caused by the introduced masses, but not to resulting modifications of the chamber performance parameters.

15.2 Maximum load per shelf

15.2.1 Test instruction

The shelves shall be evenly loaded with metal test specimens, taking into account the wall clearances according to the definition of the useable volume. The predictable normal maximum load shall be defined in advance. At least 4 cycles of changing temperatures between the chamber’s minimum and maximum temperature shall be performed to cover different linear expansions in the interior.

15.2.2 Measurement result

Maximum mass in kilogram [kg] per shelf

15.3 Maximum total load

15.3.1 Test instruction

The number of shelves with maximum load (see chap. 15.2) shall be determined, which is supported safely and without permanent deformation due to the construction of the lateral panels of the inner chamber.

15.3.2 Measurement result

Maximum total load in kilogram [kg] resulting from the total of the shelves tested positive.

16. Normative reference

This factory standard was developed based on the following standards:

DIN 12880:2007 „Electrical laboratory devices – Heating ovens and incubators“

ASTM D 5374-93:2005 „Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation”

IEC 60068-3-5:2001 „Environmental testing – Part 3-5: Supporting documentation and guidance – Confirmation of the performance of temperature chambers”