

RCC-CERT

The drafting of a study on the definition and organisation of a Remote Control Centre (RCC) with a view to its CERTification

Appendix B: Ergonomic Standards applicable to an RCC

FPS Federal Public Service Mobility and Transport – DG Shipping

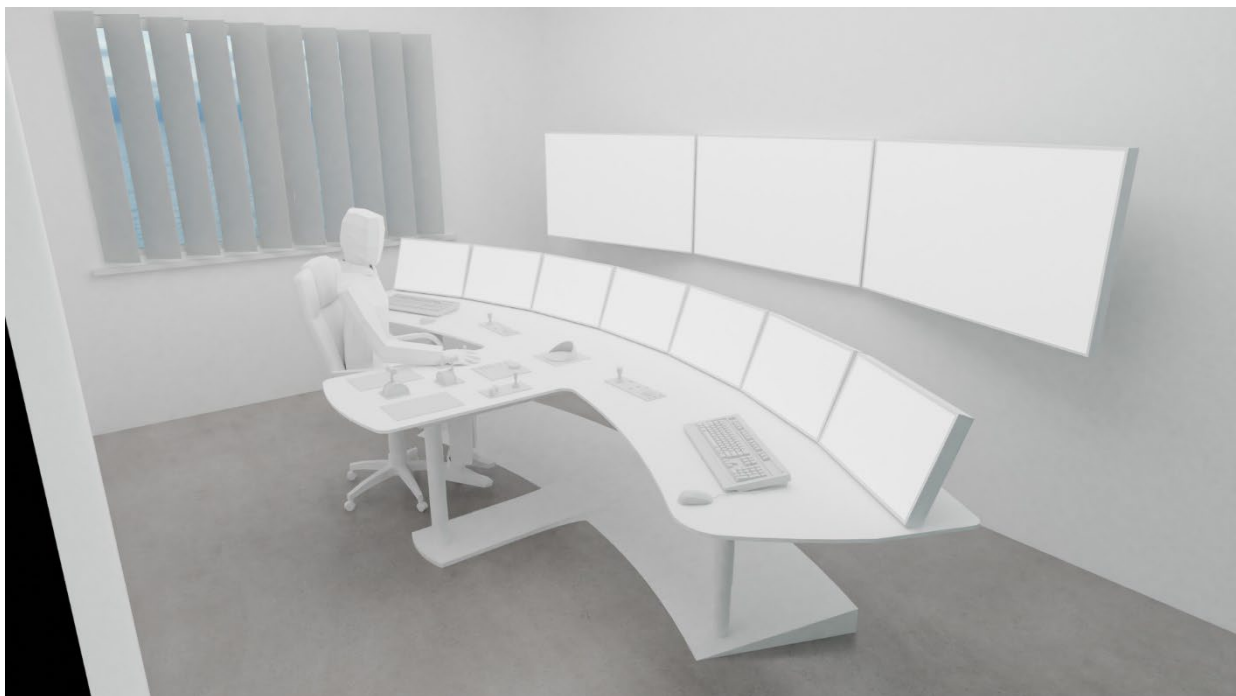
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1. Introduction

The goal of this annex is to present and compile a series of international ergonomic standards applicable to the design of an RCC.

The following standards should be considered. They all apply to the design of control rooms or workspaces.

- **ISO 11064** Ergonomic design of control centres
- **ISO 9241** Ergonomics of human-system interaction
- **NEN 1824** Office space
- **NBN ISO 11226** Static working postures
- **EN 1335** Dynamic office chairs (optional NPR 1813)
- **NPR 1813** Ergonomics of office furniture
- **EN 527** Office tables
- **NBN-EN 12464** Indoor workplace lighting
- **NBN EN 17037** Daylight in buildings
- **ISO 7730** Ergonomics of the thermal environment
- **NPR 3438** Noise pollution

We will now detail the content of some of these standards in relation to the steps of an RCC design process as described in the main report.

