Technical Report
W6835-T5-1-11/98

ACCESSION NUMBER ML-003714971

Draft

Evaluating the Impact of Environmental Factors on Control Room Operator Performance

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Prepared for the U.S. Nuclear Regulatory Commission
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May, 2000

ABSTRACT

Since issuing NUREG-0700, Revision 1, "Human System Interface Design Review Guideline," in June 1996, the U. S. Nuclear Regulatory Commission (NRC) has been committed to the periodic update and improvement to this document to ensure that it will remain a state-of-the-art design review tool. The technical content of the guidelines in Revision 0 and 1 were reviewed to determine whether updating may be needed as a result of new, validated guidance that may have been developed since their publication, and to modify the guidelines accordingly. NUREG/CR-5680 presents the results of a comprehensive review of the technical literature on the impact of environmental conditions on human performance in nuclear power plant settings. Although that report was not intended to provide design review guidelines for environmental conditions, it was recognized that the information developed in this effort might provide a basis for updating and/or augmenting the existing review guidance. This report summarizes the results of comparing the guidance in NUREG-0700, Rev.1 for environmental conditions against the information in NUREG/CR-5680. It contains summaries of the scope and content of NUREG/CR-5680, and the information for each of the environmental factors considered in NUREG/CR-5680 that pertain to the guidance in NUREG-0700. Proposed modifications to NUREG-0700, which are based on the information in NUREG/CR-5680, are contained in the appendices.

CONTENTS

PREFACE

This draft report has been prepared for the Human Factors Branch of the Nuclear Regulatory Commission's Office of Nuclear Regulatory Research. This document is submitted as part of the work performed for the "NUREG-0700, Rev.2" project (FIN W-6835), specifically Task 5, Incorporate New Design Review Guidance. The U.S. Nuclear Regulatory Commission (NRC) Project Manager for this effort is Jerry Wachtel. The BNL Principal Investigator is John O'Hara.

ACRONYMS

ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
HVAC	heating, ventilation, and air conditioning
IES	Illuminating Engineering Society
ISO	International Standards Organization
SIL	speech interference level
WBGT	wet bulb globe temperature

1 INTRODUCTION

NUREG-0700, Revision 1, "Human System Interface Design Review Guideline," was published in June 1996 after a comprehensive development and review process. Since its issuance, it has been used successfully by NRC staff, contractors and nuclear industry organizations, as well as by interested organizations outside the nuclear industry. The NRC is committed to the periodic update and improvement to the document to ensure that it will remain a state-of-the-art design review tool. To this end, an effort has been undertaken to review the technical content of the guidelines in Revision 0 and 1 for updates that may be needed as a result of new, validated guidance that may have been developed since their publication, and to modify the guidelines accordingly. This report summarizes proposed updates to the guidance pertaining to environmental factors that may affect operator performance.

Much of the guidance in Rev.1 related to environmental considerations was taken unchanged from Rev.0, as described in O'Hara et al. (1996a). Specifically, the guidelines for environmental conditions in the control room that appear in Section 7.3, Environment of NUREG-0700, Rev. 1 are for the most part identical to those that appear in Section 6.1.5 of NUREG-0700, Rev.0, which contained similarly titled subsections. Guidelines for operator interfaces outside the control room appear in Section 8, Local Control Stations of NUREG-0700, Rev.1; environmental conditions at such interfaces are treated in Section 8.5, Environment. This guidance differs from the control room guidance in Section 7.3 in that the effects of high temperatures and noise levels are considered; Rev.0 did not contain guidance for areas other than the control room (and remote shutdown facility).

The NRC sponsored a comprehensive review of the technical literature on the impact of environmental conditions on human performance in nuclear power plant settings; the results of this effort were reported in NUREG/CR-5680. The report was not intended to provide design review guidance for environmental conditions. However, it was recognized that the information developed in this effort might provide a basis for updating and/or augmenting the existing review guidance.

This report summarizes the results of comparing the guidance in NUREG-0700, Rev.1 for environmental conditions against the information in NUREG/CR-5680. The scope and content of NUREG/CR-5680 are briefly described in Section 2. Section 3 contains summaries of the information for each of the environmental factors considered in NUREG/CR-5680 that pertains to the guidance in NUREG-0700. The appendices contain the modifications to NUREG-0700 that are proposed based on the information in NUREG/CR-5680. Appendix A contains proposed revisions to guidance for control room conditions, which currently appears in the following subsections of NUREG-0700, Rev. 1:

- 7.3.1 Temperature and Humidity
- 7.3.2 Ventilation
- 7.3.3 Illumination
- 7.3.4 Emergency Lighting
- 7.3.5 Auditory Environment

Appendix B contains proposed revisions to guidance for conditions outside the control room, which currently appears in the following sections of NUREG-0700, Rev. 1:

- 8.5.1 Temperature and Humidity
- 8.5.2 Noise

In some cases standards and literature referred to in NUREG/CR-5680 were consulted directly to clarify, update, or verify proposed guidance modifications; in such cases an extended discussions of the topic is provided.

2 CONTENTS AND ORIENTATION OF NUREG/CR-5680

The purpose of NUREG/CR-5680 was to assemble information on the likely impact of environmental conditions on human reliability in nuclear power plant. The authors of NUREG/CR-5680 drew a distinction between limits that are intended to protect workers from harm as a result of extreme environmental conditions and levels that are aimed at ensuring optimal acceptable levels of human performance. Where possible, they have attempted to identify ranges of environmental conditions within which no effects on task performance would be expected and to provide information on which to base an assessment of the likely effects on human performance of a specified set of environmental circumstances. The effects of five environmental factors - vibration, noise, heat, cold, and lighting - are considered in NUREG/CR-5680. The document consists of two volumes. The first volume is a handbook intended for use in assessing the effect of environmental factors on performance. The second volume contains the technical basis for the handbook, consisting of a literature review and discussion for each environmental factor.

3 REVISIONS TO NUREG-0700. REV.1 BASED ON NUREG/CR-5680

This section describes how the information presented in NUREG/CR-5680 relates to the guidance in NUREG-0700, Rev.1. Four environmental factors are considered: noise, lighting, temperature, and vibration. (Heat and cold are treated together as 'temperature' in NUREG-0700.) The relevant information from NUREG/CR-5680 is briefly summarized for each factor and its relationship to the material in NUREG-0700, Rev.1 is discussed. Where appropriate, revisions or additions to the guidance in NUREG-0700, Rev.1 are proposed. These are summarized at the end of each subsection.

3.1 Noise

3.1.1 Discussion

The review of the effects of noise in NUREG/CR-5680 begins with the physics and measurement of sound and a description of occupational noise exposure limits. Temporary and permanent hearing losses associated with noise exposure are discussed. The mechanisms underlying and effects of auditory masking of speech and other audio information are summarized. The review concentrates noise how noise affects task performance.

The discussion in NUREG/CR-5680 of the masking of speech by noise is based on the same basic findings as the guidance on this topic in NUREG-0700; the manner in which communication in the presence of noise varies with vocal effort and speaker/listener distance is illustrated graphically and presented in tabular form. The same relationship is illustrated in Exhibit 6.1-26 and Figure 7.10 of Rev.0 and Rev.1, respectively. It is pointed out in NUREG/CR-5680 that being able to see a speaker's lips can result in a change in performance equal to that associated with a 15dB change in the masking noise levels. In a check of the validity of the distance versus speech interference curves, Waltzman and Levitt (1978) found that the curves adequately predicted performance when visual cues were not available, but substantially underestimated performance in conditions where visual cues were present. Nevertheless, in the interest of being conservative (see below), and because operators monitoring instruments or using procedures will likely be verbally communicating without the benefit of visual cues, the curves should remain as currently presented. The potential improvements in speech intelligibility associated with visual cues should be noted in the guidance, however. NUREG/CR-5680 also notes that intelligibility may be improved if communication includes simple, standardized phrases; this should also be reflected in the guidance.

