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13 Environment

This section contains human factors design rules pertaining to the workplace environment. The topics covered in this section include: (1) general criteria and rules, (2) ventilation, (3) temperature and humidity, (4) illumination, and (5) noise.

13.1 General

There are three major categories of environmental factors that affect systems and equipment design:

a. environmental factors that design can control such as illumination, ventilation rate, and temperature,

b. environmental factors that are a function of design such as noxious substances, vibration, and noise, and

c. environmental factors that design cannot control such as solar radiation, dust, mud, and rain.

- **13.1.1 General environmental extremes.** To maximize the effectiveness of the FAA systems and equipment that are maintained by FAA personnel, the designer shall accommodate the environmental extremes to which the system will be subjected and their effects on human-system performance. FAA systems and equipment shall be capable of sustained operations within the climatic extremes specified in the material requirements documents pertaining to each system or specification. Workplaces shall conform to the rules specified in this document. [Source: Department of Defense (MIL-HDBK-759B), 1992]

▫ **13.1.2 Deviations from tolerable conditions.** When deviations from the tolerable conditions stated in this section are necessary, the designer should take into account adverse effects such as:

a. protective clothing or devices which affect the mobility, reach, workplace, access size, maintainability, time to restore, efficient and effective use,

b. reduced human performance,

c. conditions that have little or no direct effect on equipment, but may seriously impair the ability of the user to perform effectively, and

d. conditions that contribute to longer use time or to increased use errors, oversights, or erroneous decisions, and that are detrimental to system availability and performance. [Source: MIL-HDBK-759B, 1992]

Discussion. The above adverse effects can sometimes be minimized through the use of alternatives such as: (1) remote system monitoring, (2) increased workplace area, (3) individual protective measures or supplemental equipment, (4) decreased workloads, (5) acclimation of operating personnel, (6) personnel rotation from one workstation to another, and (7) personnel selection and training.

13.2 Ventilation

General ventilation of the workplace contributes to the comfort and efficiency of the workers. Good ventilation also makes a positive contribution to health. Adequate general and, if needed, specialized ventilation can ensure that concentrations of toxic substances do not reach levels that are hazardous to health.

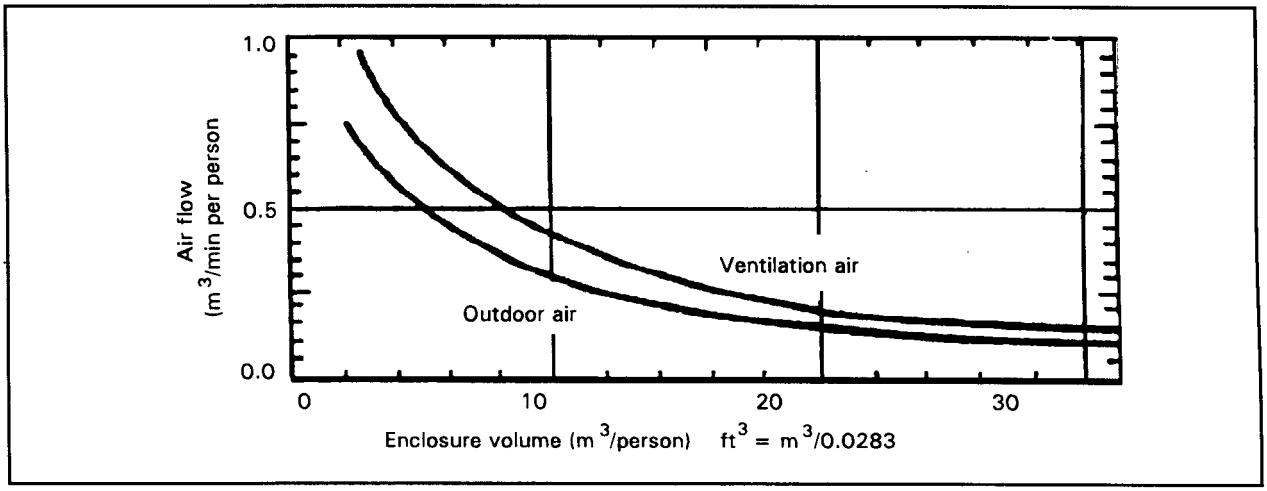
Definition. Ventilation is the process of supplying air to or removing air from any space by natural or mechanical means. From the standpoint of comfort and health, ventilation issues involve both quantity and quality.

▪ **13.2.1 General ventilating systems and temperature differentials.** General ventilating systems shall not produce air velocities exceeding 100 ft/min. Temperature differentials between any two points within the workplace shall be maintained below 5.6°C (10°F). [Source: Department of Defense (MIL-STD-1800A), 1990]

▪ **13.2.2 Small enclosure ventilation.** If the enclosure volume is 4.25 m^3 (150 ft^3) or less per person, a minimum of 0.85 m^3 (30ft^3) of ventilation air per minute shall be introduced into the enclosure; approximately two-thirds shall be outdoor air. [Source: Department of Defense (MIL-STD-1472D), 1989; MIL-HDBK-759B, 1992]

- **13.2.3 Large enclosure ventilation.** For large enclosures greater than 4.25 m3 (150 ft3), the air supply per person shall be in accordance with the curves in Exhibit 13.2.3. Air shall be moved past personnel at a velocity of not more than 60 m (200 ft) per minute. If personnel use manuals or loose papers, airspeed past these items shall not be more than 30 m (100 ft) per minute. If possible, the preferred air velocity of 20 m (65 ft) per minute shall be used to preclude manual pages from being turned or papers from being blown off work surfaces. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

Exhibit 13.2.3 Large enclosure ventilation



- **13.2.4 Verification of ventilation.** Performance of the ventilation system shall be verified by analysis, test, and verification. [Source: MIL-STD-1800A, 1990]

  Discussion. The analysis will ensure that enough fresh air is supplied to maintain occupant comfort and that toxic substances are properly ventilated. Tests will measure air velocity at all workplaces and ensure that no "dead air" spaces exist. A demonstration will verify that occupants do not experience discomfort due to inadequate ventilation.

