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# GUIDELINES ON INDOOR ENVIRONMENTAL QUALITY (IEQ) FOR GOVERNMENT OFFICE BUILDING

JABATAN KERJA RAYA MALAYSIA

EDITION 1

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**FOREWORD**

**Assalamualaikum Warahmatullahi Wabarakatuh**

I am honoured to be given the opportunity to say a few words in this important document – Guidelines on Indoor Environmental Quality (IEQ) for Government Office Building.

First of all I would like to congratulate the team led by Mechanical Engineering Branch of JKR comprising architects, engineers and quantity surveyors for their contributions in preparing this document. Special mention also goes to the various government agencies and industry players who had contributed their experience and knowledge in completing this document. This guideline represents a strategic initiative by JKR to incorporate sustainable elements in project implementation and continuously improve the quality of its products and services.

This document provides guidance that focus on IEQ right from the design, construction, operation and maintenance stages. This document will assist our organization in moving forward in achieving indoor building environment that is safe, healthy and comfortable for the occupants. It is also useful for building operators, building owners and consultants as well as a reference document for training purposes.

I hope JKR as a leading technical organization shall continue to produce other relevant guidelines that will help to improve our delivery system.

Once again, my utmost appreciation to the committee involved in successfully producing this important document.

Dato' Seri Ir Hj Mohd Noor Bin Yaacob
Director General
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**GLOSSARY**

1 ACMV system refers to the air-conditioning and mechanical ventilation system of the building.

2 Acceptable indoor air quality refers to air in which there are no known contaminants at harmful concentrations as determined by the public health authorities and with which a substantial majority of the people exposed do not express dissatisfaction.

3 Air-conditioning refers to the process of treating air to meet the requirements of a conditioned space by controlling its temperature, humidity, cleanliness and distribution.

4 Air temperature refers to the dry-bulb temperature of the air surrounding the occupant.

5 Building-related illness refers to any illness which occurs directly as a result of human exposure to a specific health hazard present in the building.

6 Contaminant refers to an unwanted airborne constituent that may reduce acceptability of the indoor air quality.

7 Indoor air refers to the air inside a building, including air which is within a room and air which is removed from a room by mechanical means.

8 Occupied zone refers to the region normally occupied by persons within a space, generally considered to be between the floor and 1.8 m above the floor and more than 0.6 m from the walls.

9 Outdoor air refers to the air in the external surroundings.

# 1.0 GENERAL

## 1.1 Background

Indoor Environmental Quality (IEQ) refers to all environmental factors that affect the health and comfort of building occupants. IEQ includes such factors as indoor air quality, thermal comfort, humidity, ventilation rate, acoustics, and lighting quality.

Consequences of indoor environmental quality such as volatile organic compounds (VOC), poor ventilation, high humidity, mould, distracting noise, odours, poor lighting, glare, water damage, carbon dioxide, carbon monoxide, and uneven heat have long been recognized as sick building syndrome and implicate life threatening risks.

In general, the ultimate success or failure of a project rests on its indoor environmental quality (IEQ). Healthy, comfortable employees are invariably more satisfied and productive. Facilities should be constructed with an appreciation of the importance of providing high-quality, interior environments for all users.

Without proper design, construction, operation and maintenance, buildings can quickly become a source of distraction, discomfort and even illness.

Effective management of the indoor environmental quality (IEQ) in buildings with an appreciation of the importance of providing high-quality interior environments for all users are essential to the maintenance of occupant health, comfort and are invariably more satisfied and productive.

## 1.2 Introduction of IEQ

Indoor Environmental Quality refers to the character of the air and environment that contribute to the health and comfort of occupants inside office buildings. The air and environment can be influenced by chemical, biological, and physical agents that may come from occupant activities, building materials or the ambient environment.

Indoor environments are highly complex and building occupants may be exposed to a variety of contaminants (in the form of gases and particles) from office machines, cleaning products, construction activities, carpets and furnishings, perfumes, cigarette smoke, water-damaged building materials, microbial growth (fungal / mould and bacterial), insects and outdoor pollutants.

Other factors such as indoor temperatures, relative humidity and ventilation levels, noise and lighting can also affect how individuals respond to the indoor environment and in combination contribute to complaints.

Understanding the indoor environmental sources and influences and controlling them can often help prevent or resolve building-related worker symptoms.

## 1.3 General Factors Affecting the IEQ in Building

In general, the quality of indoor environment could be affected by temperature, dust/dirt, mould, insects, carbon monoxide (CO), bacteria/viruses, moisture, ventilation, allergens (e.g. pollen, animal dander) and chemicals (e.g. formaldehyde, household cleaners, pesticides).

From the above general factors, the causes of poor indoor environmental quality could be elaborated as follows:

### 1.3.1. Inadequate Ventilation

Inadequate ventilation, which may also occur if air conditioning and mechanical ventilation (ACMV) systems do not effectively distribute air to people in the building, is thought to be an important factor in poor IEQ in building.

In an effort to achieve acceptable IEQ while minimizing energy consumption, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recently has published the Ventilation Rate for Indoor Air Quality Standard (ASHRAE 62.1) in providing indoor air quality that is acceptable to human occupants and minimises adverse health effect.

### 1.3.2. Chemical Contaminants from Indoor Sources

Most indoor air pollution comes from sources inside the building. For example, adhesives, carpeting, upholstery, manufactured wood products, copy machines, pesticides and cleaning agents may emit volatile organic compounds (VOCs), including formaldehyde.

Environmental tobacco smoke contributes high levels of VOCs, other toxic compounds and respirable particulate matter. Low to moderate levels of multiple VOCs may also produce acute reactions.

### 1.3.3. Chemical Contaminants from Outdoor Sources

The outdoor air that enters a building can be a source of indoor air pollution. For example, pollutants from motor vehicle exhausts; plumbing vents and building exhausts (e.g., bathrooms and kitchens) can enter the building through poorly located air intake vents, windows and other openings.

### 1.3.4. Biological Contaminants

Bacteria, fungi and viruses are types of biological contaminants. These contaminants may breed in stagnant water that has accumulated in ducts, humidifiers and drain pans or where water has collected on ceiling tiles, carpeting, or insulation.

Physical symptoms related to biological contamination include cough, chest tightness, fever, chills, muscle aches and allergic responses such as mucous membrane irritation and upper respiratory congestion.

### 1.3.5. Acoustical Discomfort

The sound generated by mechanical, electrical and lighting equipment affects on the overall acoustical environment in an office building. Noise propagates from the sources through the air distribution duct systems, through the structure and through combinations of paths and discomforting the occupants.

### 1.3.6. Thermal Discomfort

People are more sensitive to local discomfort when the whole body is cooler than neutral and less sensitive to local discomfort when the whole body is warmer than neutral.

Thermal discomfort caused by a vertical air temperature difference between the feet and the head by an asymmetric radiant field, by local convective cooling (draft), or by contact with a hot or cold floor must be considered in determining conditions for acceptable thermal comfort.

Asymmetric radiant field may cause local discomfort and reduce the thermal acceptability of the space. In general, people are more sensitive to asymmetric radiation caused by a warm ceiling than that caused by hot and cold vertical surfaces.

Draft is unwanted local cooling of the body caused by air movement. It is most prevalent when the whole body thermal sensation is cool (below neutral). Draft sensation depends on the air speed, the air temperature, the turbulence intensity, the activity and the clothing.

## 2.0 OBJECTIVES

The IEQ Guidelines objectives are as follows:

a) To outline IEQ need statement or brief of requirement relating to new projects, renovations or retro-fitting.

   The guidelines will cover:

   1) Design stage
   2) Construction stage
   3) Operation &Maintenance

b) To provide general guidance on improving the indoor environmental quality for air conditioned government office buildings.

# 3.0 SCOPE

## 3.1 Scope of The Guidelines

The scope of this IEQ Guidelines is to outline IEQ Need Statement for new and existing building project development stages including design, construction and maintenance phases.

This guideline provides general guidance on improving and maintaining the indoor environmental quality for air conditioned government office buildings.

### 3.1.1. Design Phase

**General**

During the planning and design process, all projects must have a comprehensive, integrated perspective that seeks the followings:

a) Facilitate quality IEQ through good design practices;

b) Value aesthetic decisions, such as the importance of views and the integration of natural and man-made elements;

c) Provide thermal comfort with a maximum degree of personal control over temperature, humidity and airflow;

d) Supply adequate levels of ventilation and outside air to ensure indoor air quality;

e) Prevent airborne bacteria and other fungi/mould through air-conditioning and mechanical ventilation (ACMV) system designs that are effective at controlling indoor humidity and building envelope design that prevents the intrusion of moisture;

f) Avoid the use of materials high in pollutants, such as volatile organic compounds (VOCs) or toxins;

g) Assure acoustic privacy and comfort through the recommended internal noise levels which can be achieved using sound absorbing material and equipment isolation;

h) Control disturbing odours through contaminant isolation and selection of air cleaning products;

i) Create a high performance luminous environment through the integration of natural and artificial light sources.

**Testing, Adjusting and Balancing (TAB)**

The purpose of testing, adjusting and balancing (TAB) is to assure that an ACMV system is providing maximum occupant comfort at the lowest energy cost possible. A comprehensive TAB activity during planning/design and construction phase especially for ACMV system is also significant to achieve successful indoor environmental quality in buildings.

Most of today's ACMV systems are being designed with many more individually controlled temperature zones to improve occupant comfort. The combination of constantly changing ACMV airflow rates and increased demand for fresh- and filtered-ventilation air for all occupants is placing more emphasis on fine tuning ACMV system operation.

The building construction industry is experiencing a major growth in demand for experienced and certified testing, adjusting and balancing (TAB) specialist/contractor who can balance today's complex ACMV systems.

### 3.1.2. Construction Phase

New construction and renovation projects in office settings can adversely affect building workers/occupants by the release of airborne particulates, biological contaminants, gases and noise.

Careful planning for IEQ and the prevention of exposure during these activities is essential. Measures of prevention are stated below:

a) Particulate material such as dusts and fibres are likely to be produced during construction and renovation activities. Sources include drywall, plaster, concrete, soil, wood, masonry, flooring, roofing and ductwork.
b) All floor areas shall be constructed to be watertight. Water leakage in the building shall be avoided. The leakage can be caused by improper materials, process and workmanship in construction, especially in water proofing works.
c) A plan to minimize dusts exposure should be implemented before and during construction and renovation process.

If construction activities are not well managed, the IEQ of the finished project will be compromised.

The pre-occupancy indoor air quality test which consists of assessment and sampling shall be done before handing over of the building to verify and reduce indoor air quality problems and minimizing any health issues of the occupants occupying the building.

### 3.1.3. Operation and Maintenance Phase

Maintaining good IEQ requires constant attention to the building's ACMV system, which includes the design, layout and pollutant source management or air filtration.

Improper operation and maintenance of ACMV systems is one of the most common problems that impact workplace IEQ.

ACMV systems alone can act as sources of pollutants. If these systems are not appropriately maintained, ventilation air filters can become saturated leading to potential microbial growth and odour concerns.

