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ARCHITECTURAL/ENVIRONMENTAL HANDBOOK FOR EXTRATERRESTRIAL DESIGN

Martin Marietta Corporation
Denver, CO

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ARCHITECTURAL/ENVIRONMENTAL HANDBOOK FOR EXTRATERRESTRIAL DESIGN

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FOREWORD

This document was prepared by the Martin Marietta Corporation under Contract NAS9-10761, DRL Line Item 8, "Architectural/Environmental Handbook for Extraterrestrial Design", for the Manned Spacecraft Center of the National Aeronautics and Space Administration. The work was administered under the technical direction of the Spacecraft Design Office with Mr. Clarence D. Council as the Technical Manager.

NOTICE

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ABSTRACT

This handbook defines the environmental and space utilization criteria for extraterrestrial design of spacecraft and the effect of related environmental elements for providing an optimum habitat for man in space. Standards were developed for the specific environmental elements of Lighting, Acoustics, Temperature, Color, and Volume. The related environmental elements, Texture and Design, Hygiene and Mess Provisions, Dual Room Usage, Gravity, and Interrelated Environments, were analyzed and their effect on the habitability for extraterrestrial habitats and vehicles. This effort was accomplished under DRL Line Item 8 of Contract NAS9-10761.

TABLE OF CONTENTS

	Page
Foreword	ii
Abstract	iii
Table of Contents	iv
I. INTRODUCTION	1-1
II. GENERAL DESIGN CRITERIA	2-1
A. Lighting	2-3
B. Acoustics	2-31
C. Temperature	2-73
D. Color	2-93
E. Volume	2-107
F. Texture and Design	2-127
G. Hygiene and Mess Provisions	2-133
H. Dual Room Usage	2-153
I. Gravity	2-163
J. Interrelated Environments	2-187
III. CREW AREA CRITERIA	3-1
2.1 Crew Compartments, Bedroom	3-3
3.1 Dining Room	3-7
3.2 Lounge	3-9
3.3 Recreation	3-11
3.4 Library	3-13
3.5 Study	3-15
3.6 Conference	3-17
3.7 Passageway	3-19
3.8 Chapel	3-21
3.9 Gym	3-23
3.10 Locker Room	3-25
3.11 Theatre	3-27
3.12 Briefing Room	3-29
4.1 Galley	3-31
4.2 Snack Bar	3-33
4.3 Bathroom	3-35
4.4 Dispensary	3-37
4.5 Laundry	3-39
4.6 Barber Shop	3-41

Page

5.1 Equipment 3-43
5.2 Maintenance 3-45
5.3 Power 3-47
5.4 Storage, Food 3-49
5.5 Supply 3-51
5.6 Control Room 3-53
5.7 Communications 3-55
5.8 Computer 3-57
5.9 Shop 3-59
5.10 Offices 3-61
5.11 Laboratories 3-63
5.12 Docking 3-65
5.13 Photographic Support 3-67
5.14 Animal Housing 3-69
5.15 Agricultural Study Area 3-71
5.16 Air Locks 3-73

IV. UTILIZATION OF HANDBOOK 4-1

FIGURES

II-B-1 Decibel Scale of Sound Intensities 2-34
II-B-2 Absolute Thresholds for Reception of Signals 2-40
II-B-3 Spectrum Level of Instantaneous and RMS Pressure of Speech 2-41
II-B-4 Masking of a Signal by Pure Tones 2-45
II-B-5 Masking of a Signal by Narrow-Band Noise 2-46
II-B-6 Masking of a Signal by Wide-Band Noise 2-46
II-B-7 Critical Masking Bandwidth as a Function of Frequency 2-47
II-B-8 Masking in the Critical Band 2-48
II-B-9 Speech Interference Levels 2-49
II-B-10 Intelligibility as a Function of the Articulation Index 2-51
II-B-11 Articulation Index Computation Chart (Octave-Band Method) 2-52
II-B-12 Contribution to the Articulation Index 2-53
II-B-13 Damage Risk Contours for One Exposure Per Day to Certain Octave and One-Third Octave or Narrower Bands of Noise 2-55

FIGURES (cont.)

		Page
II-B-14	Damage Risk Contours for One Exposure Per Day to Octave and One-Third Octave or Narrower Bands of Noise	2-56
II-B-15	Damage Risk Contours for One Exposure Per Day to Pure Tones	2-57
II-B-16	Damage Risk Contours for One Exposure Per Day to Octave and One-Third Octave or Narrower Bands of Noise	2-57
II-B-17	Damage Risk Contours for One Exposure Per Day to Pure Tones	2-58
II-C-1	Thermal Requirements for Tolerance and Comfort in Crew Compartments	2-81
II-C-2	Approximate Human Time-Tolerance Temperature with Optimum Clothing	2-82
II-C-3	Clothing Requirements for Various Temperatures	2-82
II-C-4	Human Body Temperature Extremes Defining Zones of Temperature Regulations	2-86
II-C-5	Air Velocity Effects on Human Comfort Zones	2-89
II-E-1	Point Restraint Area Requirement	2-113
II-E-2	Passageway Area Requirement	2-114
II-E-3	Zero Gravity Open Area Transfer	2-115
II-E-4	Overall Station Volumetric Requirements as a Function of Crew Size and Mission Duration	2-120
II-G-1	Distance in Feet From Hygienic Facilities as Function of Time	2-142
II-G-2	Distance in Levels to Hygienic Facilities as Function of Time	2-142
II-G-3	Water Closet Use Ratio Chart #1	2-143
II-G-4	Water Closet Use Ratio Chart #2	2-144
II-G-5	Water Closet Use Ratio Chart #3	2-145
II-G-6	Lavatory Use Ratio Chart #1	2-146
II-G-7	Lavatory Use Ratio Chart #2	2-147
II-G-8	Lavatory Use Ratio Chart #3	2-148
II-G-9	Shower Use Ratio Chart #1	2-149
II-G-10	Seating Use Ratio Chart #1	2-150
II-H-1	Compatibility Rating As A Function of Crew Size and Mission Duration.	2-158
II-I-1	Forces in Artificial Gravity	2-176
II-I-2	Artificial Gravity Design Envelope	2-178
II-I-3	Artificial Gravity Design Envelope	2-179
II-I-4	Artificial Gravity Design Envelope	2-180
II-I-5	Artificial Gravity Design Envelope	2-181
II-I-6	Composite Artificial Gravity Design Envelope	2-182

FIGURES (cont.) Page

II-J-1	The Brightness Judged to be at the Borderline Between Comfort and Discomfort, as Selected by Each of a Group of Observers	2-188
II-J-2	Kruithof's Principle	2-199
II-J-3	Minimum Odor-Free Requirements to Remove Objectionable Body Odors	2-200
IV-A-1	Compatibility Rating as a Function of Crew Size and Mission Duration	4-2
IV-A-2	Example Mission Worksheet	4-4

TABLES

I-1	Frequency of Usage by Mission Model	1-4
I-2	Crew Areas by Mission Model	1-5
II-A-1	General Illumination Levels for Various Tasks	2-7
II-A-2	Maximum Brightness Ratios	2-7
II-A-3	Types of Surface Reflectances	2-9
II-A-4	Glare Reduction Methods	2-9
II-A-5	Illumination Methods	2-10
II-A-6	Lamp Sources	2-11
II-A-7	General Lamp Source Performance Characteristics	2-12
II-A-8	Lamp Source Evaluation	2-13
II-A-9	Lamp Source Evaluation Summary	2-17
II-A-10	Luminaire Types	2-18
II-A-11	Evaluation of Luminaire Systems	2-19
II-A-12	Light Loss Causes	2-20
II-A-13	Color Temperature Designations	2-21
II-A-14	Fluorescent Color Atmosphere Effects	2-21
II-A-15	Crew Area Lighting Requirements	2-23
II-A-16	Psychological Moods in Lighting	2-25
II-A-17	Psychological Architectural Emphasis	2-25
II-B-1	Octave Band Frequency Ranges	2-37
II-B-2	One Third Octave Bands	2-38
II-B-3	Standard Octave Band Frequencies	2-39
II-B-4	Characteristics of Various Alarms	2-43
II-B-5	Design Recommendations for Auditory Alarm and Warning Devices	2-44
II-B-6	Speech Communication Criteria	2-50
II-B-7	Octave-Band Spectrum of Speech	2-51
II-B-8	Intelligibility Criteria	2-54
II-B-9	Presbycusis in Men and Women	2-55

TABLES (cont.) Page

II-B-10	Presbycusis in Men and Women	2-58
II-B-11	Performance Effects	2-60
II-B-12	Non-Aural Effects	2-62
II-B-13	Discomfort to Ear	2-63
II-B-14	Ear Damage	2-63
II-B-15	Sound Absorption Coefficients	2-66
II-C-1	Components of the Biothermal Equation	2-78
II-C-2	Environmental Design Criteria	2-80
II-C-3	He-O_2 and N_2-O_2 Atmosphere for One-G	2-83
II-C-4	He-O_2 and N_2-O_2 Atmosphere for Zero-G	2-84
II-C-5	Metabolic Rate for Space Activities	2-87
II-C-6	Area Activities in Space Vehicle	2-88
II-D-1	Psychological Effects of Hue	2-99
II-D-2	Psychological Effects of Color Upon Habitable Areas	2-101
II-F-1	Types and Effects of Textures and Patterns	2-131
II-G-1	Occupancy Classification	2-134
II-G-2	Hygiene Requirements	2-137
II-G-3	Evaluation of Various Hygienic Facility Concepts	2-139
II-G-4	Hygiene Facilities Requirements	2-140
II-G-5	Evaluation of Various Mess Seating Concepts	2-141
II-I-1	Stimulation and Response of Sense Organs (and Their Manner of Operation) to Subgravity	2-167
II-I-2	Physiological Effects of Weightlessness	2-168
II-I-3	Effects of a Zero-Gravity Environment on Performance	2-169
II-I-4	Zero-Gravity Design Considerations	2-170
II-I-5	Major Effects of Artificial Gravity	2-171
II-I-6	Habitability Design Considerations for Artificial Gravity	2-173
II-J-1	Effects of Multiple Stresses	2-189
II-J-2	Color Effects on Perceptions of Time, Size, Weight and Volume	2-190
II-J-3	Brightness, Color Saturation, and Illumination Level Effects on Perception of Volume	2-191
II-J-4	Reflectance factors for Federal Color Standards	2-192
II-J-5	General Reflectance Factors of Paint, Paper, and Wood	2-193
II-J-6	Reflectance Range for Interior Surfaces	2-194
II-J-7	Color Effects of White Fluorescent Lamps	2-197
II-J-8	Color Effects of Mercury and Filament Lamps	2-198
II-J-9	Kelvin Color Temperatures of White Fluorescent Lamps	2-200

I INTRODUCTION

1.0 General

The data and concepts presented in this handbook have been selected and developed for the purpose of establishing desirable standards of habitability for extraterrestrial habitats and vehicles. The minimum values given are to be used only when power is critical and performance can be compromised or in emergency situations. It should also be noted that the designer could select all optimum environmental values for a specific area, but because of mission objectives or the crew's personal taste, the area is not the optimum habitat. Therefore, the criteria, as presented, are not intended to be construed as absolute requirements, but are to be used as a guideline in determining the best habitat for the designer's particular mission objective. Another consideration is that the designer should provide a variety in long term spacecraft by purposely changing environmental criteria and the decor.

So that the standards would have a broad range of application to extraterrestrial vehicles over the next twenty years, all standards of criteria are plotted for crews from 2 to 100 and for mission durations from 7 to 1040 days. The rationale for the criteria presented in this report is based upon a combination of terrestrial modules, standards, and the best known psychophysiological data on personnel confined in terrestrial environments. This data has been extrapolated to cover extraterrestrial environments of long duration. The establishment of these criteria was made with the consideration of personnel first, equipment second.

Since there is not an exact earth model that will simulate both the type of personnel and the long-duration closed environment experienced in extraterrestrial missions, it will be necessary to continually evaluate the standards recommended herein. For example, in the area of zero-gravity standards, it is essential that a great deal of data be gathered relative to spatial perception, visual orientation, modes of transportation for individual and groups, etc. As new data becomes available, the handbook can be updated in that specific area without affecting the rest of the handbook.

2.0 Format

The handbook is organized as simply as possible, using the section number and subsection alphabetical notation as the basic organizational element. The subsection alphabetical notation is organized in numbered paragraphs and subparagraphs for ease of reference and use. To facilitate cross-referencing between this handbook and the Rationale Handbook, identical sections and subsection headings are used in both books.

Illustrative material such as table, nomographs, drawings, and figures are presented as integral parts of the sections and subsections. They are identified by the number of the section, the alphabetical letter of the subsection, and the number they appear in the section or subsection by consecutive numbers. Tables and figures are each numbered separately to avoid confusion with references.

Reference material such as technical reports, journal articles, books, etc., are assigned alphanumeric identification in sequence for the section or subsection they first appear. The lest of references will be at the end of each subsection and will be referred to by identification only; e.g., "Ref. A.7..." or Extracted in part from Ref. G.3...", as appropriate.

3.0 Use of Handbook

The handbook is divided into four sections, to reflect the intended use of the handbook by the user.

3.1 Introduction, Section I

This section gives the purpose and the intended use of the handbook. In addition, the format is discussed and a summary of the type of data in each of the remaining three sections is presented.

3.2 General Design Criteria, Section II

The individuals desiring information as related to one specific criteria such as acoustics, would utilize Section II, General Design Criteria. In this section the data and concepts are presented by criteria. Those individuals

desiring information relative to the data sources rationale which served as a basis for the recommendations presented should refer to the rationale volume which is organized by paragraph numbers parallel to the handbook general design.

3.3 Crew Area Criteria, Section III

For designers requiring criteria relating to a specific activity center such as the dining area, Section III is so organized. This section has been organized in this manner to reduce redundancy in looking up the various criteria each time the design initiates would have questions on a new activity area or each time the mission parameters change.

3.4 Criteria Usage, Section IV

This section provides an example of how the criteria provided in Sections II and III can be applied to a specific mission model specification. As presented in the example, one should start with the optimum requirements with the flexibility to compromise as the governing restrictions become known.

The following two tables, Table I-1, "Frequency of Usage by Mission Model", and Table I-2, "Crew Areas by Mission Model", are included to provide a reference for crew time by area and mission model. These are not intended to be concrete requirements, but were to be used as a guide for determining the standards and concepts of this study.

Table I-1 Frequency of Usage by Mission Model

AREA	Hours per Day in Crew Areas					
	Logistics Spacecraft		Earth Orbital Space Station		Planetary Space Vehicle	
	Nom. Work-day	Off-Duty Day*	Nom. Work-day	Off-Duty Day	Nom. Work-day	Off-Duty Day
LIVING AREAS						
Lounge			1	4	1	4
Recreation			1	3	1	3
Passageways	N		N	N	N	N
Study or Library			.5	2	.5	2
Bedroom	8		9	9	9	9
Bathroom	1		1	1	1	1
Conference			N	0	N	0
FOOD PREPARATION AND SERVING						
Kitchen	2		1	1	1	1
Dining Room	2		2	2	2	2
Food Storage,	N		N	N	N	N
Snack Bar			N	N	N	N
SERVICES						
Laundry			0	1	0	1
Briefing Room	.5		.5	0	.5	0
Locker Room			N	N	N	N
Theater			0	N	0	N
Dispensary			N	N	N	N
Chapel			0	N	0	N
Barber			0	N	0	N
Supply			0	N	0	N
Maintenance			N	N	N	N
Equipment			N	N	N	N
Gym			0	1	0	1
Power			N	0	N	0
WORK AREAS						
Control Room	10		8	0	8	0
Airlocks	N		N	0	N	0
Inspection	N		N	0	N	0
Photographic Support			N	N	N	N
Animal Housing			N	0	N	0
Docking	N		N	0	N	0
Agricultural Study			N	0	N	0
Computer			N	0	N	0
Offices			N	0	N	0
Laboratory			N	0	N	0
Shops			N	0	N	0
Communications			N	0	N	0

*It is assumed that no off-duty day will occur on Logistics Spacecraft

N = nominal time period (less than 2 hours per day - time in area would depend on duties for that day)

Table I-2 Crew Areas by Mission Model

A R E A	Mission Models		
	Logistics Spacecraft	Earth Orbital Space Station	Planetary Space Vehicle
LIVING AREAS			
Lounge	NR	D	D
Recreation	NR	R	R
Passageways	D	R	R
Study or Library	NR	R	D
Bedroom	D	R	R
Bathroom	D	R	R
Conference	NR	D	D
FOOD PREPARATION AND SERVICE			
Kitchen	D	R	R
Dining Room	D	R	R
Food Storage	R	R	R
Snack Bar	NR	D	D
SERVICES			
Laundry	NR	R	R
Briefing Room	NR	D	D
Locker Room	NR	D	D
Theater	NR	D	D
Dispensary	NR	R	R
Chapel	NR	D	D
Barber	NR	R	R
Supply	NR	R	D
Maintenance	NR	R	R
Equipment	NR	R	R
Gym	NR	D	D
Power	NR	R	R
WORK AREAS			
Control Room	R	R	R
Airlocks	R	R	R
Inspection	NR	D	D
Photographic Support	NR	R	D
Animal Housing	NR	D	D
Docking	R	R	R
Agricultural Study	NR	D	D
Computer	NR	R	D
Offices	NR	D	D
Laboratory	NR	R	D
Shops	NR	R	D
Communications	NR	D	D

LEGEND: R = required
NR = not required
D = desirable but not absolutely required

II GENERAL DESIGN CRITERIA

1.0 Introduction

This section has been developed in order to provide the designer with a general understanding of the effect and importance of the below listed environmental elements on habitability:

Specific Environmental Elements	Related Environmental Elements
A. Lighting	F. Texture and Design
B. Acoustics	G. Hygiene and Mess Provisions
C. Temperature	H. Dual Room Usage
D. Color	I. Gravity
E. Volume	J. Interrelated Environments

Each of the specific environmental elements, A through E, is discussed in relation to applicable terminology, physiological and psychological effects of the environment on man, and how man is to control these elements in order to optimize his environment. The related environmental elements, F through J, are discussed and their effects in creating an optimum environment for man in a confined spacecraft. These related elements are more subjective than the specific elements since there are no specific values for such items as the interrelationship of the environmental elements. However, these related environmental elements cannot be overlooked when determining an optimum environment for man.

1.1 Background Data

Background data in terms of references and concept development are provided in a separate rationale book.

The rationale book will present the justification for the standards and concepts presented in this handbook. To facilitate cross-referencing between the Handbook and the rationale book, identical section, subsection, and paragraph headings are used in both.

II-A LIGHTING

1.0 Introduction

Both the proper quantity and proper quality of light within an enclosed habitat and in the total seeing environment create an atmosphere which has a positive effect on the health, safety and comfort of the personnel. Thus, proper lighting improves personnel morale, motivation, and output efficiency. Poor visual environments caused by low levels of illumination, glaring fixtures, and highly reflective surfaces will affect personnel visual performance. This directly affects the speed and accuracy with which he must perform his required tasks. In addition, it will also cause reduced alertness due to eyestrain and fatigue, thus increasing the change of an accident.

It is therefore apparent, lighting design encompasses considerably more than the specification of illumination levels. It collectively involves consideration of the total luminous environment in which inhabitants of the closed environment must live and perform their various tasks.

2.0 Definitions

2.1 Light

That part of the radiant energy spectrum which can be seen by the human eye. The electromagnetic spectrum includes radiant energy of many wavelengths, but only a narrow band, from about 400 to 700 millimicrons, is visible to the normal eye for vision.

2.2 Candela

Unit of luminous intensity of a light source in a specified direction. Defined as 1/60 the intensity of a square centimeter of a black body radiator operated at the freezing point of platinum (2047°K).

2.3 Lumen

A unit to measure the intensity of luminous output of lamps and luminaires. Defined as the rate at which light falls on a 1 square foot area surface which is equally distant one foot from a source whose intensity is one candela.

2.4 Illumination

Amount of light incident upon a surface measured in foot candles.

2.5 Foot Candle

The measure of illumination at any point that is a distance of one foot from a uniform point source of one candle power. It is also equivalent to a density of one lumen uniformly distributed over an area of one square foot.

2.6 Brightness

That which the eye actually sees and is the result of light being reflected or emitted by a surface directly into the eye. Measured in foot lamberts or candelas per square inch.

2.7 Foot Lambert

The measure of brightness of a surface, when viewed from a particular direction, emitting, or reflecting one lumen per square foot.

2.8 Contrast

A measure of the brightness of an object compared to its immediate surroundings.

2.9 Reflectance

The ratio of the flux reflected by a surface or medium to the incident flux. In simplified terms it is the ratio of the brightness to the illumination.

2.10 Glare

The sensation produced by brightness within the visual field that are sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort or loss in visual performance and visibility.

2.11 Visual Acuity

The ability to distinguish fine details. Quantitatively, the reciprocal of the angular size in minutes of the critical detail which is just large enough to be seen.

2.12 Lamp Source

A generic term for an artificial source of light.

2.13 Luminaire

A complete lighting unit consisting of a lamp, or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

2.14 Color Temperature

As applied to a light source, refers to the absolute temperature in degrees Kelvin of a theoretical black body or full radiator whose color appearance matches that of the source in question.

3.0 Factor Detailed Discussion

3.1 General

Lighting standards tend to emphasize only the quantity aspects of lighting design. Of equal, or perhaps, greater importance is the attention given to the quality and the integration of the total seeing environment. No amount of light can compensate for poorly placed lighting or poorly shielded sources. The optimum condition for glare, either direct or reflected, is total absence or elimination. Most standards for quality in lighting are concealed in the various recommended lighting practices

publications. However, the rules are quite simple and easy to follow.

3.2 Quantity of Lighting

The quantity of light should be tailored to the seeing tasks involved. This is accomplished by specifying the illumination on a surface as measured in foot candles. Table II-A-1 presents some general illumination levels for various seeing tasks. See Section III of this document for particular crew area illumination requirements.

3.3 Quality of Lighting

The quality of light refers to the proper distribution and control of light within the habitat. This requires the proper balance of brightness in the whole visual environment.

3.3.1 Brightness Ratios

Excessive brightness ratios in the field of view, or brightness contrasts between adjacent surfaces, even though not severe enough to be called glare, may be seriously detrimental to lighting quality. A high brightness of the task with a comparatively low brightness of the surroundings is undesirable, since it forces continual adjustments of the eyes from one brightness level to the other. Brightness in the peripheral field higher than the brightness of the task tends to attract the eye away from the task. For these reasons it is desirable to maintain a comfortable balance of perceived luminances in the luminous environment to prevent eye fatigue.

The brightness or luminance of a surface can be approximated by taking a reading with a standard light meter held approximately 2 to 4 inches from the surface. If the meter reading from the task is 100 and a reading from the surrounding surface is 50, the brightness ratio is 100:50 or 2 to 1. Recommended maximum brightness ratios are provided in Table II-A-2.

Table II-A-1 General Illumination Levels for Various Tasks

Task (Seeing)	Description	Illumination		
		Max.	Desirable Range	Min.
General	General lighting requirements for proper identification of items and general maintenance.	10	5-10	1
Casual	Suitable for relaxing or reading. More detailed maintenance and movement of people.	30	20-30	10
Functional	Emphasis placed on efficiency and functional aspects. Investigation and observation of experiments and animals.	70	50-70	20
Medium Detail	Detail inspection and reading small markings.	100	50-100	30
Fine Detail	Fine detail on intricate tasks examining human patients. Generally short duration.	1000	500-1000	100

Table II-A-2 Maximum Brightness Ratios

Condition Between Task and Surfaces/Surroundings	Maximum Brightness Ratio for Optimum Seeing Conditions
Adjacent darker surroundings	3 to 1
Adjacent lighter surroundings	1 to 3
Remote darker surfaces	10 to 1
Remote lighter surfaces	1 to 10
Luminaires and surfaces adjacent	20 to 1
Within normal field of view	40 to 1

3.3.2 Glare

Substantial losses in task contrast, hence, in visibility and visual performance, can result when light sources are reflected in specular or semi-specular visual tasks. This effect can be insidious in the fact that it can occur even in seemingly matte-type tasks. Table II-A-3 lists types of surface reflectances. Table II-A-4 lists types of glare and provides suggestive reduction methods.

3.3.3 Reflectance

The reflectance of the ceilings, walls, floors and furnishings contribute significantly to the general illumination level. As the reflectance of a surface is increased, its brightness is also increased. This makes it essential to pay particular attention to the brightness ratio of all visible surfaces so visual comfort is maintained. See Section III of this document for particular crew area reflectance requirements. (Ref. II-J-4, II-J-5, II-J-6)

3.4 Illumination Methods

There are five general illumination methods as shown in Table II-A-5.

3.5 Lamp Sources

The various lamp sources are shown in Table II-A-6. Table II-A-7 is an indication of these lamp sources performance characteristics and Table II-A-8 is an evaluation of the various lamp sources. The results of the lamp source evaluation is provided in the summary, Table II-A-9.

3.6 Luminaire Types

The types of luminaires that will distribute light are described in Table II-A-10 and evaluated in Table II-A-11.

3.7 Light Loss Causes

Table II-A-12 lists various causes of illumination reduction levels.

Table II-A-3 Types of Surface Reflectances

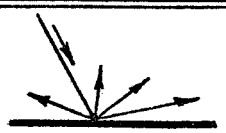
Type	Surface
Diffuse (matte surfaces) 	Rough, irregular particles
Specular 	Indicent light on polished surface such as mirror, that is reflected at an angle equal to angle of incidence.
Compound	Surfaces which are a combination of diffuse and specular.

Table II-A-4 Glare Reduction Methods

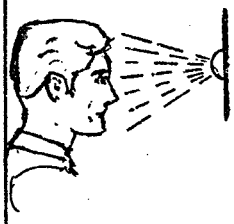
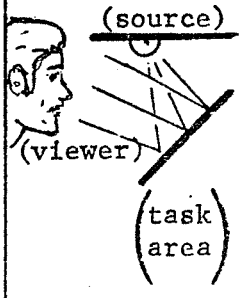
Type	Description	Reduction Methods
Direct	(source) 	Avoid bright light sources within 60 degrees of the center of the visual field. Use indirect lighting. Use several low-intensity sources rather than one high-intensity source. Lights placed high and directly above task area. Use shields, hoods, and visors to keep direct light from source out of viewers eyes.
Indirect		Use diffuse light. Use dull, unpolished surfaces. Place direct light source so that viewing of task area is not equal to the angle of incident.

Table II-A-5 Illumination Methods

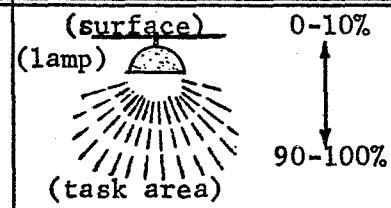
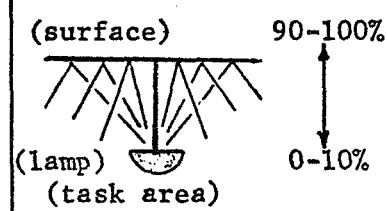
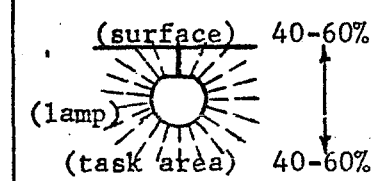
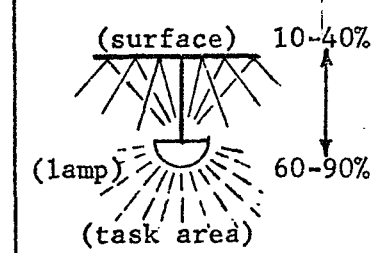
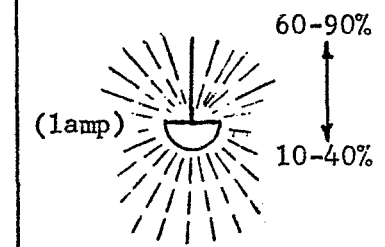
Method	Description	Comments
Direct		90-100% of the output travels directly from the source to the task area. Maximum light, but has undesirable characteristics of brightness contrasts, shadows and glares.
Indirect		90-100% of the output is directed toward ceiling or away from task area. Less efficient since more power required for same illumination level. Eliminates shadows and glare and distributes light evenly.
Diffused		Source enclosed in translucent bowl so that light is scattered evenly. More efficient than indirect but does cause glare and shadows.
Semi-Direct		60-90% directed toward task area. Combines advantages of direct and diffused illumination methods.
Semi-Indirect		10-40% directed toward task area. Combines advantages of indirect and diffused illumination methods.

Table II-A-6 Lamp Sources

Lamp	Description
Incandescent - general service	A lamp in which light is produced by a filament heated to incandescence by an electric current.
Incandescent - tungsten-halogen	A regenerative lamp in which light is produced by heating of a metal filament. It contains a halogen (Iodine) atmosphere enclosed in quartz. This provides redeposition of tungsten back to the filament to achieve extended filament life.
Fluorescent	A low-pressure mercury electric-discharge lamp in which a fluorescing coating (phosphor) transforms some of the ultraviolet energy generated by the discharge into light. Colors are produced by use of special phosphors which convert the ultraviolet energy within the lamp to visible light of the desired wavelengths.
High Intensity Discharge (HID)	Lamp that produces light by establishing an arc between two electrodes located a few inches apart in opposite ends of a small, sealed, translucent or transparent arc tube. The arc of electricity generates heat and pressure high enough to vaporize the atoms of various metallic elements contained within the arc tube. This vaporization causes the atoms to emit large amounts of electromagnetic energy in the visible range. These types include mercury, metal halide and high pressure sodium types.

Table II-A-7 General Lamp Source Performance Characteristics

SOURCE	Luminous Efficiency		Max. Lumen Maintenance (% at end of life)	Life at Rated Voltage (hr)
	Power (watts)	Max. Lumen/ watt		
Incandescent				
a) general service	40	11	80	1000-1500
	100	17	80	
b) tungsten-halogen	500	20	94	2000-4000
Fluorescent				
type CW	20	45	90	9000
CWX	20	28	90	9000
CW	40	64	90	18000+
CWX	40	44	90	18000+
High Intensity Discharge				
Deluxe White Mercury	100	33	75	24000+
	250	38	75	24000+
Metal Halide	400	63	50-55	7500
High Pressure Sodium	400	92	85	6000

Table II-A-8 Lamp Source Evaluation

Source	Evaluation
Incandescent - general service	Color acceptance is excellent. Flattering to skin tones. Source is strong in the red end of spectrum (longer wavelengths), weak in the blue end of the spectrum. Compact source lending itself to optical systems and projection. Available in any wattage and physical size and shape. Brightness is readily controlled over infinite range by simple voltage control (dimmer). Operates on DC or AC (any frequency) equally well. Susceptible to shock and vibration (filament sagging or shorting). Relatively insensitive to operating environment temperature. Vibration and rough service lamps are available. Additional filament supports cool filament temperature and reduce luminous efficacy. No radio interference with equipment. No hazard other than broken glass; no mercury contamination. Lamps available with protective nonshattering plastic coating. Available in most common voltages. Excellent heat source.
Incandescent - tungsten-halogen	Same comments as for general service except as follows: No bulb blackening due to tungsten-halogen cycle. Bulb temperature must be maintained at 250°C minimum temperature for cycle to operate. Lamp (long, linear filament types) must be operated within 4° of horizontal; not a necessary limitation with short, compact filament types.

Table II-A-8 Lamp Source Evaluation (continued)

Source	Evaluation
Incandescent - tungsten-halogen (continued)	Available in double-ended, linear bulb configuration; increasing expansion of product line includes jacketed lamps, reflector lamps, and compact source lamps that can be operated in any position. Slight danger to UV radiation (quartz envelope) especially when operated at over-voltage or high color temperature. More rugged than general service lamps due to additional filament supports.
Fluorescent	Requires auxilliary equipment (ballast) for starting and limiting of lamp current. Range of colors available is excellent. Standard cool white and warm white lamps have very good color acceptance although object colors tend to have a washed out appearance. Skin complexions can be sallow. Excellent color rendition can be achieved with deluxe color lamps at the expense of approximately 30% reduction in luminous output. Lamps are long, linear, low brightness source which does not lend itself to optical systems or projection. Lamp brightness must still be shielded for glare control. DC operation is possible but limited by polarization of lamp and relative inefficiency of current limiting device (ballast). Development of solid-state inverters has allowed efficient operation of fluorescent lamps from DC supplies. Low voltage systems available on same basis. Operation at high frequency results in improved luminous efficacy. Ballast size and weight is reduced. Possible mercury contamination if lamp envelope would break. Dimming possible with properly designed auxiliary equipment although not as flexible and reliable as incandescent dimming.

