CLASSIFICATION OF INDOOR CLIMATE, CONSTRUCTION, AND FINISHING MATERIALS

June 15, 1995

Finnish Society of Indoor Air Quality and Climate, FiSIAQ

Finnish Association of Construction Clients, RAKLI
Finnish Association of Architects, SAFA
Finnish Association of Consulting Firms, SKOL

PREFACE

Indoor climate has become more important for health and comfort during recent years. As people stay approximately 90% of their time indoors, the quality of indoor air for the health is even more important than outdoor air. Good indoor climate reduces the number of illnesses and the symptoms of sick building syndrome. It also influences comfort and working efficiency. Good indoor climate is one of the most important goals when constructing a building. However, research and practice have shown that good indoor climate that satisfies the users of buildings is far too seldom achieved. **The final quality of indoor climate is influenced simultaneously by heating, ventilation and air-conditioning systems and equipment, by ways of construction, performance of construction and materials used, and by the operation and maintenance of buildings.** To achieve good indoor climate provides that all matters presented consideration in all the phases of design, constr

The Classification of Indoor Climate, Construction, and Finishing Materials has three parts. It is intended to be used in the design and construction of buildings and their mechanical systems to build healthier and more comfortable buildings. It also helps manufacturers of equipments and materials to produce less emittive building products. The Classification can be used both in new constructions and in evaluating old buildings, and also, when applicable, in renovations. The Classification is not an official building code, and it does not define liabilities of construction projects.

The Classification of Indoor Climate, Construction, and Finishing Materials is developed by Finnish Society of Indoor Air Quality and Climate (FiSIAQ) based on Finnish and international research results. The work was initiated by the Finnish Ministry of the Environment. A public hearing of the Classification was held in January 1995, and the publication was considered necessary unanimously. The comments and statements proposed are taken into account in this completed version of the Classification. It is supported by the Finnish Association of Construction Clients (RAKLI), the Finnish Association of Architects (SAFA), Association of Finnish Architect's Offices (ATL), and the Finnish Association of Consulting Firms (SKOL) who recommend their members to take the Classification into use to improve the quality of constructions.

This document is translated from Finnish by Professor Olli Seppänen, Risto Ruotsalainen, M.Sc. (Eng), and Leila Sarajärvi, M.A.

Helsinki, June 15, 1995

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INTRODUCTION

The Classification of Indoor Climate, Construction, and Finishing Materials has three parts and it is intended to be used in the design and contracting of construction works and mechanical systems for buildings and in the manufacturing of equipment and materials to build healthier and more comfortable buildings. The Classification can be used in new constructions and in evaluation of all buildings and, when applicable, also in renovation. The Classification gives target and design values for indoor climate and supports the work of clients, designers, equipment manufacturers, contractors and operation personnel. The Classification can be referred to when writing specifications of construction and mechanical systems. It can be used even as an enclosure of such specifications. The Classification supplements the Finnish Building Codes, General Requirements for Quality in Construction Works, Model Specifications for Constructions, Model Specifications for Mechanical Systems of Buildings, General Agreement between Contractors, design guidelines published by the Finnish Building Information Institute, and other documents related to construction. **The Classification does not overrule official building codes or interpretations of them.**

The categories for indoor climate, construction cleanliness, and finishing materials shall be selected at an early stage of a construction project. The client selects the categories with the design team. With the help of the Classification of Indoor Climate, the target values for indoor climate are specified. After this, the category of Construction Cleanliness is selected in accordance with the Classification of Construction Cleanliness. The Classification of Finishing Materials is used when selecting building materials. When the ultimate goal is good indoor climate, the best category of each part of the Classification shall be selected. The low category of one part cannot be totally compensated by a high category of an other part. **Thus, for example, the high emissions of building materials are difficult to be compensated by increasing ventilation.** So far, it has not been possible to take into account material emissions when selecting airflows for ventilation because the finishing materials have been selected at a late stage of the construction process.

The first part of the Classification, **Classification of Indoor Climate**, deals with thermal climate, noise levels, ventilation and air pollutants. It is limited to factors from which there is information based on research or building practice so that guideline values can be given. The factors presented in the Classification can be measured with generally approved methods at a reasonable cost. In addition to the target values, the Classification of Indoor Climate gives the most important design values for heating, ventilation and air conditioning equipment and systems. Design values of thermal climate are based on design weather, which is also defined.

The second part of the Classification, **Classification of Construction Cleanliness**, deals mainly with the principles and procedures to be followed at various stages of construction works. The Classification of Construction Cleanliness is necessary so that the objectives of indoor climate of various spaces would be taken into

consideration at all stages of construction. The procedures presented are intended mainly for construction and mechanical contractors but they also contain requirements for design, equipment manufacturing and operation.

The third part of the Classification, **Classification of Finishing Materials**, is intended to enhance the development and use of low-emitting building materials. The materials are characterized only from the viewpoint of chemical emissions to indoor air. The Classification of Finishing Materials contains target values for emissions of building materials to be used mainly inside the building and their classification. In addition, it presents the maximum surface area of materials allowed in a space to obtain the requirements of the selected indoor climate category. The Classification of Finishing Materials is intended to be used for each product separately.

The Classifications of Indoor Climate and Finishing Materials have three categories, and the Classification of Construction Cleanliness two categories. Indoor Climate category S1, Construction Cleanliness category P1, and Material category M1 correspond to the best quality. Categories S3, P2 and M3 present approximately the official quality set by building codes and regulations. The Finnish Building Codes are to be changed, and, thus, it shall be checked in every case that the official codes are fulfilled.

Problems related to moisture and molds are considered indirectly: if the ventilation operates as stated in the Classification and the building does not have moisture damages, the occurrence of mold problems is improbable. To prevent moisture damages, it shall be seen that the construction is designed and completed properly and that ventilation in bathrooms is adequate and operating continuously. The Classification does not deal with prevention of moisture damages by construction techniques because it is dealt with in details in other publications, such as guidelines published by the Finnish Building Information Institute.