Microbial growth can also result from stagnant water in drain pans or from uncontrolled moisture inside of air ducts and cooling coils.

The post occupancy indoor air quality test may be conducted to a newly-constructed building with the goals of reducing indoor air quality problems and minimizing any health issues of the building occupants that may otherwise occur from the construction/renovation process.

## 4.0 IEQ ELEMENTS

IEQ elements essentially need a multi-disciplinary approach. In this guideline, the elements of each criteria of IEQ are described below:

Table 1: IEQ Elements

| NO | IEQ ELEMENTS | SUB ELEMENTS | PARAMETER |
|---|---|---|---|
| 1 | Indoor Air Quality | Outdoor Air Performance | - |
| | | Mould Prevention | - |
| | | Indoor Air Pollutants Control | Low VOC material |
| | | | Non-Added Urea formaldehyde material |
| | | | Tobacco Smoke |
| | | | Air Treatment |
| | | | Legionella |
| | | | Odour |
| | | | Non-Carcinogenic Material |
| | | | Component of Furniture |
| | | | Floor Finishes |
| | | | Building Flush Out |
| | | | Ozone |
| | | Indoor Air Quality Assessment | Pre-Occupancy Indoor Air Quality Test |
| | | | Post Occupancy Indoor Air Quality Test |
| | | Radon | - |
| | | $CO_2$ Monitoring and Control | - |
| | | CO Monitoring | - |
| 2 | Acoustic Comfort | Internal Noise and Vibration Control | General System |
| | | | Lighting and Noise |
| | | | Acoustic Treatment |
| 3 | Thermal Comfort | - | - |
| 4 | Visual Comfort | Daylighting | - |
| | | View and Sufficient Daylighting | - |
| | | Glare Control | - |
| | | Artificial Lighting | Illumination |
| | | | Artificial Lighting Glare |
| | | | Lighting Flicker |
| 5 | Housekeeping | Construction | Clean Site |
| | | Operation and Maintenance | Cleaning Services |
| | | | Waste Disposal Service |
| | | | Pest Control |
| 6 | Safety and Health | Renovation | Dust Control |
| | | | Noise Control |

## 4.1 Indoor Air Quality

### 4.1.1. Outdoor Air Performance

Outdoor air performance means the fresh air ventilation which refers to the process of "changing" or replacing air in any space to control temperature or remove moisture, odours, smoke, heat, dust, airborne bacteria and/or carbon dioxide and to replenish oxygen. Ventilation includes both the exchange of air with the outside as well as circulation of air within the building. It is one of the most important factors for maintaining acceptable indoor air quality in buildings.

Designing a building with a reduced environmental footprint requires a fully integrated design process in which all members of the design team work in an integrated framework, thinking about all design decisions within the context of indoor air quality and the impact of the design decision upon the environment.

The outdoor air performance can be monitored by using Outdoor Air Monitoring System (OAMS). OAMS is a direct total outdoor airflow measurement device capable of measuring flow within appropriate accuracy on the minimum outdoor airflow rate.

**a) Design Phase**

All Air Conditioning and Mechanical Ventilation (ACMV) design provision shall meet the minimum requirements of ventilation rate in Ventilation for Acceptable Indoor Air Quality, ASHRAE 62.1. The detail figure refers Appendix 1 - Minimum Ventilation Rate in Breathing Zone). The ventilation rate procedure in ASHRAE 62.1 is a design procedure in which outdoor air intake rates and other system design perimeters are based on an analysis of contaminant sources, contaminant concentration targets and perceived acceptability targets.

In general, the purpose of ventilation rate procedure is to identify the value of the design outdoor intake flow ($V_{OT}$) for a ventilation system in accordance to appropriate procedure and calculations so that it (design outdoor intake flow) will be consider in the air conditioning zone supplied by any air handling units.

The outdoor air intake shall be properly located to avoid taking in contaminated outdoor air from kitchen exhaust, cooling tower, toilet, refuse collector, fume cupboard exhaust, waste disposal area for the purpose of ventilation.

**b) Construction Phase**

The installation of ACMV System shall be supervised in accordance with the design and specification.

The ACMV systems shall be properly tested and commissioned so that they operate as per design.

**c) Operation and Maintenance Phase**

Maintenance of outdoor air intake components in the Air Handling Unit (AHU) room shall be carried out by competent ACMV contractor to the following but not limited to:

1) Regular inspection of outdoor air intake components such as air grilles, ducting, dampers, bird screen, etc
2) Correction of any deficiencies found during inspections
3) Repair or replacement of malfunctioning and consumable components such as air grilles, ducting, dampers, bird screen etc
4) Adjustment and calibration of control system components

The operation and maintenance of the building and facilities shall be carried out according to operation and maintenance (O&M) manual.

Operation and maintenance (O&M) manual contents shall at least comprise as follow:

1) Owner's Project Requirements and Basis of Design
2) Record Documents
3) Commissioning Report
4) Operations Manual
5) Training Manual
6) Schedule of Maintenance
7) Format of O&M Documentation
8) Post Occupancy Evaluation (JKR SPB : SPK)

In addition, the operation and maintenance shall also comply with the minimum requirement of *Garispanduan Berjadual Penyenggaraan Bangunan Kerajaan*.

### 4.1.2. Mould Prevention

Moulds play a major role in causing decomposition of organic material, enabling the recycling of nutrients throughout ecosystems. Many moulds also secrete mycotoxins which, together with hydrolytic enzymes, inhibit the growth of competing micro-organisms.

Mould requires a nutrient source, proper temperature and moisture to grow. Mould does not require light to grow. Nutrients to support mould growth are everywhere in the building environment. The temperatures required for mould growth is in the same range as indoor building environment. The pervasive nature of nutrients and a temperature range suitable for mould growth leaves control of moisture as the only practical way to control mould growth.

**a) Design Phase**

All building design system(s) such as architectural, structural and mechanical (ACMV) shall reduce the risk of mould growth and its associated detrimental impact on occupant health in accordance to JKR Guidelines on The Prevention of Mould Growth in Buildings.

Architects, Civil & Structural Engineers and Mechanical Engineers should design the building and its internal services in such a way that the risk of mould growth inside the building is reduced or if possible, eliminated.

**b) Construction Phase**

Skilled and experienced labour shall be able to handle materials and they should adhere to specified procedures during building erection in eliminating the risk of mould growth in a building.

All supplied building materials and equipment shall be of good quality that does not promote mould growth (i.e. materials with low moisture absorption rate).

Establishing a comprehensive ACMV equipment installation on the element such as equipment selection, proper duct installation, excessive infiltration of outside air, approved sealant, drain pan gradient, collar joint and control valve and signal will ensure the achievement of good mould control for a building project. ACMV equipment and accessories shall be selected and install according to approved JKR specification and nearest design data.

Furthermore, after the completion of installation, the testing and commissioning for the ACMV system shall be done and specifically covers the elements as follows:

1) Air Balancing
2) Water Balancing
3) Testing & Commissioning Procedure
4) Air Tightness Test
5) Control System
6) Leakage Test

**c) Operation and Maintenance Phase**

Building owner or facility manager shall establish an effective maintenance program to avoid mould growth in the building. A preventive maintenance program must include:

1) Regular inspection of all critical components of ACMV system such as dampers, fans, belts, ductwork, diffusers and control system
2) Regular inspections for conditions such as water leaks or stagnant water pools that would promote the growth of micro-organisms
3) Correction of any deficiencies found during inspections
4) Repair or replacement of malfunctioning and consumable components such as filters and cleaning of air distribution systems, ducts and dampers
5) Adequate treatment of open loop water system associated with ACMV equipment, such as cooling tower and humidifiers, to control biological growth
6) Regular housekeeping scheduling of all furnitures and carpet
7) Adjustment and calibration of control system components
8) Conduct assessment and sampling test annually or when required in accordance to Industry Code of Practice on Indoor Air Quality (DOSH), ASHRAE guidelines and standard

The operation and maintenance of the building and facilities shall be carried out according to operation and maintenance (O&M) manual.

Operation and maintenance (O&M) manual contents shall at least comprise as follow:

1) Owner's Project Requirements and Basis of Design
2) Record Documents
3) Commissioning Report
4) Operations Manual
5) Training Manual
6) Schedule of Maintenance
7) Format of O&M Documentation
8) Post Occupancy Evaluation (JKR SPK)

In addition, the operation and maintenance shall also comply with the minimum requirement of *Garispanduan Berjadual Penyenggaraan Bangunan Kerajaan*.

### 4.1.3. Indoor Air Pollutants Control

The effective indoor air pollutants control is important to reduce negative impact on occupant health from furnishes, moisture, odours, smoke, heat, dust, airborne bacteria and/or carbon dioxide and to replenish oxygen that emit internal pollutants.

All components used shall be safe and shall not possess any harmful materials to the environment. The furniture item shall be non-toxic to the indoor environment.

**a) Low Volatile Organic Compound (VOC) Material**

**1) Design Phase**

Designer should take into consideration of using building materials with low VOC such as:

i) Carpet / flooring
ii) Adhesive /sealant for wall papers, duct insulation etc.
iii) Paint or coating

In some application, VOC material may be avoided by leaving the structure exposed without site-applied paints or coatings.

**2) Construction Phase**

Whenever the removal of paint is applied, make sure that:

i) paint stripper does not contain methylene chloride
ii) do not use uncontained hydroblasting
iii) do not use uncontrolled abrasive blasting

**b) No Added Urea Formaldehyde Products**

**1) Design Phase**

Formaldehyde is a colourless gas with a characteristic pungent odour. Commercial solutions of formaldehyde in water, commonly called formalin, were formerly used as disinfectants and for preservation of biological specimens.

In view of its widespread use, toxicity and volatility, exposure to formaldehyde is a significant consideration for human health. Thus, building materials with added urea formaldehyde products shall not be used in building design to reduce the impact of indoor air quality.

**c) Environmental Tobacco Smoke(ETS)**

ETS is important to avoid exposure of building occupants and health problems associated with tobacco smoke.

**1) Design Phase**

ETS is required:

ETS prohibit smoking area in government building premises [*Peraturan – Peraturan Kawalan Hasil Tembakau 2004 & 2008 P.U.(A) 324/2004 & P.U.(A) 315/2008*] with signage.

**2) Construction Phase**

Appropriate method statement and sample mock-up of signage shall be submitted and approved by Project Director (P.D) before construction.

**d) Air Treatment**

The indoor air treatment is required to enhance the quality of indoor air that the AHU/FCU serves to meet the room condition as per IAQ requirement.

**1) Design Phase**

The designated air conditioned area shall be treated by appropriate air treatment system as the main medium of eliminating contaminants such as Ultraviolet Germicidal Irradiation, Electronic Air Cleaner, Cooling coil treatment, Magnetized Air Filtration, Ionizer, Oxidizer, Gas Phase Air Filtration, Carbon Filters, etc.

