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Strategy for Studying Air Quality in Office Buildings

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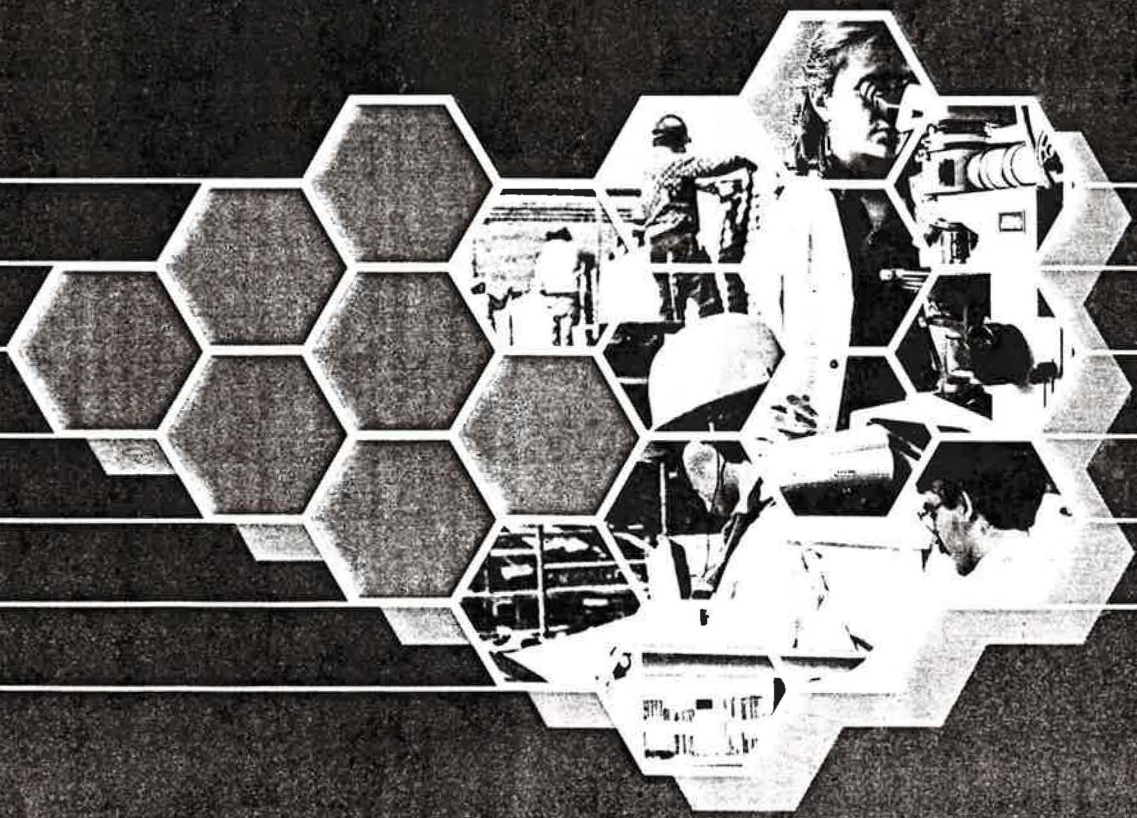

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 FOREWORD

This guide has been developed for building owners, managers, employers and workers who must solve air quality problems in their buildings. It is an action tool allowing problems related to the physical performance of a building and its HVAC system to be identified, evaluated and controlled.

The proposed procedure has been developed for air quality studies in office buildings. Cases related to other non-industrial work environments such as hospitals, schools, and day-care centres present more complex problems and require adapted strategies. Nevertheless, the same steps (understanding the environment, evaluating suspected problems, and implementing corrections at source) apply to all these environments.

Lastly, the procedure retained covers all factors most often affecting air quality in office buildings. Its precise and achievable objectives result in concrete solutions, and in the milieu involved assuming responsibility for the quality of their air.

2.0 INTRODUCTION

Increased insulation and reduced ventilation of buildings to save energy, the growing use of synthetic materials and household chemical products, and the increased pollution of outdoor air are all phenomena that contribute to deterioration in indoor air quality. The number of complaints related to this deterioration continues to increase.

The World Health Organization estimates that 30 % of newly-built or renovated buildings have characteristics which can be related to " tight building syndrome ", and that the number of occupants affected is between 10 and 30 % [1]. This syndrome is defined as a phenomenon generally associated with the indoor environment of certain non-industrial workplaces that produces a combination of non-specific symptoms related to comfort and health (such as eye, nose and throat irritation, mental fatigue, headaches, non-specific hypersensitivity, and other similar complaints) in a significant number of occupants, and whose causes are generally unknown [2].

Although the direct causes of these symptoms are unknown, factors that contribute to this syndrome can be determined. Among them are inefficient ventilation, poor air quality, inadequate layout of work stations, insufficient

[1] *All the numbered references are listed on page 31 of this document. References marked with a cross appear at the foot of the corresponding page.*

lighting, ambient noise, and all factors related to working conditions and work relations. The numerous studies published indicate that inefficiency of the ventilation from the standpoint of the quantity of new air and its distribution to the work stations, as wellas insufficient maintenance of the components, are the main sources of problems.

In the present procedure, four groups of parameters are retained because they are the ones most likely to explain the observed problems, and can also be measured directly and objectively. They are: the characteristics of the ventilation system, comfort parameters, air quality in relation to chemical contaminants and bioaerosols, and the working environment including noise and lighting.

3.0 PROPOSED PROCEDURE

The proposed procedure is divided into three steps, namely: identification, evaluation, and control. In several cases involving problems in office buildings, the first step (consisting of identifying the components of the problem) can directly result in the implementation of solutions without the use of elaborate technical measures. However, when this technical evaluation is necessary, the measurement strategy must take into account observations, findings and information obtained during the preliminary study.

The first step, which consists of collecting information, must establish the scope of the study, the procedures to be carried out, and the appropriate strategy. This is achieved through an inspection of the building and its environment. The factors to be considered are: the type of building, the materials used in its construction, any renovations or modifications, and the type and condition of the HVAC system. Other observations must be noted, such as layout of the premises, the use of space, and the actual activities carried out.

In order to make this information-gathering easier, a questionnaire has been developed for each of the series of parameters considered, namely ventilation, comfort, chemical and biological contaminants, and the work environment.

The second step of the evaluation is based on direct measurement of the contaminants and the different ventilation, comfort, noise, and lighting parameters. The method used and the equipment required are given for each of the parameters. A list of the measuring instruments is provided in *Appendix I*. The results obtained are then compared to the various available standards and recommendations. In Quebec, regulatory provisions concerning the parameters related to air quality in work environments are found in the *Regulation respecting the quality of the work environment* (S-2.1, r.15) [3] and in the *Regulation respecting industrial and commercial establishments* (S-2.1, r.9) [4]. The *National Building Code of Canada* is also applicable in Quebec [5]. The standards contained in this code deal with design and construction criteria for buildings. ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.) is the most frequently used reference source for ventilation and maximum allowable concentrations of contaminants in office buildings [6, 7, 8]. The Canadian Government has also issued guidelines concerning air quality in residences [9]. ISO (International Standards Organization) has issued recommendations concerning comfort parameters [10]. Our reference source on bioaerosols is the Committee on Bioaerosols of the ACGIH (American Conference of Governmental Industrial Hygienists) [11].

The final and essential step consists of finding solutions to the deficiencies observed in the ventilation system, its components, in air distribution, and layout of the premises, and of implementing them, verifying their effectiveness, and primarily, of ensuring continuity. In other words, this means establishing a regular preventive maintenance program for the mechanical components and making sure that any modification to the layout or use of the space will take into account the ventilation and the occupant comfort parameters. In addition, corrective measures for contaminant emission and noise sources will have to be implemented and their effectiveness periodically checked.

This three-step procedure, namely identification, evaluation and control, is presented separately for each of the four groups of parameters: ventilation, comfort, contaminants, and the work environment. However, the procedure must be carried out in an integrated way since several of these parameters are interrelated and all contribute to the quality of life in the workplace.

3.1 VENTILATION

Since deficient ventilation is the most frequent cause of the problems encountered in office buildings, understanding ventilation is essential.

In most mechanically-ventilated office buildings, the purpose of the system is to supply the workplace with air-conditioned and humidified fresh air, and to exhaust vitiated air to the outdoors. The distributed air is usually a mixture of fresh air (i.e., outdoor air) and recirculated air (i.e., indoor air that has been treated). This air mixture is then filtered, humidified, heated or cooled, and distributed throughout the building. The diagram in *Figure 1* illustrates the operation of such a ventilation system, called a free-cooling system.

Two types of air distribution systems are normally encountered: constant flow systems and variable flow systems. In a constant volume system, the amount of air that comes out through the diffusers is always the same. This air comes from a mixture of hot and cold air, and the temperature set at the thermostat sets the proportion of each. In a variable air volume system, the amount of air that comes out of the diffusers is a function of the temperature set at the thermostat, since the air being supplied is at constant temperature of about 16°C. Therefore, when heat is needed, the air inlet will be at a minimum, and conversely, it will be at a maximum when cooling is desired.

3.1.1 Identification of problems

The problems associated with mechanical ventilation can be grouped into four categories:

- total air flow;
- fresh air flow;
- total air distribution to work areas;
- operation and maintenance of the ventilation system and its components.

