We measure it.

Practical Guide

Comfort level measurement in the workplace

Introduction.

Several hundred million people all over the world work in offices. Many of them are dissatisfied with the climatic conditions that they work in. The most common reasons are complaints about thermal comfort and indoor air quality.

The complaints usually need to be investigated by an air conditioning/ in-house engineer. This person is faced with the challenge of objectively evaluating employees' thermal sensations in order to determine whether the complaints are justified and, where applicable, pinpoint their causes and eliminate them.

From a business perspective alone, it goes without saying that the complaints need to be taken seriously since employee performance directly relates to the ambient conditions in the workplace.

The aim of this practical guide is to offer support to those responsible for indoor climate and to identify ways of objectively evaluating subjective impressions about the level of comfort.

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Contents:

1. What is thermal comfort?

Thermal comfort plays a decisive role in physical and mental capabilities.

The human body's sensitivity to heat essentially depends on the body's thermal equilibrium (thermal balance). This thermal equilibrium is affected by physical activity and clothing as well as ambient atmospheric parameters. These are:

- Air temperature
- Radiation temperature
- Air velocity (draught)
- Humidity

Thermal comfort occurs when a person feels thermally neutral. This happens when someone finds the climatic parameters (temperature, humidity, draught and thermal radiation) in his surroundings pleasant. There is no requirement for warmer or colder, dryer or more humid ambient air. Thermal comfort also depends on the person's type of activity and clothing.

Fig. 1: Thermal comfort depends on various factors.

2. Reasons for using measuring technology for thermal evaluation in the workplace

Thermal comfort in the workplace is not an unnecessary luxury for the employees, it is actually a basic requirement for performance and productivity. Which is why, from an economic perspective, appropriate ambient conditions need to be created.

If an employee complains about feeling uncomfortable at work, this is always an issue that the in-house/air conditioning engineer needs to give high priority to.

The employee's comments about thermal discomfort are converted into an objective measurement result using appropriate measuring technology. In this way, the situation can be optimally evaluated.

If the measurement results are all within the normal range, the in-house or building climate engineer can go ahead and rule out any incorrect configuration of the HVAC system.

Analysis of the employee's thermal discomfort must then be resumed on another level.

There could be other reasons for the complaints, for example dissatisfaction with the work, problems with colleagues, private issues or health complaints can all have an impact on the sensation of thermal comfort.

Advantages of professional measuring technology.

1. Subjective assessments are evaluated objectively.
2. Proof can be provided that the HVAC system is functioning correctly.
3. Measurements are documented and can be analyzed.
4. If you use high-quality measuring technology, the employee making the complaint feels as though he is being taken seriously.

3. Measures taken by the air conditioning engineer in the event of a complaint

3.1 Preparation

If an employee complains about the thermal conditions at his place of work, the first step should be to take this complaint seriously and begin investigating promptly.

Check the HVAC system.
Prior to undertaking a detailed investigation at the place of work, the engineer should examine the HVAC system settings while bearing in mind the following questions: What is the status of the HVAC system's temperature control? Here, check the on-site temperature that is fed back by the room temperature sensors. Or have any changes been made to the HVAC system settings recently?

Initial investigation at the place of work.
Before beginning an evaluation of the comfort criteria at the place of work, you should enquire about the exact nature of the employee's complaint. Is it too cold, too hot, too dry, too stuffy for him or is he exposed to a draught? Are the problems permanent or do they only manifest themselves at certain times of the day?

Conditions on site.
To form an initial impression of the site, pay attention to the following:

- Temperature sensors installed incorrectly in the room (in direct sunlight, covered, near a draught). This would result in incorrect feedback to the HVAC system's central control.
- Blocked/dirty air outlets
- Open windows
- Structural modifications

Fig. 2: Blocked air outlet.

3.2 Measurement of ambient air temperature and humidity

Irrespective of the employee's complaint, it is useful to get some initial information about the climatic conditions by carrying out a simple room temperature/humidity measurement.

Measuring process using the multi-functional measuring instrument testo 480.
Go to the middle of the room with the testo 480. Swing the ambient air humidity probe slightly back and forth at a height of approx. 60 cm (speed approx. 1.5 m/s), until the displayed values have stabilized. Care must be taken that the measurement is not falsified by breath.

