VENTILATION OF SLEEPING ROOMS EXAMINED WITH FLAMES WHICH SIMULATE HUMAN CARBON DIOXIDE EMISSION AND HEAT DISSIPATION

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Principle and Applications of this Method

The concentration of carbon dioxide in e.g. a sleeping room is known to be a suitable hygienic index of the performance of the ventilation. But if humans shall be replaced by any other suitable source of tracer gas, it is necessary to take properly account of the effect of body heat too. This heat will break up thermal stratifications inside an enclosure and by increasing the inside-outside temperature difference it will also provide a stable and the most reliable force for a natural ventilation. Ventilation due to the wind must be kept at a minimum in cold environments, just sufficient to ensure the ventilation and drying-up of an enclosure not in use. Such is the situation in e.g. caravans or in pleasure boat cabins and also in snow shelters in the mountains. Under such conditions freezing people are susceptible to tighten up sources of inrushing cold air.

When in the late 60-ies the increasing rate of asphyxiations in caravans and in similar accomodations alarmed the Swedish authorities, the test method with so-called person-equivalent flames was developped. The resulting carbon dioxide concentration during the test was measured. Further of course, regulations had to be enforced against the common sources of carbon monoxide from the applyances. (1, 2).

Standardized bottle gas burners were found to be the most suitable gas sources. They are easily handled and they are acceptable and understandable for everybody, much more than other possible methods or the use of exotic tracer gases. But that the heat production was very instrumental too, we found when physically examining the ventilation of a well-insulated caravan. But it is not necessary to simulate exactly humans by burners, if only ratios are known and the carbon dioxide concentration is sufficiently above any background.

The use of bottle gas burners was extended to ordinary buildings also. Here of course, the source strength has to be related to the volume of the room and not to the maximum number of persons possibly present. Finally, for the conditions where bottle gas equipment by itself was less convenient, and for the benefit of amateurs, candles were also examined and standardized for the purpose. Carbon dioxide can everywhere easily be measured, e.g. by means of cheap pocket gas analyzers, which everybody can handle.

The examination of caravans and of pleasure boat cabins

For every bedplace a flame is ligthened as is specified in Table 1. It is placed either on the bed or on the floor nearby in a flameproof way. In

FIG. 1. EXAMINATION OF BOATS

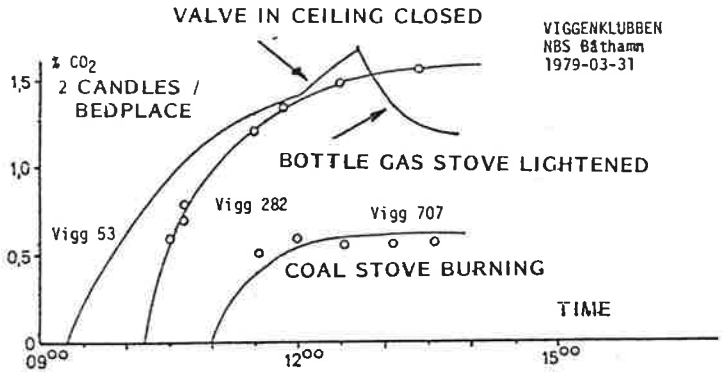
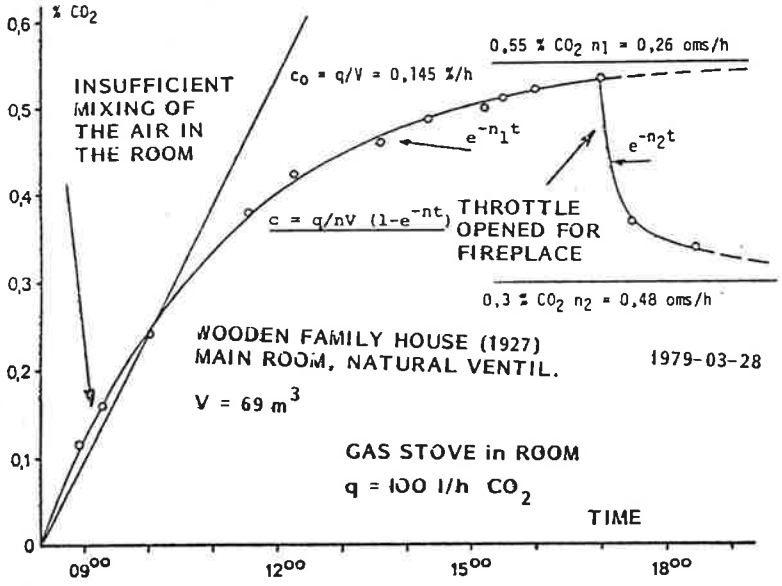


