The Fanger factor

If a proposed European standard on indoor air quality gets the green light, architects and engineers could face the biggest upheaval in design practice since the invention of air conditioning. Dogged by constant controversy, the so-called Fanger standard is now out for a European vote. The Scandinavians say it will work, the UK says not. Who is right? *Building Services Journal* and the BRE convened a top team of designers and architects to find out.

The European pre-standard on indoor air quality has been seven years in the making. Seven years of debate, negotiation, lobbying and, one might reasonably claim, seven years of clashing egos and political coercion.

At the beginning was a simple objective: the creation of a European standard to improve indoor air quality in buildings. At the end, a fault line running across the European Community between those countries in favour of the resulting pre-standard and those against.

And leading from the front, Professor Ole Fanger, chairman of the Working Group (WG6) responsible for producing the proposed standard, and the creator of its most controversial part: the olf and decipol method of assessing indoor air quality[1].

The standard has long courted controversy, with strong disagreement between those countries in support of any attempt to reduce pollution levels in buildings, and those whose concern about indoor pollution is eclipsed by doubts about enshrining the olf and decipol in a European standard.

The proposed document *prENV 1752 Ventilation for buildings: design criteria for the indoor environment* has now reached the end of a long and often acrimonious development period. It has been extensively rewritten, largely to balance the olf and decipol with other methods of assessment, but also to reduce an inherent tendency towards massively high ventilation rates caused by attempts to classify buildings into high or low polluting.

In March 1997 all seemed settled, with agreement being reached to relegate contentious clauses relating to high and low polluting buildings – along with recommended rates of additional ventilation – to informative annexes. The final document was passed to the European standards-making body (CEN) in preparation for a postal vote by participating countries this September. If voted through, *prENV 1752* would become a fully-fledged European standard after three years.

Unfortunately, clauses remained in the draft that require designers to refer to the disputed annexes, and on careful reflection the UK steering committee felt the revisions were not sufficient to make the standard workable. Come the EC vote this September, the UK vote is likely to be against[2].

Despite this decision, the pre-standard is not necessarily consigned to history. While the British claim that *prENV 1752* is fundamentally flawed, the Scandinavian countries believe otherwise. The vote hangs in the balance. So who is right?

To find out, *Building Services Journal* and the BRE invited nine practising building services consulting engineers, two architects and a ventilation manufacturer to use the pre-standard in a typical design context. Based on the specifications for three hypothetical new buildings, the team applied the pre-standard's tables and equations to assess the likely building pollution load, and to come up with an appropriate level of ventilation.

Three specifications, two for an air conditioned building and one for a naturally ventilated building, were created for the purposes of the *prENV 1752* road test. These specifications were based on actual structures for which the loads and ventilation rates were known (the latter being withheld from the delegates).

Building A would be a conventional three-storey, largely open-plan, air conditioned office building with typical cooling loads and a design occupancy density of one person/10 m^2, one pc per person and a printer/fax per every fifteen people.

The occupants would be mostly sedentary with a typical but relaxed clothing code. The fifteen-year old furniture would be imported from an earlier building, while the fixtures and fittings would be of standard quality. A smoking room would be provided.

Building B would also be air conditioned. As a head office building it would have both cellular and open-plan offices for mainly sedentary staff on a density of one person/17 m^2.

Clothing levels would conform to a corporate dress code of jacket, collar and tie. Internal building materials would be high quality, such as exposed granite and hardwoods, and

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Stephen Turner

TABLE A8: POLLUTION LOAD CAUSED BY THE BUILDING, INCLUDING FURNISHINGS, CARPETS AND THE VENTILATION SYSTEM

Building type	Sensory pollution load (olf/m² floor) Mean	Range
Existing buildings		
Offices[1]	0·3[4]	0·02-0·95
Offices[2]	0·6[3]	0·3
Schools (classrooms)[1]	0·3	0·12-0·54
Kindergartens[1]	0·4	0·20-0·74
Assembly halls[1]	0·3[4]	0·13-1·32
New buildings (no tobacco smoking)		
Low polluting buildings (see Annex G)	0·1	–
Not low polluting buildings	0·2	–

[1]Data based on more than 40 mechanically ventilated buildings in Denmark.
[2]Data based on European audit project to optimise indoor air quality and energy consumption in office buildings, 1992-1995.
[3]Includes load caused by present and previous tobacco smoking.
[4]Includes load caused by previous tobacco smoking.

Table A8: Note that the mean value of 0·6 olf/m² for existing offices was obtained from a database of 56 offices throughout Europe, many of which were only 2-3 years old.