Table II-A-8 Lamp Source Evaluation (continued)

Source	Evaluation
Fluorescent (continued)	Some minor amounts of UV radiation; glass envelope contains most. Special composition glass envelopes available for passing UV radiation for photo-biological needs if required. Fluorescent lamps are very sensitive to ambient temperature changes with light falling off with either increased or decreased temperatures from optimum. Electrodes are fairly rugged and resistant to shock and vibration. Possible radio-frequency interference with sensitive equipment; proper shielding of lamp and filtering of power supply can eliminate.
High Intensity Discharge - mercury vapor	Requires auxiliary equipment (ballast) for starting and operation. Clear lamp is excellent compact source for optical systems and projection but color is unacceptable due to blue-green appearance (lack of red color). Phosphor coated lamps (specifically, Deluxe White) has color rendition comparable or slightly better than Standard Cool White fluorescent, but phosphor coating increases the source size significantly to reduce its efficiency in optical and projection systems. Extremely rugged construction. Cannot be dimmed. DC operation would require solid-state inverter systems. Straight DC operation would require special lamp construction to avoid polarization of lamp electrodes. Operation at higher frequencies results in higher efficacies. However, at certain frequencies standing waves occur in the arc tube which extinguish the arc.

Table II-A-8 Lamp Source Evaluation (concluded)

Source	Evaluation
High Intensity Discharge - mercury vapor (continued)	Momentary power interruption results in lamp being extinguished. 10-15 minutes required before lamp will restrike. Auxiliary incandescent or fluorescent sources would have to be available during this period. Double-jacketed lamp construction filters out most, if not all, UV radiation. Lamp is insensitive to ambient temperature variations, although extremely low temperature operation would require special low temperature ballast for starting. Mercury contamination would be a problem. RF interference might be a problem with certain types of electronic equipment. Could be screened without much effort.
HID Metal Halide and High Pressure Sodium (additional comments)	Momentary power interruption results in the lamp being extinguished. The high pressure sodium lamp restrikes within several minutes; the metal halide lamp, 10-15 minutes. The high pressure sodium lamp requires a special high voltage (20,000 v) surge for starting purposes. This is provided by a special circuit within the ballast housing. Available only in higher wattages. Reliability of performance has not been as well established as with mercury vapor and fluorescent lamps. Both are clear jacketed lamps having small compact arc tubes that lend themselves to optical systems and projection. Color rendition of the metal halide lamp is very good. The high pressure sodium lamp has a definite yellow or golden appearance which might bother some people in interior applications.

Table II-A-9 Lamp Source Evaluation Summary

Rating Scale 1 - Optimum 2 - Acceptable 3 - Some Compromise 4 - Undesirable 5 - Unacceptable	Incandescent - General Service	Incandescent - Halogen Cycle	Fluorescent - Standard Colors	Fluorescent - Deluxe Colors	Mercury Vapor - Deluxe White - HID	Metal Halide High Intensity Disch.	High Pressure Sodium - HID
Efficacy, lms/watt	5	4	1	2	2	1	1
Life, rated	5	4	1	1	1	3	3
Color							
Acceptable	1	1	2	1	2	2	4
Flattering	1	1	3	1	3	2	5
Color Rendering	1	1	3	1	3	2	5
Optical Characteristics							
Point Source	1	1	5	5	3	1	1
Large Source, low brightness	5	5	1	1	3	5	5
Projection	1	1	5	5	3	1	1
Appearance							
Warm	1	1	1	1	4	4	1
Cool	5	5	1	1	1	1	5
Luminaire Characteristics							
Auxiliary Equipment	1	1	4	4	5	5	5
Size	1	1	5	5	3	2	2
Weight	1	1	4	4	5	5	5
Lumen Depreciation	2	1	2	3	4	4	1
Costs, first	1	1	2	3	4	5	5
operating	5	5	1	2	2	3	4
Ruggedness	5	4	2	2	1	2	2
Effects of ambient cond.	1	1	5	5	1	1	1

Table II-A-10 Luminaire Types

Luminaire	Description
Recessed	Mounted above ceiling or behind a wall or other surface with the opening of the luminaire level with the surface.
Surface Mounted	Mounted directly on the ceiling or surface.
Pendant Mounted	Mounted on an extension type structure.
Cone	Comprises light sources shielded by a ledge or recess that distributes light over the shield (example: over the ceiling and upper wall)
Luminous Ceiling	Ceiling area lighting system comprising a continuous surface of transmitting material of a diffusing or light controlling character with light sources mounted above it.
Retractable	Lighting which can be maneuvered for localized needs.
Portable	Mobile-type lighting for localized needs.

Table II-A-11 Evaluation of Luminaire Systems

Luminaire System	Merits	Deficiencies
Recessed Lighting	Luminaires flush with room surfaces, no dangerous projections. Sealed units to minimize dirt depreciation. Available in combination air handling units. RF interference can be effectively shielded.	Generally provide little light on ceiling to minimize brightness contrasts. Maintenance from room below might be difficult. Requires space above plane of ceiling.
Surface Mounted Lighting	Requires no space above plane of ceiling. Can provide light on adjacent ceiling to help improve comfort. Maintenance will be easy. RF interference can be effectively shielded.	Appearance may be objectionable, not a clean look. Cannot be combined with air handling equipment.
Pendant Mounted Lighting	Maximum utilization of light from luminaire. Lends itself to indirect lighting. Minimizes temperature problems within luminaire.	Not feasible in low ceiling areas. Possible dangerous projections within room. Cannot be combined with air handling functions.
Cove Lighting	May be one of most effective. Can be very comfortable.	Design information available minimal.
Luminous Ceilings	Low brightness and excellent uniformity of lighting levels.	Excellent illumination but very bland and uniform. Might be too expensive.
Retractable Lighting	Combines advantages of suspended and recessed lighting. Excellent for placing localized lighting where needed.	Greater maintenance problems. Expensive. Additional weight of retracting mechanism.
Portable Lighting	Excellent for localized lighting.	Provide means for securing in position. Power cord necessary.

Table II-A-12 Light Loss Causes

Cause	Remarks
Lamp Lumen Depreciation	As shown in Table II-A-7, there is a normal loss of light output as the lamp source ages. To maintain the desirable level, the design foot candle level should be increased to allow for this aging.
Luminaire Dirty	As luminaires become dirty, their reflectance characteristics are decreased. This prevents the proper designed light distribution about the environment.
Lamp Outages	As shown in Table II-A-7, there is a definite life of a lamp source as defined by the number of hours of life. This aging is a maintenance problem which must be considered for both replacement and disposal.
Luminaire Surface Deterioration	As luminaire surfaces deteriorate, less light is reflected, thus preventing light distribution as originally designed.
Room Surfaces Dirty	As with luminaires, as surfaces become dirty, their reflectances are changed. This causes variation of light distribution with the original design.
Temperature and Variation	Variation in voltages can change the operating temperature of a lamp source. This can cause variations in color output of the lamp that changes the illumination levels.

3.8 Color Temperature in Lighting

All objects will emit light if they are heated to a sufficiently high temperature. As the object is raised in temperature, the color of the light emitted from it will change. Table II-A-13 is color designations for various black body temperatures. Technically, a color temperature designation can only be applied to incandescent sources and, as such, it is the specification of both the degree of whiteness and the spectral energy composition of the source. However, the term "apparent color temperature" is often used to specify the degree of whiteness of fluorescent lamps as well as mercury vapor lamps, etc.

Table II-A-13 Color Temperature Designations

Black Body Temperatures ^{o}K	Color Designation
300	Black
800	Red
3000	Yellow
5000	White
8000	Pale Blue
60,000	Brillant Blue

Some lamps tend to flatter object colors which is another way of saying they emphasize the dominant color of the object while deemphasizing complementary colors. Table II-A-14 are the color atmosphere effects of a few fluorescent sources as an example.

Table II-A-14 Fluorescent Color Atmosphere Effects

Fluorescent Lamp	Designation	Atmosphere Effects
Warm White	WW	Warm
Deluxe Warm White	WWX	Warm
Cool White	CW	Neutral to Moderately Cool
Deluxe Cool White	CWX	Neutral to Moderately Cool
White	W	Moderately Warm
Daylight	D	Very Cool

People are emotionally responsive to their surroundings, and color is one of the chief characteristics of those surroundings. Every light source produces light of distinctive color spectral characteristics. This requires that when selecting or comparing colors for any purpose, utilize the type of light source under which the colors are ultimately to be seen.

3.9 Crew Area Factors in Lighting

Table II-A-15 provides various crew area requirements in lighting.

4.0 Psychophysiological Effects

4.1 General

The problem of creating a luminous environment that is conducive to high personnel morale and, consequently, high productivity, is more than just providing adequate lighting levels for performing individual work tasks. Within the framework of required lighting specifications, visual interest must be created.

4.2 Moods

First impressions of rooms have to be positive to provide the proper incentive to the occupants to encourage optimum performance. Table II-A-16 provides various psychological moods in lighting.

4.3 Emphasis

To create various psychological architectural emphasis in lighting, refer to Table II-A-17.

Table II-A-15 Crew Area Lighting Requirements

Crew Area	Requirements	Applications
Public Areas - Relaxation Includes: Lounge, Snack Bar, Recreation Room, Gym, Locker Room, Chapel, and Dining Room	Visual tasks are not critical. Prime emphasis is on relaxation, change of pace lighting. Lighting must have capability of being adjusted or varied. Localized lighting for creating visual centers. Lighting levels match activities. Deluxe colors desirable.	Work in psychological aspects of lighting very limited. Difficult to specify perceived visual pleasantness.
Public Areas - Work Areas Includes: Communications, Computer, Control Room, Briefing Room, Library, Offices and Laboratories	Visual tasks are of a critical nature. Lighting levels must be based on effective foot candles which can be measured in actual situation (prototype). Lighting must have subtle variations from space to space. Localized lighting to increase levels on severe visual tasks and to create visual centers. Deluxe color lamps enhance visual interest.	Veiling reflections can be severe and reduce effectiveness of lighting levels. Uniform lighting, while necessary, can be boring or monotonous. Deluxe color lamps have lower efficacies.
Living Areas - Includes: Bedroom, Bathroom and Study Room	Visual tasks may or may not be of critical nature. Lighting colors should be flattering and relaxing. Good lighting essential for personal hygiene. Lighting should be adjustable to individual tastes and requirements.	Personal lighting should not interfere with or be imposed on others.
Transition Areas - Includes: Passageways, Halls, Stairs, Elevators, Air Locks and Docking	Lighting must provide smooth transition between areas both in lighting levels and colors. Lighting must be adequate for avoiding obstacles and general safety.	Redundant systems and emergency standby power should be available to provide safe movement in case of crisis.

Table II-A-15 Crew Area Lighting Requirements (continued)

Crew Area	Requirements	Applications
Service Areas - Includes: Kitchen, Barbershop, Dispensary, Laundry, Photographic, Shops, and Inspection	General lighting must provide sufficient levels with supplementary lighting for specific visual tasks of severe nature. Lighting is functional in concept with attention given to maintenance. Deluxe color sources may be critical in specific applications. Lighting is for safety of operations in each area.	Specular reflections from metallic surfaces may cause difficulty in seeing tasks. Special lighting techniques for specific tasks and inspection jobs may have to be provided. Darkroom lighting would be provided by proper filtering of standard sources. Filters, especially dichroic types, would provide proper color temperature and heat rejection for operating and inspection lighting in dispensary.
Maintenance Areas - Includes: Supply, Power, Maintenance, Storage and Equipment	Lighting levels are generally minimal with supplementary lighting for critical tasks. Emergency lighting must be available in power and equipment areas. Color code equipment and areas for safety.	Rotating equipment may be subject to stroboscopic effects with discharge sources.
Agricultural Areas	Lighting levels must be adequate for hygiene and safety. Control must be provided for creating time-light cycles.	Growth chambers require special spectral compositions of light.

Table II-A-16 Psychological Moods in Lighting

Mood	Lighting
Gaiety	Higher levels of illumination with color and movement. Changing effects of color and changes in illumination should not be sudden, but should be smooth and stimulating.
Solemnity	Subdued patterns of light with emphasis at dramatic points. Color should be used sparingly and with atmospheric effect. Changes of illumination should be imperceptible.
Restfulness	Low brightness patterns, no visible light sources, subdued color, dark upper ceiling, and a low wall brightness, decreasing upward to the ceiling.
Activity	Higher levels of illumination, with proper local lighting for the more difficult visual tasks.
Warmth	Colors at the red end of spectrum: red, red-orange, orange, yellow, amber, gold and pink.
Coolness	Colors at cool end of spectrum, such as blue, blue-green, green, magenta, violet. These colors mixed with white produces various cool tints.
Human Complexion	Light tints of red, such as pink and rose, improve human complexion and produce pleasant effects. Blue, blue-green, purple and green detract from the human complexion, and produce ghastly effects.
Dramatize Color of Object	Spotlight by a beam of light of same color.
Prevent Fatigue	Avoid use of intense red, blue or purple light.

Table II-A-17 Psychological Architectural Emphasis

Emphasis on Increasing	Lighting Pattern
Height	Verticle lighting patterns from floor to ceiling.
Width	Accentuate lines of light across room, on both walls and ceilings.
Length	Use lighting lines that give perspective such as parallel, longitudinal lines.

5.0 Sample Calculations

5.1 Illumination Calculations

Examples are given here of the basic calculations used in determining the number of luminaires necessary to achieve a given illumination level. Of primary importance is not the equations themselves, but the influence each factor in the equation plays in the final determination of the required number of luminaires. Two methods are presented: the lumen method that is generally used in determining the average illumination within the room; and the point-by-point method which is used to determine the illumination at a specific point due to one or more luminaires.

5.2 The Lumen Method

$$\text{No. of Luminaires} = \frac{E \times \text{Area}}{(\text{No. of Lamps/Luminaire})(\text{Lumens/Lamp})} \times \frac{1}{(CU)\ (LLD)\ (LDD)}$$

where:

E = Maintained foot candles

Area = Area in square feet of the working surface; typically room width x room length

No. of Lamps/Luminaire is obtained from luminaire description.

CU = Coefficient of Utilization; the percentage of light leaving a luminaire and eventually reaching the working surface either directly or through interflections. Luminaire manufacturers provide this information in tabular form for their equipment. The CU table is calculated from photometric data of the luminaire.

LLD and LDD = Lamp lumen depreciation and luminaire dirt depreciation. Taken together these two factors relate initial foot candles to maintained foot candles. This information may come from the manufacturers' catalogs or from typical data presented in the 4th Edition of the IES Lighting Handbook, pages 9-16 and 9-17.

The lumens per lamp or luminous efficacy of the light source plays a direct part in determining the number of luminaires. A high efficacy source, such as the fluorescent lamp, would require fewer luminaires, and consequently, lower power requirements than a lower efficacy source, such as the incandescent lamp.

The lamp lumen depreciation factor (percent of initial lumens produced at 70% of rated life) varies with the type of light source. Typical values for several different sources are:

General service incandescent	90%
Tungsten-halogen incandescent	95%
Phosphor coated mercury	75-83%
Fluorescent	
Standard Colors	86%
Deluxe Colors	80%

Dirt depreciation factors for luminaires also varies with the type of luminaire (open or enclosed), the cleanliness of the environment, and the maintenance schedule. Typical factors for most luminaires are given in the IES Lighting Handbook.

The Coefficient of Utilization (CU) for a luminaire is perhaps the one most significant figure in determining the overall performance of a luminaire. It is directly related to the luminaire's efficiency. It takes into account the light distribution and transmittance of the luminaire's shielding. Computations based on the interflections of radiant energy within enclosures are used in deriving the CU tables. These computations are performed by the fixture manufacturer from the photometric data of the luminaire according to the IES

standardized procedure known as the Zonal Cavity Method. The CU tables are calculated for various room sizes and surface reflectances.

To enter the CU table one must calculate a Room Cavity Ratio. This technique mathematically determines equivalent room configurations from the actual room dimensions and allows standardization of the CU tables.

$$\text{Room Cavity Ratio} = \frac{5\ h_r\ (\text{Room Length} + \text{Room Width})}{(\text{Room Length X Room Width})}$$

where: h_r = height of room cavity from the working plane to the plane of the luminaires

$$\text{Ceiling Cavity Ratio} = \frac{5\ h_c\ (\text{Room Length} + \text{Room Width})}{(\text{Room Length X Room Width})}$$

where: h_c = height of ceiling cavity from the luminaire to the ceiling. With a totally direct light distribution, $h_c = 0$ for recessed or surface mounted luminaires.

$$\text{Floor Cavity Ratio} = \frac{5\ h_f\ (\text{Room Length} + \text{Room Width})}{(\text{Room Length X Room Width})}$$

where: h_f = height of floor cavity from the floor to the working plane, normally 2-1/2 feet.

From these ratios and the reflectances of the room surfaces, one can determine the effective ceiling and floor reflectances from tables in the IES Lighting Handbook, page 9-4. Having determined these effective reflectances, one can then enter the CU table to determine the proper value to use in the illumination calculation formula. Although the method seems cumbersome, it is straight-forward in its application. The Zonal Cavity Method allows greater flexibility and accuracy in making these illumination calculations than previous systems.

Ceiling and wall luminance tables are also available which are very similar in appearance and used as the CU tables. These luminance tables are important in determining brightness ratios within a room from the luminaire data.

5.3 Point-by-Point Method

The point-by-point method of illumination calculations is used when it is necessary to know the illumination at a specific point from a limited number of luminaires. It is not generally used for determining average lighting levels in a room. It is used for calculating the illumination from supplementary sources used to increase the lighting levels in localized areas.

The basic formula is the inverse square law:

$$E = \frac{I \quad \text{Cos } \theta}{D^2} \qquad \text{for Horizontal surfaces}$$

$$E = \frac{I \quad \sin \theta}{D^2} \qquad \text{for Vertical surfaces}$$

where:

E = the illumination at a particular point.

I = the candlepower intensity of the luminaire in the direction . θ is the angle between the luminaire and the point for which the illumination is being calculated. θ is measured as the vertical angle, 0° being directly below the luminaire. This candle power data is obtained from the photometric data on the luminaire.

D = the distance from the luminaire to the point for which the illumination is being calculated.

Illumination values calculated by this formula are additive. When several luminaires are involved, the illumination resulting from each is added directly to determine the illumination from total. This method does not take into account interflected light. There are several

published papers on the subject which present methods of including interflected light if it is deemed important enough to consider.

II-B ACOUSTICS

1.0 Introduction

In an extraterrestrial environment, men will be confined in a limited volume habitat for relatively long periods of time, therefore, particular attention must be given to acoustics to insure the safety, well-being, and optimum performance of the occupants. High intensity sound can produce temporary or permanent damage to the ear, interfere with communications and interfere with the performance of critical tasks. Conversely, the oppressive quality of the absence of sound can be as exhausting as excessive noise stimulation.

In order to determine whether a particular noise environment is likely to be detrimental or hazardous, the designer must compare the characteristics of the acoustical environment with the applicable criteria (damage risk, communications, annoyance, etc.). To make such a comparison the designer needs to know:

(a) The sound pressure level and spectrum of the noise.
(b) The type of noise (wide band, pure tone, or impulsive).
(c) The duration and nature of the exposure (continuous, intermittent, etc.).

When the comparison results in an unfavorable acoustical environment, suitable noise control techniques must be implemented to correct this condition.

2.0 Definitions

2.1 Absorption Coefficient

The sound-absorption coefficient of a surface which is exposed to a sound field is the ratio of the sound energy absorbed by the surface to the sound energy incident upon the surface.

2.2 Acoustics

The science of sound.

2.3 Articulation Index

A predictive measure of speech intelligibility. Formulation of the articulation index is based on the fraction of the total speech band-width to the listener's ear and the signal-to-noise ratio at the listener's ear.

2.4 Attenuation

Attenuation is the term used to express the reduction in decibels of sound intensity at a designated point A as compared to sound intensity at point B which is acoustically farther from the source.

2.5 Acoustic Impedance

The complex ratio of the effective (rms) sound pressure over a surface to the effective volume velocity through it.

2.6 Characteristic Impedance ($\rho_o C$)

The ratio of the effective sound pressure at a given point to the effective particle velocity at that point in a free, plane, progressive wave.

2.7 Dynamic Range (of speech)

Difference, in decibels, between the pressure level at which overload occurs (according to some overload criterion) and the pressure level of the noise of the system.

2.8 Decibel

The decibel is a dimension used for expressing the ratio of two powers and is referred to a reference level of 0.0002 dynes per square centimeter. Mathematically, the number of decibels is 10 $\log_{10}$ of the power ratio. Since sound pressure is proportional to the square root of sound power, the number of decibels in sound pressure

level ratios is expressed as 20 $\log_{10}$ of the ratio of the two sound pressures.

2.9 Energy Density

The average energy per unit volume in a medium due to the presence of a sound wave.

2.10 Free-Field

A field in which the effects of the boundaries are negligible over the region of interest.

2.11 Frequency

The rate of repetition in cycles per second of the sound wave. Frequency is equal to the ratio of the speed of sound to the wave length of sound. It is normally expressed as Hertz. Approximate frequency =

$$\frac{\text{speed of sound}}{\text{wave length of sound}}$$

2.12 Hearing Loss

Hearing loss is the difference in decibels between the threshold of audibility for that ear and the normal threshold of audibility at the same frequency.

2.13 Intensity

The average rate at which sould energy is transmitted through a unit area perpendicular to the direction of wave propagation. A decibel scale of sound intensities is indicated in Figure II-B-1.

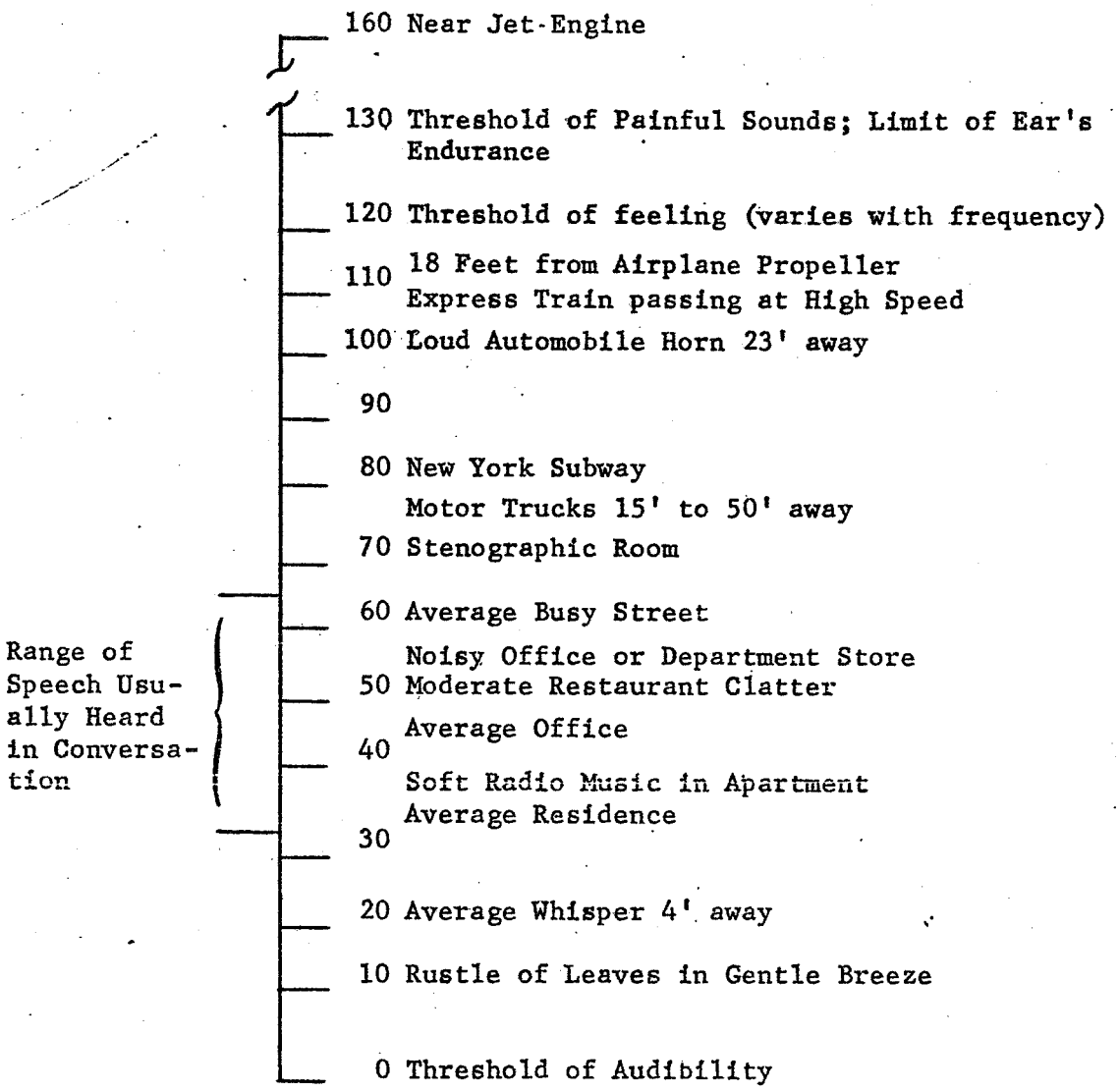
2.14 Intensity Level

Ten times the logarithm to the base 10 of the intensity under consideration to the reference intensity.

2.15 Microbar

A unit of pressure commonly used in acoustics. One microbar is equal to one dyne per square centimeter.

Figure II-B-1 Decibel Scale of Sound Intensities



2.16 Noise

Noise is any undesired sound. As used broadly in acoustics, this may include not only aircraft noise and industrial sounds, such as traffic and machinery, but also speech and musical sounds if they are undesired at any particular location.

2.17 Phon

A unit of loudness level. The loudness level of any sound is defined as the sound pressure level of a 1000 hertz tone that sounds as loud as the sound in question.

2.18 Preferred Frequency Speech Interference Level (PSIL)

The average in decibels of the sound pressure levels of a noise in the three octave bands of frequency centered at 500, 1000, and 2000 Hz.

2.19 Reverberation Chamber

An enclosure in which all the surfaces have been made as sound reflective as possible.

2.20 Reverberation Time

The time required for the average sound pressure level, originally in a steady state, to decrease 60 db after the source is stopped.

2.21 Sound Power Level (PWL)

A computed quantity which expresses the acoustic power of a sound source relative to a reference power.

2.22 Sound Pressure Level

Twenty times the logarithm (to the base 10) of the ratio of a sound pressure to the reference pressure.

2.23 Speech Interference Level (SIL)

The speech interference level of a noise is the average in decibels of sound pressure levels of a noise in the three octave bands of the frequency 600-1200, 1200-2400, and 2400-4800 cycles (hertz).

2.24 Specific Acoustic Impedance

The complex ratio of the effective sound pressure at a point of an acoustic medium to the effective particle velocity at that point.

2.25 Spectrum

Spectrum is the composition of the frequency distribution of a sound wave. In noise survey work, the spectrum

of primary importance includes frequencies from 20 to 10,000 cycles per second. For the purpose of presenting damage risk, speech interference, and nuisance levels, the spectrum is broken down into eight octave bands.

2.26 Threshold of Audibility

The threshold of audibility for a specified signal is the minimum effective sound pressure of the signal that is capable of evoking an auditory sensation in a specified fraction of the trials.

2.27 Temporary Threshold Shift

A shift in the threshold of audibility after exposure to even a moderate noise level.

2.28 Transmission Loss

Transmission loss is the ratio expressed in decibels of the sound energy incident on a structure to the sound energy which is transmitted through it. The term is applied both to building structures, such as walls and floors, as well as to air passages, such as mufflers and ducts.

3.0 Factors Detail Discussion

Sound waves can be described by any of several characteristics, such as the displacement of particles of the medium, the particle velocity, or the sound pressure measurements under certain conditions.

The passage of a sound wave is accompanied by a flow of sound.

3.1 Frequency

3.1.1 Types of Spectra

3.1.1.1 Pure-tone vs Wide-band Noise - A pure-tone noise is predominantly made up of pure frequency components such as propellor noise, compressor whine, and sirens. In wide-band noise the acoustical energy is spread throughout the spectrum. In most cases, especially within

aerospace vehicles, the noise is a combination of pure-tone and wide-band noise. Since there are different criteria for each case, the designer must decide whether the noise is predominantly pure tone or wide band. A practical rule of thumb is that, if the OB SPL in a band is more than 3 db above the adjacent bands, the noise is pure tone or has narrow-band components.

3.1.2 Spectrum Types and Ranges

3.1.2.1 Frequency Bands - Electrical filters are normally used for analyzing noise. These filters reject signals of frequency below a lower "cutoff" frequency and above the upper "cutoff" frequency. Signals between these two frequencies are passed by the filter; this intermediate region is referred to as the passband. The difference between the cutoff frequencies is normally referred to as the bandwidth.

Until recently passbands usually included in filters intended for noise measurement used the frequency ranges listed in Table II-B-1.

Table II-B-1 Octave Band Frequency Ranges

Lower Cutoff Frequency (Hertz)	Upper Cutoff Frequency (Hertz)	Center Frequency (Hertz)
37.5	75	53
75	150	106
150	300	212
300	600	425 } Average of
600	1200	850 } these three
1200	2400	1700 } bands = SIL
2400	4800	3400
4800	9600	6800

When more detailed information about a noise spectrum is required, then third-octave bands are normally used. These bands are one-third the range of the octave bands. The standard set of 1/3 octave bands as used by the Acoustical Society of America is indicated in Table II-B-2.

Table II-B-2 One Third Octave Bands

N	Mean Freq.	Bandwidth Cut-off Frequencies f_1	f_2	Bandwidth f
4	2.5	2.2	2.8	0.6
5	3.1	2.8	3.5	0.7
6	4.0	3.5	4.4	0.9
7	5.0	4.5	5.6	1.1
8	6.2	5.6	7.0	1.4
9	8.0	7.0	8.8	1.8
10	10.0	8.9	11.2	2.3
11	12.5	11.1	14.0	3.0
12	16.0	14.0	17.5	3.5
13	20.0	17.5	22.0	4.5
14	25.0	22.3	28.0	5.7
15	31.5	28.0	35.0	7.0
16	40	35.7	44.9	9.0
17	50	44.6	56.1	11.5
18	63	56.2	70.7	14.5
19	80	71.3	89.8	18.5
20	100	89.1	112.2	23.1
21	125	111.4	140.3	29
22	160	142.6	179.5	37
23	200	178.2	224.4	46
24	250	222.8	280.5	58
25	315	280.7	353.4	72
26	400	357	448.8	92.3
27	500	446	561.0	115
28	630	562	706.9	145
29	800	713	897.6	185
30	1000	891	1122	231
31	1250	1114	1403	288
32	1600	1426	1795	369
33	2000	1782	2244	462
34	2500	2228	2805	577
35	3150	2807	3534	727
36	4000	3565	4488	923
37	5000	4456	5610	1154
38	6300	5615	7069	1454
39	8000	7130	8976	1846
40	10,000	8912	11,220	2808
41	12,500	11,140	14,030	2880
42	16,000	14,260	17,950	3890
43	20,000	17,820	22,440	4320
44	25,000	22,280	28,050	5770
45	31,500	28,070	35,340	7270
46	40,000	35,650	44,880	9230
47	50,000	44,560	56,100	11,540

Mean Frequency = $10^{0.1\ N}$

In order to make the octave bands consistent with the accepted 1/3 octave band values indicated in Table II-B-2, a new set of octave band preferred frequencies for acoustical measurements has recently been set forth as A.S.A. Standard S-1.6 - 1960. The standard octave bands fit the ratio $f_h/f_l = 10^{0.3} = 1.9952$. The values are indicated in Table II-B-3.

Table II-B-3 Standard Octave Band Frequencies

Lower Frequency (Hertz)	Upper Frequency (Hertz)	Center Frequency (Hertz)
11.2	22.4	16.
22.4	44.7	31.5
44.7	89.2	63.
89.2	178.	125.
178.	355.	250.
355.	709.	500.
709.	1410.	1000.
1410.	2820.	2000.
2820.	5630.	4000.
5630.	11200.	8000.
11200.	22400.	16000.

3.1.2.2 Range of Hearing/Speech

3.1.2.2.1 Hearing - The range of hearing for people is of considerable interest. Tests have indicated that some people can hear sounds at frequencies as low as 2 hertz, however, at that frequency a sound pressure level of approximately 135 db would be necessary to produce audibility. The upper limit of hearing is quite variable from person to person. Tests have shown that young people may hear up to 20,000 hertz if the tone is intense enough. This upper limit tends to decrease as people age, with middle aged people usually being able to hear only up to 12,000 to 16,000 hertz. However, the level at which the tome is presented, is important in determining these upper and lower limits.

The auditory response to the frequency of pure tones is commonly accepted as falling between about 16 Hz and 20,000 Hz as indicated in Figure II-B-2.