The air treatment system shall be installed either within the AHU, FCU or ductwork to provide a complete air purification and sterilization by supplying clean and healthy air to the conditioned space.

**2) Construction Phase**

The installation of air treatment system shall be supervised in accordance with the design and specification.

The air treatment systems shall be properly tested and commissioned so that they operate as per design.

**3) Operation and Maintenance Phase**

Maintenance of air treatment system components in the AHU/FCU shall be carried out by competent ACMV contractor to the following but not limited to:

i) Regular inspection of air treatment system components such as filter, UV light, ballast, multiple-enzym coating, carbon processor, etc
ii) Correction of any deficiencies found during inspections
iii) Repair or replacement of malfunctioning and consumable components such as filter, UV light, ballast, multiple-enzym coating, carbon processor, etc
iv) Adjustment and calibration of control system components
v) Cleaning of internal duct to prevent dust and particulates from getting into the air and landing on clean surfaces.

The operation and maintenance of the building and facilities shall be carried out according to operation and maintenance (O&M) manual.

Operation and maintenance (O&M) manual contents shall at least comprise as follow:

i) Owner's Project Requirements and Basis of Design

ii) Record Documents
iii) Commissioning Report
iv) Operations Manual
v) Training Manual
vi) Schedule of Maintenance
vii) Format of O&M Documentation
viii) Post Occupancy Evaluation (JKR SPK)

In addition, the operation and maintenance shall also comply with the minimum requirement of *Garispanduan Berjadual Penyenggaraan Bangunan Kerajaan*.

**e) Legionella**

Legionnaires' disease is a respiratory infection that strikes susceptible individuals exposed to Legionella pneumophila. Infection results from inhaling airborne water droplets or mist containing viable Legionella pneumophila, which are small enough to pass deep into the lungs and be deposited in the alveoli, the small pockets in the lungs.

The most common sources of Legionella and Legionnaires' disease outbreaks are cooling towers, domestic hot water systems, and large central air conditioning systems.

Initial symptoms of Legionnaires' disease include high fever, chills, headache and muscle pain. A dry cough soon develops and most patients suffer breathing difficulty.

**1) Design Phase**

According to Table 5.1 of ASHRAE Standard 62.1, outdoor air intakes need to be located at least 25 ft (7.6 m) from plume discharges and upwind (prevailing wind) of cooling towers, evaporative condensers, and fluid coolers. In addition, outdoor air intakes need to be located at least 15 ft (4.6 m) away from intakes or basins of cooling towers, evaporative condensers and fluid coolers.

Buildings designed with smaller separation distances from cooling tower can increase the risk of occupant exposure to Legionella and other contaminants, such as the chemicals used to treat the cooling tower water.

The control of Legionella in cooling tower can be achieved through proper siting/location of cooling tower, condenser water treatment and proper operation and maintenance scheduling activity.

**f) Odour**

**1) Design Phase**

Any paints, coatings, primers and adhesives, for internal areas, shall be water based and the Permissible Exposure Limit (PEL) to formaldehyde or any carcinogen as adopted by Occupational Safety & Health Act (OSHA).

Refuse bin facilities shall be provided to the authorities' requirements and approval, located at suitable and accessible location to avoid unpleasant odour in building compound.

Water tap, light fittings, discharge points and proper ventilation shall be provided at covered central refuses collection points.

**g) Non Carcinogenic Material**

Carcinogen is a radiation that is an agent directly involved in causing cancer. Common examples of carcinogens are inhaled asbestos, certain dioxins and tobacco smoke.

**1) Design Phase**

Use of non- carcinogenic material shall be considered in building design.

**h) Component of Furniture**

**1) Design Phase**

All components of the furniture item shall be either non-flammable or shall not support combustion and shall not emit harmful gases in times of danger from fire. Therefore, the suppliers shall provide to P.D a written statement listing all components in either non-flammable or treated-flammable categories. The statement shall also include flammability details of all materials listed in the treated-flammability category in terms of test results from recognized testing authorities with testing certificates.

Furniture components, material and fabrics, containing or manufacture by process in which chlorofluorocarbons are used, shall not be accepted.

Ergonomical and psychological factors must be considered in the overall furniture design as recommended in The Guidelines on Occupational Safety and Health in The Office and Seating at Work by DOSH.

**i) Floor Finishes**

Dust caused by cement screed debris (cement render flooring) in areas such as mechanical plant room (chiller plant room, AHU room, etc) can be prevented by using heavy duty floor finishes.

**1) Design Phase**

Epoxy coating and floor hardener shall be provided to areas needed such as mechanical plant room (chiller plant room, AHU room, etc) as per functional requirement.

**2) Construction Phase**

This type of finishes shall be of approved equivalent and applied strictly in accordance to the manufacture's instruction before the installation.

**j) Building Flush Out**

**1) Construction Phase**

In an effort to remove indoor air pollutants, some buildings undergo a pre-occupancy flush-out where a large amount of tempered outdoor air is forced through the building via the ventilation system. The recommended minimum flush-out period is depending on the building material and furnishings, allowing the majority of pollutants to be removed from the building prior to occupancy.

A building flush-out should be carefully planned due to time, costs and possible occupancy delays.

**k) Ozone**

**1) Operation and Maintenance Phase**

Building equipment and activities can be significant sources of ozone. Ozone is a highly toxic gas produced by office equipments such as photocopiers and printers.

Ozone is about 1½ times heavier than air. In low concentrations, depending on the period of exposure, inhaled ozone may cause dryness of the mouth, throat irritation, coughing and headaches. At higher concentrations, the ozone becomes pungent and can be irritating to eyes, nose and throat.

The acceptable limits for indoor contaminants such as ozone shall not exceed 0.05 ppm as per Table 2.

### 4.1.4. Indoor Air Quality Assessment

The assessment shall include the measurement of the specific physical parameters and indoor air contaminants as listed in Table 2.

Table 2: Indoor Air Contaminants (Courtesy of Industry Code of Practice on Indoor Air Quality - DOSH)

| Indoor Air Contaminants | Acceptable limits | | |
|---|---|---|---|
| | ppm | $mg/m^3$ | $cfu/m^3$ |
| Chemical contaminants | | | |
| (a) Carbon monoxide | 10 | - | - |
| (b) Formaldehyde | 0.1 | - | - |
| (c) Ozone | 0.05 | - | - |
| (d) Respirable particulates | - | 0.15 | - |
| (e) Total volatile organic compounds (TVOC) | 3 | - | - |
| Biological contaminants | | | |
| (a) Total bacteria counts | - | - | 500* |
| (b) Total fungal counts | - | - | 1000* |
| Ventilation performance indicator | | | |
| (a) Carbon dioxide | C1000 | - | - |

Notes:

i) For chemical contaminants, the limits are eight-hour time-weighted average airborne concentrations.

ii) $mg/m^3$ is milligrams per cubic meter of air at 25° Celsius and one atmosphere pressure.

iii) ppm is parts of vapour or gas per million parts of contaminated air by volume.

iv) $cfu/m^3$ is colony forming units per cubic meter.

v) C is the ceiling limit that shall not be exceeded at any time. Readings above 1000ppm are indication of inadequate ventilation.

vi) * Excess of bacterial counts does not necessarily imply health risk but serve as an indicator for further investigation.

**a) Pre-Occupancy Indoor Air Quality Test**

**1) Construction Phase**

The pre-occupancy indoor air quality test shall be conducted by the contractor/builder before handing over of the building. The test consists of assessment and sampling in accordance to Industry Code of Practice on Indoor Air Quality (DOSH) and shall be done after the completion of building flush out.

**b) Post Occupancy Indoor Air Quality Test**

**1) Operation and Maintenance Phase**

Post occupancy indoor air quality test which consists of assessment and sampling in accordance to Industry Code of Practice on Indoor Air Quality (DOSH) shall be conducted by the contractor/builder after the building has been occupied during defect and liability period.

It shall be the responsibility of the building owner or facility manager to investigate concerns about indoor air quality at any time, whenever necessary (e.g occupant complaints, renovation, occupancy in the space exceeds the recommended number of occupancy in the original design, etc)

### 4.1.5. Radon

Radon is a radioactive gas formed from the decay of uranium in rock, soil, and groundwater. Control entry of radon describes mitigation techniques for radon, a naturally occurring radioactive soil gas that is one of the causes of lung cancer.

Radon most commonly enters buildings in soil gas that is drawning through joints, cracks, or penetrations or through pores in concrete masonry units when the building is at negative pressure relative to the ground.

The potential for high radon levels varies regionally, with additional variation from building to building in the same region and even from room to room in the same building.

**a) Design Phase**

1) Active soil depressurization (ASD), which uses one or more suction fans to draw radon from the area below the building slab and discharge it where it can be harmlessly diluted to background levels. By keeping the sub-slab area at a lower pressure than the building, the ASD system greatly reduces the amount of radon-bearing soil gas entering the building. A permeable sub-slab layer (e.g., aggregate) allows the negative pressure field created by a given radon fan to extend over a greater sub-slab area.
2) Sealing of radon entry routes, including ground-contact joints, cracks, and penetrations and below-grade concrete masonry units walls.
3) Use of ACMV systems to maintain positive building pressure in ground-contact rooms and to provide dilution ventilation, as an adjunct to ASD and sealing of radon entry routes.