Waltzman and Levitt (1978) also noted some other factors affecting the accuracy of the curves, including the level and power spectrum of the speaker's voice, the listener's hearing sensitivity, and the acoustical characteristics of the environment. The power spectrum of the background noise also must be considered. The level of the noise is typically given in dB(A) rather than speech interference level (SIL). The SIL used in the research on which the speech interference functions were based represents an average of the noise power in the bands around 500, 1000, 2000, and 4000Hz - frequencies which are important to speech comprehension. The translation to dB(A) is valid only if the masking noise has a uniform spectrum in the frequency region of

500-4000Hz. Masking of speech by noise with sharp spectral peaks (i.e., tonal components) can not be predicted from the curves based on the overall dB(A) level of the noise.

According to the illustration of vocal effort necessary to overcome background noise shown in Figure 3.4 of NUREG/CR- 5680, Vol. 1, communication is possible over distances of 10-20 feet without raising the voice at a background level of roughly 55dB(A); at a background of 65 dB(A) the upper limit is reduced to several feet. The background noise limit recommended for "large workspaces" in MIL-STD-1472D (which contains a similar vocal effort/distance illustration) is 55 dB(A); the recommendation for "special areas" including "command and control centers" is 45 dB(A). While NUREG/CR-5680 shows that noise interference with task performance depends on familiarity (and not just overall noise level), it nevertheless seems reasonable to reduce the recommended limit in NUREG-0700 (the source of which is specified in Rev. 0 as "HFEB Preferred Practice"). At a minimum, it should be noted that communication over distances of more than several feet may require lower background noise levels.

It is noted in NUREG/CR-5680 that speakers will spontaneously raise the levels of their voices in the presence of noise, though to such an extent that intelligibility is maintained despite increasing noise. This effect is typically shown in figures illustrating vocal effort required to maintain intelligibility in the presence of noise (see, e.g., MIL-STD 1472D); it is not shown in NUREG-0700.

3.1.2 Summary of Proposed Revisions

Based on material presented in NUREG/CR-5680 and related literature, the following revisions to NUREG-0700, Rev.1 are proposed:

- Guideline 7.3.5-2, Background Noise - note in Additional Information that noise interference with spoken communication may be lessened if operators face each other (i.e., when visual cues are available) or use standardized vocabulary. Note also factors other than noise level that can affect speech communication.

- Figure 7.10 - consider revising the curves to reflect the spontaneous increase in voice level in response to noise.

- Guideline 7.3.5-2, Background Noise - include a Discussion of speech intelligibility and the assumed power spectrum of the background noise.

- 7.3.5-3, Background Noise Level - note in Addition Information that spoken communication in a large control areas may require a lower levels of background noise.

3.2 Lighting

3.2.1 Discussion

The review of the effects of light on performance includes a brief discussion of measurement of light intensity and the measurement of visual acuity. The lighting recommendation of the

Illuminating Engineering Society (IES) are briefly discussed in the literature review (i.e., Volume 2); detailed consideration of the IES method for arriving at lighting recommendations is provided in the handbook (i.e., Volume 1). The literature on the effects of light on specific tasks (e.g., reading, visual inspection, color judgement) is summarized and factors such as glare and the effects of aging on vision are also considered.

The procedure recommended by the IES for selecting illuminances for industrial settings is summarized in NUREG/CR-5680. The process assigns a range of acceptable illuminances based on the demands of the visual task (e.g., the types of displays to be used). Weighting factors are applied to take into account the reflectance of the background or surroundings, the age of the viewer, and the criticality of the activity. Low background reflectance, operators more than 55 years of age, or highly critical activities are assumed to indicate a need for higher lighting levels and a positive weight is assigned for the factor; high background reflectance, operators under 40 years of age, or non-critical activities indicate that lower lighting levels are sufficient and a negative weight is assigned. From the range assigned for a given task, the low, moderate, or high value is selected based on the combined weights.

The IES recommended ranges for control room settings were the basis for the values originally specified in Exhibit 6.1-22 of NUREG-0700, Rev.0. The low, middle, and high range values given in the IES Handbook were identified as "Minimum," "Recommended," and "Maximum," but no guidance was for selecting an appropriate value. The same presentation appears in Table 7.2 of NUREG-0700, Rev.1.

Research (performed by EPRI) on lighting levels in nuclear power plant control rooms is discussed in NUREG/CR-5680. The authors conclude that while the speed and accuracy of reading meters does not appear to be compromised at minimum recommended lighting levels (per the IES Lighting Handbook), the research on operator alertness suggests that levels well above the minimum value for reading should be used in control rooms.

An argument could be made that the high end of the range should be used as a basis for the for the criterion illuminances since it is probably not reasonable to assume that any of the three weighting factors will consistently be negative in a control room environment. Use of the higher values is also indicated by the EPRI findings. Accordingly, the table of recommended illuminances that appears in NUREG-0700, Rev.1 can be simplified by including just the values formerly designated "Maximum."

Recommended illuminances for in-plant areas (which would include local control stations), derived from the IES Lighting Handbook, are given in Table 6.4 of NUREG/CR-5680. No specific criteria were given in Section 8 of NUREG-0700 Rev.1 for lighting levels. Therefore, a guideline and accompanying table (similar to guideline 7.3.3-1 and Table 7.2) are added to Section 8.

3.2.2 Summary of Proposed Revisions - Light

Based on the material presented in NUREG/CR-5680 and related sources, the following changes to guidance in NUREG-0700, Rev.1 are proposed:

- Table 7.2, Illumination Levels - revise table of recommended illuminances to include only the high range from the IES Handbook.

- 7.3.3-1, Levels - note in additional information that lower illuminances may be acceptable depending on the particular condition and the associated weighting factors.

- 7.3.3-8, Color - include in additional information a caution against use of lights with poor color rendering properties.

- 7.3.3-10, Use of Colored Ambient Illumination - include in additional information a caution against use of lights with poor color rendering properties.

- 8.5.3-1, Levels - insert a Guideline that specifies recommended illuminances for locations outside the control room.

- Table 8.6, Recommended illuminances.... - add a table that specifies recommended illuminances for locations outside the control room

3.3 Temperature

3.3.1 Discussion

The review of the literature in NUREG/CR-5680 considers both the effects of heat and of cold on performance. It is stated that variations in temperature above or below that which is considered comfortable can indirectly affect performance if the conditions cause operators to be distracted. However, it is also suggested that if the discomfort results in an increase of arousal, it may improve task performance when operators are under-simulated. Larger deviations in temperature have more conspicuous negative effects on performance. Relevant information on both comfort (applicable in control room settings) and extremes of temperature (applicable primarily outside the control room) is summarized below.

3.3.1.1 Comfort

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) issues a standard (ASHRAE 55) on thermal comfort conditions. The Standard defines a "comfort zone" which specifies temperature/humidity conditions that most people would be expected to find acceptable. The temperature/humidity recommendation in NUREG-0700, Rev.0 referenced ASHRAE 55-74, shown on a psychrometric chart (Exhibit 6.1-21). (In Rev.1 the recommendation is given in text, without the illustration. The temperature limits given in Rev.1 are based on those specified in MIL STD-1472D, not the ASHRAE 55-74 values.) In NUREG/CR-5680, the comfort zone is shown in a simplified diagram (Figure 4.1 in Volume 1) as a function of dew point temperature and relative humidity; the figure is adapted from a psychrometric chart illustrating the comfort zone given in ASHRAE 55-81. However, the humidity limits in the comfort zone in Figure 4.1 are defined in terms of relative humidity while the ASHRAE 55-81 limits (like those in ASHRAE 55-74) are defined by dew point. This

discrepancy is unimportant, since as will be described below, the humidity limits in the Standard are much less well-defined than the temperature criteria.

The humidity limits defining the upper boundary of the ASHRAE comfort zone have changed with each revision of Standard 55. The following summary is based on Fountain (1998) and Berglund (1998).