Preliminary inspection of the ventilation system will reveal certain anomalies or defects. The questionnaire in *Table1* lists the most useful observations to be made during this walk-through study. These observations can lead to technical evaluation of parameters or to direct corrective action.

3.1.2 Evaluation of problems

Technical measurements will be necessary for certain parameters that cannot be determined by observation, such as new air and total air flows, and for certain detected anomalies. Measurement methodologies are explained below.

TOTAL AIR

Total air ventilation (or general ventilation) is the mechanical ventilation by which the total air (or the supply air) is distributed to the work stations. Total air is a mixture of fresh air (or new air) and recirculated air (or return air). Total air is generally conditioned, that is, filtered, humidified or dehumidified, and heated or cooled. Total air is used to exhaust thermal loads as well as air contaminants from work areas, and to provide occupants with comfortable conditions (air temperature, humidity, air velocity).

Article 16 of the Quebec *Regulation respecting the quality of the work environment* [3] requires a minimum total-air flow of 45 L/s/person for an occupancy rate of one person per 10 m^2 of office floor area.

To determine this flow, only the following need to be known:

- the system's total flow rate;
- the occupancy rate for the area served by this system.

Three methods are available for evaluating the total air flow in a ventilation system.

a) Theoretical evaluation

The total air flow is normally indicated on the original design plans and specifications for the ventilation system. However, the actual flow can be lower or higher due to wear or unbalancing of the fans, and subsequent modifications.

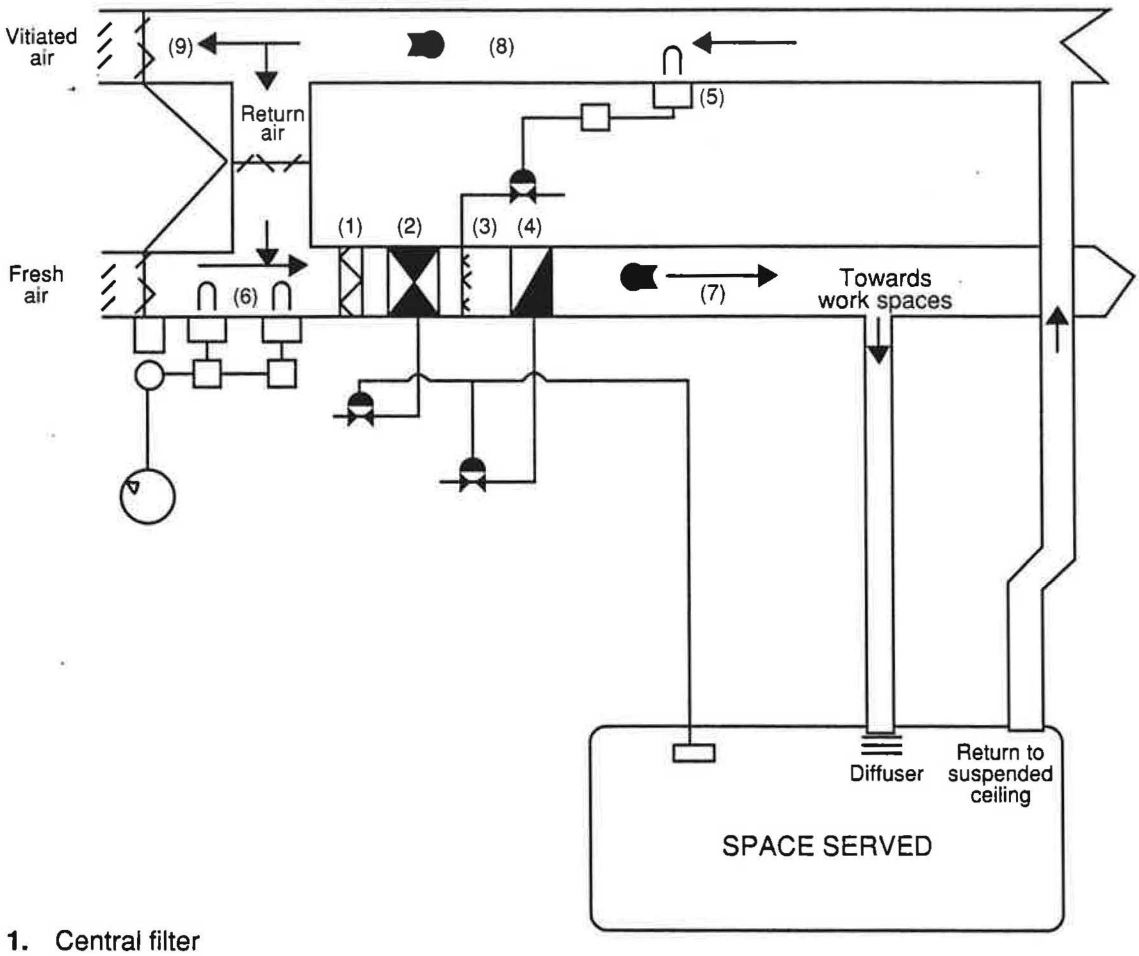
b) Measurement of the total air flow in the supply duct

Total air supplied to work areas passes through the supply duct of a central ventilation system.

The total air flow is measured in this duct by hot-wire or revolving vane anemometers or by a Pitot tube and a manometer according to the methods recommended in the " Industrial Ventilation " manual of the American Conference of Governmental Industrial Hygienists (ACGIH) [12].

Another measurement technique uses a computerized omnidirectional multisensor velometer system. The sensors installed in the air supply duct are connected to a computer that continuously records air velocities. The average air velocity multiplied by the cross-sectional area of the duct gives the total air flow.

FIGURE 1: DIAGRAM OF A VENTILATION SYSTEM



1. Central filter
2. Heating coil
3. Water spray humidification system
4. Cooling coil
5. Humidistat in the return duct
6. Thermostat in the fresh air duct
7. Supply fan
8. Return-air fan
9. Dampers

c) Measurement of the total air flow from the diffusers

The total air is distributed throughout the work areas by diffusers located in the walls or in the ceiling. The flows from all the diffusers connected to the ventilation system are measured using a velometer, and their sum becomes the total air flow for the ventilation system.

The occupancy rate for a work area should also take into account occasional occupants and the regular comings and goings of the public. This is important in buildings where the public is continuously present in significant numbers.

FRESH AIR (NEW AIR)

Fresh air (or new air) is introduced into each building by the mechanical ventilation system to dilute the indoor contaminants. Fresh air flow is usually variable and depends mainly on the outdoor temperature. In general, at extreme outdoor temperature conditions (very hot or very cold), the fresh air flow entering the building is at a minimum.

The *Regulation respecting the quality of the work environment* [3] requires a minimum flow of 2.5 L/s/person, whereas international organizations such as ASHRAE recommend higher flows in the order of 7.5 L/s/person [7].

There are four ways of measuring the fresh air flow in a building:

a) Measurement in the fresh air duct

The fresh air flow is measured directly in the fresh air duct using anemometers or a multisensor velometer, as in the case of total air flow. In order to measure the minimum fresh air flow, the evaluation must be carried out at extreme outdoor temperature conditions (at -20°C or +30°C, for example).

b) Temperature measurement

Fresh air flow can also be measured indirectly using temperature measurements by the following formula:

$$\text{Fresh air flow} = \frac{TR - TM}{TR - TE} \times \text{Total air flow}$$

where:
- TR = Temperature of the return air in the return duct
- TM = Temperature of the total air in the supply duct
- TE = Temperature of the outdoor air.

This measurement method is approximate. However, it is the easiest to use and requires only a thermometer.

c) Tracer gas method

The tracer gas principle is relatively simple: a homogeneous and known concentration of a tracer gas is generated artificially in a given space, and its disappearance rate is then continuously measured. From the disappearance rate, the fresh air flow introduced into the given space can be determined.

This method is based on the following mass-balance equation:

$$V \frac{dc}{dt} = F - Qc$$

where:
- V = Physical volume of the space in question
- dc/dt = Rate of variation in the tracer gas concentration as a function of time
- F = Rate at which the tracer gas is introduced into the occupied space
- Q = Fresh air flow entering the occupied space
- c = Tracer gas concentration.

Technical problems, such as choosing the tracer gas and the monitoring equipment, make the tracer gas method usable only by specialized personnel.

d) CO_2 method

This method is a simplified version of the tracer gas method. It is based on the rate of disappearance of the carbon dioxide (CO_2) generated by the occupants, and the fresh air flow rate per work station can be evaluated as follows:

$$Q = \frac{R \times V \times 10^3}{N \times 3600}$$

where:
- $R = \frac{1}{T} \ln (C_o / C_t)$
- Q = Fresh air flow per person (L/s/person)
- R = Fresh air flow rate per hour ($hour^{-1}$)
- T = Time (hours)
- C_o = Concentration of CO_2 at the beginning of the test minus the concentration in the outdoor air (ppm)

C_t = Concentration of CO_2 at time t minus the concentration in the outdoor air (ppm)

V = Volume of the room (m^3)

N = Number of persons in the room (persons)

This method is relatively easy to use. However, several aspects must be considered in interpreting the results: the presence of occupants who continue to generate CO_2; the number of persons N, which can vary; and the room volume, which is difficult to evaluate in the case of open areas. CO_2 is measured using a direct-reading instrument (*Appendix I*).