ANNEX G GUIDELINES

Annex G provides information on the selection of building materials and the selection, maintenance and operation of a hvac system.

Building materials have been placed in three categories, M1 to M3. M1 is designated for emission-tested materials whose emissions fulfill the following requirements:

- ☐ emission of total volatile organic compounds (tvoc) below 0·2 mg/m^2h;
- ☐ emission of formaldehyde (H_2CO) below 0·05 mg/m^2h;
- ☐ emission of ammonia (NH_3) below 0·03 mg/m^2h;
- ☐ emission of carcinogenic compounds according to Category 1 of the WHO guidelines[1] below 0·0005 mg/m^2h.

Category M1 also includes natural materials that are known to be safe in respect of emissions, such as brick, stone, glass and metal.

Category M2 covers emission-tested materials from Category M1, but at higher concentrations, while Category M3 includes materials without known emission data, or for materials whose emissions exceed the values given in Category M2.

Low polluting buildings are deemed to meet the values laid down in Category M1. "Only office machines with an insignificant pollution load should be used," says the Annex. A building which fails to fulfill the requirements is classified as "not low-polluting".

[1]*Air quality guidelines for Europe*, World Health Organisation, 1987.

the office furniture could be considered to be of a prestige quality. There would be two pcs per person (55 W/m²) and a printer/fax for every five occupants. Smoking would be permitted in informal meeting areas.

Building C represents a new, naturally ventilated research and development office. The three-storey, mostly open-plan building would possess modest cooling loads, medium quality office furniture, low polluting carpet and paint finishes, one pc per person and a printer/fax for every 10-15 occupants.

The office work could be considered mainly sedentary, with no dress code and freedom of choice. Smoking would not be allowed.

The exercise

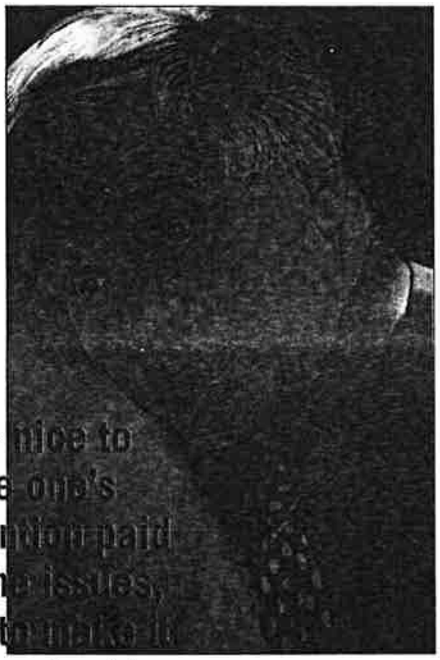
The three buildings were distributed evenly among the design panel, who were asked to devise an appropriate ventilation rate for their chosen building, using the methodology and guidance laid down in *prENV 1752.* All the buildings were considered to be in a rural location to remove any complications caused by external air pollution.

Each designer was asked to follow the steps laid down in the pre-standard, using the ppd (percentage persons dissatisfied) thermal comfort equation in order to determine operative temperature.

Thedesigners were then required to determine pollution values for each building, rather than read off the values from 'Table 1: Design criteria for spaces in different types of buildings'. This disputed table only gives ventilation rates for buildings deemed to be "low polluting", values for high polluting buildings having been deleted.

This meant that the designers had to use the olf and decipol method to determine the sensory pollution loads from occupants and the building in olf/m². The resulting value was then used to determine a ventilation rate in litres/s/m² and litres/s/person.

To work this out, building designers have to use several other tables listed in the standard, the important ones being 'Table A6: Pollution load caused by occupants', and 'Table A8: Pollution load caused by the building' (reproduced above). Table A8 gives pollution values for materials in olf/m² for both new and existing buildings. The values are selected by the designer for the building under design, and added to the load estimated to be generated by the building's occupants to arrive at the total building load.



"It's nice to have one's attention paid to the issues, but to make it a standard is a bit stupid"
Max Fordham

Table A8 refers designers to an informative annex, Annex G, which gives more detailed information on volatile organic compounds, along with threshold pollution values. Designers are expected to either avoid these materials, or to dilute them through ventilation (see box 'Annex G guidelines').

Designers could also opt to use Table C1 in Annex C, 'Design criteria for spaces in different types of building'. This provides advice on extra ventilation – up to 2·0 litres/s/person – which designers would add for buildings that are judged to be "not low polluting". This data was originally part of Table 1 in the pre-standard, but was relegated to Annex C (the disputed data was brought back into the design sequence at the last moment by being referenced – hence the UK's objection).

