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Ergonomic design of control centres —

Part 6:
Environmental requirements for control centres

Conception ergonomique des centres de commande —

Partie 6: Exigences relatives à l'environnement pour les centres de commande

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11064-6 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

ISO 11064 consists of the following parts, under the general title *Ergonomic design of control centres*:

— *Part 1: Principles for the design of control centres*

— *Part 2: Principles for the arrangement of control suites*

— *Part 3: Control room layout*

— *Part 4: Layout and dimensions of workstations*

— *Part 6: Environmental requirements for control centres*

— *Part 7: Principles for the evaluation of control centres*

Introduction

The environmental aspects associated with the design of man–machine systems need to be addressed, since poor environments can seriously affect operator performance. In control rooms, these environmental factors include lighting, humidity, temperature, vibration and noise. These factors also need to take account of shift work, real-time operations under time pressure and the specialised equipment used in control rooms.

In this part of ISO 11064, environmental requirements are presented which optimize work conditions in such a way that safety is ensured, health is not impaired and the efficiency of control room operators is promoted.

The degree of specificity of this standard does not extend to national and local requirements, which can vary between countries and/or regions. In such cases, experts in the relevant areas (human factors and ergonomics, lighting, acoustics, thermal environment, etc.) will need to be consulted. For specific values on environmental variables, see Annex A and/or consult local and/or national standards for the relevant country or region.

Ergonomic design of control centres —

Part 6: Environmental requirements for control centres

1 Scope

This part of ISO 11064 gives environmental requirements as well as recommendations for the ergonomic design, upgrading or refurbishment of control rooms and other functional areas within the control suite.

The following aspects are covered:

— thermal environment (temperate regions);

— air quality;

— lighting environment;

— acoustic environment;

— vibration;

— aesthetics and interior design.

It is applicable to all types of control centres, including those for the process industry, transport and dispatching systems and emergency services. Although primarily intended for non-mobile control centres, many of its principles are relevant to mobile centres such as those found on ships, locomotives and aircraft.

It does not cover the influence of electromagnetic fields. Guidance on the influence of electromagnetic fields on the image quality of visual displays is given in ISO 9241-6.

This part of ISO 11064 is closely connected with ISO 11064-2 and ISO 11064-3, which describe the control room layout. It also relates to the design of equipment interfaces, which are influenced by environmental factors. It would be prudent for designers to also take account of the more general environmental requirements associated with display screen equipment use presented in ISO 9241-6 and ISO 9241-7.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7731, *Ergonomics — Danger signals for public and work areas — Auditory danger signals*

ISO 7779, *Acoustics — Measurement of airborne noise emitted by information technology and telecommunications equipment*

ISO/CIE 8995, *Lighting of indoor work places*

ISO 9241-6, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 6: Guidance on the work environment*

ISO 13731, *Ergonomics of the thermal environment — Vocabulary and symbols*

IEC 60651, *Sound level meters — Electromagnetic and electrostatic compatibility and test procedures*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
A-weighted sound pressure level
sound level
logarithm to the base 10 of the ratio of a given sound pressure to the reference sound pressure of 20 µPa, the sound pressure being obtained with a standard frequency weighting and with standard exponentially weighted time-averaging

NOTE The sound level in decibels is twenty times the logarithm to the base ten of that ratio.

[IEC 60651]

3.2
air velocity
v_a
average of the effective velocity of the air, i.e. the magnitude of the velocity vector of the flow at the measuring point considered, over an interval of time (measuring period), expressed in metres per second

3.3
brightness
attribute of a visual sensation associated with the amount of light emitted from a given area

NOTE 1 It is the subjective correlate of luminance.

NOTE 2 See ISO 8995.

3.4
contrast
⟨subjective sense⟩ subjective assessment of the difference in appearance of two parts of a field of view seen simultaneously or successively

NOTE Hence: brightness contrast, colour contrast, simultaneous contrast, successive contrast.

3.5
contrast
⟨objective sense⟩ quantities usually defined as a luminance ratio (usually for successive contrasts L_2/L_1) or, for surfaces viewed simultaneously, by the equation

$$\frac{L_2 - L_1}{L_1}$$

where

L_1 is the dominant or background luminance

L_2 is the object luminance

NOTE 1 When the areas of different luminance are comparable in size and it is desirable to take an average, the following formula can be used instead:

$$\frac{L_2 - L_1}{0,5(L_2 + L_1)}$$

NOTE 2 See ISO 8995.

3.6
equivalent continuous A-weighted sound pressure level
$L_{\text{Aeq},T}$
A-weighted sound pressure level, in decibels, given by the equation

$$L_{\text{Aeq},T} = 10 \text{ lg}\left(\frac{1}{t_2 - t_1}\int_{t_2}^{t_1} \frac{p_{\text{A}}{}^2(t)}{p_0^2}\text{d}t\right)$$

where $t_2 - t_1$ is the period T over which the average is taken started at t_1 and ending at t_2

NOTE See ISO 7779.