Table 1 Summary of humidity limits

Revision	Humidity Limit	Parameter
ASHRAE 55-66	60%	relative humidity
ASHRAE 55-74	5-14mmHg	vapor pressure
ASHRAE 55-81	12g/Kg	humidity ratio
ASHRAE 55-92	60%	relative humidity
ASHRAE 55a-92	64° F winter 68° F summer	wet bulb temperature (see below)

From this summary it can be surmised that the limits given in Rev.0 (Exhibit 6.1-21) are apparently those specified in ASHRAE 55-66 (in terms of relative humidity), not ASHRAE 55-74 (where the limits are specified in terms of vapor pressure). As suggested above, there have been changes in the Standard since the preparation of NUREG/CR-5680.

It is also evident from the changes summarized above that in the most recent (1992) revision of the Standard the acceptable relative humidity range is narrowed. The lower limit was raised to 30% in recognition of discomfort (and possible health effects) associated with very low humidity, as reflected in the rendering of the comfort zone in Figure 4.1 of NUREG/CR-5680. The upper limit was lowered to 60% owing primarily to concern about the growth of mold under very humid conditions (Berglund, 1998); an upper relative humidity limit of 70% is shown in Figure 4.1 of NUREG/CR-5680.

Subsequent to the 1992 revision, Standard 55 was amended so that the upper humidity limits for the winter and summer comfort zones are defined (respectively) by 64° F and 68° F wet bulb temperatures (American Society of Heating Refrigeration and Air Conditioning Engineers, 1997). The rationale for the change was that the Standard addresses the acceptability of temperature/humidity conditions (not health issues), that the lower humidity limits were too restrictive for some types of HVAC systems, and that there was no empirical evidence to indicate that relative humidity levels greater than 60% would necessarily be judged unacceptable. Using the limits defined by the wet bulb temperatures has the effect of allowing relative humidity of roughly 80% at the low end of both the winter and summer temperature ranges. At the upper end of both ranges, the recommended relative humidity remains roughly 60%.

While recent studies (Berglund, 1998; Fountain, 1998) provided evidence that the higher humidity levels allowed in the amended Standard are judged acceptable with respect to comfort, the ASHRAE indoor air quality standard (ASHRAE 62-1989) recommends a relative humidity limit of 60% in order to minimize the potential for microbial growth.

The authors of NUREG/CR-5680 noted that the summer comfort zone can be extended (that is, it can encompass higher temperatures), if air flow rates greater than 50 ft/min are assumed. However, high rates of flow are not appropriate in the control room (see Guideline 7.3.2-2).

3.3.1.2 Extreme Heat

Based on a review of the literature on the effects of heat on the performance of the types of tasks that operators perform in nuclear power plants, the authors of NUREG/CR-5680 concluded that for simple tasks there is little deterioration in performance as a result of exposure to excess heat. For more complex tasks, performance decrements are noted in the 86° to 92° F WBGT range. The authors noted that "[t]hese decrements occur at temperatures just below the recommended heat stress limits, which define the range when the body begins to show signs of physiologic strain." That is to say, performance decrements become evident when the body begins to accumulate heat; the inability of the body to maintain heat ultimately balance results in heat stress. The body's heat balance depends not only on temperature but also on the amount of heat generated by the body (metabolic) and how effectively the heat is dissipated. Therefore, it is necessary to consider the level of physical activity required of operators and the kind of clothing they wear in order to assess the potential effects of heat on performance.

Because the stay times and temperature limits given in EPRI NP-4453 (adapted as Tables 8.2 and 8.3 in NUREG-0700, Rev.1) are intended to define conditions in which heat balance can be maintained, they can also be used to identify conditions under which adequate human performance is likely to be achieved. The tables are retained, with slight modifications, since they encompass temperature, metabolic rate, and clothing effects in a readily useable form. It should be noted however that the EPRI recommendations are ceiling values, i.e., they assume that protective practices (such as acclimatization, training, and a cool place to rest) are in place (Ramsey, 1994). It should also be noted (per EPRI NP-4453) that the ranges given in the tables reflect the inherent variability among workers and the possible imprecision of using WBGT as an indicator of heat stress.

The Botsball temperatures given in the original EPRI table of stay times, reproduced in Table 8.2, are omitted from the proposed revision. Other compact devices are now available that directly indicate WBGT; Botsball measurements were not mentioned in the review presented in NUREG/CR-5680. Thus, including the Botsball conversions complicates the Table unnecessarily.

3.3.1.3 Cold

According to NUREG/CR-5680, research results on performance in cool temperatures are equivocal. While some impairment in the performance fine manual tasks may occur at temperatures below about 64° F, the mild discomfort experienced may increase arousal leading

to improved performance in some cases. At lower temperatures (about 54° F), decreases in manual dexterity can begin to affect tracking and gross manual tasks. At low temperatures, prolonged discomfort may be distracting, leading to poorer performance.

It is noted in NUREG/CR-5680 that while cool temperatures (66-69° F) may lead to increased alertness (by increasing arousal as stated above), such temperatures, common in spaces housing computerized equipment, are a source of dissatisfaction in control room operators.

Except for noting that operator located outdoors should be protected from the elements, NUREG-0700, Rev.1 does not provide guidance on the effects of cold on operator performance. Therefore, a subsection containing such guidance should be included in Section 8.

3.3.2 Summary of Proposed Revisions

Based on the material presented in NUREG/CR-5680 and related sources, the following changes to guidance in NUREG-0700, Rev.1 are proposed:

- 7.3.1-1, Comfort Zone - revise temperature / humidity values to correspond to current ASHRAE thermal comfort and indoor air quality recommendations.

- 7.3.1-1, Comfort Zone - include additional information on temperature/humidity limits.

- 7.3.1-1, Comfort Zone - add Discussion humidity recommendation.

- 8.5.1-3, Engineering Controls - add a reference to table of temperature ranges for different stay times.

- 8.5.1-3, Engineering Controls - note in additional information that limits in Table 8.2 assume protective measures such as acclimatization, training, and a cool place to rest.

- 8.5.1-4, Work Practices - delete reference to table of temperature ranges for different stay times.

- 8.5.1-4, Work Practices - note in additional information that limits in Table 8.3 assume protective measures such as acclimatization, training, and a cool place to rest.

- Table 8.3 - remove Botsball temperature values; specify temperature units.

- 8.5.1 Temperature - rename the section as indicated.

- 8.5.1.1 Heat - add this section; place current contents of 8.5.1 (which pertain to heat) in this section.

- 8.5.1.2 Cold - add this section containing guidance from NUREG/CR-5680.

- Table 8.4 - wind chill.

- Table 8.5 - no effect temperatures.

Note that the order in which the stay time and temperature tables appear in Appendix A is reversed as compared with NUREG-0700; it is preferable to consider engineering controls (i.e., limiting temperature) before administrative controls (i.e., limiting stay time). Note also that the glossary should be revised to contain a definition of relative humidity (the ratio of the amount of water vapor in the air to the total amount of water vapor the air could hold at that temperature)

3.4 Vibration

3.4.1 Discussion

NUREG/CR-5680 describes research indicating that observing the exposure time limits given in ISO 2631 and MIL-STD 1472 for maintaining proficiency in the presence of vibration may not protect against unacceptable rates of error in visual and manual tasks. It is recommended that the potential effects of vibration be evaluated relative to performance isodecrement curves derived from empirical studies.

NUREG-0700 does not address the potential effects of vibration on performance. Since vibration at levels sufficient to affect performance is more likely to be present at interfaces outside the control room, a subsection containing guidance related to vibration should be added to Section 8, Local Control Stations. Contents of the subsection should provide some quantitative information on the effects of vibration on performance and recommend engineering and administrative controls to mitigate the effects.

3.4.2 Summary of Proposed Revisions - Vibration

Based on the material presented in NUREG/CR-5680 and related sources, the following changes to guidance in NUREG-0700, Rev.1 are proposed:

- 8.5.5-1, Levels - add an item referring to the figure from NUREG/CR-5680 showing effects of vibration on performance.