2. Control room Design

ISO 11064 is the main standard for the design of control centres.

Part 1 describes the main principles to apply when designing control centres with a Human Factors centric mindset.

ISO 11064: Ergonomic design of control centres	Part 1: Principles for the design of control centres <ul style="list-style-type: none">• Apply a human-centred design approach• Integrate ergonomics in engineering practice• Improve design through iteration• Conduct situational analysis• Conduct task analysis• Design error-tolerant systems• Ensure user participation• Form an interdisciplinary design team• Document ergonomic design basis
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3. Work positions and workstations

Workstations and operating desks more generally are central to modern human work. There are therefore many aspects of their design that are addressed in international standards.

<p>ISO 11064: Ergonomic design of control centres</p>	<p>Part 4: General visual recommendations for workstations</p> <ul style="list-style-type: none"> • For VDUs, the minimum height of monochrome Latin characters shall subtend 15 minutes of angle. Recommended Latin character heights are, however, 18 to 20 minutes of angle • Viewing distance, for identification of characters and symbols, shall be > 500 mm, • For minimizing eye strain, the viewing distance should be 700 mm or greater • Assuming a reclined seated position, the normal line-of-sight is straight forward in the horizontal plane and approximately 15° below the horizontal in the vertical plane
	<p>Part 4: General auditory requirements and recommendations</p> <ul style="list-style-type: none"> • Sound-producing devices shall be located and mounted such that their function is not compromised. • Where alarm indications can be provided by other than auditory means, silencing may be permissible. Silencing should be possible from the normal working position of the operator. • Global silencing, i.e. silencing from any one workstation where multiple workstations exist, may be employed depending on specific operational and safety practices. • It shall be possible to readily associate a particular audible signal with a unique workstation in multiple control workstation configurations. • Use of spatial separation to aid identification when multiple auditory sources are present. • The impact of background noise should be considered when designing auditory alarms
	<p>Part 4: Posture requirements and recommendations</p> <ul style="list-style-type: none"> • The design shall accommodate the different viewing distances and the inclination of the normal line-of sight for the varying postures. • The reach envelope should accommodate the bent forward and erect postures only. • The leg clearance should accommodate a 120° knee bend and a 10° ankle bend. • Chairs shall be height-adjustable. For details concerning control room operator chair requirements, see ISO 9241-5. • Adequate forearm support should be provided.
	<p>Part 4: Control workstation layout - displays</p> <ul style="list-style-type: none"> • For table-top displays; it should be possible to tilt and swivel the display screen. • For built-in displays; built-in displays have fixed orientations. When carefully designed in terms of anthropometric data and viewing conditions, this solution may be acceptable. • The arrangement of the displays should consider operator tasks which may require access while sitting, standing or both. • Preferably, the user should be able to adjust the control workstation easily to ensure a good working posture. • In the case of a non-adjustable working height, special attention should be given to the vertical position of the displays. Important factors are eye height, viewing distance, field of vision, cone of fixations and normal line-of-sight.