3.7
glare
discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the brightness of the general surroundings to which the eyes are adapted

NOTE See ISO 8995.

3.8
illuminance
E
density of the luminous flux (ϕ) incident at a point, expressed in lux (1 lx = 1lm/m^2)

NOTE 1 In practice, the average illuminance of a given surface is calculated by dividing the flux falling on it by the area (A) of the illuminated surface:

$$E = \frac{\phi}{A}$$

NOTE 2 See ISO 8995.

3.9
luminance
L
physical measurement of the stimulus which produces the sensation of brightness, in terms of the luminous intensity in a given direction, ε, (usually towards the observer), per unit area, of an emitting, transmitting or reflecting surface, expressed in candelas per square metre

NOTE 1 It is the luminous intensity of the light emitted or reflected in a given direction from an element of the surface, divided by the area of the element projected in the same direction.

NOTE 2 The luminance L, in candelas per square metre, of a perfectly matt surface is given by:

$$L = \left(\frac{\rho \times E}{\pi}\right)$$

where

E is the illuminance, in lux (lx);

ρ is the reflectance of the surface considered.

NOTE 3 See ISO 8995.

3.10
luminance balance
ratio between the luminances of the displayed image and its adjacent surround, or sequentially viewed surfaces

[ISO 9241-6:1999, 3.13]

3.11
reflectance
ρ
ratio of the luminous flux reflected from a surface (ϕ_r) to the luminous flux incident (ϕ_0) on it

NOTE 1 The reflectance depends on the direction of the incident light, except for matt surfaces, and on its spectral distribution.

NOTE 2 Reflectance $\rho = \frac{\phi_r}{\phi_0}$

NOTE 3 See ISO 8995.

3.12
reflected glare
glare resulting from specular reflections from polished or glossy surfaces

NOTE See ISO 8995.

3.13
relative humidity
RH
ratio (× 100) between the partial pressure of water vapour in the air and the water vapour saturation pressure at the same temperature and the same total pressure

[ISO 13731:2001, 2.96]

3.14
reverberation
continuation of a sound in an enclosed space after the source has stopped, result of reflections from the boundary surfaces of the room

[ISO 9241-6:1999, 3.21]

3.15
air temperature
t_a
dry-bulb temperature of the air surrounding the occupant

NOTE It is expressed in degrees Celsius (°C).

[ISO 13731:2001, 2.2]

4 General principles for environmental design

The following nine general ergonomic principles shall be followed for good environmental design.

NOTE 1 It is important to recognise that design features related to one particular environmental principle can have an impact on other principles.

Principle 1: Operator task demands and comfort shall be the primary focus when designing control centre environments.

Principle 2: In order to optimize operator's performance and comfort, levels of illumination as well as temperature shall be adjustable in accordance with the operator's needs.

Principle 3: Where conflicting demands exist between different environmental features (i.e. thermal conditions, air quality, lighting, acoustics, vibration, and interior design and aesthetics), a balance shall be sought which favours operational needs.

NOTE 2 One way to achieve this would be to consult experts in human factors and ergonomics with the aim of identifying optimal compromises between conflicting demands, e.g. to design a lighting system in which old and new equipment work in parallel in upgraded control centres.

Principle 4: External factors providing operational information (e.g. security views, weather conditions) shall be taken into account when designing the control centre.

Principle 5: Environmental factors work in combination and shall be taken into account in a holistic way, i.e. the whole environmental entity needs to be taken into account, (e.g. interaction between air conditioning systems generating noise and the acoustic environment).

Principle 6: Environmental design shall be used to mitigate the detrimental effects of shift work, e.g. raising ambient air temperature in the early morning.

NOTE 3 A complementary approach would be to consider improved shift work schedules.

Principle 7: The design of environmental systems shall take account of future change (e.g. equipment, workstation layouts, and work organisation).

NOTE 4 This can be done by designing for flexibility (location of lighting, ventilation ducts, etc.). Another possible measure would be to reserve extra capacity in the environmental systems.

Principle 8: The quality of the working environment shall be an integral part of the overall design process for control centres, as shown in Figure 1.

NOTE 5 The steps presented in Figure 1 are part of a wider process discussed in ISO 11064-1.

Principle 9: An iterative and multi-disciplinary design approach shall be taken in order to achieve an appropriate balance between buildings, equipment and the control centre environment. This approach shall be checked and evaluated as the design develops.

NOTE 6 This approach is necessary because most building and equipment design features have a potential impact on the design of the control centre environment. For example, the heat dissipation of lighting equipment can affect an air conditioning system.