- Figure 8.1 - add a figure (Figure 3.12 in NUREG/CR-5680, Vol.2) manual and visual performance as a function of vibration frequency and acceleration.

- 8.5.5-2, Reducing Vibration - add an item recommending on reducing vibration at its source.

- 8.5.5-3, Limiting Transmission of Vibration - add an item on limiting the transmission of vibrations to operators.

- 8.5.5-4, Reducing the Effects of Vibration - add an item on error-resistant interface design

- 8.5.5-5, Limiting Exposure to Vibration - add an item on operator protection.

3.5 Ventilation

3.5.1 Discussion

Ventilation is addressed in NUREG/CR-5680 only insofar as air movement affects the body's gain or loss of heat. For purposes of discussing temperature/humidity and operator comfort, the velocity of air movement in the control room was assumed to be less than 50 ft/min; a maximum of 45 ft/min is called for in Guideline 7.3.2-2. No change is the guidance is indicated.

Guideline 7.3.2-1 recommends that the ventilation system supply fresh air to the control room at a rate of 15 cfm per occupant. Like the humidity limit, the recommended amount of fresh air has changed. Before energy costs became a major factor, the ventilation standard (ASHRAE 62) called for fresh air to be supplied to 'office' spaces at a rate of 20 cfm per occupant; that figure was subsequently reduced. With increasing concern about indoor air quality and the potential accumulation of pollutants in very "tight" buildings, the amount of fresh air called for in the Standard has been increased again. The 1989 revision of ASHRAE 62 specifies 20 cfm per occupant. The guidance should reflect the change in the Standard.

3.5.2 Summary of Proposed Revisions - Ventilation

Based on the material presented in NUREG/CR-5680 and related sources, the following change to the guidance in NUREG-0700, Rev.1 is proposed:

- 7.3.2-1, Air Quantity - change the amount of fresh air to be supplied from 15 cfm to 20 cfm per recent ASHRAE standard.

4 GENERAL SUMMARY

Based on material presented in NUREG/CR-5680 and related literature, revisions to NUREG-0700, Rev.1 are proposed. The following summaries these changes according to their respective sections in NUREG-0700, Rev. 1.

Section 7.3.1, Temperature and Humidity

Proposed changes:

- 7.3.1-1, Comfort Zone - revise temperature / humidity values to correspond to current ASHRAE thermal comfort and indoor air quality recommendations.

- 7.3.1-1, Comfort Zone - include additional information on temperature/humidity limits.

- 7.3.1-1, Comfort Zone - add Discussion humidity recommendation.

Section 7.3.2, Ventilation

Proposed change:

- 7.3.2-1, Air Quantity - change the amount of fresh air to be supplied from 15 cfm to 20 cfm per recent ASHRAE standard.

Section 7.3.3, Illumination

Proposed changes:

- Table 7.2, Illumination Levels - revise table of recommended illuminances to include only the high range from the IES Handbook.

- 7.3.3-1, Levels - note in additional information that lower illuminances may be acceptable depending on the particular condition and the associated weighting factors.

- 7.3.3-8, Color - include in additional information a caution against use of lights with poor color rendering properties.

- 7.3.3-10, Use of Colored Ambient Illumination - include in additional information a caution against use of lights with poor color rendering properties.

Section 7.3.5, Auditory Environment

Proposed changes:

- Guideline 7.3.5-2, Background Noise - note in Additional Information that noise interference with spoken communication may be lessened if operators face each other (i.e., when visual cues are available) or use standardized vocabulary. Note also factors other than noise level that can affect speech communication.

- Figure 7.10 - consider revising the curves to reflect the spontaneous increase in voice level in response to noise.

- Guideline 7.3.5-2, Background Noise - include a Discussion of speech intelligibility and the assumed power spectrum of the background noise.

- 7.3.5-3, Background Noise Level - note in Addition Information that spoken communication in a large control areas may require a lower levels of background noise.

Section 8.5.1, Temperature and Humidity:

Proposed changes:

- 8.5.1-3, Engineering Controls - add a reference to table of temperature ranges for different stay times.

- 8.5.1-3, Engineering Controls - note in additional information that limits in Table 8.2 assume protective measures such as acclimatization, training, and a cool place to rest.

- 8.5.1-4, Work Practices - delete reference to table of temperature ranges for different stay times.

- 8.5.1-4, Work Practices - note in additional information that limits in Table 8.3 assume protective measures such as acclimatization, training, and a cool place to rest.

- Table 8.3 - remove Botsball temperature values; specify temperature units.

- 8.5.1 Temperature - rename the section as indicated.

- 8.5.1.1 Heat - add this section; place current contents of 8.5.1 (which pertain to heat) in this section.

- 8.5.1.2 Cold - add this section containing guidance from NUREG/CR-5680.

- Table 8.4 - wind chill.

- Table 8.5 - no effect temperatures.

Section 8.5.3, Lighting

Proposed changes:

- 8.5.3-1, Levels - insert a Guideline that specifies recommended illuminances for locations outside the control room.

- Table 8.6, Recommended illuminances.... - add a table that specifies recommended illuminances for locations outside the control room.

Section 8.5.5, Vibration (New)

Proposed changes:

- 8.5.5-1, Levels - add an item referring to the figure from NUREG/CR-5680 showing effects of vibration on performance.

- Figure 8.1 - add a figure (Figure 3.12 in NUREG/CR-5680, Vol.2) manual and visual performance as a function of vibration frequency and acceleration.

- 8.5.5-2, Reducing Vibration - add an item recommending on reducing vibration at its source.

- 8.5.5-3, Limiting Transmission of Vibration - add an item on limiting the transmission of vibrations to operators.

- 8.5.5-4, Reducing the Effects of Vibration - add an item on error-resistant interface design

- 8.5.5-5, Limiting Exposure to Vibration - add an item on operator protection.

5 REFERENCES

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Appendix A - Revision of Section 7.3, NUREG-0700, Rev.1

7 WORKPLACE DESIGN
7.3 Environment
7.3.1 Temperature and Humidity

7.3.1-1 Comfort Zone
The climate control system should maintain temperatures of about 68-75° F in winter and about 73-79° F in summer and relative humidity levels between 30% and 60%.

ADDITIONAL INFORMATION: The temperature ranges given are based on the ASHRAE summer and winter comfort zones as specified in ASHRAE 55-1992. In the summer comfort zone workers wearing light clothing will be comfortable; in the winter comfort zone, workers wearing heavy indoor clothing (e.g., sweaters) will be comfortable The range of relative humidity given is based on ASHRAE 62 and is narrower than that currently specified in ASHRAE 55. The comfort zones assume sedentary work; operators performing 'light work' (e.g., actively monitoring spatially distributed equipment, or retrieving procedures or manuals) will be comfortable at lower temperatures. Air movement rates less than 50 ft/min are also assumed.