Fig. 3: Measuring the ambient air temperature and humidity using the testo 480 climate measuring instrument.

Measurement result/ interpretation.
The measurement result consists of the air temperature in °C and the relative humidity in %. A person in an office generally feels most comfortable at a room temperature of 22 – 24 °C and an ambient air humidity of 40% – 60%.

DIN EN 15251 Category II permits maximum temperatures of 26 °C in cooling mode and 20 °C in heating mode at 25% - 60% humidity.

This measurement is used to obtain some initial information about the indoor climate. If the measured values already strongly deviate from the above-mentioned comfort level range, further evaluations are not needed for the moment. In all probability, this is caused by a HVAC system malfunction.

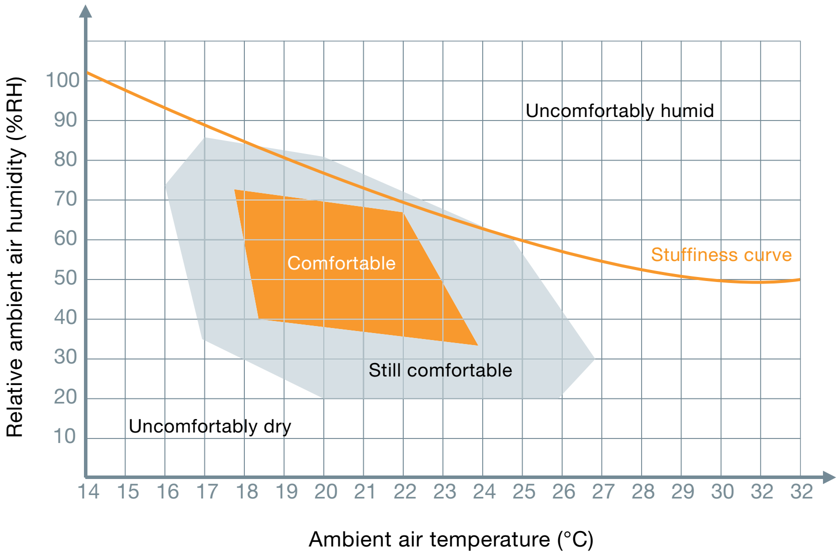

Fig. 4: Graphic presentation of the comfort level with respect to ambient air humidity and ambient air temperature.

3.3 PMV/PPD measurement

The PMV/PPD value provides an integrated examination of thermal factors under the respective working and ambient conditions at the place of work. The measurement result is an objective statement about the level of thermal comfort.

PMV (Predicted Mean Vote).
PMV is a measure of the average thermal sensation of a large group of people.
This value is calculated from the parameters

- Ambient temperature
- Radiation temperature
- Flow
- Relative humidity

and the input values

- Clothing index
- Activity

Clothing index.
Clothing influences a person's heat balance. It constitutes the boundary layer between body and indoor climate and therefore has a direct impact on thermal comfort. Physically, clothing is characterized by its thermal transmission resistance between skin and surrounding environment.

Activity.
The activity level is a measure of a person's energy turnover. A person at complete rest has a basal metabolic rate of M = 0.8 met (met = metabolic rate = metabolic unit, 1 met = 58 W/m^2 body surface).

PPD (Predicted Percentage Dissatisfied).
PPD describes the predicted percentage of people dissatisfied with the indoor climatic conditions. The value is expressed as a percentage and does not fall below 5% dissatisfied people, since it is impossible to specify an ambient climate that will satisfy everyone due to variance between individuals.

Measurement parameters with recommended probes

Measurement parameter	Item no.	Description
(Radiation) temperature	0602 0743	Globe thermometer
Air temperature	0632 1543	0632 IAQ probe (recommended) or temperature/ humidity probe (item no. 0636 9743)
Relative humidity		
Air flow velocity	0628 0143	Comfort probe

Table 1: Measurement parameters with appropriate probes.