- **13.2.5 Protective measures.** Ventilation or other protective measures shall be provided to maintain the levels of gases, vapors, dust, and fumes within the permissible exposure limits specified by OSHA 29 CFR 1910 and the limits specified in the American Conference of Governmental Industrial Hygienists Threshold Limit Values. If a discrepancy exists between these documents, OSHA 29 CFR 1910 shall take precedence. [Source: 29 CFR 1910; MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

- **13.2.6 Intakes.** Intakes for ventilation systems shall be located to minimize the introduction of contaminated air from s such as exhaust pipes. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

- **13.2.7 Control of toxic substances.** If exhaust systems or special ventilating systems are needed to control the concentration of toxic substances, a detailed analysis shall be conducted to identify the substances to be controlled, the health hazard of the substances, and the optimal location and orientation of the ventilating system. For instance, OSHA 29 CFR 1910 addressed ventilation requirements for special operations such as those involving grinding, polishing, buffing, spraying (OSHA 29 CFR 1910.94) and welding (OSHA 29 CFR 1910.252-257). Small confined spaces (inside tanks) present special ventilation problems that may require respirator support. [Source: 29 CFR 1910; 29 CFR 1910.94; 29 CFR 1910.252-257; MIL-STD-1800A, 1990]

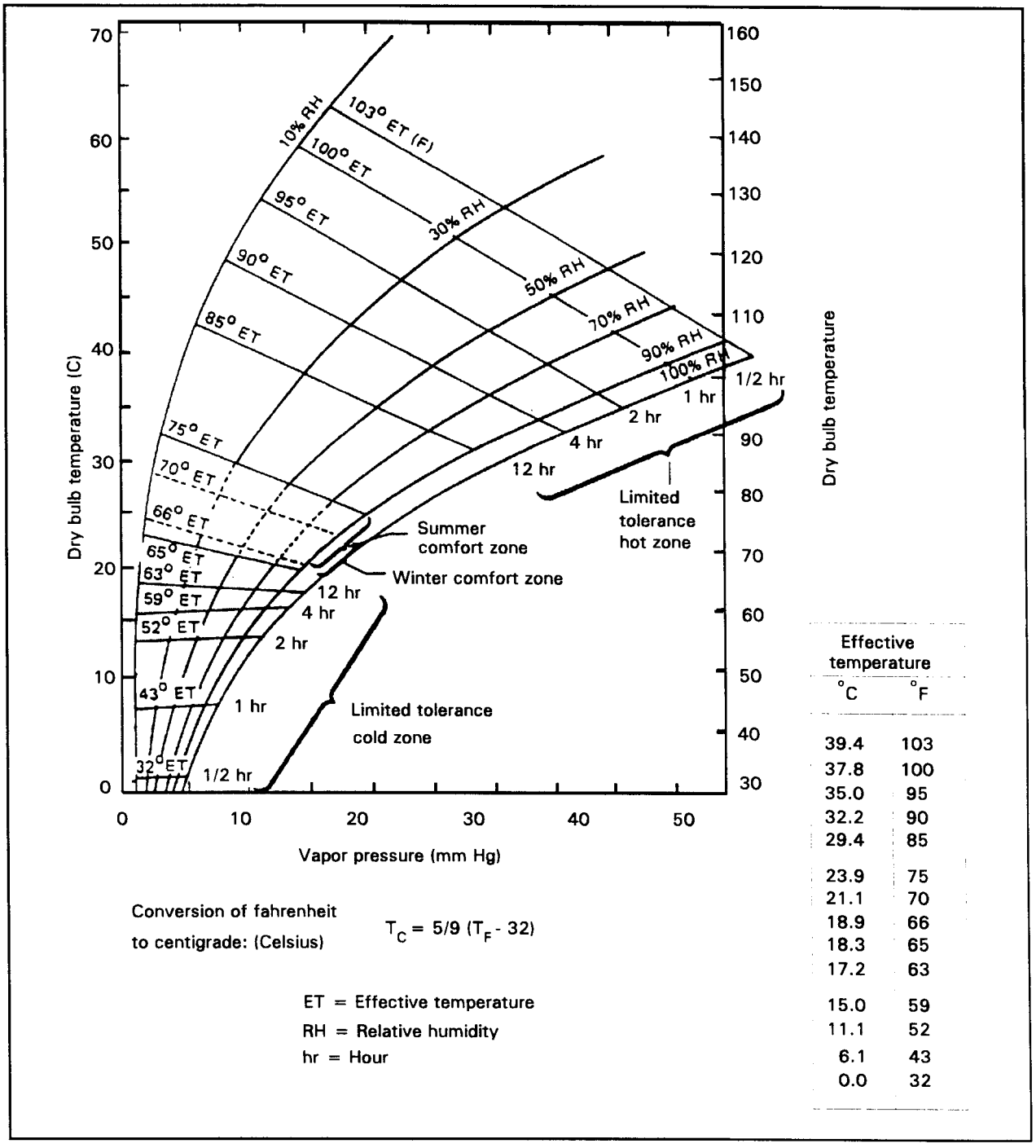
13.3 Temperature and humidity

Maintaining the workplace thermal environment within the range of human tolerance ensures the health, safety and efficiency of the worker.

