Thermal indoor climate evaluated on the basis of a snapshot

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ABSTRACT
Evaluating thermal indoor climate without knowing the conditions is a long and often barren process and documented data is actually not that hard to obtain. A 'snapshot' of the thermal indoor climate in an office building with room for approximately 80 work-places can be taken in only 3 days: 2 days used for measuring and 1 day for reporting. The measuring procedure that is developed for taking a snapshot is based on ISO 7730. The problem of using the ISO 7730 is that it only describes the thermal assessment of one single work-place and we want to use it for evaluation of an entire building section. The paper first describes the organizing of the measuring sequence with registration of data for each work-place, then, the method developed for evaluating the measurements and, finally, the results of a measurement performed in a building section with 85 work-places are presented.

INDEX TERMS
Thermal Comfort; ISO 7730; Field measurement; Office building; Low time consumption

INTRODUCTION

Poor thermal comfort is not the only indoor climate problem, but it is the problem that most complaints are about. If the indoor climate is already on the agenda or if preventing indoor climate problems is part of company policy, then a snapshot of the thermal environment might be very helpful. A snapshot gives a factual basis for discussions, a common foundation that can quickly bring the discussion to an assessment of whether or not the thermal indoor climate is acceptable.

Figure 1 Thermal measurement station at work.

THE METHOD

The starting point for an assessment of the indoor climate is the international standard ISO 7730 (ISO 7730 1994).

The complaints that traditionally are most numerous are: 'It's too cold in the room', 'It's too hot in the room' and 'It's draughty'. For this reason we decided to formulate the investigation so the risk of these three types of complaints can be assessed. According to ISO 7730, the parameters we needed to measure were PMV, PPD and DR.

The subsequent analysis of the measurement results is completely statistical and the measurement process is, therefore, formed so we get a large number of independent measurements. We chose to measure once at every work-place in the part of the building under investigation. Similarly, during the measurement process we proceeded alphabetically from the office's telephone directory to remove possible systematic errors that can occur if one proceeds room by room. The process was:

1. The people who use the work-places to be measured were informed by e-mail a couple of days before the measurement.
2. At the start of the measurement, the person at the work-place completed a questionnaire and then moved away.
3. The chair at the work-place was removed and the measurement station was set up instead; see Figure 1.
4. The position of the work-place was keyed into the measurement set-up and measurement started.
5. Measurement was completed after 5 min and the measuring equipment was moved to the next work-place on the list.

MEASUREMENT SET-UP

The measurement set-up can be seen in action in Figure 1 and in more detail in Figure 2. All of the measuring units are mounted on a stand on wheels and the whole measurement station is thus easy to transport from one place of measurement to another.

The measurement set-up is arranged so that it can measure PMV/PPD and draughts at the ankles and neck simultaneously. There are three omni-directional air velocity sensors, an operative temperature sensor, a humidity sensor and a battery mounted on the stand. All of the measuring units have their own memory for storing the measurement data. The units are connected internally so they can share the battery and enable the operator to communicate with the whole set-up at one time.

Figure 2 Thermal measurement station seen from above. Air velocity is measured at heights of 0.1 and 1.1 m, and operative temperature, air velocity and humidity are measured at 0.6 m above the floor.

The measurement is set up using a PDA. The measurement itself is defined in a template, so the operator only needs to key in the identity of the measurement position and then press the start button at each measurement position. Measurement data are stored in the units as measurement proceeds and are then transferred to a PC a couple of times a day. The PDA used to start the measurement also helps during the measurement process in that it indicates when each measurement ends.

QUESTIONNAIRE

A simple questionnaire was issued at every work-place; see Figure 3. If the person was not at the work-place, the measurement operator filled in the employee's name and the last two lines of the questionnaire. The questionnaire is deliberately formed so it is both easy to complete and easy to process afterwards.

STARTING THE MEASUREMENT

- Clothing
- Level of activity
- Time of measurement

These three parameters must be determined before measurement begins.

Please complete this form and return it to dept 420.
Thank you.

If you have just arrived back at your work-place, please wait half an hour before completing the form.

Employee's name: ______________________________

When completed: date: _________ time: ____________

How is your work-place right now?