The Classification is developed by Finnish Society of Indoor Air Quality and Climate, FISIAQ, by Risto Ruotsalainen, M.Sc. (Eng.) and Prof. Olli Seppänen from the Laboratory of Heating, Ventilating and Air Conditioning at Helsinki University of Technology. The work was financed by Ministry of the Environment and FiSIAQ. Specific expertise in the work was given by Alvar Hausen, M.Sc. (Eng.) (Hepacon Oy); Esko Kukkonen, M.Sc. (Eng.) (Ministry of the Environment); Hannu Martikainen, M.Sc. (Eng.) (Projectus Team Oy); Eero Palomäki, Architect (Tampere University of Technology); Jari Palonen, M.Sc. (Eng.) (Helsinki University of Technology); Jorma Railio, M.Sc. (Eng.) (Association of Finnish Manufacturers of Air Handling Equipment, SITY); and Kristina Saarela, M.Sc. (VTT Chemical Technology). The work was supervised by Sampo Martiskainen, Eng. (Ministry of the Environment); Marja Saari, M.Sc. (Eng.) (Ministry of the Environment); Timo Sarpila, M.Sc. (Eng.) (Construction Establishment of Finnish Defence Administration); Ass.prof. Matti Seppänen, Architect (Tampere University of Technology); and Helena Vuorelma, M.Sc. (Eng.) (Nordic Committee on Building Regulations, NKB).

INSTRUCTIONS ON HOW TO SELECT THE CATEGORIES

The Classification is intended to be used in the design of buildings. **The categories shall be selected at an early stage of a building project. The client selects the categories with the design team.** With the help of the Classification of Indoor Climate, the target values for indoor climate are specified either by choosing all the values from the selected category or by setting individually considered values for various factors. For design and guiding of construction work, the Construction category shall be selected (by choosing all the requirements of the selected category or by setting individually considered requirements for various points). For specifying finishing materials, the Material category shall be selected. The Classification is prepared so that the target values of the selected Indoor Climate category are fulfilled by using the corresponding Construction and Material categories. Thus, for example, the target values for air pollutants of Indoor Climate category S1 are not usually fulfilled by using finishing materials of Material category M3.

The Classification can also be used in evaluation of indoor climate of buildings and on the basis of the certificates given to the buildings on their indoor climate.

If necessary, the target values in a construction project can be selected from different categories. In practice, Indoor Climate category S1 requires mechanical cooling and room control of temperature. Indoor Climate category S2 may be achieved with skillful building design without mechanical cooling. In Indoor Climate category S3, room temperature may rise high in warm weather due to solar radiation and other heat loads.

Differences between the categories of Construction Cleanliness are risks which may lead to poor indoor air quality. The number of risks that pollutants and moisture generate during construction works will decrease when the work is performed in accordance with cleanliness and thoroughness of category P1. At a clean construction site under favorable circumstances, good results can be obtained when the work is performed in accordance with category P2. However, especially when the building is intended to be used continuously and it has also been built for allergic and other sensitive people, category P1 for the Construction Cleanliness shall be selected.

Use of low-emitting building materials shall be encouraged. Especially when the building is intended to be used also by allergic and other sensitive people, even small emissions from building materials may cause symptoms. Thus, emission tests of materials and product development shall be enhanced by requiring materials of high-quality and of low-emission with their product information and emission data.

CLASSIFICATION OF INDOOR CLIMATE

The Classification of Indoor Climate deals with common work and occupied spaces (office and public buildings, schools, day-care centers, dwellings, and other buildings of similar type). Exceptional requirements for rooms or requirements for special spaces are not presented in the Classification but they shall be specified case by case. The Classification of Indoor Climate has three categories: Category S1, S2 and S3. Category S1 is the best meaning higher satisfaction with indoor climate and lower level of complaints. For example in respect of room temperature, category S1 corresponds to 90% of satisfaction. Category S3 corresponds to the minimum requirements set by building codes. The target and design values of various factors can be selected from different categories, or, if required, the value of a factor can be specified separately or left without specification. The Classification can be referred to in the building specifications.

Target values

Table 1 presents the target values of indoor climate factors which are used to specify the target level of indoor climate at an early stage of a construction project. The target values can also be used for checking the indoor climate and compliance with the requirements. The target values apply to the occupied zone of a room which usually extends from the floor surface up to 1.8 meters from it, and begins from 0.6 meters from the walls /1/.

The concentrations of indoor air pollutants presented in Table 1 will not be exceeded in general if the ventilation rates are as high as specified in the Tables and if there are no specific pollutant sources in the room. Thus, measuring of indoor air pollutants is required only in special cases. It should be noted that the target values of indoor air pollutants do not necessarily guarantee healthiness of indoor air completely because the concentrations even smaller than the target values may still cause symptoms for sensitive people.

The Classification of Indoor Climate does not give target values for bioaerosols because the building may have mold damages even though the room air does not contain high concentration of bioaerosols. The concentration of bioaerosols may vary strongly depending on time, location, conditions and species of microbes. However, the concentration of microbes in room air shall be lower than in outdoor air. Higher concentration and different species of microbes in indoor air compared to outdoor air are usually signs of mold damage.

The compliance of the target values of indoor climate will be influenced not only by mechanical systems of the building but also by the building design, construction and operation. For this reason also the requirements presented in the Classification of Construction Cleanliness and of Finishing Materials shall be taken into consideration at the construction work. The categories of Indoor Climate, Construction Cleanliness and Finishing Materials shall be selected by the client together with the design team at an early stage of the construction project.

Design values

The design values presented in Table 2 shall be used specifically in dimensioning of heating and air-conditioning equipment. The designer also shall define the conditions where the building conforms to the design values, including:

- internal loads and operation of the room (number of occupants, lighting load, equipment load, etc.), and
- external loads of the room (weather conditions).

Outdoor design temperatures used in the dimensioning of heating systems are defined in the Finnish Building Codes /2/. When calculating indoor temperatures in summertime and dimensioning cooling systems, the climatic data shall be in accordance with the test year (1979 weather data) specified by the Finnish Climatic Institute (calculations to be performed with a one-week summer period so that the temperature of constructions is leveled off at the beginning of the calculations) /3/. When dimensioning the air conditioning of summertime, the maximum temperatures and the enthalpy value of 55 kJ/kg d.a. shall be used (in Northern Finland 50 kJ/kg d.a.). The design temperature of supply air to air condensers and air coolers shall be a minimum of 30 °C.