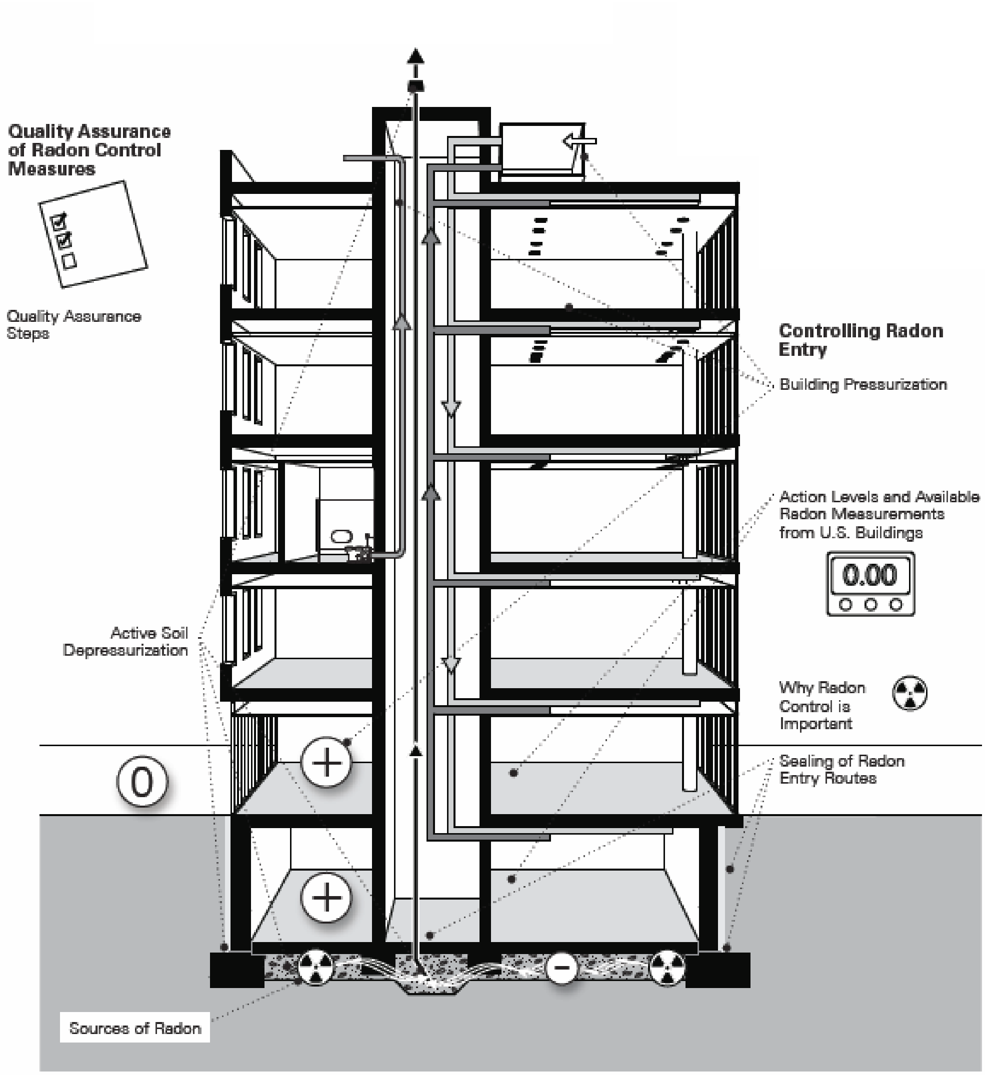


Figure 1: Control Entry of Radon (Courtesy of IAQ Guide-Best Practices for Design, Construction, and Commissioning-ASHRAE)

### 4.1.6. Carbon Dioxide Monitoring and Control

Carbon Dioxide, $CO_2$ is one of the most common gases found in our atmosphere.$CO_2$, like all gases, will rapidly diffuse in outside air, variations in concentrations in a particular location are generally less than 50 ppm and tend to be seasonal in nature.

The accumulation of carbon dioxide in the environment is recognized as a major contributor to the Global Warming Problem caused by this Green House Gas. Measurement of outdoor $CO_2$ levels above 500 ppm may indicate that a significant combustion source is nearby.

Hence, $CO_2$ based demand controlled ventilation (DCV) or $CO_2$ monitoring and control is increasingly used to modulate outside air ventilation based on real-time occupancy. Properly installed, carbon dioxide monitoring and control can reduce unnecessary over-ventilation that might result if air intakes are set to provide ventilation for a maximum assumed occupancy.

The basis of using $CO_2$ for ventilation control is established in well-quantified principles of human physiology. All humans, given a similar activity level, exhale $CO_2$ at a predictable rate based on occupant age and activity level.

As a result, $CO_2$ can be used as a good indicator of human bio effluent concentration and/or occupancy (i.e., doubling the number of people in a space will approximately double $CO_2$ production).

**a) Design Phase**

$CO_2$ monitoring and control system shall be designed to deliver the required amount of fresh air to the occupants to suit variation in occupancy according to DOSH Industry Code of Practice on Indoor Air Quality as per Table 2.

The acceptable limits for indoor contaminants such as $CO_2$ shall not exceed 1000 ppm.

**b) Construction Stage**

The installation of $CO_2$ monitoring and control system shall be supervised in accordance with the design and specification.

The $CO_2$ monitoring and control system shall be properly tested and commissioned so that they operate as per designed.

**c) Operation and Maintenance Stage**

Schedule of maintenance for AHUs and$CO_2$ monitoring & Control System

1) The operation and maintenance of the AHUs and $CO_2$ Monitoring & Control System in the building shall be carried out according to operation and maintenance (O&M) manual and minimum requirement of *Garis Panduan Berjadual Penyenggaraan Bangunan Kerajaan*.
2) All sensors should be tested and calibrated based on manufactures recommendation.

3) During the normal operation of a building, an audit should be conducted by the competent person to ensure that the indoor air quality is acceptable and conforms to the specification and DOSH Guidelines
4) All records or data should be kept by the Building Owner or the Facility Managers and made available for inspection when necessary.

### 4.1.7. Carbon Monoxide Monitoring

Carbon monoxide (CO), also called carbonous oxide, is a colourless, odourless, and tasteless gas that is slightly lighter than air. It is highly toxic to humans and animals in higher quantities. Carbon monoxide is produced from the partial oxidation of carbon-containing compounds; it forms when there is not enough oxygen to produce carbon dioxide ($CO_2$), such as when operating a stove or an internal combustion engine in an enclosed space.

Carbon monoxide combines with hemoglobin to produce carboxy hemoglobin, which is effective for delivering oxygen to body tissues.

Currently, there is no commercially available air cleaner for CO that operates at room temperature.

**a) Design Phase**

CO monitoring system shall be designed to monitor the existing amount of CO in the building to suit variation in occupancy according to DOSH Industry Code of Practice on Indoor Air Quality as per Table 2.

The CO shall activate extraction fan automatically through CO sensor.

The acceptable limits for chemical contaminants such as CO shall not exceed 10 ppm.

**b) Operation and Maintenance Phase**

Scheduling of activities and the ventilation system operation, as well as outdoor air intake location, are strategies to reduce the impact of CO on the indoor environment.

## 4.2 Acoustic Comfort

### 4.2.1. Internal Noise and Vibration Control

Mechanical vibration and vibration-induced noise are often major sources of occupant complaints in modern buildings. Lightweight construction in new buildings increases susceptibility to vibration and vibration-related problems.

The noise which originates inside the office room is called internal noise. The main caused due to improper designs, installation, operations and maintenances of the air-conditioning system such as whistling sound from supply air diffuser, disturbing noise from ducting and AHU system. Others due to conversation in office, rustling of papers, scrapping of chairs and rattling of papers are the examples of internal noise.

Internal noise level throughout the building shall be maintained at an acceptable and tolerable level.

**a) General System**

**1) Design Phase**

Adequate noise and vibration control in any mechanical system is best achieved during the design phase. (ASHRAE Chapter 47, Sound & Vibration Control)

Hence, design shall avoid excessive noise levels particularly from building services and also from office equipment & external sources as follows;

i) Management of noise-generating plant and equipment to control resulting noise levels experienced by staff & occupants. For example, chiller plant room shall not be located near to noise and vibration sensitive areas such as meeting rooms, conference rooms and office area.

ii) Centralized printer, fax and photocopier zones to reduce noise in general office areas.

iii) Double glazing to reduce outside radiated noise and save energy.

iv) Ventilation inlets on the sides of the building away from the principal noise sources.

v) Sound absorption and acoustic barriers should be used to provide privacy where needed.

vi) Design consideration should be used to place point sources of sound (such as ACMV air compressor, fans, gen set etc) away from areas where low acoustic level are critical.

Operational design for the recommended internal noise levels shall be as follows;

i) Open offices (open plan) : Not more than; 45 dBA

ii) Closed/Individual office area : Not more than 40 dBA.

All mechanical and electrical equipment (building services equipment and any other rotating or reciprocating equipment), or any other facilities with rotation or reciprocating dynamic motion that results in moderate to significant dynamic excitation or motion of structures, including floor slabs, when installed within buildings should be mounted with suitable vibration isolation systems or devices. Such systems or devices include elastomeric or rubber pads, steel spring isolators, or pneumatic isolators. The use of matching inertia blocks is recommended.

Mechanical and electrical plants or process that result in low frequency noise and consequently perceivable as low frequency vibration and/or resulting in vibration of lightweight building elements or structures, should be located away from noise and vibration sensitive areas.

The design and implementation of appropriate attenuating elements or devices within the discharge or emission points (exhaust stacks, blowout points, etc) of the low frequency noise source should be included in all new or retrofitted installation in proximity to residential and noise and vibration sensitive areas.

On the structural part, strategies used to improve acoustic performance by using heavier material to decrease sound transmission can be related to structural design and must be considered during design stage.

The use of interior masonry walls for acoustic purposes can serve as multiple purposes wall when designed as part of load bearing masonry structure.

Acoustic block can act as load bearing units and can be incorporated with reinforcement design.

**2) Operation and Maintenance Phase**

Building Owners or Facility Managers shall carry out preventive maintenance and routine inspection to ensure all ACMV system are operating based on design requirement and Operation and Maintenance Manual recommendations.

During this stage, Building Owners or Facility Manager shall conduct a noise level assessment using the measurement tools such as Sound Level Meter to ensure all excessive noise level from office equipment or external noise is below the noise level limits in Noise and Vibration Control-JKR Technical Specification (Appendix 2).

Occupant complaints associated with building vibration typically take one or more of three forms:

i) The level of vibration perceived by building occupants is of sufficient magnitude to cause concern or alarm.
ii) Vibration energy from mechanical equipment, which is transmitted to the building structure, is transmitted to various parts of the building and then is radiated as structure-borne noise.

iii) The vibration present in a building may interfere with proper operation of sensitive equipment or instrumentation.

It is recommended to conduct Condition Based Monitoring (CBM) for all ACMV rotating/vibrating equipments with right method of CBM such as Low Frequency Method and High Frequency Method.

**b) Lighting and Noise**

**1) Construction Phase**

The induction coil (part of the control of discharge lamps) is usually a source of noise. The fitting housing may become a resonator for this noise especially if it has loose fitting parts which are free to vibrate. Thus special precautions must be taken when lighting equipment is installed in very quiet interiors, such as libraries and places of worship.

**c) Acoustic Treatment**

**1) Design Phase**

The acoustic treatment is to ensure the best setup of a room so that sound waves do not reverberate or echo, back and forth of walls and rigid surfaces and cause interference.

The insulation shall prevent sound travels from one room to another room and vice versa. The room design shall have proper insulation to absorb internal sounds which will not affect the appearance and aesthetics of the room.

Qualified technicians shall assist designer to add custom made sound traps and insulation that can be designed to match the decor and layout of the room.

In such cases, effective acoustic treatment shall be provided if the acoustic conditions cannot be met, for example if chiller plant rooms and AHU rooms is located adjacent to noise sensitive space. The noise level criteria shall be as specified in mechanical / electrical brief.

**2) Construction Phase**

Method statement and sample mock-up shall be submitted and approved by P.D's before the construction done.

### 4.3 Thermal Comfort

Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment. Thermal conditions indoors, combined with occupant activity and clothing, determine occupant thermal comfort, which in turn impacts occupant productivity and perceptions of air quality.

There are six primary factors that must be addressed when defining conditions for thermal comfort:

i) Metabolic rate
ii) Clothing insulation
iii) Air temperature
iv) Radiant temperature
v) Air speed
vi) Humidity

All six of these factors may vary with time. However, Thermal Environmental Conditions for Human Occupancy Standard, ASHRAE 55 only addresses thermal comfort in a steady state. As a result, people entering a space that meets the requirements of this ASHRAE 55 standard may not immediately find the conditions comfortable if they have experienced different environmental conditions just prior to entering the space.