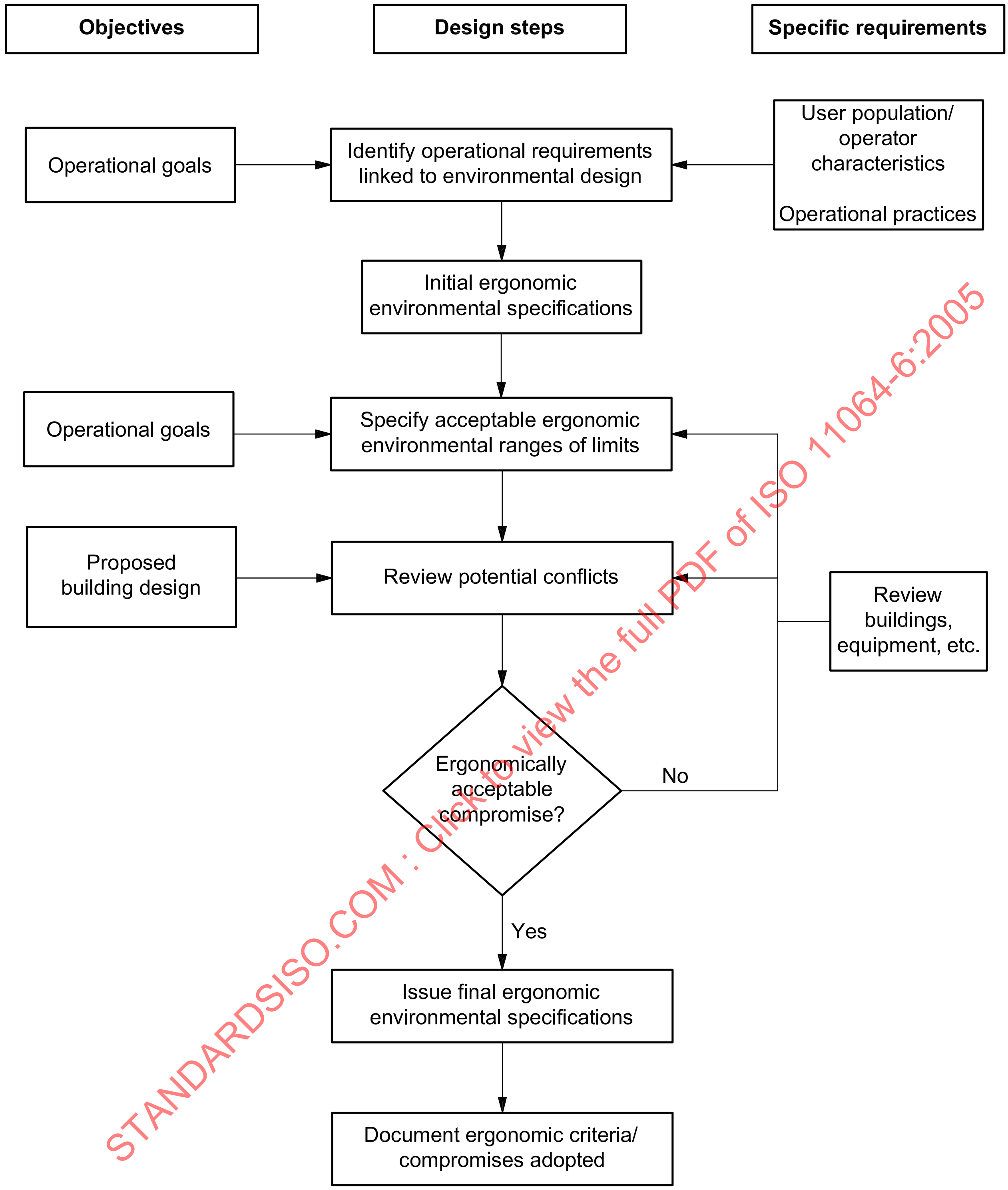

Figure 1 — Overall process for control room environmental design

5 Requirements and recommendations

5.1 Ergonomics and thermal conditions

5.1.1 The design of an appropriate thermal environment needs to take account of such factors as building design, operator activities and climatic factors. The following should be taken into account:

— the nature and range of operator activities (sitting or walking);

— the typical clothing to be worn by operators (including any special protective clothing);

— operator numbers and shift patterns;

— total heat dissipation generated by the equipment and lighting;

— the orientation of control room in respect of solar gain;

— the requirement, if any, of pressurized rooms;

— thermal transfer from external walls;

— the number of doors and windows;

— shielding properties of construction materials;

— the potential for shielding direct sunlight;

— the geographical location of the building.

5.1.2 Localised heat in control rooms due to thermal radiation or hot air should be avoided by suitable control of the climatic conditions.