Heat transfer relationships can become extremely complicated in terms of calculating individual heat balances in the workplace. A tool for determining workplace temperature requirements is the comfort zone chart shown in Exhibit 13.3. The comfort zone varies, depending on clothing and workloads, as shown in the graph. A method of ensuring comfort, in cases where the proper temperature is unknown, is to allow the personnel to set the conditioning controls. In this way, the problem simply becomes one of engineering a heating or cooling system to cope with internal and external hot and cold sources.

Further information for the building environment, including offices, is contained in the latest edition of ANSI/ASHRAE Standard 55. [Source: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1992]

Exhibit 13.3 Comfort zone chart



Effective temperature °C	°F
39.4	103
37.8	100
35.0	95
32.2	90
29.4	85
23.9	75
21.1	70
18.9	66
18.3	65
17.2	63
15.0	59
11.1	52
6.1	43
0.0	32

▫ **13.3.1 Thermal tolerance and comfort zones.** Temperature and humidity exposure should not exceed the effective temperature limits given in Exhibit 13.3 when corrected for air velocity (see Exhibit 13.3.1). [Source: MIL-STD-1472D, 1989]

Definitions. The **comfort zone** is defined as that range of environmental conditions in which humans can achieve thermal comfort. It is affected by work rate, clothing, and state of acclimatization. **Thermal comfort** can be defined as a mental condition that is based upon the lack of perception of noticeable changes in temperature, and that results in a personal expression of satisfaction with the environment.

Discussion. The optimum temperature for personnel varies according to the nature of the tasks, the conditions under which the tasks are performed, and the clothing personnel are wearing. The optimum range of effective temperature for accomplishing light work while dressed appropriately for the season or climate is 21 - 27°C (70 -80°F) in a warm climate or during the summer, and 18 24°C (65 - 75°F) in a colder climate or during the winter. Effective temperature for the environment can be derived from Exhibit 13.3.