As in the case of total air, the flow of new air per person must take into account the building's clientele, where applicable.

AIR DISTRIBUTION

Supply air or total air is distributed locally to the work areas by a distribution network consisting of ducts, mixing and control boxes, and diffusers located in the suspended ceiling or in the walls. Distribution systems function at constant or variable air volumes, as explained in section 3.1.

The distribution network is said to be well-balanced if the flows from the diffusers respect the original specifications. In addition, supply air must be supplied in conformity with the standards in the *Regulation respecting the quality of the work environment* [3] which requires a rate of 45 litres of total air per second per person, or 90 cubic feet per minute per person.

Total air flows from the diffusers are measured using a velometer. In the case of a variable air volume system, however, they must be measured at extreme thermostat conditions. The sum of the flows from the diffusers divided by the total number of occupants in this work area must comply with the standard of 45 L/s/person.

The method for calculating new air flow using the CO_2 method also allows air distribution to be determined, since measurements are taken locally.

SYSTEM OPERATION AND MAINTENANCE

Regulatory provisions dealing with the operation and maintenance of ventilation systems are contained in articles 21, 22 and 80 of the Quebec regulation [4].

Three important points are to be verified: the lead time for the system, the filters, and the system controls.

- Lead time for the ventilation system before the arrival of workers

The ventilation system must be started before workers arrive in order to exhaust contaminants that have accumulated inside the building during the night.

ASHRAE has established a curve giving the minimum lead time for a system as a function of the minimum fresh air flow set per person (L/s/person) and the volume occupied per person (m^3/person). *Figure 2* shows this curve taken from ASHRAE standard 62-1981R [7].

Thus, for a flow of 7.5 L/s/person and an occupation density of 21 m^3 per person, start-up of the system must precede the arrival of the workers by four hours.

- Air filters

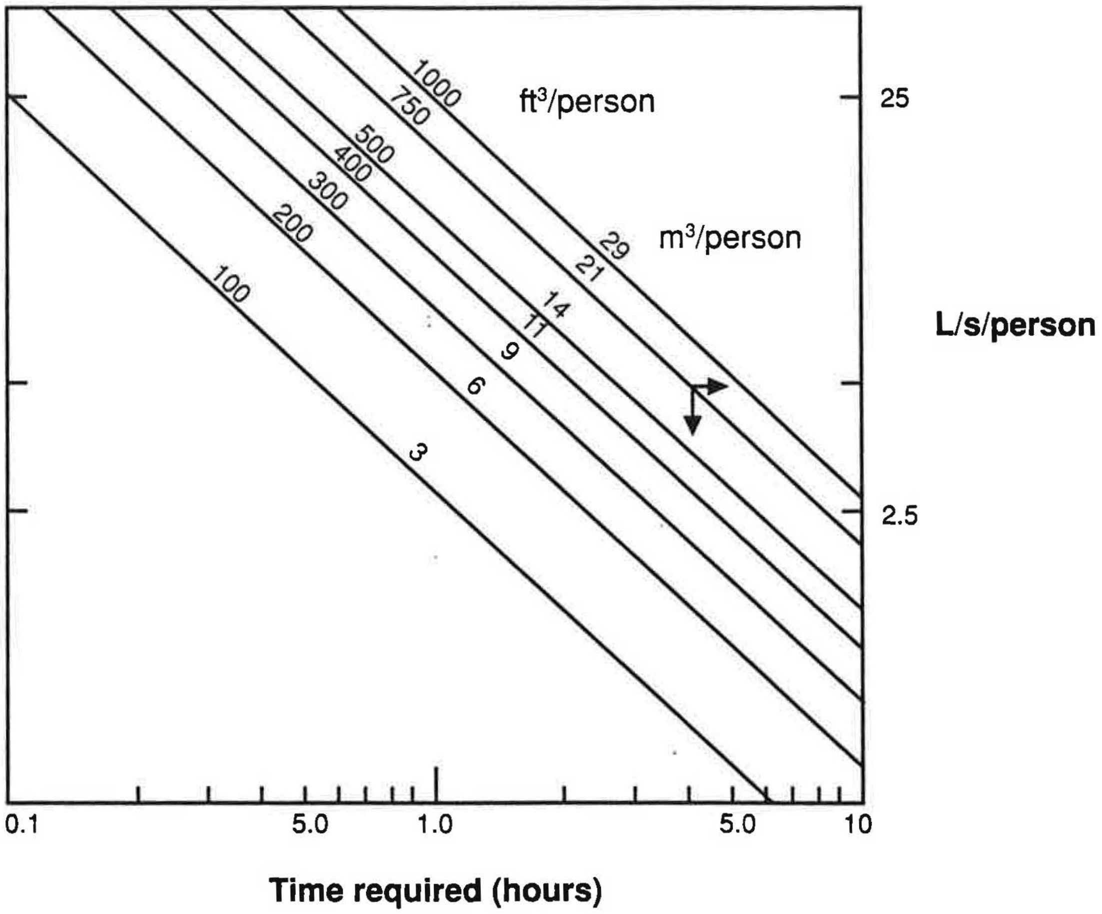
Air filters are installed in the supply duct of the central ventilation system in order to collect outdoor and indoor dusts (cigarette smoke, carpet dust, etc.) and bioaerosols. Recommended practice is to install two layers of filters: prefilters are used to collect large dust particles, insects, etc., while high efficiency filters will collect microorganisms and dust of micron size. Filters should have an efficiency of 85 % according to ASHRAE. Furthermore, filters must be regularly changed in accordance with the manufacturer's recommendations. Filters that are too dirty will reduce flows from the fans and can be breeding grounds for bacteria and fungi.

In addition to visual verification of the existence and condition of the filters, the pressure drop must be measured. A filter is effective only if the pressure drop across it falls within the pressure range recommended by the manufacturer. For example, a manufacturer may recommend that a filter be changed when the pressure drop reaches 5 cm w.g. The pressure drop across a filter can be measured using a U tube or a differential manometer (*Appendix I*).

- System controls

Periodic calibration of all system controls (electrical, pneumatic, or mechanical) is absolutely necessary for the ventilation system to operate properly. According to IRSST studies, the humidistat (relative humidity sensor) is the component that is most often defective. According to the same studies, 10 to 20 % of thermostats are poorly calibrated. Controls for opening and closing the fresh air and diffusion air dampers must be regularly monitored, in addition to the temperature, pressure and relative humidity dials in the central control room.

FIGURE 2: MINIMUM LEAD TIME FOR THE VENTILATION SYSTEM BEFORE THE ARRIVAL OF OCCUPANTS



Two control devices which are easily checked are the humidistat and the thermostat. This involves measuring the temperature and the relative humidity in the return duct using a psychrometer, and comparing the values obtained with those indicated by the reference humidistat and thermostat.

3.1.3 Corrective and control measures

When measurements reveal an insufficient supply of total or new air per person, uneven air distribution, or deficiencies in system components, it is important that the causes be determined. The most frequent causes are mentioned in *Table 2*, as well as the solutions to be implemented.

TABLE 1: OBSERVATION QUESTIONNAIRE ON THE VENTILATION SYSTEM

OBSERVATION	ACTION TO BE TAKEN (if necessary)
Is there a mechanical ventilation system?	Evaluation of flow: theoretical or measured
Has the original system been modified?	Evaluation of the new flow
Does the system operate continuously?	Knowledge of the schedule
Is there an energy savings program?	Understanding its operation
How is the degree of opening of the fresh air dampers controlled?	Evaluation of the new air flow
Where is the fresh air intake located?	Relocation of the fresh air intake
Are there pollutant emission sources near the fresh air intake?	Evaluation of pollutant concentrations in the fresh air, or relocation of the intake
Are the fresh air dampers in good condition and unobstructed?	Replacement and cleaning
Filters:	
• *What type are they?*	Change filter type
• *What is their theoretical efficiency?*	Change filter type
• *How often are they changed?*	Change of schedule, or measurement of the pressure difference
• *Are they properly installed?*	Improved installation
• *Are they in good condition?*	More frequent change or measurement of the pressure drop
Is there a water spray humidification system?	Regular maintenance
• *Does it operate continuously?*	Continuous operation
• *What is the pan emptying frequency?*	Increase in frequency
• *Are there viscous deposits in the pans?*	Periodic cleaning
• *Is there a musty odor?*	Evaluation of microorganisms and decontamination
• *Is there mildew in the ducts?*	Cleaning and decontamination
• *Are there deposits on the blades?*	Cleaning
• *Is there water accumulation on the ground?*	Locating leaks
Is there a steam humidification system?	Regular maintenance
• *Does it operate continuously?*	Continuous operation
• *Are chemical products used to prevent corrosion?*	Replacement of product
• *Is there water accumulation on the ground?*	Locating leaks

TABLE 1: OBSERVATION QUESTIONNAIRE ON THE VENTILATION SYSTEM (cont'd)