5.1.3 Heating, ventilation and air-conditioning (HVAC) systems shall provide appropriate internal climatic environmental conditions (i.e. air temperature, humidity and air velocity), whatever the external thermal conditions.

NOTE 1 Suggested values are presented in Annex A.

NOTE 2 Control rooms in non-temperate parts of the world can necessitate different requirements due to the nature of the ambient environment, for example in very hot climates.

5.1.4 Human operators shall be provided with appropriate equipment for controlling and monitoring the temperature in cases where the HVAC systems do not provide suitable internal climatic environmental conditions.

NOTE Suggested values are presented in Annex A.

5.1.5 When specifying the thermal values, the ranges presented in Annex A should be taken into account for the following variables relating to temperate environments:

— air temperature (t_a);

— mean radiant temperature;

— air velocity (v);

— humidity.

NOTE The relationship between the thermal environment, air quality and acoustics is presented in Figure 2.

5.2 Ergonomics and air quality

5.2.1 Airflows shall be controlled such that personnel do not suffer direct air draughts. In order to help achieve this, the air velocity shall be checked.

NOTE The correct arrangement of airflows can involve careful location of air distribution inlets and outlets.

5.2.2 Extractor grilles should be located to avoid short-circuits between inlets and outlets and to encourage even distribution of air throughout the room.

5.2.3 Air conditioning/air handling systems should be designed so as to avoid vibration and minimize noise from the system.

5.2.4 The rate of air change (i.e. the relation between the capacity of the HVAC system and the physical volume of the control centre) shall be adjusted in order to maintain good air quality.

NOTE Sources of information are presented in the Bibliography.

5.2.5 The ingress of dust and other particles from the ceiling and floor plenum to the HVAC system should be avoided (physical location of HVAC inlets and outlets, room cleaning, etc.).

5.2.6 The location of ducts should take account of cleaning and maintenance requirements.

5.2.7 Rooms such as toilets, canteens, locker rooms and smoking rooms should be maintained at a lower pressure from other areas in order to avoid any odour ingress.

5.2.8 Operators should be protected against air pollution through the air supply.

NOTE Sources of information concerning threshold limit values (TLV) are presented in the Bibliography.

5.2.9 Potential contamination by external sources of solid particles, e.g. sand, construction materials, plant chemicals, should be controlled through the design of the air handling systems.

5.2.10 Where safety and security issues arise, the malicious introduction of materials into air distribution systems should be taken into account.

5.2.11 Humidification plant, such as steam humidifiers, should be of a type designed to minimize the proliferation of micro-organisms, including bacteria, that cause Legionnaire's disease and fungi.

5.2.12 The following protective measures should be taken into account when designing air provision systems for control room environments:

— the selection of non-toxic construction material (especially in case of fire);

— the separation of operators' areas from equipment which might emit pollutants in the environment (e.g. photocopiers/ozone, battery rooms);

— an appropriate air change rate which will reduce the concentration of the impurities;

— the presence of specific safety procedures and personal protective equipment in case of suspected specific risk (chemical pollution for instance);

— the use of airtight control rooms in case of exceptionally dangerous and polluted working areas;

— the installation of gas detection systems;

— the installation of fire extinguishing systems using non-toxic products.

The factors relevant to the specification of an appropriate air quality are presented in Figure 2.