Verification of target values

The compliance of design and target values of a building shall be checked when the building is in operation; in winter when the outdoor temperature is below -5 °C, and in summer when the outdoor temperature is above 20 °C and the weather is clear. The compliance of design and target values in other than design conditions shall be checked with calculations taking into consideration also the capacity of heating and cooling equipment. Design and target values of indoor climate shall be measured with instruments which have a calibration certificate. The extent of measurements shall be made in accordance with the Finnish Standard SFS 5511 (the category of Indoor Climate S1 is equivalent to standard level C, and category S2 to level B, and category S3 to level A) /4/.

TARGET VALUES

Table 1. Target values of indoor climate.

Factor	Unit	Category S1	S2	S3	Remarks
Room temperature, winter	°C	21-22	21-23	20-24	1)
Room temperature, summer	°C	22-25	22-27	22-27(35) *	1)
Floor temperature	°C	19-29	19-29	17-31	4)
Vertical temperature difference	°C	<2	<3	<4	5)
Air velocity, winter 21°C	m/s	<0.10	<0.15	<0.15	6)
Air velocity, summer 24°C	m/s	<0.15	<0.20	<0.25	6)
27°C		<0.20	<0.25	<0.30	
Relative humidity of air, winter	%	25-45	–	–	7)
Relative humidity of air, summer	%	30-60	–	–	7)
Noise level of heating and air conditioning equipment	dB(A)				8)
offices		<30	<35	<35	
living and bedrooms		<25	<25	<28	
Air change rate (residence)	1/h	>0.8	>0.6	>0.4	9)
Ammonia (NH_3)	mg/m^3	<0.02	<0.03	<0.05	10)
Formaldehyde (H_2CO)	mg/m^3	<0.03	<0.05	<0.15	11)
Total volatile organic compounds (TVOC)	mg/m^3	<0.2	<0.3	<0.6	12)
Odor intensity	desipol	<2	<4	<5,5	13)
Carbon dioxide (CO_2)	ppm	<1000	<1250	<1500	14)
	mg/m^3	<1800	<2250	<2700	
Carbon monoxide (CO)	mg/m^3	<2	<5	<8	15)
Ozone (O_3)	mg/m^3	<0.05	<0.07	<0.10	16)
Total suspended particles	mg/m^3	<0.06	<0.06	<0.06	17)
Radon (Rn)	Bq/m^3	<200	<200	<200	18)

* room temperature shall never exceed +35 °C; room temperature shall not be above +27 °C when outdoor temperature is below +15 °C

'–' stands for no specific requirements are set

DESIGN VALUES

Table 2. Design values for indoor climate.

Factor		Unit	Category S1	S2	S3	Remarks
T1	Room temperature, winter	°C	21	21	20	1)
T2	Room temperature, summer	°C	24	26	27 (35) *	1)
T3	Control range of room temperature, winter	°C	±2	±2	–	2)
T4	Control range of room temperature, summer	°C	±2	–	–	2)
T5	Maximum temperature difference within a zone, winter	°C	**	<2	–	3)
T6	Maximum temperature difference within a zone, summer	°C	**	<5	–	3)
T7	Air velocity, winter	m/s	<0.10	<0.15	<0.15	6)
T8	Air velocity, summer	m/s	<0.15	<0.25	<0.30	6)
H1	Relative humidity, winter	%	25	–	–	7)
H2	Relative humidity, summer	%	60	–	–	7)
N	Noise level of heating and air-conditioning equipment	dB(A)				8)
	offices		<30	<35	<35	
	living and bedrooms		<25	<25	<28	
	kitchens		<30	<30	<35	

Q	Airflow for air quality	S1 l/s,p	S1 l/sm²	S2 l/s,p	S2 l/sm²	S3 l/s,p	S3 l/sm²	Remarks
	offices	16	2	12	1.5	8	1	9)
	conference rooms	12	8	9	6	6	4	
	classrooms	12	6	9	4.5	6	3	
	lecture halls	12	12	9	9	6	6	
	day-care centers	10	4	7.5	3	5	2	
	living and bedrooms	8	1	6	0.7	5	0.5	

* no mechanical cooling; temperature can be controlled with window airing; measures have to be taken that room temperature never exceeds +35 °C; room temperature shall not be above +27 °C when outdoor temperature is below +15 °C

** does not apply to category S1 because of room control of temperature

'–' stands for no specific requirements are set

REMARKS

Thermal conditions

1) Room temperature is the air temperature in the occupied zone. Target values apply to conditions where individual control of room temperature is not utilized at the maximum capacity. Room temperature shall be measured with a thermometer or an electrical sensor in accordance with the Finnish Standard SFS 5511 /4/. If the surface temperature of a room differs much from the air temperature (e.g. poorly insulated exterior constructions, double glazed windows, large windows, several external walls, floor faced by unheated space, solar radiation, floor heating, ceiling heating, cooled ceiling), the operative temperature shall be used as room temperature. Operative temperature can be calculated from the air and surface temperatures, or measured, for example, with a globe thermometer in accordance with the Finnish Standard SFS 5511 /4/.

2) Room control of temperature means the possibility to adjust the room temperature from the design value. In design conditions in summertime, the room temperature is required to be adjusted only to higher temperatures than the design temperature, and in wintertime to lower temperatures than the design temperature.

3) When room temperatures are controlled by a zone or system, the room temperature within a zone shall not differ from the design value more than presented in Table 2.

4) The floor temperature shall not be higher or lower than the temperature range in Table 1. In bathrooms, the floor temperature shall not be below 27 °C. The surface temperature shall be measured, for example, with an infrared thermometer or with a surface sensor in accordance with the Finnish Standard SFS 5511 /4/.

5) Vertical temperature difference means a temperature difference between the ankle and neck level with measuring heights of 0.1 and 1.1 m (1.8 m).

6) Air velocity is the omnidirectional average air velocity during three minutes in the occupied zone. It shall be measured, for example, with a hot wire anemometer in accordance with the Finnish Standard SFS 5511 /4/.

7) Relative air humidity may be below the target value for short periods during minimum outdoor temperatures. When the air is humidified, the humidifiers shall not increase the level of pollutants in the air. The air humidity shall be measured, for example, with a psychrometer or capacity sensor in accordance with the Finnish Standard SFS 5511 /4/.