Parameters for the PMV/PPD calculation	
Measurement parameter	**Measuring range**
Activity	0.1 … 4.0 met (met = Metabolic Rate, evaluation of the human activity)
Parameter [met]	**Explanation**
0.1 - 0.7	Lying down, relaxed
0.8 - 0.9	Sitting down, relaxed
1.0 - 1.1	Seated activity
1.2 - 1.5	Standing up
1.6 - 1.7	Standing up, light activity
1.8 - 1.9	Standing up, moderate activity
2.0 - 2.3	Slow walking
2.4 - 2.9	Quick walking
3.0 - 3.4	Strenuous activity
3.4 - 4.0	Extremely strenuous activity
Measurement parameter	**Measuring range**
Clothing factor	0.1 … 3.0 clo (clo = Clothing factor, evaluation of clothing)
Parameter [clo]	**Explanation**
0 - 0.02	No clothing
0.03 - 0.29	Underwear
0.30 - 0.49	Shorts and t-shirt
0.50 - 0.79	Trousers and t-shirt
0.80 - 1.29	Light business attire
1.30 - 1.79	Warm business attire
1.80 - 2.29	Jacket or coat
2.30 - 2.79	Warm winter clothing
2.80 - 3.00	Extremely warm winter clothing

Table 2: Parameters for the PMV/PPD calculation.

Measuring process using the testo 480.

1. The testo 480 climate measuring instrument with its relevant probes is set up at the problem workplace. The probes are erected at the employee's working height. (The standard DIN EN ISO 7730 does not specify the measuring height.)
2. Before starting the actual PMV/ PPD measurement, the equalization time of the globe probe must be taken into consideration (approx. 20 - 30 min). Therefore, delay starting the measurement program until a stationary value has been established for the globe temperature.
3. The PMV/PPD measurement program guides the engineer through the measurement step by step. In addition to the clothing index and the activity, the measurement period and the measuring cycle also need to be defined. These latter depend primarily on the respective measuring task or the nature of the complaint.

Fig. 5: A relatively quick measurement is often sufficient to get an outline of the thermal conditions.

Fig. 6: The thermal conditions are apparent straight away, at a glance.

Measuring cycle/measurement period.

If an employee complains about general, permanent discomfort at his workplace, then a quick measurement lasting a few minutes is often sufficient in order to get some idea about the thermal conditions.

However, if the employee is only unhappy with the thermal conditions intermittently, at different times of the day, then it makes sense to carry out a long-term measurement over the entire working day.

Day-dependent control of the HVAC system may result in temporary thermal discomfort. The measuring cycle selected for the long-term measurement should be relatively finely tuned (5 – 30 s), because more data makes it possible to undertake an investigation that is more accurate in terms of timing. With its memory catering for up to 60 million readings, the testo 480 can also document very large volumes of data.

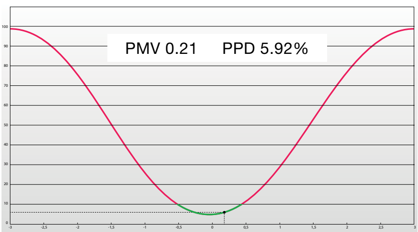

Fig. 7: Extract from the measurement protocol of the testo 480.

Measurement result/ interpretation.

Regardless of whether you are carrying out a relatively short measurement or a long-term measurement over the course of a day, once the measurement program has ended you obtain a PMV/PPD value that is averaged over the respective measurement period. Under certain circumstances, this may be sufficiently informative.

However, you also have the option of carrying out an individual value analysis of the PMV/PPD values in order to filter out values which, in the case of a long-term measurement, are only outside the norm at a certain time. This is very convenient using the supplied testo EasyClimate software.

PMV climate rating scale	
+3	hot
+2	warm
+1	slightly warm
0	neutral
-1	slightly cool
-2	cool
-3	cold

Table 3: PMV climate rating scale.

The measurement result is a value between +3 and -3 and relates to the surrounding environment. A PMV value of -0.5 to +0.5 equates to thermal comfort.
The evaluation can be carried out in graphic or table form. Figure 7 shows the measurement result as a graphic, where a PMV value of 0.21 and a PPD value of 5.92% is shown as a blue dot on the green line. All values on the green line correspond to thermal comfort Category B according to DIN EN ISO 7730.