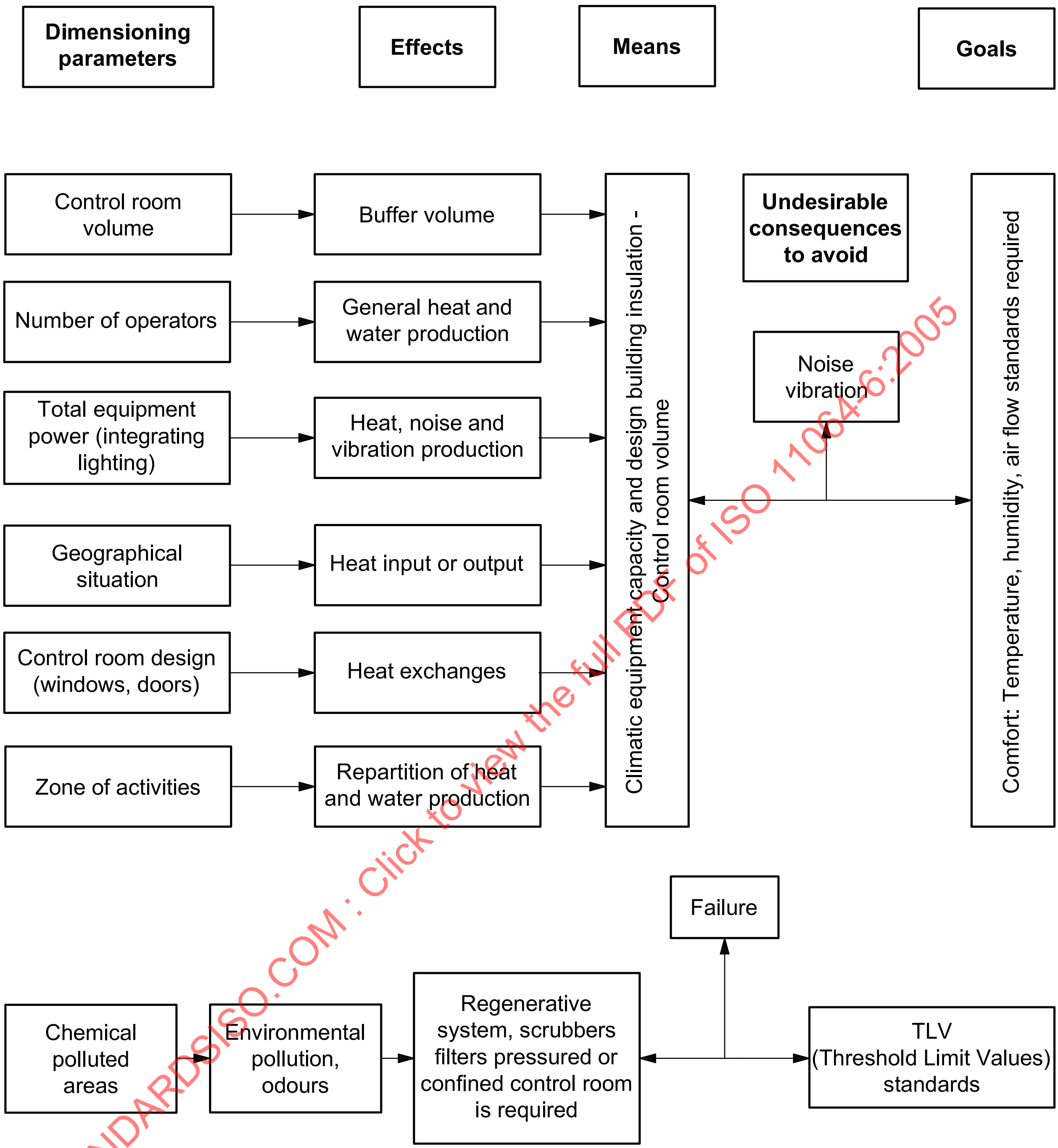

Figure 2 — Main factors in design of thermal environments, air quality and acoustic parameters

5.3 Ergonomics and lighting

5.3.1 The design of lighting should

— provide flexibility for a range of different visual tasks (including, for example, paper-based as well as electronic work) to be undertaken by a range of different operators of varying ages, etc.,

— optimize visual performance at the workplace,

— minimize degradation in human performance,

- enhance safety,
- enhance legibility of information — from both active and passive displays,
- improve operator vigilance,
- enhance the comfort and the health of the operator,
- facilitate the reading of vertical and horizontal printed material at workstations, if required,
- facilitate the reading of wall maps or reference material,
- facilitate viewing of self-illuminated equipment such as CCTV (closed circuit television) monitors, VDTs, warning indicators and status boards,
- facilitate the reading of illuminated displays on control consoles, and
- facilitate the reading of off-workstation displays.

5.3.2 Lighting arrangements should be appropriate to the visual demands of the tasks to be carried out in the working environment and should take into account the demands of normal and emergency work as well as the effects of artificial and natural light.

NOTE Local lighting at an operating position might be necessary where a significant part of an operator's duty involves the use of a large amount of self-illuminated equipment. This might necessitate the facility to be able to dim the general lighting.

5.3.3 Operator-controlled task lighting shall not be a source of glare to other occupants in the room.

5.3.4 Operators should have some control of the local maintained illuminance associated with their workstation.

5.3.5 Lighting schemes should avoid veiling reflections and reflected glare off screens.

5.3.6 Lighting systems should take into account future changes in equipment, workstation layouts, operating procedures, and team working. Options for rearrangement of lighting should be examined.

5.3.7 The location of any windows, skylights and fixed luminaries should minimize the potential for generating reflections and glare.

5.3.8 Natural references, such as daylight through outside windows and plants, should be used to enable control room staff to maintain linkage with the external world.

5.3.9 Suitable control over natural light shall be provided to avoid the difficulties of intense natural light.

NOTE Windows are of psychological value.

5.3.10 Account should be taken of the differing visual demands associated with perception of data presented on an electronic screen (e.g. reading texts, viewing graphs) and non-screen-based information (e.g. reading text on drawings, looking at wall-mounted displays) which might be present in the same working environment.

