For Discussion At

WORKSHOP: A CRITICAL REVIEW OF CRITERIA AND PROCEDURES FOR DEVELOPING INDOOR AIR QUALITY GUIDELINES AND STANDARDS

Convened By

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for the

International Academy of Indoor Air Sciences

Berlin, March 29-31, 1993

WORKING PAPER: "VENTILATION GUIDELINES"

Prepared by Hal Levin

"I thought I heard Buddy Bolden say,
Open up that window, let the foul air get away!
Open up that window, let the foul air out!
That's what I heard him shout."
-- Traditional (from Banham, 1984)

INTRODUCTION

The need for indoor air quality (IAQ) guidelines and standards has grown along with the increased attention to indoor air quality during the past two decades. Values for subtsances found in indoor air and for ventilation expected to control indoor air quality are relied upon by many professionals, researchers, regulators, and members of the public at large. This has resulted in more investigations of problems attributed to poor indoor air quality. Professional building designers including architects and engineers attempting to create healthy buildings. Those attempted to establish criteria for buiding performance or specific design criteria seek benchmark or reference values. These values take the form of air quality and ventilation standards and guidelines. Diverse criteria and procedures used in the development of these standards and guidelines results in varying values. When these values are not explicity stated in the documents and understood by those referring to them, they may be misinterpreted and misapplied.

It is the purpose of the Workshop: A Critical Review Of Criteria And Procedures For Developing Indoor Air Quality Guidelines And Standards to review existing critiera and procedures used in the development of many of the most widely used standard and guidelines in Europe and North America with the goal to develop recommended practices that can be uniformly applied. Following is a discussion of some of the guidelines and standards most relevant to ventilation. A separate discussion paper will describe the various air quality guidelines and standards relevant to indicate or evaluate indoor air quality.

SELECTIVE HISTORICAL OVERVIEW OF INDOOR AIR QUALITY GUIDELINES AND VENTILATION STANDARDS

Early ventilation standards focused on odor and thermal comfort. Separate standards for thermal comfort have evolved, but their importance for the design of building ventilation systems may make a review helpful to understanding ventilation standards themselves.

Benjamin Franklin
In the late 18th and early 19th Century, the American inventor, politician, statesman, and author Benjamin Franklin advised people suffering from smoke emanating from freshly started fires in the hearth to simply open the door until the smokey emissions diminshed sufficiently for comfort. Later, others developed methods for starting fires in the hearth while limiting the amount of smoke entering the occupied space. Franklin's approach was one of dilution ventilation; the later was one of source control.

Pettenkofer, M. (1858).
Established a maximum CO_2 concentration value of 0.7 %. Public health officials in several countries concerned about air quality in public buildings, schools, hospitals, theaters, and other building types measured CO_2 and compared the values to Pettenkoffer's criterion.

Sir John Simon, Report to the Privy Council:
"In the year (1863) the deaths from consumption in country districts being taken as 100, the deaths in Manchester counted 263, and in Leeds 218. The greatest mortality took place among printers and tailors, classes who work largely by night, requiring a strong light, which necessitates the burning of much gas. On the other hand, contemporary statistics showed that the miners of Northumberland and Durham, where the p[its were freely ventilated, formed an im portant expection to this rule..." Ernest Jacob, 1894, *Notes on the Ventilation and Warming...etc.* (SPCK Manuals of Health), London.

Reyner Banham
Discussing the shift in responsibility for the design of building environmental controls from the profession of architects to a new bread of engineers, Reyner Banham wrote the following:
"Because of th[e] failure of the architectural profession to -- almost literally -- keep its house in order, it fell to another body of men to assume responsibility for the maintenance of decent environmental conditions: everybody from plumbers to consulting engineers. The represented 'another culture,' so alien that most archtiects held it beneath contempt and still do. The works and opinions of this other culture have been allowed to impinge as little as possbile on the teaching o architecture schools, wehere the preoccupation still continues to be with the production of elegant graphic compositions rendering the merely structural aspects of plan, elevation, and sometimes section. ('Never mind all that environmental rubbish, get on with your archttecture.')" (1984)

M.S. Goromosov
Russion scientist M.S. Goromosov reviewed the history of thermal comfort research, formulas, models, and standards in the landmark review published by the World Health Organization, *The Physiological Basis Of Health Standards For Dwellings,* a 1968 World Health Organization publication. Goromosov was Assistant Director and Head of the Department of Health Aspects of the Microclimate and of Radiant Energy, Institute of Sciences, at the USSR Academy of Medical Sciences, Moscow. Following are some of his findings.

Houghton and Yaglou, (1922-24) developed the "modern American scale of effective temperatures." Their scale was revised first by them, then later in 1933 by the Harvard Medical School. That scale defined the effective temperature as a combined index of individually perceived warmth or coolness as a result of the combined impacts of air temperature, humidity, and air movement. Later, radiation factors were added by Bedford.

Winslow, Herrington, and Gaage proposed a scale of operative temperatures to add skin temperature to the factors taken into account previously. Plummer, Ionides, and Siple introduced the idea of the so-called coefficient of thermal acceptability (1945). Missenard (1959) developed an analytical expression for estimating the net influence of the principal factors that affect human perception of heat (including radiant heat); he defined this as "resultant temperature" (RT).

Goromosov summarized much of the research on thermal comfort, particularly that done in areas formerly part of the Soviet Union, He listed the recommendations of various investigators spanning from 1887 to 1954 as shown in Table 1 below.

Table 1. Thermal control recommendations reported by Goromosov

Author	*Year*	*Air temperature (°C)*
Erisman	1887	18 - 20
Flügge	1925	17 - 19
Hlopin	1930	17 - 18
Bürgers	1932	19 - 20
Liese	1933	17 - 18
Bedford	1934	15.5 - 20

The recommendations or standards in various countries at the time of Goromosov's book were as follows: Switzerland, 18-20 °C; Germany (Federal Republic), 18-20 °C, USA, 19.6-21.8 °C; USSR, 18-21 °C; England, 15.5-20 °C. He commented that the differences were attributable so much to differences in methods of determining comfort and health requirements as much as to differences "in the living habits and climatic conditions in the countries concerned."

From the standpoint of health, Goromosov recommended relative humidity be maintained between 30% and 60%, coincidentally, identifical to the values currently recommended by ASHRAE in its Standard 62-1989.

Goromosov also discussed air movement, radiant heating versus convective heating, and optimum microclimate conditions in dwellings during various seasons of the year and in differing climatic regions. The major criteria for his recommendations were health and comfort, and the process was a critical and comparative review of the available literature.

Goromosov concluded that there was insufficient information to establish a definitive model for thermal comfort that would incorporate all of the essential factors. He recognized the need for additional research which did follow and result in the modern models and standards. Nonetheless, research continues to improve the reliability of models developed in laboratory settings and apply them to natural settings and to various cultural and climatic contexts (Brager, 1991).