If the PMV value is outside the ±0.5 limit, a cause analysis must be carried out. As a first step, the measurement results of the individual parameters globe temperature, room temperature, humidity and flow velocity should be examined more closely (see Table 4). If, for example, you detect a significant temperature difference between the room and globe temperature, the cause could be high solar radiation through the window.

Depending on which individual parameters deviate from the norm, causes could be defective components, an incorrect HVAC system setting or the ambient conditions on site (e.g. air outlets, windows, structural modifications).

Room type	Activity in met	Clothing factor in clo		Category	Operative (globe) temperature in °C		Max. average air velocity in m/s	
		Summer	Winter		Summer	Winter	Summer	Winter
Single office Office environment Conference room Auditorium Cafeteria / restaurant Classroom	1.2	0.5	1.0	B	24.5 ± 1.5	22.0 ± 2.0	0.19	0.16
The maximum average air velocity is based on turbulence of 40% and an air temperature that is equal to the globe temperature. For summer and winter, a relative humidity of 60% or 40% respectively is used. To determine the maximum average air velocity, the lower temperature of the range is selected both in summer and in winter.								

Table 4: Extract from DIN EN ISO 7730.

3.4 Measurement of turbulence and draught

In addition to the PMV/PPD measurement, there are other measurement methods for objectively evaluating employee complaints. For example, if an employee complains specifically about draughts, then a turbulence or draught risk measurement should always be carried out.

Definition of measurement parameters.
The measurement is a non-directional recording of air velocities using the comfort probe. The comfort probe from Testo complies with the technical requirements of DIN 1946 Part 2/EN 13779.

Turbulence.
Turbulence describes the uniformity or non-uniformity of the air flow velocity and is necessary for calculating the draught risk. To calculate turbulence, the standard deviation (Sv) of the determined air velocity value must be measured.

$$T_u = \frac{S_v}{\bar{v}} * 100 \ [\%]$$

S_v = standard deviation of the instantaneous values of the air velocity
= average air velocity

Fig. 8: First draught measurement at a height of 0.1 m on the ground.

Fig. 9: Second draught measurement at table height (0.6 m).

Fig. 10: Third draught measurement above the desk at a height of 1.1 m.

Draught.

The draught rate constitutes the predicted percentage of dissatisfied room users due to the air velocity being too high. The calculation includes the ambient air temperature (ta), the average air velocity (v) and the turbulence (Tu).

$$DR = (34 - ta)(v - 0{,}05)^{0{,}62}\,(0{,}37 \times v \times Tu + 3{,}14)\ [\%]$$

DR = draught rate
ta = local air temperature [°C]
v = local average air velocity [m/s]
Tu = local turbulence [%]
(calculated variable)

Measurement.

The following requirements must be met for the measurement:

- Fast, massless thermal flow sensor (comfort probe)
- Three measuring heights depending on the activity
  Standing activity:
  0.1 m/1.10 m/1.70 m
  Seated activity:
  0.1 m/0.6 m/1.10 m
- Measurement period: 180 seconds per measuring height (recommended)
- Measuring cycle: 1 second

Measurement result/ interpretation.

With the testo 480, you get the following measurement protocol:

Fig. 11: Measurement protocol extract.

Here the measured average flow velocity, the average temperature and also the turbulence and draught rate calculated from these can be viewed. In the example we have a draught rate of 7%.

A maximum permissible draught rate according to DIN EN ISO 7730 – Category B corresponds to DR = 20%. Therefore a draught rate of DIN EN ISO 7730 – Category B can be assigned to this measuring location.

3.5 Other criteria for evaluating the comfort level

Vertical air temperature difference.
A high vertical air temperature difference in the area between the head and ankle can result in discomfort.

Measurement.
When checking the vertical air temperature difference, a spot measurement of the differential temperature between head (1.10 m) and ankle height (0.10 m) of a seated person is sufficient.

Measurement result/ interpretation.
In order to comply with the comfort criteria as per DIN ISO 7730-Category B, the temperature difference should be smaller than 3 K.

Warm and cold floors.
If the floor is too warm or too cold, the people in the room may feel uncomfortable due to the sensation of heat in their feet. For those wearing light indoor shoes, it's not the flooring material that is the decisive factor with regard to the comfort level, but rather the floor temperature.