The analysis

Table 2 shows the results of the design process. Despite working independently, the designers reached reasonable agreement on operative temperature for the winter and summer condition, and were also reassuringly close on their estimates for sensory pollution load due to occupants.

This initial agreement stemmed from the simple task of reading from tables. However, it became much more difficult when the designers tried to use Table A8 to assess the pollution load caused by the building and its materials. Some were unsure of whether to use values for new buildings or existing buildings. Some designers thought that existing buildings would have a higher olf load due to absorption and general degradation, while others worked on the basis that off-gassing from materials would be high initially, but then reduce with time.

All the designers expressed difficulty in using the advice given in Annex G, claiming it to be inconclusive and oversimplified. Hence some (arguably optimistic) designers opted to use the pollutant loads for a new building, whereas others, playing safe and sticking doggedly to the prescriptive nature of the pre-standard, used the worst-case values. The result: estimates of building sensory pollution ranged from 0·1 olf/m² to 0·6 olf/m².

The differences were further exaggerated by estimation of the degree of ventilation effectiveness (ie: one representing a total mixing system, 0·5 being chosen by one designer for the displacement ventilation system in Building B). This variation was mostly due to assumptions on supply air conditions and temperature in the breathing zone.

All these difficulties came to a head when the designers were asked to produce ventilation rates for the three buildings. Even with some designers opting for the "low polluting rate" in Table A8, rates ranged from 87·5 l/s/person to 178·0 l/s/person for the air conditioned Building A, and between 83·0 l/s/person to 164·0 l/s/person for Building B.

Even for the naturally ventilated building, Building C, the required ventilation rate varied between 17·5 l/s/person (twice the current recommended rate) to 59·0 l/s/person. Such rates would torpedo any chance of the building being naturally ventilated. These stunning results stimulated a lively debate.

The discussion: building pollution

The designers zeroed in immediately on the guidance on building pollutants. David Arnold, senior partner at Troup Bywaters & Anders, swiftly drew attention to what he regarded as a fundamental flaw in the pre-standard.

"There is a disparity," he said, "between the two halves of the equation. While the supporting evidence for the toxin load is detailed (Annex G), the other half (Table A8) comes in two large lumps that force you to double and double again as you go through the equation."

Table A8 gives empirical data for pollution in existing buildings between 0·02 to 0·95 olf/m². However, the mean value for new "not low polluting" buildings has been set at 0·2 olf/m², a figure which Max Fordham found "extraordinary, and obviously picked out at random".

Fulcrum's Brian Mark was moved to label Table A8 as "terrifying in its implications", while the Chelsea Group's Stephen Turner slammed both Table A8 and Annex G.

"Annex G doesn't take you anywhere, it just gives thresholds but no guidance on a load per square metre," said Turner. "If you go into litigation in five or six years time...you will not be able to produce any calculations to support what you've done. There is simply not enough information in the standard to enable good advice to be given to the architect and interior designer on the choice of building materials and furnishings."

Brian Mark agreed. "It lacks the details," he complained. "We might know what the building contains, but we aren't told what difference each of them will make, and whether a photocopier, for instance, is worse than any other pollutant."

This led to a debate on whether architects would be prepared to accept the evidence in Annex G as a basis for avoiding certain materials, in order to get to what Ole Fanger would regard as the only acceptable default: a low polluting building with 0·1 olf/m².

Architect David Lloyd Jones, known for passive low energy architecture, was doubtful. "It would depend," he said, "on what sort of range (of materials) one was left with. It would also depend on the expectations of the client. While I don't have any problem with the materials listed in Annex G, it fails to address the chemicals often required to clean them. Annex G also fails to address the issue of finishes."

David Arnold predicted that the lack of useful guidance in Annex G would tempt engineers to use Table 1 in the pre-standard (ventilation rates for low polluting buildings, not reproduced here) and avoid making certain whether the architect has actually chosen to use low polluting materials. "A case of passing over liability on trust," said Arnold.

Should designers go outside of the standard for advice? "Annex G does highlight the importance of using volatile organic compounds with a total volatility which is below a level of 0·2 mg/m²h," commented Max Fordham. "We have to research the availability of those materials."