Noise

8) Noise level is the sound pressure level either generated or transferred by heating and air conditioning equipment in an unfurnished room. The noise level can temporarily exceed the values of Tables 1 and 2 by 5 dB(A). The target values of narrow band noise are 5 dB (A) lower than in Tables 1 and 2. The noise level shall be measured, for example, with a sound pressure level meter in accordance with the Finnish Standard SFS 5517 /4/.

Airflows

9) The values of airflows are for the rooms with non-smoking occupancy. Outdoor airflows are specified in order to maintain good air quality. Usually the temperature control of the rooms requires higher airflows. Airflows are mainly used to remove the pollutants generated by occupants. Pollutants from building and interior decoration shall be primarily controlled by using low-emission materials (see Classification of Finishing Materials, category M1 or M2). It is recommended that outdoor airflows could be controlled according to the use and pollutant loads of the rooms.

   Airflows shall be measured, for example, with fixed sensors, anemometer tube or bag method in accordance with the Finnish Standard SFS 5512 /4/.

Air quality

The measurement of indoor air pollutants is necessary only in specific cases. Concentrations of indoor air pollutants are usually lower than the target values in Table 1 if the outdoor airflows correspond with the values in Table 2 and there are no specific pollutant sources in the room.

10) The concentration of ammonia in the room air shall be measured with an ion-selective method.

11) The concentration of formaldehyde in room air shall be measured, for example, with a liquid chromatograph (DNPH-method) or chromotrope-acid method in accordance with the Finnish Standard SFS 3862 /5/. The odor threshold of formaldehyde is approximately 0.05 mg/m^3.

12) The total concentration of volatile organic compounds (TVOC) in room air can be measured according to the references /6, 7/.

13) The odor intensity of room air shall be determined with a trained panel /8,9/.

14) The concentration of carbon dioxide includes carbon dioxide from outdoor and from human sources. CO_2 concentration shall be measured, for example, with an infrared analysator. The target values of CO_2 concentration are not exceeded usually if the outdoor airflows are higher than the lowest values specified for the corresponding category.

15) The concentration of carbon monoxide in room air shall be measured with an electro-chemical cell or infrared analysator in accordance with the Finnish Standard SFS 5412 /10/.

16) The concentration of ozone in room air shall be measured, for example, with a chemiluminence or UV-absorption method.

17) The concentration of total suspended particles of room air shall be measured, for example, with a filter method in accordance with the Finnish Standard SFS 3860 /11/.

18) The target value for radon concentration in room air for new residences is 200 Bq/m³. The annual average concentration of radon in residences shall not exceed 400 Bq/m³. The annual average radon concentration in work places during working hours shall not exceed 400 Bq/m³. Radon concentration shall be measured with the methods or equipment approved by Finnish Institute for Radiation Safety, STUK.

References

1. National Building Code of Finland, D2. Indoor climate and ventilation in buildings. Regulations and guidelines 1987. Ministry of the Environment. Helsinki 1987.

2. National Building Code of Finland, D5. Calculation of power and energy needs for heating in buildings. Guidelines 1985. Ministry of the Environment, Helsinki 1984. (in Finnish)

3. Tammelin B, Erkiö E. Energialaskennan säätiedot - suomalainen testivuosi. (Weather information for energy computation - a Finnish test year.) Raportti N:o 1987:7. Ilmatieteen laitos, Helsinki 1987. (in Finnish)

4. Suomen Standardisoimisliitto SFS. SFS-käsikirja 103. Ilmastointitekniikka, osa 2. (Handbookd of Finnish Standards 103, Air conditioning technology, part 2.) Helsinki 1992. (Including standards SFS 5511, SFS 5512 and SFS 5517) (in Finnish)

5. Suomen Standardisoimisliitto SFS. Standardi SFS 3862. Ilman laatu. Työpaikkailma. Formaldehydipitoisuuden määritys kromotrooppimenetelmällä. (Finnish Standard SFS SFS 3862. Air quality. Air quality at work places.

Determination of formaldehyde concentration by a chromotrope method.) Helsinki 1981. (in Finnish)

6. FiSIAQ. Indoor Air '93. Summary Report. FiSIAQ 1. Finnish Society of Indoor Air Quality and Climate (FiSIAQ), Helsinki 1993.

7. Tirkkonen T, Mroueh U-M, Orko I. Evaluation of Tenax TA adsorbent as a collection medium for volatile organic compounds in indoor air and material emission measurements - a literature survey. NKB committee and work report 1995:06E. Nordic Committee on Building Regulations (NKB), Indoor Climate Committee, 1995.

8. Clausen G, Pejtersen J, Bluyssen PM. Research manual of European audit project to optimize indoor air quality and energy consumption in office buildings. Technical University of Denmark, Laboratory of Heating and Air Conditioning, Lyngby 1993.

9. Jantunen M, Hyvärinen A, Jauhiainen A, Nevalainen A, Kangas J. Hajupaneelimenetelmän sisäänajo toimistotilojen sisäilmatutkimuksiin. (Breaking in of the odor panel method for investigating indoor climate in offices.) Raportti Työsuojelurahastolle. Kansanterveyslaitos, ympäristöhygienian ja toksikologian osasto, Kuopio, 1991. (in Finnish)

10. Suomen Standardisoimisliitto SFS. Standardi SFS 5412. Ilmansuojelu. Päästöt. Palamiskelpoiset savukaasut. Hiilimonoksidin määritys ei-dispersiivisellä infrapuna-absorptiomenetelmällä. (Finnish Standard SFS 5412. Air conservation. Emissions. Combustionable flue gases. Determination of carbon monoxide concentration by a non-dispersive infra-red absorption method.) Helsinki 1987. (In Finnish)

11. Suomen Standardisoimisliitto SFS. Standardi SFS 3860. Työpaikan ilman pölypitoisuuden mittaaminen suodatinmenetelmällä. (Finnish Standard SFS 3860. Measuring of dust concentration at a work place with a filter method.) Helsinki 1988. (in Finnish)

Chemical measurements

Chemical measurements are performed at least by the following Finnish institutes:

- Municipal health inspectors
- National Public Health Institute
- Institute of Occupational Health, and Regional Institutes of Occupational Health in Helsinki, Turku, Tampere, Lappeenranta, Kuopio, and Oulu
- Finnish Research Institute (VTT), Chemical Technology
- Universities

CLASSIFICATION OF CONSTRUCTION CLEANLINESS

The Classification of Construction Cleanliness gives the requirements for construction and air handling equipment and their installation and use for ordinary work spaces and residences. The extent and level of requirements depend on the category which is aimed at. The Classification has two categories: Category P1 corresponds to the best quality and category P2 to the level of the present construction practice specified by the Finnish building codes. In the specifications of a building, the requirements can be selected from either of the categories or leave some requirements out. It is appropriate for specifying the same category of Construction Cleanliness for rooms of the same type within the same zone. The Classification of Construction Cleanliness can be referred to in building specifications.