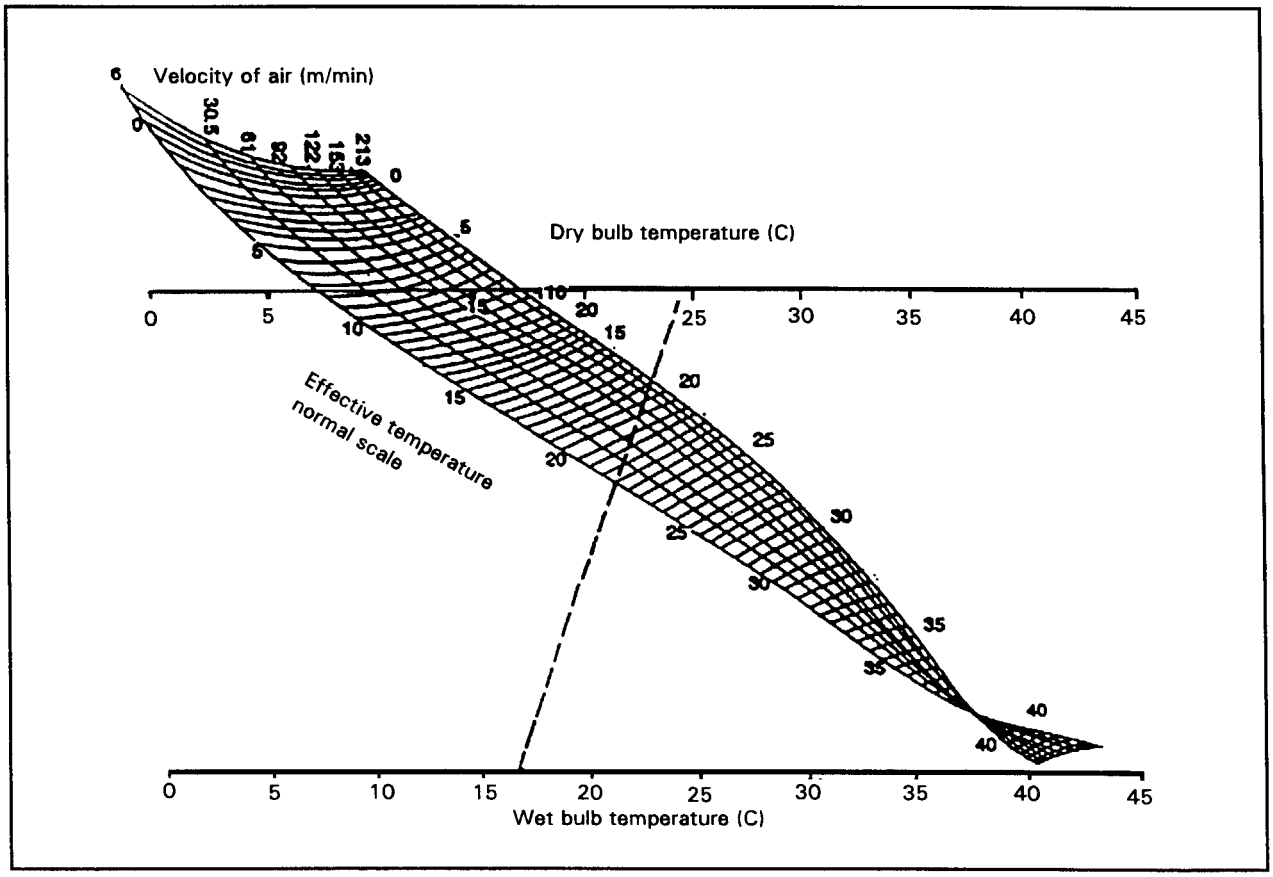


Exhibit 13.3.1 Deriving effective temperature

- **13.3.2 Hot air discharge.** Heating systems shall be designed so that hot air discharge is not directed at personnel. [Source: MIL-STD-1472D, 1989]

  Definition. The **effective temperature** (ET) is an empirical thermal index that illustrates how combinations of dry bulb air temperature, wet bulb temperature, velocity of air, and clothing affect people. Numerically, it is equal to the temperature of still saturated air that would induce the same sensation, as shown in Exhibit 13.3.1. This chart assumes a worker wearing customary indoor clothing and doing sedentary or light muscular work. It does not include any additional heat stress from special purpose clothing such as chemically protective clothing. Likewise, it does not consider radiant heat sources such as the sun or equipment components.

  Discussion. To use the chart above, draw a straight line between dry bulb temperature and wet bulb temperature. The effective temperature is indicated at the point where this straight line crosses the appropriate value for velocity of air. (In this example, the effective temperature is 21.5°C for a dry bulb temperature of 24.5°C, a wet bulb temperature of 16.5°C, and an air velocity of 30.5 mpm).

- **13.3.3 Cold air discharge.** Air conditioning systems shall be designed such that cold air discharge is not directed at personnel. [Source: MIL-STD-1472D, 1989]

- **13.3.4 Minimum effective temperature.** Minimum temperature requirements are dependent upon the tasks to be performed in specific applications. Within permanent and semi-permanent facilities, provisions shall be made to maintain an effective temperature (ET) not less than 18°C (65°F) (see Exhibit 13.3.1), unless dictated otherwise by workload or extremely heavy clothing. [Source: MIL-STD-1472D, 1989; MIL-HDBK-759B, 1992]

- **13.3.5 Maximum effective temperature.** The ET within enclosed workplaces for detailed work during extended periods shall be maintained at or below 29.5°C (85°F). This ET is considered the maximum limit for reliable human performance. [Source: MIL-STD-1472D, 1989]

- **13.3.6 ET ranges as a function of work activity.** The ET ranges are flexible because they vary according to the amount of work activity. In general, the ranges should be extended upwards for tasks requiring minimal physical effort and downward for tasks requiring continuous muscular exertion. Dry bulb temperature should be decreased by 1.7°C for each 29 watts per hour increase in metabolic rate above the resting 117 watts per hour level. Relative humidity should be kept at or below 60% to allow sufficient evaporation to avoid perspiration. [Source: MIL-HDBK-759B, 1992]

- **13.3.7 Arctic clothing.** A person wearing arctic clothing should not be exposed to temperatures higher than 15.5°C (60°F); a temperature of 1.5° to 7.0°C (32° to 45°F) is optimal. [Source: MIL-HDBK-759B, 1992]

- **13.3.8 Temperature of enclosed workplaces.** The temperature throughout enclosed workplaces should be relatively uniform. The temperature of the air at floor level and at head level should not differ by more than 5.6°C (10°F). [Source: MIL-HDBK-759B, 1992]

- **13.3.9 Side wall temperatures.** Side walls of enclosed workplaces should be kept at equal temperatures in so far as possible; however, temperature differences of 11°C (20°F) or less do not significantly degrade comfort. [Source: MIL-HDBK-759B, 1992]

- **13.3.10 Minimum relative humidity.** A minimum relative humidity of 15 percent should be maintained within all facilities to prevent irritation and drying of body tissues, for example, eyes, skin, and respiratory tract. [Source: MIL-STD-1800A, 1990]

- **13.3.11 Relative humidity.** Approximately 45% relative humidity should be provided at 21°C (70°F). This value should decrease with rising temperatures. [Source: MIL-STD-1472D, 1989]

  Discussion. Humidity requirements may be driven by the requirement to maintain effective temperature levels.

- **13.3.12 Verification of humidity.** Humidity levels shall be verified by tests conducted during normal operations to ensure an acceptable level. [Source: MIL-STD-1800A, 1990]

  Discussion. If humidity level requirements are imposed, estimating is inadequate. Direct measurement is the only means of providing the desired accuracy.

- **13.3.13 Humidity measurements.** Humidity measurements should be taken at all personnel work stations. [Source: MIL-STD-1800A, 1990]

13.4 Illumination

Criteria for appropriate illumination cannot be satisfied merely by providing a sufficient amount of light to perform tasks or by providing emergency lighting (approximately 32 lux) to enable personnel to operate important controls or to find the exit. The following factors need to be considered:

a. the brightness contrast between each visual task object and its background,

b. the glare from work surfaces and light sources,

c. the level of illumination required for the most difficult tasks,

d. the color composition of the illumination source and the equipment surfaces,

e. the time and accuracy required in task performance, and

f. the possible variations in operating conditions (such as outdoor panel blackout operation or outdoor panel visibility under bright sunlight) that may affect the lighting system, the task, or the personnel.