In addition to thermal comfort, Goromosov discussed indoor atmosphere and contaminants including CO_2, airborne bacteria, organic substances, carbon monoxide, sulfur dioxide, and odor. He recommended that CO_2 concentrations not exceed 0.05% and calculated that this required more than three air changes per hour in order to maintain that concentration if a person had an "air cube" of 25 to 30 m^3. To maintain CO_2 at 0.1% or less, he calculated that one air change per hour would be necessary.

Goromosov cites Russian research supporting a value of one air change per hour to maintain sanitary conditions in an air cube of 25 - 30 m^3 per person, the volume of a typcial bedroom.

The United Kingdom adopted standard in 1952 for ventiation of various types of spaces, as shown in Table 2 below. These standards were based on the build-up of body odor. Investigations in the USA reported by Goromosov state that 16.8 m^3 of fresh air per hour is necessary to odors that are unpleasant or difficult to tolerate.

Table 2. Minimum Standard Ventilation Rates (After Crowden 1952)

Type of room	Cubic capacity (m^3/man)	Minimum supply fresh air (m^3/hour/man)	Frequency of air replacement (changes per hour)
Living rooms	8.5	20.5	2.5
and bedrooms	11.5	17.0	1.5
	14.0	12.0	0.75
Kitchens	--	56.5	--

Becher in Denmark (1961) recommended round the clock air extraction rate of 32 m^3 per hour for kitchen ventilation and 29 m^3 per hour for that of the combined bathroom and toilet. The French Centre scientifique et technique du bâtiment recommended an extract air volume for inhabited rooms of no less than 30 - 45 m^3 per hour.

Goromosov identified gas cooking appliances as important sources of contaminants and stated that "...[s]uch appliances are ... clearly unsatisfactory from the health standpoint." He went on to discuss improved burner design intended to reduce emissions of contaminants, particularly of carbon monoxide.

Goromosov also discussed illumination, insolation, acoustic comfort, the "psychogenic aspects of comfort," and "new materials of public health importance in housing construction. Clearly, many of the topics of concern today were at least discussed in his monograph.

ASHRAE Std 55-1991, Thermal Comfort for Human Occupancy (ISO 7730 is similar.)

The two documents are similar and provide thermal comfort standards for human occupancy based on computations using a complex set of environmental and occupant factors. The consider the integrated effects of environmental factors including air temperature, mean radiant temperature, air movement, local turbulence, and relative humidity resulting in a value called the "effective temperature." The occupant factors include clothing ensemble, activity level (metabolic rate), and skin wettedness. The mathematical models and constants on which they are based are derived empirically from extensive laboratory studies including concepts of environmental acceptability which are then converted to a predicted percentage of occupants who are dissatisfied with the thermal environment.

Recently field studies have shown that there may be some variation between the results obtained in the laboratory and those obtained in office environments (Brager et al, 1991). The investigators and other observers have suggested that the differences may be due to the variations between the laboratory conditions and the conditions in actual office environments as well as considerations related to the assignment of an activity level (assumed metabolic rate) for the office workers. There may also be a need to consider the insulation value of furniture for seated subjects as well as the subjects' activity levels during the period prior to the measurement period (Levin, 1992).

RECENT IAQ AND VENTILATION STANDARDS AND GUIDELINES

ASHRAE STD 62, VENTILATION FOR ACCEPTABLE INDOOR AIR QUALITY

ASHRAE STANDARD 62-1989
Excerpts Taken From the Foreword of the Most Recent Version

"This reprint incorporates ANSI/ASHRAE 62a-1990 Addendum as a supplement to *ANSI/ASHRAE 62-1989.* It also incorporates an editorial change to Section 1, "Purpose,' to satisfy a concern of the ANSI Board of Standards Review and a change in the designation of the standard to denote its status as an American National Standard.
The Purpose was revised by deleting the word "avoid" and substituting the phrase "minimize the potential for" in front of the words "adverse health effects"

"ASHRAE's first ventilation standard was ASHRAE Standard 62-73, "Standard for Natural and Mechanical Ventilation". The standard provided a prescriptive approach to ventilation by specifying both minimum and recommended outdoor air flow rates to obtain acceptable indoor air quality for a variety of indoor spaces. This standard is still referenced in many building codes and was referenced by ASHRAE's first energy standard, 90-75, which specified use of the minimum outdoor air flow rates from 62-73. The revised energy standard, 90A-1980, also took this approach.

"Under the normal five-year review cycle, the multidisciplinary standards project committee appointed in 1978 addressed the question of whether these minimum values could be defended under all conditions. The revised Standard 62-1981, "Ventilation for Acceptable Indoor Air Quality", recommended outdoor air flow rates for smoking-permitted and for smoking-prohibited conditions in most spaces. The 1981 standard also introduced an alternative air quality procedure to permit innovative, energy conserving ventilation practices. The alternative procedure allowed the engineer to use whatever amount of outdoor air he deemed necessary if he could show that the levels of indoor air contaminants were held below recommended limits. However, some of the users of Standard 62-1981 found the application of the different ventilation rates for smoking and nonsmoking areas confusing, and the recommended maximum concentration of formaldehyde was challenged. For these reasons and in the light of rapidly changing technology, ASHRAE authorized an early review of Standard 62-1981 beginning in January 1983.

"This revised standard retains the two procedures for ventilation design, the Ventilation Rate Procedure and the Air Quality Procedure. The goals of achieving acceptable indoor air quality and of minimizing energy consumption appear to imply a compromise. An interdisciplinary committee of engineers, architects, chemists, physiologists, product manufacturers, and industry representatives has endeavored to achieve the necessary balance between energy consumption and indoor air quality in this standard. It must be recognized, however, that the conditions specified by this standard must be achieved during the operation of buildings as well as in the design of the buildings if acceptable indoor air quality is to be achieved. To facilitate this, the standard includes requirements for ventilation design documentation to be provided for system operation. The purpose of the standard is to specify minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects. For substantive information on health effects, the standard must rely on recognized authorities and their specific recommendations. Therefore, with respect to tobacco smoke and other contaminants, this standard does not, and cannot, ensure the avoidance of all possible adverse health effects, but it reflects recognized consensus criteria and guidance.

"The appendices are not part of this standard but are included for information purposes only."

COMMENTS ON ASHRAE STANDARD 62-1989

An oft-repeated criticism of ASHRAE Standard 62 ("Ventilation for Acceptable Indoor Air Quality") is that it provides little practical guidance on indoor air pollutant concentrations even though it mandates maintaining IAQ within "acceptable" limits. It provides Threshold Limit Values (TLVs) for occupational exposures and guidance information on scores of contaminants in an appendix. Yet the appendix advises that the TLVs are too high for non-industrial indoor air. It suggests that 1/10 of the TLVs be used as guideline values, but that these values might not protect sensitive individuals. In sum, the ASHRAE standard backs away from establishing exposure guideline values.