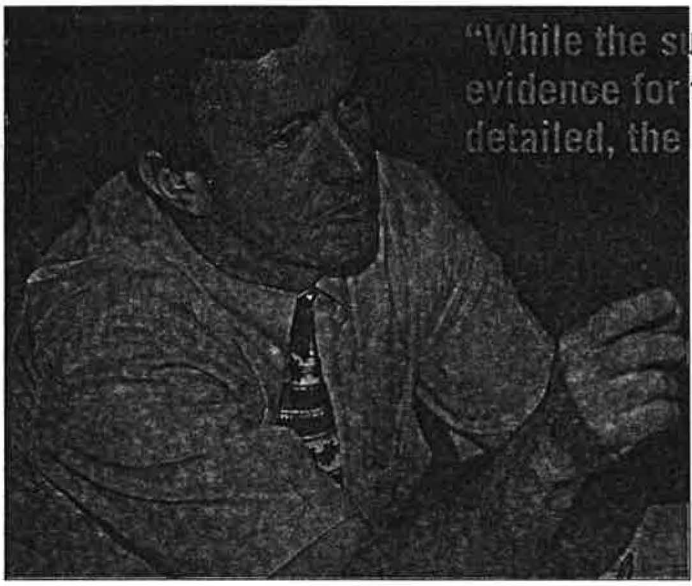
"The whole area is a minefield," said Oscar Faber's research director Steve Irving. "If you study existing data on volatile organic compounds, some are solvents and some are not, some chemicals are important and some less so, and some data is authoritative and some isn't. If you haven't got the full picture your assessment could be wrong."

TABLE 2: SPREAD OF RESULTS FOR THE THREE BUILDINGS DESIGNED USING *prENV 1752*.

Calculation	Building A	Building B	Building C
Winter temperature (°C)	21±2, 21±2	21±2, 21·5±2, 22±2	22±2, 22±2, 21±2·3, 21±2
Summer temperature (°C)	24±2, 22±2	22±2, 22±2, 23±2	25±1·5, 23±1·8, 25±1·8, 23±1·5
Sensory pollution load (occupants, olf/m²)	0·1, 0·04	0·12, 0·12, 0·12	0·08, 0·08, 0·07, 0·07
Sensory pollution load (building, olf/m²)	0·3, 0·6	0·4, 0·3, 0·3	0·1, 0·6, 0·3, 0·3
Sensory pollution load (total, olf/m²)	0·4, 0·64	0·52, 0·42, 0·42	0·18, 0·62, 0·37, 0·37
Outdoor air quality (decipol)	0, 0·1	0·3, >0·5, >0·5	0, 0, 0, 0
Ventilation effectiveness (nd)	0·95, 0·8	0·8, 0·5, 0·9	0·9, 1·0, 0·8, 0·8
Required ventilation rate (l/s/m²)	3·0, 6·1	5·9, 9·3, 5·0	1·5, 4·9, 3·3, 3·3
Required ventilation rate (l/s/person)	87·5, 178·0	98·0, 164·0, 83·0	17·5, 59·0, 47·1, 47·1
Noise levels (dBA)	40, not available	40, 45, 40	40, 35, 40, 40
Original specification	Winter 20±2°C, Summer 22±2°C, 40-70% rh, 22 l/s/person, 35 NR	Winter 20°C, Summer 22°C, 50-60% rh (ventilation rate not recorded but assumed to be orthodox)	Winter 18-21°C, Summer 28°C<1% year and 25°C<5%, 40-70% rh, 8 l/s/person

Note that the prENV 1752 pre-standard assumes a ventilation effectiveness at various operative temperatures, and all the designers in this exercise were conservative in their estimations.

"I would be very concerned if a building services engineer were to use this document to set the level of ventilation in a building I was designing"
David Lloyd Jones



> **"While the supporting evidence for the toxin load is detailed, the other half comes in two large lumps that force you to double and double again as you go through the equation"**
> **David Arnold**

DRAMATIS PERSONAE

The participants in the design exercise were invited on their basis as industry practitioners, and for their standing in the services and architectural professions:

- David Arnold, Troup Bywaters & Anders;
- Ron de Caux, Roger Preston;
- Ken Dale, Dale & Goldfinger;
- Max Fordham, Max Fordham & Partners;
- Steve Irving, Oscar Faber Consulting Engineers;
- Jacob Knight, Max Fordham & Partners;
- David Lloyd Jones, Studio E Architects;
- Brian Mark, Fulcrum Consulting;
- Kevin Mitchell, Hoare Lea & Partners;
- Andrew Morrison (architect), Battle McCarthy;
- Stephen Turner, Chelsea Group;
- David Walshe, Battle McCarthy;
- Terry Wyatt, Hoare Lea & Partners.

The design meeting, sponsored by the Department of Environment, Transport and the Regions, was organised by the BRE's Nigel Oseland and Claire Aizlewood and chaired by Mike Woolliscroft, ex-head of the BRE's ventilation design section. Alan Green of Trox (UK), leader of the UK delegation on WG6, attended as an observer.