**a) Design Phase**

All ACMV design (for air side) shall be provided with high level of thermal comfort system control by individual occupant or by specific groups in multi-occupant spaces to enhance the productivity, comfort and well-being of occupants.

Each person having control over his or her own environment, referred to as personalized ventilation and conditioning is the ideal situation but is not easily attained in buildings. It is recommended, therefore, to select zones carefully and consider using as many as is needed to create sufficient homogeneity within each zone to improve the ability to satisfy comfort needs of occupants in the zones.

The design condition of an air conditioned space for comfort cooling shall meet the minimum requirement of *Garispanduan Pematuhan*

*Rekabentuk Sistem Mekanikal kepada MS1525:2007* but not limited to the following:

1) Zoning and Occupant Control
2) Relative Humidity (55 - 70%)
3) Air Movement (0.15 – 0.5 m/s, max: 0.7 m/s)
4) Thermal Radiation
5) Room Dry Bulb Temperature (23 – 26°C, min: 22°C)

Notes: For higher dry bulb temperature design, air movement shall be taken into consideration.

On the structural part, the use of thermal mass or interior masonry or exposed concrete walls will minimize the interior (room) temperature swings.

The increase in building weight due to such material must be designed for and also be an opportunity for an efficient load bearing design.

**b) Construction Phase**

The installation of ACMV system shall be supervised in accordance with the design and specification.

The ACMV system shall be properly tested and commissioned so that they operate as per design.

**c) Operation and Maintenance Phase**

Maintenance of ACMV system relating to comfort cooling shall be carried out by competent ACMV contractor to the following but not limited to:

1) Regular inspection of hydronic and air side conditions/components such as chilled water temperature, chilled water pump, motorized valve, cooling coil temperature, air filter, AHU fan, thermostat, duct air speed, volume and balancing, control signal cabling /wiring, etc

2) Correction of any deficiencies found during inspections
3) Repair or replacement of malfunctioning and consumable components such as chilled water pump, chilled water pipe, motorized valve, cooling coil, air filter, AHU fan, ducting system, control signal cabling /wiring, etc
4) Adjustment and calibration of control system components

The operation and maintenance of the building and facilities shall be carried out according to operation and maintenance (O&M) manual and minimum requirement of *Garispanduan Berjadual Penyenggaraan Bangunan Kerajaan*.

Operation and maintenance (O&M) manual contents shall at least comprise as follow:

1) Owner's Project Requirements and Basis of Design
2) Record Documents
3) Commissioning Report
4) Operations Manual
5) Training Manual
6) Schedule of Maintenance
7) Format of O&M Documentation
8) Post Occupancy Evaluation

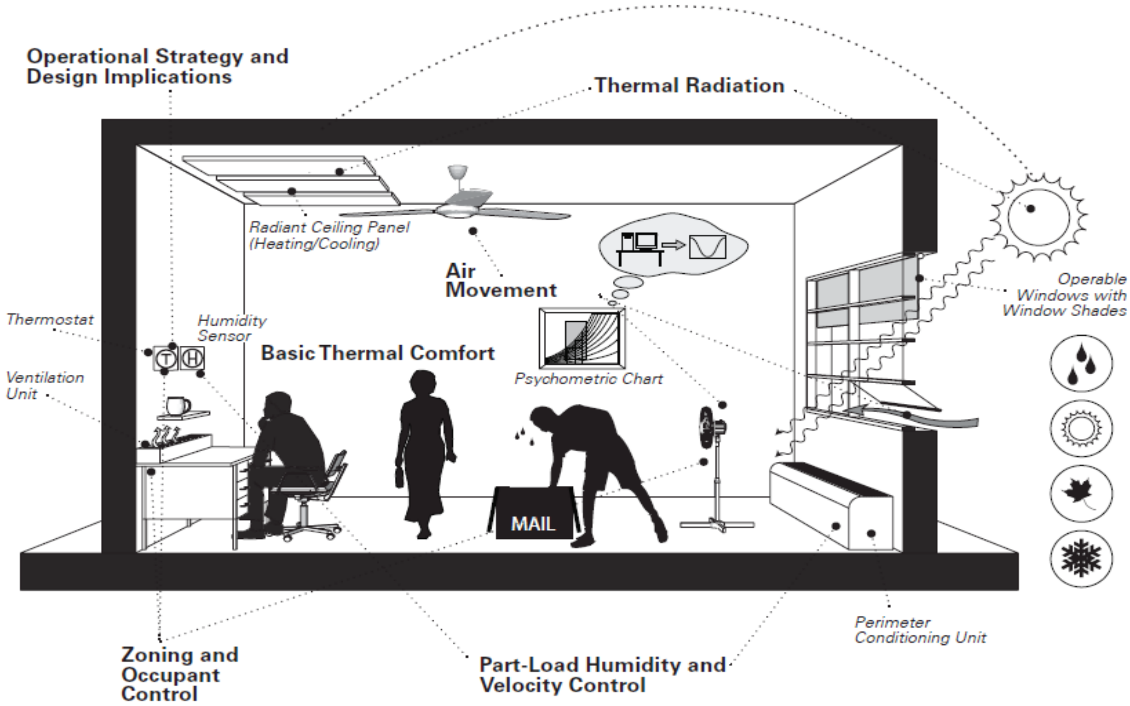


Figure 2: Thermal Comfort (Courtesy of IAQ Guide-Best Practices for Design, Construction, and Commissioning-ASHRAE)

## 4.4 Visual Comfort

### 4.4.1. Daylighting

Effective window design shall be provided to allow natural light distributed properly throughout the workspace without overheating the space and too much glare.

**a) Design Phase**

The design of the building shall consider the achievement of visual comfort where:

1) To get visual comfort for spaces far from building perimeter.
2) To get maximum space comfortness through good daylighting.

On the structural part, daylighting strategies can impact the structural design in several ways. Building orientation and location of window openings to provide outside views can limit the location of shear walls and other loadbearing elements in the building. Consideration must be made to all openings when detailing the load path for the building structure.

Loads from external shading or cladding materials intended to provide visual comfort to occupants must be considered in the structural design.

### 4.4.2. View and Sufficient Daylighting

Allowing long distance views from building facade perimeter will provide visual comfort for building occupants.

**a) Design Phase**

Open plan concept (usable space) should be zoned nearer to the building facade and non-usable space/storage area should be located far from building facade in order to get maximum daylight and external views. Storage rooms shall be functional and well ventilated in compliance to *Jabatan Bomba dan Penyelamat* (BOMBA) requirements.

Internal partition wall with more 1.2 meters height is encouraged to use transparent or glazed materials in order to get optimum daylight and visual comfort towards external views.

Deep planning layout should be avoided and if not, courtyard design with roof skylight shall be introduced to encouraged optimum daylight.

Effective floor to ceiling height should be discussed amongst all discipline during preliminary design stage (to identify M& E requirements) to avoid any discrepancies during and after construction stage.

Selection of light-coloured for wall & ceiling are encouraged to enhanced quality of light and space comfortness.

In designing the interior of the building, specific functional requirements will have to be adhered. Any architectural element or material chosen shall take into consideration towards a healthy and easily maintained environment. The use and exploitation of all specific and prominent cues of the building interior architectural elements will be maximized. Simple interior functional parts like appropriate lighting and colours for the wall and floor will be used in providing aesthetics and in capturing the atmosphere desired for each individual space intended. Interior decoration works shall integrate with the operational and functional requirement, as well as comfortness.

Light shelves shall be used as light reflectors (to project / bounce natural light deeper into internal space) to get optimum daylight.

### 4.4.3. Glare Control

Glare control will reduce and avoid direct sunlight to building occupants, but allow diffuse light into the building.

**a) Design Phase**

Use shading device to avoid direct sunlight / glare by using blinds or facade screening. In order to get maximum view, the use of night curtain is not encouraged.

The use of blinds or removable screen will reduce glare and to maintain lux level below 1000. Designers are required to get complete information such as catalogue, technical specification and building material certification from suppliers and certified by P.D's.

Computer simulation shall be used during design stage to evaluate level of lux as required.

**b) Operation and Maintenance Phase**

The accurate level of lux can be measured after building operation and can be used as a baseline to control glare and lux level.

### 4.4.4. Artificial Lighting

**a) Illumination**

**1) Design Phase**

Good lighting practice for workplace is more than just providing good task visibility. It is essential that tasks are performed easily and in comfort. Thus, the lighting must satisfy the quantitative and qualitative aspects demanded by the environment. In general lighting is to ensure:

i) Visual comfort, where the workers have a feeling of well-being

ii) Visual performance, where the workers are able to perform their visual tasks, speedily and accurately, even under difficult circumstances and during long periods

iii) Visual safety, to see one’s way around the detect hazards.

Accordingly, to have a good lighting design, the following criteria should be taken into consideration:

i) Luminance distribution

ii) Illuminance

iii) Glare

iv) Directionality of light

v) Colour aspects of light and surfaces

vi) Lighting Flicker

vii) Daylight

viii) Maintenance

Design values for the quantifiable parameters of illuminance, discomfort, glare and colour rendering are presented in Appendix 3.

**b) Luminance Distribution**

**1) Design Phase**

The luminance distribution in the field of view controls the adaptation level of the eyes, which affect task visibility. A well-balanced adaptation luminance is needed to increase:

i) Visual acuity (sharpness of vision)

ii) Contrast sensitivity (discrimination of relatively small luminance differences)

iii) Efficiency of the ocular functions (such as accommodation, convergence, papillary contraction, eye movements, etc.)

Diverse luminance distribution in the field of view also affects visual comfort and should be avoided:

i) Too high luminance can give rise to glare

ii) Too high luminance contrasts will cause visual fatigue due to continuous re-adaptation of the eyes

iii) Too low luminance and too low luminance contrasts results in a dull and non-stimulating working environment

iv) Attention should be given to adaptation in moving from zone to zone within a building

The luminance of all surfaces is important and will be determined by the reflectance of and the illuminance of the surfaces. The range of useful reflectance for the major interior surfaces is given in Table 3 below.

Table 3: Range of useful reflectance for the major interior surfaces

| No | Interior Surfaces | Range of Useful Reflectance |
|---|---|---|
| 1 | Ceiling | 0.6 – 0.9 |
| 2 | Walls | 0.3 – 0.8 |
| 3 | Working Planes | 0.2 – 0.6 |
| 4 | Floor | 0.1 – 0.5 |

## c) Illuminance

### 1) Design Phase

The illuminance and its distribution on the tasks areas and the surrounding area have a major impact on how quickly, safely and comfortably a person perceives and carries out the visual task. For spaces where the specific area is unknown, the area where the task may occur is taken as the task area.