FIG. 2. EXAMINATION OF A ROOM



an official test, the authority will consider the ventilation to be satisfactory if the resulting carbon dioxide concentration does not rise above 1.0 %. But what actually would be experienced by people sleeping here, is indicated in the last row of the table. This final test was actually made in a pleasure boat on land during its hibernation and at about 0°C, with two men sleeping on board.

Mostly, some additional heating is provided e.g. in an occupied caravan. Then, the ventilation increases and the carbon dioxide concentration may drop to say 0.5 %, which is by the way the occupational limit. There will be no serious inconveniences for healthy people up to at least 1 %. However, a foreign government has stated a lower test value of only 0.5 % for caravans in their own country.

If gas lamps are installed in a caravan, they are required to be "on" during such a test. This demand has discouraged their installment! But as far as candles are concerned for occasional use by the occupants, one candle is approximately equivalent to one person. Further, candles have always under extreme conditions, in caves, snow shelters and so on, served as a convenient indicator of possible lack of oxygen. This is explained below.

Figure 1 reports from an examination of the cabins of an identical group of pleasure boats. The influence of stoves which do not change by themselves the quality of the air, is visible here. These boats were ashore.

Table 1. Standardized flames and man.

	Consumption	Heat	+ CO_2	+ H_2O	- O_2	Relative CO_2 - concentrations
Bottle gas	10 l/h	260 W	30 l/h	29 g/h	48 l/h	100, nominal!
2 Candles	20 g/h	210	28	23	40	93 - 95
Man at rest		115	20	40	25	70 - 90