Measurement.
The floor temperature can be determined using the testo 480 and a surface probe (cross-band head probe) or even quicker using an infrared measuring instrument.

Fig. 12: Measurement at floor level.

Measurement result/ interpretation.
According to DIN EN ISO 7730, the temperature of the floor must be between 19 and 29 °C.

3.6 Evaluating the indoor air quality

In addition to the thermal comfort, maintaining the indoor air quality is an important factor when it comes to comfort level. The carbon dioxide concentration (CO_2) is a key indicator of "good" indoor air quality. "Poor" air quality resulting from excessive CO_2 concentration results in tiredness, lack of concentration and can even make someone ill.

Fig. 13: Measuring indoor air quality using the testo 480.

Measurement.

Position the multi-functional measuring instrument testo 480 in the centre of the room, as described in the room temperature/humidity measurement, and hold the probe outside its own "atmosphere" (height 0.6 m).
Depending on the complaint, an initial statement can be made after just a short equalization time of the CO_2 probe (approx. 30 – 60 s).
For the CO_2 measurement, it usually makes sense to carry out a long-term measurement over a working day. Subsequently, you can use an evaluation via software to analyze at what time of the day high concentrations are reached and whether the air conditioning system is providing an appropriate air exchange rate. From the CO_2 concentration, conclusions can also be drawn about the room user's ventilation habits.

Measurement result/ interpretation.

Table 5 lists the permitted benchmark figures for the CO_2 concentration.
In practice, the CO_2 concentration in the workplace should not exceed 1000 ppm (according to Pettenkofer). To achieve appropriate indoor air quality, an air exchange rate of at least 50 m^3/h per room user should be observed.

CO_2 concentration – benchmark figures		
CO_2 Vol%	**CO_2 ppm**	**Description**
0.033 … 0.04	330 … 400	Fresh air out in the countryside
0.07	700	Urban air
0.1	1,000	Limit value in offices, maximum value according to Pettenkofer
0.5	5,000	MAC value
0.7	7,000	Maximum value in cinemas after the showing
2	20,000	Short-term physiological tolerance value
2 … 4	20,000 … 40,000	Heavier breathing, increased pulse rate
4 … 5.2	40,000 … 52,000	Exhaled air
4 … 8	40,000 … 80,000	Headaches, dizziness
8 … 10	80,000 … 100,000	Convulsions, rapid loss of consciousness, a burning candle goes out
20	200,000	Fatal in a few seconds

Table 5: Benchmark figures for CO_2 concentration.

The curve shows the percentage of those persons who are unhappy with the indoor air quality at a particular CO_2 concentration.

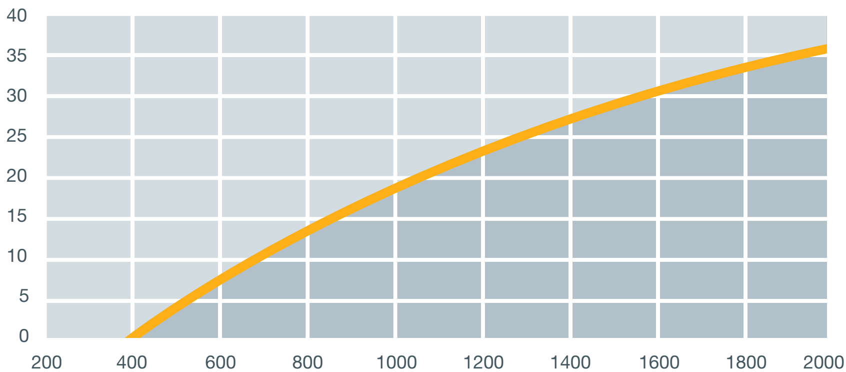

Fig. 14: Percentage of dissatisfied people at a particular CO_2 concentration.

4. What makes a measuring instrument ideal for evaluating the comfort level of workplaces?

In the field of climate measurement, there are various manufacturers of temperature and climate measuring instruments. Yet comfort level measurement in workplaces is more than "just" an on-site temperature or humidity measurement.
So, in addition to the normal selection criteria, you should primarily concentrate on the following selection factors before purchasing a climate measuring instrument:

1. Which measurement parameters can be recorded?
2. Can I use the measuring instrument to carry out measurements in compliance with the standards? What assistance will I be given with this?
3. Can long-term measurements (storage capability, battery life, mains unit) be carried out without a problem?
4. Is there any software for analyzing my measurements?
5. How can I document my measurements?