The notion that design is targeted to achieve a certain level of acceptability derives from the ASHRAE thermal comfort standard. The design temperature range is intended to result in no more than 20% of the occupants expressing dissatisfaction with the thermal environment if the design conditions are met. Since no set of thermal conditions can produce 100% satisfaction, there will always be some occupants who, when asked about their thermal comfort, will express dissatisfaction.

The ventilation standard (ASHRAE Standard 62-1989) borrowed this approach of limiting dissatisfaction as a design basis. As with thermal conditions, there are always likely to be some building occupants who will perceive the air quality as unacceptable under any conditions. The ASHRAE standard is based on limiting dissatisfaction with bioeffluents (emissions from occupants) and uses CO^2 as a surrogate for bioeffluent concentrations. This derives from the historic situation where people bathed far less frequently and human body odor was a significant source of complaints and odor discomfort in buildings. Ventilation rates were established to control body odor concentrations and the ASHRAE ventilation standard still reflects this heritage.

While the standard calls for use of more than simply a set of minimum outside air ventilation rates, many professionals and contractors use little else from the standard. In fact, so few copies of Standard 62 are actually sold by ASHRAE, it is questionable how familiar the engineering community actually is with the standard.

ASHRAE STANDARD 62 — THE NEXT GENERATION

ASHRAE Standard 62, "Ventilation for Acceptable Indoor Air Quality," is probably the most important indoor air standard in the world. It goes far beyond simply specifying ventilation rates (although many use it just for that). As the basis for good design practice and building operation, it is invariably cited in lawsuits involving problem buildings and occupant health problems.

Now, even before the world has really figured out how to use the standard, a revision is in progress. A proposed revision outline was approved in January.

SOURCE CONTROL EMPHASIZED

The revised standard (if it follows the outline) will emphasize the control of indoor air pollution sources. It will reward building designers and owners who implement source control strategies and penalize those who don't. It will do this by having tables for "minimum ventilation rates" and "additional ventilation rates."

The revised standard's table of minimum ventilation rates for commercial and institutional buildings will be similar to that found in Standard 62-1989. However, the proposed revision will also have "additional ventilation rates" that must be added to minimum ventilation rates if a designer does not consider sources in the design. These additional ventilation rates will be listed for sources with "potentially high emission rates of contaminants." (In fact, this is no different from what is implied in the current standard's Indoor Air Quality Procedure.) These additional ventilation rates could significantly increase the total design minimum ventilation rates above those contained in the current standard.

EMISSIONS-BASED VENTILATION RATES

According to the outline, maximum emission rates would be specified for listed source types such as floor coverings, wall coverings, organic solvents, furniture, office machines, smoking, and unvented space heaters. These specified emission rates would be the maximum allowable at minimum ventilation rates. The proposal would exempt "certified low-emission products" although there were no details provided.

New testing methods and programs must be developed and adopted for various types of materials and products for this provision to be implemented. An approach similar to the Carpet and Rug Institute's (CRI) for "green label" carpets might work. Another workable emissions testing program is operated by Underwriters Laboratory to measure ozone emissions from photocopiers.

For architectural coatings where most of the VOCs contained in the bulk product evaporate (off-gas) as the product cures, the certification might be based on the total VOC content of the bulk product. A labeling program already exists in California and several other states that requires measurement of total VOCs in paints, adhesives, and other architectural coatings. We expect the EPA to help develop the standards and, probably, review the performance of laboratories doing the testing.

There are no details available on the proposed basis for determining additional ventilation rates other than for purposes of explaining the approach. Default values for additional ventilation will be based on assumptions about the source strengths. The values could be quite high if committee members assume that they are on the high end of normal values for the important pollution source products, materials, and activities in a space. Using these values will require more capacity in HVAC systems and more energy to operate them. However, source control can result in ventilation requirements that will be roughly equal to the values in the current standard. Thus, the standard, if adopted along the lines outlined above, will generate even more motivation for the designer to consider trade-offs between additional ventilation and management of sources. The standard will also generate more source emissions testing and source control measures by industry and their customers respectively.

IMPORTANT DIFFERENCES BETWEEN THE STANDARDS

The outline contains some important differences compared to the existing standard. It has separate sections for commercial-institutional buildings and residential buildings. This is a response to many comments on the existing standard and the experience of several SSPC 62 committee members with ASHRAE's Standard 90 on energy conservation. The outline also addresses buildings with and without mechanical ventilation systems, an expansion on the guidance provided in Standard 62-1989.

The outline also includes new sections on "Documentation of Design and Operation Guidelines," and "Operating and Maintenance Procedures." There has been much discussion in ASHRAE about both these topics. Documentation is mentioned, even required, by the current version of the standard, but there is no guidance provided in terms of what is to be documented or what is to be done with it. Some guidance exists in ASHRAE's Guideline 1, Commissioning HVAC Systems, but even that guidance is sketchy at best. Operation and maintenance problems are constantly referred to as major contributors to IAQ problems at conferences and meetings on IAQ. It is not yet clear what the revised ventilation standard might say about the subject, but it is clear that there is a need to address the subject.

Comments

The committee was concerned that the approach proposed was too cumbersome for designers. In effect, what has been proposed is that indoor air contaminant loads be considered when determining required ventilation rates. While the general methodology exists for doing this, the data necessary does not. However, there is a very rapid movement by many building industry components to initiate emissions testing programs of various sorts. The data will be far more abundant by the time the standard is revised; realistically speaking, this will be no less than three years from now.

More importantly, what has been proposed is not new at all in terms of the way buildings are designed to handle thermal or structural loads. Constant and variable loads are calculated, estimated, predicted, or determined by whatever means is appropriate and feasible. Then the mechanical system or structural system is sized to handle these loads based on what we know about the performance of the systems. The same principle must be applied to pollution loads if air quality is to be truly acceptable by design.

EUROPEAN COMMISSION VENTILATION GUIDELINE

In 1992, the Commission of the European Communities (CEC) published a ventilation guideline with a two-fold approach to determining ventilation rates. First, the guideline requires that there be no more than a negligible health risk for occupants breathing indoor air. Second, that occupants should perceive the air as "fresh and pleasant rather than stale, stuffy, and irritating." It says that "the quality of the indoor air may be expressed as the extent to which human requirements are met. The air quality is [considered] high if few people are dissatisfied and there is a negligible health risk."

The report presents more explicit guidance on indoor air VOC concentrations than has previously been adopted by any authoritative body. The VOC guidelines, if followed, will severely limit pollutant source strengths.