All value of illuminance specified in this guideline are maintained illuminance and will provide for visual safety at work and visual performance needs. This can be referred to Appendix 4.

i) Recommended illuminance at the task area

The values given in Appendix 4 are the maintained illuminance over the task area on the reference surface which may be horizontal, vertical or inclined. The average illuminance for each task shall not fall below the value given in Appendix 4 regardless of the age and condition of the installation. The values are valid for normal visual conditions and take into account the following factors:

- requirement for visual tasks
- safety
- psycho-physiological aspects such as visual comfort and well-being
- economy
- practical experience.

The value of illuminance may be adjusted, by at least one step on the scale of illuminance, if the visual conditions differ from the normal assumptions. The illuminance should be increased when:

- unusually low contrasts are present in the task
- visual work is critical
- errors are costly to rectify
- accuracy or higher productivity is of great importance
- the visual capacity of the worker is below normal.

The required maintained illuminance may be decreased when:

- the details are of an unusually large size or high contrast
- the task is undertaken for an unusually short time.

In area where continuous work is carried out, the maintained illuminance shall not be less than 200 lux.

ii) Scale of illuminance

A factor of approximately 1.5 represents the smallest significant difference in subjective effect of illuminance. In normal lighting conditions, approximately 20 lux of horizontal illuminance is required to just discern features of the human face and is the lowest value taken for the scale of illuminance. The recommended scale of illuminance is:

20 – 30 – 50 – 75 – 100 – 200 – 300 – 500 – 750 – 1000 – 1500 – 2000 – 3000 – 5000 lux.

iii) Illuminance of immediate surroundings

The illuminance of the immediate surroundings areas shall be related to the illuminance of the tasks area and should provide a well-balanced illuminance distribution in the field of view. Rapid spatial changes in luminance around the tasks area may lead to visual stress and discomfort.

The maintained illuminance of the immediate surroundings areas may be lower than the tasks illuminance but shall not be less than the values given in the Table 4.

Table 4: Illuminance of immediate surroundings and task illuminance

| Task illuminance lux | Illuminance of immediate surrounding lux |
|---|---|
| ≥ 750 | 500 |
| 500 | 300 |
| 300 | 200 |
| ≤ 200 | Same as task illuminance |

iv) Uniformity

The uniformity of the illuminance is the ratio of the minimum to average value. The illuminance should change gradually. The task area should be illuminated as uniformly as possible. The uniformity of the task illuminance shall not be less than 0.7. The uniformity of the illuminance of the immediate surrounding areas shall be not less than 0.5.

v) Colour aspects

The colour qualities of a near-white lamp are characterized by two attributes:

- The colour appearance of the lamp itself

- Its colour rendering capabilities, which affect the colour appearance of objects and persons illuminated by the lamp.

These two attributes must be considered separately.

vi) Colour Appearance

The variation in the amount of colours within a light mixture affects the appearance of the light in terms of its relative 'warmness' or 'coolness'. To describe this 'warmness' and 'coolness' of the colour of the light sources, the term 'colour temperature' is used.

Colour Temperature or Correlated Colour Temperature (CCT) due to its theoretical basis in the study of 'black body' radiation should apply only to source with a continuous spectrum (such as incandescent lamps and natural light). However, for light sources with non-continuous spectral distribution (such as fluorescent lamps where the spectrum consists of peaks of energy), CCT is used mainly on an empirical sense (i.e. in a very 'near approximate' sense).

vii) Colour Rendering

A more common method of characterizing light sources by its colour is the Colour Rendering Index (CRI). The CRI compares the spectral energy content of a light source to that of a standard reference source with full spectrum. The CRI value is the numerical value and is 100 for full-spectrum natural white-light. Incandescent lights are considered nearly white and have CRI close to 100. Most lights have CRI typically in the range of 20 – 80.

The CRI model is not a perfect model and should only be used to compare light source with the same colour temperature. For example, (about) 6000K daylight fluorescent and clear mercury has CRI of 76 and 22 respectively. The daylight fluorescent will therefore render colours better than clear mercury. The difference between a 3400K tungsten halogen with CRI 99 and an ordinary 2800K incandescent with CRI 92 can usually also be differentiated by most observers. Despite the small difference in CRI values, the tungsten halogen will render colours more vividly compared to the ordinary incandescent. Colour rendering is important especially in the case of (building) façade and monument building.

An automatic or manual switching or dimming of the lamps is required during day time depending on the visual acceptance limit.

viii) General Principles of Efficient Lighting Practice

Lighting must provide a suitable visual environment within a particular space, i.e. sufficient and suitable lighting for the performance of a range of tasks and provision of a desired appearance.

**2) Operation & Maintenance Phase**

Maintained illuminance depends on the maintenance characteristic of the lamp, the luminaire, the environment and maintenance programed. The lighting scheme should be designed with overall maintenance factor calculated for the selected lighting equipment, space environment and specified maintenance schedule. The calculated maintenance factor should not be less than 0.70.

Best practice guideline is established for periodical maintenance and appropriate selection and usage of lighting equipment.

**d) Artificial Lighting Glare**

**1) Design Phase**

Glare is experienced if a source of light, (luminaire or a reflecting shiny surface) is too bright compared with the general brightness of the surrounding. Glare will makes it more difficult to see detail or contrast in an object and it is known as disability glare. Discomfort glare is the more common type of glare experienced in interiors. It causes visual discomfort, though this may not be apparent but the effect is sense of tiredness, especially towards the end of a working day. This discomfort will also have an effect on working efficiency.

The level of discomfort glare can be expressed numerically as a glare index. (The method of calculating glare index is a bit too details to be included in this manual, however the reader can consult the references mentioned to learn the method). The glare index worked out for a particular interior should not be more than the limiting value found in the IES Code for that particular activity.

i) Controlling glare

One way of reducing glare is to direct visual task away from the line of sight of a bright luminaire. When luminaries are mounted in regular pattern, the glare index should be calculated and if it is greater than the limiting value then the following changes might be necessary:-

- a change in the orientation of the luminaire.
- a change in the type of luminaire.
- a change in the room surface reflectance.

Open luminaries should be fitted with louvers whose cut off angle is sufficient to prevent the lamp being seen at normal angle of view.

Unscreened fluorescent lamps should be mounted in line with the normal direction of view and not across it.

**e) Lighting Flicker**

**1) Design Phase**

The 50Hz flicker in discharge lamps can prove distracting to some people. For fluorescent tube, the 50Hz flicker occurs mainly at the lamp ends, and the effects is more apparent in 5 ft. 80W tubes than the lower rate current tubes. Flicker can be reduced in these fluorescent lamps of high rated current (5ft., 6ft., and 8ft. tubes) by employing the shielded electrode type.

Alternatively, high frequency ballasts can be used to eliminate the 50Hz lamp flicker, making lighting much easier on the eyes. There is no audible hum and lower heat generation, contributing to improved working conditions. Lamp starting is instantaneous; these ballasts also prevent stroboscopic effects which can be dangerous where rotating machinery is used. These confusing stroboscopic effects can also be diminished by supplementing the light over task areas with light from local incandescent lamps.

## 4.5 Housekeeping

Housekeeping refers to the general cleaning of buildings, including the floors, walls, certain types of equipment, tables and other surfaces. A housekeeping activity is more than just a cleaning program. It involves:

a) Actions to prevent dust and dirt from entering the environment as well as its removal once it is there which could otherwise become sources of contamination.

b) Choices of products and methods that minimize the introduction of pollutants into the environments that the housekeeping activities is designed to clean.

c) Tasks designed for health and safety as well as tasks designed for appearance.

d) Training, negotiating, and monitoring performance.

Establish good housekeeping activities can prevent pollutant of indoor air quality inside the building.

### 4.5.1. Construction Phase

**a) Clean Site**

To help sustain long-term occupant health and safety from poor indoor quality problem resulting from construction process, housekeeping need to be performed during and after construction (Before commissioning).

During construction, everyday housekeeping activities is required to prevent indoor air quality problem such as below:

1) Minimize dust: Methods of minimizing dust from cut-off saws, drywall sanders, etc. shall be used. This means using dust collection systems on these tools and emptying them into receptacles located outside the building. Use damp rags, mops or vacuum cleaners to clean up dust as necessary within the job site.

2) Minimize dirt: Sweeping compounds shall be used to keep floors clean of dirt and dust. Floors shall be swept daily in the work areas or more frequently if required.
3) Keep work area clean and dry: If water leaks occur, promptly mop areas dry.
4) Seal containers containing VOCs: Containers of fuel, paints, finishes, and solvents shall be kept tightly sealed when not in use. These containers shall be stored outside the building and remain outside the building to the greatest extent possible.

Before a new building is commissioned into service, all the areas and the entire ACMV system should be cleared of any construction debris and dirt, and cleaned before operation starts.

### 4.5.2. Operation and Maintenance Phase

#### a) Cleaning Services

Cleaning Services shall include for all spaces in the building and outside the buildings within the boundary, including both sides external walls and the surrounding area that is associated with the buildings such as roads, driveways, footpath, landscape, assets, gadgets, fittings, fixtures, equipments, structures and installations situated in the area. To remove indoor air contamination, cleaning activities shall comprise as follow:

1) Scrubbing (frictional cleaning) is the best way to physically remove dirt, debris and microorganisms.
2) Using Low Volatile organic compounds for cleaning.
3) Using organic, bio-degradable, toxin-free cleaners that do not generate harsh fumes
4) Cleaning using vacuum cleaners and avoid using dry sweeping, mopping and dusting to prevent dust, debris and microorganisms from getting into the air and landing on clean surfaces.

5) Follow all instructions for mixing and dilution when using disinfectants to ensure effectiveness of disinfectants.
6) Choose right cleaning methods and written cleaning schedules should be based on the type of surface, amount and type of soil present and the purpose of the area.
7) Provide consistent and posted schedules (Daily Cleaning) and procedures to maintain a standard of cleanliness.

**b) Waste Disposal Services**

Waste, redundant materials and rubbish arising from the execution of the services shall be disposed off from the building daily to a waste disposal centre designated in the building compound. It shall follow proper waste disposal procedure to avoid indoor air contamination.

**c) Pest Control**

Implement pest control activities to provide an effective control and preventive action to all types of pest inside and outside the building and the surrounding area that is associated with the buildings to ensure the building is free from pests.

Pest control activities depend on the use of pesticides that involve the storage, handling, and application of material that can contaminate indoor air quality. To eliminate the source of indoor air pollutant contribute by pesticides, the activities shall comprise of:

1) Scheduling pesticide application for unoccupied periods
2) Selection of pesticides for specific species and attempt to minimize toxicity for human and non-target species.
3) Ventilation of areas where pesticides are applied
4) Use organic, non-toxic pesticides

All pest control works shall follow the specifications and minimum requirement of Industry Code of Practice on Indoor Air Quality (DOSH) to ensure safety and health of occupants and workers.

## 4.6 Safety and Health

### 4.6.1. Construction/Renovation

Renovation works can release contaminants and pollutants that affect indoor air quality of a workspace such as dust and noise. These contaminants may be transported to other areas via the ventilation and air conditioning systems and affect occupants beyond the immediate work area. Hence, proper scheduling of renovation work shall be required during low occupancy in the renovated or adjacent building.