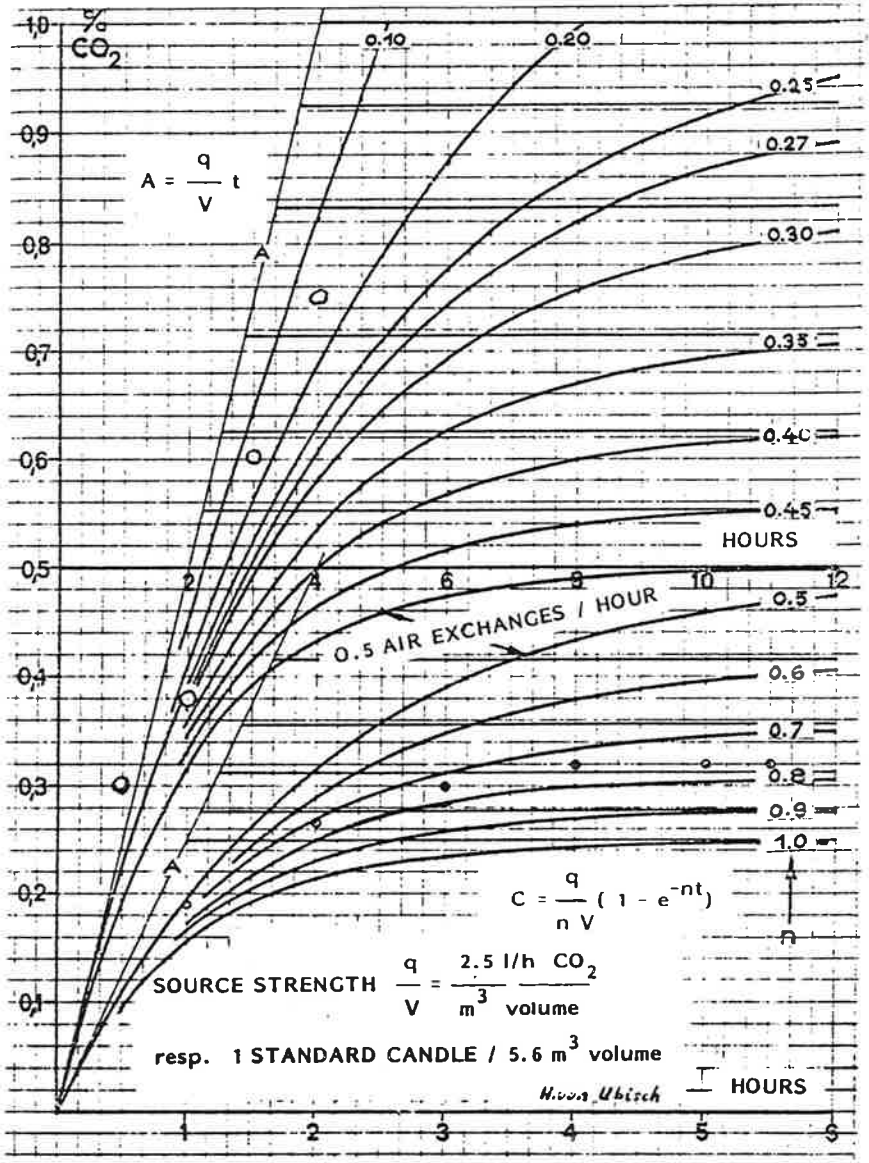
Remarks to table:
Bottle gas: Propane-propene at normal pressure, testing temperature 10-25°C
Candles: Pure stearine, as "Liljeholmens vita kronljus". The consumption varies between -30° and +35°C by 7 % only. The flames will dwindle by about 10 % around 1 % CO_2. They extinguish later.
Man: Nominal values from textbook.

Houses examined

The figure of interest is here the number of air exchanges per hour, to be calculated from the dilution of the tracer gas. Figure 2 gives an example from such a measurement and the calculation. Here, an ordinary mobile stove with a gas meter in the supply line stood on the floor. Air was collected up under the ceiling by means of a small pump and led to an infrared gas analyzer. The operator remained in the room, watching the equipments.

Two things are apparent from Figure 2: If a proper exponential rise of the concentration curve is really demanded, an e.g electric fan should

FIG. 3. NOMOGRAM FOR THE MEASUREMENT OF AIR EXCHANGES WITH A CALIBRATED SOURCE FOR CARBON DIOXIDE



break up possible stratifications, if the air is not taken from an air exit such as in Figure 1. Second, the change of a parameter during the test, such as here the opening of a throttle, is easily observed and can be evaluated too.

The whole procedure of measurement and of evaluation can be considerably speeded up and facilitated by standardizing the source strength for the volumes in question and by using a nomogram such as that shown in Figure 3. The measurements inserted into the grid in the figure, which run towards 0.15 and 0.75 air exchanges per hour, have actually been performed by two quite young teenagers who examined their own room when doing their school work. He who measured 0.15 followed the given instruction and terminated the experiment, when conditions grew worse! Their candles stood on metal dishes on the floor and the boy himself replaced just one candle. Carbon dioxide was measured by means of a pocket gas analyzer.

The risks

Candles and bottle gas equipments constitute familiar fire risks. Special care should be taken however, not to place large groups of burning candles too close together, lets say keep a minimum of 5 inches apart! Otherwise they may stimulate each other, in the worst case into a fire storm. As far as oxygen consumption is concerned however, candles constitute no risks to an observer, because they extinguish eventually around 2-3 %. This is by the way the emergency shelter limit, which is quite easily tolerated by healthy people. There is no risk from carbon monoxide from candles only.