A major new aspect of the guidelines is that they allow the designer to specify air quality based on quality levels, A, B, and C. The three levels correspond to three categories of indoor air quality acceptability to the occupants: 10%, 20%, and 30% or less of occupants being dissatisfied -- dissatisfaction is the correlate of finding the air unacceptable. Determining acceptability is based on the predicted percent of occupants that will be dissatisfied with the perceived air quality and a subjectively determined assessment of the odor, comfort, and irritation aspects of the air.

The creation of three levels allows for independent consideration of economic, social, and other local or regional geo-political factors as designers apply the guidelines and as the member nations deliberate adoption of the guidelines into regulations or laws.

The document, *Guidelines for Ventilation Requirements in Buildings,* reflects a voluntary consensus among representatives from the CEC member nations. It is a set of recommendations rather than a regulatory document. Its provisions are extremely important; however, they are not free from controversy. Ultimately, each member nation independently determines whether to adopt the *Guidelines'* provisions. However, the publication of the *Guidelines* report may lead to the adoption of at least some of its significant recommendations.

PURPOSE

The Purpose statement says: "This document recommends the ventilation required to obtain a desired indoor air quality in a space. Selection of low-polluting materials and products in buildings is recommended." The scope statement excludes thermal comfort parameters but references ISO Standard 7730, which is essentially the same set of thermal comfort requirements as ASHRAE Standard 55-1981.

Individuals involved in the *Guidelines*' development and adoption acknowledge that implementing the detailed requirements requires data that are not yet generally available. However, they believe the document will stimulate developing the necessary data. These data include chemical emissions rates from building materials, subjective evaluations of emissions, and subjective evaluations of indoor air quality in a representative range of buildings and building types.

CONTAMINANT EXPOSURE

The guideline provide guidance on contaminant exposures by reference to the World Health Organization (WHO) *Air Quality Guidelines for Europe.* It also provides rather detailed guidance on VOCs. Guidance is also given for several indoor air pollutants including radon, gases from landfills and waste sites, combustion products, environmental tobacco smoke, formaldehyde, metabolic gases, humidity, and micro-organisms. Specific discussions of each of these contaminants or categories address sources and public health significance. In most cases, the reader is referred to other publications for more detail. Most of the *Guidelines*' health goals are addressed by referencing existing CEC guidelines (contained in various publications) and the World Health Organization limits (contained in *Air Quality Guidelines for Europe*) for specific substances.

The report does not address complex mixtures or combinations of pollutants. It says that efforts to address combinations are hampered by the diverse nature of the effects of mixtures compared to individual compounds. In different cases effects may be additive, synergistic, antagonistic, or independent. Instead, it says that the "preferred method for indoor air quality management is control of the pollution sources. The choice methods for controlling the dominant sources are source removal/replacement, isolation, and local ventilation."

VOC CONTROL

Tthe report says that while its two approaches to VOC control are different, their practical implications are in agreement. The first suggests a comfort range of <200 μg/m^3 and the second a target value of 300 μg/m^3 for TVOC. The report says that since TVOC are "emitted by certain building materials, furnishings, consumer products and equipment, it is recommended to select materials and designs that minimize the emission of VOC."

The second method derives from the work of Bernd Seifert of Germany. Starting with Mølhave's work, Seifert establishes a TVOC target guideline value based on looking at the ten most prevalent compounds in each of six compound classes. The classes (and guidelines for them individually) are as follows:

- alkanes (100 μg/m^3),
- aromatics (50 μg/m^3),
- terpenes (30 μg/m^3),
- halocarbons (30 μg/m^3),
- esters (20 μg/m^3),
- carbonyls excluding formaldehyde (20 μg/m^3), and
- "other" (50 μg/m^3).

The totals from each class are added to derive the TVOC value. A target of 300 μg/m^3 for TVOC is given, but a disclaimer is immediately added that the values are not based on toxicological considerations. Rather, they are based on existing values and professional judgment about achievable levels.

Guideline recommendations for controlling VOCs refer to two methods. The first is attributed to Lars Mølhave of Denmark. It classifies exposures to total VOC (TVOC) as measured by flame ionization detection calibrated to toluene. The levels are listed as follows:

- "comfort range" of <200 μg/m^3,
- "multifactorial exposure range" of 200 to 3000 μg/m^3
- "discomfort range" of 3000 to 25000 μg/m^3, and
- "toxic range" of >25000 μg/m^3.

The report does not state what the "multifactorial" range is, but we know from other work by Mølhave that it refers to a range where individual factors cannot adequately explain the discomfort and health complaints of occupants.

PERCEIVED AIR QUALITY

The most unique aspect of the guideline is that it establishes three categories of perceived air quality -- A, B, and C. The ventilation rates required to achieve each category vary according to the strength of the sources to be controlled and the percent of dissatisfied occupants that is deemed acceptable. Category A limits dissatisfied occupants to less than 10%, category B to less than 20%, and category C to less than 30%.

The notion that design is targeted to achieve a certain level of acceptability derives from the ASHRAE thermal comfort standard. The design temperature range is intended to result in no more than 20% of the occupants expressing dissatisfaction with the thermal environment if the design conditions are met. Since no set of thermal conditions can produce 100% satisfaction, there will always be some occupants who, when asked about their thermal comfort, will express dissatisfaction.

PREDICTING DISSATISFACTION

Dissatisfaction rates are predicted on the basis of the research by Ole Fanger and his colleagues at the Technical University of Denmark. The method involves subjective air quality assessment by trained panels of visitors to a building who render judgments as to the acceptability of the air quality. The judgments are made from a combination of odor intensity, pleasantness, and the degree of irritation. The weighting or precise combination of odor intensity and pleasantness and the degree of irritation are not well defined.

This subjective approach, developed by Fanger and his collaborators at the Technical University of Denmark, involves quantifying the perceived intensity of pollution from various sources by defining one olf as the perceived indoor air pollution emitted by one standard person -- defined as one who bathes every 1.6 days. One decipol "is the perceived air quality in a space with a pollution source strength of one olf, ventilated by 10 l/s [20 cfm] of clean air." Thus, 1 decipol = 0.1 olf/(l/s). Figure 1 shows the relationship between ventilation rate in l/s per standard person and percent dissatisfied as predicted by Fanger's model. This approach is directly traceable to the CO^2-based ASHRAE standard. Note that since the decipol value increases as the pollution increases, the unit is actually an indication of perceived indoor air pollution, its inverse, perceived indoor air quality. [See FIGURE 1

Figure 2 shows the relationship between perceived air quality (in decipols) and the *Guidelines'* percent dissatisfied with the three levels, A, B, and C, plotted based on 10%, 20%, and 30% dissatisfied respectively. As we pointed out above, the x-axis is mislabeled; since the units are decipols, then the x-axis should be labeled "perceived air pollution." [See FIGURE 2]

LIMITATIONS OF SUBJECTIVE EVALUATIONS

An acknowledged weakness of relying on subjective evaluations is lack of any established relationship between perceived air quality and human health effects from harmful pollutants. For example, harmful odorless gases may contain radon, asbestos, and other carcinogens; carbon monoxide is odorless and lethal. Some members of the CEC committees that developed and adopted the guidelines were concerned about excessive or exclusive reliance on subjective evaluations of air quality. The *Guideline,* like the ASHRAE standard, argues the risks of potential health effects are normally lessened when poor perceived air quality is addressed by removing pollutant sources and improving ventilation. The problem is that there is no guarantee.