Discussion: Subsequent to the 1992 revision, ASHRAE Standard 55 was amended so that the upper humidity limits for the winter and summer comfort zones are defined (respectively) by 64° F and 68° F wet bulb temperatures. The rationale for the change was that the Standard addresses the acceptability of temperature/humidity conditions (not health issues), that the lower humidity limits were too restrictive for some types of HVAC systems, and that there was no empirical evidence to indicate that relative humidity levels greater than 60% would necessarily be judged unacceptable. Using the limits defined by the wet bulb temperatures has the effect of allowing relative humidity of roughly 80% at the low end of both the winter and summer temperature ranges. At the upper end of both ranges, the recommended relative humidity remains roughly 60%. While there is evidence that the higher humidity levels allowed in the amended Standard are judged acceptable with respect to comfort, the ASHRAE indoor air quality standard (ASHRAE 62-1989) recommends a relative humidity limit of 60% in order to minimize the potential for microbial growth. [0700,5680]

7.3.1-2 Temperature Differential
Air temperature at floor level and at head level should not differ by more than 10 degrees (F). [0700]

7 WORKPLACE DESIGN
7.3 Environment
7.3.2 Ventilation

7.3.2-1 Air Quantity
The ventilation system should be capable of introducing outdoor air into the control room at a rate of at least 20 cubic feet per minute per occupant. [0700,NewNote]

7.3.2-2 Air Velocity
Air velocities in the primary operating area should not exceed 45 feet per minute measured at operator head level and should not produce a noticeable draft. [0700]

7 WORKPLACE DESIGN
7.3 Environment
7.3.3 Illumination

7.3.3-1 Levels
The illumination levels should conform with those listed in Table 7.2.
ADDITIONAL INFORMATION: The values in the table are based on conservative assumptions about the reflectance of the task background, the age of the operator, and the criticality of the task being performed. Lower illuminances may be justified for more favorable visual conditions or where the need to perform critical tasks can be ruled out. [0700,5680]

7.3.3-2 Uniformity
The level of illumination should not vary greatly over a given work station. [0700]

7.3.3-3 Supplemental Light
Supplemental lighting should be provided for personnel performing specialized visual tasks in areas where fixed illumination is not adequate. [0700]

7.3.3-4 Task Area Luminance Ratios
To ensure effective visual performance, the task area luminance ratios in Table 7.3 should not be exceeded.
ADDITIONAL INFORMATION: To determine task lighting requirements, it is necessary to consider the levels of lighting which surround a task. Great disparities between task and background lighting can lead to adaptation problems. [0700]

7.3.3-5 Shadowing
To reduce operator fatigue and eyestrain, shadows should be avoided.
ADDITIONAL INFORMATION: Ambient illumination should be provided via indirect or diffuse lighting. Labels, instructions, and other written information should not be in shadowed positions. [0700]

7.3.3-6 Glare
Glare should not interfere with the readability of displays, labels, or indicators.
ADDITIONAL INFORMATION: Glare increases the probability that an individual will misread a display or will fail to notice displayed information. Glare can also produce discomfort. Direct sources of glare include light emitted from luminaires, indicators, and displays. Indirect sources of glare include reflected light from all surfaces, e.g., paint, metal, and glass. The surface of a VDU screen should reduce specular glare. Positioning of VDUs relative to light source affects glare as can use of a shield or filter on the VDU or light source. If glare reduction or contrast enhancement techniques are used, they should not violate the requirements of luminance, contrast, and resolution as stated in this document. [0700,5908]

7.3.3-7 Reflectance
Reflectance should conform to the recommendations shown in Table 7.4.
ADDITIONAL INFORMATION: See also Table 7.5. The amount of reflected light is affected by illuminated surface colors. Surfaces adjacent to a VDU should have a dull matte finish to reduce glare. The luminance range of surfaces immediately adjacent to VDUs should be between 10 percent and 100 percent of screen background luminance. [0700,5908]

7.3.3-8 Color
Surface colors should be recognizable under both normal and emergency lighting conditions.
ADDITIONAL INFORMATION: Some types of lamps (e.g., mercury or sodium lamps) have very poor color rendering properties. Such lamps should not be used for normal or emergency lighting if operators' ability to distinguish among colors may be important. [0700,5680]

Table 7.2 Illumination levels

Work Area or Type of Task	Task Illuminance, footcandles
Panels, primary operating area	50
Auxiliary panels	50
Scale indicator reading	50
Seated operator stations	100
Reading:	
- handwritten (pencil)	100
- printed or typed	50
- VDU	10
Writing and data recording	100
Maintenance and wiring areas	50
Emergency operating lighting	20

(Source: adapted from NUREG/CR-5680, Tables 6.2 and 6.3)

Table 7.3 Maximum task area luminance ratios

Areas	Luminance Ratio
Task area versus adjacent darker surroundings	3:1
Task area versus adjacent lighter surroundings	1:3
Task area versus more remote darker surfaces	10:1
Task area versus more remote lighter surfaces	1:10
Luminaires versus surfaces adjacent to them	20:1
Anywhere within normal field of view	40:1

Table 7.4 Recommended workplace reflectance levels

	Reflectances	
Surface	**Preferred**	**Permissible**
Ceiling[a]	80%	60-95%
Upper Wall	50%	40-60%
Lower Wall	15-20%	
Instruments/Displays	80-100%	
Cabinets/Consoles	20-40%	
Floor	30%	15-30%
Furniture	35%	25-45%

[a] Recommended reflectances are for finish only. Overall average reflectance of acoustic materials may be somewhat lower. The upper walls (one to two feet below the ceiling) may be painted with the same paint as is used on the ceiling.

Table 7.5 Surface color reflectance values

Color	Reflectance
White	85
Light:	
Cream	75
Gray	75
Yellow	75
Buff	70
Green	65
Blue	55
Medium:	
Yellow	65
Buff	63
Gray	55
Green	52
Blue	35
Dark:	
Gray	30
Red	13
Brown	10
Blue	8
Green	7
Wood Finish:	
Maple	42
Satinwood	34
English Oak	17
Walnut	16
Mahogany	12

7 WORKPLACE DESIGN
7.3 Environment
7.3.3 Illumination

7.3.3-9 Ambient Illumination and VDUs

The ambient illumination in the VDU area that is necessary for other visual functions (e.g., setting controls, reading instruments) should not degrade the visibility of signals on the VDU.
ADDITIONAL INFORMATION: Illumination of 20-50 footcandles in the work area is normally sufficient (ANSI/ HFS 100-1988); VDUs are expected to meet the requirements given in Section 1.5.1 under these conditions. Illumination should not exceed 75 footcandles in spaces with VDUs (IES Lighting Handbook, 1984 Application Volume). [5908,Note]

7.3.3-10 Use of Colored Ambient Illumination

Colored ambient illumination should not be used if color coding is used in the workplace.
ADDITIONAL INFORMATION: Colored lighting will interfere with color-coded VDU displays and other color coding. Some types of lamps (e.g., mercury or sodium lamps) have very poor color rendering properties. Such lamps should not be used for normal or emergency lighting if operators' ability to distinguish among colors may be important. [5908]

7.3.3-11 Illuminance of Areas Immediately Surrounding VDUs

There should be no light source (direct or reflected) in the immediate surrounding area of the VDU that is of greater luminance than the VDU. [5908]

7 WORKPLACE DESIGN
7.3 Environment
7.3.4 Emergency Lighting

7.3.4-1 Automatic Action
A control room emergency lighting system should be automatically activated and immediately available upon failure of the normal control room lighting system.
ADDITIONAL INFORMATION: This system should be independent of any other plant lighting system that is available in the control room. [0700]

7.3.4-2 Operability
Failure of the normal control room lighting system should not degrade operability of the emergency lighting system. [0700]

7.3.4-3 Lighting Levels
The control room emergency illumination system should be designed to provide a minimum illumination level of 20 footcandles at all work stations in the primary operating area. [0700, IES]

7 WORKPLACE DESIGN
7.3 Environment
7.3.5 Auditory Environment

7.3.5-1 General
The acoustic design of the control room should ensure that verbal communications between operators are not impaired; auditory signals are readily detected; and auditory distraction, irritation, and fatigue of operators are minimized. [0700]

7.3.5-2 Background Noise
Background noise should not impair verbal communication between any two points in the primary operating area.

ADDITIONAL INFORMATION: Verbal communications should be intelligible using normal or slightly raised voice levels. Figure 7.10 shows the voice levels needed for spoken communication over specified distances in the presence of different levels of background noise. Noise interference may be lessened if operators are facing each other (i.e., can use lip reading) and if communication consists of short, standardized phrases. Intelligibility of speech in noise is also affected by the frequency spectra of the noise and of the speakers' voices and by the speakers' hearing sensitivity.