	<p>Part 4: Control workstation layout - controls</p> <ul style="list-style-type: none"> • Keyboards should preferably be located in the center of the operator's usual work space. • If movable keyboards are used, sufficient space should be provided to allow swiveling of the keyboard around a vertical axis 30° in a clockwise or counter-clockwise direction from normal (60° total). • Other keyboard requirements shall include: inclination: 5° to 15°, height (front side): < 20 mm, height above work surface (middle row): 30 mm, distance between key top: 17 mm to 19 mm • A minimum space of 150 mm deep and the width of the keyboard shall be available for supporting the operator's forearms and wrists in front of the keyboard. • The control workstation design shall be “ambidextrous” as far as the placement of one-handed devices such as a mouse, trackball, etc. • Similar ambidextrous requirements shall be considered for “mouse-only” control workstation designs.
	<p>Part 4: Seated control workstations</p> <ul style="list-style-type: none"> • there should be enough vertical, horizontal, and lateral clearance of legs, knees and feet under the work surface; sufficient clearance shall be available for the tallest user’s legs (95th percentile), • work surface at or slightly below elbow height • support for the buttocks and legs and support for the lower back • controls within optimum or maximum reach envelopes depending on frequency, priority of use (outcome of the task analysis) • characters on instruments or displays shall subtend the required minimum visual angle to the seated control room operator • height of the seat pan (a footrest may be necessary in some circumstances), • the seat height shall be adjustable. • an adjustable footrest shall be available for the smaller users (down to 5th percentile). Footrest dimensions should be as follows: minimum surface: (450 × 350) mm (width × depth); minimum height at front side 50 mm, height adjustable to at least 110 mm; minimum slope 5°, and adjustable to at least 15°.
	<p>Part 4: Standing control workstations</p> <ul style="list-style-type: none"> • Work-top surfaces shall not be higher than the elbow height of a 5th percentile user. • Where a view over the top is required, the maximum vertical dimension of the workstation should not exceed the standing eye height of a 5th percentile user. • Where items need to be passed across the workstation, the horizontal dimensions should take account of the reach of 5th percentile users. • Adequate clearance should be allowed for the feet when standing at the workstation
<p>NBN ISO 11226: static working postures</p>	<p>Head Inclination</p> <ul style="list-style-type: none"> • < 0° (extension): OK, with full support • 0 - 25°: OK • 25°: max. 8minutes

	<ul style="list-style-type: none"> • 35°: max. 6'50 • 45°: max. 5'40 • 55°: max. 4'30 • 65°: max. 3'20 • 75°: max. 2'10 • 85°: max. 1' • > 85° not acceptable
NBN ISO 11226: static working postures	Neck flexion <ul style="list-style-type: none"> • < 0° (extension): not acceptable • 0 - 25°: OK • > 25: not acceptable
EN1335 dynamic office chairs (optional NPR 1813)	Seat <ul style="list-style-type: none"> • height: <40-54>, >16cm adjustable • Width: 40> • Depth: <38-43>, >7cm adjustable • inclination: <0°>, >5° tiltable Backrest <ul style="list-style-type: none"> • Height: 36 • Width: 36> • Low backrest: <17-30>, >7cm adjustable • Inclination: 90°>, >15° adjustable Armrests <ul style="list-style-type: none"> • Height: <20-29>, >10cm adjustable • Width: >5 • Spacing: 41-51 • Length: >15 • Distance to the back: <20 Sitting height <ul style="list-style-type: none"> • All monitor workers can rest with their feet flat on the floor. • The height of the seat is then adjusted to the hollow of the knee. • A good sitting height assumes an adjustable desk. Movement mechanism <ul style="list-style-type: none"> • The backrest should be able to tilt by 15°, the seat by 5°
NPR 1813 - Ergonomics of office furniture	Office chairs <ul style="list-style-type: none"> • For an individual workstation used for less than two hours a day, the office chair should be able to be adjusted properly to suit that particular desk worker • For longer use, the chair should have a movement mechanism to allow for variation in posture. Office desks <ul style="list-style-type: none"> • For short-term use of the workstation, a fixed table height is allowed (74-76cm). • For longer use, a sit-stand table is assumed as standard. • For the individual workstation: 65 to 125 cm • For the flexible workstation: 65 to 135 cm
EN 527 Office tables	Types <ul style="list-style-type: none"> • Adjustable (sit-stand tables) : 65-125cm • Adjustable: 65-85 cm • Fixed table height: 74 +/- 2 cm Height

	<p>An adjustable desk is recommended so that the height can be adjusted to the individual employee</p> <ul style="list-style-type: none"> • non-adjustable: 74 cm (+ / - 2 cm) • adjustable: 65 - 85cm • sit-stand table: 65 - 125 cm <p>Surface area</p> <ul style="list-style-type: none"> • depth: 80 cm • width: 120 cm • Thickness: < 5,5 cm at the front, < 8 cm at a depth of 50 cm. <p>Legroom</p> <ul style="list-style-type: none"> • width: non-adjustable 85cm, adjustable 120 cm • depth (floor level): 80 cm deep, 12 cm high
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4. Physical room

The RCC is a control room. As any control room it needs to be spatially organized (room layout) in ways that favour the operations performed in the room.