Another potential weakness is that indoor air acceptability cannot be determined until a building is completed and occupied. Then it is too late to revise the design to achieve better air quality. As more data become available on the strengths of emissions from building materials and other sources, it will be more feasible to add the subjectively perceived strengths of separate sources and predict the concentrations in the completed building under various ventilation rates. The proposed procedure is similar to one already used to estimate airborne concentrations of VOC from material sources based on environmental chamber measurements of chemical emissions. Critics argue that sufficient data won't become available in the foreseeable future to make the method practical. Defenders of the *Guidelines'* approach note that it is only a qualitative guideline; its real intent is to push things in a positive direction.

DETERMINING SENSORY POLLUTION LOADS

Fanger and his collaborators report that sensory pollution loads can be obtained by adding separate loads. He includes occupants, buildings, furnishings, and ventilation systems on his list of usual sources. Therefore, to design ventilation, we have to know all of the pollution sources and their olf values. Then we calculate the total sensory pollution load (olf/m^2) in order to determine the required ventilation to achieve the target air quality level: A, B, or C.

However, the report indicates that presently data are available "...for only a few materials." Therefore, it says, a more feasible approach is to estimate the pollution loads in different types of existing buildings. The report provides some information developed by Fanger on typical sensory pollution loads based on field research. The sensory load is defined as the pollution load from those sources that impact perceived air quality. Fanger and his collaborators at the Technical University of Denmark in Copenhagen have evaluated the sensory pollution loads (given in olf/m^2 of floor area) in a variety of building types and published their results elsewhere. These results are tabulated in the report and are shown in Table 1. [See TABLE 1]

Reviewing Table 1, we see a very large range of olf values for the building types listed. Offices varied by a factor of 47 for the 24 mechanically ventilated offices studied. The researchers evaluated far fewer buildings for the other building types and found smaller ranges of sensory pollution loads. As more buildings in each building type are evaluated, the range of olf/m^2 values observed is likely to increase. This suggest that we cannot simply assume what a pollution load will be; we must identify sources in each building we design to accurately predict the sensory pollution loads.

The report acknowledges the wide range of values occurring in various buildings. To address this it says that "...it is essential that new buildings be designed as low-polluting buildings." It then provides target values for "low-polluting" buildings of the types listed in Table 1. To achieve these target values, the report says, requires "a systematic selection of low-polluting materials for the building including furnishing, carpets, and ventilation system." [In Europe, the term "carpet" often refers to all rolled, sheet or tile floor coverings including textile and resilient materials.] The target values are shown in Table 2. [See TABLE 2]

The report provides some data on sensory pollution loads from certain types of occupants (see Table 3), but it does not provide any values for the pollution contributions of the other sources identified as important, i.e., "the building including furnishings, carpeting, and ventilation system." Table 3 shows some examples based on a standard person emitting 1 olf. A smoker equals 6 olfs while smoking, a physically active person equals 10 to 20 olfs, and school children equal 1.2 to 1.3 olfs, depending on age.

The report concludes this section by recommending the calculation of total sensory pollution loads "by simple addition of the loads from the individual pollution sources in the space." This, the report says, provides a reasonable first approximation of the combined loads. Then it qualifies this statement by saying that future research might show that simple addition of individual loads will fail to adequately predict total pollution loads.

OTHER FACTORS
The report says that the quantity of outdoor air required depends on the quality of that air. It lists perceived values for outdoor air quality, but these listings are rather vague with respect to the decipol values. Air "at sea" is rated as 0 decipol, air in towns with "good air quality" is rated as <0.1 decipol, and air in towns with "poor" air quality is rated as >0.5 decipols. These values are of little use to the designer and, again, leave us only with qualitative information for design.

The report's final consideration for determining required ventilation rates is the efficiency of ventilation. It uses pollution removal efficiency (rather than outside air delivery efficiency like ASHRAE Standard 62). The lower the pollution removal efficiency, the greater the required ventilation rate. This is a logical and important consideration.

The required ventilation for health and comfort "...should be calculated separately and the highest value used for design." Thus, the report does not rely solely on either evaluation, but suggests full consideration of both. It then gives examples of how to calculate the required ventilation for comfort (sensory pollution load) and then for health based on some examples.

(health based and subjective-evaluation based)

INDOOR CLIMATE - AIR QUALITY
(NKB Publication No. 61E, June 1991)

The Nordic Committee on Building Regulation, NKB, is a coordinating agency for the central building authorities of the five Nordic countries. These authorities represent their respective organizations in Denmark, Finland, Iceland, Norway, and Sweden. The guidelines are reccommended for regulations but do not themselves have the force of law. They are comprehensive in scope covering thermal comfort, air quality, ventilation rates, source control, and reviewing significant relevant recent research results from Nordic countries.

The Nordic Committee on Building Regulations, NKB, issued "Indoor Climate - Air Quality." The 36 page booklet contains a digest of the consensus knowledge obtained in the Nordic countries where indoor air quality has received considerable attention far longer than in most other parts of the world. The publication, dated June 1991, is a revision of a May 1981 publication.

The report contains two principal sections: one on pollution sources and one on ventilation. Each has its own set of requirements and of guidelines. The report's provisions are not law but constitute recommendations to the governing bodies in each of the Nordic countries. Compliance with the recommendations is voluntary on the part of each member country -- Denmark, Finland, Iceland, Norway, and Sweden. Represetnatives of each country were on the indoor climate committee appointed by the Nordic Committee on Building Regulations. Most of the contents are in the form of discussion of what is known, especially as a result of research and experience in the Nordic countries, and of objectives statements summarizing good practice. These statements tend to be qualitative rather than quantitiavtive, and it is difficult to evaluate rigorously whether a design or building meets the objectives.

THE FOREWORD

The Foreword outline four major cuases of problems experienced in buildings that create the need for the report. They are as follows:

- The use in buildings of materials, fixtures, fittings, and furniture that emit various pollutants.
- The use of materials and constructions sensitvie to moisture without sufficient preventive measures to control moisture accumulation.
- Insufficient outdoor air provided by HVAC systems due to poor design, improper use, contamination of supply air by HVAC system components, or neglect of maintenance and cleaning.
- Unsatisfactory coordination (quality control) in the building process to maintain good indoor climate: unsatisfactory or incorrect construction, operation, cleaning, and maintenance.