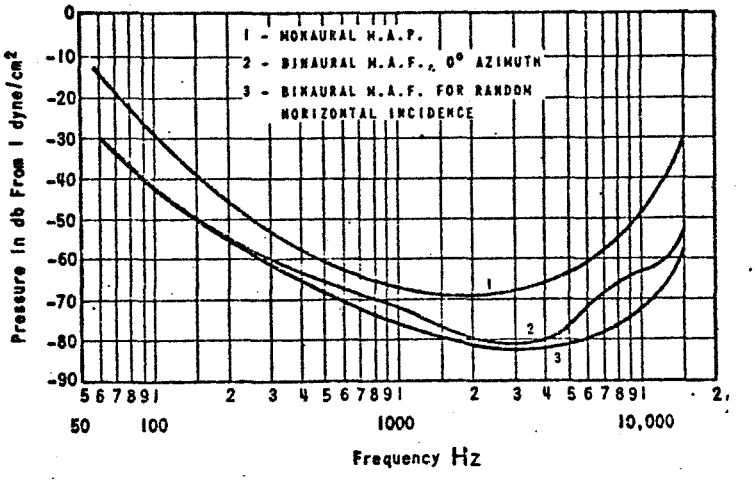


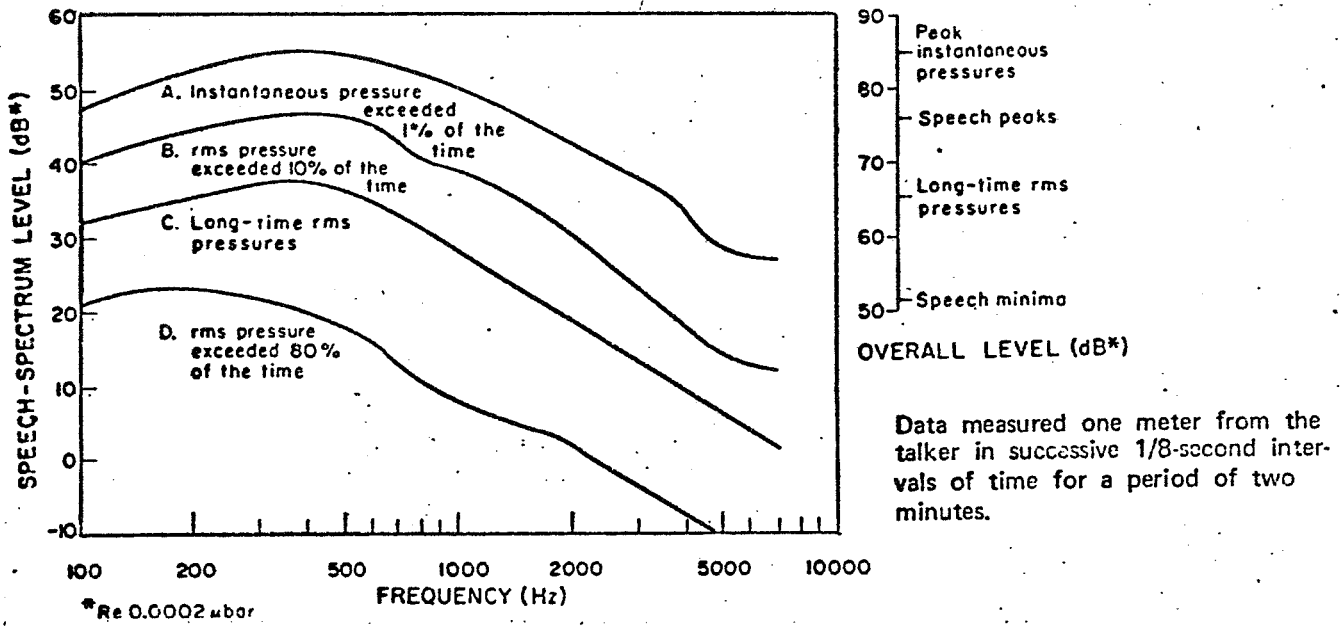
Figure II-B-2 Absolute Thresholds for Reception of Signals (Ref. B.1)

Note: M.A.P. (Minimum Audible Pressure)
M.A.F. (Minimum Audible Field)

The limits for response to intensity vary as a function of frequency. They are often different for different individuals and the threshold may vary from time to time in the same individual (Ref. B.2). The limits for response to intensity extend from the minimum level (i.e., absolute threshold) at which a sound can be heard to intensities where feeling and discomfort begin. The minimum intensities to which the ear will respond vary as much as 80 db with the greatest sensitivity between 2000 and 4000 Hz. Individual differences in absolute thresholds vary as much as 20 db and can vary as much as 5 db within a short period of time.

The audibility of a signal depends on the duration since the response of the ear is not instantaneous. For pure tones, about 200-300 msec. are required for buildup and approximately 140 msec. to decay. Thus, tones of less than 200-500 msec. do not sound as loud and are not as audible in noise background as sounds of longer duration.

3.1.2.2.2 Speech - Four curves relating sound-pressure level to frequency are shown in Figure II-B-3. Curve A shows, for each frequency band of 1 Hz width, the instantaneous



Data measured one meter from the talker in successive 1/8-second intervals of time for a period of two minutes.

Figure II-B-3 Spectrum Level of Instantaneous and RMS Pressure of Speech (Ref. B.3, B.4)

pressure that was exceeded in only 1 percent of the 1/8-sec intervals. This curve is, in a sense, a "peak-instantaneous-pressure" curve. Curve B shows, for each frequency band, the root-mean-square pressure that was exceeded in only 10 percent of the 1/8-sec intervals. One can call this one the curve of "speech peaks". Curve C is the long-time-rms pressure. Curve D shows, for each frequency band, the rms pressure that was exceeded in 80 percent of the 1/8-sec intervals. Inasmuch as about one-fifth of ordinary conversational speech is dead time, this lowermost curve represents, in a sense, the rms pressure of the weakest sounds. One can refer to this curve as the "speech minima" curve. At the right-hand side of the graph are represented the corresponding overall levels - the values for unanalyzed, unfiltered speech.

3.2 Sources

3.2.1 Types

Sound and noise problems arise at several points in long-term space operations. These problems can be

broadly categorized into three phases:

a) Launch and boost
b) Orbit and interplanetary cruise (experiment and life support items)
c) Entry and landing

Noise sources during the launch and boost phase and entry and landing phase include rocket engine noise and aerodynamic noise developed during exit and entrance through the atmosphere. The duration of exposure is usually of the order of a few minutes.

During orbit and interplanetary cruise conditions, the number and types of noise sources are dependent upon the mission requirements. Certain sources of noise are inherent in any mission requirement; for example, fans, motors, pumps and compressors associated with the environmental control systems, and teleprinters, intercomms, etc. associated with communications.

3.2.2 Audio Warning Signals

Auditory signals are often used as alarms and warning devices to call attention to an urgent situation that may require instant action. Table II-B-4 summarizes the principal characteristics and special features of various types of auditory alarm and warning devices. Table II-B-5 summarizes design recommendations for such devices. In selecting and designing signals for alarm and warning, use sounds with frequencies between 200 and 5000 hertz, since the normal human ear is most sensitive to this middle range. Auditory signals should be used for only a few of the most urgent warnings.

3.3 Masking Effects

Because few environments are free of noise, noise is usually a limiting factor in a signal-processing system. Design of a signal-processing system must separate signal from noise. Noise mixed with a signal tends to raise the threshold for hearing that signal above the threshold in quiet, or absolute threshold. This phenomenon is called masking, and the elevated threshold is known as the masked threshold.

Table II-B-4 Characteristics and Special Features of Various Alarms*

Alarm	Intensity	Frequency	Attention-Getting Ability	Noise-Penetration Ability	Special Features
Diaphone (foghorn)	Very high	Very low	Good	Poor in low-frequency noise, good in high-frequency noise.	
Horn	High	Low to high	Good	Good	Can be designed to beam sound directionally; can be rotated to get wide coverage.
Whistle	High	Low to high	Good, if intermittent.	Good, if frequency is properly chosen.	Can be made directional by reflectors.
Siren	High	Low to high	Very good if pitch rises and falls.	Very good with rising and falling frequency.	Can be coupled to horn for directional transmission.
Bell	Medium	Medium to high	Good	Good in low-frequency noise.	Can be provided with manual shutoff to insure alarm until action is taken.
Buzzer	Low to medium	Low to medium	Good	Fair, if spectrum is suited to background noise.	Can be provided with manual shutoff to insure alarm until action is taken.
Chimes and Gong	Low to medium	Low to medium	Fair	Fair, if spectrum is suited to background noise.	
Oscillator	Low to high	Medium to high	Good, if intermittent	Good, if frequency is properly chosen.	Can be presented over intercom system.

*Extracted from Ref. B.5

Table II-B-5 Design Recommendations for Auditory Alarm and Warning Devices*

Conditions	Design Recommendations
If distance to listener is great	Use high intensities and avoid high frequencies.
If sound must bend around obstacles and pass through partitions	Use low frequencies (<500 Hz).
If background noise is present	Select alarm frequency in region where noise masking is minimal.
To demand attention	Modulate signal to give intermittent "beeps" or modulate frequency to make pitch rise and fall at rate of about 1-3
To acknowledge warning	Provide signal with manual shutoff so that it sounds continuously until action is taken.

*Extracted in part from Ref. B.5

Monaural (Pure Tone) Masking - The masking of a signal, basically a pure tone, by another pure tone must be determined experimentally. The masking thresholds of signals for various representative frequencies and amplitudes are depicted in Figure II-B-4. These are based on monaural reception of signals and noise. It will be noted from these curves that the masking effect is greatest when the signal and noise are of similar frequencies and is greater for noise frequencies below the signal frequency than for noises above the signal frequency. At relatively high intensities however, the masked threshold of signals that are some integral multiple of the masking tone is raised more than the threshold of those signals having no harmonic relationship to the masking tone.

In interaural masking (i.e., when the signal is fed into one ear and the noise into the other) no masking occurs when the noise SPL is relatively low (below 40 or 50 db). When the noise SPL is above 50 db, the sound is conducted through the bone of the skull to the opposite ear to produce masking as in the monaural case.

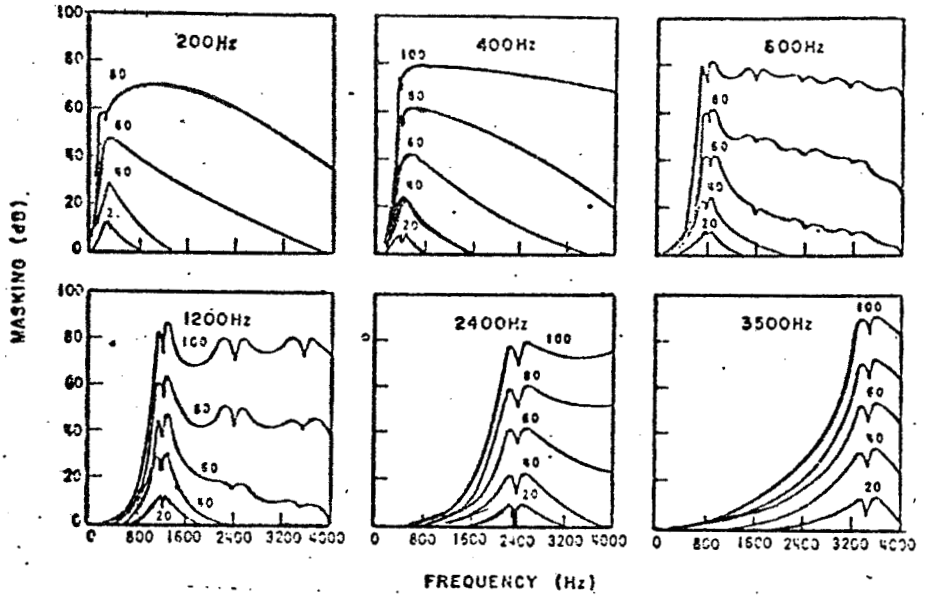


Figure II-B-4 Masking of a Signal by Pure Tones (Ref. B.6)

Note: Masking as a function of frequency for masking by pure tones of various frequencies and levels. Number at top of each graph is frequency of masking tone. Number on each curve is level above threshold of masking tone.

Masking by Narrow-Band Noise - The masking of a signal by narrow-band noise is similar to those for pure-tone masking except that the sharp dips caused by harmonics are absent. Figure II-B-5 shows representative curves for monaural reception.

Masking by Wide-Band Noise - Figure II-B-6 shows the masked thresholds for a pure tone masked by wide-band noise of uniform spectrum (i.e., white noise). The amount of masking of a signal by wide-band noise can be predicted if the spectrum level of the noise is known at the frequency of the signal tone. In making such a prediction it is assumed that the masking is caused by noise frequencies which lie in a band near that of the signal. When used to predict masking, this critical band-width is so defined that the SPL of the noise in the critical ban is just equal to the SPL of the signal at its masked threshold. Figure II-B-7 shows the generally accepted values of critical band-width as function of frequency.

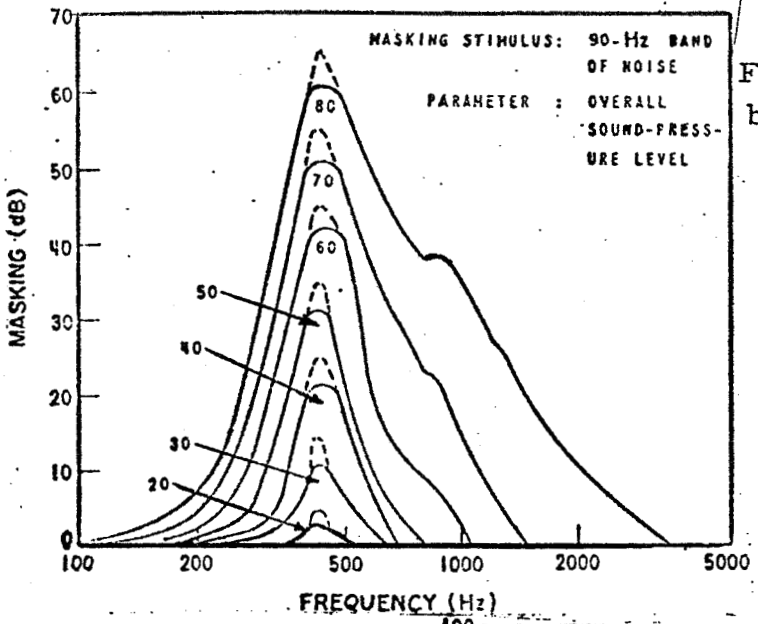


Figure II-B-5 Masking of a Signal by Narrow-Band Noise (Ref. B.7)

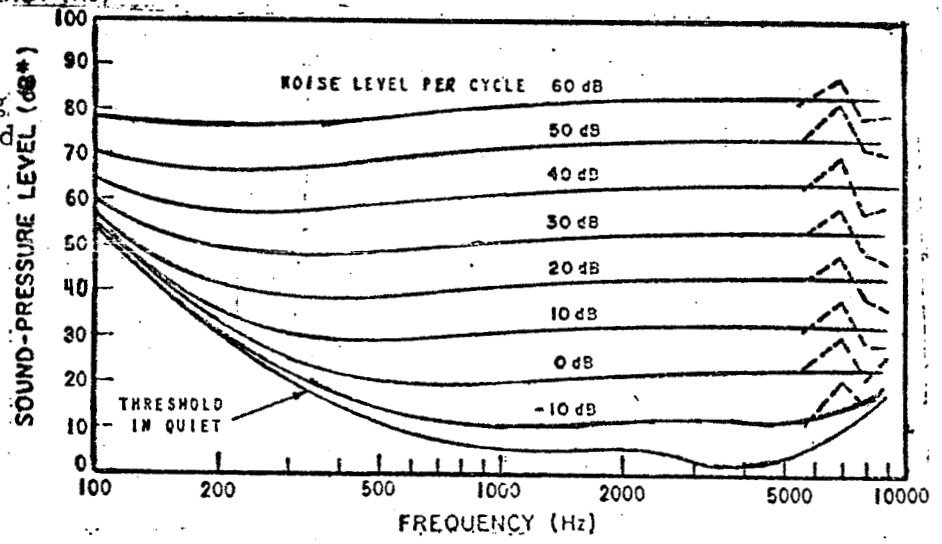


Figure II-B-6 Masking of a Signal by Wide-Band Noise (Ref. B.8)
*Re: 0.0002 Microbar

The prediction of masking threshold at a given signal frequency (f) may be determined by measuring the spectrum level of the wide-band noise at the frequency of the signal. Correct this measured level to the level in the critical band at (f) by adding the 10 log of the critical band-width. This correction can be read directly from the left-hand ordinate in Figure II-B-7. The corrected value is the masked threshold at (f) if the value is more than 20 db above the absolute threshold at (f). If it is less than 20 db, a correction must be made for non-linearity in the masking versus noise level function near the absolute threshold. To correct for masked threshold below 20 db absolute threshold, use the curve in Figure II-B-8.

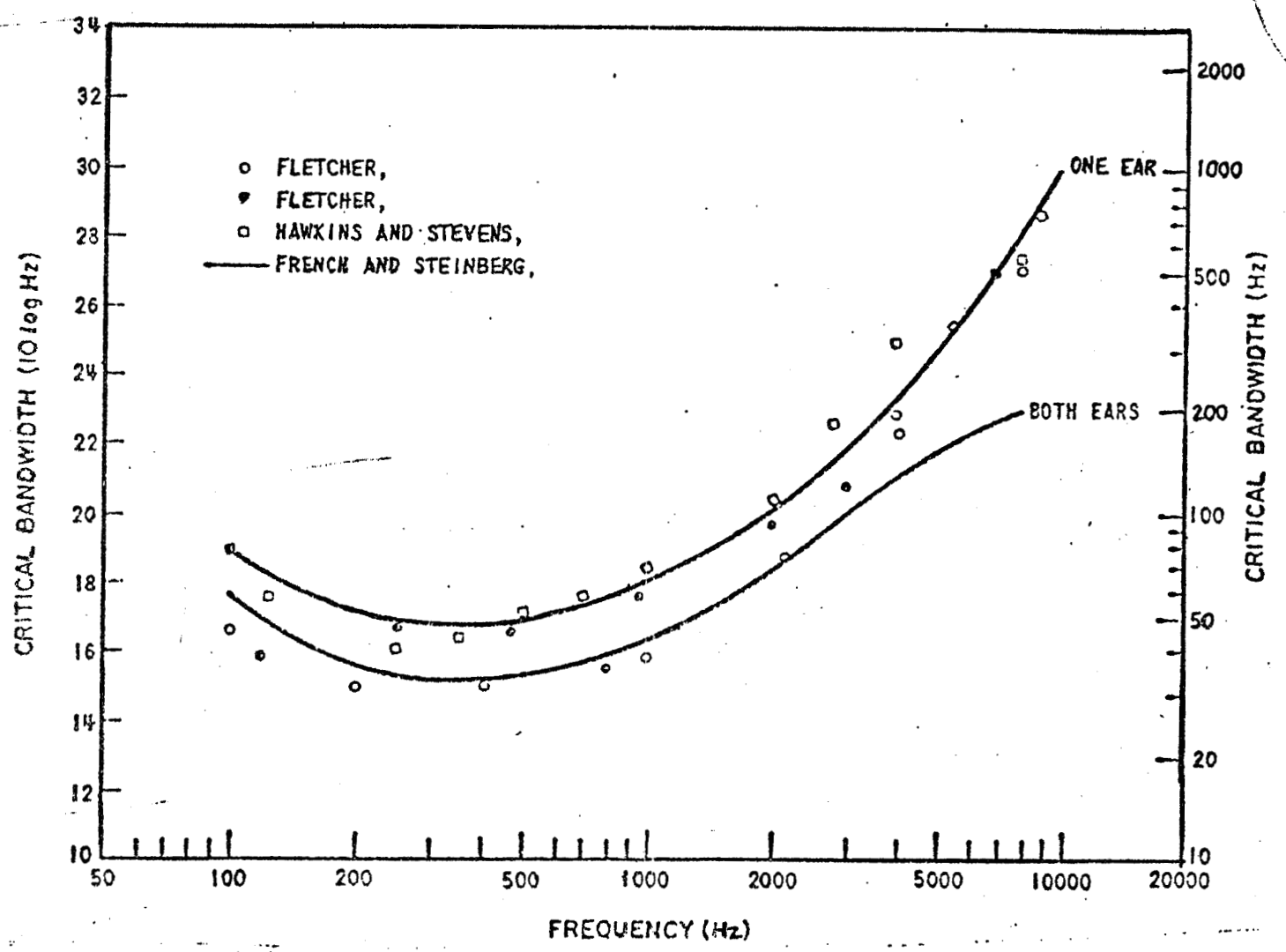


Figure II-B-7 Critical Masking Bandwidth as a Function of Frequency (Ref. B.3)

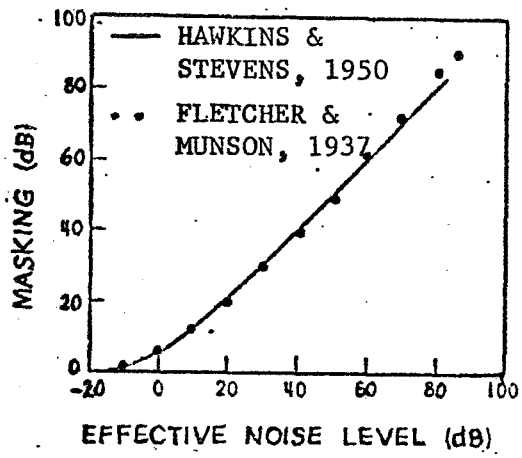


Figure II-B-8 Masking in the Critical Band (Ref. B.3)

3.4 Speech and Hearing

3.4.1 Speech Intelligibility

A variety of criteria exist for determining whether an acoustical environment is suitable for auditory communication. One of the more useful of these criteria is the Speech Interference Level (SIL). In addition, the Articulation Index (AI) method of predicting speech intelligibility can and usually should be used to assess the effects of noise on speech communication.

3.4.1.1 Speech Interference Level - The speech interference level (SIL) can be defined as the average, in decibels, of the SPL's of the masking (or interference) noise existing in the three octave bands, 600 to 1200, 1200 to 2400 and 2400 to 4800 hertz. The SIL provides a measure of the extent to which noise can interfere with the ability to communicate. The SIL method indicates the maximum noise level that will permit correct reception of 75% of phonetically balanced (PB) words or about 98% of test sentences. This criterion is equivalent to an AI of approximately 0.5.

To determine the SIL of a given noise spectrum, proceed as follows:

a) Measure the sound pressure level of the noise in octave bands 600 to 1200, 1200 to 2400, and 2400 to 4800 hertz.

b) Determine the arithmetic average of the decibel levels in the three octave bands. This average value is the SIL.

Figure II-B-9 can then be used to obtain the maximum distance between the talker and listener at which 75% of PB words will be heard correctly. The use of SIL's in estimating speech interference is also indicated in Table II-B-6.

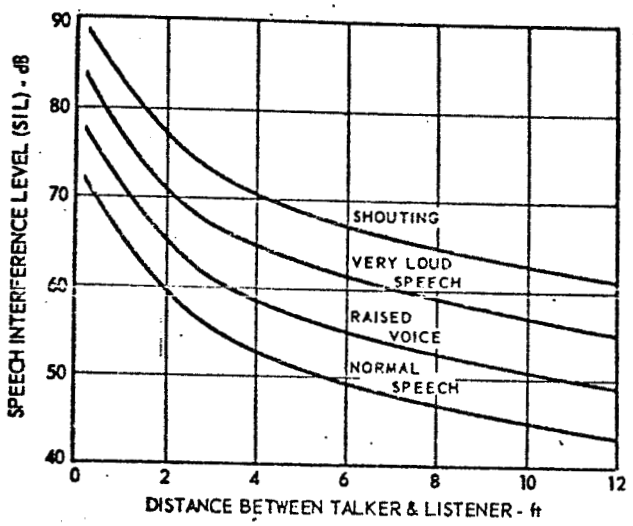


Figure II-B-9 Speech Interference Levels (Ref. B.3, B.9, B.10)

3.4.1.2 Preferred Frequency Speech Interference Level (PSIL) - The PSLL method of specifying the speech interference aspects of noise is based on averaging octave band sound pressure levels centered at 500, 1000, and 2000 hertz. This method was recently developed from a comparison among many known methods of measuring equally speech - interfering noises (Ref. B.11) and relating these to the extensive validation studies of the older SIL. Since PSIL shows the smallest expected variability over diverse spectra noise and is simpler to measure with current acoustic acquisition equipment, it is increasingly becoming the recommended method of assessing the

Table II-B-6 Speech Communication Criteria (Ref. B.3, B.9)

Speech Communication Criteria			
SIL dB	Voice Level and Distance	Nature of Possible Communication	Type of Working Area
45	Normal voice at 10 ft.	Relaxed conversation	Private offices, conference rooms
55	Normal voice at 3 ft; raised voice at 6 ft; very loud voice at 12 ft.	Continuous communication in work areas	Business, secretarial, control rooms of test cells, etc.
65	Raised voice at 2 ft; very loud voice at 4 ft; shouting at 8 ft.	Intermittent communication	
75	Very loud voice at 1 ft; shouting at 2-3 ft.	Minimal communication (danger signals, restricted prearranged vocabulary desirable)	

speech interference aspects of noise. To convert from SIL to PSIL, 3 db can be added to the old SIL's.

3.4.1.3 Articulation Index (AI) - The articulation index is a general criterion applicable for effects of noise on communication. The AI predicts the intelligibility of speech (i.e., the percentage of words or sentences which are correctly understood) for a specified noise environment.

Intelligibility depends on the type of message material or vocabulary. Three types of message material are generally used: (1) lists of nonsense syllables, (2) phonetically balanced monosyllable word lists, and (3) sentences. The relationship between intelligibility and the AI for various types of message material is indicated in Figure II-B-10.

Two methods are available to determine the AI, referred to as the 20-band method and the weighted-octave-band (WOB) method. The 20-band method is more detailed and accurate, since it divides the frequency range of interest (200 to 6100 hertz) into 20 bandwidths. For wide-band noise, the WOB method may be used for noise with a smooth spectrum and for communication systems with no significant distortion. To compute an

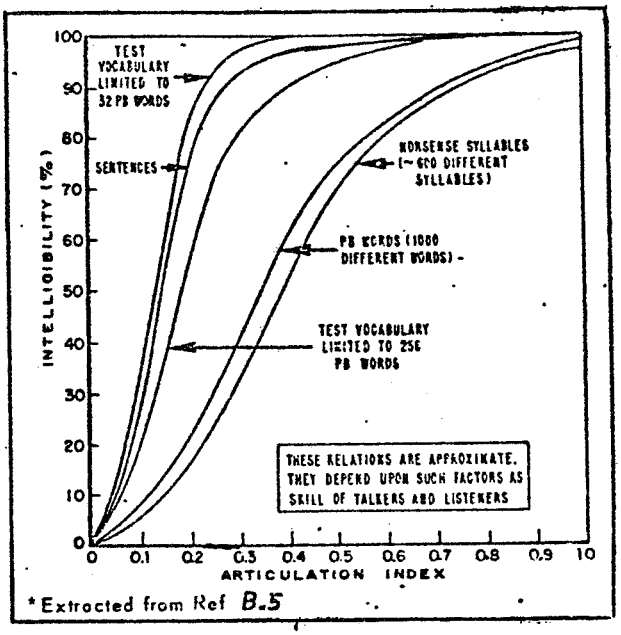


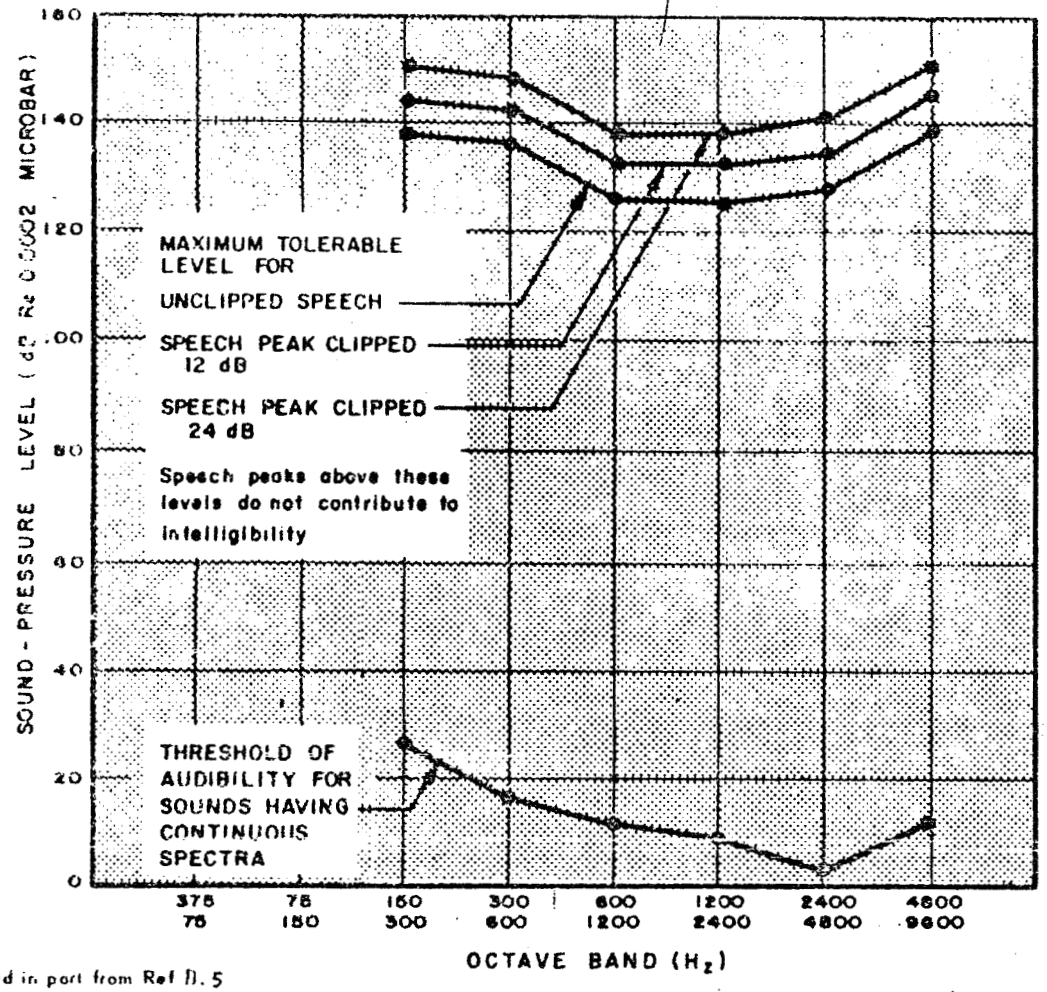
Figure II-B-10 Intelligibility as a Function of the Articulation Index*

AI by the weighted average method, the following steps should be taken (Ref. B.5):

a) Draw a curve showing the speech spectrum level as a function of frequency on a chart similar to that shown in Figure II-B-11. If there is no significant frequency distortion present in the communication system, use the octave-band speech spectrum indicated in Table II-B-7.

Table II-B-7 Octave-Band Spectrum of Speech

Octave Band	Speech Level (db)* (re 0.0002 microbar)
150-300	58
300-600	62
600-1200	58
1200-2400	52
2400-4800	46
4800-9600	40
*Overall speech level is 65 db re 0.0002 microbar (moderate voice)	



Extracted in part from Ref B. 5

Figure II-B-11 Articulation Index Computation Chart (Octave-Band Method)*

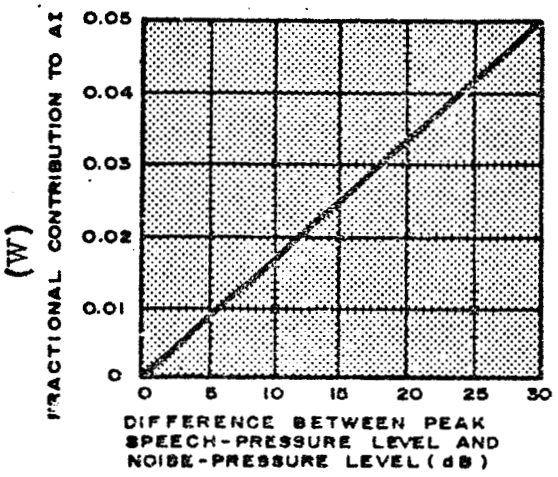
b) Adjust the level to coincide with the level to be used in actual operation.

c) Draw a curve on the same chart showing the octave band levels of the noise.

d) At each octave band, measure the difference between the speech-peak level and the noise spectrum level. If in any octave band the noise level is below the threshold of audibility, use the threshold curve rather than the noise curve. If in any octave band

the speech peak curve is above the appropriate limiting curves at the top of the chart, use that curve rather than the speech-peak curve.

e) Obtain the fractional contribution (W) of each octave by entering Figure II-B-12 with the ratios of speech peaks to rms noise (or quiet threshold) in each indicated octave band.



Extracted from Ref. B.5

Figure II-B-12 Contribution to the Articulation Index

f) For octave bands of ---	Multiply W by ---
150-300 hertz	1
300-600 hertz	1
600-1200 hertz	5
1200-2400 hertz	7
2400-4800 hertz	5
4800-9600 hertz	1

g) Add the values obtained in step f to obtain the applicable articulation index.

Table II-B-8 Intelligibility Criteria

An AI of	Provides communications ....
0.7 to 1.0	Satisfactory to excellent
0.3 to 0.7	Slightly difficult to satisfactory up to 98% of sentences are heard correctly
0.0 to 0.3	Impossible to difficult; special vocabularies and radio-telephone voice procedures are required.

(Extracted from Ref. B.5)

3.4.1.4 Noise Criteria (NC)

A more sophisticated, general standard for determining the effect of noise on communication is based on noise criteria (NC). These criteria were developed to evaluate noise in offices and workspaces, and are essentially an extension of the SIL's from a single number to a set of numbers representing the octave-band spectra. The NC are designed to take into account both the effect of noise on speech communication and the annoyance of the noise, since the former has an important influence on the latter. Figure II-B-13 contains the NC curves and Table II-B-9, the NC for various situations. Note that the rank of the criteria (for example, 40 in NC-40) is the octave-band level in the 1200-to-2400 Hz band, and that a noise with a spectrum the same as the NC curve would have an SIL equal to the rank. As with the SIL's, these criteria should be used only when the noise is fairly steady and has a continuous spectrum. To find the NC of a given communication environment, proceed as follows:

a. Measure or predict the noise in octave bands.

b. Plot the octave-band spectrum of the noise.

c. Find the NC curve which is higher than any of the measured or predicted octave-band level in each octave band; this is the NC of the noise environment.

d. On Table II-B-9 find the description of the communication environment.