Design requirements are provided in this section for (1) illumination of specific tasks, (2) illumination for dark adaptation, (3) glare from light sources, (4) reflected glare, (5) brightness ratios, (6) lighting fixtures and controls, and (7) workstation illumination.

13.4.1 General

In addition to the following illumination rules, see the "Lighting Handbook from the Illuminating Engineering Society", for general lighting design footcandle levels and formulas. [Source: Illuminating Engineering Society of North America, 1993]

- **13.4.1.1 General and supplementary lighting.** Both general and supplementary lighting shall be used as appropriate to ensure that illumination is compatible with each operation and maintenance task situation. [Source: MIL-STD-1472D, 1989]

- **13.4.1.2 Dimming capability.** A light dimming capability shall be provided. [Source: MIL-STD-1472D, 1989]

- **13.4.1.3 Illumination in workplaces.** As a general rule, illumination in workplaces should eliminate glare and shadows that interfere with prescribed tasks. [Source: National Aeronautics and Space Administration (NASA-STD-3000A), 1989]

  Definitions. Illumination is the amount of light (luminance flux) falling on a surface. Measured in lumen/m2 = lux = 0.093 ft-c. Illumination decreases with the square of the distance from a point source. **Luminance** is the amount of light per unit area emitted or reflected from a surface. Measured in candela per square meter (cd/m2), footlamberts (ft-L), or millilamberts (mL). 1.0 cd/m2 = 0.31 mL = 0.29 ft-L. The luminance of a surface does not vary with the distance of the observer from the surface being viewed.

13.4.2 Illumination for the workplace and specific tasks

- **13.4.2.1 Lighting level.** The lighting level shall be measured on the work surfaces, (30 inches above the floor in the absence of work surfaces), or at visual interfaces, (for example, CRT and panels), where appropriate. [Source: NASA-STD-3000A, 1989]

- **13.4.2.2 Illumination.** Workplace illumination shall be appropriate to the tasks to be accomplished. See Exhibit 13.4.2.2 for illumination requirements. [Source: NASA-STD-3000A, 1989]

Exhibit 13.4.2.2 Specific task illumination requirements

Illumination levels

Work area or type of task	Lux (ft - C) Recommended		Minimum	
Bench work				
rough	540	(50)	325	(30)
medium	810	(75)	540	(50)
fine	1615	(150)	1075	(100)
extra fine	3230	(300)	2155	(200)
Business machine operation (calculator, digital, etc)	1075	(100)	540	(50)
Console surface	540	(50)	325	(30)
Corridors	215	(20)	110	(10)
Dials	540	(50)	325	(30)
Electrical equipment testing	540	(50)	325	(30)
Emergency lighting	NA		30	(3)
Gauges	540	(50)	325	(30)
Inspection tasks, general				
rough	540	(50)	325	(30)
medium	1075	(100)	540	(50)
fine	2155	(200)	1075	(100)
extra fine	3230	(300)	2155	(200)
Machine operation, automatic	540	(50)	325	(30)
Meters	540	(50)	325	(30)
Office work, general	755	(70)	540	(50)
Ordinary seeing tasks	540	(50)	325	(30)
Panels				
front	540	(50)	325	(30)
rear	325	(30)	110	(10)
Passageways	215	(20)	110	(10)
Reading				
large print	325	(30)	110	(10)
newsprint	540	(50)	325	(30)
handwritten reports in pencil	755	(70)	540	(50)
small type	755	(70)	540	(50)
prolonged reading	755	(70)	540	(50)
Recording	755	(70)	540	(50)

Exhibit 13.4.2.2 (continued) Specific task illumination requirements

Illumination levels

Work area or type of task	Lux (ft - C) Recommended		Minimum	
Repair work:				
general	540	(50)	325	(30)
instrument	2155	(200)	1075	(100)
Screw fastening	540	(50)	325	(30)
Service areas, general	215	(20)	110	(10)
Stairways	215	(20)	110	(10)
Storage				
inactive or dead	55	(5)	30	(3)
general warehouse	110	(10)	55	(5)
live, rough or bulk	110	(10)	55	(5)
live, medium	325	(30)	215	(20)
live, fine	540	(50)	325	(30)
Tanks, container	215	(20)	110	(10)
Testing				
rough	540	(50)	325	(30)
fine	1075	(100)	540	(50)
extra fine	2155	(200)	1075	(100)
Transcribing and tabulation	1075	(100)	540	(50)

- **13.4.2.3 Glare.** Lighting sources shall be designed and located to avoid creating glare from working and display surfaces, as viewed from any normal working position. [Source: NASA-STD-3000A, 1989]

13.4.3 Illumination levels to maintain dark adaptation

- **13.4.3.1 Maximum dark adaptation.** All transilluminated displays and controls shall be visible when all other lighting is turned off. If maximum dark adaptation is required, red lighting or low level white lighting [CIE color coordinates for x and y equals 0.330 +/- 0.030 (1932)] is acceptable. [Source: NASA-STD-3000A, 1989]

▪ **13.4.3.2 Dark adaptation for task performance.** If dark adaptation is required for performance of tasks, the following steps shall be taken:

a. Low level lighting that minimizes loss of dark adaptation shall be provided for task performance.

b. Areas requiring low level illumination shall be protected from external light sources.

c. All external windows shall be provided with protective light shields (shades or curtains).

d. All doors shall be light-proof when closed. [Source: NASA-STD-3000A, 1989]

Definition. Dark adaptation is the process by which the eyes become more sensitive in dim light. The eyes adapt almost completely in about 30 minutes, but the time required for dark adaptation depends on the color, duration of exposure and intensity of the previous light.