OVERALL OBJECTIVES

The report briefly discusses various important indoor air contaminants, their occurrence indoors, and available guidance on acceptable concentrations. It concludes that "on the whole, knowledge is not available to lay down quantified criteria for risk assessments regarding the quality of indoor air." It refers the reader to the WHO "Air Quality Guidelines for Europe" (see references), then establishes the following overall objective:

"Buildings inclusive of their installations shall be planned, designed, constructed, maintained and operated so that satisfactory comfort is achieved with reagard to air quality and so that danger to health does not arise when rooms are used in the way intended."

It goes on to define "satisfactory" air quality as follows: that the "great majority of visitors, on entry into the room, perceive the air as acceptable (do not express displeasure), if the air does ot cause irritation to the skin, mucous membranes, or air ways, not even in persons who are somewhat more sensitive than normal, if there is no risk of sensitization, and if the risk of health effects after long term exposure is negligible." It also says that the indoor air quality must not cause disease.

The term "in the way intended" is defined operationally -- activities that occur, such as smoking, should have been part of the design conditions. It calls for a margin for "short term pollution loads" giving the example of openable windows as such a margin. In residences, normal hobbies, housekeeping, and cleaning activities should be able to be carried out without "causing inconvenience."

To assess buildings in operation, it says, "the experience and complaints of people can be used in judging the 'health' of the building."

BUILDING MATERIALS AND SURFACE FINISHES

The report says that the goal for materials is that they impose no need to provide ventilation to remove the gases they emit. But, it says, present knowledge is insufficient regarding the nature and significance of emissions. The first step, therefore, is to choose materials "which emit the smallest quantities of pollutants." [This is similar to the "pollution prevention" strategy adopted by the United States Congress and being implemented by the Environmental Protection Agency.]

The potential of materials "to act as storage areas for pollutants" (the sink effect) is also a significant factor in material selection. The report says the storage effect depends, among other factors, on the surface area of the material, and can be both positive and negative. It says that fleecy surfaces have larger storage area than smooth ones.

The report also focuses on material handling during construction. It says that faulty handling that increases moisture load is a significant cause of sick buildings. It cites the of chipboards and glued timber structures in the 1970s that emitted formaldehyde especially in conuunction with moisture. It also cites casein screeds (levelling compounds) used over insufficiently dried concrete before floor covering or carpet was laid. Other examples cited are acoustic tiles of loosely compacted mineral wool, certain paints, and adhesives.

Four factors cause emissions from materials: 1) solvent residues
2) remnants of raw materials (e.g., monomers); 3) reaction and decomposition porducts from the manufacturing process; and, 4) additives. The first three are greatest in new materials and within one to six months decrease asymptotically to a level characteristic of the particular material and emission type.

RECOMMENDED REGULATION
"Bulding materials and surface finishes shall have the lowest possible emission properties. They shall be manufactured, selected, handled, stored, and used so that emission to the room air is the least possible. The material shall be able to stand up to the intended use. The material shall not contain any genotoxic or neurotoxic substances, substances which cause sensitization or irritation of the mucous membranes or substances harmful in any other way, which pose a health hazard when used as intended in the building."
A note following the recommendation says: "Intended use includes e.g., cleaning."

REQUIREMENTS FOR VENTILATION: OUTDOOR AIR FLOW RATES
This subject is treated similarly to its treatment in the CEC Ventilation Guidelines with respect to the use of subjective criteria and the three levels of perceived air quality, A, B, and C based on less than 10, 20, and 30% dissatisfied respectively. To achieve level B, less than 20% dissatisfied, it says that 7 l/s person outdoor air supply is required. This is identical to ASHRAE's 15 cubic feet per minute per person (cfm/p) to achieve the same level of satisfaction. This is no accident; the research basis for both standards has the same roots and a common history.

It recommends that ventilation be sufficient to maintain the conditions described in Section 2, Overall Objectives. But it leaves the detailed airflow requirements unspecified beyond the discussions related to subjective evaluation. It references air pollutant concentrations in documents such as the WHO *Air Quality Guidelines for Europe*. It also discusses the need to achieve the intended air quality after unoccupied periods, and the need to prevent the spread of contaminants by the ventilation system when the building is not being used.

In general, the recommendations define good practice but do not prescribe values or conditions in a regulatory fashion. For example, in the discussion of air flow conditions (Section 4.3), one of the recommendations for regulations is as follows: "Air change efficiency shall be satisfactory." On the other hand, the report is unambiguous about the issue of operable windows. It states: "Every workroom and habitable room shall be provided with an openable window for ventilation.

SCANVAC VENTILATION GUIDELINES

Excerpted From
Classified Indoor Climate: A Way to a New Indoor Climate Technology

by U. Rengholt. Swedish Society of Heating and Air-Conditioning Engineers (Swedevac).

Presented At ASHRAE IAQ 91, Washington, D.C.,

THE NEW INDOOR CLIMATE TECHNOLOGY-- SOME CHARACTERISTICS

It is not my intention to discuss the means and ends of the new indoor climate technology, but as background to the Scanvac guidelines, I would like to present some of its most important characteristics.

• The new indoor climate technology recognizes the importance of the indoor climate for people's well being, health, and performance ability--in other words, the productivity of the indoor climate.

• The new indoor climate technology expresses the indoor climate and its effect on human beings in terms that enable us to make an economic estimate of its importance. In that way, both decision makers (clients, managers, etc.) and consumers can get a clear view of and put a price on the indoor climate.

• The new indoor climate technology considers the indoor climate to be a complex factor. Different people perceive the indoor climate differently depending on age, sex, activity, etc. It is influenced by many different technical factors, such as pollution sources and thermal loads inside and outside the building. The indoor climate in each case must rest on the basis of the prevailing conditions and with respect to who is going to use it. In other words, the indoor climate must be "individualized" Thus, the new indoor climate technology is far removed from the view that has dominated up to now, namely, that the indoor climate is a fixed entity that is the same for most people and can be based on rigid standards valid for most types of buildings.

These characteristics of the new indoor climate technology are sufficient as an explanation of the background to the new Scanvac guidelines.

PRINCIPLES BEHIND THE INDOOR CLIMATE GUIDELINES

The Scanvac guidelines are built on the following principles, derived from the new indoor climate technology.

• The quality of the indoor climate is characterized according to the effect of the indoor climate on people's comfort and well being (also health aspects) by means of frequencies of dissatisfaction, so-called "PPD values"

• The quality specifications are classified by a limited number of different quality levels, which enable the customer (the house owner) to choose a suitable (but to some extent standardized) indoor climate in each individual case.

• From a technical point of view, the quality of the indoor climate is defined by a number of indoor climate factors (air quality factors, thermal quality factors, etc.) and by specifications of acceptable values for them in the various classes.

• The quality of the indoor climate is regarded as separate from the technical solutions that are applied to establish it.