The categories of Construction Cleanliness are:

Category P1: Work spaces and residences where good air quality is aimed at
Category P2: Ordinary work spaces and residences

Requirements for specific spaces are not presented in the Classification of Construction Cleanliness but they shall be specified case by case when selecting the categories.

The Classification of Indoor Climate and the Classification of Finishing Materials shall be taken into consideration also in the design and construction of buildings. The categories of Indoor Climate, Construction Cleanliness and Finishing Materials are selected by the client together with the design team at an early stage of the construction project.

Good indoor air quality requires co-operation between all parties involved in the construction project and the fulfillment of all the requirements given. In the following chapter, important tasks are specified for various parties depending on the task: for designers (D), equipment manufacturers (M), contractors (C), and building users (U).

1 AIR CONDITIONING

1.1 Ducts and accessories and their installation

1.1.1 Manufacturing of ducts and accessories (M)

Category P1

Ducts and accessories shall be manufactured taking into consideration the following:

- they shall be cleaned after the manufacturing so that the interior surface does not contain oil or other harmful substances;
- tapes or tags shall not be attached on the interior surfaces;
- they shall not contain duct sealants with high emissions;
- the interior surfaces shall be smooth without any burs which may make the cleaning of the ducts difficult or break the cleaning equipment;
- the tightness of the ducts and accessories shall fulfill the requirements of category C specified in the Finnish Standard 4699 /1/.

Ducts and accessories shall be protected from dirt and moisture during the storage at the factory. The ends of the ducts shall be closed and accessories packed in closed boxes.

Category P2

Ducts and accessories shall be manufactured taking into consideration the following:

- they shall be cleaned from loose dirt;
- tapes or tags shall not be attached on the interior surfaces;
- they shall not contain duct sealants with high emissions;
- the interior surfaces shall be smooth without any burrs which may make the cleaning of the ducts difficult or break the cleaning equipment;
- the tightness of the ducts and accessories shall fulfill the requirements of category B specified in the Finnish Standard 4699 /1/.

Ducts and accessories shall be protected from dirt and water during the storage at the factory.

1.1.2 Transportation of ducts and accessories (M, C)

Category P1

Ducts and accessories shall be protected from dirt during transportation by closing the open ends of the ducts or by packing the accessories in closed boxes and by protecting the load by covering or by other means. If ducts are transported within each other, the exterior surfaces shall be as clean as the interior surfaces.

Category P2

The ducts and accessories shall be protected from dirt during the transportation by covering them or by protecting the load by other means.

1.1.3 Storage of ducts and accessories at the construction site (C)

Category P1

The ducts and accessories shall be protected against dirt and moisture both at the construction site and in temporary storage at the installation site. The caps of the duct ends shall be checked and broken caps repaired.

Category P2

The ducts and accessories shall be protected by covering during the storage.

1.1.4 Installation and protection of ducts during installation (C)

Category P1

The following items shall be noted when installing ducts and accessories:

- covers of ducts and accessories shall be removed only just before the installation
- during the installation, dirt shall not accumulate into the ducts and accessories;
- interior surfaces of ducts and accessories shall not have any burs, screws or other items which may accumulate dirt or make the cleaning of the ducts difficult;
- duct sealants with high emission rates shall not be used in sealing of ducts;
- all open ends of ductwork shall be closed dust-tight during the breaks of installation of ducts;
- ductwork shall be airtight (tightness class C according to the Finnish Standard 4699) /1/.

Category P2

The following items shall be noted when installing ducts and accessories:

- during the installation, dirt shall not accumulate into the ducts and accessories;
- open upper ends of vertical main ducts shall be covered during the breaks of installation of ducts;
- ductwork shall be airtight (class B in accordance with the Finnish Standard 4699 /1/).

1.1.5 Provisions for cleaning of ducts (D, C)

Category P1
The ductwork shall be built so that it is easy to clean without damaging the equipment installed in the ductwork or the cleaning equipment by using the selected cleaning method. A plan for cleaning of ductwork showing provisions of cleaning, including service accesses, shall be handed over to the user of the building during the commissioning process of air-conditioning system. The operation of service accesses shall be checked during the installation work.

Category P2
The ductwork shall be built so that it can be easily cleaned without damaging the equipment installed in the ductwork or the cleaning equipment by using the selected cleaning method. A plan for cleaning of ductwork showing provisions of cleaning, including service accesses, shall be handed over to the user of the building during the commissioning process of the air-handling system. The operation of service accesses shall be checked during the installation work.

1.1.6 Cleaning of the ducts (D, C)

Category P1
The ductwork shall be cleaned before the operational test of the building.

Category P2
The ductwork shall be cleaned before the operational test of the building.

1.1.7 Use of the hollowcore slabs as air ducts (D, M, C)

Category P1
If hollowcore slabs are used as air ducts, they shall be cleanable and stay dry and clean.

Category P2
If hollowcore slabs are used as air ducts, they shall be cleanable and stay dry and clean.

1.1.8 Protection of the sound damping materials (M, C)

Category P1
Sound damping materials in ducts and accessories shall be covered so that fibers from the material do not break loose even during the cleaning operation, or the sound attenuators shall be removed for the cleaning process of the ductwork and cleaned individually, or sound attenuators shall be replaced during the cleaning process of the ductwork.

Category P2
Sound damping materials in ducts and accessories shall be covered so that fibers from the material do not break loose even during the cleaning operation, or the sound attenuators shall be removed for the cleaning process of the ductwork and cleaned individually, or sound attenuators shall be replaced during the cleaning process of the ductwork.