Discussion. Ambient light is incompatible with dark adaptation. If it is dimmed enough so that it does not interfere with dark adaptation, it will not be bright enough by which to work. Minimum interference with adaptation is produced by brief exposure of the lowest intensity possible. Colors often appear different under different types of illumination, so unless a display will always be used under ambient light, do not use color coding.

▫ **13.4.3.3 Ambient light and dark adaptation.** Where both ambient light and dark adaptation are required, the conflict should be resolved by evaluating the priorities of the operator's tasks. [Source: MIL-HDBK-759B, 1992]

13.4.4 Glare from light sources

One of the most serious illumination problems is glare from surfaces. Relatively bright light shining into the observer's eyes as he or she tries to observe a dim visual field, and reflected glare from work surfaces are common causes of reduced performance in visual tasks. Glare not only reduces visibility of objects in the field of view but causes visual discomfort.

Definition. Glare is produced by any luminance within the visual field that is sufficiently greater than the luminance to which the eye is adjusted. Glare causes eye fatigue, discomfort, and annoyance, as well as interfering with visual performance and visibility.

- **13.4.4.1 Glare from artificial light sources.** The following measures shall be taken to avoid glare from artificial light sources:

  a. Locate light sources so that they do not shine directly at personnel. Light sources shall not be located within 60 degrees in any direction from the center of the visual field.

  b. If additional lighting is needed, use dim light sources rather than bright ones.

  c. Use polarized light, shields, hoods, lens, diffusers, or visors.

  d. Use indirect lighting where possible.

  e. Ensure that the maximum to average luminance ratio does not exceed 5:1 across the viewing area. Six test readings shall be taken in the work area to determine the average luminance of the area. [Source: NASA-STD-3000A, 1989]

  Definition. Luminance ratio is the difference between the source of light of an object and its surroundings.

13.4.5 Reflected glare

- **13.4.5.1 Specular reflectance from the task area and the surrounding area.** Luminance of specular reflectance from the task area shall not be greater than 3 times the average luminance of the surrounding area. [Source: NASA-STD-3000A, 1989]

  Definitions. A **Specular surface** is one that provides a specular reflection, a shiny surface. **Reflectance** is the ratio of luminous flux reflected from a surface to luminous flux striking it.

- **13.4.5.2 Work surface reflection.** Work surface reflection shall be diffused and shall not exceed a reflectance of .2°. [Source: NASA-STD-3000A, 1989]

- **13.4.5.3 Angle of incidence.** Direct light sources shall be arranged so their angle of incidence to the visual work area is not the same as the operator's viewing angle. [Source: NASA-STD-3000A, 1989]

- **13.4.5.4 Polished surfaces.** Placement of smooth, highly polished surfaces within 60° of the user's normal visual field shall be avoided. [Source: NASA-STD-3000A, 1989]

- **13.4.5.5 Light source behind user.** The placement of light sources behind users that reflect glare into the user's eyes shall be avoided. [Source: NASA-STD-3000A, 1989]

13.4.6 Brightness ratio

- **13.4.6.1 Wall surface luminance.** Wall surface average luminance shall be within 50 to 80 percent of ceiling surface average luminance. [Source: NASA-STD-3000A, 1989]

- **13.4.6.2 Maximum and minimum luminance ratio.** The maximum to minimum luminance ratio for any surface shall not exceed 10:1. [Source: NASA-STD-3000A, 1989]

- **13.4.6.3 Brightness ratio.** The brightness ratios between the lightest and darkest areas or between a task area and its surroundings shall be no greater than specified in Exhibit 13.4.6.3. [Source: NASA-STD-3000A, 1989]

  Definition. Brightness is an attribute of visual sensation that is determined by the intensity of light radiation reaching the eye.

Exhibit 13.4.6.3 Required brightness ratios

	Environmental classification		
Comparison	**A**	**B**	**C**
Between lighter surfaces and darker surfaces within the task	5 to 1	5 to 1	5 to 1
Between tasks and adjacent darker surroundings	3 to 1	3 to 1	5 to 1
Between tasks and adjacent lighter surroundings	1 to 3	1 to 3	1 to 5
Between tasks and more remote darker surfaces	10 to 1	20 to 1	b
Between tasks and more remote lighter surfaces	1 to 10	1 to 20	b
Between luminaries and adjacent surfaces	20 to 1	b	b
Between the immediate work area and the rest of the environment	40 to 1	b	b

Notes:

A - Interior areas where reflectances of entire space can be controlled for optimum visual conditions.

B - Areas where reflectances of nearby work can be controlled, but there is only limited control over remote surroundings.

C - Areas (indoor and outdoor) where it is completely impractical to control reflectances and difficult to alter environmental conditions.

b - Brightness ratio control not practical.