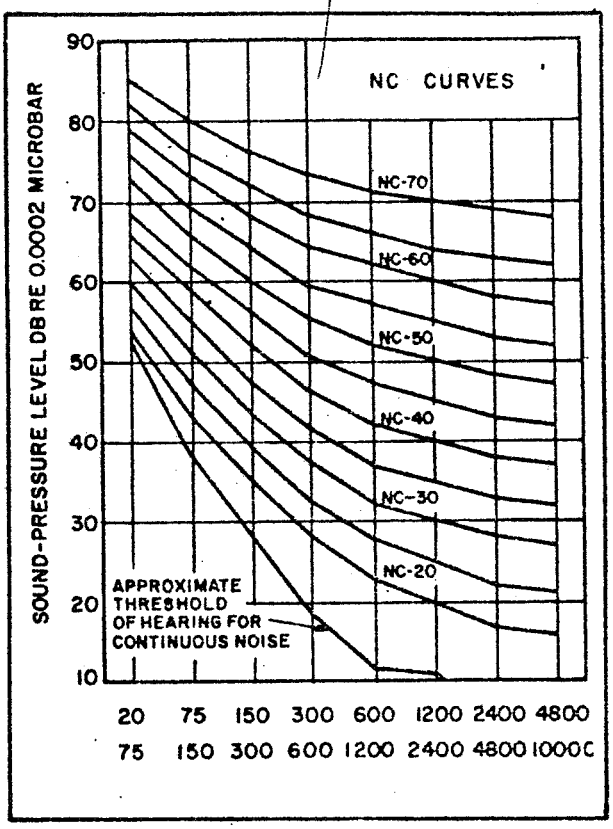


Figure II-B-13 Noise Criteria Curves (Ref. B.5)

Table II-B-9 Recommended Noise Criteria for Offices and Workspaces (Ref. B.5)

OFFICES	
NC (or NCA) CURVE	COMMUNICATION ENVIRONMENT
NC–20 to NC–30	Very quiet office; suitable for large conferences. Telephone use satisfactory.
NC–30 to NC–35	"Quiet" office; satisfactory for conferences at a 15-ft table; normal voice, 10 to 30 ft. Telephone use satisfactory.
NC–35 to NC–40	Satisfactory for conferences at a 6- to 8-ft table; normal voice, 6 to 12 ft. Telephone use satisfactory.
NC–40 to NC–50	Satisfactory for conferences at a 4- to 5-ft table; normal voice, 3 to 6 ft; raised voice 6 to 12 ft. Telephone use occasionally slightly difficult.
NC–50 to NC–55	Unsatisfactory for conferences of more than two or three people; normal voice, 1 to 2 ft; raised voice 3 to 6 ft. Telephone use slightly difficult.
Above NC–55	"Very noisy." Office environment unsatisfactory. Telephone use difficult.
WORKSPACES, SHOP AREAS, ETC.	
NC–60 to NC–70	Person-to-person communication with raised voice satisfactory, 1 to 2 ft; slightly difficult, 3 to 6 ft. Telephone use difficult.
NC–70 to NC–80	Person-to-person communication slightly difficult with raised voice, 1 to 2 ft; slightly difficult with raised voice, 1 to 2 ft; slightly difficult with shouting, 3 to 6 ft. Telephone use very difficult.
Above NC–80	Person-to-person communication extremely difficult. Telephone use unsatisfactory.
NOTE: Noise measurements made for the purpose of comparing the noise in an office with these criteria should be performed with the office in normal operation, but with no one talking at the particular desk or conference table where speech communication is desired (i. e.), where the measurement is being made). Background noise with the office unoccupied should be lower, say by 5 to 10 dB.	

Figure II-B-14 presents the alternate noise criteria (NCA), which are the maximum octave-band levels recommended when the noise is steady and free from beats between low-level components.

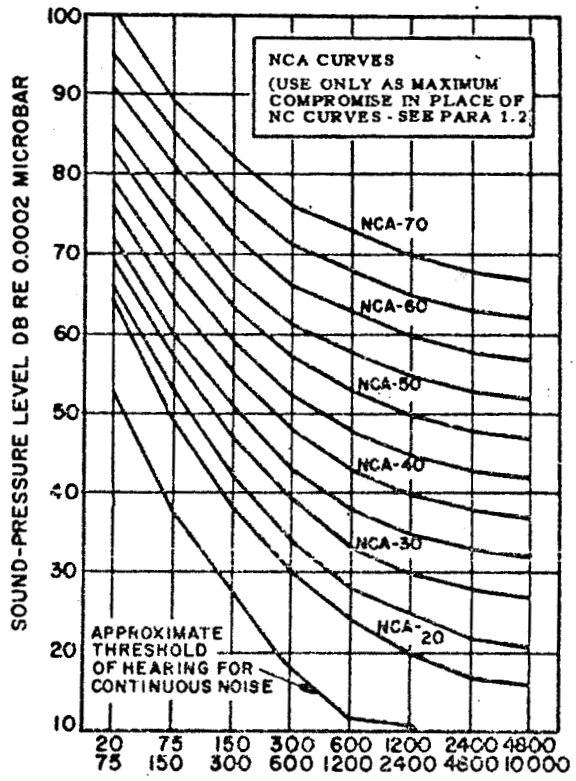


Figure II-B-14 Alternate Noise Criteria (NCA) (Ref. B.5)

3.4.2 Hearing Loss

3.4.2.1 Damage Risk Criteria - Figures II-B-15, II-B-16, and II-B-17 are damage risk contours for one exposure per day to certain one-third octave, full octave and pure tones of noise as accepted by the CHABA Working Group NG. 46 (Ref. B.15). If any single band exceeds the damage risk contours specified, the noise can be considered as potentially unsafe. The relations shown in the figures are based either upon direct measures of temporary threshold shift (TTS) or permanent noise induced hearing losses resulting from exposure to sound. These data have been verified from sufficient research by more than one independent investigation with the following exceptions:

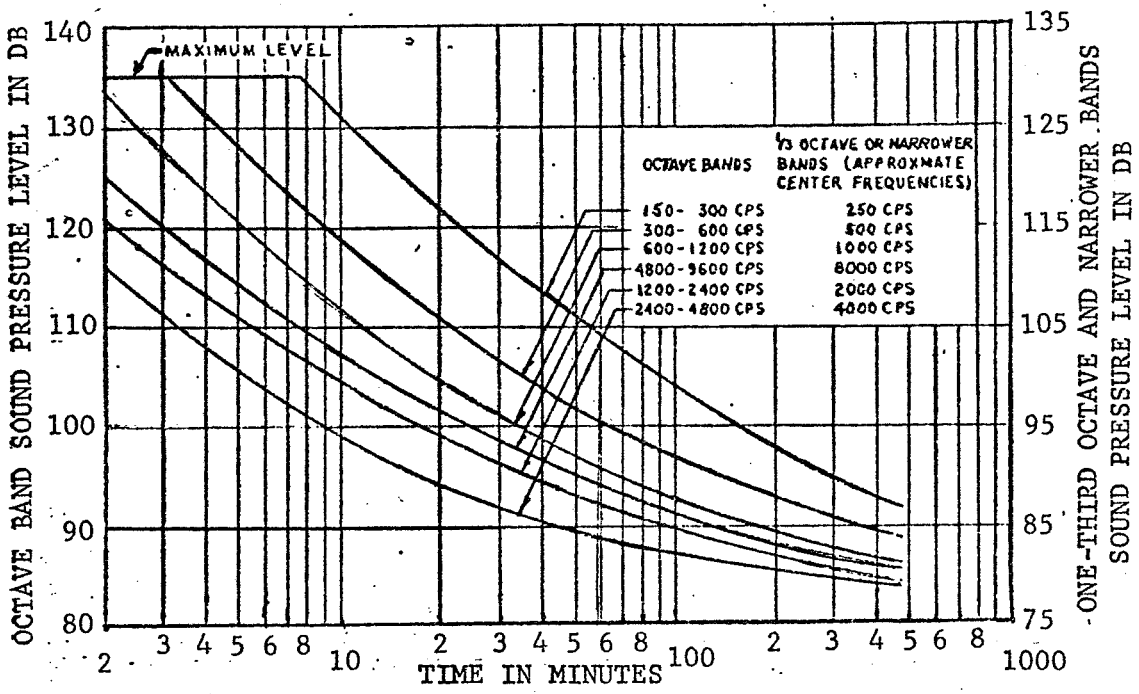


Figure II-B-15 Damage Risk Contours for One Exposure Per Day to Certain Octave and One-Third Octave or Narrower Bands of Noise (Ref. B.15)

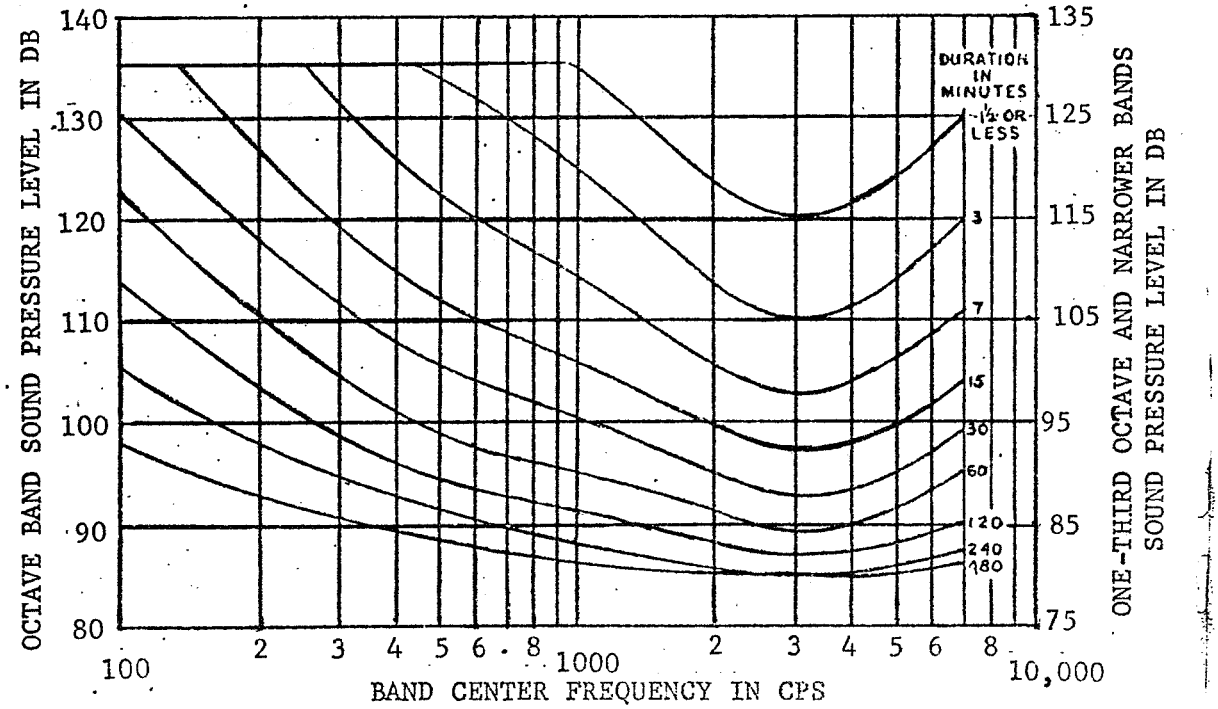


Figure II-B-16 Damage Risk Contours for One Exposure Per Day to Octave and One-Third Octave or Narrower Bands of Noise (Ref. B.15)

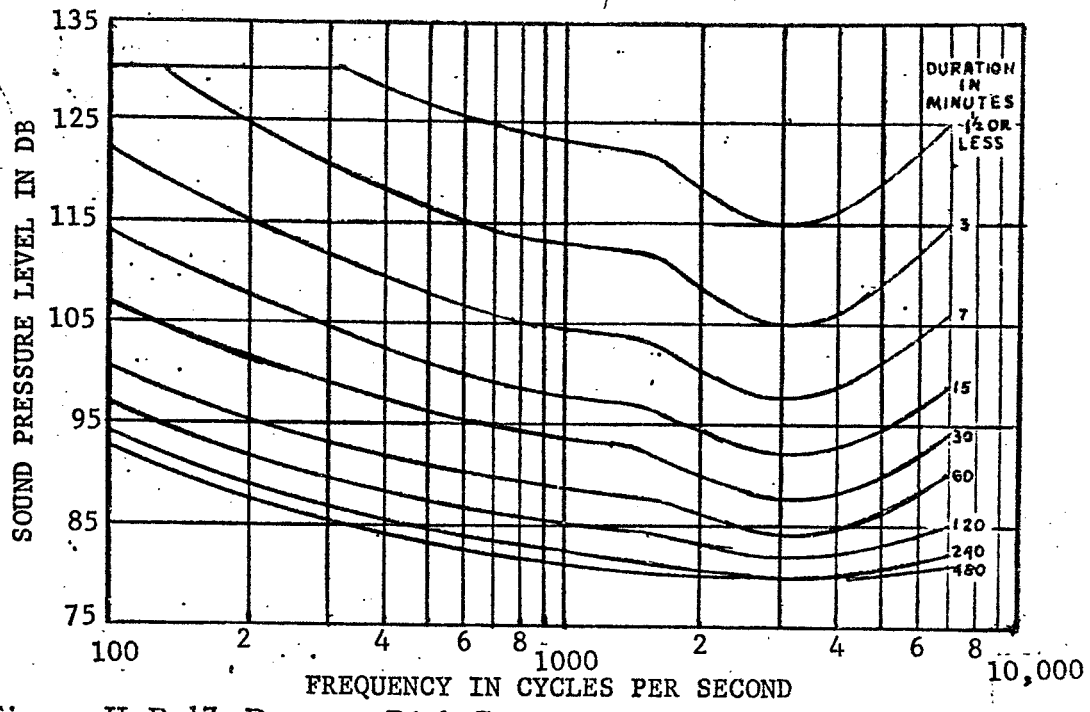


Figure II-B-17 Damage Risk Contours for One Exposure Per Day to Pure Tones (Ref. B.15)

Table II-B-10 Presbycusis in Men and Women (Ref. B.16, B.17, B.18)

A. M E N

Test Frequency in cps	Age Range										
	30-39			40-49			50-59			Over 60	
	B*	WF*	SD*	B	WF	SD	B	WF	SD	B	SD
440		1.4	0.3		3.7	1.3		6.8	4.2		7.0
512	-1.0			-2.0			3.5			8.0	
880		1.3	1.3		4.5	2.4		7.7	4.9		9.0
1024	0			-2.0			0			10.5	
1760		2.3	2.2		7.0	6.0		12.1	11.9		19.3
2048	0			6.0			12.5			23.5	
3520		8.2	7.7		17.7	13.2		25.6	25.0		33.5
4096	6.0			12.5			21.5			35.5	
5793	1.0			17.5			32.0			39.0	
7040		7.7	6.5		16.8	13.3		24.0	27.9		36.1
B. W O M E N											
440		2.6	3.6		6.0	5.3		10.3	6.9		9.5
880		2.6	3.1		5.8	4.3		9.8	7.3		9.0
1760		2.9	2.7		6.7	5.2		11.0	10.4		14.8
3520		2.4	-0.7		7.8	0.7		13.8	7.3		15.6
7040		4.8	-0.1		11.9	3.6		19.7	12.2		23.3

*B = survey by Bunch; WF = World's Fair survey by Steinberg et al.; SD = San Diego County Fair Survey by Webster et al.

- The maximum levels specified for the top curves in the figures are estimates not supported by direct experimental data.

- The data supporting the damage risk contours for pure tones are not as extensive as those for octave or one-third octave bands of noise.

3.4.2.2 Occupational Deafness - The effects of occupational deafness on hearing accumulate over many years. In addition, loss of sensitivity for tones of high frequency take place as part of the average aging process. This normal aging process is defined as prebycusis. In an effort to separate the effects of noise from the effects of aging, several studies have been carried out which present data in particularly accessible form, pertaining to the presbycusis effect. The resulting data are indicated in Table II-B-10.

4.0 Psychophysiological Effects

4.1 Physiological Effects

4.1.1 Performance

Work efficiency on tasks involving alertness over extended time periods has been observed to be reduced in noise environments of the order of 100 db. In fact, levels of noise exceeding 90 db degrade performance of multiple-choice, serial reaction type tasks. In addition, it has been noted that high-pitched noise having a major spectral content above 2000 hertz has a more deleterious effect than low-pitched noise below 2000 hertz. It has also been concluded that in tasks calling for both speed and skill, that noise increases the incidence of mistakes although the rate of working may remain unchanged (Ref. B.27).

In general, it may be said that the effect of intense noise on work is distracting rather than disabling, and noise is most troublesome when it is irrelevant to the task in hand. Extremely high noise levels can interfere with the accuracy of precision manual - dexterity tasks through noise-induced vibrations of body parts. They can affect the

sense of equilibrium, add to disorientation, motion sickness, etc., depending on the specifics of the environment and the type of noise. It should be remembered that the level of noise required to exert a measurably degrading effect on task-performance (over-all SPL greater than 90 db) is considerably higher than the highest level which are acceptable according to other criteria (e.g., hearing conversation of communication) (Ref. B.27). See Table II-B-11 for the noise effects on performance.

Table II-B-11 Performance Effects

• General

SPL dB	Effect
> 90	Degrades multi-choice performance
100	Reduced alertness
114	Speed and skill mistakes increases

4.1.2 Sleep Interference

Almost everyone has been interrupted during sleep by unexpected intermittent or transient noises. Some examples are dripping faucets, telephone ringing, or the barking of a neighbor's dog. However, it is also a common occurrance for people living near an airport or railroad track to become adapted to the noise, if it occurs on a regular schedule.

A series of tests were carried out in the Neurophysiology Laboratories at the Methodist Hospital, Houston, Texas, between January 8 and January 23, 1970 to investigate the effects of spacecraft noise on sleep (Ref. B.28).

The results of this study indicate that none of the three spacecraft-noise environments which were tested resulted in a significant abnormality in either subject's sleep characteristics. Under the controlled conditions in the laboratory, the few changes in sleep patterns which could

be casually related to the noise were of only minimal degree and could not be considered to have truly disrupted the sleep profiles.

Since the laboratory environment in which these studies were carried out did not simulate the other, both demanding and stressful, features of spaceflight, the results must be interpreted with some caution. The relatively small observed influence of the noise condition on sleep could conceivably become a more significant factor under the actual spaceflight conditions.

4.1.3 Non-Aural (low frequency) Effects

Exposure to low-frequency, high-intensity noise has had little study prior to the space program. Pain thresholds had been recorded at approximately 179 db for static pressure, 165 db at 3 hertz, and decreasing to the range of 140 db from 15 to well above 100 hertz. The noise-experienced subjects of previous studies had observed no sensations of disturbed equilibrium or nausea during exposures to tones below 30 hertz even at SPL's inducing pain (Ref. B.29).

Recent studies performed by Mohr, et. al. (Ref. B.23) have indicated new information, however, relating to effects on humans of low-frequency and infra-audible sound.

In summary, the maximum infrasonic exposure levels produced by the available simulation devices did not reach the voluntary tolerance limit for noise-experienced subjects; however, the unusual sensations excited by the oscillating pressure environment could be alarming to the naive observer. In the very low sonic frequency range, chest wall vibration, gag sensations, and respiratory rhythm changes were regularly observed. But the limits of voluntary tolerance were not exceeded by the exposure levels available from the various devices.

In the 50-100 Hz range, the simulator capability for discrete-frequency noise was sufficient to generate subjectively intolerable environments. Responses including headaches, choking, coughing, visual blurring,

and fatigue were sufficiently alarming to preclude undergoing higher level exposures without more precise control of the noise environment and definition of the physiologic effects elicited.

The presently available data (Ref. B.3) thus support the conclusion that noise-experienced human subjects, wearing ear protectors, can safely tolerate broad-band and discrete frequency noise in the 1-100 Hz range for short durations at sound pressure levels as high as 150 db (Ref. B.23). At least for the frequency range above 40 Hz, however, such exposures are undoubtedly approaching the limiting range of subjective voluntary tolerance and of reliable performance. As would be expected, the responses reported by these five subjects during the various test series reflect considerable variability in the subjective effects. At present, the magnitude of possible individual and group variability cannot be accurately estimated. See Table II-B-12 for values of non-aural effects.

Table II-B-12 Non-Aural Effects

SPL dB	Frequency (Hz)	Effect
> 150	77	anal sphinter resonates
> 150	40-60	chest resonates
> 150	700-1500	blurred vision
120-150	1.6-4.4	vertigo, disorientation, nausea, and vomiting
120 continuous	< 7500	irritability and sense of fatigue

4.2 Psychological Effects

Apart from subjective effects and interference with performance and communication, intense noise can also induce certain neurophysiological reactions. For example, very loud or sudden noises can evoke fear and avoidance reactions in humans and animals. Continuous loud jet noise can produce irritability and a sense of fatigue (Ref. B.31, B.32).

Recent investigators (Ref. B.33) have attempted to investigate the hypothesis that greater human energy expenditure is needed for adaptation to loud unpredictable noise, in contrast to loud predictable noise, and that this increased energy expenditure is reflected in a lower tolerance for frustration and in greater deterioration of performance on tasks. The actual discomfort and damage noise range to the ear is shown in Tables II-B-13 and II-B-14.

Table II-B-13 Discomfort to Ear

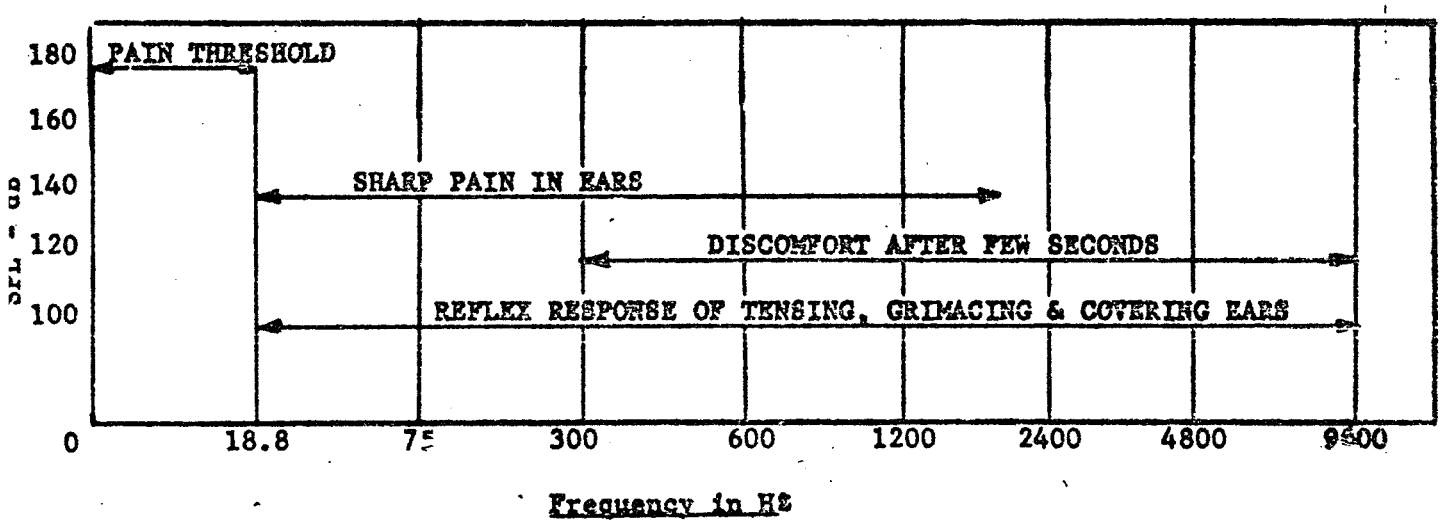


Table II-B-14 Ear Damage

Condition	SPL dB
. Single blast pulses of low frequency	>175
. Sound cycles in range of maximum ear sensitivity	>155

5.0 Noise Control Applications

Noise control for extraterrestrial architectural design will include the reduction of undesirable sound and the introduction of desirable sound for masking effects and the alleviation of mental stress which can result from the absence of sound.

The noise criteria for the various areas and performance requirements for the occupants must be established. Acoustical design and analyses should then indicate whether:

- The sound level of the auditory signal devices is sufficiently above the ambient noise levels to permit reception of the signal. Particular attention should be payed to auditory signals indicating malfunction. Auditory warning signals must be easily detectable and must be quickly and accurately identifiable. They should not be of an intensity or frequency content to induce discomfort of panic response.

- The auditory devices are sufficiently distinctive to permit discrimination between them under all ambient noise conditions.

- The ambient noise level is sufficiently low in either the shirtsleeve or pressure suit environments, to permit face-to-face verbal communications when required with an acceptable level of intelligibility, with half effort.

- The signal-to-noise ratio and bandwidth for the intercommunication equipment is sufficiently high to permit an acceptable level of intelligibility.

- The ambient noise level does not exceed intensity levels and durations which cause undue discomfort or could be expected to cause temporary or permanent damage.

Based on these comparisons if there are any areas disclosed in which performance and/or tolerance limits are exceeded or marginal, analyses should be performed

to determine where corrections can be made. These include:

- Reduction of the ambient noise level at its source.
- Reduction of the ambient noise level in the cabins through the use of sound absorbing materials.
- Reduction of the ambient noise level in the cabins through the use of sound absorbing materials.
- Reduction of the ambient noise level at the ear through the use or modifications of helmet, earphones, and/or earplugs.
- Modification of the auditory signal devices to increase the signal-to-noise ratio and/or distinctiveness.
- Modification of the intercommunication equipment to increase the intelligibility.
- Modification in the mode of operation to be less dependent on auditory signal devices and/or verbal communications, with the appropriate programming of face-to-face and interphone modes.

Usually, the preferred approach to reducing equipment noise is to treat the source through the use of isolators, enclosures, etc. When this approach is impractical, treatment of the receiving space can be accomplished by application of sound absorbing materials. Transmission of noise from one area to another can be controlled by treatment and isolation of partitions, ceilings, floors, and common ducts connecting the areas. Major emphasis is placed on eliminating direct air paths from one area to another.

Studies will be required to insure that materials used in sound treatments meet requirements for flammability, toxicity, cleanliness, etc. Absorption materials which are optimum for standard atmospheric pressure may not be applicable at reduced pressure. In the application of noise control techniques, the analyses must account for the effects of reduced atmospheric pressure on noise

sources, loudspeakers, speech and hearing (if applicable). See Table II-B-15 for absorption coefficients of various materials.

Table II-B-15 Sound-Absorption Coefficients

MATERIAL	ABSORPTION COEFFICIENT AT INDICATED FREQUENCIES						NOISE-REDUCTION COEFFICIENT	WEIGHT lb/ft^2	SURFACE
	128	256	512	1024	2048	4096			
Metal (steel and aluminum)	0	0	0	0	0	0	0	Depends on thickness	Any
Cushiontone Cork, 3/4"	.10	.28	.66	.91	.82	.69	.65	1.05	484 hole/ft^2 3/16" dia., 5/8" deep painted
Fiberglass Tile, 3/4"	.04	.20	.63	.91	.82	.82	.65	0.69	Painted
Wood Floor	.05	-	.03	-	.03	-	.03		
Cork or Rubber Tile	-	-	.03-.08	-	-	-	.05		
Glass	.035	-	.027	-	.02	-	.02		

6.0 Sample Calculations

6.1 Example of Spacecraft Interior Acoustic Calculations

An orbital spacecraft has the following applicable internal dimensions: total surface areas = 1490 square feet, volume = 1600 cubic feet. The composite average absorption coefficient applicable to the internal spacecraft surfaces is 0.08. A sound source with a power of 0.01 acoustic watts is put in the enclosure. There are 5 people in the spacecraft with an $S\alpha$ absorption of 6.0 (feet) squared each. Determine (a) the reverberation time of the interior of the spacecraft; (b) the interior sound pressure level at 5 feet for Q = 1. The equations required are as follows:

$$T = \frac{0.049V}{S\bar{\alpha}},$$

$$PWL = 10 \log_{10} W + 130 \text{ db},$$

$$R = \frac{S\bar{\alpha}}{1-\bar{\alpha}},$$

$$SPL = PWL + 10 \log_{10} \left(\frac{Q}{4\pi r^2} + \frac{4}{R} \right) + 0.5 \text{ db},$$

where T = reverberation time in seconds
V = volume of spacecraft, in cubic feet
S = total internal surface area of spacecraft, in feet

$$\bar{\alpha} = \frac{S_1 \alpha_1 + (S\alpha \text{ for people})}{S_1 + S}$$

where S_1 and S are the areas of absorbing surfaces of the spacecraft and the people in square feet, and α_1 and α are the absorption coefficients associated respectively with those areas, $\bar{\alpha}$ is the average sound absorption coefficient for the spacecraft interior as a whole.

$$PWL = \text{acoustic power level} = 10 \log_{10} \frac{W}{10\text{-}13}$$

W = power emitted by the noise source, in watts
R = "room constant", in square feet
r = distance from the center of the source, in feet
Q = directivity index

$\therefore$ Internal Volume of Spacecraft = 1600 cubic feet

Total Interior Surface Area = 1490 square feet

$$\bar{\alpha} = \frac{(1490)(.08) + 100\,(2)(3.0)}{1490 + 100\,(2)}$$

$\therefore \bar{\alpha} \approx 0.425$

$$T = \frac{0.049(1600)}{1690(0.425)} = \underline{0.109 \text{ seconds}}$$

$PWL = 10 \log_{10}(0.01) + 130 \text{ db} = 10 \log(100) + 130 =$

$-20 + 130 = 110 \text{ db};$

$R = \frac{S\,\bar{\alpha}}{1-\bar{\alpha}} = \frac{(1690)(0.425)}{0.575} = 1250 \text{ square feet};$

$SPL = 110 + 10 \log_{10} \frac{1}{4\pi \times 25} + \frac{4}{1.250 \times 10^3} + 0.5$

$= 110 - 22 + 0.5 = 88.5 \text{ db};$

$\therefore$ SPL = 88.5 db ref. 0.0002 microbar

6.2 Example of Articulation Index Calculations

The articulation index applicable to three fans operating in an enclosure is required using the methods indicated in 3.4.1.3 of this document. The overall SPL of the speech criteria curve used as a reference shall be 74 db. This is an extremely high level, applicable to very loud speech, at close distances.

a) A curve similar to that indicated in Figure II-B-11 is initially drawn, and referred to as Figure 7.2. The dashed line in this figure is a plot of the octave-band speech spectrum, indicated in Table II-B-7. This dashed line is then replotted as the solid line directly above it. The solid line has an overall SPL of 74 db, or an increase of nine db above the overall SPL of the dashed line (65 + 9 = 74 db).

b) The estimated octave band levels of the fan noise are then drawn on Figure II-B-16 as the circles.

c) The differences between the modified speech-peak level (solid line) and the noise levels, in octave bands, is then obtained. Note: differences of 0 db or less have a fractional contribution of zero.

Frequency	DB Difference	W Fractional Contribution				AI
150-300	6.0	.01	x	1	=	.01
300-600	12.0	.02	x	1	=	.02
600-1200	12.0	.02	x	5	=	.10
1200-2400	6.5	.012	x	7	=	.084
2400-4800	0.5	.0085	x	5	=	.0425
4800-9600	-5.0	0				
		Applicable AI			=	.2565

d) The fractional contribution (W) of each octave is then obtained by entering Figure II-B-12 with the differences obtained in step c.

e) Multiply the fractional contributions (W) by the factors indicated in paragraph 3.4.1.3, step f of this document. (See step c of these calculations).

f) The values obtained in step e (indicated in step c) are then added to obtain an applicable articulation index of approximately 0.26.

g) The resulting computed AI of 0.26 can then be used in conjunction with Figure II-B-10 and Table II-B-8 to determine the acceptability of the fan noise environment. It would indicate close or direct speech communications are required.

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II-C TEMPERATURE

1.0 Introduction

Thermal control and limits within any confined space is required for mission success. Not only is thermal control essential for crew comfort, but equipment operation is dependent on the surrounding environment. However, the crew thermal limits are the determining factor since equipment thermal limits exceed the human limits. Crew comfort and performance are to a large extent determined by the environment thermal limits of the space occupied by the crew. To determine these limits, the physical parameters and the more subjective element of the sensation the crew will feel were considered. The two sensations that are used to reflect the comfort zone are warm and cool since these two feelings are the most common terminology associated with a comfortable temperature. Any environmental condition outside the comfort zone is either uncomfortably warm or uncomfortably cool.

The principal factors affecting human comfort in a gaseous environment include the dry-bulb temperature, relative humidity, gas flow rate, total pressure, and density of the gas. Some other related factors that must be considered are crew activity which determines metabolic rate, temperature of the enclosure structure, type of clothing for Clo factor, physiological and psychological state of crew, and gravity condition. Combining the principal factors into a single value will determine the effective temperature. The effective temperature can be defined as an empirical index of the thermal effect of the environment upon the human body. This index is acceptable for use when radiant heat exchange is relatively insignificant in comparison with other modes. Spacecraft, with adequate insulation, will normally be in this category.