These principles will be discussed in concrete detail in the following section.

THE STRUCTURE OF THE CLASSIFICATION SYSTEM

The purpose of the Scanvac guidelines is to indicate a new way of thinking that enables us to *understandthe* indoor climate, *evaluate* it in economic terms, and *adapt* it to the various conditions--technical and consumer-oriented--in the individual case.

In accordance with these guidelines, the indoor climate is divided into different quality classes with respect to thermal comfort, air quality, and noise level. Each class is characterized by a statistically determined value of the percentage of dissatisfied persons that the class is estimated to yield, the so-called "PPD value"

There are three thermal classes, two air quality classes, and two noise level classes. Each thermal class and each air quality class is composed of a number of indoor climate factors, the values of which are given in Tables I and 2. The noise level classes are directly defined by the noise level values allowed (see Table 5).

A PRACTICAL APPLICATION OF THE CLASSIFICATION SYSTEM

The indoor climate is determined by thermal, air quality, and noise level classes. Within the 12 combinations possible (see Figure 6), that which agrees most closely with the type of building, use, etc., is chosen for each individual object.

A classified quality system of this kind has many effects on the practical work. The builder or the building owner must consider and specify which indoor climate quality he needs. He must choose a quality level before the projecting or design stage.

The functions of the building, its ventilation, and other factors will be better adapted to individual needs instead of following a rigid standard that is taken for granted in every case.

The choice of quality level is documented. If the building owner has chosen a lower quality than is justified, that is documented, and the information is preserved for the life of the building.

The consulting engineers are given clear specifications of demands to follow and use as a basis for the choice of technical solutions that meet the quality demands in the best possible way.

CALCULATION OF AIRFLOW WITH REGARD TO EMISSIONS

In order to create an air quality in accordance with air quality classes AQI and AQ2, the major indoor pollution sources must be identified and their source strength determined (calculated). The correct airflow should be determined on the basis of the generated quantity of pollution--the so-called "source control principle" Major pollution sources are people (emitting carbon dioxide), building materials and surface materials (emitting VOCs), and office equipment.

Up to now, the necessary airflow has been calculated only with regard to people (carbon dioxide) as a source of pollution.

Now, that is an unacceptable simplification. Emissions from building materials often prove to be more serious.

The indoor climate guidelines therefore indicate new methods for calculating the airflow, taking into account pollution both from people and from building and surface materials. These methods rest on building materials being divided into three different emission classes, defined by emissions under operation (low, medium, and high emissions).

The calculation has been simplified to a diagram, indicating the necessary airflow as a function of the percentage of medium or high emission materials prevailing and the person load (number of persons per square meter of floor surface) (see Figure 7).

These new calculation methods give considerably higher airflows than has been customary. An airflow of 0.7 to I.0 L/s m2 (1.4 to 2.0 cfm/ft2) proves sufficient only if low-emission material is used. When high-emission material is used, 5 to I0 times that figure is required.

Airflows of that magnitude are unrealistic. For that reason, the use of high-emission building materials must be limited if an air quality in accordance with the Scanvac guidelines is to be obtained. By demonstrating the results of the use of high-emission building materials, the guidelines indicate a method for choosing suitable materials with regard to the indoor climate, in other words to limit emissions from building materials.

COOPERATION

The quality of the indoor climate is established by a complex interrelationship between factors of building technique, ventilation technique, and external environment loads. This requires cooperation between many different professional groups.

AN ECONOMIC ESTIMATE OF THE INDOOR CLIMATE

The guidelines open a possibility of estimating the quality of the indoor climate in economic terms on a statistical basis. The PPD values for each class are then used to calculate the overall costs for bad indoor climate in a building with respect to dissatisfaction, health problems, and lower productivity. Such calculations had been made in the Scandinavian work. They indicate that bad indoor climate has a big price tag. Indeed, it is not the mission of this paper to discuss that issue.

ADDITIONAL GUIDELINES AND STANDARDS OF INTEREST

Cal-OSHA operation and maintenance standard: buildings must be operated to the standard to which they ar designed. They must be regularly maintained, and records of the maintenance must be posted in a prominent position. They must be checked annually to determine their performance, and if necessary, they must be re-adjusted, and balanced to achieved required ventilation system performance.

Thomas Lindvall (S). Lindvall has presented a listing of various ventilation rate recommendations and standards (Lindvall, 1989; Levin, 1991) These various rates reflect the diverse criteria used in their development. The very large range of recommended ventilation rates clearly illustrate the importance of criteria. See Table XX, Ventilation Rates According to Varying Criteria (from Levin, 1991) after Lindvall.

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TABLE I Thermal Quality--Acceptable Values of Different Factors in Various Quality Classes

The table indicates valuesfor the normal case.

Item	Indoor climate factor	Factor value in quality class TQI	TQ2	TQ3	TQX
1*	**Operating temperature (to)**				As specified
1.1	Winter mode				
	highest value °C	23	24	26	
	optimum value °C	22	22	22	
	lowest value °C	21	20	18	
1.2	Summer mode				As specified
	highest value °C	25.5	26	27	
	optimumvalue °C	24.5	24.5	24.5	
	lowest value °C	23.5	23	22	
2*	**Air velocity within the occupation zone**				As specified
	winter mode m/s	0.15	0.15	0.15 (0.25)	
	summer mode m/s	0.20	0.25	0.40	
3*	**Vertical temperature difference, summer/ winter mode °C**	2.5	3.5	4.5	As specified
4*	**Radiant temperature asymmetry**				As specified
	to warm ceiling °K	4	5	7	
	to cold wall (window) °K	_	10	12	

~This table does not cover the Ruidelines completely and onlygives instances of how indoor climatefactors vary between classes.

TABLE 2 Iodoor Air Quality--Acceptable l~vels of Pollutants in Indoor Air of Different Air Quality Classes

Maximum permissible quantity mg/m3 in class

Item	Pollutant		AQ1~	AQ2	AQX
I	Carbon monoxide, total	MV 0.5 h MV8 h	60 6	60 6	As specified
	--from tobacco smoke	MVI h	2	5	As specified
2	Carbon dioxide	MVI h (in ppm*)	I000 600	1800 I000	As specified
3	Ozone	MVI h	0.05	0.07	As specified
4	Nitrogen dioxides	MV I h MV 24 h	0.11 0.08	0.11 0.08	As specified
5	Volatile organic compounds (VOC) --total MV 0.5 h --formaldehyde MV 0.5 h		 0.2 0.05	 0.5 0.1	As specified
6	Particles from tobacco smoke, inhalable MVIh		0.1	0.15	As specified

**This table does not cover the guidelines completely and only gives instances of how indoor climatefactors vary between classes.* Air (;2ualit~ c~asses

TABLE 3 Noise Level--Acceptable Values for Conlinuous Noise Levels in Different Quality Classes