Bottle gas burners are more dangerous, dependently on their type and their special use. Any oxygen depletion, expressed here as a related carbon dioxide concentration, interfers with the combustion and a very severe carbon monoxide risk may sometimes develop. However, an approved burner properly used, is anyway safe up to about 1 % CO_2, but it may became really dangerous beyond say 3 %. Eventually the flame extinguishes and escaping gas now confined to the room may later constitute a very explosion risk!

Both these risks can be avoided by means of atmospheric guards, small flames sometimes installed in e.g.. caravans, which extinguish around 1 % CO_2, whereafter they thermomechanically throttle the gas line.

References

(1) Ubisch, H.von . The examination of the ventilation of caravans. Nordisk Hygienisk Tidskrift 1972 nr 35, 21-25.

(2) Ubisch, H.von . Lufthygienen i fritidslivet. Forebyggende Medicin, Editor Ø.Larsen, Universitetsforlaget i Oslo 1975, 137--144. (Festskrift til prof. H.Natvig)

SUMMARY

H.von Ubisch: Ventilation of sleeping rooms examined with flames which simulate human carbon dioxide emission and heat dissipation. The measurement of carbon dioxide concentrations is practical from the hygienic point of view. Especially it is so in cold climates in caravans, in pleasure boat cabins and in other occasionally used enclosures where ventilation is kept at a minimum and should be maintained by at least human heat dissipation as its driving force. Wind forces do behave much too erratic. A table compares humans with standardized bottle gas burners and also with candles. In a test, the suitable limit for carbon dioxide is set at 1.0 %, or perhaps better at 0.5 %. If on the other hand the number of air exchanges per hour is asked for as in ordinary buildings, a nomogram is presented for a specified source strength. This facilitates and speeds up the whole procedure. The use of candles can be recommended to amateurs.

The possible risks are also discussed.

RESUME

H.von Ubisch: Ventilation des chambres à coucher examinée à l'aide des flammes imitant l'émission du bioxyde de carbone humain et la dissipation de la chaleur. La détermination de la concentration du bioxyde de carbone est très importante du point de vue hygiénique, en particulier dans les climates froids, dans les caravanes, les bateaux de plaisance et autres espaces fermés où la ventilation est réduite au minimum et où, pour des raisons évidentes, la chaleur du corps humain peut-être la force principale de ventilation. Ici, il faut réduire la force du vent au minimum. Un tableau compare de ce point de vue le corps humain avec les brûleurs pour bouteilles à gaz standardisés et les chandelles utilisées. Dans le test la limite maximale acceptable pour la concentration du bioxyde de carbon a été fixée à 1.0 %, ou mieux à 0.5 %. Si, d'autre part, on veut connaître le nombre d'échanges d'air par heure dans un immeuble ordinaire, un nomogramme pour une source spécifiée pour la volume accélera et facilitera l'évaluation. - Les chandelles peuvent être utilisées même par des amateurs.

Les risques possibles sont discutés aussi.

KURZFASSUNG

H.von Ubisch: Durchlüftung von Schlafräumen geprüft mit Flammen welche so wie Menschen Kohlendioxyd und Wärme abgeben. Die sich einstellende Konzentration ist natürlich ein gutes hygienisches Maass. Ganz besonders so in einem kalten Klima in Hauswagen, Freizeitbooten oder in anderen mehr zufälligen Übernachtungsräumen wo die Durchlüftung beschränkt wird und wo eine natürliche, durch Körperwärme angetriebene, das Gegebene ist. Eine windgetriebene ist ja zu sehr unzuverlässig. In der Tabelle werden Menschen mit genormter Flaschengasflamme und mit Kerzen verglichen. Bei einer Messung wird dann das zweckmässige Maximum für Kohlendioxyd zu 1,0 % gesetzt, oder vielleicht besser zu 0,5 %. Falls jedoch in einem Gebäude der Luftumsatz pro Stunde erfragt wird, lassen sich diese bequemen Spurengasquellen normieren und mit Hilfe eines Nomogrammes wird Messung und Auswertung beschleunigt. Kerzen sind hier für Amateure zu empfehlen..

Gefahrenmomente werden auch beschrieben.