Equipment heat loads such as lights have not been accounted for since they are unknown at this time. This is a significant part of the total heat load and cannot be overlooked when determining environmental control equipment.

2.0 Definitions

The terms used to explain the temperature standards and design requirements are defined here to prevent misinterpretation of the criteria.

2.1 Comfort Zone

The area enclosed by the boundaries of the effective temperatures and relative humidity that induces a feeling of comfort to humans. All factors affecting the thermal condition of man are used in determining the comfort zone.

2.2 Dry-Bulb Temperature

The terms temperature, air temperature, ambient air temperature, and dry-bulb temperature are all synonymous. Can be measured with common thermometer.

2.3 Wet-Bulb Temperature

This is the temperature obtained when the thermometer bulb is cooled by the rapid evaporation of water by air moving at a velocity of 900 feet per minute. Wet-bulb temperature varies with humidity and is the same as dry-bulb temperature when the humidity is 100%.

2.4 Relative Humidity

This is the ratio between absolute humidity and the saturation value at a given temperature expressed in percent (%). When a quantity of air holds all the water vapor it can, it is said to be saturated and the humidity is 100%.

2.5 Gas Flow Rate

This is the velocity that the gas moves past an object and is expressed in feet per minute. Determining factors are the mass of gas, volume, and rate of gas change per unit of time.

2.6 Clo Factor

The thermal resistance of clothing to the flow of heat from or to the body is expressed in Clo units. It is directly proportional to the sum of the thickness of the fabrics plus the thickness and composition of the gas layers between the fabrics. One Clo is equal to 0.88°F hr ft^2/BTU when used in mathematical calculations. The Clo values of garment resistance vary from zero for the nude man to approximately 5 for pressure garment assemblies. Another way to define Clo is the insulation value of that quantity of clothing that will maintain comfortable thermal equilibrium in a man sitting at rest in an environment of: (a) 70°F air and wall temperature, (b) 50% relative humidity or less, and (c) 20 ft/min air movement.

2.7 Metabolic Rate

Metabolic rate is the thermal exchange between the human body and the environment. The rate of heat production, metabolism, is always positive in value and is expressed in BTU/hr.

2.8 Pressure

This refers to the absolute total pressure of the environment and is expressed in pounds per square inch. The pressures considered for this study are 5, 10, and 14.7 psia with a constant partial pressure of oxygen at 3.01 to 3.45 psia.

2.9 Radiation

This is a process by which heat flows from a high-temperature body to a body at a lower temperature when the bodies are physically separated with no barrier between them. Heat transfer by radiation becomes increasingly important as the temperature of an object increases. The intensity of the emissions depends on the temperature and nature of the surface.

2.10 Conduction

Conduction is a process by which heat flows from a region of higher temperature to a region of lower temperature within a medium (solid, liquid, or gaseous) or between different mediums in direct physical contact. In conduction heat flow, the energy is transmitted by direct molecular communication without appreciable displacement of the molecules.

2.11 Convection

Convection is a process of energy transported by the combined action of heat conduction, energy storage, and mixing motion. The transfer of energy by convection from a surface whose temperature is above that of a surrounding fluid takes place in several steps. First, heat will flow by conduction from the surface to adjacent particles of fluid. The fluid particle will then move to a region of lower temperature in the fluid, due to the increase in temperature and internal energy of the fluid particle, where they will mix with, and transfer a part of their energy to, other particles. This is known as free convection as the change in density is the motivating force causing the mixing motion. When the mixing motion is induced by some external agency, such as a pump or blower, the process is called forced convection. An increase in humidity increases heat transfer to the body for a given temperature difference and air velocity, since water vapor has a heat absorptive capacity twice that of dry air.

2.12 Evaporation

The evaporative heat exchange mode is limited to sensible and insensible perspiration from the surface of the body. The evaporative heat loss is a function of volume flow rate, absolute humidity, temperature, and pressure of the atmosphere. If the air is saturated with water vapor at skin temperature, evaporation does not occur; in fact, if the vapor content is such that the air will be super-saturated when cooled to skin temperature, condensation will occur with rapid transfer of heat to the skin. If the human body is surrounded by saturated

air at a higher temperature, it responds by producing an excess amount of perspiration, without losing any heat. A continuation of this condition may result in fever, discomfort, weakness, rapid heart action, difficulty in breathing, delirium, and collapse.

3.0 Factors Detail Discussion

To determine the temperature criteria for spacecraft applicability, the avenues must be known by which heat is exchanged between man and the environment. These avenues, radiation, convection, conduction, and vaporization, represent the means that must be considered to keep the human body in equilibrium, and therefore comfortable. Exchanges of radiation may occur with surfaces having higher or lower temperatures than that of the skin or radiation may be absorbed by the skin from high temperature sources such as the sun. The body may exchange heat by convection and this is an important mode of heat loss especially if the velocity of the air around the body is high and of a low temperature. Body heat exchanged by conduction occurs when direct physical contact is made with objects. Heat is lost by vaporization from the lungs through respiration and the skin by sweating. Body heat may also be lost in urine and feces. The body also stores heat in the tissues and body fluids which is used to maintain the body thermal balance.

The conditions for thermal equilibrium between the human body and the environment can be examined in terms of the biothermal equation. This equation attempts to balance the normal heat gains and losses and is usually expressed as follows (Ref. C.1):

$$q_{sr} + q_m = q_s \pm q_r \pm q_c + q_v \pm q_k + q_e + q_w \qquad (1)$$

Table II-C-1 gives the functions or criteria affecting these terms and their effect upon the biothermal equation.

For a state of thermal equilibrium, the heat storage rate is zero ($q_s = 0$). The conductive heat transfer mode is usually quite small and can be assumed, in most instances, to be included in the radiant and/or convective

Table II-C-1 Components of the Biothermal Equation (Ref. C.7)

Term	Function	Effect on System
Metabolism, q_m	f (activity level, body temp.)	Gain at all times
Solar radiation, q_{sr}	f (h_{sr}, t)	Gain when present
Infrared radiation, q_r	f (h_r, t)	Gain: $t_w > t_g$; Loss: $t_w < t_g$
Convection, q_c	f (h_c, t)	Gain: $t_a > t_g$; Loss: $t_a < t_g$
Evaporation, q_e	f (D_v, ΔC. P, t)	Loss in all usual conditions
Respiration, q_v	f (Resp. mass flow, P, t)	Small gain or loss
Storage, q_s	f (W, C_p, A_b, $dt_b/d\theta$)	Gain: $dt_b/d\theta > 0$; Loss: $dt_b/d\theta < 0$
Work, q_w	nature of activity	Gain: Work done on body; Loss: Work done by body

heat transfer terms ($q_k = 0$). Finally, if external heat fluxes are accounted for in terms of induced, environmental parameters, such as internal air and wall temperatures, the term (q_{sr}) can be omitted from the expression.

With comfort as the reference state ($q_s = 0$), the biothermal equation can be expressed as:

$$q_m = \pm q_r \pm q_c + q_e + q_v + q_w \qquad (2)$$

and the system can be examined qualitatively in the light of these terms after they have been adequately defined.

Heat of metabolism (q_m) is considered to be the sum of the basal metabolic rate (energy required to maintain the body in good health and at equilibrium temperature while at rest) plus an incremental increase in heat energy due to activity and/or stress.

Radiant heat exchange (q_r) is a measure of the heat lost (or gained) as a result of the temperature difference between the skin of the human body and the walls of the surroundings.

Convective heat exchange (q_c) is a measure of the heat lost (or gained) as a result of the temperature difference between the skin and the immediate atmosphere.

Evaporative heat exchange (q_e) is the heat exchange resulting from the vaporization of moisture at the surface of the skin.

Respiratory heat exchange (q_v) is a measure of the heat lost (including vaporization of water) from the lungs due to respiration.

In any environment, all of the above modes of heat transfer may be present. In general, the ambient dry bulb temperature, humidity, air velocity, and ambient pressure determine the partition of mechanisms actually used by the body.

3.1 Design Criteria

The biothermal equation delineates the parameters that must be considered to arrive at a comfort level for man. It is important to note that man has the ability to live and function within a broad range of thermal conditions because of his capacity to maintain a relative constant deep body temperature. This deep body temperature is also referred to as the body core temperature and is considered normally to be 98.6°F. Skin temperature can vary for different parts of the body with the mean being approximately 93°F. With these considerations in mind, the following table was prepared to be used as a guide in determining a spacecraft environment limits.

Table II-C-2 Environmental Design Criteria (Ref. C.2)

Item	Limits	Remarks
Temperature, Air		
Minimum	60°F at 0.0 Clo 45°F at 1.0 Clo	Experimental data show low air temperatures are offset by high metabolic rates or radiation. Prevents uncomfortable cooling of any skin area.
Maximum	100°F	To avoid high skin temperature and prevent uncomfortable heating of any skin area.
Temperature, Surface		
Minimum	55°F	To prevent overcooling or overheating of skin areas coming in contact with the surfaces.
Maximum	105°F	
Gas Flow Rate		
Minimum	15 ft/min	Equal to natural convection. This is required to avoid dead hot or cold gas pockets, dissipation of carbon dioxide and other waste gases, and avoids large changes in convective heat loss with body movement.
Maximum	100 ft/min	Flow rates above this level are subjectively drafty and to prevent uncomfortable local skin temperatures.
Humidity		
Minimum	8 mm Hg partial of water	Below this level the mucus membranes begin to dry resulting in discomfort and increased possibility of respiratory infection.
Maximum	95% R.H.	At this relative humidity level, liquid water is usually condensed on some surfaces. At high metabolic rates where sweating may occur, humidity will be limited by comfortable air or wall temperature.

The table on environmental design criteria did not incorporate the element of time in the limits of the environmental factors or the tolerance levels. For this data, Figure II-C-1 is presented to show the thermal requirements for tolerance and comfort in crew compartments.

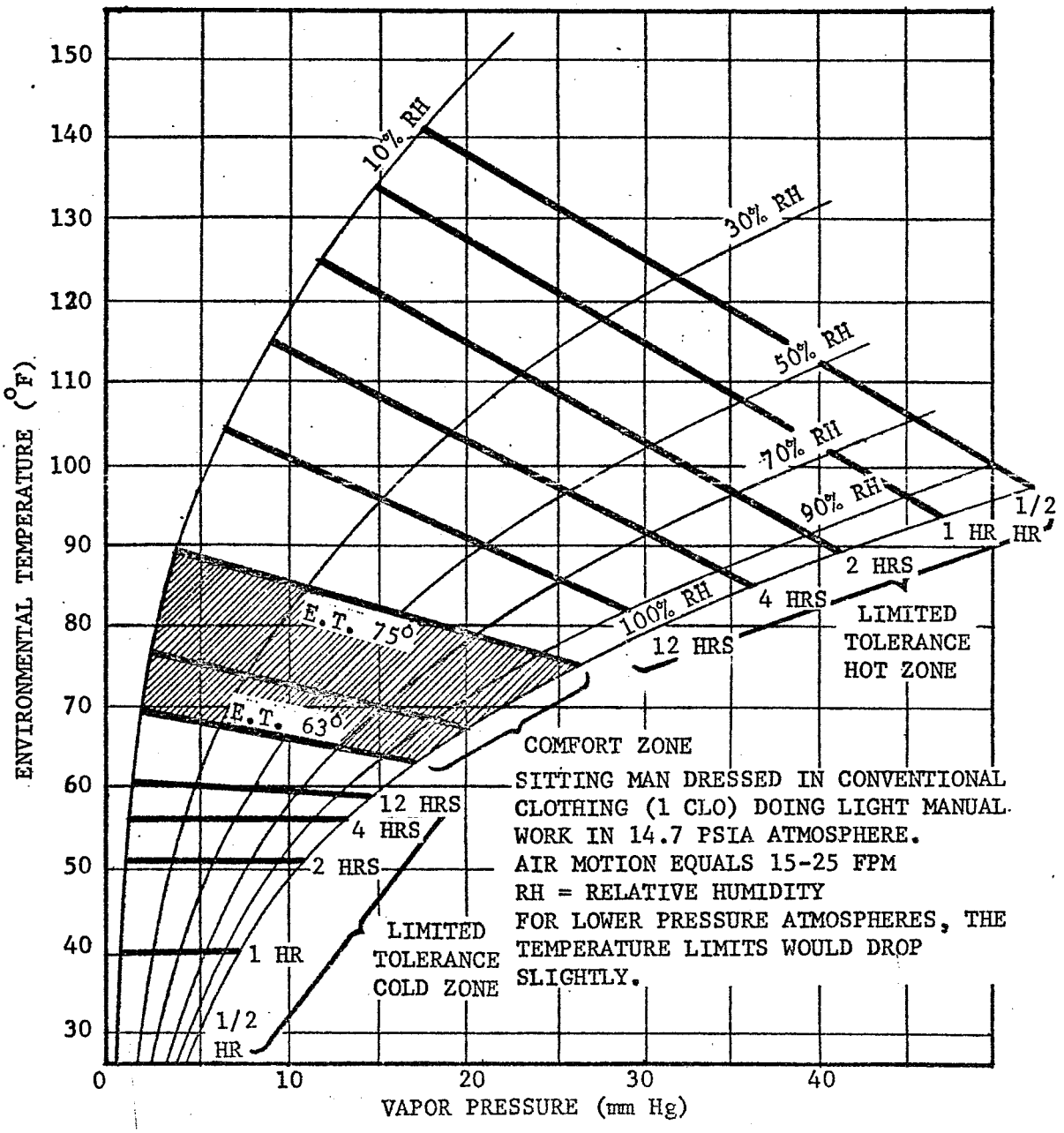


Figure II-C-1 Thermal Requirements for Tolerance and Comfort in Crew Compartments (Ref. C.3)

The insulation effect of clothing with regard to time must be considered for various temperatures. The following figures, Figure II-C-2 and II-C-3 are presented to depict the approximate human time tolerance relationship with temperature and the clothing requirements for men working at different temperatures.

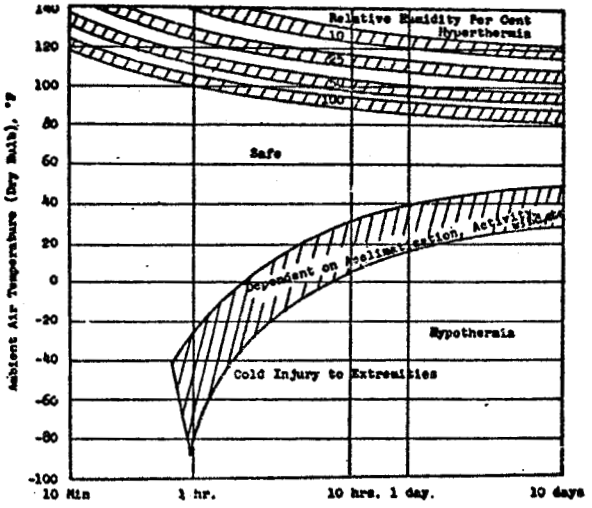


Figure II-C-2 Approximate Human Time-Tolerance Temperature with Optimum Clothing (Ref. C.4)

Temperature		Clothing Requirements (clo)	
C	F		
26.7°	80°	0.0 -	Nude
21.1°	70°	0.5 -	Light
10.0°	50°	1.2	Medium
-1.1°	30°	2.0	
-12.2°	10°	2.8	
-23.3°	-10°	3.8	Heavy
-34.4°	-30°	4.8	
-45.6°	-50°	5.5	

Figure II-C-3 Clothing Requirements for Various Temperatures (Ref. C.8)

3.2 Atmospheric Composition Comparison

In addition to a nitrogen-oxygen (N_2-O_2) atmosphere, the possibility of using a helium-oxygen (He-O_2) atmosphere is possible. Generally, the comfort zones for the helium-oxygen environment are higher than for a nitrogen-oxygen atmosphere. This effect is negligible at low Clo values but became more significant (7°-10°F) at Clo values near 1.0. In all cases, the clothing values were corrected for increased thermal conductivity of the helium mixtures.

For normal gas velocities of 20 ft/min to 80 ft/min, medium clothing (0.7 Clo) and one earth gravity, the following data are representative for the temperature comfort zone, see Table II-C-3.

Table II-C-3 $He-O_2$ and N_2-O_2 Atmosphere for One-G (Ref. C.5)

	5 psia (3.5 psia O_2)	7 psia (3.5 psia O_2)
$He-O_2$	92°F upper limit 82°F average 73°F lower limit	94°F upper limit 85°F average 76°F lower limit
N_2-O_2	83°F upper limit 77°F average 71°F lower limit	84°F upper limit 78°F average 73°F lower limit

From these data, it can be seen that with a helium-oxygen atmosphere, a 5° to 7°F higher temperature can be used and crew comfort will still be maintained.

An assumption made for the comparison was that the temperature of the spacecraft interior wall is very close to the spacecraft cabin gas temperature. For several reasons, this assumption is reasonable until vehicle design details are known. High-performance super-insulation will minimize heat lost or gained by the spacecraft. In addition, equipment items in the cabin tend to block radiation. Insulation in the spacecraft and on the equipment will prevent moisture condensation on the walls and also prevent large fluctuations in wall temperature. Therefore, mean radiation will be almost equal to cabin gas temperature. If the radiate temperatures are greater than the cabin temperature, equations show that the comfort temperature difference between an $He-O_2$ and an N_2-O_2 atmosphere are greater than shown above.

The following are representative data modified to approximate zero-gravity conditions. The gas velocity is 50 ft/min and the metabolic rate is 460 BTU/hr. Wall temperature is assumed to be within $\pm$ 1°F of average cabin temperature. These data are presented in Table II-C-4.

Although no data were presented at 14.7 psia, it can be seen from the above data that at this higher pressure the temperature comfort zone will be slightly elevated for both mixtures and the difference between the two mixtures

will remain substantially the same or increase slightly.

Table II-C-4 $He-O_2$ and N_2-O_2 Atmosphere for Zero-G (Ref. C.5)

	5 PSIA	7 PSIA	10 PSIA
$He-O_2$			
0 Clo	76° - 80°F	78° - 81°F	79° - 83°F
0.5 Clo	72° - 75°F	75° - 78°F	77° - 80°F
1.0 Clo	68° - 71°F	72° - 75°F	74° - 78°F
N_2-O_2			
0 Clo	75° - 79°F	76° - 80°F	77° - 81°F
0.5 Clo	68° - 71°F	69° - 72°F	70° - 73°F
1.0 Clo	61° - 64°F	61° - 65°F	62° - 66°F

Two effects seem to be present to account for the higher temperature comfort zone with the helium-oxygen atmosphere. One is due to the larger gas conductivity of Helium. The second results from the influence of gas conductivity on the resistance to heat flow in the clothing. Thermal resistance of clothing appears to be dependent on the thermal resistance of the atmospheric gas entrapped in the clothing.

More extensive testing is required to further evaluate the effects of a helium-oxygen atmosphere. For example, the effects of the mixture during a heavy exercise period with its increased metabolic rate need to be investigated. Tests at varying pressures with different amounts of clothing should be conducted. The long-term physiological effects of a helium-oxygen atmosphere are largely unknown. Leakage rates for $He-O_2$ are higher than for N_2-O_2 environments.

These factors lead to the conclusion that a nitrogen-oxygen atmosphere is most suitable for the anticipated

mission profiles. Special applications of the helium-oxygen atmosphere might be possible in some specific cases.

4.0 Psychophysiological Effects

For any mission, the controllable factors that will affect the crew from a psychophysiological standpoint are the dry-bulb temperature, relative humidity, and gas velocity. If the limits of any one of these are exceeded, the other two factors will be affected. It is almost a direct relationship in that as discomfort increases, performance efficiency decreases. Of the controllable factors, relative humidity is difficult to detect when it is out of the acceptable range before some physical effects are recognized. The most physical harm is done when the relative humidity is too low, below approximately 10% relative humidity or 8 mm Hg vapor pressure, for this will dry out and irritate the mucous membranes. However, it must be noted that relative humidity can vary more than any other factor without affecting crew performance.

4.1 Heat Regulation

The human body modifies its surface with variations in the environment so as to maintain heat balance in the body. This is accomplished by varying the size of the blood vessels to either restrict or increase blood flow through the skin, activation of sweat glands, and the adding or removing of clothing. The following figure, Figure II-C-4, depicts the human body temperatures and zones of temperature regulations.

5.0 Application

In determining the temperature criteria for spacecraft applicability, the activities and their corresponding metabolic rates for each area of the spacecraft are required. It is also necessary to know to what extent each factor, that determines the comfort zone, contributes to the total environment. To satisfy the first requirement, Tables II-C-5 and II-C-6 were constructed as typical activities by spacecraft area and metabolic rates for space missions. Of the principal factors affecting

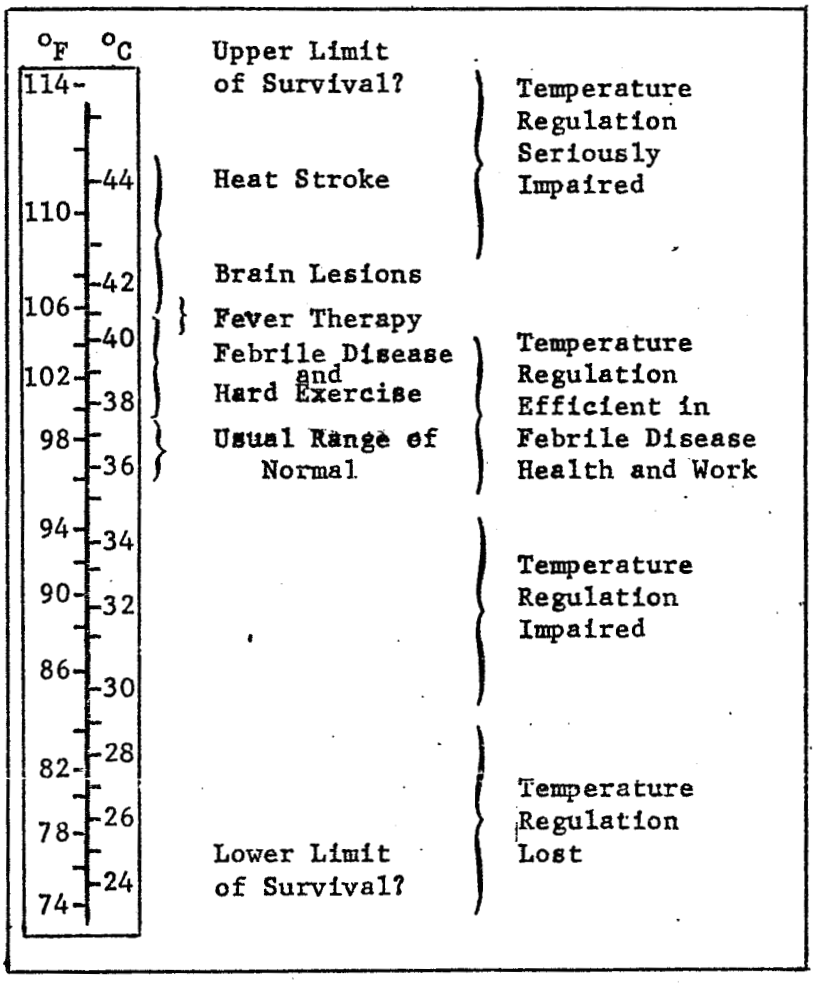


Figure II-C-4 Human Body Temperature Extremes Defining Zones of Temperature Regulations (Ref. C.4)

human comfort, dry-bulb temperature carries the greatest weight in maintaining the comfort zone. This is due to the fact that for any specific pressure or gas composition, the dry-bulb temperature must be held to the optimum value plus or minus 5°F. Dry-bulb temperature is also the determining factor for the relative humidity of the environment.

Next to dry-bulb temperature, the gas flow rate has the most effect on the human comfort zone. This effect is graphically shown in Figure II-C-5. As can be seen from this graph, at the optimum gas flow rates of 30 to 80 fpm and on the low temperature side of the comfort zones, a change of 10 fpm in gas velocity results in an

Table II-C-5 Metabolic Rate for Space Activities in Zero-G

Activity	Metabolic Rate Range BTU/hr	Nominal BTU/hr
Sleeping	250 - 350	300
Eating	350 - 550	450
Monitoring Systems	350 - 650	500
Sitting at Rest	300 - 500	400
At Lecture	400 - 800	600
Typing	500 - 700	600
Cooking	600 - 1000	800
Assembling Parts	800 - 1000	900
Walking	650 - 950	800
Exercising	1200 - 2200	1700
Transporting Cargo	800 - 1600	1200
Changing Clothes	600 - 900	750
Strenuous Sports	1800 - 2800	2300
General Office	500 - 900	700
Welding	550 - 750	650
Sheet Metal Work	1000 - 1750	1350
Electrical Assembly	800 - 1200	1000
Machining	550 - 750	650
Electronic Repair	500 - 700	600
System Checkout	500 - 1000	750
Writing	350 - 550	450
Playing Games (cards, chess, pool)	400 - 650	525
Watching/Listening Entertainment	300 - 500	400
Washing	700 - 1300	1000

Table II-C-6 Area Activities in Space Vehicle

AREA \ ACTIVITY	Sleeping	Eating	Monitoring Systems	Sitting at Rest	At Lecture	Typing	Cooking	Assembling Parts	Walking	Exercising	Transporting Cargo	Changing Clothes	Strenuous Sports	General Office	Welding	Sheet Metal Work	Electrical Assembly	Machining	Electronic Repair	System Checkout	System Operator	Writing	Playing Games	Watching/Listening Entertainment	Washing
LIVING AREAS																									
Lounge				X					X													X			
Recreation				X					X													X	X	X	
Passageways									X		X														
Study or Library				X																		X			
Bedroom	X								X			X													
Bathroom									X			X													X
Classroom					X																	X			
FOOD PREPARATION AND SERVING																									
Kitchen							X		X																
Dining Room		X		X					X																
Food Storage									X		X														
Snack Bar		X							X																
SERVICES																									
Laundry			X						X		X														X
Briefing Room					X				X													X			
Locker Room									X		X														X
Theater				X					X															X	
Dispensary									X		X											X			
Chapel				X																					
Barber				X					X												X				
Supply									X		X														
Maintenance			X					X	X		X					X	X		X	X					
Equipment								X	X		X									X					
Gym									X	X			X												
Power			X						X								X			X					
WORK AREAS																									
Control Room			X						X												X	X			
Airlocks									X		X														
Inspection			X						X											X					
Photographic Support									X		X											X			
Animal Housing									X		X											X			
Docking									X		X														
Agricultural Study									X		X											X			
Computer			X			X															X	X			
Offices						X			X					X								X			
Laboratory			X						X												X	X			X
Shops								X	X		X				X	X	X	X	X						
Communications			X																		X				

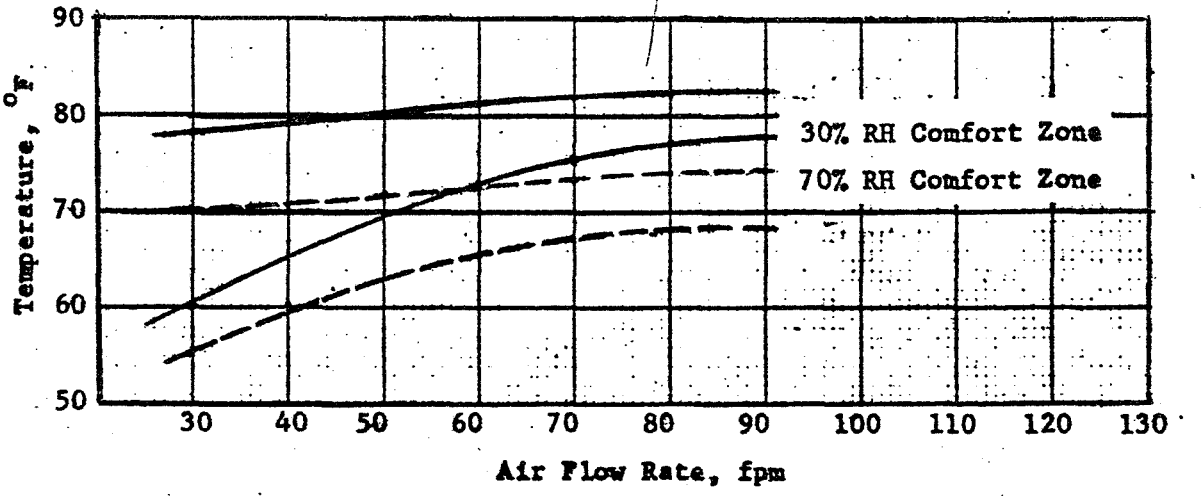


Figure II-C-5 Air Velocity Effects on Human Comfort Zones

approximately 5°F change in temperature. The rate of temperature change on the high side of the comfort zone is much less due to the sensation that increasing the gas velocity has a cooling effect and movement of the warmer gas does not create as great a change in the feeling of coolness as does the cooler gas.

6.0 Sample Calculations

Since gas velocity ranks second only to temperature in air conditioning, it was reasoned that if the same mass of gas at a given temperature flows past the crew member in a given time period, the amount of heat removed or added to the crew member could be directly correlated to the sea level comfort zone. This is assuming the gas behaves like an ideal gas. Gases at the low pressures of the spacecraft do behave as ideal gases and the relationships were worked out using the perfect gas law, $P = \rho RT$ and the general energy equation $Q = hA(T_g - T_A)$, (Ref. C.6). The gas constants (R) for the gases were determined by dividing the molecular weight of the gas composition into the universal gas constant, 1545. The molecular weight of the gas composition is found by taking the percentage of each part and multiplying the percentage times the molecular weight of that part and adding the two together. With the gas constant known, the density of the composition can be found.

Sample

O_2-N_2 gas at 5 psia, and O_2 partial pressure of 3.07 psia

FIND: Gas Composition Constant (R)

KNOWN FACTORS: Molecular Weight of Oxygen = 32

Molecular Weight of Nitrogen = 28

STEP 1. Calculate the percentage of Oxygen = $\frac{3.07 \text{ psia}}{5 \text{ psia}}$ = 61% O_2

Therefore percentage of Nitrogen = 100% - 61% = 39% N_2

STEP 2. Calculate Molecular Weight of Composition = (61%)(32) + (39%)(28) = 30.44

STEP 3.

$$\text{Gas Constant (R)} = \frac{\text{Universal Gas Constant}}{\text{Molecular Weight of Composition}} = \frac{1545}{30.44} = 50.76$$

Note: For an Oxygen-Helium composition at 5 psia, repeat steps 2 and 3 but use the molecular weight of Helium (4) instead of the molecular weight of nitrogen.

To determine density of the O_2-N_2 gas at 5 psia with the new R value and using the perfect gas law, $P = \rho RT$, a temperature of 75°F was arbitrarily selected. Therefore, T is equal to 75° + 460°F = 535° Rankine.

STEP 4. $\rho = \frac{P}{RT} = \frac{(5 \text{ psia})(144 \text{ in}^2/\text{ft}^2)}{(30.44)(535)} = .0264 \text{ lb/ft}^3$

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II-D COLOR

1.0 Introduction

The use of color in spacecraft is necessary in providing visual stimulation for the occupants and in creating different moods to relieve the monotony of prolonged confinement.

For the design of stations whose mission time is of a relatively short duration, the selection of colors to serve both functional and psychological requirements presents the least difficult problem. However, for missions of long duration the need for visual stimulation and variety increases. Extended missions with a single crew requires the capability for color changes within the envelope to break the monotony of the same surroundings over an extended period of time.

Factors involved in color planning are: room volume, area function from the real aspect, and room function from a psychological and behavioral aspect, and considerations as to who the observer will be. This point is important, due to the fact that the crews will be made up of average individuals selected for their professional stature, without undue regard to their sex, age, or emotional and physical make-up.

2.0 Definitions

2.1 Hue

The property that distinguishes one color from another; e.g. green from blue.

2.2 Intensity

The quality which indicates the degree of color strength of hue. As a color is muted or softened by the addition of its own complement on the color wheel, its intensity diminishes.

2.3 Value

The degree of lightness or darkness of the color relative to a white to black scale.

2.4 Dominant Hue

The general overall color of the area, or the largest color application.

2.5 Subdominant hue

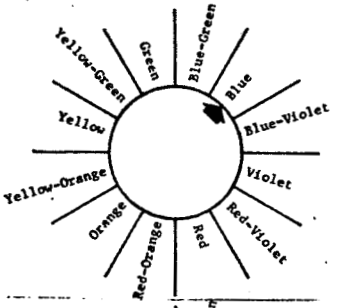
The second largest color application.

2.6 Subordinate hue

Those colors used to accent the dominant and subdominant hues.

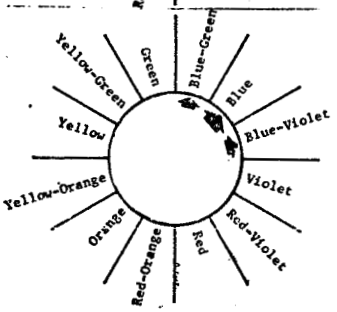
2.7 Monochromatic Color Scheme

A scheme utilizing one spectral hue, e.g., blue in varying values and intensities.