13.4.7 Lighting fixtures

- **13.4.7.1 Emergency lights.** An independent, self-energizing illumination system shall be provided that will be automatically activated in the event of a major primary power failure or main lighting circuit malfunction resulting in circuit breaker interruption. If the back-up illumination system is a standby engine generator, it shall provide power within 15 seconds of a failure and shall be capable of sustained operation for a minimum of 72 hours. If the back-up illumination system is a standby battery system, it shall provide power immediately upon failure and shall be capable of sustained operation for a minimum of four hours. [Source: NASA-STD-3000A, 1989; Department of Transportation (FAA Order 6950.2C), 1985]

- **13.4.7.2 Controls location.** Lighting controls shall be provided at entrances and exits of enclosed workplace areas. [Source: NASA-STD-3000A, 1989]

- **13.4.7.3 Artificial illumination controls.** Lighting controls for artificial illumination of a workstation shall be located within the reach envelope of the user at the display and control panel or workstation affected. [Source: NASA-STD-3000A, 1989]

- **13.4.7.4 Control identification.** Lighting controls shall be illuminated in areas that are frequently darkened. [Source: NASA-STD-3000A, 1989]

- **13.4.7.5 Flicker.** Light sources shall not have a perceptible flicker. [Source: NASA-STD-3000A, 1989]

- **13.4.7.6 Protection from personnel activity.** Light sources shall be protected from damage by personnel activity. [Source: NASA-STD-3000A, 1989]

- **13.4.7.7 Portable lights.** Portable lights shall be provided for illumination of inaccessible areas or as supplemental lighting for tasks. [Source: NASA-STD-3000A, 1989]

13.5 Noise

Exposure to high levels of noise can cause hearing loss. The nature and extent of the hearing loss depends upon the intensity and frequency of the noise and the duration of the exposure. Noise induced hearing loss may be temporary or permanent. Temporary loss results from short-term exposure to noise; loss from prolonged exposure is irreversible. It can be arrested and prevented through administrative and engineering controls or through the use of ear protection.

13.5.1 Hazardous sound levels

- **13.5.1.1 Reducing sound levels.** Administrative or engineering controls shall be used to reduce sound levels within the permissible exposure limit (PEL). These PELs are established in FAA Order 3910.4 and are given in Exhibit 13.5.1.1. [Source: Department of Transportation (FAA Order 3910.4), 1985]

Exhibit 13.5.1.1 Permissible exposure limits

Duration per day (hours)	Sound level (dBA slow)
8.0	90
6.0	92
4.0	95
3.0	97
2.0	100
1.5	102
1.0	105
0.5	110
0.25 or less	115

Maximum exposure to impulse or impact noise is 140 dB peak sound pressure level.

- **13.5.1.2 Providing personal protection.** If administrative or engineering controls fail to reduce sound levels within the PELs, personal protective equipment shall be provided and a continuing effective hearing conservation program shall be administered in accordance with FAA Order 3910.4. [Source: FAA Order 3910.4, 1985]

- **13.5.1.3 Noise exposure**. Occupational noise exposure levels shall be predicted, tested, monitored, and computed in accordance with FAA Order 3910.4. [Source: FAA Order 3910.4, 1985]

  Discussion. Monitoring the noise levels will identify users who are exposed to levels equal to or greater than:

  a. the 90 dBA, 8-hour time-weighted average (TWA) (or 100 percent dose) PEL, or

  b. the 85 dBA, 8-hour TWA (or 50 percent dose) action level.

  Definitions. Action level is an 8-hour time-weighted-average noise level of 85 dBA or, equivalently, a noise dose of 50 percent, at which affected users will be provided hearing protection and placed in an audiometric testing program. **Dose** is the accumulated exposure to noise.

- **13.5.1.4 Monitoring results and corrective action.** If testing or monitoring reveals that the 8-hour TWA exposure level is:

  a. less than 85 dBA (or 50 percent dose); no further action shall be required,

  b. equal to or greater than the action level, 85 dBA (or 50 percent dose), the user(s) affected shall be provided hearing protection and placed in a hearing conservation program, or

  c. equal to or greater than the PEL, 90 dBA (or 100 percent dose), the user(s) affected shall be provided hearing protection and placed in a hearing conservation program, and feasible administrative and engineering controls shall be used to reduce the noise to acceptable levels. [Source: FAA Order 3910.4, 1985]

13.5.2 Nonhazardous sound levels

- **13.5.2.1 Acoustical design objectives.** The acoustical design objectives for a work space should consider a balance of sound from all sources. [Source: American National Standards Institute (ANSI/HFS 100-1988), 1988]

  Discussion. Where appropriate, the background noise level should be low enough to avoid interference with activity or speech, but high enough to mask intrusive sounds from adjacent spaces.