5.3.11 Where levels of illumination are specified, these should be *maintained levels* for the lifetime of the luminary.

5.3.12 For good visual conditions, a balanced ratio of luminance values in the field of vision should be sought.

5.3.13 Glare shall be avoided irrespective of its source, for example from luminaries, reflections and excessive differences in luminance in the visual field. The glare rating of lighting installations shall be determined using the CIE Unified Glare Rating method (see ISO/CIE 8995). The UGR value for lighting installations shall not exceed the value given in ISO/CIE 8995.

5.3.14 The location of light fittings, for example, windows or skylights, shall be such they do not result in glare when shared workstation displays are viewed.

5.3.15 The needs of those with visual disabilities should be taken into account when preparing specifications.

5.3.16 Wherever possible, lighting systems should make use of different light sources, both natural and artificial.

Annex A provides guidance on the values for the lit environment that have been found to be satisfactory for control rooms.

The key considerations for control room lighting design are presented in Figure 3.

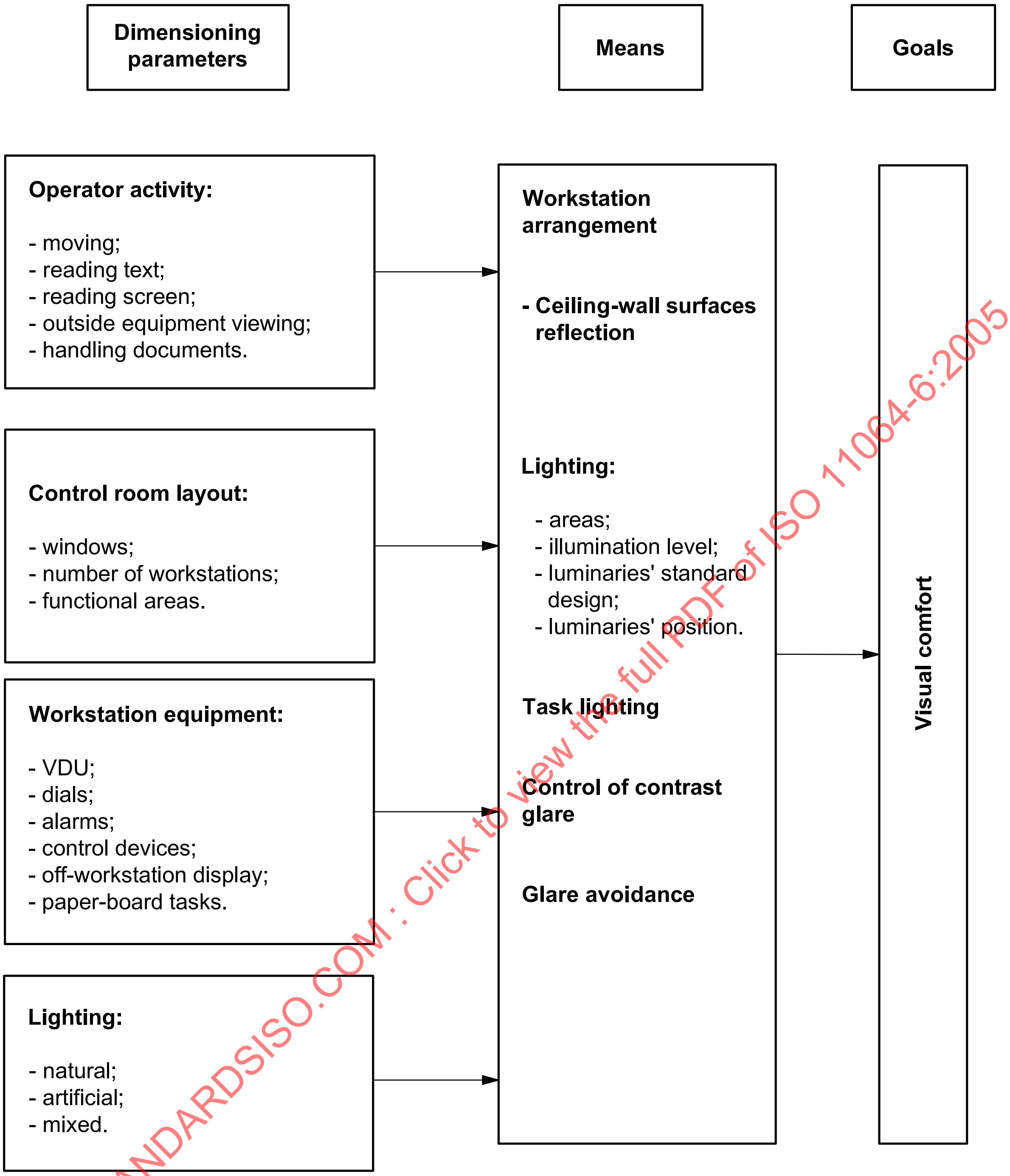

Figure 3 — Main factors in the design of lighting environments

5.4 Ergonomics and acoustics

5.4.1 In order to optimize the acoustic environment, the control room should be designed to

— reduce noise levels in the general environment around the control room,

— reduce sound levels within the control room, and

— reduce reverberation times.