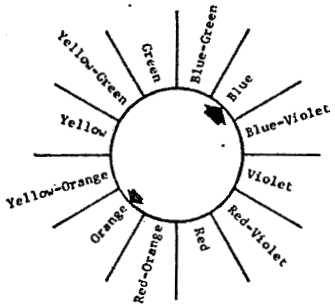
2.8 Analogous Color Scheme

A scheme utilizing two or more hues next to each other on the spectrum e.g. blue with blue-green or blue-violet.

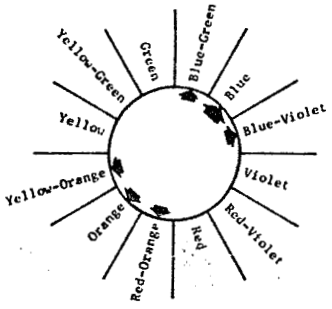


2.9 Monochromatic or Analogous Schemes with Complementary Color Accents

The basic monochromatic or analogous color scheme utilizing the complementary color(s) of the basic hue(s) as an accent.



Monochromatic Complementary



Analogous Complementary

3.0 Factors Detail Discussion

There are three factors which determine the quality of a color. These factors are hue, intensity, and value. Used in the proper manner these factors can make a room look expansive or cramped dark or light, and calm or exciting.

3.1 Hue

Most good color schemes consist of no more than three hues. Whether warm or cool hues should be used is determined by the function of the room involved. Warm hues are associated with extroverted responses and feelings. Where it would be beneficial to emphasize feelings of extroversion, e.g. an area in which social contact is implicit to the function of the area, usage of warm hues will maximize these feelings, usage of cool hues will minimize them. Warm hues generally should be used if the temperature of the room is cool, the noise element is low, the room size is too large, texture is smooth, physical exertion is light, time exposure is short, a stimulating atmosphere is desired and lamps are fluorescent (cool). The introverted response is associated with cool hues. Where a contemplative atmosphere is dictated by the function of the area cool hues will add emphasis; warm hues will dilute this type of atmosphere. Cool hues should generally be used when the temperature is warm, the noise element is high, room size is too small, texture is rough, physical exertion is heavy, time exposure is long, a restful atmosphere desired and lamps are incandescent or fluorescent (warm).

3.2 Intensity

Color intensity induces two basic mental sets which may be described as centrifugal and centripetal. A centrifugal mental set is one in which an individual's attention is directed outward. High color intensity and high levels of illumination as well as warm hues evoke this set to its highest degree.

Conversely, the centripetal mental set directs an individual's attention, inward. Low color intensity and low illumination as well as cool hues maximize the centripetal mental set.

Intense colors will be used primarily as accent colors. Intense colors should be used if time exposure is short responsibility low, noise level is low and stimulating atmosphere is desired.

Muted (less intense) colors are used where time exposure is long, responsibility high, a restrained atmosphere is desired and noise level is high.

3.3 Value

In determining the color value of a room the desired level of illumination should be kept in mind. Light color values should be used if a high level of illumination is required. Dark values tend to produce a low level of illumination.

Contrast within a room is achieved by using light values with dark values. Contrast should be low if time exposure is long, room size is small, a restrained atmosphere is desired and wall surfaces are textured. Contrast should be higher if time exposure is short, room size is large, an exciting atmosphere is desired and wall surfaces are flat.

As a color is grayed the further it appears to be from the eye of the observer. Atmospheric perspective conditions the eye to perceive gray colors in this manner and this natural phenomenon is retained by the observer in artificial environments. Thus, color value can be used to visually enlarge a space.

3.4 Dominant Hue

The dominant hue in most cases will be the wall color, and is generally the lightest in value.

Ceilings are usually white or off-white in the direction of the dominant hue.

3.5 Subdominant Hue

The subdominant hue is of a higher intensity of deeper value than the dominant hue, and is applied to the second largest surface (generally floor surfaces). The subdominant hue will usually be of the same hue or adjacent to the dominant hue on the color wheel.

3.6 Subordinate Hue

Subordinate hues will be used on furnishings, accessories or as accent colors in areas relative to the space involved. Two or more subordinate colors may be used but a judicious use of the colors is recommended. The subordinate hues are of a higher intensity of deeper value than the dominant and subdominant hues. They may be of the same hue, or adjacent or opposite to the dominant hue on the color wheel.

3.7 Monochromatic Color Schemes

Monochromatic schemes tend to be dull to the observer and should generally be avoided, but they serve well in storage areas and the like. They should also be considered in areas where relief from too constant an effect of color saturation exists.

3.8 Analogous Color Schemes

Analogous schemes (those utilizing colors adjacent on the color wheel) create low key interest, due to the subtle differences inherent in this type of scheme. This scheme is recommended for areas where relaxation and reflection are desired.

3.9 Monochromatic or Analogous Color Schemes with Complementary Accents

The greatest range of contrast and interest is available through the use of complementary color accents to either the monochromatic or analogous color schemes. Care should always be exercised in maintaining a pleasing balance between these accent colors and the basic color scheme.

When complementary accents are employed, no more than three hues should be considered; most often a single hue varying in intensity or value is the most effective.

The use of complementary color accents can control the degree of excitement in any given space. A broad

application of complementary colors creates more excitement than will a limited application.

4.0 Psychophysiological Effects

The association of colors with definite mental conditions and moods is general, and much has been written on the psychology of color. No absolute relationships have been established, and the subject is open to individual interpretation. However, research has shown that certain general reactions are common to most people. Thus, yellow is considered a warm color and blue a cool color.

No specific psychological responses to color will be presented here. General information is presented as a basic guideline in color planning.

Obviously, reflectance values of colors are important in planning areas where sight requirements are high; low reflectance values are sufficient where sight is not an important requirement in the accomplishment of work tasks. Reflectance values should therefore be considered in these areas.

Colors affect perception of space and are capable of creating different feelings and moods. The simplest of these considerations is discussed below.

4.1 Spatial Perception

Color affects the apparent size of objects and their position in space. Warm colors (reds, oranges, yellows) are advancing colors, and cool colors (blues, greens, purples) seem to recede in space. As these hues are muted their effects upon position diminish.

When a small colored area is surrounded by other colors, intense red is the most advancing color and dark blue and black are the most receding.

When color is applied to a large area such as the walls of a room, black and dark red are the most advancing colors;

white and light blue are the most receding colors. Intense colors mixed with black tend to advance, making rooms seem smaller; intense colors mixed with white tend to recede making a room seem larger.

4.2 Psychological Effects

See Table below for psychological effects of various colors.

Table II-D-1

PSYCHOLOGICAL EFFECTS OF HUE

PSYCHOLOGICAL EFFECT	HUE	CONTRAST
Exciting	Bright Red Bright Orange	High
Stimulating	Red Orange	Moderate
Cheering	Light Orange Yellow Warm Gray	Moderate
Neutralizing	Gray White/Off-White	Low
Retiring	Cool Gray Light Green Light Blue	Low
Relaxing	Blue Green	Low
Subduing	Purple	Moderate
Depressing	Black	Low

5.0 Application of Color Standards

5.1 Reference

Color schemes as presented herein have been developed from the Ostwald Color System in order to communicate color implementation to the handbook user.

This system is broadly used, but is by no means intended as a sole source. As with any system, there are certain

inherent limitations in expressing all nuances of color. Color variants which present themselves at various design stages should be handled on an individual basis.

5.2 Usage and Implementation

This paragraph presents, in general terms, the procedure to be followed in establishing a color scheme for a specific area. In an actual working situation, an activity area (particularly a combined activity area) must be thoroughly defined in terms of mood (s) desired prior to selecting a color scheme.

Table II-D-2 has been developed to define, in general terms, desirable and undesirable psychological moods in various areas. Table II-D-1 is then employed to select the hue which will best evoke the desired mood.

Having assigned a hue, the intensities and values should be considered next. High intensity hues are used to create a stimulating atmosphere and low intensity hues are used to create a relaxed atmosphere (see para. II-D-3.2) The value of the hue to be applied will be dependent primarily upon the level of illumination required. The use of light values with dark values creates contrast. Value contrast should be high for areas where an exciting atmosphere is desired and low for areas where a dignified or relaxed atmosphere is desired (see para. II-D-3.3).

The color schemes presented are intended to serve as a guideline only. These do not represent specific standards but are generally acceptable color schemes for the designated areas.

Monochromatic and Analogous Color Schemes are included; in addition, Complementary color Accents are provided for both schemes.

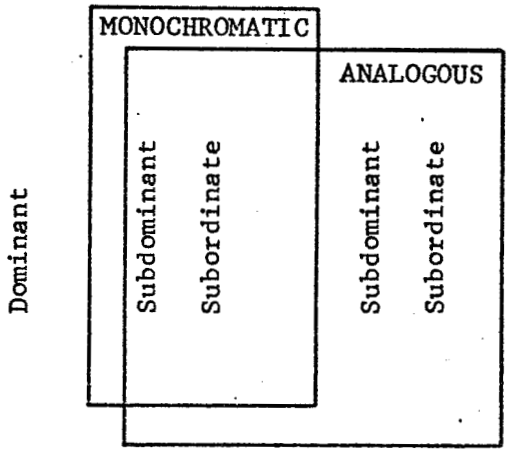
Table II-D-2

PSYCHOLOGICAL EFFECTS OF COLOR UPON HABITABLE AREAS

		EXCITING	STIMULATING	CHEERING	NEUTRALIZING	RETIRING	RELAXING	SUBDUING	DEPRESSING
PRIVATE	Crew Compartments			X	O		X	O	O
PUBLIC	Dining Room			X			X	O	O
	Lounge			X			X		O
	Recreation	X	X						O
	Library	O	O		X		X	X	O
	Study	O			X	X			O
	Conference		X						O
	Passageways				X			O	O
	Chapel	O	O			X	X	X	O
	Gym	X	X			O	O	O	O
	Locker Room			X		O	O	O	O
	Theater		X					O	O
	Briefing Room		X					O	O
SERVICE	Galley			X					O
	Snack Bar			X	O				O
	Bathroom		X	X	X		X		O
	Dispensary			X			X		O
	Laundry				X				O
	Barber Shop			X			X		O
WORK	Equipment				X				O
	Maintenance				X				O
	Power				X				O
	Storage, Food				X				O
	Supply				X				O
	Control Room	O	O		X				O
	Communications	O	O		X				O
	Computer	O	O		X				O
	Shop	O	O		X				O
	Offices	O			X				O
	Laboratories	O			X				O
	Docking	O			X				O
	Photographic Support				X				O
	Animal Housing				X				O
	Agri. Study Area				X				O
	Air Locks	O			X				O

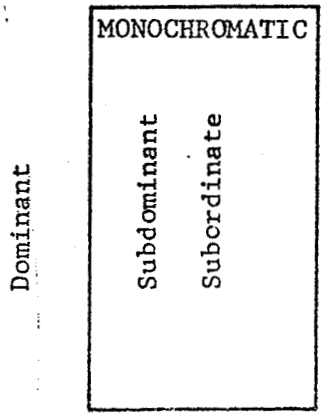
Legend: X = Desirable Effect
O = Undesirable Effect

The following charts have been prepared in a combined format since certain of the colors are shared by both monochromatic and analogous schemes. Complementary accents are provided for each scheme. The dominant color remains constant throughout.



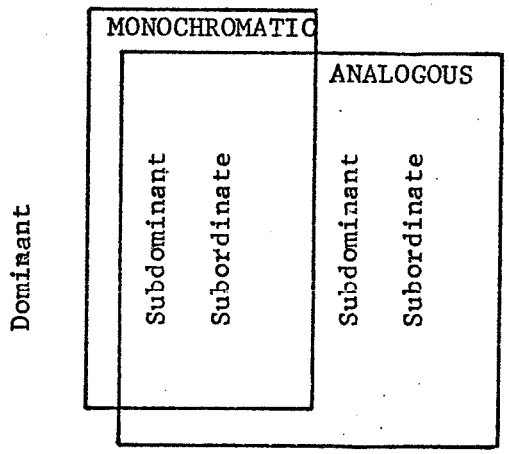
5.2.1 Monochromatic Color Scheme

The Monochromatic Color Scheme consists of the Dominant Color, the Subdominant Color and no more than three of the Subordinate Colors:



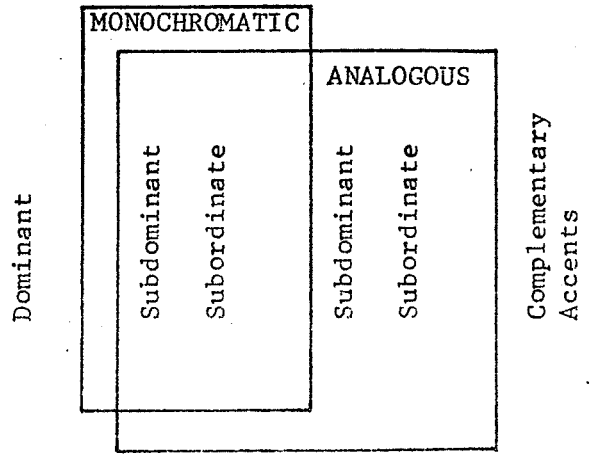
5.2.2 Analogous Color Scheme

The Analogous Color Scheme utilizes the same Dominant Color; the Subdominant Color may be selected from either the Monochromatic Scheme or from the Analogous Scheme. Subordinate Colors may be selected from either category, as well. (Subdominant and Subordinate Colors may be intermixed in any combination to produce an Analogous Color Scheme). Obviously, selection of colors solely from Monochromatic category would result in a Monochromatic Scheme.



5.2.3 Complementary Color Accents

Complementary Color Accents are provided for both Monochromatic and Analogous Color Schemes. Selection of these accent colors should be made with great discretion and should never exceed three in number.



5.3 Informational Color Application

The United States of America Standards Institute recommends that the following colors be utilized in connection with accident prevention, the marking of physical hazards, the location of safety equipment, and the identification of fire and other protective equipment, etc.

Red: Red shall be the basic color for identification of:
(1) Fire protection equipment and apparatus
(2) Danger
(3) Stop

Orange: Orange shall be used to designate exposed unguarded hazards, such as:
(1) Inside of transmission guards for gears pulleys, chains, etc.
(2) Exposed parts (edges only) of pulleys, gears, rollers, cutting devices, power jaws, etc.
(3) Safety starting buttons

Yellow: Yellow shall be the basic color designating caution
(1) Waste containers for explosive or highly combustible materials.
(2) Caution Signs
(3) Piping Systems containing dangerous materials.

Green: Green shall be used as the basic color designation for safety and the location of first aid equipment.

Blue: Blue shall be the basic color for designation of caution limited to warning against the starting the use of, or the movement of equipment under repair or being worked upon.

Purple: Purple shall be the basic color for designating radiation hazards.
(1) Rooms where such material is stored or handled.
(2) Disposal cans for radioactive material
(3) Contaminated equipment
(4) Signal lights which indicate when radiation-producing units are in operation.

Color coding standards for marking fluid lines and valves for military equipment are as follows:

Red:	Fuel
Green, Gray:	Rocket Oxidizer
Red, Gray:	Rocket Fuel
Red, Gray, Red:	Water Injection
Orange, Green:	Inerting
Yellow:	Lubrication
Blue, Yellow:	Hydraulic
Orange, Blue:	Pneumatic
Orange, Gray:	Instrument Air
Blue:	Coolant
Green:	Breathing Oxygen
Brown, Gray:	Air Conditioning
Yellow, Orange:	Monopropellant
Brown:	Fire Protection
Gray:	De-Icing
Yellow, Green:	Rocket Catalyst

Orange: Compressed Gas

Brown, Orange: Electrical Conduit

White: All other

The Interstate Commerce Commission requires that dangerous products be marked in the following manner when being shipped.

Red letters on white background:
(1) Poisons
(2) Explosives
(3) Poisonous gases
(4) Tear gas

Black letters on green background:
(1) Compressed gases

Black letters on red background:
(1) Inflammable liquids

Black letters on Yellow background:
(1) Inflammable solids
(2) Oxidizing materials

Black letters on white background:
(1) Acids

The above list is by no means complete. Many color codes exist within specific industries for designation of certain materials and operating conditions.

II-E VOLUME

1.0 Introduction

The volumetric objective of this study was to define the minimum desirable volume for specific activities as related to mission parameters. Specifically, the study addressed itself to developing standards for extraterrestrial habitats, in which the average person could work, sleep, eat and relax comfortably and efficiently over long periods of time.

This study therefore represents a departure from many past studies directed at developing volumetric guidelines of manned space flight in that it concerns itself with average individuals in no special combinations rather than exceptionally fit (mentally and physically) individuals and ideally matched groups. The objectives are clear; that the habitability should be such that individuals (scientists) could be selected on their professional qualifications alone without undue regard for their physical or emotional makeup.

Insufficient data exist to determine what minimum desirable standards are, therefore, the reader must recognize that the volumetric recommendations developed should be used as guidelines only and do not represent fixed standards. The unknown figures include not only total volume but also the apportionment of volume.

It is probable that within any randomly selected highly talented group of professionals, a high percentage of dominant types would exist. Confining such a group in very tight quarters could possibly lead to considerable interpersonal stress. It is because of these potentially stressful situations that the adequate and appropriate division of space becomes so critical. This is not to say that adequate volume alone will make a space habitable. One factor which is impossible to determine at this time is that of leadership which some behavioralists consider to be one of the most important single

factors in determining group response, effectiveness and morale.

A factor which can be affected by the designer and is common to all confined habitats from Arctic camps to submarines and experimental simulation, is the monotony of the environment. This sensual boredom seems to have less to do with volume of space (assuming a baseline of acceptability) than it does with the treatment and geometry of that volume, the boredom that sets in after an extended period of confinement appears to be one area in which existing confined habitats are the least successful in solving. In this area lies a challenge to the designer to develop a habitat which will, to the maximum extent possible, provide for some degree of change in the physical environment of the habitat. The need for change is discussed further in the sections on lighting, acoustics, color, texture and dual room usage, sections A, B, D, F and H respectively.

Using what may be considered an additive approach to determining total volumes, general volumetric guidelines have been developed for all those activities for which the volumes are not mission-equipment related. That is, recommendations have been developed for only those areas in which all furniture could be defined. These areas are:

1. Crew quarters
2. Bathrooms
3. Dining Room
4. Conference/Briefing Room
5. Chapel
6. Theater
7. Lounge
8. Library
9. Gym
10. Locker Room
11. Barber Shop
12. Dispensary
13. Office
14. Passageway

Schematic layouts illustrating acceptable layouts as well as various activity-related key dimensions, appear in section III.

While it has been the intent of this study to determine extraterrestrial volumetric needs, the recommendations are presented in terms of square feet of floor space and ceiling height requirements. This has been done to facilitate visualization of the recommended volumes. For instance, it is easier to visualize a 100 square foot room with a 7 foot ceiling than it is to visualize a room with a volume of 700 cubic feet.

As a general rule, it is recommended that volumetric provisions for individual activity areas such as dining sleeping, etc., increase in a direct arithmetic progression in relation to crew size. In other words, a dining room designed to support a crew of 15 should double in size to support a crew of 30 in a similar fashion.

In regard to the total volumetric needs of the overall station, it is recommended that the total space provided for activities other than work be expanded by more than an arithmetic amount when the crew size is increased substantially and an increase in station volume should accompany a substantial increase in mission duration. These recommended increases are a direct result of the increased need for compartment specialization experienced with longer missions and larger crew sizes. This is explained in more detail in paragraph II-E-4.3.2.

2.0 Definition

2.1 Gross Area

Gross Area is the approximate area required to attain the minimum tabulated net area. Gross area is found

by deducting only large ventilation trunks, access trunks and other similar items. No deduction should be made for normal access ladders or main passageways within the space. This area represents the entire wall to wall area.

2.2 Area per Man

Area per man refers to the numerical figure arrived at by dividing the gross area of a space by the number of occupants the space is designed to hold.

2.3 Net Area

Net area is defined as deck area that can actually be walked upon. Deck area occupied by trucks, hatches fixed berths, lockers, installed furniture, etc., excluded.

2.4 Visual Space

Visual area is the amount of space visually perceived as usable. This space is related to physical objects in a room (e.g., furniture and partitions) and the placement of these objects relative to the observer's eye level (sitting and standing). For example, a 7 foot long X 3 foot wide X 5 foot high bunk bed placed against the wall in a 7 foot X 7 foot X 7 foot room appears to make the room look smaller. On the other hand, a single low bed 7 feet long, 3 feet wide and 18 inches high, placed against the wall in the same 7 X 7 room does not significantly reduce the visual area of the room.

Room and Furnishings	Area (Square Feet) Gross	Net	Visual
7 X 7 No furniture	49	49	49
7 X 7 Low Bed	49	28	49
7 X 7 Bunk Bed	49	28	28

2.5 Minimum Desirable Volume

That volume provided for a specific activity which man will perceive as adequate.

A minimum desirable volume provides adequate space to support the dynamic envelope man describes in performing the activities related to that space, the volume in which man feels comfortable in regard to distance between himself and others, and the volume which man visually perceives as adequate during all activity conditions.

3.0 Factor Detail Discussion

3.1 Gross Area

Gross area represents the total area occupied by an activity and is useful in tabulating the overall station volumetric requirements. Because gross area takes in all of the area occupied by built-in furniture, storage units and the like, it is not a useful figure for visualizing the usable area in space.

3.2 Area Per Man

Since this figure relates to the number of occupants a space is designed for, it is useful in figuring area requirements for public areas and other areas in which the number of occupants determines the spatial requirements of the room.

3.3 Net Area

This figure is especially relevant in those areas which are occupied for extended periods of time and are of limited size (e.g., offices and private quarters).

3.4 Visual Area

Like the net area this area consideration is especially important in small areas in which people are likely to spend a considerable amount of time, such as private quarters and [illegible] space.

3.5 Minimum Desirable Volume

The perception of space as adequate, small, large, etc. is a subjective response to an area based on a number of factors, among them being:

1. Kinesthetic response
2. Interpersonal or social response
3. Visual response

3.5.1 Kinesthetic/Anthropometric Spatial Requirements

Kinesthetic and anthropometric spatial requirements refer to the size and shape of a space required to contain both "point" and "transfer" body movements related to specific tasks in both an artificial gravity and a zero gravity environment.

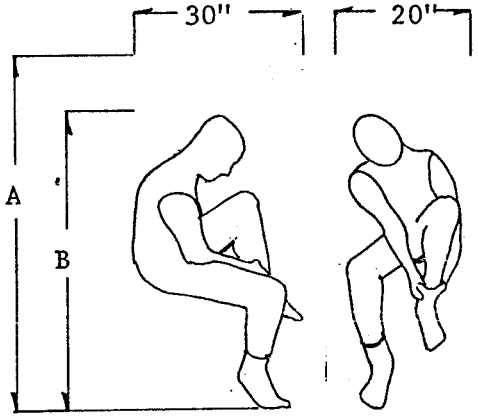
3.5.1.1 Point Movement

That movement occurring at a fixed point of restraint or positioning such as movement related to the act of putting on a pair of socks as illustrated in Figure II-E-1.

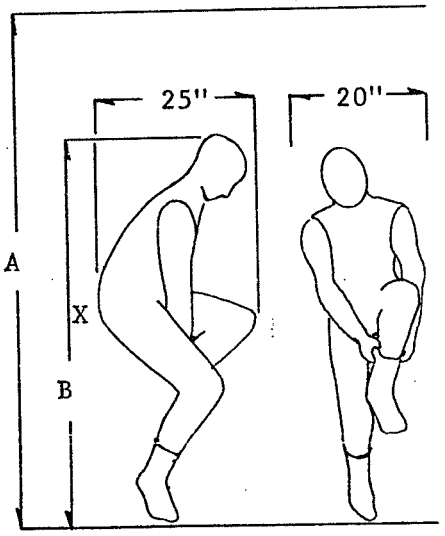
3.5.1.1.1 Effect of Gravity Level on Point Movement Spatial Requirements

Point movement spatial requirements established in a gravity environment will most likely prove sufficient in zero gravity. However, as illustrated in Figure II-E-1, point movement spatial standards established in a gravity environment may prove to be extravagant in some cases if used to establish zero-gravity spatial standards.

Figure II-E-1
Point Restraint Area
Requirement



Putting on Socks: 50% Male
Seated - Artificial Gravity
A-54" Seated Erect
B-45" Seated Crouched

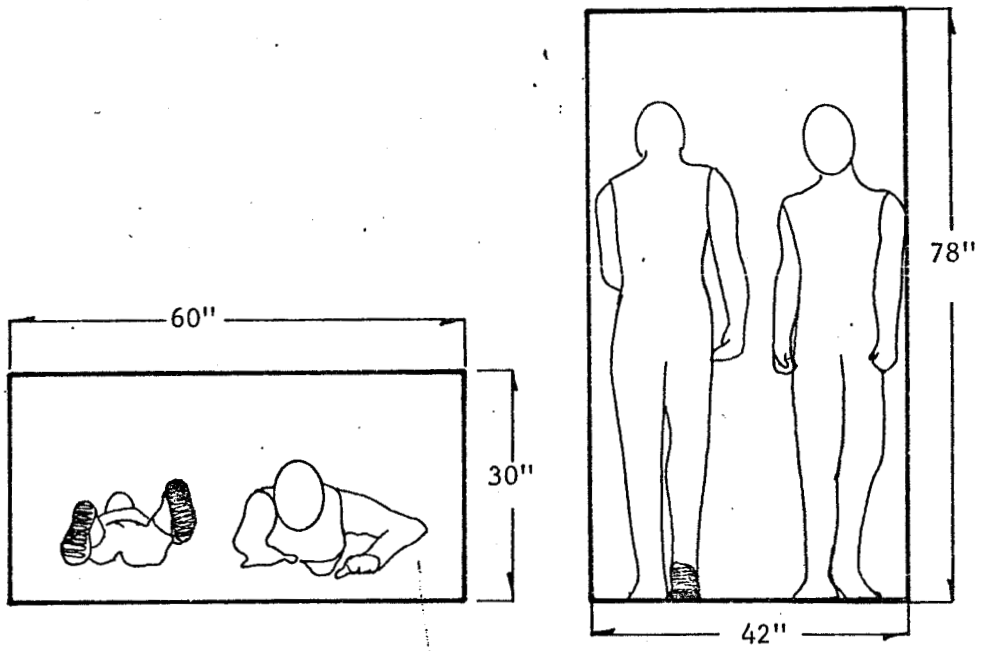


Putting on Socks: 50% Male
Waist Restraint - Zero Gravity
A-70" Standing Erect
B-60" Standing Crouched
X - Point of Restraint

3.5.1.2 Transfer Movement

That movement occurring during bodily transfer from one point to another. Each type of activity requires that a certain amount of space be provided to contain the related movements. It is this type of movement which determines minimum widths for passageways and establishes the minimum distance between chair backs in a dining area.

Figure II-E-2
Passageway Area Requirement



Zero-Gravity Artificial-Gravity

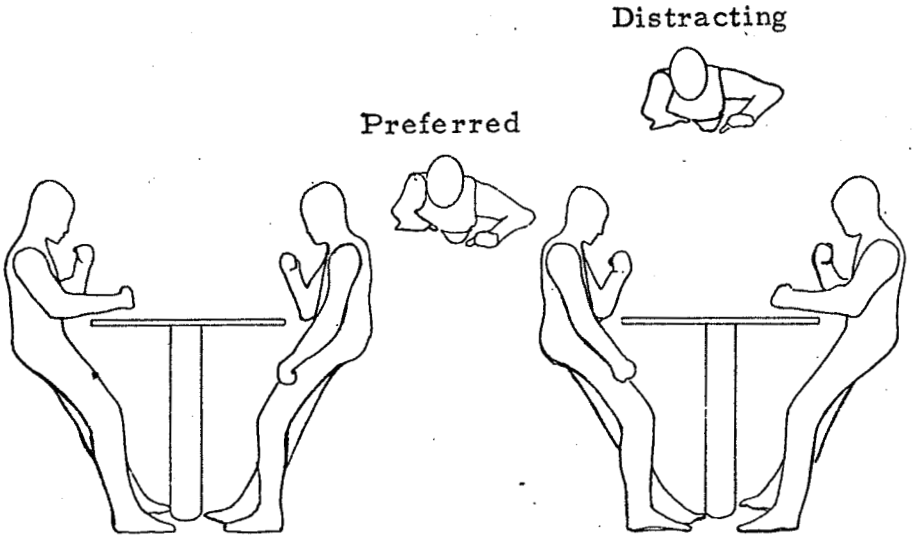
3.5.1.2.1 Effect of Gravity Level on Transfer Movement Spatial Requirements

As illustrated in figure II-E-2 it appears that an enclosed 30" X 60" passageway will be sufficiently large for two way traffic in a zero gravity environment. This figure is substantiated by both operational (Apollo) and simulated missions. This represents a 45% reduction in volume over an

acceptable artificial gravity two way passage. For extended open area transfer, to facilitate what appears to be the most natural type of movement, that is, head first "push off and glide", and to minimize the possibility of collision between people in motion and people restrained, it is recommended that straight aisles 30-60 inches wide be provided between all obstacles such as restrained people or tables. This recommendation is based on zero-G parabola experience. This degree of table separation in areas such as the dining room has the additional benefit of maintaining a degree of audio privacy between tables.

While it is not recommended that traffic be directed overhead it is recognizable that traffic patterns should be high enough to allow individuals to pick up visual cues for seat selection. This concept is illustrated in figures II-E-3.

Figure II-E-3
Zero Gravity Open Area Transfer



The best arrangement is to provide individual personal quarters for each crew member; any other arrangement has inherent disadvantages. It is, in fact, recommended that private quarters be provided for the individual even at the cost of a reduced spatial enclosure. It is recommended that the rooms should provide a minimum of approximately 38 square feet of visual area. This recommendation is based on the premise that the crew quarters support the following six activities; sleep, private relaxation, limited social relaxation, personal work, personal storage and limited grooming. Depending on the arrangement of the room the gross area requirement would be about 45-50 square feet.

Because of the lack of data regarding the interpretation of visual space in zero gravity it was not possible to develop a recommended minimum desirable size for a zero gravity private room. It is probably safe to assume that a private room which is adequate in a gravity environment will be adequate in a zero gravity environment.

When there is no alternative but multiple occupancy in personal quarters, it is best that the number of crew be in even increments rather than odd, i.e., 2, 4, 6, 8, rather than 3, 5, 7, 9. Group studies have indicated that these even patterns reduce the chance of the "ODD MAN OUT" condition to occur. It is essential that partitions or curtains be provided that ensure privacy as well as territorial definition of the individual's personal space. Also, the prior selection of particular crew members to share quarters will be required since interpersonal adaptation can be a problem in the sharing of personal quarters.

The following gross area requirements were developed providing each individual in the room with the same furniture and storage equipment that he would be provided within a private room. Additional spatial economy could be realized by reducing individual furniture standards. For instance, the desk could be shared by two people.

3.5.2 Social Spatial Requirements

The standards recommended herein have been established so that interpersonal contact may occur at the social range established by behavioralists as comfortable to individuals in our society. It is felt that contact at personal and intimate distances should be a matter of choice rather than an imposed necessity. Examples of the application of these standards may be seen in the recommended sizes for crew quarters which provide adequate space for limited socializing.

3.5.3 Visual Spatial Requirements

A space will usually be visually perceived as adequate if sufficient room is provided for movement and comfortable social interaction.

4.0 Psychophysiological Effects

4.1 Privacy Requirements of Crew Quarters

Crew quarters designed to accommodate more than one crewman must take into careful consideration the psychological factors of individual behavioral patterns. A fundamental need in man appears to be the provision for "territoriality" or in other words furtherance in the concept of possession of property and rights of ownership. The nature of the scientific personality operating in a new dimension of exploration who may be keenly possessive of his data and findings during their formative stages might be threatened by a situation in which other individuals invade his private sanctuary. If the function of the personal quarters is to serve more than simply a place to "sack out" during off-duty hours, it must take into account these human reactions. The term "personal quarters" must be in fact uniquely personal in the sense that this specific volume of space belongs to a specific individual for the duration of the mission. Active and outgoing personalities in opposition to introspective types can create untenable reactions that could have disruptive effects on the entire crew morale.

Men/Room	Square Feet/Man (Gross)
1	45-50
2	38
3	42
4	36
5	40
6	39
7	40
8	39
9	42

The savings realized by utilizing multiple occupancy quarters does not, in our opinion, justify their use in an extraterrestrial habitat.

4.2 Volume Requirements Related to Responsibility Level

For the purpose of this report, the crew would be organized into three levels of responsibility; command, line officers and working crew.

The private facilities volumetric recommendations for individuals at each level are illustrated and discussed in section III of the handbook and rationale book respectively. It is recommended that the commander's office and bathroom be located adjacent to his private room and therefore, because of their accessibility they will be considered a part of the commander's personal space.

It is recommended that, depending on the size of the crew, the deputy commander and line officers making up the management core of the station, be provided with direct access into semi-private or private bathroom facilities located adjacent to their bedrooms. It is recommended that, like the captain's sea cabin in the U.S. Navy, the

private room serve only as a bedroom and as a place for limited private work or discussions, and as such, it need be no larger for the captain than for any other crew member.