Fig. 15: Multi-functional measuring instrument testo 480.

The solution: the multi-functional measuring instrument testo 480.

1. Which measurement parameters can be recorded?

testo 480 records all climate-related parameters:

- Air temperature
- Globe temperature
- Surface temperature
- Humidity
- Flow (turbulence, draught)
- CO_2
- Pressure
- Illuminance
- Parameters calculated in addition, such as dew point, differential temperature, etc.

The testo 480 can be custom-equipped with probes depending on the measuring task.

Fig. 16: testo 480 can be equipped with many probes.

2. Can I use the measuring instrument to carry out measurements in compliance with the standards? What assistance will I be given with this?

Particularly in the field of comfort level measurement, the testo 480 offers the user very convenient assistance with integrated measurement programs that provide step-by-step guidance through the measurement. Use the PMV/PPD measurement program to obtain a clear and objective measurement result in accordance with DIN EN ISO 7730.
The turbulence measurement as per EN 13779 for calculating the draught risk can also be performed intuitively.

3. Can long-term measurements be carried out without a problem?

testo 480 is ideal for long-term measurements. Not only does it feature a very large internal memory which can record 60 million readings, measurements can also be carried out over longer periods of time using the powerful Li-ion rechargeable battery or the supplied mains unit.

Fig. 17: Measurement analysis software.

4. Is there any software for analyzing my measurements?

The measurement results can be transferred directly to a PC via a USB cable, and presented and analyzed extremely easily using the testo EasyClimate software provided. The software is helpful for filtering and evaluating the measurement data, particularly when carrying out long-term measurements.

5. How can I document my measurements?

The measurement results are transmitted to a PC via USB or SD card and then transferred to a final measurement report in just a few clicks. Customize these using the report designer provided. If necessary, the measurement results can also be printed out directly on site using the fast printer, which is optionally available.

Fig. 18: Software extract.

5. Further training

Standard operation of a climate measuring instrument should not present any major problems for an air conditioning/in-house engineer. Confusion tends to arise when it comes to the following:

- How do I measure correctly?
- What is prescribed by the standards?
- What are the main reasons for incorrect measurements?
- How should I interpret my measurement results correctly?
- What conclusions can I draw from a measurement?

These and other questions can be answered in special seminars held at the Testo Academy.

With respect to comfort level measurement, we particularly recommend the 2-day climate seminar “Practice-based measuring technology on HVAC systems”, at the end of which you will receive a certificate from the Deutsche Fachverband für Luft- und Wasserhygiene [German Professional Association for Air and Water Hygiene].

Fig. 19: Climate seminar at the Testo Academy.

The key topics are:

- Measurement parameters temperature, humidity, flow, pressure and CO_2 in rooms
- Indoor air quality, comfort level, turbulence
- Pitot tube, vane and hot-wire measurement
- Lux and sound measurement
- Measuring point planning at air ducts
- Volume flow measurement with error calculation according to DIN
- Immersion, surface, infrared and globe temperature measurement
- Inlet and exhaust apertures with practical measurements
- Comfort level measurement in the workplace
- Practical measurement at air ducts.

For more information on the Testo Academy seminars go to: www.testo.de/akademie

6. Conclusion

With an increasing number of fully air-conditioned workplaces in new buildings or buildings renovated to make them more energy-efficient, employee complaints about thermal discomfort at work are also on the increase.

Without the appropriate measuring technology, it is virtually impossible for air conditioning/in-house engineers to detect the difference between personal discomfort and real, negative effects on the indoor climate. However, this is absolutely necessary in order to eliminate any negative impacts from the HVAC system on a regulatory basis. Simple and economical implementation of the measurement procedure far outweighs the risks, which poorly or incorrectly configured ventilation and air conditioning technology in buildings can cause.

With the testo 480 climate measuring instrument and its extensive range of probes, managers can record, analyze and document all the key parameters quickly and efficiently so that they can take the appropriate corrective measures.

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