5.4.2 Acoustic design should take account of the following operational needs:

— verbal communications between operators;

— telephone conversations;

— hearing alarms;

— performance decrements;

— interference with cognitive functions, e.g. domestic radios;

— minimising operator annoyance, e.g. noise from canteens;

— the loss of essential auditory information.

5.4.3 An acoustic survey should take into account both internal and external equipment-related noise sources and other generators of noise.

5.4.4 When the location of the control suite within the building is being determined, potential sources of external noise (e.g. roads, car parks, appliance garaging or machinery, airports, process units) shall be minimized in accordance with ISO 11064-2.

5.4.5 Where external noise might provide information to the operators concerning the processes they are controlling, such as the starting-up of production in a steel mill, this should be taken into account in the layout of the control suite.

5.4.6 The effect of voice communications within the control room arising from, for example, visitors, social discussions and maintenance teams, should be taken into account.

5.4.7 Auditory alarms shall be sufficiently distinguishable from background noise in order that they can be reliably detected.

5.4.8 Different frequencies and levels of loudness should be used to differentiate between alarm priorities and alarm sources.

NOTE For guidance on specific acoustic values, see Annex A.

5.4.9 Where noisy equipment has been identified, it should be housed separately in acoustically modified rooms or surrounded with sound shielding.

5.4.10 Noise from machines should be minimized by their removal from the control room or by measures to minimize this source of interference.

NOTE Measures for noise reduction include noise reduction at source, insulation and reduction in reverberation times.

5.4.11 Noise levels in control rooms shall not cause hearing damage.

5.4.12 The needs of those with acoustic disabilities should be taken into account of when preparing specifications.

Some key values that have been found to be satisfactory for control rooms are presented in Annex A: these values are specified in ISO 9241-6.

The interrelationship between parameters connected with the acoustic environment is shown in Figure 4.