1.2 The use of air-handling equipment during the construction work (C)

Category P1
Air-handling equipment shall not be used to heat, ventilate or air condition the building during the construction process. The operation of air-handling equipment shall be limited to perform only the balancing and measurements after the operational tests. During the use, the filters shall be on their positions as designed.

Category P2
If the air-handling equipment is used during the construction work, the air handling units shall be equipped with the filters as designed. Air-handling units shall be cleaned and filters replaced before the operational tests.

1.3 Air-handling units

1.3.1 Filters of air-handling units (D, C)

Category 1

The supply air of the air-handling units shall be cleaned with filters whose dust removal efficiency fulfills at least the European class EU 7 (F7). The air shall not bypass the filter media through the holes or leakages between the frames and air-handling units (total bypass of air shall be below 2% of airflow). The air-handling unit shall be airtight so that air does not flow through leakages to the supply air between fan and filter due to under pressure in the system (air tightness class C in accordance with the Finnish Standard 4699 /1/) or the filter shall be located after the supply fan.

Category P2

The supply air of the air-handling units shall be cleaned with filters whose dust removal efficiency fulfills at least the European class EU 4 (G4). The air shall not bypass the filter media through the holes or leakages between the frames and air-handling units (total bypass of air shall be below 6% of airflow). The air-handling unit shall be airtight so that air does not flow through leakages to the supply air between fan and filter due to under pressure in the system (air tightness class A in accordance with the Finnish Standard 4699 /1/) or the filter shall be located after the supply fan.

1.3.2 Heat recovery from the exhaust air (D, C)

Category P1

The pressure of supply and exhaust air in heat recovery equipment shall be such that exhaust air cannot flow through possible leakages in the heat recovery unit to the supply air. Regenerative heat recovery equipment (heat wheel, etc.) can be used only when the exhaust air does not contain tobacco smoke or other contaminants.

Category P2

The pressure of supply and exhaust air in heat recovery equipment shall be such that exhaust air cannot flow through possible leakages in the heat recovery unit to the supply air. Exhaust air shall be filtered with a filter classified to at least the European class EU 3 (G3) before regenerative heat recovery equipment.

1.3.3 Use of return air (D)

Category P1

Return air shall not be used in air-handling units with the exception of air-handling units which serve only one dwelling.

Category P2

Return air can be taken only from spaces with similar or better cleanliness. Return air shall be filtered with a filter classified at least to the European class EU 6 (F6).

1.3.4 Humidifiers (D)

Category P1
Humidifiers shall be hygienic and easy to clean. Only steam humidifiers can be used in air-handling units.

Category P2
Humidifiers shall be hygienic and easy to clean. Only steam or evaporative humidifiers can be used in air-handling units.

1.3.5 The construction of air handling units (D, M, C)

Category P1
The interior surfaces of air-handling units shall be easily cleaned. Motors and belt driven power transfer shall not be in the supply airflow of the air-handling units, or supply air shall be cleaned with minimum EU 7 (F7) filters after the fans.

Category P2
The interior surfaces of air-handling units shall be easily cleaned.

1.3.6 Outdoor air intake (D)

Category P1
Air-handling units shall have outdoor air intake of their own which shall locate in respect of exhaust openings and other sources of contaminants so that contaminated air does not re-entrain outdoor air intakes (Finnish Building Code D2 /2/).

Category P2
Air-handling units shall have outdoor air intake which shall locate in respect of exhaust openings and other sources of contaminants so that contaminated air does not re-entrain outdoor air intakes (Finnish Building Code D2 /2/). The air-handling units which take the outdoor air from the same outdoor air plenum shall have the same operation time or they shall be equipped with tight dampers.

1.4. Operation and maintenance

1.4.1 Instructions for operation and maintenance (D, U)

Category P1
The operation and maintenance instructions of air-handling equipment shall be handed over to the building users during the commissioning process of the air-conditioning system.

Category P2
The operation and maintenance instructions of air-handling equipment shall be handed over to the building users during the commissioning process of the air-conditioning system.

1.4.2 Operation of air-handling units (U)

Category P1
Air-handling units shall be running continuously at least one year after the building has been taken into use. Even after one year of occupancy, the air-handling units shall be started in the morning for a minimum of two hours before the building becomes occupied. Exhaust air fans of toilets and other similar spaces with contaminant sources shall be run continuously.

Category P2
Air-handling units shall be running continuously at least one year after the building has been taken into use. Even after one year of occupancy, the air-handling units shall be started in the morning for a minimum of two hours before the building becomes occupied. Exhaust air fans of toilets and other similar spaces with contaminant sources shall be run continuously.

1.4.3 Cleaning of the ducts (U)

Category P1
Supply air ductwork shall be inspected with a maximum interval of five years. If the duct contains dust (dust accumulates when sweeping the surface), the ductwork shall be cleaned. If necessary, the dustiness of the ducts can be checked by measuring the dust accumulation on the lower interior surface of the ductwork, for example, with a filter method /3/. If the accumulation of the dust is higher than 2 g/m², the ductwork shall be cleaned.

Category P2
Supply air ductwork shall be inspected with a maximum interval of five years. If the duct contains dust (dust accumulates when sweeping the surface), the ductwork shall be cleaned. If necessary, the dustiness of the ducts can be checked by measuring the dust accumulation on the lower interior surface of the ductwork, for example, with a filter method /3/. If the accumulation of the dust is higher than 5 g/m², the ductwork shall be cleaned.

1.4.4 Replacement of filters (D, U)

Category P1

Fiber filters of air-handling units shall be replaced according to final pressure drop defined by the designer or, at latest, when more than half of its back surface has changed its color due to accumulated dust. However, fiber filters shall be replaced with maximum intervals of six months, with the exception of a two-stage filtering when the course filters shall be replaced with maximum intervals of three months and fine filters with maximum intervals of one year.

Category P2

Fiber filters of air-handling units shall be replaced according to final pressure drop defined by the designer or, at latest, when its whole back surface has changed its color due to accumulated dust. However, course filters shall be replaced with maximum intervals of six months and fine filters with maximum intervals of one year.