- It is highly dependent on the interaction requirements (interaction matrix, see main report) between the RCC actors: who needs to interact with whom and how? The layout will for example place people that need to interact frequently in relatively close work positions in the room.
- It needs to provide comfort and sufficient space for each work position, including for physically disadvantaged people and people with various morphologies and sizes.
- It needs to provide enough space for circulating in the room, while at the same time avoiding disturbances to the other actors in the room

ISO 11064: Ergonomic design of control centres	<p>Part 1: Principles for the design of control centres</p> <ul style="list-style-type: none"> • Apply a human-centred design approach • Integrate ergonomics in engineering practice • Improve design through iteration • Conduct situational analysis • Conduct task analysis • Design error-tolerant systems • Ensure user participation • Form an interdisciplinary design team • Document ergonomic design basis
ISO 11064: Ergonomic design of control centres	<p>Part 2: Ergonomic aspects to be considered for the design of the control suite layout</p> <ul style="list-style-type: none"> • Communication within and outside the suite • Traffic and routing within and outside the suite • Entrances and exits • Environmental conditions • Cleaning • Maintenance • Visitors • Supporting information
ISO 11064: Ergonomic design of control centres	<p>Part 3: Control room layout design principles</p> <ul style="list-style-type: none"> • Room layout. Control rooms which exhibit either overcrowding of work positions, or widely dispersed work positions, are not recommended. Layouts should allow, wherever practical, direct

	<p>verbal communication between the control room operators and avoid excessively short separations between adjacent operators.</p> <ul style="list-style-type: none"> • Consistency. Control rooms with similar functions and in the same plant or facility, such as occur in a control complex, should adopt the same ergonomic principles of room layout to facilitate decision-making and teamwork. • Physically disadvantaged. Where physically disadvantaged control room operators or visitors (those exhibiting a disability) are expected to use the control room, adequate facilities should be provided. • Posture variation. There are ergonomic benefits in varying postures during periods of work. Wherever practicable, it is recommended that control workstation layouts and work regimes allow control room operators to change their posture at the control workstation and to move from their workstations from time to time. • Body size. Room dimensions and control workstation layout dimensions and features for which peoples' sizes are relevant, e.g. seated view over workstations, shall take account of the range of control room operators for which these items are being provided • Windows. Control room operators using visual displays should not be facing windows unless these windows are a primary information source. The location of control workstations where windows are behind the operator should be avoided since this may give rise to reflections on the display screen. • Off-workstation shared visual displays. The layout of the control room shall ensure that all off-workstation visual displays, necessary for the control room operators' task, are visible from all relevant control workstations • Circulation of personnel and maintenance access. Circulation of control room staff, maintenance staff and all visitors should be achieved with minimum disruption to the work of control room operators
<p>NEN 1824:2010 - office space</p>	<p>Office space workplace</p> <ul style="list-style-type: none"> • standard 7m² per person <p>Passages</p> <ul style="list-style-type: none"> • 90 cm: passageway • 90 cm: space behind desk to wall/cabinet/obstacle • 120 cm: passageway as walking route • 120 cm: space behind desk with passage possibility • 180 cm: sitting back to back <p>General guidelines for office space</p> <ul style="list-style-type: none"> • Desk tables perpendicular to the window • No door or eyes in the back of the employee • Provide depth visibility (free space in front of desk)

5. Lighting

Lighting is essential and should be taken very seriously. Inappropriate lighting can lead to difficulties for performing some tasks, and therefore to user frustrations.