Discussion: The level of the noise is given in Figure 7.10 in dB(A) rather than speech interference level (SIL). The SIL used in the research on which the speech interference functions were based represents an average of the noise power in the bands around 500, 1000, 2000, and 4000Hz - frequencies which are important to speech comprehension. The translation to dB(A) is valid only if the masking noise has a uniform spectrum in the frequency region of 500-4000Hz. Masking of speech by noise with sharp spectral peaks (i.e., tonal components) can not be predicted from the curves based on the overall dB(A) level of the noise. Thus the extent to which various alarm sounds might interfere with spoken communication can not necessarily be predicted based in the overall noise level in dB(A). [0700,5680]

7.3.5-3 Background Noise Level
Background noise levels should not exceed 65 dB(A).

ADDITIONAL INFORMATION: Operators eight feet apart will have to speak loudly to be heard in the presence on a 65 dB(A) background noise. Therefore, if workstations, display panels, or control interfaces are widely separated in the control room, the background noise limit should be reduced. [0700,5680]

7.3.5-4 Further Reductions
Where communications between the primary operating area and other control room locations are necessary, and voice transmission systems are not provided, further reductions in background noise should be implemented. [0700]

7.3.5-5 Noise Distractions
Noise distractions (especially extraneous speech) generated either inside or outside the control room should be minimized.

ADDITIONAL INFORMATION: Noise that is unfamiliar (such as bursts of sound or unwanted speech) will cause distraction and possible performance decrements at lower levels than continuous, familiar sound. Extraneous speech, even at low levels, will disrupt reading. [0700,5680]

7.3.5-6 Reverberation Time and Sound Absorption
The acoustical treatment of the control room should limit reverberation time to 1 second or less. [0700,5908]

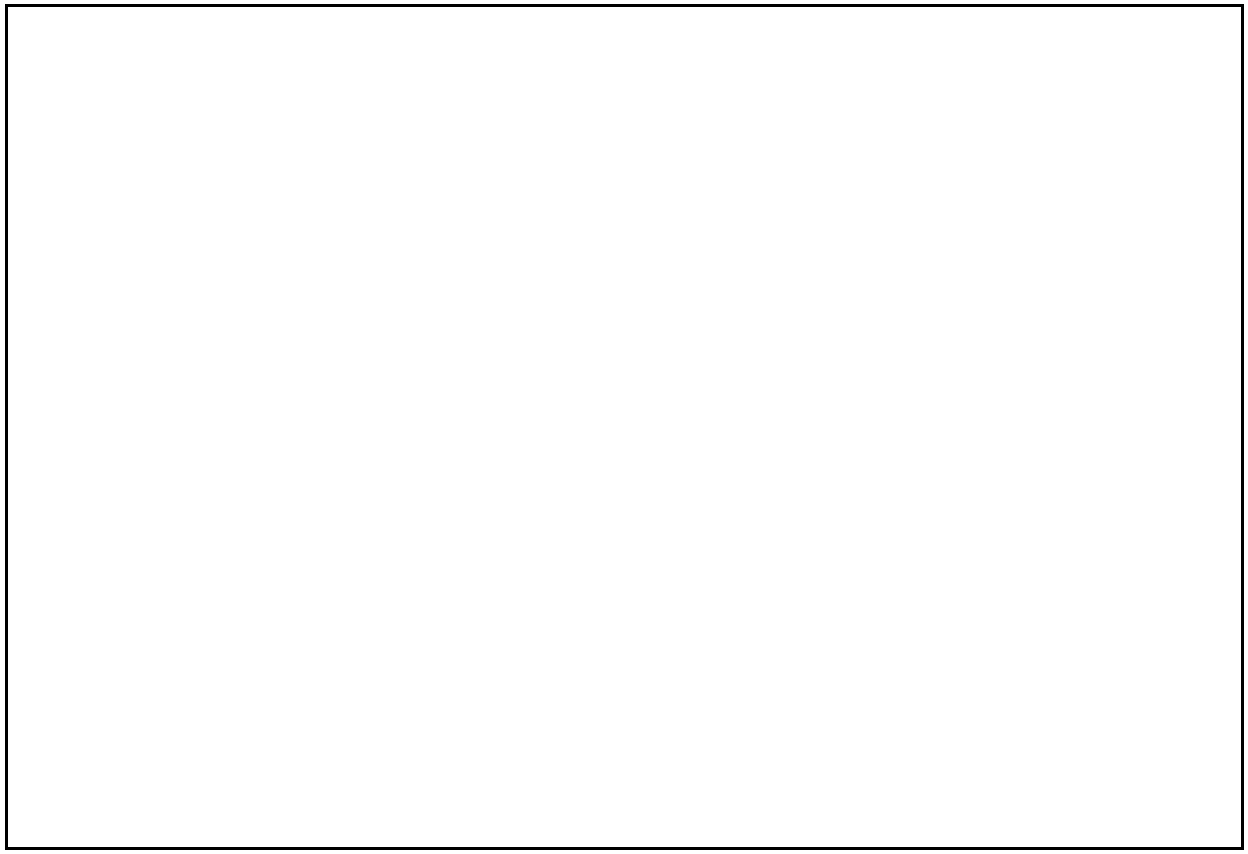

Figure 7.10 Voice level as a function of distance between speaker and listener and ambient noise level

7 WORKPLACE DESIGN
7.3 Environment
7.3.6 Personal Storage

7.3.6-1 Storage Locations
There should be a suitable, out-of-the-way, but secure place in which control room personnel may keep their coats and other personal belongings. [0700]

7.3.6-2 Storage Suitability
If lockers are provided, they should be large enough to hold the items that might reasonably be expected to require storage. [0700]

7 WORKPLACE DESIGN
7.3 Environment
7.3.7 Ambience and Comfort

7.3.7-1 Decor

Decor should create a pleasant working environment for control room operators.

ADDITIONAL INFORMATION: Features to be considered include: (1) Color coordination, (2) Use of color and lighting to create a cheerful atmosphere (without introducing glare and brightness to a degree that causes eye fatigue or an overly intense atmosphere), (3) Visual relief from arrays of instrumentation, (4) Comfortable seating, and (5) Carpeting to lessen the fatigue of standing and walking. [0700]

7.3.7-2 Restroom and Eating Facilities

A restroom and kitchen or eating area should be provided within (preferably) or near the control room isolation boundary.

ADDITIONAL INFORMATION: Since formal breaks are not scheduled in most control rooms, it is important that personnel have access to these facilities without delay. It is preferable that they be used only by control room personnel. Provision should be made for communication if facilities are out of voice contact, so that an operator taking a break can be contacted as necessary by personnel in the control room (see Guideline 6.2.6-2). [0700]

7.3.7-3 Rest Area/Lounge

Consideration should be given to providing a rest area (possibly in conjunction with the eating area) conducive to relaxation and revitalization, especially where shifts are long. [0700]

7 WORKPLACE DESIGN
7.3 Environment
7.3.7 Ambience and Comfort

Appendix B - Revision of Section 8.5, NUREG-0700, Rev.1

8 LOCAL CONTROL STATIONS
8.5 Environment
8.5.1 Temperature
8.5.1.1 Heat

8.5.1.1-1 Heat Stress
The level of physical activity and required protective clothing, as well as temperature and humidity, should be considered when assessing the danger of heat exposure posed to operators.
ADDITIONAL INFORMATION: Important considerations are the amount of metabolic heat being generated by the operator and the restriction of evaporative heat loss associated with protective clothing. [6146]

8.5.1.1-2 Engineering Controls
Engineering controls should be applied where heat may impair the effectiveness or threaten the well-being of operators.
ADDITIONAL INFORMATION: Examples of engineering controls include: shielding or insulating sources of radiant heat, eliminating steam leaks, increasing ventilation, and providing assists to reduce the strenuousness of the task. Temperature ranges intended to minimize performance decrements and potential harm to workers as a result of excessive heat are given in Table 8.2. The temperature ranges in the table are ceiling values; i.e., they assume that protective practices (such as acclimatization, training, and a cool place to rest) are in place. [6146]