(only one cross, please)
[ ] Cold
[ ] Cool
[ ] Slightly cool
[ ] Neutral
[ ] Slightly warm
[ ] Warm
[ ] Hot

Is your comfort reduced right now because of draughts?
[ ] Yes [ ] No

Did the sun shine on your work-place during measurement?
[ ] Yes [ ] No

Were you at your work-place when measurement started?
[ ] Yes [ ] No

Figure 3 The questionnaire used.

All PMV measurements are carried out using the same setting for clothing—we chose a winter level of 0.85 clo. This closely resembles the average for the place of work and is a level everyone can adapt to. By choosing a uniform level of clothing it is easier for us to compare the thermal indoor climate at different work-places, but we lose the ability to compare measurements with the vote from work-place to work-place. From actual measurements we have concluded that the method described here is the only practical possibility, as one must expect that about 50% of the work-places where measurements are made are empty when measurement starts. Values for individual levels of clothing cannot be determined in these cases.

Similarly, PMV measurements are performed with a uniform level of activity for the same reason. The level of activity is set to 1.3 met. This value is perhaps a little low considering that only 47% of staff was at their work-places when measurement started. An investigation carried out by Tatsuo Nobe and others (Nobe, 2002) indicates even lower occupation times at own work-place. Occupation times of 33–50% of the working day at own work-place were measured during that investigation.

The time when measurements are made should be chosen carefully, so the results tell us something about the capability of the thermal regulation system. There should, therefore, be a certain external load on the building in the form of cold or heat in addition to a normal internal heat load. The criteria should be set beforehand and the start of the measurements delayed until the criteria are met. The criteria for performing the present measurements were an external temperature below 0°C and normal internal heat load.

PROCESSING DATA

Data from the measurements and questionnaire were keyed into a pre-programmed spreadsheet that produced a result table as shown in Annex 1. Data processing is almost exclusively calculations of statistical values and distribution diagrams. Only processing of the measured PMV values was slightly different.

The assessment of the thermal indoor climate should cover a complete section of the building with many work-places, but the term PMV/PPD is only formed to assess a single work-place. If we simply average the measured PMVs and PPDs then we lose some information, so a starting point is taken in the distribution of the votes lying behind the calculation of both PMV and PPD.

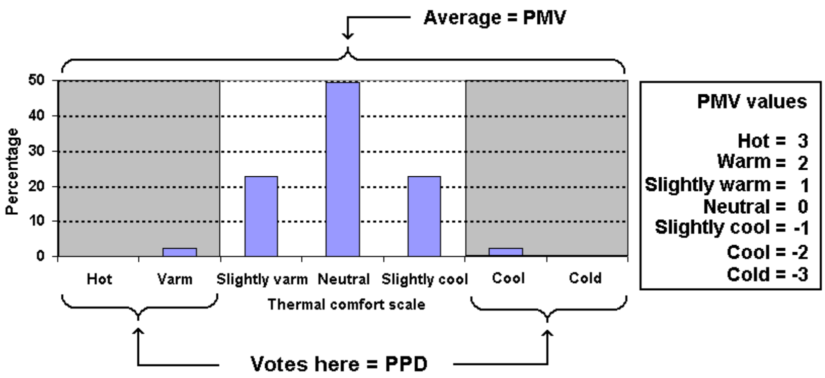

Figure 4 Statistical distribution of votes at PMV = 0. The number of dissatisfied (PPD) is defined as the percentage of votes falling into the scale values ‘hot’, ‘warm’, ‘cool’ and ‘cold’. Here PPD = 5%. This distribution is from Fanger (Fanger, 1970).

Differences between people mean that they do not all vote the same. The votes that, for example, give PMV = 0 are distributed statistically as in Figure 4. Fanger (Fanger, 1970) has shown that the votes have a normal distribution with a standard deviation of 0.75 of a vote step. We use this knowledge to calculate the predicted distribution of votes for the whole section of the building.

RESULTS

From the processed measurement results given in Annex 1 it can generally be concluded that the thermal indoor climate in the building measured is good. The estimated number of dissatisfied people (PPD) is 6%, which is a good figure, and draughts are not a general problem. Complaints about draughts can, however, be expected from some work-places, and they might be quite justified.