4.3 Spatial Requirements as Related to Crew Size and Mission Duration

4.3.1 Individual Activity Spatial Requirements

It is recommended that space provided for individual activities such as dining, sleeping, etc., as a general rule, increase in a direct arithmetic progression in relation to crew size. In other words, a dining area which was designed to support a crew of 15 men would double in size to support a crew of 30 men in a similar fashion.

Spatial standards recommended for the various individual activities are such that there will be no increase in spatial standards required as a result of increased mission duration. For example, a dining area which is considered as desirable for a 60-day mission would remain so for a 180-day mission.

4.3.2 Total Habitat Spatial Requirements

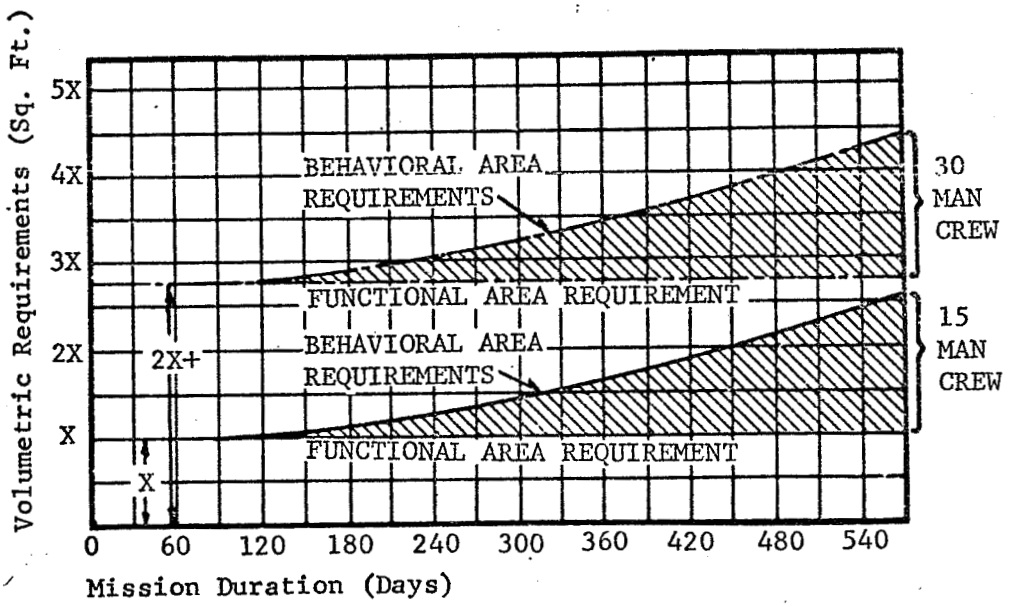
It is recommended that increased space be provided in the overall habitat as a result of a significant increase in mission duration and that more than a direct arithmetic increase in the overall habitat space be provided due to a significant increase in crew size. This increased need is illustrated in figure II-E-4. Hypothetical spatial requirements are shown for habitats containing 15 and 30 men.

The reason for the increased area requirement is that there exists an increased need for compartment specialization as crew size and/or mission duration increase. This splitting off of activities into separate compartments results in an increased level of sensual stimuli required by extended mission duration and reflects the increased complexity in scheduling activities for larger crews.

For example, an area in a 20 man habitat which as its main function supports the activities of lounging, training conferences, theatre, passive recreation and snacks, will become less effective as mission duration increases (same sized crew) or as the crew size increases.

The historical trend for habitat activity areas to become increasingly specialized as mission duration and/or crew size increase is discussed in section H on Dual Room Usage.

Figure II-E-4 Overall Station Volumetric Requirements as a Function of Crew Size and Mission Duration



Increased Behavioral Area Due to Specialization.

NOTE: Specialization refers to physical separation of activities which may have formerly occupied a "Dual Room Usage" area.

4.4 Effect of the Location of Living Quarters to Work Area

It is recommended that crew compartments be located at a distance from the work areas for the following reasons:

a) Enforced social interaction

Locating the personal quarters at a distance from the work area will have the effect of combating any tendency for individual isolation to occur by forcing individuals to pass through other activity zones.

b) Provide change of environment

Variety of spatial experience that should occur during transit from one area to another is desirable as semsory stimuli providing the "change of pace" between the schedule of activities.

The determining factor of proximity between an individual's crew compartment and his work station should be based on:

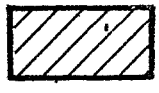
a) Responsibility for critical decision making
b) Under emergency conditions--what are the minimal time limitations for decision making.

These factors will have to be determined according to the individual requirements of station configuration, crew size and mission responsibility.

5.0 Application

The volumetric standards recommended in the crew area criteria section may be utilized in the early planning stages to establish approximate volumetric figures for the off duty areas only. It should be realized that these figures are based on rectangular shaped rooms. Because of the unusual geometry of some of the spaces resulting from the relationship of the space to the vehicle pressure shell, the desirable gross area recommendations will not always prove sufficient. Additionally, the degree of spatial

efficiency and the resulting volume of dual room usage combinations must be studied on an individual mission basis to accurately determine acceptable area standards. Ideally, these combinations should be studied in full scale mock-ups to evaluate the spatial adequacy under all conditions of occupancy. To aid in the development of graphic layouts, select pieces of furniture are illustrated on the following pages with acceptable standard dimensions where appropriate. In addition to the furniture dimensions, the related net or clear floor area is also shown as illustrated below. These figures may be used to develop dimensionally acceptable furniture relationships within the area being studied.



Clear floor area required relative to furniture elements (no passageway considerations).



Clear floor area required relative to furniture elements (passageway area).

No attempts have been made to specify exact furniture standards to be used in extraterrestrial habitats. Rather the information provided is of a fairly general nature and is based on only those basic units commonly found in a off-duty section of any habitat.

The graphic representations of the furniture units have been kept simple and so as to facilitate usability in a typical drafting situation.

For artificial gravity layout studies, arrows indicating the desirable direction of spin relative to furniture units are shown to the right of appropriate units.

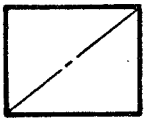
5.1 Graphic Symbols

5.1.1 General

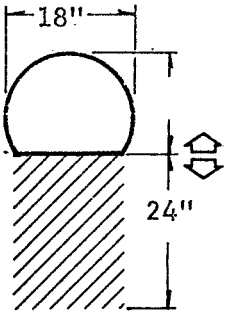


Spin Direction

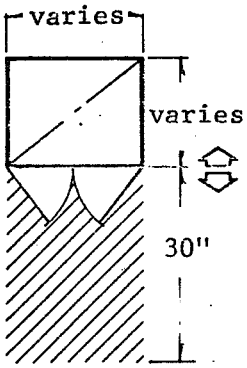
Spin Axis



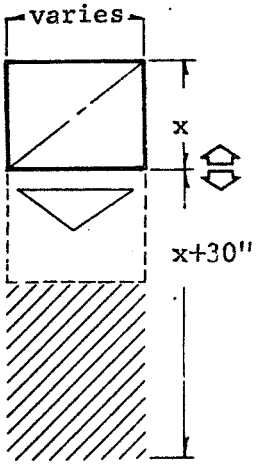
Storage Unit



Desk Chair
15"-17" height

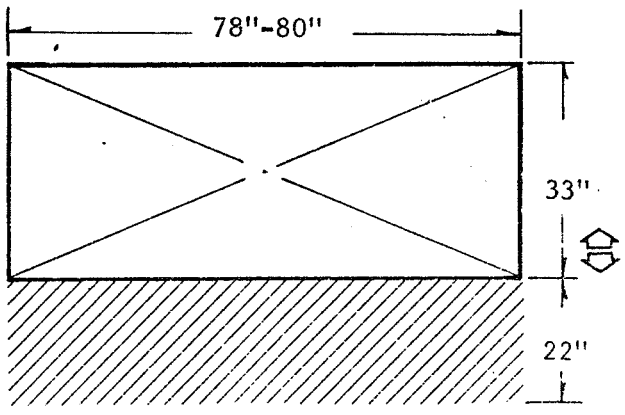


Cabinet Storage

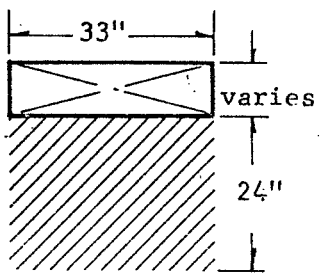


Drawer Storage

5.1.2 Crew Quarters

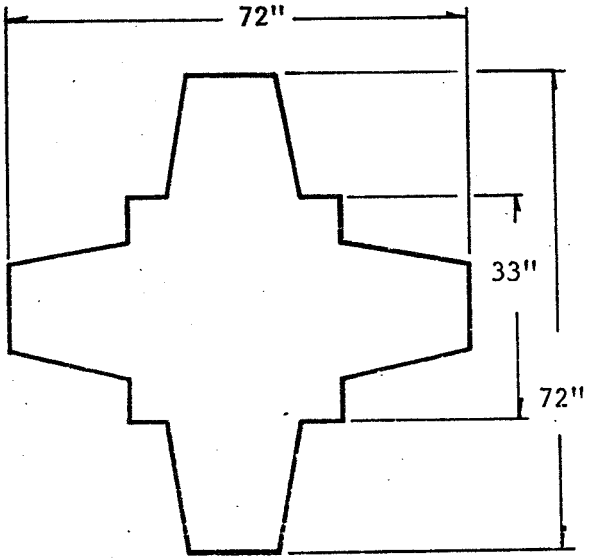


Berth
18" height

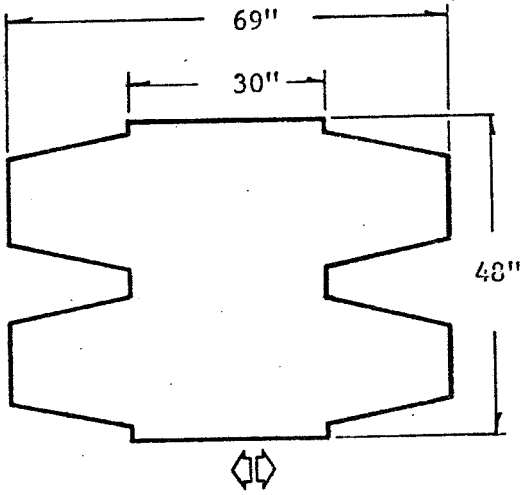


Vertical Berth
(Zero "G" only)
78"-80" height

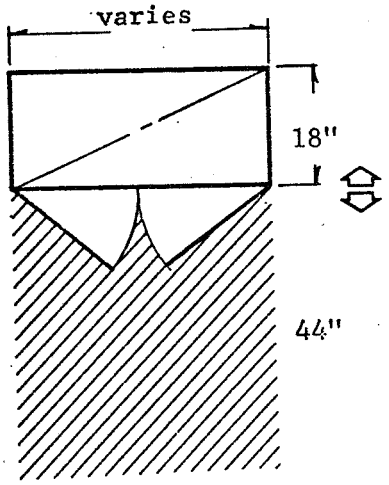
5.1.3 Dining Room



4-Man Table
(Non-coriolis)
30" height

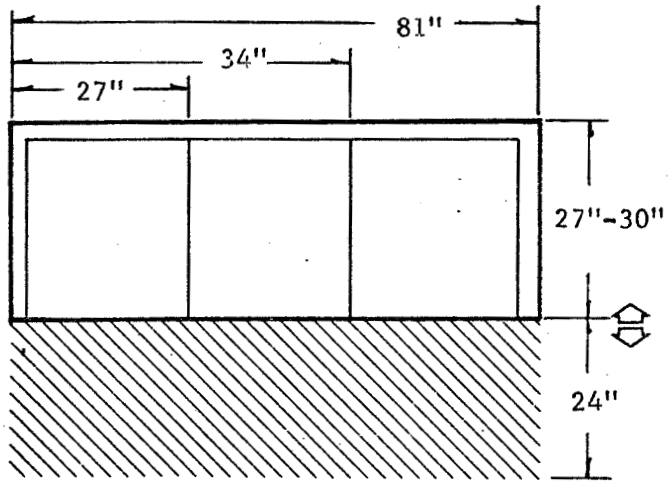


4-Man Table
(Coriolis)
30" height

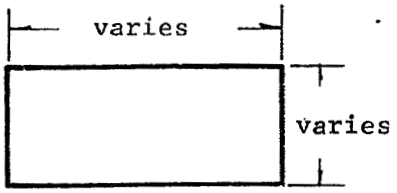


Storage Buffet/Serving Table
30" height

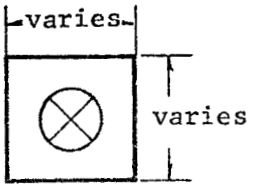
5.1.4 Lounge



1-3 Man Seat
15"-17" height

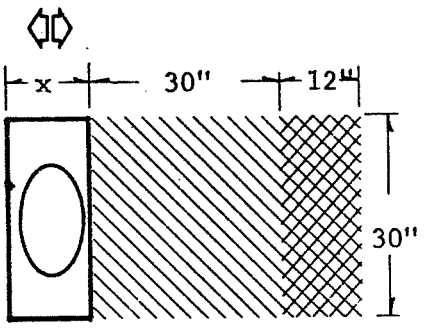


Varying Length Coffee Table
14"-16" height

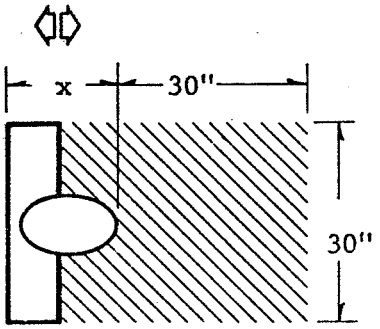


End Table
15"-20" height

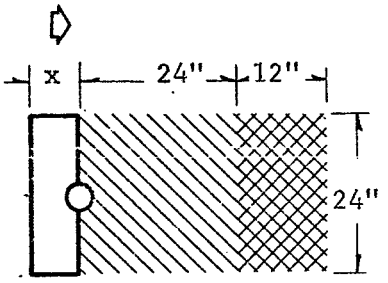
5.1.5 Bathroom



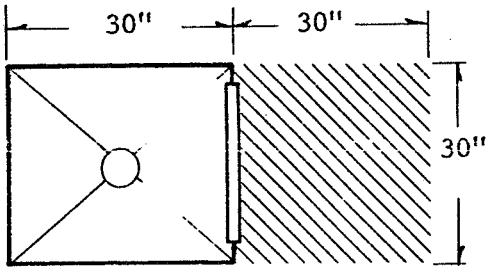
Sink
34"-38" height



Toilet
9"-13" height

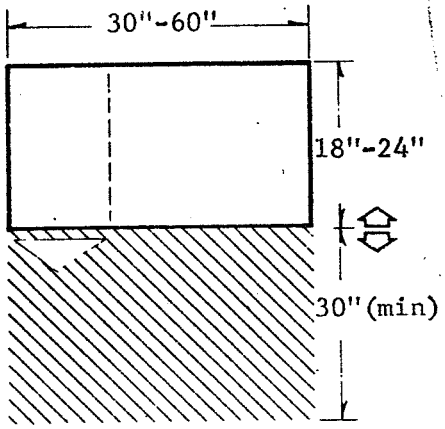


Urinal
24" height

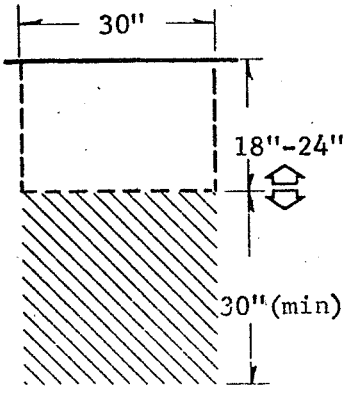


Shower

5.1.6 Study/Office



Desk with Drawer or File
30" height



Folding Desk
30" height

II-F TEXTURE AND PATTERN

1.0 Introduction

1.1 Texture produces the most common yet the least acknowledged sensory experience, that of tactile response. Textures produce such a common source of stimuli to us that we tend to take them for granted. Hence, very little objective data are available on the subject. Textures provide a very valuable means of replacing some of the stimuli which man may be deprived of in the extraterrestrial environment.

Virtually every part of the body is affected by one texture or another throughout the course of a day. The clothes we wear, the surfaces which surround us, every aspect of the environment has one or another quality of surface. Texture is appraised and appreciated almost entirely by touch, even when it is visually presented. With few exceptions it is the memorary of tactile experiences that enables us to appreciate texture.

1.2 Patterns

A pattern may be described as a two-dimensional or three-dimensional design put together in a particular arrangement of motifs. Motifs used for patterns may be natural, conventional, abstract or imaginary.

There is close correlation between pattern and texture; in fact, the difference is almost indiscernible, since every pattern creates a texture of some sort. Frequently this texture is only visual, since it does not have a tactile quality. We tend to think of pattern as basically visual and texture as something essentially tactile. The two are thus highly interrelated, and too clear a definition between the two may be misleading.

2.0 Definition

2.1 Texture

Simply stated, texture is the tactile surface quality of an object. It relates to or identifies the tactile reactions of man to the quality of the surface of materials such as smooth, rough, soft, hard, warm, cool, or the many other characteristic variations or combinations possible and available in today's materials technology.

2.2 Pattern

Patterns used in the context of this report are design motifs of two or three dimensions. These design motifs can be applied to various materials by a number of processes such as printing, silk screening and painting in a two dimensional form, or by molding, embossing, casting, or forming in a three-dimensional form.

3.0 Factors Detail Discussion

3.1 Texture

We generally think of texture in terms of roughness or smoothness, but our senses also discern between the hardness or softness of that object. Additionally, we anticipate that certain surfaces will be either warm or cool to the touch; we remember what a particular object should feel like. We expect a shaggy rug to be soft and warm, a metal surface to be smooth, hard and cold, etc.

Broad definitions of each type of surface texture are given following; these are relative terms, in order to make some distinction possible in discussion of various textures:

Rough

Absorbs light and makes colors appear darker than they are, due to shadows created. Rough textures are generally considered more rustic, and are, therefore less formal. Rougher textures are practical where hard wear is expected and generally can be considered to be humanizing in their effect. These textures broadly fall into the category of more natural type materials...deep wood grains, coarse fabrics or fibers, pebbled surfaces, etc.

Smooth

A smooth texture gives little or no decorative interest except for its color or pattern. Smooth surfaces tend to be cool-looking and are appropriate in spaces where cleanliness and function are of primary importance.

Very Smooth

The natural result of a very smooth surface is a high reflectance factor. Not to be used in any area where eyestrain could result. It should be noted that highly reflective surfaces can be used effectively in contrast with roughly textured surfaces to create variable visual interest. Particularly good for use on small decorative items.

In addition to these types of surface texture, the quality of the surface should also be considered:

Soft

Deep pile textures create a feeling of warmth and luxury and are most effective where the body comes into contact with the surface. Soft materials retain temperature and produce an inherent warmth. Absorption and retention of body heat over prolonged periods should be considered.

Hard

We visually tend to equate smooth surfaces with hard qualities. Also, we generally tend to expect such a surface to be cool. This can be modified with the use of color and roughness to produce the desired warmth.

3.2 Pattern

The proper use of patterns depends on the principles of good design, but special attention should be given to the effect of overall rhythm and color. Patterns generally have movement, and they should be used in the most effective 'flow' in the interior.

Patterns are primarily used to provide interest, contrast, variety, illusions of surface textures, space, height or length, or for design emphasis. Patterns may also be used for more functional purposes such as directional guides, sports or games.

In rooms where function is primary, such as kitchens, baths, and certain kinds of workrooms, patterns can be more daring or amusing as long as color and scale are appropriate. Surfaces or spaces adjoining patterned areas should be planned to harmonize, otherwise the spaces will not have unity and will not be pleasant.

It is most difficult to define specifics for application of patterns. The use of the properly selected patterns is related to so many variables that specifics are almost impossible to define. Discretion in application is the most important factor, and a sense of 'pacing' of busy areas related to less involved areas is important to build into planning. It will sometimes be possible to incorporate decorative interest into those areas where friction and grip requirements exist, rather than treating these requirements separately.

4.0 Psycho-physiological Effects

All tests to date within confined areas (regardless of volume) have produced a common result. The need for sensory stimuli of a variable nature is extremely important. Particularly necessary are those objects or surfaces which produce a "humanizing" influence on the environment. Plants, wood grains, and soft carpeted surfaces are indicated as major psycho-physiological factors in overcoming normal sensory deprivation.

Texture can create sensory variants within a fixed area. All the senses of man have the characteristic of adaptation to stimuli impinging on them - hearing organs adapt to a fixed noise level; eyes adapt to fixed intensity levels, etc. Our sensory apparatus responds best to a varying sensory environment, and variation in surface quality provides a simple method of achieving this. Thus, texture and pattern represent very valuable tools in the creation of a

habitable environment. Touch is the most personal of all sensory stimuli, and as such is a major psychological aspect of the environment.

Certain psycho-physiological relationships can be noted for use in application of textures or patterns. A number of relationships are indicated in Chart II-F-1; these are general in nature and should be used for basic guidance only.

Chart II-F-1 Types and Effects of Textures and Patterns

Basic Type	Psycho-physiological Relationship
Large	Tends to make spaces appear smaller than they actually are. Large bold patterns are stimulating and seem to make time go slower. Good for recreation dining, snack bars, etc.
Small (Directional)	When used on walls, small vertical patterns tend to increase the apparent height of ceilings, while horizontal patterns tend to lower the apparent ceiling height. The small pattern should be used in spaces where neat symmetry and quietness is desirable, such as a bedroom or study.
All-Over (Non-directional)	Tends to camouflage jogs in walls and unify odd-shaped spaces. Should be used in conjunction with solid colors, since other patterns used in the same space would compete for dominance.
Mural or Scenic	Gives illusions of space, such as mountain scenes, countrysides, gardens. Used to carry the eye out and away from enclosing walls. Very restful, used most effectively in small confined spaces. Essentially a deceptive device, and not intended to really fool the observer. Should be used with great discretion.

Copies (and) Natural Materials	Woods, stones, brick, leather, etc. may be either imitaion or natural materials. Textures and patterns of natural materials create feelings of warmth and well-being and are associated with home and earth. Good for studies, lounges, libraries, etc.
Textured Patterns	These patterns have a three-dimensional appearance, such as woven threads or fibers. They are usually found in neutral tones that give variety without adding color or strong pattern. Can be used effectively in work spaces, libraries, offices, etc.
Borders and Stripes	Provides vivid color or accent motif where fully patterned wall would be too strong. Used primarily for accents.

5.0 Application

The functional applications of texture (or pattern) are fairly obvious - providing non-skid surfaces where necessary, providing for grip surfaces, etc. Smooth textures should be used in those areas which have cleanliness as a primary consideration - personal hygeine areas, laboratories, galleys, etc.

Where smooth surfaces are desirable, their appearance can easily be modified by the application of any pattern to the surface, so that cleanliness can easily be accomplished without sacrificing visual effectiveness.

Textures and patterns should be applied with great discretion, and in conjunction with all other interior disciplines. Other factors can affect a texture or pattern significantly. Light, for example, placed at a severe angle to a textured surface, will greatly enhance the textural quality, as the shadows created magnify the illusion of the texture. Similarly, placing a dark color in the recesses of a texture or pattern and a lighter shade on the foremost surface achieves a greater illusion of depth.

II-G HYGIENIC AND MESSING FACILITIES

1.0 Introduction

The hygienic and messing facilities provided on a spacecraft are important not only from the standpoint of crew personal cleanliness, but also because of psychological and social considerations. A situation where personal hygiene is largely neglected can be tolerable for limited time periods for small crews. Makeshift eating arrangements are acceptable for the same conditions. For the anticipated future mission profiles, however, functionally distinct and more permanent facilities are required.

With larger crews performing a variety of tasks in many different locations in the vehicle, the arrangement of hygiene facilities, the type and number of facilities required, and the dining seat arrangement will vary according to the specific mission profile. General standards have been established by considering those profiles and by analyzing expected usage rates and periods.

Data pertaining to hygienic facilities required for internal body waste elimination, full body cleansing, and various external surface activities concerned with personal hygiene are presented in this section. Use ratios for the various hygienic facilities and design considerations are also included in this section. Classification of spaces into basic occupancy groups has been employed as a means of determining more precisely the numbers, types and locations of hygienic facilities.

Hygienic facilities concerned with general housekeeping, medical, dental, or laboratory functions are specialized areas that are beyond the scope of this section. Also, mess provision data pertaining to types of food preparation equipment, food storage, menus, or refuse disposal are beyond the scope of this section.

2.0 Definitions

2.1 Persons

As used in this section, the term persons refers to both men and women. Separate hygienic facilities are to be provided for each sex unless noted otherwise.

2.2 Occupancy Group

The term occupancy group refers to the basic purpose for which a space is to be used. Occupancies are classified into five basic groups: 1) assembly spaces, 2) living spaces, 3) work spaces, 4) food preparation and serving spaces, and 5) service spaces. See Table II-G-1 for detailed classification of occupancy groups.

Table II-G-1 Occupancy Classification

Occupancy Group	Description of Occupancy
Assembly Spaces	Places of worship, auditoriums, theaters, etc., where persons congregate for periods of one hour or more
Living Spaces	Sleeping compartments, lounges, studies, libraries, dormitories, recreation rooms, etc.
Work Spaces	Control rooms, offices, laboratories, shops, computer rooms, communications, etc.
Food Preparation and Serving Spaces	Kitchens, galley, snack bars, food storage, dining rooms
Service Spaces	Laundry, supply, equipment, power, storage, etc.

Note: Medical and dental spaces are not included in any occupancy group. Special criteria and requirements for hygienic facilities will be established by the organization having control over the standards for design of these spaces.

2.3 Maximum Fixtures Per Person

As used in the graphs, maximum fistures per person refers to a ratio of fixtures to persons that would result in a low to

moderate usage of fixtures. There would be little or no waiting time or inconvenience even during "peak" period.

2.4 Optimum Fixtures Per Person

As used in the graphs, optimum fixtures per person refers to a ratio of fixtures to persons that would result in a moderate to high usage of fixtures. One could expect some waiting and inconvenience during "peak" periods.

2.5 Minimum Fixtures Per Person

As used in the graphs, minimum fixtures per person refers to a ratio of fixtures to persons that would result in a high usage of fixtures with an anticipated moderate to high inconvenience factor, due to waiting for fixture during "peak" or "rush" hours. Some waiting or inconvenience might be expected during off-peak hours.

2.6 Personal Hygiene Module

A personal hygiene module is a facility or space that contains individual personal items such as mouth care equipment, shaver, mirror, hairbrush, comb, nail clipper and file, deodorant, hair dressing, shampoo, soap, first aid, towels, etc.

2.7 Classification of Occupancy Groups

Table II-G-1 has been prepared to define the occupancy groups.

2.8 Watercloset - A fixture or receptacle in which a person can defecate or urinate. The fixture must dispose of, or flush away, the waste matter.

2.9 Urinal

A fixture or receptacle in which a person can urinate. The fixture must dispose of, or flush away, the waste matter.

2.10 Lavatory

A bowl or basin designed specifically for washing the face or hands.

2.11 Dental Lavatory

A small lavatory designed specifically for oral hygiene functions such as brushing teeth, mouth wash, etc.

2.12 Shower

A fixture or facility for full-body cleansing under a spray of water or other suitable liquid.

3.0 Factors Detail Discussion

In establishing the hygienic facilities standards, the usage rates of the facilities were considered. The normal micturation rate is six per man per day at one-minute per event and the normal defecation rate is one per man per day at five minutes per event. These figures indicate the large rate at which facilities could be used if necessary.

Usage periods were also considered in establishing the facilities standards. Since twelve to sixteen hours will be spent each day in the living spaces, the facilities in these areas will get the most usage. The daily defecation and three or four urinations will probably occur in these areas over widely spaced periods throughout the day. Two other micturations should occur in work spaces and one other micturation may take place in the other occupancy areas. Hygiene facilities in food preparation and serving spaces or assembly spaces will experience periods of very heavy use between periods of little or no use.

The dining area must be capable of seating certain percentages of the total crew at any one time. For small vehicles and minimum crews, this percentage is at or near 100 percent; that is, the complete crew could eat at one time. As vehicle and crew sizes increase, the required seating percentage decreases

until, for a crew of 100, the optimum dining seat requirement is 60 seats and the minimum is 40 seats. Consequently, eating periods for larger crews will be staggered in order to minimize the required dining space.

3.1 Design Considerations

Personal hygiene can be distinguished between activities concerned with internal waste material elimination, full body cleansing, and various external surface activities. See Table II-G-2 for general classification and arrangement.

Table II-G-2 Hygiene Requirements

Classifications	Activities	Arrangement
Internal Waste Elimination	Urine Elimination Fecal Elimination	Individual privacy required
Full Body Cleansing	Bathing	Individual privacy highly desired
External Surface Activities	Washing Hands Washing Face Hair Grooming Shaving Oral Hygiene	Individual privacy desired but may be acceptably performed in communal spaces.

Separate hygienic facilities are to be provided for each different occupancy group when feasible. Water closets, lavatories, showers, etc., are to be selected and arranged so the personnel can use them in the shortest time. If a hygienic facility is provided to serve all occupancy groups, maximum effort shall be made to locate it in the vicinity of the living spaces. If overlapping usage of hygienic facilities by different occupancy groups is necessary, then the most stringent occupancy condition must govern the fixture/person ratio. Overlapping periods of maximum usage must also be taken into consideration when designing communal facilities.

The maximum distance from any space to a hygienic facility required for that space must not exceed the distances in feet or levels shown in Figures II-G-1 and II-G-2.

Access to wash room facilities shall be provided in a manner to eliminate the need for passing through a water closet area enroute to or from a wash room facility. In the event a communal hygienic facility is essential due to spatial limitations, it is important that all of the crew utilizing a specific facility be of the same peer group if housekeeping is to be divided equally. Therefore, it is recommended that communal hygienic facilities be avoided when possible, but where spatial limitations enforce their existence, it is essential that privacy partitions be installed isolating the individual waste equipment.

Table II-G-3 presents an evaluation of the merits and deficiencies of various concepts of hygienic facility arrangements.

Messing facilities are to be located adjacent to lounge and rest room facilities when possible. In multi-level structures the messing facility shall be near stairwells or elevators. However, maximum effort shall be made to provide messing facilities that permit a variation in the type of food services available for each meal, i.e., cafeteria, self-service, table service.

3.2 Requirements

Table II-G-4 lists the requirements for hygiene facilities for the various occupancy groups. This table is to be utilized with "use ratio charts" shown in Figures II-G-3 through II-G-9.

Table II-G-5 presents an evaluation of the merits and deficiencies of various mess seating concepts.

Figure II-G-10 presents recommended maximum, optimum, and minimum seating ratios for dining spaces.

Table II-G-3 Evaluation of Various Hygienic Facility Concepts

Concepts	Merits	Deficiencies	Development Status	Applicability & Reliability	Other Factors
Have separate hygienic facilities only within sleep compartments and dormitories, have other hygienic facilities serve several occupancy groups.	Saves in weight, and volume. Makes good use of facilities.	Greater inconvenience for crews. Facility requirements between certain areas may conflict.	Logistics problems require development of suitable arrangement of facilities. No other unique development problems.	Distance restrictions may present problems on multi-level space station/base. Some other separate facilities may be required.	
Locate all hygienic facilities in central communal area to serve all occupancy groups.	Requires minimum facilities, simplifies plumbing.	Lack of privacy & walking distances may make this concept unfeasible.	Development of low-gravity facilities required. No additional development problems.	Possible only on small space stations because of distance and privacy considerations.	Restriction to communal facilities only may be unacceptable both psychologically and socially.
Have separate facilities in each different occupancy group based on expected manpower and requirements in each space.	Most convenient for crew. Optimum privacy.	High cost in volume, weight, complexity.	Specific requirements for each facility would be fixed by actual mission model. No unique development problems.	Most suitable for very long-term missions and very large spacecraft.	Psychological importance of convenience factor significant on long-term mission.

Table II-G-4 Hygiene Facilities Requirements

Occupancy Group	FACILITY TYPES					
	Water Closets	Urinals	Lavatories	Showers	Laundry	Other Facilities
Assembly Spaces	See Figure II-G-3	See Figure II-G-3	See Figure II-G-6	Not Required	Not Required	
Work Spaces	See Figure II-G-4	See Figure II-G-4	See Figure II-G-7	Safety Showers are to be provided for each 10 persons exposed to excessive heat or irritating materials.	Not Required	Provide sanitary napkin dispensing and disposal facilities in each women's rest room.
Living Spaces	See Figure II-G-5	See Figure II-G-5	See Figure II-G-8	See Figure II-G-9	Not Required	Provide sanitary napkin dispensing and disposal facilities in each women's rest room. Provide separate personal hygiene modules for each person.
Kitchen and Food Preparation Spaces	See Figure II-G-4	See Figure II-G-4	See Figure II-G-7	Not Required	Not Required	Special design criteria to be established for each kitchen or food preparation space.
Service Spaces	See Figure II-G-4	See Figure II-G-4	See Figure II-G-7	Not Required	Wash and dry facilities 15# per per-person per day.	