Lighting, typically through an appropriate mix of natural and artificial light, contributes to the overall ambiance in the room. Inappropriate lighting, and in particular inappropriate lighting control, can also induce glare on the displays, making them hardly usable.

Lighting study and design should be performed by a lighting expert.

<p>ISO 11064: Ergonomic design of control centres</p>	<p>Part 6: Lighting</p> <ul style="list-style-type: none"> • Illuminance levels on worksurfaces where paperwork is undertaken should be “maintained” at a level of 200 lx to 750 lx with an upper limit of 500 lx where VDUs are used; this can be a combination of ambient and task lighting. • Dimming should be provided with a lower limit of “maintained” 200 lx on the worksurface at all times. • For working areas where mainly paperwork is undertaken, an illumination level of 500 lx should be maintained. • Electric lighting should achieve a glare index (UGR) of 19 or less for all work positions. • Lamps with a general colour-rendering index of over 80 should be used. • High-frequency control gear should be used to avoid flicker. • Where self-illuminated equipment is used, its contrast ratio to the immediate surrounds should not exceed 3:1 and its contrast ratio to the peripheral parts of the visual field should not exceed 10:1. • The average luminance of luminaries and bright room surfaces should not exceed 1 000 cd/m² for class I and class II screens, and should not exceed 200 cd/m² for class III screens (based on ISO 9241).
<p>NBN-EN 12464-1: Indoor workplace lighting</p>	<p>Illuminance</p> <p>The standard defines three zones: task area, immediate surroundings and background</p> <ul style="list-style-type: none"> • task area (reading and writing tasks): 500 lux • immediate surroundings: 300 lux • background: the minimum illuminance is at least one third of the direct surroundings. At workstations where work is continuous, 200 lux is a minimum. <p>Uniform light distribution</p> <p>Light should be uniformly distributed. This is expressed by the uniformity or the ratio of the lowest and average illuminance within a zone.</p> <p>Depending on the visual task, this uniformity is at least between 0.4 and 0.7 in the task area.</p> <ul style="list-style-type: none"> • immediate environment: >0.4 task area • background: >0.1 task area <p>Minimum reflectance value</p>