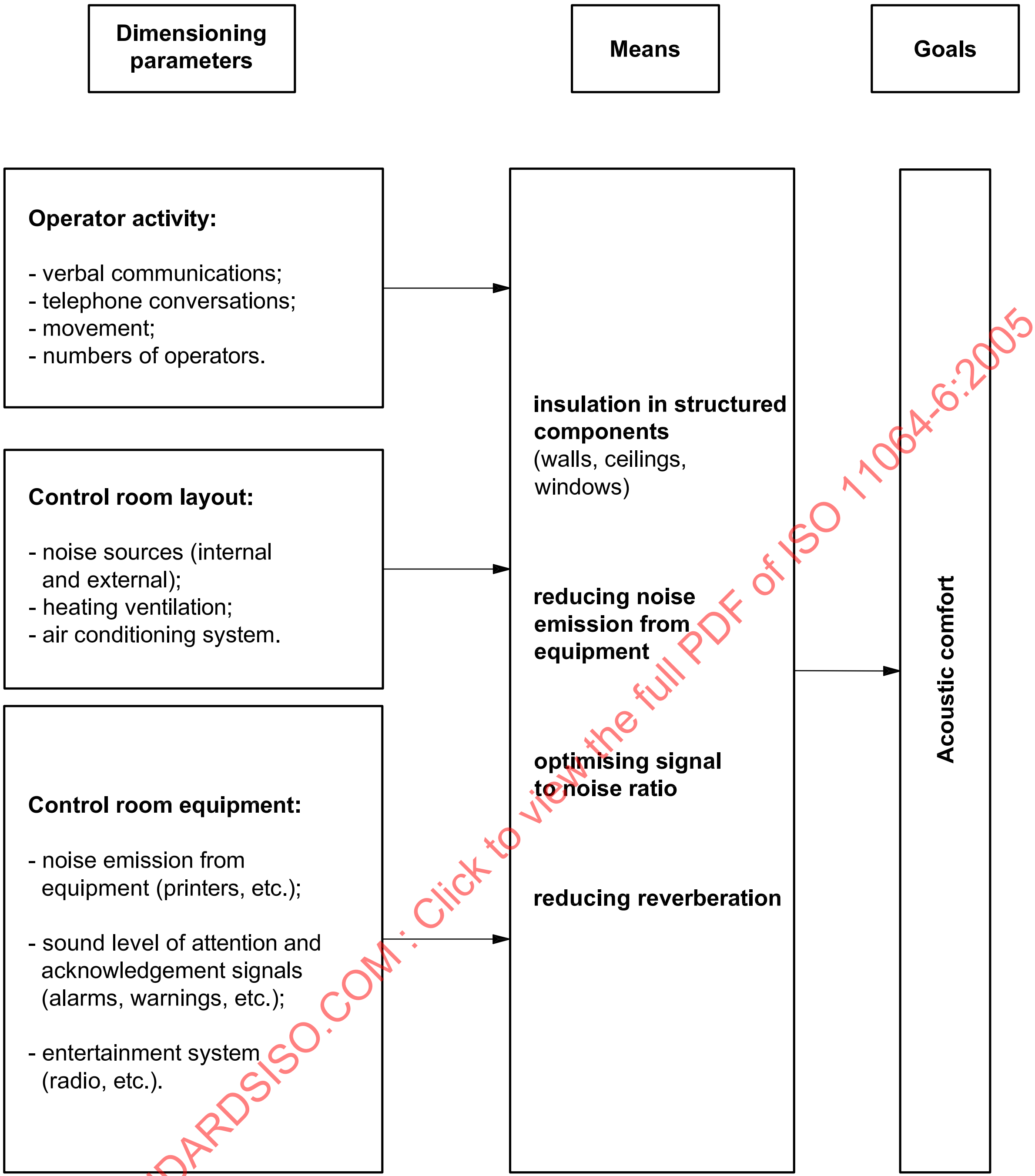

Figure 4 — Main factors in design of acoustic environment

5.5 Ergonomics and vibration

5.5.1 Control rooms should be positioned as far as possible from sources of vibration such as back-up generators and compressors.

5.5.2 Insulation shall be used to protect control-room operators and their associated equipment from vibration transmitted from the general environment.

5.5.3 If necessary, the control-room floor, walls and ceilings should be isolated from vibrating structures by vibration absorbers.

NOTE The effects of mechanical vibration on the user, optical devices and operating elements are presented in ISO 9241-6.

5.6 Ergonomics and interior design and aesthetics

5.6.1 The ratio of dimensions determining the overall space should be taken into account when planning a control room.

NOTE Ceiling heights that are too low in proportion to the overall plan area can generate feelings of claustrophobia.

5.6.2 The interior design of a control room should support the primary operational activities being conducted. Colours, textures and materials should be selected to provide a pleasant working environment and a calming backdrop to the control activities being undertaken.

5.6.3 End users and senior management should, wherever practical, be involved in the selection of the final interior scheme; alternative schemes should only be offered once they have met the criteria of not conflicting with operational ergonomic requirements.

5.6.4 The selection of furniture and control room finishes should "humanise" the working environment in contrast to other more "mechanical" areas of the plant.

EXAMPLE Skirting that provides protection to the base of walls and the use of natural hardwoods adds quality and warmth to the environment.

5.6.5 The selection of control operator seating should be based on ergonomic criteria. The choice of colour and finishes should be made with long-term and 24-hour usage and associated wear-and-tear in mind.

EXAMPLE Darker chair fabrics, with a "fleck" rather than of plain colour, are more practical in the longer term.

5.6.6 Wall finishes should be pale rather than bright and the colours selected to avoid psychological effects; textured finishes help reduce reflected glare.

NOTE Colours can create oppressive environments when inappropriately selected or can interfere with visual tasks associated with looking at desk-based screens or overview displays.

5.6.7 The excessive use of either dark or light finishes on building structures or on furniture should be avoided.

NOTE The balance of finishes will be part of the overall visual field of the operator and needs to take full account of all the visual demands associated with control room operation.

5.6.8 Excessively strong patterns, seen as a backdrop to visual display units or other control equipment, should be avoided.

5.6.9 Where used, carpets should be of heavy contract grade and include a small random pattern with subtle colour variation; large patterns and geometric designs should be avoided.

5.6.10 Planting, or other forms of visual relaxation, should be provided to offer variation in texture and colour to the rigid geometry imposed by workstations, cupboards, overview displays and ceiling grids.

5.6.11 The reflectance gradient should be consistent with normal expectations, with ceilings being generally brighter than walls that in turn are lighter than the floor finishes.

5.6.12 All finishes should be selected to take account of the additional wear and tear from 24 h operation: they should provide easily cleaned surfaces which can also be repaired should they sustain light damage.

5.6.13 Workstation finishes, general furniture and equipment finishes — including those associated with off-workstation shared displays — should be such that glare is eliminated.

5.6.14 Large differences in colour contrast should be avoided on workstations, general furniture and equipment finishes.

5.6.15 The use of matt or non-reflective surfaces, and low brightness reflector assemblies for luminaries, should be taken into account when planning the control centre design.

5.6.16 Where glare from windows is unavoidable, means shall be provided to enable the impact to be minimized by the use of, for example, adjustable blinds or tinted glazing.

5.6.17 The control room finishes should be selected to achieve a specified reverberation time based on the need for good verbal communications and transmission of auditory warnings.

NOTE Reverberation time values are given in ISO 9241-6.