OBSERVATION	ACTION TO BE TAKEN (if necessary)
Is there an air-conditioning system?	Regular maintenance
• *What is its operating schedule?*	Change of schedule
• *What is the condenser plate cleaning frequency?*	Increase in cleaning frequency
• *Are there viscous deposits on the plates?*	Periodic cleaning and decontamination
• *Are there viscous deposits on the cooling coil?*	Periodic cleaning and decontamination
• *Are there musty odors?*	Evaluation of microorganisms and decontamination
• *Is there water accumulation on the ground?*	Locating leaks
Which system components are controlled automatically?	Regular maintenance
• *What is the monitoring frequency?*	Increase in frequency
• *What is the calibration frequency?*	Increase in frequency
Which system components are controlled manually?	Regular maintenance
• *What is the monitoring frequency?*	Increase in frequency
• *What is the calibration frequency?*	Increase in frequency
Is it a constant volume distribution system?	Evaluation of supply rates in work areas
• *What is the frequency of duct maintenance?*	Increase in frequency
• *What is the frequency of network balancing?*	Increase in frequency
Is it a variable air volume distribution system?	Evaluation of air flow rates in work areas under extreme occupancy conditions
• *Is there a minimum guaranteed flow?*	Evaluation of, and increase in this flow
• *What is the duct maintenance frequency?*	Increase in frequency
• *What is the network balancing frequency?*	Increase in frequency
Are the diffusers blocked or obstructed?	Clearing the diffusers
Do the partitions reach the floor?	Raising partitions to 10 cm above the floor
Is there a general maintenance program for the ventilation system?	Setting up a regular maintenance program
• *Is there a person responsible for the system?*	Naming and training a person responsible

TABLE 2: CAUSES OF DEFICIENCIES IN THE VENTILATION SYSTEM AND CONTROL MEASURES

CAUSES	CONTROL MEASURES
I. TOTAL AIR	
Insufficient fan capacity	Increasing the capacity and flow of the supply fan
Reduction in fan capacity due to wear	Replacement of belts, wheels, blades or any other part; rebalancing of fan
Deficient fan components	Maintenance and replacement of parts: belts, pulleys, ball bearings, etc.
Increase in occupation density	Increasing the capacity and total air flow; redistributing occupants
Unbalancing of the distribution system	Balancing the distribution system
II. FRESH AIR (NEW AIR)	
Defective instruments for controlling the opening of the fresh-air supply dampers	Calibrating and periodically inspecting thermostats, sensors, dials, etc.
Opening of fresh-air inlet dampers set too low	Increasing fresh air entry; addition of a fixed minimum fresh-air inlet damper
Heating capacity insufficient for thermal requirements	Increasing heating capacity in the ventilation system or in rooms
Unbalancing of supply and return fans	Balancing supply and return fans
III. AIR DISTRIBUTION	
Unbalancing of diffusion networks	Network balancing
Poor operation of control boxes, their pistons and dampers	Repairing and periodically checking the operation of control boxes
Disadjustment of thermostats controlling the dampers of control boxes	Periodically calibrating thermostats
Change in function or rearrangement of space without concern for diffuser capacity	Balancing the distribution with each modification to the space
Blocking or obstruction of the diffusers	Removing any obstruction in front of diffusers
Use of office partitions resting on floor	Using partitions raised approximately 10 cm from the floor

TABLE 2: CAUSES OF DEFICIENCIES IN THE VENTILATION SYSTEM AND CONTROL MEASURES (cont'd)

CAUSES	CONTROL MEASURES
IV. SYSTEM COMPONENTS	
Delayed start of the system before the arrival of workers	Starting the system in compliance with ASHRAE standard 62-1981R [7]
Inefficient filters	Using high efficiency filters preceded by prefilters
Infiltration around the filters	Properly installing filters
Clogged filters	Periodically changing filters based on pressure-drop measurements
Defective humidistats and thermostats	Monitoring and periodic calibration

3.2 COMFORT

The lack of comfort is what most office-building occupants complain about. It is affected by several environmental and personal factors. The measurable comfort parameters are as follows:

- ambient and operative temperature;
- localized thermal discomfort;
- relative humidity;
- air stratification;
- comfort indices.

3.2.1 Identification of problems

During the preliminary visit, it will be easier to identify comfort-related problems by surveying occupant complaints, monitoring certain ventilation system components, and measuring some simple parameters such as humidity and temperature. The questionnaire in *Table 3* lists the points to consider in the first evaluation step.

3.2.2 Evaluation of problems

If the results of this first stage indicate that a lack of comfort is the main factor in occupant dissatisfaction, all of the parameters mentioned above must undergo a detailed evaluation.

TEMPERATURE

The temperature of the ambient air is the best-known and most common comfort index. Article 30 of the *Regulation respecting the quality of the work environment* requires a minimum dry bulb temperature of 20°C for light office work. The ASHRAE standard [8] recommends the use of the operative temperature. This takes into account the temperature of the ambient air, the mean radiant temperature, clothing, and the activity level of the worker in question. Therefore, according to this standard, the operative temperatures in winter would be, for an activity level in an office estimated at 1.2 mets †, clothing of 0.9 clo ††, a relative humidity of 50 %, and an air velocity below 0.15 m/s:

- optimum operative temperature: 21.7°C
- operative temperature to satisfy 80 % of the occupants: 20 to 23.6°C.

† *One met corresponds to a heat production of 58 Watts per cubic metre of body surface. A normal person has an average surface of 1.8 m ^{2}. One met therefore corresponds to a heat production of approximately 100 Watts.*

†† *One clo corresponds to* 0.155 m^2 x °C ÷ W. *A naked person has 0 clo and a person dressed for polar temperatures has 4 clo of clothing.*

The ambient temperature is measured using a thermometer, whereas the operative temperature can be measured with a thermal comfort meter or an indoor climate analyzer.

Variation in temperature during the day can also create discomfort. ASHRAE recommends a maximum acceptable fluctuation in the operative temperature of 0.6°C/hour .

LOCALIZED THERMAL DISCOMFORT

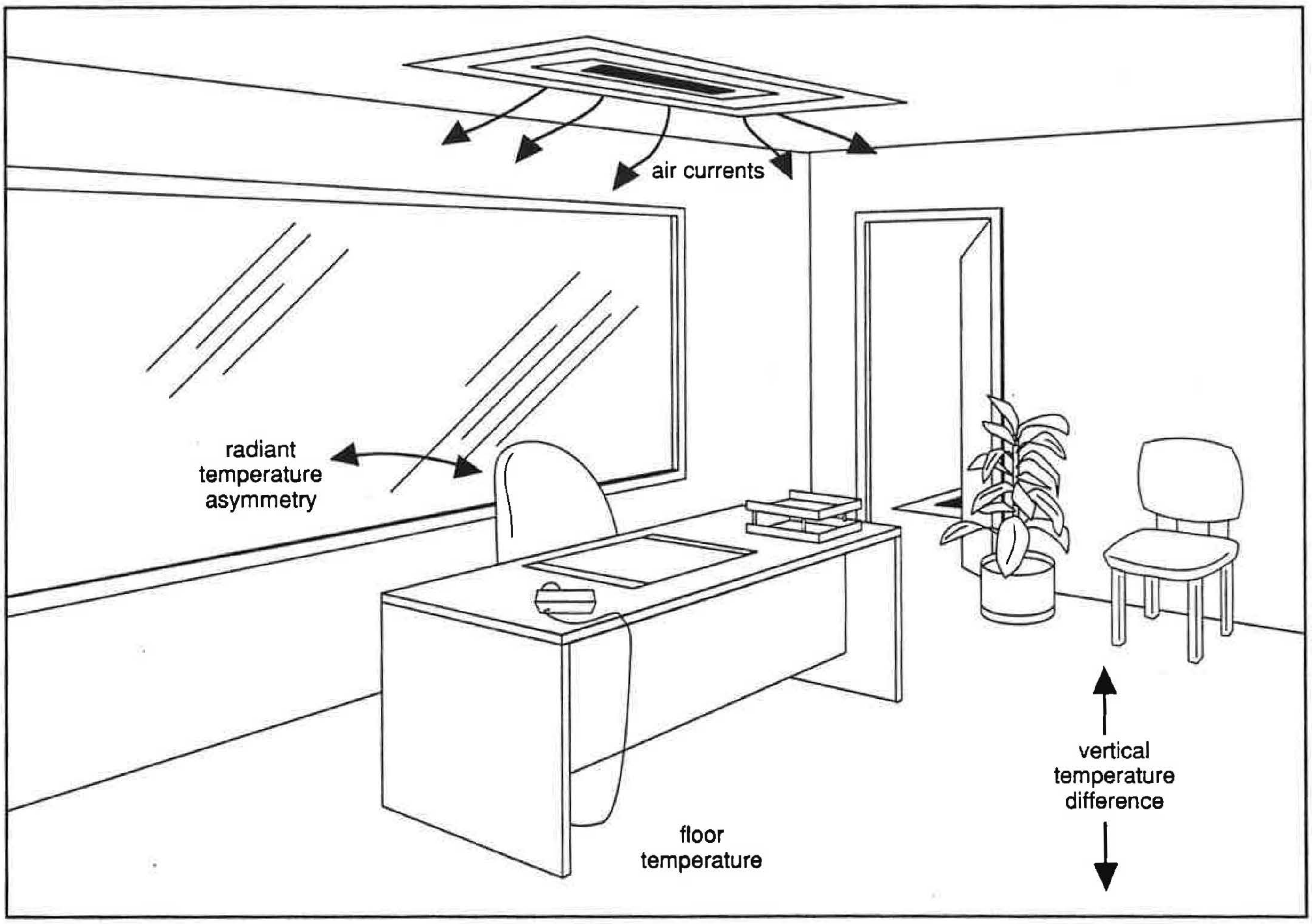
The second thermal comfort condition is the absence of localized discomfort. There is localized discomfort when only one part of the body feels uncomfortable; for example, when only a worker's feet are cold, or the worker occasionally feels uncomfortable air drafts on his neck or feet.