	<ul style="list-style-type: none">• Ceiling : 0.7 - 0.9• Wall : 0.5 - 0.8• Floor : 0.2 - 0.4• Large objects : 0.2 - 0.7 <p>Minimum illuminance levels (office)</p> <ul style="list-style-type: none">• Walls: 75 lux• Ceiling: 50 lux <p>Glare</p> <p>The glare rating, UGR or Unified Glare Rating, is given an important place in the standard.</p> <p>This is a measure of glare from luminaires and is defined for each type of task.</p> <p>The scale runs from 10 to 28, the lower the value the less the glare.</p> <ul style="list-style-type: none">• Lamp luminance kcd/m² 20 - 50 => Angle of illumination 15°.• Luminance lamp kcd/m² 50 - 500 => Angle of coverage 20°.• Luminance lamp kcd/m² > 500 => Angle of coverage 30°. <p>Light color: color rendering index (Ra)</p> <ul style="list-style-type: none">• workrooms : not lower than 80 Ra• workrooms with special, high requirements : not lower than 90 Ra <p>Color temperature</p> <p>No limit values for color temperature mentioned in the standard because this parameter mainly depends on psychological and aesthetic factors</p> <ul style="list-style-type: none">• Warm : < 3000 K• Neutral : 3000 - 5300 K• Cold : > 5300 K <p>Daylight</p> <p>The use of daylight is encouraged in the standard.</p> <p>The variation in amount of light, its direction and color provide variety which is beneficial for people working inside.</p> <p>Maintenance</p> <p>The specified minimum illuminance levels assume proper maintenance and should be met in all conditions.</p> <p>Major manufacturers have had the maintenance factor calculated for different types of lamps, fixtures, environment, replacement and maintenance schedules.</p> <p>With a maintenance factor of 0.85, the lighting in an office will need to provide 588 Lux to meet the minimum value of 500 at all times.</p> <p>Display screen workstations.</p> <ul style="list-style-type: none">• Positive contrast, normal precision, office, education : High luminance (> 200 cd/m²) => < 3000 : Low luminance (< 200 cd/m²) => < 1500
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	<ul style="list-style-type: none"> Negative contrast, high precision, inspection CAD colors : High luminance ($> 200 \text{ cd/m}^2$) \Rightarrow < 1500 : Low luminance ($< 200 \text{ cd/m}^2$) \Rightarrow < 1000
<p>NBN EN 17037 daylight in buildings</p>	<p>Amount of daylight Three performance levels defined for which specific recommendations apply: low, medium and high. The minimum illuminance should be realized at least half of the daylight hours for 50% or 95% of the space respectively. The following recommendations apply to spaces with vertical or angled windows</p> <ul style="list-style-type: none"> Performance Level Low: 50% of the space \Rightarrow 300 Lux, 95% of the space \Rightarrow 100 Lux Performance Level Medium: 50% of room \Rightarrow 500 Lux, 95% of room \Rightarrow 300 Lux Performance Level High: 50% of space \Rightarrow 750 Lux, 95% of space \Rightarrow 500 Lux <p>Per hour, the median illuminance of daylight should cover more than half of the room and for at least half of the daylight hours, 2190 hours per year.</p> <p>Protect against glare. To reduce the risk of glare from daylight, solar shading is recommended. The degree of protection is expressed in DGP, Daylight Glare Probability The probability of glare from daylight should not exceed 5% of the time that a space is occupied</p> <ul style="list-style-type: none"> Performance level Low: DPG 0.45 \Rightarrow frequently disturbing Performance Level Medium: DPG 0.40 \Rightarrow Observable, not disturbing Performance Level High: DPG 0.35 \Rightarrow Not perceptible <p>The time this limit is exceeded should be limited 5%.</p> <p>Exposure to sunlight Should there be a sufficient number of hours of sunlight in the room all on a given day. The reference day is March 21 at the center of the window at eye level (1m20).</p> <ul style="list-style-type: none"> Performance level Low : Hours of sunlight >1.5 Performance Level Medium : Sunlight hours >3 Performance level High : Sunlight hours >4 <p>Outdoor View The quality of the view is based on the following criteria: size of the window, horizontal angle, distance from window to nearest outdoor obstacle, minimum number of components of the view (sky, city, landscape, ground).</p> <ul style="list-style-type: none"> Performance level Low : Horizontal angle of view $>14^\circ$, Viewing distance to obstacle $> 6\text{m}$ Performance Level Medium : Horizontal angle of vision $>28^\circ$, Viewing distance to obstacle $>20\text{m}$

	<ul style="list-style-type: none"> • Performance level High : Horizontal angle of vision >54°, Sight distance to obstacle >50m <p>Width of the windows The width of the windows added up to be greater than half the depth of the room. Windows are minimum 1m wide and 1m25 high.</p> <ul style="list-style-type: none"> • Performance level Low : Landscape only • Performance Level Medium : 2 layers • Performance Level High : Air, Landscape and Ground
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6. Acoustics

Room acoustics is also key to pleasant and proficient activities in the RCC. Inappropriate room acoustics can significantly impact the capability to perform operational activities in the room.

Room acoustic deals with two antagonistic aspects:

- The room should be quiet enough to perform the operations foreseen in the room (e.g., not exceeding 45 dB LAeq,T)
- The room should allow verbal communication between the room actors that need to interact verbally (see speech intelligibility below).