2 CONSTRUCTION WORK

2.1 Separation of the spaces classified according to the Classification of Construction Cleanliness

The spaces belonging to Construction Cleanliness category P1 shall not be separated from other spaces before

- Construction works generating a lot of dust, such as drilling holes, pick dressing, and grinding of surfaces have been completed in the spaces. If the space shall be protected earlier because of the overall coordination of the construction work, works generating a lot of dust shall be done with tools with local exhaust. In addition, the spaces shall be ventilated well during dust-generating construction works.
- There is no more need to transfer machines, equipment and materials through the classified spaces. The separated space shall not be used for regular passage if the adjacent spaces belong to the lower category of Construction Cleanliness.

If the classified space shall be protected before the concrete surfaces have reached the target value of humidity for surface coating, the space shall be ventilated, and in the wintertime, warm air shall be supplied into the space.

2.2 Building materials and accessories

2.2.1 Transportation of building materials and accessories

Category P1
The materials and accessories that are intended to be used inside the building shall be protected against dirt and moisture during the transportation by covering or protecting the load in other ways.

Category P2
The materials and accessories that are intended to be used inside the building shall be protected against dirt and moisture during the transportation by covering or protecting the load in other ways.

2.2.2 Storage of building materials and accessories at the construction site

Category P1
The materials and accessories that are intended to be used inside the building shall be protected against dirt and moisture both during the storage at the construction site and in temporary storage at the installation site.

Category P2
The materials and accessories that are intended to be used inside the building shall be protected against dirt and moisture both during the storage at the construction site and in temporary storage at the installation site.

2.2.3 Protection of building materials and accessories during their installation

Category P1
Uncompleted and completed parts of constructions shall be protected so that they will not get damaged or wet during the breaks of the installation work. The protecting covers of the materials that are intended to be used inside the building shall be removed only just before the actual installation. When installing the finishing materials, the air of the room shall be clean and dry, and construction works generating dust and other pollutants may not be performed in the vicinity of the worksite.

Category P2
Uncompleted and completed parts of constructions shall be protected so that they will not get damaged or wet during the breaks of the installation work.

2.2.4 Labeling during the construction

Category P1
The spaces shall have a clear label indicating the Construction Cleanliness category P1.

Category P2
The spaces do not have to be labeled with any specific signs.

2.2.5 Protection of spaces

Category P1
The spaces shall be protected so that dust and other dirt do not transfer from other spaces during the construction. The protection can be made by closing all openings and pathways to the space with plastic foil.

Category P2
Spaces do not need any specific protection or cover.

2.3. Cleaning

2.3.1 Cleaning of the spaces during the construction

Category P1
Left-overs of the building materials and course dust shall be cleaned from the spaces with a shovel, spatula or a vacuum cleaner of high efficiency. Fine dust shall be removed with a vacuum cleaner with an exhaust air filter of a minimum removal efficiency of 98% for 3 μm particles. Exhaust air filters of vacuum cleaners shall be changed regularly. Spaces shall be cleaned by vacuuming weekly and, in addition, in situations where the dust is generated in the space.

Category P2
Left-overs of the building materials and course dust shall be cleaned from the spaces with a shovel, spatula or a vacuum cleaner of high efficiency. Fine dust shall be removed with a vacuum cleaner with exhaust air filter of a minimum removal efficiency of 98% for 3 μm particles. Exhaust air filters of vacuum cleaners shall be changed regularly. Spaces shall be cleaned by vacuuming weekly and, in addition, in situations where the dust is generated in the space.

2.3.2 Final cleaning of the spaces

Category P1

The final cleaning (also for nonvisible surfaces) shall be made with a vacuum cleaner with an exhaust air filter of minimum removal efficiency of 98% for 3 μm particles, and, in addition, hard and smooth surfaces shall be wiped with a moist material. Surfaces shall be cleaned in accordance with the instructions given by the material manufacturer. Cleaning and maintenance materials (also waxes) shall be emission tested.

Category P2

The final cleaning (also for nonvisible surfaces) shall be made with a vacuum cleaner with an exhaust air filter of minimum removal efficiency of 98% for 3 μm particles, and, in addition, hard and smooth surfaces shall be wiped with a moist material. Surfaces shall be cleaned in accordance with the instructions given by the material manufacturer.

References

1. Suomen Standardisoimisliitto SFS. Standardi SFS 4699. Ilmastointi. Ilmastointilaitosten tiiviysvaatimukset. (Finnish Standard SFS 4699. Air conditioning. Requirements for tightness of air conditioning systems.) Helsinki 1988. (in Finnish)

2. National Building Code of Finland, D2. Indoor climate and ventilation in buildings. Regulations and guidelines 1987. Ministry of the Environment, Helsinki 1987.

3. Luoma M, Pasanen A-L, Pasanen P. Ilmastointilaitosten puhdistustekniikka. (Cleaning of air-conditioning systems.) VTT Tiedotteita 1492. Valtion teknillinen tutkimuskeskus, Espoo 1993. (in Finnish)

CLASSIFICATION OF FINISHING MATERIALS

There are various chemicals that are emitted from building and interior decoration materials into room air. They can originate, for example, from mistakes in manufacturing process or aging of materials. Improper use of materials may also be a reason for emissions. The concentration of chemicals in room air depends on total emission of materials and ventilation. The concentration of room air can be diminished by decreasing the total emission or by increasing the ventilation and improving the ventilation effectiveness. To achieve low concentration of chemicals, the main controlling method shall be the use of low-emitting materials and, secondly, increase of ventilation. The purpose of the Classification of Finishing Materials is to present requirements for the materials used in ordinary work spaces and residences to achieve good indoor air quality. The goal is also to enhance the development and use of low-emitting materials so that material emissions do not increase the requirement for ventilation. However, use of low-emitting materials does not guarantee good quality of room air. Ventilation shall be adequate and materials shall be used according to the manufacturers' specifications. For example, very few materials can stand for excessive moisture or installing onto moist substructure. Materials shall also be easy to clean.

The Classification of Finishing Materials has three categories, category M1 being the best and category M3 containing materials with highest emission rates. Because the total amount of emissions is also influenced by the amount of used materials, the Classification gives guidelines for the use of materials in various categories. When the best Indoor Climate category S1 is selected, the use of higher emitting materials (categories M2 and M3) shall be limited.