8.5.1.1-3 Work Practices
Work practices should be adopted to minimize risk due to heat exposure which cannot be eliminated by engineering controls.
ADDITIONAL INFORMATION: Recommended work practices include training in the recognition and treatment of heat illnesses, water and salt replacement, acclimation, and work/rest cycles (stay times). Stay times intended to minimize performance decrements and potential harm to workers are given in Table 8.3. The stay times recommended in the table are ceiling values; i.e., they assume that protective practices (such as acclimatization, training, and a cool place to rest) are in place. [6146]

8.5.1.1-4 Water Replacement
Water should be readily available in areas where the potential for heat stress exists.
ADDITIONAL INFORMATION: Unusual measures may be necessary to provide drink to workers in restricted areas. [6146]

Table 8.2 Ranges of wet bulb globe temperature in degrees Centigrade and (Fahrenheit) for different ranges of stay times[1] by combinations of clothing and metabolism

Stay Time	Work Clothes			Cotton Coveralls			Double Cottons			Cottons plus Plastics		
	Metabolism			Metabolism			Metabolism			Metabolism		
	Low	Mod	High	Low	Mod	High	Low	Mod	High	Low	Mod	High
0-15	50-52 (122-126)	42-50 (108-122)	38-42 (100-108)	48-50 (118-122)	41-49 (106-120)	37-41 (99-106)	46-48 (115-118)	38-46 (100-115)	34-38 (93-100)	44-46 (111-115)	36-44 (97-111)	32-36 (90-97)
15-30	44-50 (111-122)	36-42 (97-108)	32-38 (90-100)	42-48 (108-118)	35-41 (95-106)	31-37 (89-99)	40-46 (104-115)	32-38 (90-100)	28-34 (82-93)	38-44 (100-111)	30-36 (86-97)	26-32 (79-90)
20-45	42-48 (108-118)	34-38 (93-100)	31-34 (89-93)	40-46 (104-115)	33-37 (91-99)	30-33 (86-91)	38-44 (100-111)	30-34 (86-93)	27-30 (81-86)	36-42 (97-108)	28-32 (82-90)	25-28 (77-82)
30-60	40-44 (104-111)	33-36 (91-97)	30-32 (86-90)	38-42 (100-108)	32-35 (90-95)	29-31 (84-89)	36-40 (97-104)	29-32 (84-90)	26-28 (79-82)	34-38 (93-100)	27-30 (81-86)	24-26 (75-79)
45-90	38-42 (100-108)	32-34 (90-93)	29-31 (84-89)	36-40 (97-104)	31-33 (89-91)	28-30 (82-86)	34-38 (93-100)	28-30 (82-86)	25-27 (77-81)	32-36 (90-97)	26-28 (79-82)	23-25 (73-77)
60-120	36-40 (97-104)	30-33 (86-91)	28-30 (82-86)	34-38 (93-100)	29-32 (84-90)	27-29 (81-84)	32-36 (90-97)	26-29 (79-84)	24-26 (75-79)	30-34 (86-93)	24-27 (75-81)	22-24 (72-75)
90-3h	34-38 (93-100)	29-32 (84-90)	27-31 (81-89)	32-36 (90-97)	28-31 (82-89)	26-30 (79-86)	30--34 (86-93)	25-28 (77-82)	23-27 (73-81)	28-32 (82-90)	23-26 (73-79)	21-25 (70-77)
2h-4h	32-36 (90-97)	28-30 (82-86)	26-28 (79-82)	30-34 (86-93)	27-29 (81-84)	25-27 (77-81)	28-32 (82-90)	24-26 (75-79)	22-24 (72-75)	26-30 (79-86)	22-24 (72-75)	20-22 (68-72)

[1] Time is in minutes unless specified in hours by "h"

Table 8.3 Stay times[1] for different wet bulb globe temperatures in degrees Centigrade and (Fahrenheit) by combinations of clothing and metabolism

Wet-Bulb Globe Temp		Work Clothes			Cotton Coveralls			Double Cottons			Cottons plus Plastics		
		Metabolism			Metabolism			Metabolism			Metabolism		
°C	(°F)	Low	Mod	High	Low	Mod	High	Low	Mod	High	Low	Mod	High
50	(122)	15-30	0-10		5-15	0-5		5-15					
48	(118)	20-45	5-15		15-30	5-10		10-20			5-15		
46	(115)	20-45	5-20		20-45	5-15		15-30	0-10		15-20		
44	(111)	30-60	10-25		20-45	5-20		20-45	5-15		15-30	0-10	
42	(108)	45-90	15-30	5-10	30-60	10-25		20-45	5-20		20-45	5-15	
40	(104)	60-90	15-45	10-20	45-90	15-40	5-10	30-60	10-25		20-45	5-20	
38	(100)	90-120	20-45	15-30	60-90	15-45	10-25	45-90	15-30	5-10	30-60	10-25	
36	(97)	2h-4h	30-60	15-40	90-120	25-45	15-30	60-90	15-45	10-20	45-90	15-30	5-10
34	(93)	3h-8h	45-90	20-45	2h-4h	30-60	15-45	90-120	20-45	15-30	60-90	15-45	10-20
32	(90)	NL	90-120	30-60	3h-8h	60-100	25-50	2h-4h	30-60	15-40	90-120	20-45	15-30
30	(86)	NL	2h-4h	60-120	NL	1h-2h	30-90	3h-8h	45-90	20-45	2h-4h	30-60	15-40
28	(82)	NL	NL	2h-4h	NL	1h-4h	lh-3h	NL	90-120	30-60	3h-8h	45-90	20-45
26	(79)	NL	NL	4h-8h	NL	NL	3h-8h	NL	2h-4h	60-120	NL	90-120	30-60
24	(75)	NL	NL	NL	NL	NL	NL	NL	NL	2h-4h	NL	2h-4h	60-120
22	(72)	NL	NL	NL	NL	NL	NL	NL	NL	4h-8h	NL	NL	2h-4h
20	(68)	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	4h-8h
<20	(<68)	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL	NL

[1] Time is in minutes unless specified in hours by "h"

Note: NL = no limit

8 LOCAL CONTROL STATIONS
8.5 Environment
8.5.1 Temperature
8.5.1.2 Cold

8.5.1.2-1 Outdoor Equipment
Equipment located outdoors should be sheltered from the elements as much as possible. [6146]

8.5.1.2-2 Wind Chill
When considering the effects of cold on performance, the effect of air velocity should be taken into account.

ADDITIONAL INFORMATION: [Table 5.1 in NUREG/CR-5680, Vol.1] illustrates the wind chill effect; effective temperatures are shown for different combinations of air temperature and wind speed. [5680]

8.5.1.2-3 Effects of Cold on Performance
The potential for exposure to cold to affect task performance should be evaluated.

ADDITIONAL INFORMATION: [Table 5.2 in NUREG/CR-5680, Vol.1] shows, for various tasks, the no-effect levels for the various impacts of cold on performance (i.e., temperatures below which performance decrements may occur). [5680]

8.5.1.2-4 Engineering Controls
Engineering controls should be applied where cold may impair the effectiveness or threaten the well-being of operators.

ADDITIONAL INFORMATION: Engineering controls increase the amount of heat received by the worker or insulate the worker from the cold; examples include providing space heaters or wind breaks, and insulating tool handles or valve handwheels. In addition, equipment handles and latches and panel switches and pushbuttons should be operable with gloved hands if located in areas where operators may be exposed to cold. [5680]

8.5.1.2-5 Work Practices
Work practices should be adopted to minimize risk due to cold exposure which cannot be eliminated by engineering controls.

ADDITIONAL INFORMATION: Examples of administrative controls include scheduling outdoor maintenance for warmer seasons or times of day, assigning more worker to a job to reduce the duration of the exposure to cold, and allowing workers to take a break in warm areas when needed. [5680]

8.5.1.2-6 Protective Clothing
Insulated clothing, hats and gloves should be provided to operators who must work in the cold.