Item	*Factor*	*Highest level in class*		
		NQ1	***NQ2***	***NQX***
I	***Sound pressure level dBA***			*As specified*
Ia	*--dwelling room*	–	*30*	*As specified*
	--bedroom	–	*30*	
	--kitchen	–	*35*	
	--bathroom	–	*40*	
	-WC	–	*40*	
Ib	*--office premises*	–	*30*	*As specified*
	--conference premises		*35*	

The percentage of dissatisfied people those classes will produce, statistically seen, is given in Tables 4 and 5.1n the thermal classes, the percentage of dissatisfied varies between IO% and 20°o. In the airquality classes, the values vary between I°o and 50°o depending on which factor is regarded

TABLE 4 Thermal Comfort (TQ)--Percentage of Dissatisfied for Different Quality Classes and Indoor Climate Factors

		Quality class				
Item	**Indoor climate factor**	**TQ]~**	**T~12**	**1~3**	**TQX**	**Notes**
1	Operative temperature	<I0°70	I0~10	20%	As specified	
2	Air velocity	I0°70	I0~o	20° o	As specified	
3	Vertical temperature difference	<I0~o	I0~o	20°o	As specified	
4	Radiant temperature asymmetry	<10%	I0° o	20° o	As specified	
5	Floor temperature	<I0°70	I0°70	20°70	As specified	

~This class requires individual control of temperature and airflow.

Table 4-4: Various adopted Ventilation Rates [Lindvall, 1989]

MINIMUM VENTILATION RATES

(liter/sec/person) *(cfm/person)* *Basis or Recommending/Adopting Group and Year*

>0.3 **>0.6** **2% CO2 (maximum if respiration is to be sustained)**

1% on nuclear submarines resulted in higher incdience of kidney stones; therefore it was lowered to 0.5%. stolwijk will provide reference

>1 **>2** **0.5% CO2 (TLV, OSHA)**

>3.5 **>7.0** **0.1% CO2 (Pettenkofer Rule, 1858; body odor)**

Pettenkofer looked at different rooms - a lecture hall, a restaurant, his own working room, and a school room, when people complained he measured CO2 by trapping it in an an alkaline solution, by bubbling it through. From his analysis he concluded that air is bad and not good for continuous human occupancy which following respiration and perspiration of humans if it had more than 0.1% carbon dioxide. The complaints inlcluded complaints that the air was bad and that no one could occupy that space without adverse health effects. Über den Luftwechsel in Wohngebäuden von Dr. Max Pettenkofer. Munchen, Literaisch-Artistche anstalt der J. G. Cotta. 1858.

In 1946, German ventilation standard, now under revision, should not exceed .15%, 0.1% is the recommended maximum value. No rationale provided.

German MAK value background paper, for closed, ventilated rooms, some observations of increased pressure in the head and headaches. MAK level set at 0.5%. Because these effects occur, the MAK value should not be used in offices and similar working rooms. (July 4, 1983.)

2.5 **5.0** **ASHRAE Standard 62-1981**
With no smoking permitted. 2500 ppm CO2 factor of 2 tro tolv

10 **20.0** **ASHRAE Standard 62-1981**
With smoking permitted

3.5 **7.0** **Swedish Building Code, 1980 for offices ?**
0.35 l/s m2
Q. : 0.5 ach for dwellings?
Based on control of body odour using Yaglou's experimental data from the 1930's.

4 8 Nordic Building Regulation Committee, 1981

(established to reduce energy consumption). Body odour control based on Yaglou's work. This contained room volume assumptions - valid for rooms of 12 m3/p minimum. With higher occupant density, higher ventilation rates were required. The requirements are contained in a graph in the guideline. Ulf will get the graph and we will include a couple of representative values and the graph. They also recommended 0.35 l/s m2 in a building. The higher of the two values governed.

In addition, going so low was also intended to address energy consumption considerations.

5 - 7 10 - 15 Berglund et. al.

(level below which body odors can be perceived above the background odor level of a room or school). Laboratory experimental work ?? Stolwijk?? What was the criteria for these levels? Acceptability? Dissatisfaction? What percent acceptable.

8 16

Fanger et al (body odor). Papers from 1987, 1988 - no more than 20% finding air unaccepable when first entering the space. Indoor Air 87, Vol 4, pp. 49 ff.. Ref. Berg-Munch et all, Envt Intl (1986) vol. 12, 195-199. Fanger ety al, Proc of an engnieering Foudnation Conference on Management of Atmospheres in Tightly Enclosed Spaces. ASHRAE. Atlanbata, 1983, pp. 45-50.

7.5 - 30 15 - 60 ASHRAE Standard 62-1989

Based on 700 ppm above background

5 - 10 10 - 20 Swedish Building Code, 1988

(5 L/s-p = sedentary office work; 7 = light activity office ; 10 = office work: 20 = work with some smoking possibly taking place)

10 - 30 20 - 60 Swedish Allergy Committee, 1989

(above basic continuous air flow rate of 0.5 ACH; 10 = low emitting materials, fully checked; 15 when no pollution load has not been checked; 30 when pollution load is high)

We know too little about the health effects of the contaminants in indoor air. And there are so many of them present at the same time that we cannot tell the effects. Therefore it is insufficient to set values / standards for individual substances. In order to improve the iaq, it is necessary to increase the air exchange rate, so that all pollutants indoors are lowered. It is quite clear allergics and other hypersensitive persons will react earlier and more pronounced to lower levels of indoor air pollution than other people. Therefore, besides a coninuous ariflow that corresponds to 0.5 ach, there must be a flow of 10 to 30 l/s p.

In order to lower the water content of the air to less than 7 g h20 /kg dry air required 1 ach for three winter months each year.. control of mites in test houses (12/14 negative) effective atthis water level.

It also was based on what was reasonably achievable as determined by practical people in the field,

Intended to protect individuals who are somewhat more sensitive than normal. Figures for ?? were recommended to policy makers, but

All responders ?? (lindvall, pickering) = 46%.

10 - 20 20 - 40 Nordic Building Regulation Committee, 1991
(for non-dwelling buildings, low-emitting materials, no smoking = 0.7 L/m2 + 3.5 L/s-p, though total should never be less than 7 L/s-p). compared to 1981, the building was recognized as a much greater polluter than previously recognized. So it was decided to add the building ventilation requirements to the people ventilation requirements. The values were based on the data published by Fanger regarding the source strengths.

16 - 20 32 - 40 Weber et al; Cain et al (tobacco smoke annoyance)
1981, symp on air quality and indoor air, publ 1982: 33 m3/hr p (10 l/s -p) if there are are 10 p in the room. 23 m3/hr (7 l/s p) if there are 100 p in the room. assuming one cigarette per hour per person?

14 - 50 28 - 100 Fanger et al (total odor)