The design and construction of buildings shall comply also with the requirements set in the Classification of Indoor Climate and the Classification of Construction Cleanliness. The client selects the categories of Indoor Climate, Construction Cleanliness and Finishing Materials with the design team at an early stage of the construction project.

Requirements for finishing materials

Category M1: Category M1 is designated for emission tested materials whose emissions fulfill the following requirements:

- emission of total volatile organic compounds (TVOC) is below 0.2 mg/m^{2}h;
- emission of formaldehyde (H_2CO) is below 0.05 mg/m^{2}h;
- emission of ammonia (NH_3) is below 0.03 mg/m^{2}h;
- emission of carcinogenic compounds according to category 1 of IARC classification /1/ is below 0.005 mg/m^{2}h;
- the material is not odorous (dissatisfaction with the odor is below 15%).

Category M1 includes also natural materials which are known to be safe in respect of emissions:

- brick
- natural stone and marble
- ceramic tile
- glass
- metal surfaces
- board and log (Finnish wood) whose emissions as fresh, however, may be higher than those specified for materials of category M1.

Category M2: Category M2 is designated for emission tested materials whose emissions fulfill the following requirements:

- emission of total volatile organic compounds (TVOC) is below 0.4 mg/m^{2}h;
- emission of formaldehyde (H_2CO) is below 0.125 mg/m^{2}h;
- emission of ammonia (NH_3) is below 0.06 mg/m^{2}h;
- emission of carcinogenic compounds according to category 1 of IARC classification /1/ is below 0.005 mg/m^{2}h;
- the material is not strongly odorous (dissatisfaction with the odor is below 30%).

Category M3: Category M3 includes materials which do not have emission data or the emissions exceed the values specified for materials in category M2.

Emissions shall be measured when the material is in the actual, final form intended for its use. As to the paints, the sample can be tested according to the guidelines presented in references /2, 3, 4/. When the finishing material is not tested as it is finally used, the emission category of combined materials is defined in accordance with the material which has the highest amount of emissions. For example, if the construction board classified to category M2 is painted with a paint of category M1, it belongs to category M2 until the actual measurements of the combined material show different results. The same applies to wall papers, varnishes, and surface materials of floors (e.g. waxing of the floor may increase the emissions considerably).

The manufacturer of the material shall have an acceptable quality control system. The emission test of the material shall be renewed if the production components or process of the material changes.

Use of finishing materials

When the ultimate goal is low concentrations of chemicals in the room air, the use of high emitting materials shall be limited. When the materials are used as described below and the ventilation rates comply with the Classification of Indoor Climate, the air quality in Indoor Climate categories S1 and S2 correspond to good air quality. The concentration of total volatile organic compounds (TVOC) in category S1 is below 0.2 mg/m^3 and in category S2 below 0.3 mg/m^3. The room air in category S1 is almost odorless (odor intensity below 2 decipols), and in category S2 room air may have slight odor (odor intensity below 4 decipols).

For the Indoor Climate Category S1, the finishing materials shall be selected mainly from category M1. The finishing materials belonging to category M2 shall not cover more than 20% of the interior surfaces of a room which shall be less than 1 m^2 per floor area. The use of the materials belonging to category M3 shall be limited to minimum.

For the Indoor Climate Category S2, the finishing materials shall be selected mainly from categories M1 and M2. The finishing materials belonging to category M3 shall not cover more than 20% of the interior surfaces of a room which shall be less than 1 m^2 per floor area.

Classified materials shall have a product specification presenting emission data and possible limitations for the use of the material and requirements for environmental conditions when the material is applied, such as temperature and humidity.

Measurement methods

Material emissions shall be measured in accordance with the chamber method specified in the guidelines of Nordtest, ECA or European Data Base project /3, 4, 5, 6, 7/. The sampling and analysis of chemicals shall be made in accordance with internationally accepted methods, for example /5, 8/. Emissions from materials shall be measured after four weeks from the date of the production or the date when the material is unwrapped from its airtight packing. The samples shall be stored in a climate chamber for four weeks before testing. The time of four weeks for paints, leveling agents, adhesives, duct sealant, etc. starts from the date of application on the surface.

References

1. WHO. IARC monographs on the evaluation of carcinogenic risks to humans. Overall evaluations of carcinogenicity: an updating of IARC monographs volumes 1 to 42. Supplement 7. World Health Organization (WHO), International Agency for Research on Cancer (IARC), 1987.

2. Larsen A. Optimalt valg af malematerialer til invendige bygningsoverflader. (Ideal choice of painting materials for interior building surfaces.) NKB Utskotts- och arbetsrapporter 1993:03. Nordiska kommittén för byggbestämmelser (NKB), Inomhusklimatutskottet, Helsingfors 1993. (in Danish)

3. Nordtest. Building materials: emission of volatile compounds, chamber method. Nordtest method, NT BUILD 358. Nordtest (PL 111, 02101 Espoo), Espoo 1990.

4. ECA. Guideline for the characterization of volatile organic compounds emitted from indoor materials and products using small test chambers. EUR 13593 EN. European Collaborative Action (ECA), 1991.

5. ECA. Indoor air and its impact on man. WG10: evaluation of material emissions, final report. European Collaborative Action (ECA), 1996 (forthcoming).

6. European Data Base on Indoor Air Pollution Sources in Buildings. 1995 (forthcoming).

7. Saarela K. Preliminary investigation of ammonia levels in indoor air and evaluation of ammonia sources. Proceedings of IAQ 92, Environments for People. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta 1993.

8. Tirkkonen T, Mroueh U-M, Orko I. Evaluation of Tenax TA adsorbent as a collection medium for volatile organic compounds in indoor air and material emission measurements - a literature survey. NKB committee and work report 1995:06E. Nordic Committee on Building Regulations (NKB), Indoor Climate Committee, 1995.

9. GBR and SP. Trade standard: measurement of chemical emission from flooring materials. The Swedish National Flooring Trade Association (GBR) and the Swedish National Testing and Research Institute (SP), Stockholm 1992.

Institutes that perform chemical emission measurements

Emissions of materials are measured, for example, by the following Finnish research institutes:

- National Public Health Institute
- Institute of Occupational Health, and Regional Institutes of Occupational Health
- VTT Chemical Technology
- Universities