ADDITIONAL INFORMATION: The need to remove gloves to perform certain tasks should be taken into account, and engineering and administrative controls should be applied accordingly. [5680]

Table 8.x Wind Chill

Wind Speed	Actual Air Temperature (°F)									
(mph)	**50**	**40**	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**
Calm	50	40	30	20	10	0	-10	-20	-30	-40
5	48	36	27	17	-5	-5	-15	-25	-35	-46
10	40	29	18	5	-8	-20	-30	43	-55	-68
15	35	23	10	-5	-18	-29	-42	-55	-70	-83
20	32	18	4	-10	-23	-34	-50	-64	-79	-94
25	30	15	-1	-15	-28	-38	-55	-72	-88	-105
30	28	13	-5	-18	-33	-44	-60	-76	-92	-109
35	27	11	-6	-20	-35	-48	-65	-80	-96	-113
40	26	10	-7	-21	-37	-52	-68	-83	-100	-117
45	25	9	-8	-22	-39	-54	-70	-86	-103	-120
50	25	8	-9	-23	-40	-55	-72	-88	-105	-123

Table 8.x Temperatures above which no cold effects occur

	Air Temperature	Hand Skin Temperature
General Discomfort	69 °F	75 °F
Effects of Cold on the Hands		
Skin Sensitivity		75 °F
Numbness	54 °F	68 °F
Pain		61 °F
Finger Discrimination		37 °F
Grip Strength	14 °F	
Task Performance		
Fine Manual Tasks	64 °F	55 °F
Tracking	55 °F	
Gross Manual Tasks	54 °F	59 °F

8 LOCAL CONTROL STATIONS
8.5 Environment
8.5.2 Noise

8.5.2-1 Quieting the Work Process
Steps should be taken to reduce noise at its source.
ADDITIONAL INFORMATION: The preferred approach for mitigating the effects of noise is to reduce the vibration that is causing the noise by isolating or dampening the vibration with machine mountings. The speed of the operating machinery can be altered, thereby changing the frequency of the noise. The resonance of the vibrating objects can be reduced. [5680]

8.5.2-2 Limiting Noise Transmission
Steps should be taken to limit the transmission of noise.
ADDITIONAL INFORMATION: Noise can be reduced by increasing the distance of the noise source from the worker. This technique is less effective for low frequencies. Sound-attenuating barriers or enclosures should be used when operators are required to work near equipment which, despite quieting measures, produces high levels of noise. Sound-absorbing materials can absorb 70% of the noise that strikes them. These materials are effective for both low and high frequencies. [5680]

8.5.2-3 Limiting Noise Exposure
Steps should be taken to protect operators from noise.
ADDITIONAL INFORMATION: Administrative controls should limit the amount of time that operators spend in noisy locations. [5680]

8.5.2-4 Hearing Protection
Ear protection devices should be available and required to be worn in areas where noise levels are 85 dB or more.
ADDITIONAL INFORMATION: Hearing protection is not a substitute for engineering and/or administrative measures aimed at controlling noise levels. Personal protective equipment should be used when controls are not feasible or not sufficiently effective. An increased likelihood of error owing to annoyance or disruption of communication may occur at levels below those cited in the Guideline. Special efforts should be made to further reduce in areas in which operators perform activities requiring a high degree of coordination, verbal communication, or teamwork; see Figure 7.10 to estimate the effect of noise on verbal communication. If reductions in noise level are not feasible, tasks should be redesigned to reduce the reliance on verbal communication; alternatively, tasks may be scheduled for periods when noisy equipment is not in service. [6146, 5680]

8.5.2-5 Auditory Capabilities of Users
The hearing sensitivity of the work force should be monitored.
ADDITIONAL INFORMATION: The needs of those workers with hearing degradation should be taken into account. [6146]

8.5.2-6 Communications and Hearing Protection
Communication equipment in high noise areas should be compatible with ear protection devices. [6146]

8 LOCAL CONTROL STATIONS
8.5 Environment
8.5.3 Lighting

8.5.3-1 Levels
The illumination levels should conform with those listed in Table 8.6.
ADDITIONAL INFORMATION: The values in the table are based on conservative assumptions about the reflectance of the task background, the age of the operator, and the criticality of the task being performed. Lower illuminances may be justified for more favorable visual conditions or where the need to perform critical tasks can be ruled out. The procedure recommended by the Illuminating Engineering Society for establishing minimum acceptable illuminance levels are described in NUREG/CR-5680. [0700, 5680]

8.5.3-2 Portable Lighting
Easily used, portable lighting devices should be readily available nearby when permanent lighting (normal or emergency) may be inadequate. [6146]

Table 8.x - Range of recommended illuminances for inspection/assembly activities and for in-plant areas in a nuclear power plant.

Area/activity	Footcandles
Inspection/assembly	
Simple	50
Difficult	200
Rough Bench or Machine Work	50
In-plant areas	
Turbine Building	50
Auxiliary Building	20
Laboratory	100
Storage Room	20
ESF Equipment	50
Diesel Generator Building	50
Fuel Handling Building	50
Reactor Building	50
Stairways and Corridors	10

8 LOCAL CONTROL STATIONS
8.5 Environment
8.5.4 Accessibility

8.5.4-1 Permanent Means of Access
Permanent means of access to equipment requiring recurrent or emergency operation should be provided when it is beyond the normal standing reach of operators.
ADDITIONAL INFORMATION: Examples of access provisions include work platforms and ladders. [6146]

8.5.4-2 Temporary Means of Access
Temporary or movable access platforms to equipment should be available when the equipment is located beyond the normal standing reach of operators and permanent access provision is not feasible. [6146]

8.5.4-3 Formal Means of Access
Catwalks, ladders, and other formal means should be provided for operators to reach equipment.
ADDITIONAL INFORMATION: Operators should not be required to walk along pipes or to use components as "stepping stones" in order to reach equipment. [6146]

8.5.4-4 Sufficient Clearance
Sufficient clearance should be provided in the vicinity of equipment in contaminated or high temperature areas to allow operators easy access despite the use of protective garments and associated gear. [6146]

8.5.4-5 Impediments to Access
Access to equipment to be operated should not be impeded by structural elements.
ADDITIONAL INFORMATION: Structural elements added to the plant (e.g., seismic reinforcements) should not restrict access to equipment. [6146]

8 LOCAL CONTROL STATIONS
8.5 Environment
8.5.5 Vibration

8.5.5-1 Levels
The effects of vibration on visual and manual performance should be evaluated using [Figure 3.12 in NUREG/CR-5680, Vol.2].

ADDITIONAL INFORMATION: When vibration levels exceed those in the unshaded areas of [Figure 3.12 in NUREG/CR-5680, Vol.2], a study should be performed to demonstrate that human performance is within acceptable limits. 5680

8.5.5-2 Reducing Vibration
Steps should be taken to reduce vibration at its source.

ADDITIONAL INFORMATION: The preferred approach for reducing the vibration is to isolate or dampen the vibration with machine mountings. 5680

8.5.5-3 Limiting Transmission of Vibration
Steps should be taken to limit the transmission of vibrations to operators.

ADDITIONAL INFORMATION: Operators can be isolated from vibration in shock-mounted, energy-absorbing platforms. 5680

8.5.5-4 Reducing the Effects of Vibration
Operator interfaces should be designed to reduce the disruptive effects of vibration.

ADDITIONAL INFORMATION: Modifications that minimize the effects of vibration on task performance include installing larger dials which can be read despite vibration or providing a means for operators' to stabilize their limbs. 5680

8.5.5-5 Limiting Exposure to Vibration
Steps should be taken to protect operators from excessive vibration.

ADDITIONAL INFORMATION: Administrative controls should limit the amount of time that operators are exposed to high levels of vibration. These controls would primarily address effects on comfort and worker safety. 5680

Figure 8.x. Acceleration and frequency combinations and the accuracy of number reading and manual tracking. In the top graph, the shaded area represents conditions that will cause an error of 5% or more in number reading. In the bottom graph, the shaded area represents conditions that will cause a tracking error of 10% or more.