The localized thermal discomfort factors are:

- air currents that cause localized cooling of the body through convection (the most common reason for complaints about the thermal environment). Air currents are the result of an air velocity that is too high for a given air temperature;
- radiant temperature asymmetry, which is the difference in the radiant heat exchange between a person's two sides. In winter for example, when you are seated with your back to a glass window, there will be cooling of only this part of the body, whereas when it is sunny, it will be warmed;
- the difference in air temperature between the head and the ankles;
- a ground temperature that is too low or too high.

Figure 3 below illustrates these four elements.

FIGURE 3: LOCALIZED THERMAL DISCOMFORT FACTORS



A series of standards for localized thermal discomfort factors have been adopted by ISO [10]. They are summarized below:

1. The average air velocity for normal operative temperatures must not exceed 0.l5 m/s during winter, and 0.25 m/s during summer. The average velocity must be calculated for a period of at least three minutes.

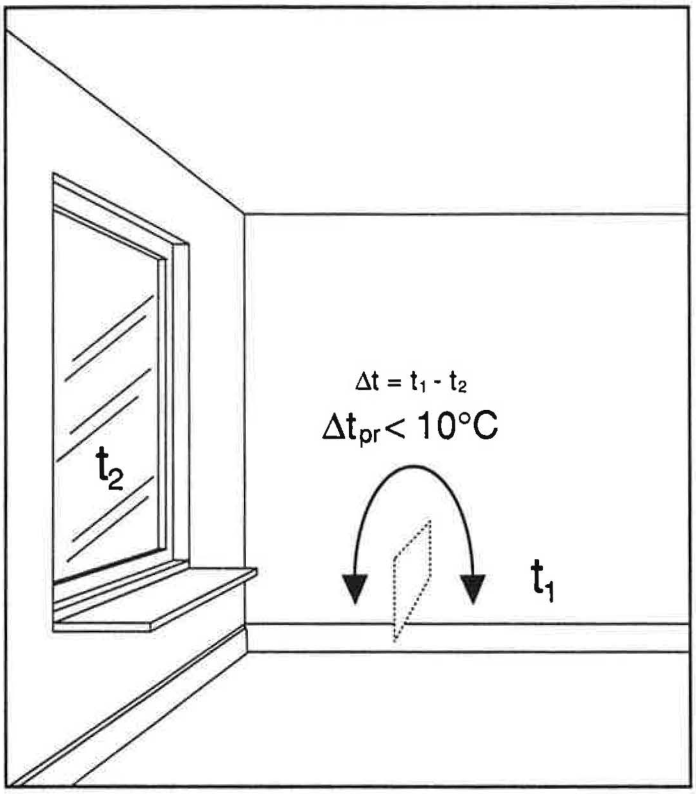
   In addition, it is suggested that the standard deviation of the air velocities be measured, and this deviation should not exceed one third of the average velocity. This calculation technique is described in the ISO document [10].

2. The asymmetry in the radiant temperature from the cold surfaces of the walls and windows must not exceed 10°C, whereas the asymmetry in radiant temperature from a warm ceiling must not exceed 5°C. Readings must be taken 0.6 m from the floor. They are illustrated in *Figure 4*.

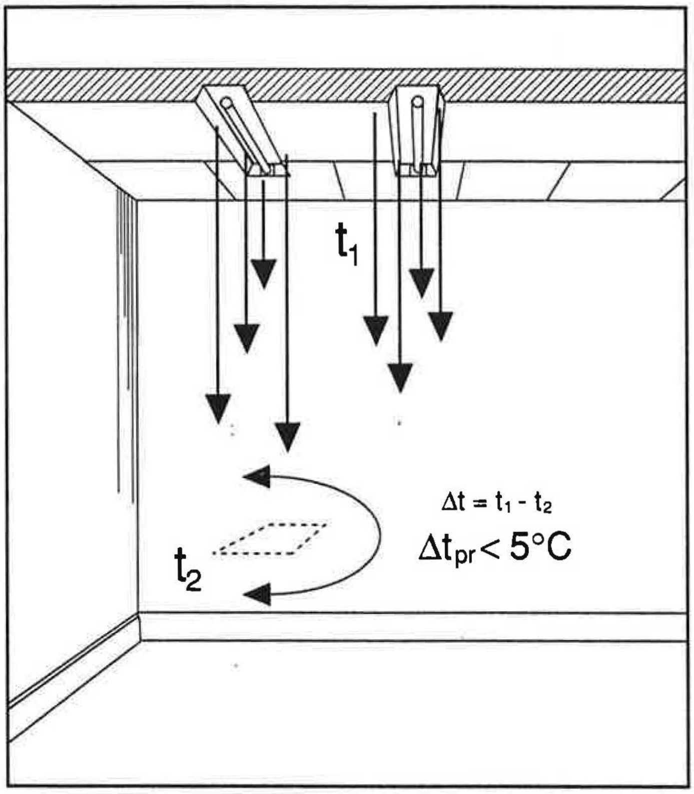
3. The vertical difference in air temperature between the floor and head level must not exceed 3°C. If the worker is seated, readings must be taken 0.1 m and 1.1 m from the floor; if he is standing, they must be taken 0.1 m and 1.7 m from the floor.

4. The temperature measured above the floor surface must be between 19 and 26°C.

FIGURE 4: RADIANT TEMPERATURE ASYMMETRY



ASYMMETRY OF RADIANT TEMPERATURES FROM COLD WINDOW SURFACES



ASYMMETRY OF RADIANT TEMPERATURES FROM WARM CEILINGS

Temperature readings are made using a thermometer. Air velocities are measured using a low-flow anemometer or an omnidirectional multisensor velometer.

Another measuring instrument, the indoor climate analyzer, is now available on the market and meets ISO standards. In addition to all localized thermal discomfort factors, this instrument also measures parameters such as:

- average air velocity;
- standard deviation of average velocities;
- vertical and horizontal radiant temperature asymmetries;
- surface temperatures of walls and floors;
- relative humidity;
- ambient air temperature.

RELATIVE HUMIDITY

In Quebec, low humidity is a problem in winter. The results of our studies show that the majority of buildings have very low humidities, often below the minimum of 20 % required by the Article 31 of the *Regulation respecting the quality of the work environment* [3]. ASHRAE standard 55-1981 [8] recommends a relative humidity in the order of 30 % for operative temperatures such as previously discussed.

Humidity is measured using a psychrometer or a direct-reading instrument (*Appendix I*).

AIR STRATIFICATION

There is air stratification when the total air from the diffusers is carried rapidly towards the return grilles in the ceiling without it having adequately swept all the space in the room. This stratification favors certain well-aerated and very comfortable working zones, whereas others have only stagnant air.

The total-air diffusion efficiency can be evaluated by the air diffusion performance index or ADPI. A minimum ADPI of 75 to 80 % has been proposed as a standard: this means that 75 to 80 % of the working space in a room will be adequately swept by the diffusion air.

Two diffusion efficiency measurement techniques are used, namely tracer gases or a flow analyzer.

THERMAL COMFORT INDICES

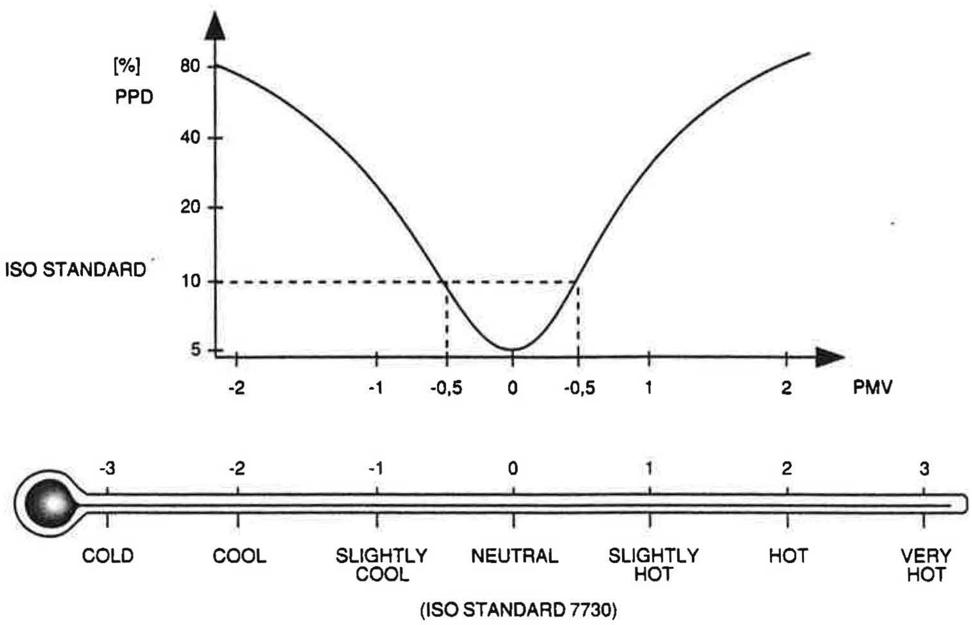
The international organization ISO [10] has defined thermal comfort as a state of satisfaction related to the thermal environment. A thermally comfortable person does not wish to be either colder or warmer. A person is comfortable when the heat produced by his body is equal to that transmitted to the outside environment by convection, radiation and by perspiration. Heat transfer between the body and its environment depends on six parameters:

- Two personal parameters:
  - — a person's level of activity,
  - — a person's clothing;
- Four environmental parameters:
  - — air temperature,
  - — mean radiant temperature,
  - — air humidity,
  - — air velocity.