The judgment: useful or useless?

Were the guest designers happy with the pre-standard, or was it judged a bed of nails?

"It depends on what you are trying to do," commented Hoare Lea's Terry Wyatt. "If you are trying to design a ventilation system, it probably isn't very useful. But there are many aspects of it which are, and which should be recorded in some form."

Did the designers believe that *prENV 1752* could survive as a technical report? Yes, came the answer, most people would benefit from reading it. But as a standard?

Fulcrum's Brian Mark said that *prENV 1752* was useful as a step-by-step guide, but not as a standard. "Not now that I have worked through it and got back garbage," he added.

Steve Irving complained that the document left too much open to engineering judgment for it to be a full standard, although Max Fordham regarded it as a good test "as to whether engineers have any common sense".

ASHRAE chapter chairman Stephen Turner also judged the *prENV 1752* to be useful as a design document, but not as a technical standard for assessing building-related pollutant loads. "If you promote a standard that pretends to concentrate wisdom...it will discourage designers to make judgments based on a wider body of knowledge. You can only make that move with a clear conscience if you are satisfied that the document adequately concentrates that information," he concluded.

Brian Mark found it "remarkable" that the standard didn't mention low energy design. "It doesn't even make reference to it," he said, "and the answers it generates could mean that some low energy designs could not be used. Annex G also fails to mention negative pollution measures, like night purging or adsorption by internal planting."

"It's not usable as far as I am concerned," said architect David Lloyd Jones. "I would be very concerned if a building services engineer were to use this document to set the level of ventilation in a building I was designing."

"If a team of thoughtful engineers came up with a range of 4:1 in the answers, then it cannot be a good document," said Ron de Caux of Roger Preston. "None of the answers we came up with were correct. It's interesting and all adds to our knowledge, but if it doesn't give the right answers then it can't be used as a standard."

A blind vote conducted by the chairman Mike Woolliscroft revealed unanimous opposition to *prENV 1752* as a draft standard, in which role it would be tested by designers throughout Europe preparatory to becoming a full European standard. By virtue of his role as the leader of the UK delegation on Working Group 6, Alan Green abstained from the vote, but spoke in support of Ole Fanger's seven-year campaign.

"Fundamentally," explained Green, "the *prENV 1752* standard recognises that definitive information is not available, hence the proposed three-year trial to establish how the standard can be improved."

But in its present form, argued Steve Irving, "the standard is sending out the wrong messages, which are all about ventilation rates rather than contaminant control – which is what's needed."

"The document should be more about building physics, not ventilation systems," agreed Hoare Lea & Partners' Terry Wyatt. "Services engineers are being trapped into making systems solutions rather than making building solutions," he said.

"The trouble is," concluded Max Fordham, "that our efforts at impartiality have carried the standard along. We keep agreeing with it almost by negation, and before we know it, it will be foisted upon us. It's nice to have one's attention paid to the issues, but to make *prENV 1752* a standard is a bit stupid."

TABLE 3: DIFFERENT VENTILATION RATES FOR TEST BUILDING C DEPENDING ON DIFFERENT ESTIMATES OF INTERNAL POLLUTION

Occupant density (per m²)	Occupant pollution load (olf/m²)	Building pollution load (olf/m²)	Total load (olf/m²)	Outside decipol	Ventilation rate (l/s/m²)	Ventilation rate (l/s/person)
0·08	0·08	0·2	0·28	0·1	2·1	26·3
0·08	0·08	0·2	0·28	0·5	3·1	38·8
0·08	0·08	0·6	0·68	0·1	5·2	65·0
0·08	0·08	0·6	0·68	0·5	7·6	95·0

The BRE's Nigel Oseland drew up a matrix showing the sensitivity of assessing a building's sensory pollution load. The data for Building C reveals that even when designing to a building pollution load of 0·2 olf/m², ventilation rates can be 26 l/s/person, three times the current recommended rate. With a building regarded as being high polluting under the standard, ventilation rates could rise as high as 95 l/s/person. Ventilation rates for the other buildings rose as high as 122 l/s/person.

References

[1]Fanger P O, 'Introduction of the olf and decipol units to quantify air pollution perceived by humans indoors and outdoors', *Energy and Buildings*, 12:1-6.

[2]'UK emphatic no to Fanger air quality standard', *Building Services Journal*, 7/97.

Building Services Journal would like to thank the engineers and architects who took part in this exercise, and the BRE's Nigel Oseland and Claire Aizlewood for organising and hosting the event. The meeting was kindly sponsored by the DETR.