For occupied buildings undergoing partial renovation, spaces to be renovated shall be effectively isolated from the occupied zones. If necessary, supply air shall be separated so that acceptable indoor air quality for the occupants is maintained.

After any major renovation to the building where the ACMV system has been affected (e.g. by partitioning of office space), rebalancing of the air distribution shall be required.

An effective approach to maintain safe and healthy Indoor Air Quality is to eliminate or reduce contaminants and pollutants generated during renovations works. All renovations works shall follow a minimum requirement of Industry Code of Practice on Indoor Air Quality (DOSH) and contract specification in the matter of safety and health to ensure safety and health of occupants and workers.

**a) Dust Control**

**1) Construction Phase**

Dust is classified by size into three primary categories:

i) Respirable dust

Respirable dust refers to those dust particles that are small enough to penetrate the upper respiratory and deep into the lungs.

ii) Inhalable dust

Inhalable dust is described as that size fraction of dust which enters the body, but is trapped in the nose, throat, and upper respiratory tract. The median aerodynamic diameter of this dust is about 10μm.

iii) Total dust

Total dust includes all airborne particles, regardless of their size or composition.

Dust can be form from a renovation works and it also can travels to adjacent building. Thus, preventive measure must be taken to control a dust and to improve Indoor air Quality. To control the dust the following action shall be given specific priority to ensure safe and healthy environment:

i) Use temporary barriers to separate renovation work areas from occupied areas and contain renovations activities that produce lots of dust;
ii) Provide walk-off mats for workers to prevent tracking dust and contaminants from the renovation area;
iii) Cover ductwork, cover open grilles to protect dust from spreading;
iv) Regular sweeping and mopping;
v) Arrange renovation works schedule to limit occupant exposure to renovation area (low occupancy);

The Particles Permissible Limit for dust generated from renovation works shall below the Particles Permissible Limit stipulated in Schedule 1: Occupational Safety & Health Act (Use and Standards of Exposure of Chemicals Hazardous to Health Regulations 2000).

**b) Noise Control**

**1) Construction Phase**

Prevent excessive noise from renovation works

Noise pollution is unwanted sounds that can affect occupant's health and productivity such as stress, aggression, high blood pressure, sleep loss and hearing loss. To prevent negative effect of noise, owners or managers should:

i) Carry out the renovation works on holiday or after office hours;

ii) Works within a renovation are using specified powered mechanical equipment;

The permissible limit for noise generated from renovation works shall follow the minimum requirement of Noise Permissible Limit under the First Schedule of the Factories and Machinery (Noise Exposure) Regulations 1989 and Guideline for Environmental Noise Limits and Control (2004 establish by Department of Environment (DOE).

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ACMV | = air conditioning and mechanical ventilation |
| AHU | = Air-Handling Unit |
| ASHRAE | = American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| CO | = carbon monoxide |
| $CO_2$ | = carbon dioxide |
| FM | = Facility Manager |
| IAQ | = indoor air quality |
| IAQP | = IAQ Procedure |
| IEQ | = indoor environment quality |
| P.D | = Project Director |

## APPENDIX 1

Minimum Ventilation Rate in Breathing Zone, ASHRAE 62.1

| Occupancy Category | People Outdoor Air rate, $R_p$ | | Area Outdoor Air Rate, $R_a$ | | Notes | Default Values | | | Air Class |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Occupant Density (see Note 4) | Combined Outdoor Air Rate (see Note 5) | | |
| | Cfm/person | L/s.person | Cfm/ft² | L/s.m² | | #/1000 ft² or #/100 m² | Cfm/person | L/s.person | |
| **Correctional Facilities** | | | | | | | | | |
| Cell | 5 | 2.5 | 0.12 | 0.6 | | 25 | 10 | 4.9 | 2 |
| Dayroom | 5 | 2.5 | 0.06 | 0.3 | | 30 | 7 | 3.5 | 1 |
| Guard stations | 5 | 2.5 | 0.06 | 0.3 | | 15 | 9 | 4.5 | 1 |
| Booking/waiting | 7.5 | 3.8 | 0.06 | 0.3 | | 50 | 9 | 4.4 | 2 |
| **Educational Facilities** | | | | | | | | | |
| Daycare (through age 4) | 10 | 5 | 0.18 | 0.9 | | 25 | 17 | 8.6 | 2 |
| Daycare sickroom | 10 | 5 | 0.18 | 0.9 | | 25 | 17 | 8.6 | 3 |
| Classroom (age 5-8) | 10 | 5 | 0.12 | 0.6 | | 25 | 15 | 7.4 | 1 |
| Classroom (age 9 plus) | 10 | 5 | 0.12 | 0.6 | | 35 | 13 | 6.7 | 1 |
| Lecture Classroom | 7.5 | 3.8 | 0.06 | 0.3 | | 65 | 8 | 4.3 | 1 |
| Lecture hall (fixed seat) | 7.5 | 3.8 | 0.06 | 0.3 | | 150 | 8 | 4.0 | 1 |
| Art classroom | 10 | 5 | 0.18 | 0.9 | | 20 | 19 | 9.5 | 2 |
| Science laboratories | 10 | 5 | 0.18 | 0.9 | | 25 | 17 | 8.6 | 2 |
| University/college laboratories | 10 | 5 | 0.18 | 0.9 | | 25 | 17 | 8.6 | 2 |
| Wood/metal shop | 10 | 5 | 0.18 | 0.9 | | 20 | 19 | 9.5 | 2 |
| Computer lab | 10 | 5 | 0.12 | 0.6 | | 25 | 15 | 7.4 | 1 |
| Media center | 10 | 5 | 0.12 | 0.6 | A | 25 | 15 | 7.4 | 1 |
| Music/theater/dance | 10 | 5 | 0.06 | 0.3 | | 35 | 12 | 5.9 | 1 |
| Multi-use assembly | 7.5 | 3.8 | 0.06 | 0.3 | | 100 | 8 | 4.1 | 1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Food and Beverage Service** | | | | | | | | | |
| Restaurant dining rooms | 7.5 | 3.8 | 0.18 | 0.9 | | 70 | 10 | 5.1 | 2 |
| Cafeteria/fast-food dining | 7.5 | 3.8 | 0.18 | 0.9 | | 100 | 9 | 4.7 | 2 |
| Bars, cocktail lounges | 7.5 | 3.8 | 0.18 | 0.9 | | 100 | 9 | 4.7 | 2 |
| **General** | | | | | | | | | |
| Break room | 5 | 2.5 | 0.06 | 0.3 | | 25 | 10 | 5.1 | 1 |
| Coffee station | 5 | 2.5 | 0.06 | 0.3 | | 20 | 11 | 5.5 | 1 |
| Conference/meeting | 5 | 2.5 | 0.06 | 0.3 | | 50 | 6 | 3.1 | 1 |
| Corridors | - | - | 0.06 | 0.3 | | - | | | 1 |
| Storage rooms | - | - | 0.12 | 0.6 | B | - | | | 1 |
| **Resort, Dormitories** | | | | | | | | | |
| Bedroom/living room | 5 | 2.5 | 0.06 | 0.3 | | 10 | 11 | 5.5 | 1 |
| Barrack sleeping areas | 5 | 2.5 | 0.06 | 0.3 | | 20 | 8 | 4.0 | 1 |
| Laundry rooms, central | 5 | 2.5 | 0.12 | 0.6 | | 10 | 17 | 8.5 | 2 |
| Laundry rooms within dwelling units | 5 | 2.5 | 0.12 | 0.6 | | 10 | 17 | 8.5 | 1 |
| Lobbies/prefunction | 7.5 | 3.8 | 0.06 | 0.3 | | 30 | 10 | 4.8 | 1 |
| Multipurpose assembly | 5 | 2.5 | 0.06 | 0.3 | | 120 | 6 | 2.8 | 1 |
| **Office Buildings** | | | | | | | | | |
| Office space | 5 | 2.5 | 0.06 | 0.3 | | 5 | 17 | 8.5 | 1 |
| Reception areas | 5 | 2.5 | 0.06 | 0.3 | | 30 | 7 | 3.5 | 1 |
| Telephone/data entry | 5 | 2.5 | 0.06 | 0.3 | | 60 | 6 | 3.0 | 1 |
| Main entry lobbies | 5 | 2.5 | 0.06 | 0.3 | | 10 | 11 | 5.5 | 1 |
| **Miscellaneous Spaces** | | | | | | | | | |
| Bank vaults/safe deposit | 5 | 2.5 | 0.06 | 0.3 | | 5 | 17 | 8.5 | 2 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Computer (not printing) | 5 | 2.5 | 0.06 | 0.3 | | 4 | 20 | 10.0 | 1 |
| Electrical equipment rooms | - | - | 0.06 | 0.3 | B | - | | | 1 |
| Elevator machine rooms | - | - | 0.12 | 0.6 | B | - | | | 1 |
| Pharmacy (prep. area) | 5 | 2.5 | 0.18 | 0.9 | | 10 | 23 | 11.5 | 2 |
| Photo studios | 5 | 2.5 | 0.12 | 0.6 | | 10 | 17 | 8.5 | 1 |
| Shipping/receiving | - | - | 0.12 | 0.6 | B | - | | | 1 |
| Telephone closets | - | - | 0.00 | 0.0 | | - | | | 1 |
| Transportation waiting | 7.5 | 3.8 | 0.06 | 0.3 | | 100 | 8 | 4.1 | 1 |
| Warehouses | - | - | 0.06 | 0.3 | B | - | | | 2 |
| **Public Assembly Spaces** | | | | | | | | | |
| Auditorium seating area | 5 | 2.5 | 0.06 | 0.3 | | 150 | 5 | 2.7 | 1 |
| Places of religious worship | 5 | 2.5 | 0.06 | 0.3 | | 120 | 6 | 2.8 | 1 |
| Courtroom | 5 | 2.5 | 0.06 | 0.3 | | 70 | 6 | 2.9 | 1 |
| Legislative chambers | 5 | 2.5 | 0.06 | 0.3 | | 50 | 6 | 3.1 | 1 |
| Libraries | 5 | 2.5 | 0.12 | 0.6 | | 10 | 17 | 8.5 | 1 |
| Lobbies | 5 | 2.5 | 0.06 | 0.3 | | 150 | 5 | 2.7 | 1 |
| Museum (children's) | 7.5 | 3.8 | 0.12 | 0.6 | | 40 | 11 | 5.3 | 1 |
| Museums/galleries | 7.5 | 3.8 | 0.06 | 0.3 | | 40 | 9 | 4.6 | 1 |
| **Residential** | | | | | | | | | |
| Dwelling unit | 5 | 2.5 | 0.06 | 0.3 | F,G | F | | | 1 |
| Common corridors | - | - | 0.06 | 0.3 | | | | | 1 |
| **Retail** | | | | | | | | | |
| Sales (except as below) | 7.5 | 3.8 | 0.12 | 0.6 | | 15 | 16 | 7.8 | 2 |
| Mall common areas | 7.5 | 3.8 | 0.06 | 0.3 | | 40 | 9 | 4.6 | 1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Barbershop | 7.5 | 3.8 | 0.06 | 0.3 | | 25 | 10 | 5.0 | 2 |
| Beauty and nail salons | 20 | 10 | 0.12 | 0.6 | | 25 | 25 | 12.4 | 2 |
| Pet shops (animal areas) | 7.5 | 3.8 | 0.18 | 0.9 | | 10 | 26 | 12.8 | 2 |
| Supermarket | 7.5 | 3.8 | 0.06 | 0.3 | | 8 | 15 | 7.6 | 1 |
| Coin-operated laundries | 7.5 | 3.8 | 0.06 | 0.3 | | 20 | 11 | 5.3 | 2 |
| **Sports and Entertainment** | | | | | | | | | |
| Sports arena (play area) | - | - | 0.30 | 1.5 | E | - | | | 1 |
| Gym, stadium (play area) | - | - | 0.30 | 1.5 | | 30 | | | 2 |
| Spectator areas | 7.5 | 3.8 | 0.06 | 0.3 | | 150 | 8 | 4.0 | 1 |
| Swimming (pool & deck) | - | - | 0.48 | 2.4 | C | - | | | 2 |
| Disco/dance floors | 20 | 10 | 0.06 | 0.3 | | 100 | 21 | 10.3 | 1 |
| Health club/aerobics room | 20 | 10 | 0.06 | 0.3 | | 40 | 22 | 10.8 | 2 |
| Health club/ weight room | 20 | 10 | 0.06 | 0.3 | | 10 | 26 | 13.0 | 2 |
| Bowling alley (seating) | 10 | 5 | 0.12 | 0.6 | | 40 | 13 | 6.5 | 1 |
| Gambling casinos | 7.5 | 3.8 | 0.18 | 0.9 | | 120 | 9 | 4.6 | 1 |
| Game arcades | 7.5 | 3.8 | 0.18 | 0.9 | | 20 | 17 | 8.3 | 1 |
| Stages, studios | 10 | 5 | 0.06 | 0.3 | D | 70 | 11 | 5.4 | 1 |