- **13.5.2.2 Personnel acoustical environment.** Personnel shall be provided with an acoustical environment that does not interfere with the performance of their tasks. They shall be protected from noise that could cause physical impairment. [Source: MIL-STD-1800A, 1990]

- **13.5.2.3 General noise levels.** Workplace noise shall be maintained at levels that do not: (1) interfere with necessary voice, telephone, and radio communication, (2) cause fatigue or injury, and (3) degrade overall system effectiveness. [Source: MIL-STD-1800A, 1990]

- **13.5.2.4 Noise criteria.** Noise criteria are defined by both the A-weighted sound level, dB(A), and the preferred speech interference level, PSIL-4. Use of the A-weighted sound level is preferable. Where it is not possible to meet the specified A-weighted sound level requirement, the corresponding PSIL-4 requirement shall be met. [Source: MIL-STD-1800A, 1990]

  Definitions. Preferred speech interference level (PSIL-4) is a measure of the effectiveness of noise in masking speech. **Speech interference level (SIL or SIL-4)** is the arithmetic mean, in dB, of sound pressure levels in the four octave bands with center frequencies of 500, 1000, 2000, and 4000 Hz. **A-weighted sound level (dB(A))** is a sound pressure level (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz, drops rapidly as frequency decreases below 1000 Hz, and gradually increases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels. ANSI S1.4 gives the definition of A-weighting filter characteristics. [Source: American National Standards Institute (ANSI/ASA S1.4-1983)), 1983]

- **13.5.2.5 Extreme quiet areas.** Ambient noise in areas requiring extreme quiet shall not exceed 35 dB(A) or 27 dB PSIL-4. [Source: MIL-HDBK-759B, 1992]

- **13.5.2.6 Small office spaces and special areas.** Ambient noise in areas requiring no difficulty with speech communication (for example, libraries and classrooms) shall not exceed 45 dB(A) or 37 dB PSIL-4; conference rooms and offices shall not exceed 38 dB PSIL-4. [Source: Department of Transportation (FAA-G-2100F), 1993; MIL-HDBK-759B, 1992]

- **13.5.2.7 Operational areas.** Ambient noise in areas requiring frequent phone use or requiring occasional speech communication (for example, operations centers, control rooms, tower cabs, and dynamic simulation rooms) at distances up to 4.6 m (15 ft) shall not exceed 55 dB(A) or 47 dB PSIL-4; shop offices and laboratories shall not exceed 48 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- **13.5.2.8 Equipment areas.** Ambient noise in areas requiring frequent telephone use or frequent speech communication (for example, computer rooms, engineering areas, equipment rooms, and telephone switching centers) at distances up to 1.5 m (5 ft) shall not exceed 65 dB(A) or 57 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- **13.5.2.9 High noise, remote areas.** High noise, remote areas that are normally unmanned shall not exceed 85 dB(A). [Source: FAA-G-2100F, 1993]

- **13.5.2.10 Occupational noise exposure and control.** Administrative or engineering controls shall be used to reduce the sound levels to within permissible noise exposure levels listed in Exhibit 12.12.8. OSHA 29 CFR 1910.95 shall be used in determining equivalent A-weighted sound levels for daily exposure. A hearing conservation program shall be administered any time an employee's noise exposure equals or exceeds an 8-hour time weighted average of 85 db measure on the A scale (slow response) or equivalent without regard to attenuation that may be provided by personal protective equipment. OSHA 29 CFR 1910.95 shall govern the hearing protection program. [Source: 29 CFR 1910.95]

Glossary

Action level - An 8-hour time-weighted-average noise level of 85 dBA or, equivalently, a noise dose of 50 percent, at which affected users will be provided hearing protection and placed in an audiometric testing program.

Brightness: an attribute of visual sensation that is determined by the intensity of light radiation reaching the eye.

Comfort zone - That range of environmental conditions in which humans can achieve thermal comfort. It is affected by work rate, clothing, and state of acclimatization.

Dark adaptation - The process by which the eyes become more sensitive in dim light. The eyes adapt almost completely in about 30 minutes, but the time required for dark adaptation depends on the color, duration of exposure and intensity of the previous light.

Dose - The accumulated exposure to noise.

Effective temperature - An empirical thermal index that illustrates how combinations of dry bulb air temperature, wet bulb temperature, velocity of air, and clothing affect people.

Glare - Is produced by any luminance within the visual field that is sufficiently greater than the luminance to which the eye is adjusted. Glare causes eye fatigue, discomfort, and annoyance, as well as interfering with visual performance and visibility.

Illumination - The amount of light (luminance flux) falling on a surface. Measured in lumen/m2 = lux = 0.093 ft-c. Illumination decreases with the square of the distance from a point source.

Luminance - The amount of light per unit area emitted or reflected from a surface. Measured in candela per square meter (cd/m2), footlamberts (ft-L), or millilamberts (mL). 1.0 cd/m2 = 0.31 mL = 0.29 ft-L. The luminance of a surface does not vary with the distance of the observer from the surface being viewed.

Luminance ratio - The difference between the source of light of an object and its surroundings.

Preferred speech interference level (PSIL-4) - A measure of the effectiveness of noise in masking speech.

Reflectance - The ratio of luminous flux reflected from a surface to luminous flux striking it.

Specular surface - One that provides a specular reflection, a shiny surface.

Speech interference level (SIL or SIL-4) - the arithmetic mean of sound pressure levels in the four octave bands with center frequencies of 500, 1000, 2000, and 4000 Hz.

Thermal comfort - Defined as a mental condition that is based upon the lack of perception of noticeable changes in temperature, and that results in a personal expression of satisfaction with the environment.

Ventilation - The process of supplying air to or removing air from any space by natural or mechanical means. From the standpoint of comfort and health, ventilation issues involve both quantity and quality.

Weighted sound level (dB(A)) - a sound pressure level (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz, drops rapidly as frequency decreases below 1000 Hz, and gradually increases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels. ANSI S1.4 gives the definition of A-weighting filter characteristics.

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