These are all measurable parameters and are considered in a comfort equation that allows the *PMV* and *PPD* indices, two new thermal comfort measurements, to be determined.

- The *PMV* (or predicted mean vote) is an index which predicts the average value of subjective reactions of a significant group of persons on a thermal sensation scale ranging from -3 (cold) to +3 (hot). The *PMV* scale is presented in *Figure 5.*
- The *PPD* (or predicted percentage of dissatisfied) is an index which predicts the percentage of persons in a significant group who feel they are in a situation of thermal discomfort, i.e., voting hot (+3), warm (+2), cool (-2) or cold (-3) on the *PMV* scale. The relationship between the *PMV* and *PPD* indices is presented in *Figure 5.*

FIGURE 5: PREDICTED PERCENTAGE OF DISSATISFIED VERSUS PREDICTED MEAN VOTE (PPD vs PMV)



According to this new *PMV/PPD* relationship, there is no thermal situation which satisfies 100 % of the people. An ideal thermal situation can satisfy only 95 % of the people due to individual differences. International standard ISO 7730 recommends an optimum thermal comfort situation which can satisfy 90 % of the people in a given environment.

A new measuring instrument, the thermal comfort meter or comfort meter, is available on the market and allows the *PMV* and *PPD* indices to be measured. The operating principle for the comfort meter is the following: it measures the four environmental parameters directly or indirectly, and indicates the *PMV* and *PPD* indices by using the two personal parameters established previously (an individual's activity level and clothing).

From our measurements carried out at more than 150 work stations in office buildings, approximately 20 % of the people are dissatisfied with the thermal environment, and the environment is then qualified as slightly cool.

3.2.3 Corrective and control measures

The discomfort problems felt by the occupants are related to variations in ambient and operative temperatures, to the generally too low humidity, to air stratification, and to unequal air velocities. The main causes of this discomfort, and the means of correcting them are presented in *Table 4.*

TABLE 3: COMFORT-RELATED OBSERVATION QUESTIONNAIRE

OBSERVATION	ACTION TO BE TAKEN (if necessary)
Do the occupants complain about:	
• *hot or cold temperatures? daily variation in temperature?*	Temperature measurement over several days; calibration of thermostats
• *a gradual increase in temperature?*	Increasing flow of cooler air
Are thermostats located in the areas they serve?	Relocation of thermostats far from sources of heat or cold
Are the thermostats periodically calibrated?	Periodic verification and calibration of thermostats
Do the occupants complain of air currents or air stagnation?	Velocity measurements and balancing of distribution network
Are some diffusers blocked or obstructed?	Removal of any obstruction
Do partitions reach the floor?	Raising partitions to 10 cm from the floor
Are the diffusers of the vertical throw type?	Installation of deflectors
Are the windows and floors well insulated?	Horizontal and vertical measurement of temperature and humidity; appropriate insulation
Are diffusers and return grilles located near one another?	Measurement of air stratification; relocation of return grilles
Do the occupants complain of dryness, and eye, nose, and throat irritation and difficulty in wearing contact lenses?	Measurement of humidity

TABLE 4: CAUSES OF DISCOMFORT AND CONTROL MEASURES

CAUSES	CONTROL MEASURES
I. TEMPERATURE	
Thermostat imprecision (too hot or too cold) in the rooms or in the supply duct	Periodic verification and calibration of thermostats
Insufficient new air supply (gradual increase in temperatures)	Increasing new air flow
Inappropriate location of thermostat	Location of thermostat in the working area it controls and far from sources of heat and cold
II. LOCALIZED THERMAL DISCOMFORT	
Unbalancing of the distribution networks (uneven air circulation, and air currents)	Periodic balancing of the distribution network
Obstruction of proper air circulation	Raising partitions 10 cm from the floor, freeing diffusers of all obstructions
Vertical throw diffuser directly over occupant	Installation of deflectors
Insufficient or inexistant insulation of windows and floors	Appropriate insulation of windows and floors
III. RELATIVE HUMIDITY	
Defective or poorly calibrated humidistat located in the return duct	Replacement; periodic verification and calibration
Humidifier defect or insufficiency	Preventive maintenance of humidifier of adequate capacity
Insufficient thermal insulation of the building shell (moisture on the windows at low humidity)	Appropriate insulation of windows
IV. AIR STRATIFICATION	
Diffuser and return grille near one another	Relocation of the return grille
Obstruction of proper air circulation	Raising partition 10 cm from the floor: removal of any obstruction
Insufficient pressure in ducts	Increase in pressure
V. COMFORT INDICES	
Temperature too low or too high	Temperature adjustment according to demand
Humidity too low or too high	Humidity adjustment according to demand
Air velocity too low (stagnant air) or too high (air currents)	Even distribution, with velocity below 0.l5 m/s in winter and 0.25 m/s in summer
Insufficient insulation of windows and floors	Appropriate insulation of windows and floors

3.3 *CHEMICAL CONTAMINANTS AND BIOAEROSOLS*

The chemical contaminants and microbiological agents that can be present in office buildings come from the outdoors through the ventilation system or are generated indoors by the occupants, their activities, and the furniture and construction materials. Before systematically measuring these numerous pollutants, it is important to identify the potential emission sources and the contaminants emitted.

3.3.1 Identification of problems

The results of numerous studies on ambient air quality in office buildings in industrialized countries have made it possible to inventory the main sources of contamination inside these buildings. These sources must be identified at the preliminary evaluation stage using the questionnaire in *Table 5*.

3.3.2 Evaluation of problems

Table 6 presents the sampling strategy to be used should an environmental evaluation of the concentrations of contaminants in the ambient air prove necessary. This strategy takes into account the major sources of contamination, their behavior with time, the analytical methods available and their limits of detection.
For microorganisms, sampling is recommended only in the case of an obvious relationship between illnesses and biological contamination: humidifier fever, hypersensitivity pneumonitis, allergic asthma, and allergic rhinitis [11].

For information purposes, *Table 7* summarizes the results of contaminant concentrations measured during fifteen studies that the IRSST carried out on ambient air quality in office buildings. These studies were performed in winter.

Table 7 also contains the standards applicable in Quebec [3], the recommendations of the American Society of Heating, Refrigerating and Air-Conditioning Engineers [7], as well as the *Canadian Guidelines for Residential Indoor Air Quality* [9].

3.3.3 Corrective measures and means of control

When abnormally high concentrations of contaminants are measured, corrective measures and means of control must be implemented in order to eliminate or at least reduce the aggressors, such as those listed in *Table 8*.

TABLE 5: OBSERVATION QUESTIONNAIRE ON CONTAMINANT-EMISSION SOURCES

IDENTIFICATION OF SOURCES	ACTION TO BE TAKEN (if necessary)
Is the new air intake located on the same side as the parking area, a terminal, a garage or an important traffic route?	Determination of CO and NO_x concentrations
• *Near cooling towers?*	Microorganism determination
In the ventilation system, are there pans of stagnant water, water leaks or water accumulations?	Microorganism determination
• *Are the filters in good condition?*	Dust determination
Is there indoor parking? Is it equipped with independent ventilation? Is this system connected to a CO monitor? Is the latter calibrated regularly? Are the access routes to the office floors isolated from the parking?	Determination of CO and NO_x concentrations
Is there a loading dock connected to the inside of the building? Is it isolated? Is it ventilated?	Determination of CO and NO_x concentrations
Are there cracks, water infiltration in the areas located in the basements?	Radon determination

TABLE 5: OBSERVATION QUESTIONNAIRE ON CONTAMINANT-EMISSION SOURCES (cont'd)

IDENTIFICATION OF SOURCES	ACTION TO BE TAKEN (if necessary)
Are there other types of activities in the building: hairdressers, drycleaners, restaurants, etc.?	Determination of volatile organic compound concentrations
Are there friable asbestos-based materials: insulants, acoustical tile? Are they in good condition?	Asbestos determination
Is the building insulated with urea formaldehyde foam?	Determination of formaldehyde concentration
Is the heating system gas or oil? Are there leaks and odors?	Determination of volatile organic compound concentrations
Are there print, reproduction, photography, wet photocopiers, or other processes using solvents? Are they equipped with an emission exhaust system?	Determination of volatile organic compound and ozone concentrations
Where are the photocopiers located? Laser printers? Are they ventilated? Is there an odor of ozone?	Determination of ozone concentration
Have there been recent renovations: paint, carpet?	Determination of volatile organic compound and formaldehyde concentrations
Is there a chemical product storage area: pesticides, cleaners?	Determination of volatile organic compound concentrations
Has new plywood- or particleboard-based furniture been added?	Determination of formaldehyde concentration
What is the occupation density? Are there areas, floors where there is a high concentration of people?	Determination of CO_2 concentration
Are there areas with high personnel and clientele traffic?	Determination of dust and CO_2 concentrations
Are there areas reserved for smokers? Are they independently ventilated?	Determination of dust and nicotine concentrations
Are rugs and furniture regularly cleaned?	Dust determination
Is there a musty smell or fungal growth on the walls, in the bathrooms?	Microorganism determination
Are there health problems diagnosed by a physician which could be related to the presence of microorganisms: humidifier fever, hypersensitivity pneumonitis, allergic asthma or allergic rhinitis?	Microorganism determination