Table 1.0 (a): Minimum Ventilation Rates In Breathing Zone (ASHRAE 62.1)

Notes:

i. A- For high school and college libraries, use values shown for Public Assembly Spaces - Libraries
ii. B- Rate may not be sufficient when stored materials include those having potentially harmful emissions.
iii. C- Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.

iv. D- Rate does not include special exhaust for stage effect, e.g dry ice vapours or smoke.

v. E- When combustion equipment is intended to be used on the playing surface, additional dilution ventilation and/or source control shall be provided.

vi. F- Default occupancy for dwelling units shall be two persons for studio and one bedroom unit, with one additional person for each additional bedroom.

vii. G- Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

**APPENDIX 2**

Recommended Noise Criteria (NC) – Room Criteria (RC) and Maximum Sound Pressure Level (Lp) for Different Indoor Activity.

| Type of Area | Max Level | |
|---|---|---|
| | NC-RC Level | Lp (dBA) |
| RESIDENCES | | |
| Residences, Apartment, Condominium | 35 | 40 |
| HOSPITALS & CLINICS | | |
| Private rooms | 35 | 40 |
| Operating rooms | 40 | 45 |
| Wards, corridors | 40 | 45 |
| Laboratories | 40 | 45 |
| Lobbies, waiting rooms | 45 | 50 |
| Washrooms, toilets | 50 | 55 |
| OFFICES | | |
| Board rooms | 30 | 35 |
| Conference rooms | 35 | 40 |
| Teleconference rooms | 25 | 30 |
| Executive offices | 40 | 45 |
| General offices | 40 | 45 |
| Reception rooms | 45 | 50 |
| General open offices | 45 | 50 |
| Drafting rooms | 45 | 50 |
| Halls & corridors | 60 | 65 |
| Tabulation and computation areas | 50 | 55 |
| AUDITORIUMS | | |
| Multi-purpose halls | 30 | 35 |
| Lecture halls | 35 | 40 |
| Planetariums | 35 | 40 |
| Lobbies | 45 | 50 |
| LABORATORIES (with fume hoods) | | |
| Testing/research, minimal speech communication | 55 | 60 |
| Research, extensive telephone use, speech communication | 50 | 55 |
| Group Teaching | 45 | 50 |

| Type of Area | Max Level | |
|---|---|---|
| | NC-RC Level | Lp (dBA) |
| PERFORMING ARTS SPACES | | |
| Drama Theaters | 25 | 30 |
| Concert and recital halls | 25 | 30 |
| Music Teaching Studios | 25 | 30 |
| Music Practice Rooms | 35 | 40 |
| MASJID / RUMAH IBADAT | 35 | 40 |
| SCHOOLS | | |
| Lecture/Classrooms | 40 | 45 |
| Classrooms up to 750 $ft^2$ [75 $m^2$] | 40 | 45 |
| Classrooms over 750 $ft^2$ [75 $m^2$] | 35 | 40 |
| Lecture rooms for more than 50 (unamplified speech) | 35 | 40 |
| Laboratories | 45 | 50 |
| Recreation halls | 50 | 55 |
| Corridors & halls | 50 | 55 |
| PUBLIC LIBRARIES | | |
| Libraries, museums | 40 | 45 |
| COURT ROOMS | 40 | 45 |
| i) Unamplified speech | 35 | 40 |
| ii) Amplified speech | 40 | 45 |
| RESTAURANTS, CAFETARIA | | |
| Restaurants | 45 | 50 |
| Cafeterias | 50 | 55 |
| INDOOR SPORTS ACTIVITIES | | |
| Gymnasiums | 45 | 50 |
| School and college gymnasiums | 50 | 55 |
| Large seating capacity spaces (with amplified speech) | 55 | 60 |
| AIRPORT | | |
| Tickets sales offices | 40 | 45 |
| Lounges, waiting rooms | 50 | 55 |
| OUTSIDE MECHANICAL PLANT ROOM | | |
| 1m away from external wall | 70 | 75 |

**APPENDIX 3**

Design values for the quantifiable parameters of illuminance, discomfort, glare and colour rendering

| Factor | Fluorescent | MH | HPS | LPS |
|---|---|---|---|---|
| Wattage | 18 – 95 | 50 – 400 | 50 – 400 | 18 – 180 |
| Output (lumens) | 1,000 - 7,500 | 1,900 - 30,000 | 3,600 - 4,600 | 1,800 - 33,000 |
| Efficacy (lumens / watt) | 55 – 79 | 38 – 75 | 72 – 115 | 100 – 183 |
| Lumen Maintenance | 85 (80) | 75 (65) | 90 (70) | 100 (100) |
| Lamp Life (hours) | 10,000 – 20, 000 | 10,000 – 20,000 | 18,000 – 24,000 | 16,000 |
| CRI | 30 – 90 | 80 – 90 | 20 – 39 | <20 |

Notes:

- Wattage and output refers to the commonly available lamp rating for outdoor lightings.
- Efficacy refers to the ratio of the measured light output of a luminaire to its active power, express in lumens per watt.
- Lumen Maintenance refers to percent of initial lamp output at 50% of mean lifetime and at end of lifetime (parenthesis).
- Lamp Life refers to the approximate mean lifetime of lamp.

**APPENDIX 4**

The maintained illuminance levels for general building areas

| Item | Area | Illumination Level (Lux) |
|---|---|---|
| 1 | Ruang Laluan (Luar) | 50 |
| 2 | Tempat Letak Kereta | 50 |
| 3 | Bilik Tidur Hotel | 100 |
| 4 | Lif | 100 |
| 5 | Koridor | 100 |
| 6 | Tangga | 100 |
| 7 | Eskalator | 150 |
| 8 | Bilik Persalinan | 100 |
| 9 | Bilik Pencuci | 100 |
| 10 | Pintu keluar & Masuk | 100 |
| 11 | Dewan Masuk | 100 |
| 12 | Lobi | 100 |
| 13 | Bilik Menunggu | 100 |
| 14 | Kaunter Pertanyaan | 300 |
| 15 | Pejabat | 300 |
| 16 | Pejabat Lukisan | 300 |
| 17 | Restoran | 150 |
| 18 | Kantin | 200 |
| 19 | Kafeteria | 200 |
| 20 | Dapur | 150 |
| 21 | Bilik Mandi | 150 |
| 22 | Tandas | 100 |
| 23 | Bilik Darjah | 300 |
| 24 | Perpustakaan | 500 |
| 26 | Muzium | 300 |
| 27 | Bilik Komputer | 500 |
| 28 | Bilik Mesyuarat | 300 |
| 29 | Bilik Pengarah | 300 |
| 30 | Bilik Pegawai | 300 |
| 31 | Bilik Perbincangan | 300 |
| 32 | Stor | 100 |
| 33 | Bilik Cetak | 300 |
| 34 | Bilik Fail | 300 |
| 35 | Bilik Kuliah | 300 |
| 36 | Bilik Makmal | 300 |
| 37 | Bilik Utiliti | 100 |
| 38 | Dewan Serbaguna | 300 |
| 39 | Surau | 300 |
| 40 | Bilik Solat | 300 |
| 41 | Ruang Wuduk | 150 |
| 42 | Bilik Seminar | 300 |
| 43 | Bilik Tukar Lampin | 200 |

| Item | Area | Illumination Level (Lux) |
|---|---|---|
| 44 | Bilik Penyusuan | 300 |
| 45 | Bilik Rawatan | 300 |
| 46 | Bilik Pemeriksaan | 300 |
| 47 | Bilik Analisa | 300 |
| 48 | Farmasi | 300 |
| 49 | Bilik Kebal | 300 |
| 50 | Bilik Pergigian | 300 |
| 51 | Bilik Sterlisasi | 300 |
| 52 | Bilik Pembedahan | 500 |
| 53 | Bengkel | 500 |
| 54 | Ruang Laluan (Dalam) | 300 |
| 55 | Auditorium | 150 |
| 56 | Gimnasium | 300 |
| 57 | Garaj | 300 |
| 58 | Bilik Demontrasi Memasak | 100 |
| 59 | Pantri | 100 |
| 60 | Bilik Penyediaan Makanan | 300 |
| 61 | Bilik Suis/Riser | 150 |
| 62 | Bilik Set Janakuasa | 150 |
| 63 | Bilik Server | 300 |
| 64 | Bilik Mesin | 300 |
| 65 | Bilik AHU | 150 |
| 66 | Bilik MDF | 150 |
| 67 | Rumah Pam | 150 |
| 68 | Bilik Motor Lif | 150 |
| 69 | Bilik Tangki / Mekanikal | 150 |
| 70 | Bilik Tayangan | 300 |
| 71 | Bilik Studio Rakaman | 300 |
| 72 | Bilik Prosedur | 300 |
| 73 | Bilik Gelap | 300 |
| 74 | Bilik Cuci/Dobi | 200 |
| 75 | Hangar | 500 |

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