This is achieved through the control of acoustic energy in the room, issued from acoustic sources (equipment, alarms, people,...), through for example appropriate choices of acoustic surfaces (walls, ceiling, floor, furniture,...), reflecting or absorbing acoustic energy, in ways that guarantee optimal conditions for operations in the room.

As for lighting, room acoustics should be designed by a specialist.

ISO 11064: Ergonomic design of control centers	<p>Part 6: Acoustic environment</p> <ul style="list-style-type: none"> • The ambient noise in the control room should not exceed 45 dB LAeq,T. Ambient noise levels should not be less than 30 dB(A-weighted). • The background level should be in the range 30 dB to 35 dB LAeq,T. • Auditory alarms should be approximately 10 dB above the background sound spectrum of the control room in order to be audible, and less than 15 dB higher than the background to avoid startling staff and affecting speech communication • Mid-frequency reverberation times should not exceed 0,75 s and should preferably be closer to 0,4 s — dependent on room
NPR3438 Noise pollution	<p>Speech intelligibility The "speech transmission index" (STI) is the parameter used to express the speech intelligibility at the workplace</p> <ul style="list-style-type: none"> • Excellent: > 0.75 • Good : 0.60 - 0.75 • Fair : 0.45 - 0.60 • Moderate : 0.30 - 0.45 • Bad : < 0,30

	<p>Design or assessment of workstations</p> <p>For each type of work it is possible to determine the level of speech intelligibility required.</p> <p>In this practice guideline, a decision scheme is given based on the importance or difficulty of the info on the one hand and the duration or frequency on the other.</p> <ul style="list-style-type: none"> • Importance: Frequency High: Duration Low => Good (STI), Duration Average => Good or Excellent, Duration High => Excellent • Difficulty: Frequency Average: Duration Low => Fair or Good (STI), Duration Average => Good, Duration High => Good or Excellent • Urgency: Frequency Low: Duration Low => Moderate (STI), Duration Average => Moderate or Good, Duration High => Good <p>Concentration</p> <p>Computer screen work:</p> <ul style="list-style-type: none"> • Concentration qualification: Fair, Maximum target value: 45 dB(A), Maximum allowable: 55 dB(A)
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7. HVAC

HVAC (Heating, Ventilation & Air Conditioning) is another key environmental aspect to consider during the design of the RCC.

<p>ISO 11064: Ergonomic design of control centres</p>	<p>Part 6: Thermal environment - Sedentary activity during winter conditions (from ISO 7730)</p> <ul style="list-style-type: none"> • the operative temperature should be between 20 °C and 24 °C (i.e. 22 °C ± 2 °C); • the vertical air temperature difference between 1,1 m and 0,1 m above floor (head and ankle level) should be less than 3 °C; • the surface temperature of the floor should normally be between 19 °C and 26 °C, but floor heating systems can be designed for 29 °C; • the mean air velocity should be less than 0,15 m/s; • the radiant temperature asymmetry from windows or other cold vertical surfaces should be less than 10 °C (in relation to a small vertical plane 0,6 m above the floor); • the relative humidity should be between 30 % and 70 %. <p>Part 6: Thermal environment - Sedentary activity during summer conditions (from ISO 7730)</p> <ul style="list-style-type: none"> • the operative temperature should be between 23 °C and 26 °C (i.e. 24,5 °C ± 1,5 °C); • the vertical air temperature difference between 1,1 m and 0,1 m above floor (head and ankle level) should be less than 3 °C; • the mean air velocity should be less than 0,15 m/s; • the relative humidity should be between 30 % and 70 %. • Control room operators should be able to increase control room temperatures by 1 °C to 2 °C in the early hours of the morning to compensate for diurnal rhythms.
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	<ul style="list-style-type: none">• In order to limit thermal shock to people moving between the inside and outside of the control room, consideration should be given to buffer zones which offer an intermediate temperature.• Where maintenance staff and others are expected to work for extended periods in equipment rooms, appropriate attention should be given to their needs concerning thermal and lighting requirements.
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