TABLE 6: SAMPLING STRATEGY FOR CHEMICAL CONTAMINANTS AND BIOAEROSOLS

CONTAMINANT	MEASUREMENT TECHNIQUE †	DETECTION LIMIT	SAMPLING DURATION AND FREQUENCY	SAMPLING SITE
I. GASES				
CARBON MONOXIDE CO	DRI - electrochemical cell (IRSST - # 3A)	1 ppm	• Instantaneous and periodic readings all day long • Instantaneous readings during peak periods	• Offices • Underground parking and loading docks
CARBON DIOXIDE CO_2	DRI - Infrared (IRSST - # 34A)	10 ppm	• Instantaneous readings before arrival and after departure of employees and periodically during the day	• Offices with high occupation density and offices open to the public and clients
NITROGEN OXIDES NO_x	DRI - electrochemical cell (IRSST - # 6A, # 30A)	NO : 0.5 ppm NO_2 : 0.05 ppm	• Instantaneous readings during the day • Instantaneous readings during peak periods	• Offices • Underground parking and loading docks
OZONE O_3	DRI - Chemiluminescence (IRSST - # 129)	0.001 ppm	• Instantaneous readings at the source and in the respiratory zone of user during and after operation	• Photocopy rooms and print shops
FORMALDEHYDE HCHO	Orbo adsorbent tube impregnated with N-benzylethanolamine and analyzed by gas chromatography (IRSST - # 216)	5 ug	• 20-30 hour consecutive sampling at 0.5 L/min	• Offices, particularly those newly renovated
RADON Rn	Passive dosimeter	0.01 pCi/L	• Sampling for 3 to 7 days	• Rooms located in basements

† *IRSST - Sampling Guide for Air Contaminants in the Workplace.*

TABLE 6: SAMPLING STRATEGY FOR CHEMICAL CONTAMINANTS AND BIOAEROSOLS (cont'd)

CONTAMINANT	MEASUREMENT TECHNIQUE	DETECTION LIMIT	SAMPLING DURATION AND FREQUENCY	SAMPLING SITE
II - VAPORS				
VOLATILE ORGANIC COMPOUNDS	Activated charcoal tube, analyzed by gas chromatography (IRSST - # 200)	—	• 20-30 hour consecutive sampling at 0.5 L/min	• Offices, particularly recent renovations • Printshops and workshops using solvents • Photocopier room (if wet process)
NICOTINE AND TOBACCO SMOKE	XAD-2 tube analyzed by gas chromatography (IRSST - # 233)	1 ug	• 8-hour sampling during workdays at 0.5 L/min	• Smoking areas; smokers' and non-smokers' offices if ventilation is same
III. DUSTS				
TOTAL DUST	Polyvinyl chloride filter, 37 mm, 0.8 u and gravimetric determination (IRSST - # 48)	25 ug	• 8-hour sampling during workdays at 2 L/min	• Offices; smoking areas; printshops; mailrooms
ASBESTOS	Cellulose ester filter, 37 mm, 0.8 u, gridded and count (IRSST - # 47) Identification by transmission electron microscopy	10 fibers	• 20-30 hour sampling at 2 L/min during working hours and when unoccupied	• Offices

TABLE 7: SUMMARY OF CONCENTRATIONS OF CHEMICAL CONTAMINANTS AND BIOAEROSOLS MEASURED IN THE AIR OF 15 OFFICE BUILDINGS BY A TEAM FROM THE IRSST

CONTAMINANT	CONCENTRATIONS MEASURED			STANDARDS AND REFERENCES		
	Minimum	Maximum	Mean †	Quebec [3]	Canada [5]	ASHRAE [7]
I. GASES						
Carbon monoxide, ppm	1 to 3	1 to 11; 330; 460	1 to 5	50 (8 hrs) 400 (15 min.)	11 (8 hrs) 25 (1 hr)	9 (continuous)
Carbon dioxide, ppm	290 to 440	570 to 1400	490 to 930 ††	5 000 (8 hrs) 15 000 (15 min.)	3 500 (long-term)	1 000 (continuous)
Nitrogen oxides, ppm	——	——	NO_2: 0.05 NO : 0.50	5 (NO_2; ceiling) 25 (NO; 8 hrs) 35 (NO; 15 min.)	0.25 (NO_2; 1 hr) 0.10 (NO_2; long-term)	0.055 (NO_2; 1 yr) 0.40 (NO; 24 hrs) 0.80 (NO; 30 min.)
Ozone, ppm	0.001 to 0.006	0.001 to 0.015; 0.130	0.001 to 0.010	0.10 (8 hrs) 0.30 (15 min)	0.12 (1 hr)	0.05 (continuous)
Formaldehyde, ug/m³	4 to 34	8 to 42	7 to 38	3 000 (ceiling)	120 (ceiling)	120 (ceiling)
Radon, pCi/L	0.1 to 0.4	0.3 to 1.5	0.2 to 0.7	——	——	2
II. VAPORS						
Volatile organic compounds, mg/m³	0.1 to 1.6	0.2 to 3.8; 15; 27	0.1 to 2.2	VMP Naphtha : 1 350 (8 hrs)	——	——
Nicotine, ug/m³	0.5 to 1.0	0.5 to 20.5	0.5 to 20.5	500 (8 hrs) 1 500 (15 min.)	——	——

† *The mean value is the arithmetic mean of all the results except those obtained at work stations where local emission sources are present (printshop, underground garage). The latter are however written in the column of maximum values and are underlined.*

†† *For CO_2, the mean value corresponds to the arithmetic mean of the highest value obtained at each station evaluated.*

TABLE 7: SUMMARY OF CONCENTRATIONS OF CHEMICAL CONTAMINANTS AND BIOAEROSOLS MEASURED IN THE AIR OF 15 OFFICE BUILDINGS BY A TEAM FROM THE IRSST (cont'd)

CONTAMINANT	CONCENTRATIONS MEASURED			STANDARDS AND REFERENCES		
	Minimum	Maximum	Mean	Quebec[3]	Canada[5]	ASHRAE[7]
III. DUSTS						
Total dust, ug/m^3	5 to 28	14 to 125; 210	10 to 46	10 000 (8 hrs)	100 (1 hr) 40 (long-term)	260 (24 hrs) 75 (1 yr)
Asbestos, fibers/cc	n. m. †††	n. m.	n. m.	5 (never to be exceeded)	—	—
IV. BIOAEROSOLS						
Bacteria + fungi colonies/m^3						
• Ventilation:						
• new air	6	512	165	—	—	—
• return air	12	288	80	—	—	—
• mixing air before filter	12	368	128	—	—	—
• mixing air after filter	0	231	65	—	—	—
• ambient air	25	181	105	—	—	1 000[11]

††† *n. m. = not measured*

TABLE 8: CONTROL OF SOURCES OF CHEMICAL CONTAMINANTS AND BIOAEROSOLS

CONTAMINANT	SOURCE	CONTROL MEASURES
I. GASES		
CARBON MONOXIDE CO	• Infiltration from underground parking and loading docks	• Independent ventilation controlled by a CO monitor; closed and ventilated space between the garages and access routes to floors: pressurization of these access routes and neighbouring areas
	• Outdoor air infiltration	• Better location of outdoor air intake
CARBON DIOXIDE CO_2	• Human respiration; high occupant density	• Increasing new air flows or decreasing the occupation density • Balancing of the ventilation system • Installation of a CO_2 control monitor
NITROGEN OXIDES NO_x	• Infiltration from underground parking and loading docks	• Independent ventilation
	• Outdoor air infiltration	• Better location of air intake
OZONE O_3	• Photocopiers, laser printers, printing equipment	• Local emission exhaust system
FORMALDEHYDE HCHO	• New materials, furniture or renovations	• Increased and continuous ventilation of the building for several days (e.g., weekends) at a temperature above 30°C and at a relative humidity of more than 50 %
RADON Rn	• Ground infiltration	• Sealing of cracks; increasing ventilation; adsorption by activated charcoal filters

TABLE 8: CONTROL OF SOURCES OF CHEMICAL CONTAMINANTS AND BIOAEROSOLS (cont'd)

CONTAMINANT	SOURCE	CONTROL MEASURES
II. VAPORS		
ORGANIC COMPOUNDS	• Printing processes, reproduction, and others	• Independent local ventilation
	• Photocopiers (if wet process)	
	• New facilities and renovations; paints, glues, varnish	• Increased and continuous ventilation of the building for several days (e.g., weekends) at a temperature above 30°C and at a relative humidity of more than 50 %
NICOTINE	• Tobacco smoke	• Smoking not permitted, or smoking area with independent ventilation
III. DUSTS		
TOTAL DUST	• Tobacco smoke	• Smoking not permitted, or smoking area with independent ventilation
	• Occupant activities	• More efficient filters in the system or in the rooms
ASBESTOS	• Damaged materials; current renovations	• Maintenance, sealing or replacement (extreme case)

TABLE 8: CONTROL OF SOURCES OF CHEMICAL CONTAMINANTS AND BIOAEROSOLS (cont'd)

CONTAMINANT	SOURCE	CONTROL MEASURES
IV. MICROBIOLOGICAL AGENTS		
	• Humidifier water pans	• Raising the temperature of the water to more than 68°C and disinfecting • Replacement by steam humidifier
BACTERIA AND FUNGI	• Filters	• High efficiency filters or more frequent change of filters • Bactericidal oil filters • Cleaning and decontamination of ducts
	• High humidity	• Decreasing the humidity; sealing leaks
	• Contaminated outdoor air inlet and ducts	• Cleaning, decontamination and periodic maintenance

3.4 WORK ENVIRONMENT

The parameters considered in this section are noise and lighting. These factors contribute to the comfort and well-being of workers in office buildings. Even if they are generally not the cause of occupant complaints and discomfort, they can be annoying, or cause irritation, difficulty in concentrating, and fatigue.