A detailed look at the results provides the following information:

- The temperature in parts of the building (rooms 6, 7, 9 and 10) should be lowered.
- There are problems with draughts at about 10% of the work-places (DR > 20%).
- The level of thermal comfort throughout the day is reasonably constant.
- The employees experience the thermal indoor climate as rather worse than the measurements show it to be.

DIFFERENCES BETWEEN MEASUREMENT AND QUESTIONNAIRE

When the distribution of the comfort votes from the measurement and the questionnaire are compared (see Annex 1), the distribution from the questionnaire is clearly the broadest. There can be several reasons for this.

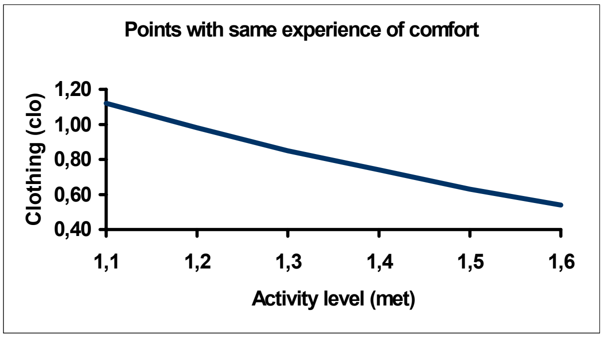

Figure 5 Set of (clo, met) values that result in the same PMV values.

During the measurements we assumed that everyone in the building section had the same level of activity and clothing. We know that this is not the case, but we supposed that the people would adapt their clothing to their level of activity. Figure 5 shows graphically which related met and clo values result in the same experience of comfort as the values used in the measurement—0.85 clo and 1.3 met. If the people working in the building did not want to adapt their level of clothing to the activity or did not have the opportunity to do so, the estimated percentage of dissatisfied from the measurement would be too low.

Another phenomenon that has arisen in a number of field measurements is differences in expectations and preferences, see, e.g. de Dear (2002). If we enter a fully air-conditioned building, our expectations to the thermal indoor climate are different to those in a naturally ventilated building. What we assess as ‘warm’ in a fully air-conditioned building we assess perhaps as only ‘slightly warm’ in a naturally ventilated building. That we apparently vote differently from situation to situation means that there is always quite a large degree of uncertainty connected with the results of questionnaires.

DISCUSSION

The thermal comfort level at all 85 work-places in a section of a building was measured. The conclusion was 'a good thermal indoor climate with a few faults'. The work involved 3.5 man-days during working hours and a limited amount of measurement equipment. The question is: 'What was the benefit?'

If there are no known problems with the thermal indoor climate in the section of the building, and if a measurement period with a reasonable load is chosen, then the measurements give a good picture of the performance of the heating and ventilation system. Other types of assessment and print out from HVAC Control Systems cannot provide an assessment of equal quality.

A good picture of the thermal indoor climate of the section of the building can be obtained if the present winter measurement is supplemented by a similar summer measurement under high heat load from the sun. If thermal indoor climate problems under special climatic or load conditions are suspected, supplementary measurements when these occur would be sensible.

REFERENCES

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ANNEX 1: RESULTS TABLE FROM THE MEASUREMENT

Indoor climate

Place of measurement: Dantec Dynamics, Tonsbakken 16-18, Skovlunde, Denmark

Outside climate

Date	Air temperature	Air speed	Direction	Sun
13/12	-2	3 m/s	Northeast	No
16/12	-1	3 m/s	East	No
17/12	-1	3 m/s	East	Some

Measurement carried out by
Bjørn Clausen and Bjørn Kvisgaard
Dantec Dynamics, Indoor Climate group
12-18 December 2002

Comfort:

General thermal comfort	Min	Mean	Max
PMV value from measurements	-0.35	0.23	0.61
Voting from questionnaire	-3.00	0.52	3.00
PPD from questionnaire		32	
PPD from measurement		6	

Data file:
File: DMS-21587 on Dantec Dynamics' net

Local thermal comfort	Mean	Max
Percentage dissatisfied with draught measured as DR	7	29
Percentage dissatisfied with draught (questionnaire)	18	
Percentage dissatisfied with temperature gradient	0	

clo value used when measuring PMV / PPD	0.85
met value used when measuring PMV / PPD	1.3