3.4.1 Identification of problems

The preliminary walk-through should result in easy identification of the problems related to noise and lighting. The observations listed in the questionnaire in *Table 9* will facilitate this task.

3.4.2 Evaluation of problems

Noise measurement, when required, is carried out using a type 2 sound level meter (*Appendix I*). Measurements are made in frequency bands that allow noise-generating sources to be identified in noise level (*A*).

Lighting is measured using a photometer consisting of a photoelectric cell which changes light radiation into electrical current (*Appendix I*).

Measurements of these two parameters are taken at the work stations, and observations regarding noise sources or lighting parameters are noted.

To identify undesirable frequency bands, the results of the frequency band analyses are compared to data supplied in noise evaluation curves such as the *NC* curves of the standard from the Bureau de normalisation du Québec [13].

The results in decibels (*A*) are compared to different standards. The standard from the *Regulation respecting the quality of the work environment* sets the level at 90 dB(*A*) for 8 hours. This value is based on the risk of hearing loss. However, the BNQ standard [13], which agrees with the recommendation issued by the International Standards Organization [14], evaluates noise in relation to disturbance of rest, work performance, social activities and peace and quiet. *Table 10* gives examples of the noise criteria proposed for non-residential space.

The average acoustical levels measured in offices vary between 45 and 55 dB(*A*). Maximum values in the order of 60 to 70 dB(*A*) have been obtained in open areas with high occupation density, whereas levels reached 85 dB(*A*) in printshops and reproduction shops.

3.4.3 Corrective and control measures

When noise levels that are sufficiently high to disturb workers are measured, different solutions are available:

- using acoustical material: ceiling tiles, partitions. It is important that tiles not be painted because this could change their acoustical properties;
- reserving certain working areas for discussions and meetings;
- isolating noisy processes: photocopiers, printers.

Lighting generally complies with the value recommended by the Quebec regulation [3] which provides standards concerning lighting values in relation to the type of work carried out. For specific office work classified as work requiring moderate perception of details, the minimum lighting level required is 550 lux.

Work stations with visual display terminals have certain layout difficulties with respect to the quality of lighting. Different factors affect this quality of lighting, such as the presence of natural and artificial light; sources of glare; and finishes on work tables, walls or floors that are pale or dark, reflecting or absorbing.

The layout of a work station must provide the worker with:

- lighting adapted to the work;
- well-distributed lighting designed such that the work surface is the most-illuminated part of the field of vision, while maintaining a minimum difference in lighting between it and the other parts of this field;
- elimination of reflection.

TABLE 9: OBSERVATION QUESTIONNAIRE ON NOISE AND LIGHTING

IDENTIFICATION OF SOURCES	ACTION TO BE TAKEN (if necessary)
NOISE	
Is the ventilation system's background noise easily noticeable?	Measurement of the noise in frequency bands
Is the noise generated by occupant activities (including typing, printers, conversation, traffic) loud enough to affect concentration?	Measurement of the sound level
Are there noisy processes: printshop, reproduction?	Measurement of the sound level at the sources and in neighboring offices
Have the acoustic tiles on the ceiling been painted?	Replacement of tiles
Are the offices located in open areas?	Measurement of the sound level
Do the occupants complain of noise?	Measurement of the sound level
LIGHTING	
At a given work station, particularly for work on display terminals, is the lighting sufficient? Well distributed? Without glare or reflection?	Improvement of lighting quality
Are the halls, stairs, storage areas and other departments adequately lit?	Increasing lighting
Do the occupants complain about the lighting?	Measurement of the luminous intensity and studying the quality of the lighting

TABLE 10: EXAMPLES OF NOISE CRITERIA PROPOSED FOR NON-RESIDENTIAL SPACE [13]

TYPE OF ROOM	NOISE CRITERION dB (A)
Large office, shop, large store, meeting room, quiet restaurant	35
Large restaurant, secretary's office (with typewriter)	45
Large typing room	55
Workshops (depending on their function)	45 to 75

4.0 CONCLUSIONS

The intervention strategy presented in this guide is based on a sequential procedure, from identification of the problem up to and including implementation of corrective measures. In the majority of cases, the procedure can be carried out by the milieu involved, with the need for specialized resources being limited to exceptional situations.

Since the main problems involve ventilation, it is important that the persons responsible for these ventilation systems have appropriate training and the instruments required for measurement. When anomalies and defects in the ventilation system (including distribution) have been corrected, the preventive maintenance program must include: calibration of controls, verification of system components, balancing of the distribution network, changing of filters, and cleaning of the system. Any modification in room layout or function must be accompanied by an adaptation to the ventilation system.

To deal with aggressors of a chemical or microbiological nature, it is necessary to locate the potential emission sources and verify the presence and efficiency of the local ventilation systems or the emission exhaust systems installed at these sources. Periodic monitoring of air quality by measuring carbon dioxide is recommended. In fact, even if correlations between the concentrations of carbon dioxide and of other contaminants are difficult to demonstrate, carbon dioxide is a good indicator of the capability of the ventilation to eliminate the contaminants generated inside buildings. Renovation work should be carried out, insofar as possible, when the rooms are unoccupied. The building should then be ventilated at maximum flow to eliminate the volatile substances emitted, while maintaining a temperature of 30°C and a humidity above 50 %.

Since air quality and thermal comfort in an office building will affect occupant performance, measures to reduce energy costs should be implemented in such a way that a deterioration in the working environment does not occur. Regular maintenance of a building will be more effective from all standpoints.

5.0 REFERENCES

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APPENDIX I: LIST OF MEASURING INSTRUMENTS

LIST OF MEASURING INSTRUMENTS †

PARAMETER	MEASURING INSTRUMENT	USUAL BRANDS	DISTRIBUTOR
VENTILATION			
Air velocities (flows) in the ducts	Hot-wire anemometer Thermocouple anemometer Rotating blade anemometer Pitot tube + manometer Multisensor velometer	Alnor, Kurz, TSI, Dwyer	Willer Engineering Levitt Safety Safety Supply
Direction of air flows	Smoke tubes + manual pump	MSA, Gastec	Levitt Safety Safety Supply
Air flow from diffusers and return grilles	Velometer	Alnor	Chevrier Instruments Inc.
Sufficient new air supply	CO_2 detector	Horiba, ADC, Gastec, ACME	Safety Supply ACME
Static, dynamic, total pressures; pressure drop	U tube + manometer Pressure gauge Differential manometer	Dwyer	Chevrier Instruments Inc.
COMFORT			
Air current velocities	Low flow anemometer Multisensor velometer	TSI, Kurz	Willer, Kurz
Temperature and humidity	Automatic psychrometer Direct-reading instrument	Cole Parmer Bacharach	Cole Parmer
PMV and PPD indices	Thermal comfort meter	Bruël & Kjaer	B & K
Temperature asymmetry; air currents	Indoor climate analyzer	Bruël & Kjaer	B & K

† *The brand and distributor names that are given are for information purposes only and do not constitute a recommendation by the IRSST.*

LIST OF MEASURING INSTRUMENTS (cont'd)

PARAMETER	MEASURING INSTRUMENT	USUAL BRANDS	DISTRIBUTOR
CHEMICAL CONTAMINANTS AND BIOAEROSOLS			
Carbon monoxide	Direct-reading instrument	Ecolyzer, MSA, Interscan	Safety Supply Levitt Safety
Carbon dioxide	Direct-reading instrument	ADC, Gastec, Horiba	Levitt Safety
Nitrogen oxides	Direct-reading instrument	Interscan Ecolyzer, CSI	Levitt Safety
Ozone	Direct-reading instrument	AID, CSI	Levitt Safety
Volatile organic compounds, nicotine, formaldehyde, dusts, asbestos	Collecting medium + sampling pump	Gilian, MSA, Sipin	Levitt Safety Safety Supply
Bioaerosols	Culture medium + impinger	Andersen	Safety Supply
WORK ENVIRONMENT			
Noise	Sound level meter	Bruël & Kjaer	B & K
Lighting	Photometer	Hagner	Optikon