Table II-G-5 Evaluation of Various Mess Seating Concepts

Concept	Merits	Deficiencies	Development Status	Applicability & Reliability	Other Factors
2 men seated per table	High accessibility personalized environment. Conversation easy.	Wasted space.	No development problems.	Applicable only for very small crews or in "special" areas.	No additional factors.
4 men seated per table	Accessible, normal eating environment. Conversation easy.	Wasted space, if number of tables is large.	No development problems.	Optimum for smaller crews.	No additional factors.
10 men seated per table	Saves space, maximum space utilization.	Impersonal environment less accessibility.	No development problems.	Necessary for larger crews.	No additional factors.
Combination of small and large tables	Diners given preference, maximum utilization of space in "odd" areas. Provides variety of dining environments.	Arrangement must be worked out to minimize wasted space. May result in status seeking.	No development problems.	May be necessary on large vehicles or long-term missions because of social and psychological requirements.	No additional factors.

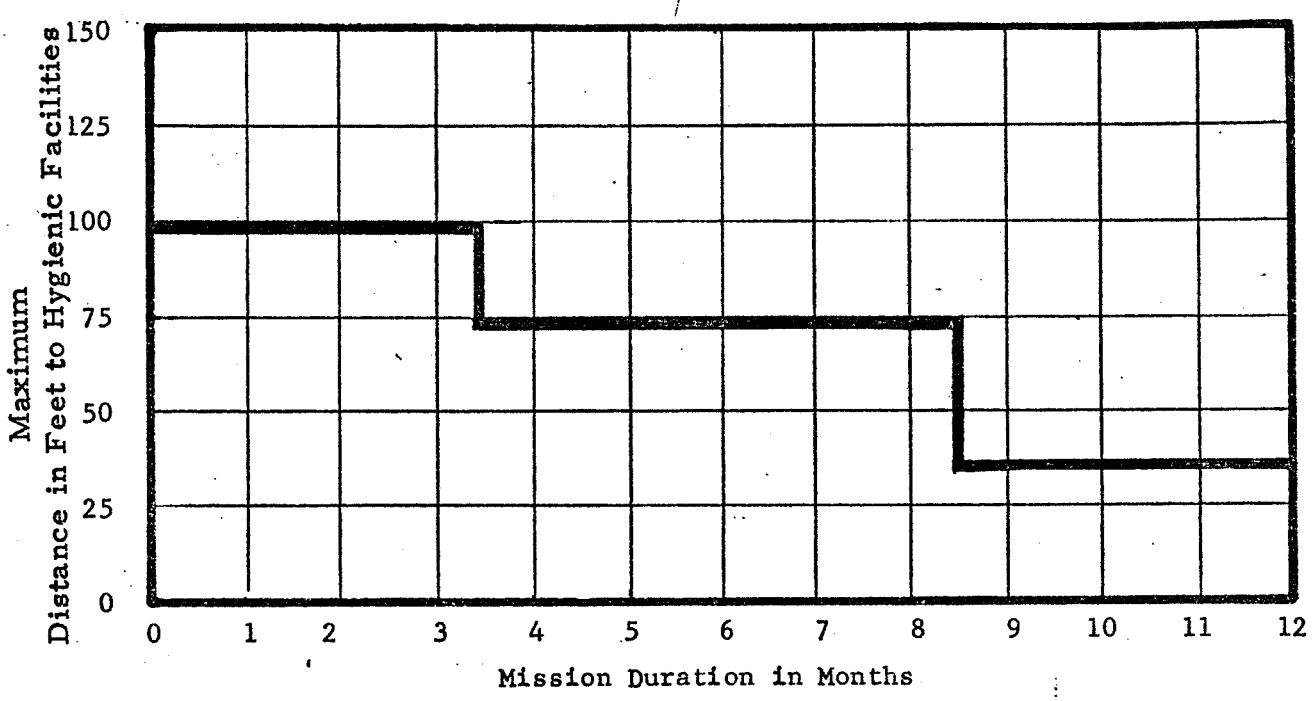


Figure II-G-1 Distance in Feet From Hygienic Facilities as Function of Time

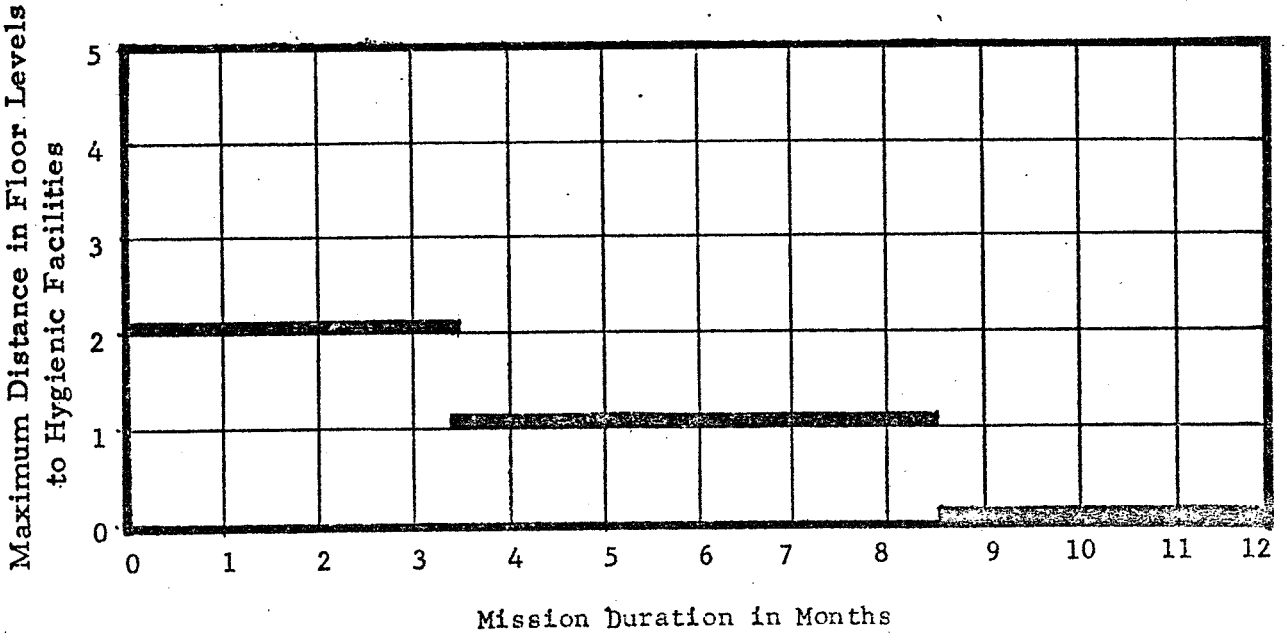


Figure II-G-2 Distance in Levels to Hygienic Facilities as Function of Time

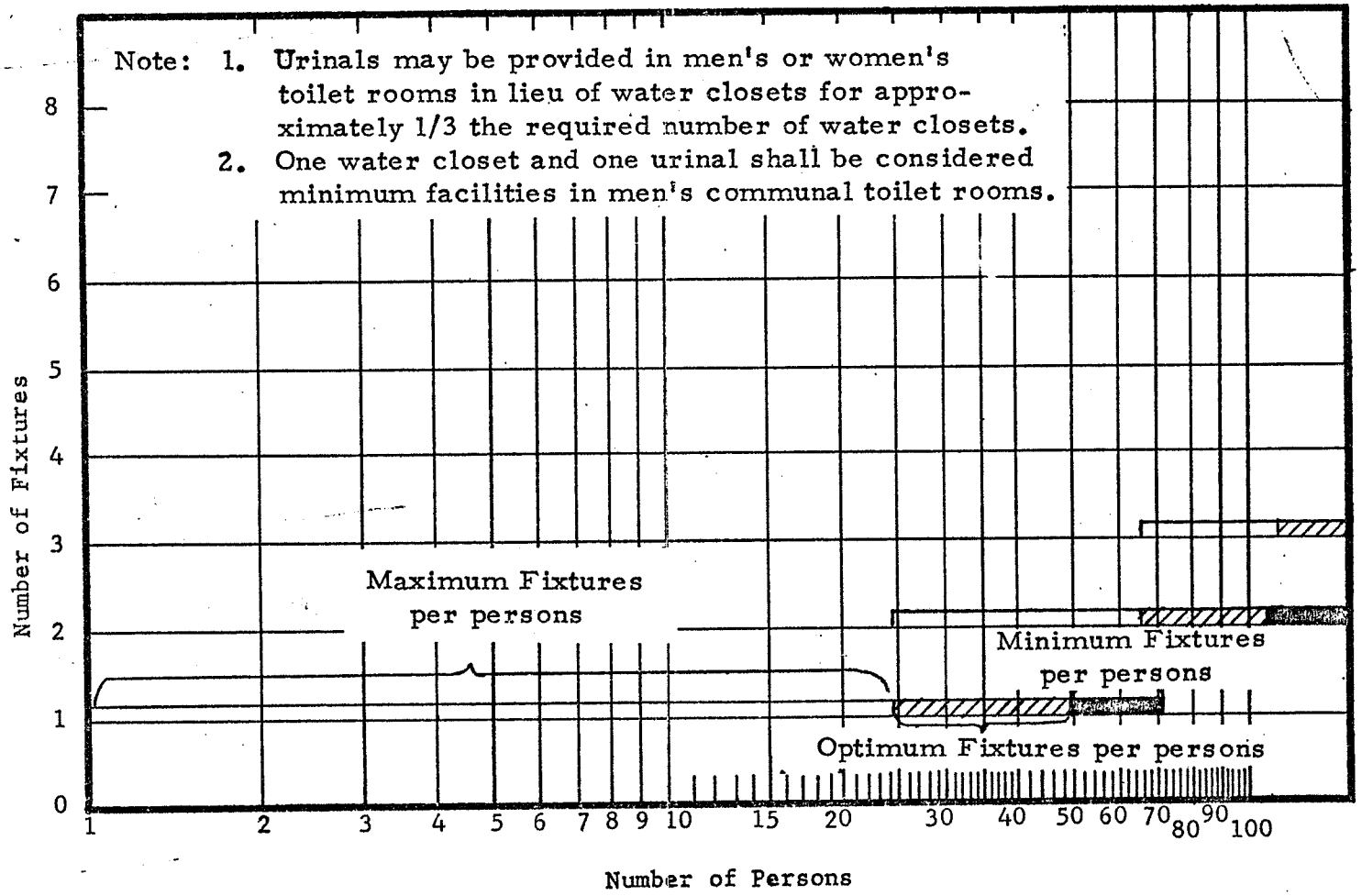


Figure II-G-3 Water Closet Use Ratio Chart #1

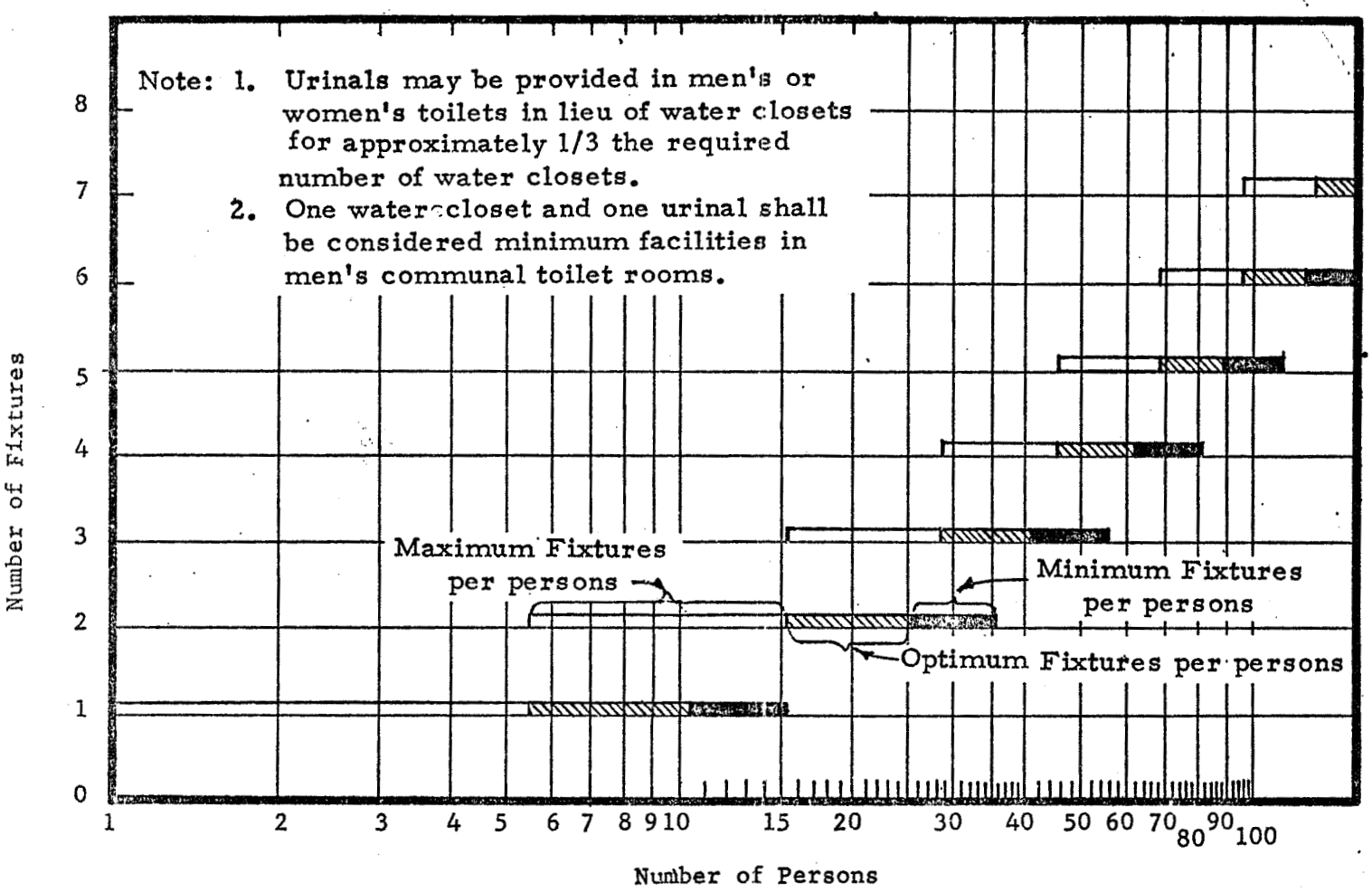


Figure II-G-4 Water Closet Use Ratio Chart #2

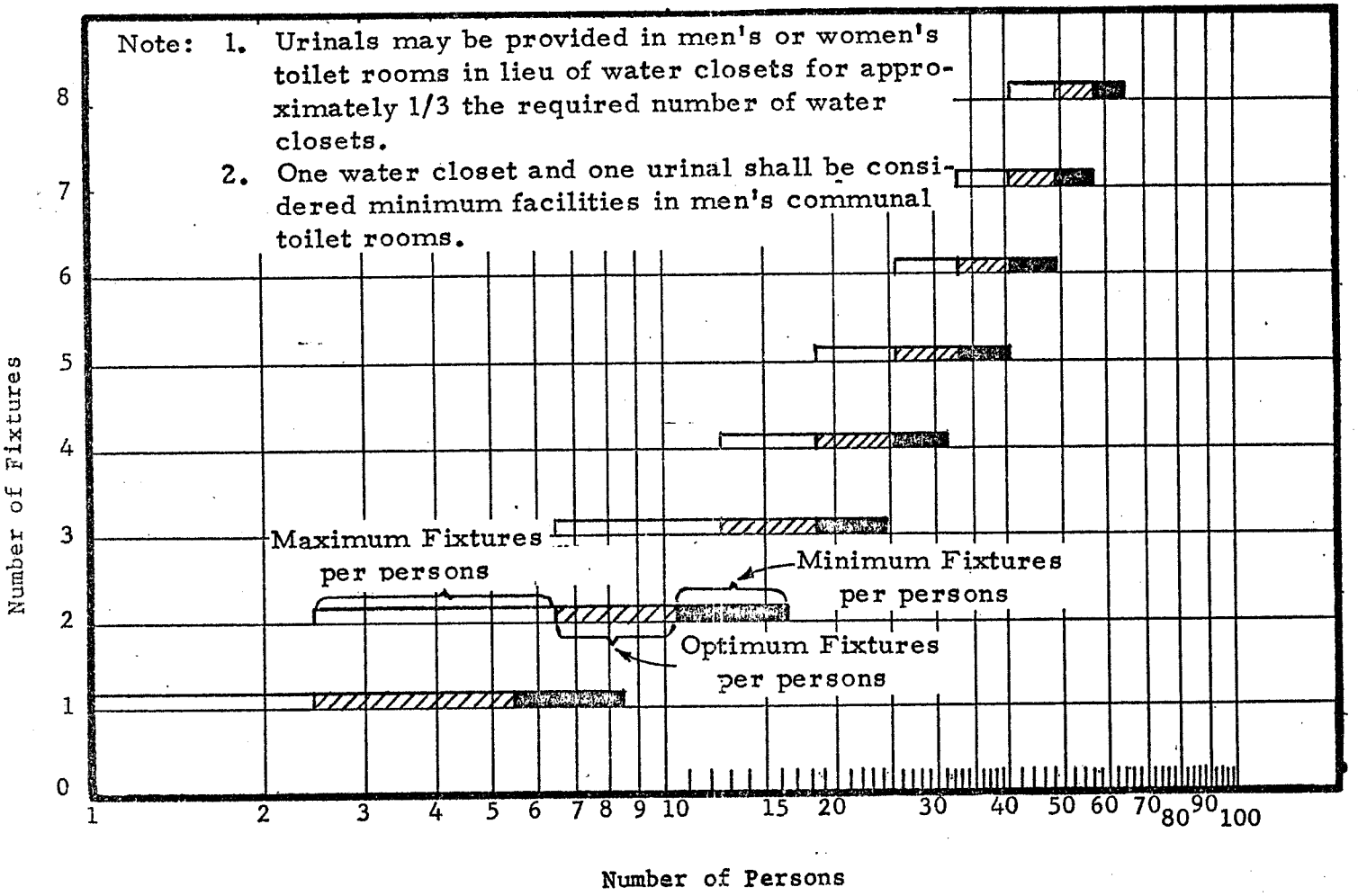


Figure II-G-5 Water Closet Use Ratio Chart #3

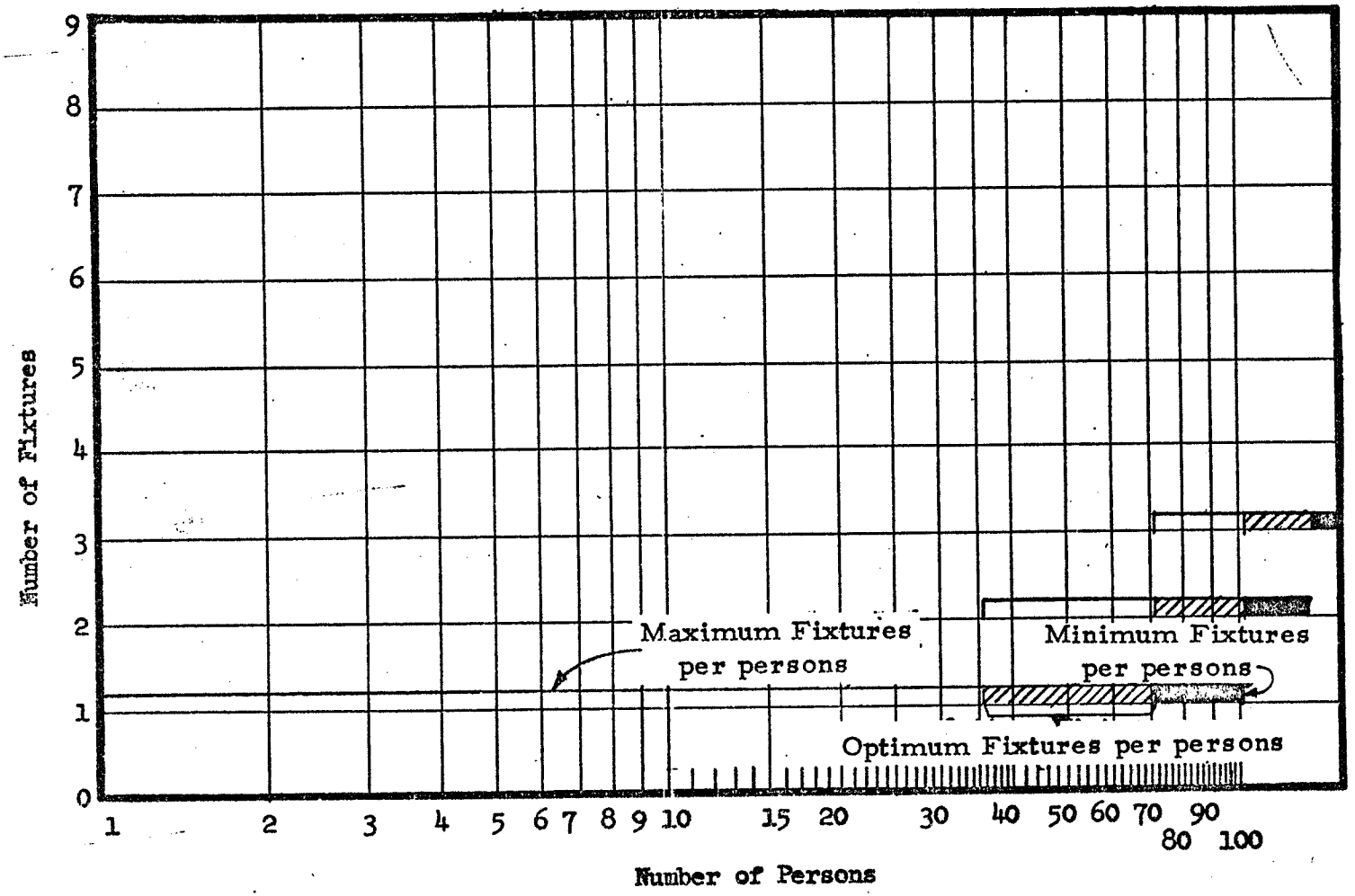


Figure II-G-6 Lavatory Use Ratio Chart #1

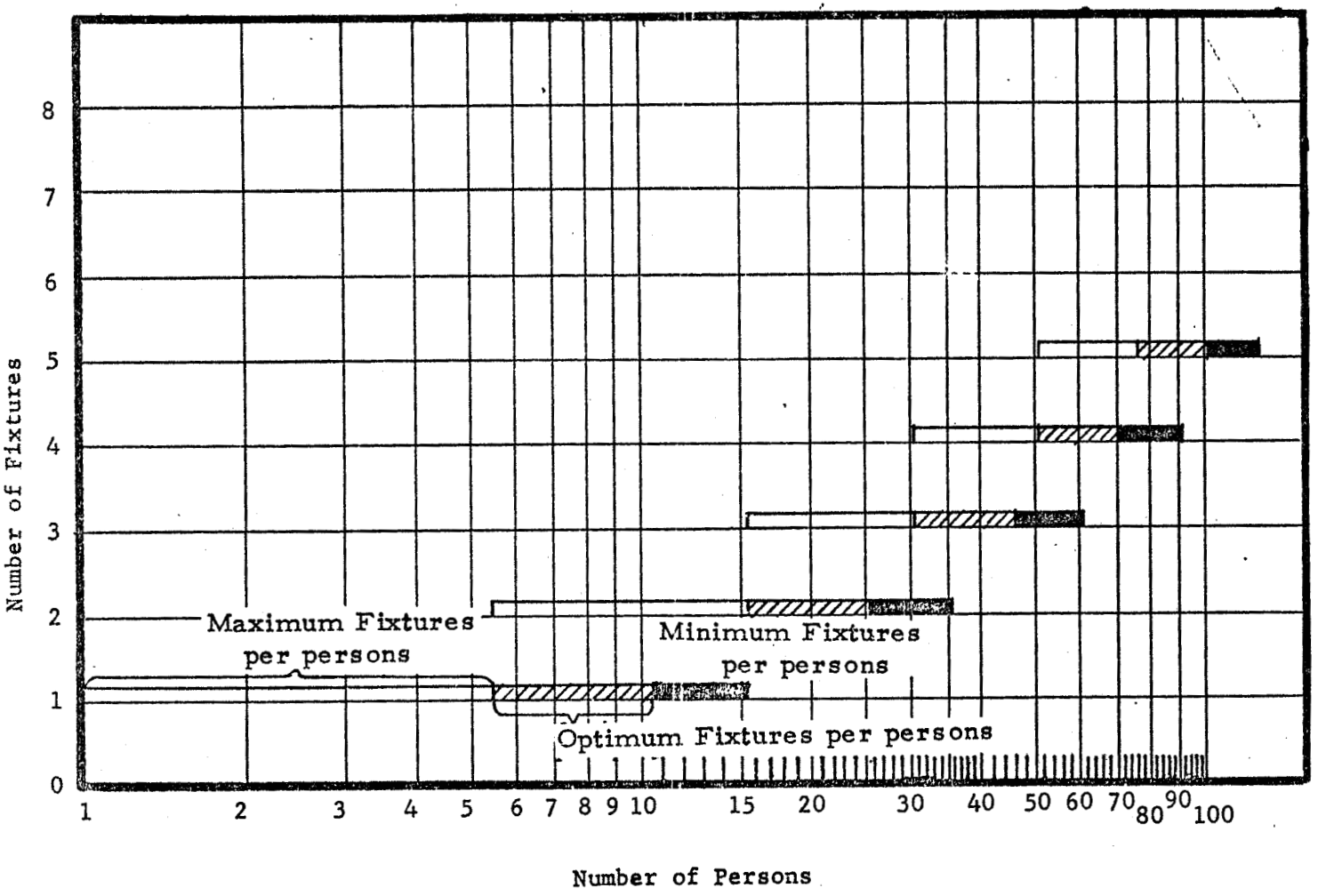


Figure II-G-7 Lavatory Use Ratio Chart #2

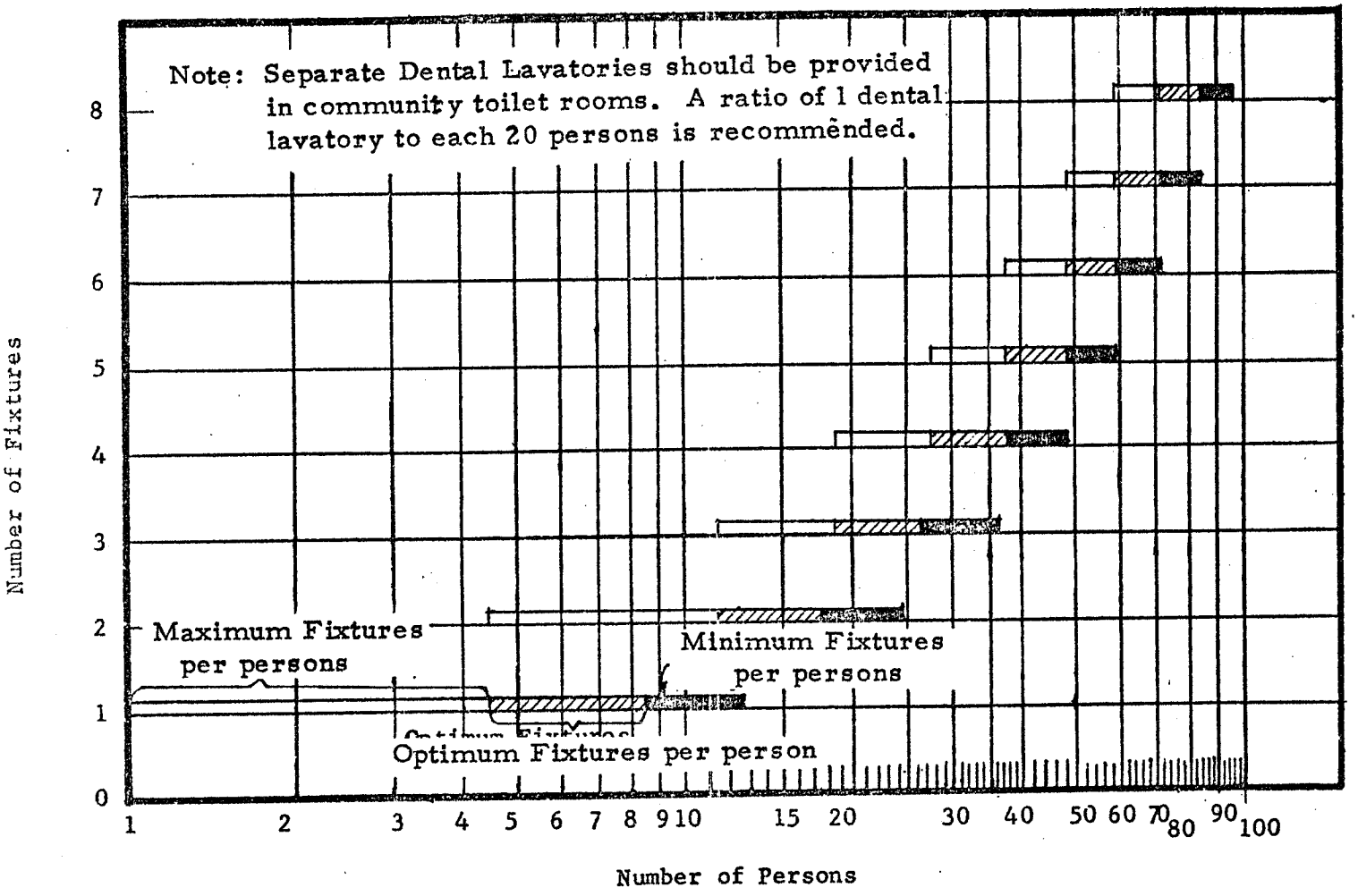


Figure II-G-8 Lavatory Use Ratio Chart #3

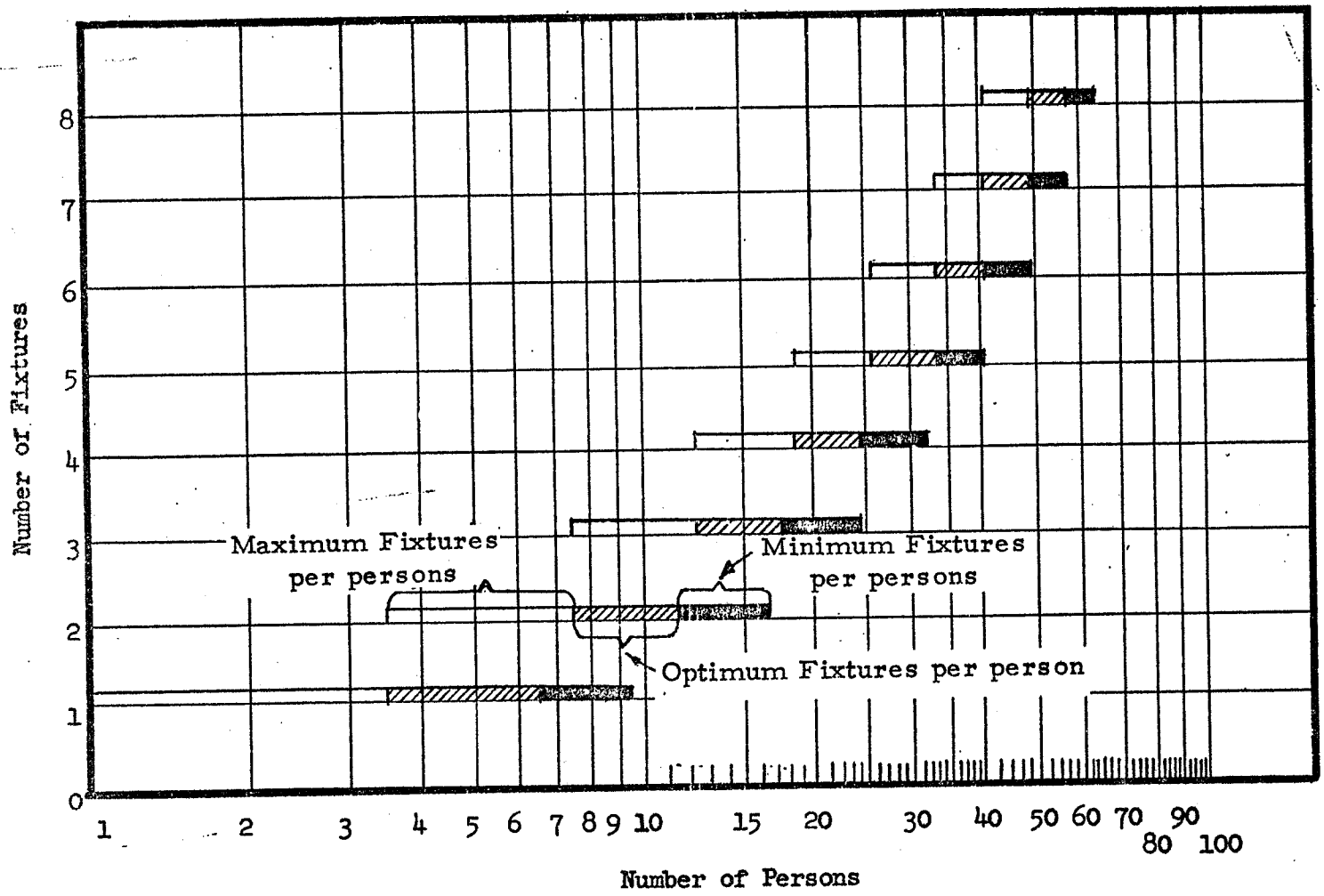


Figure II-G-9 Shower Use Ratio Chart #1

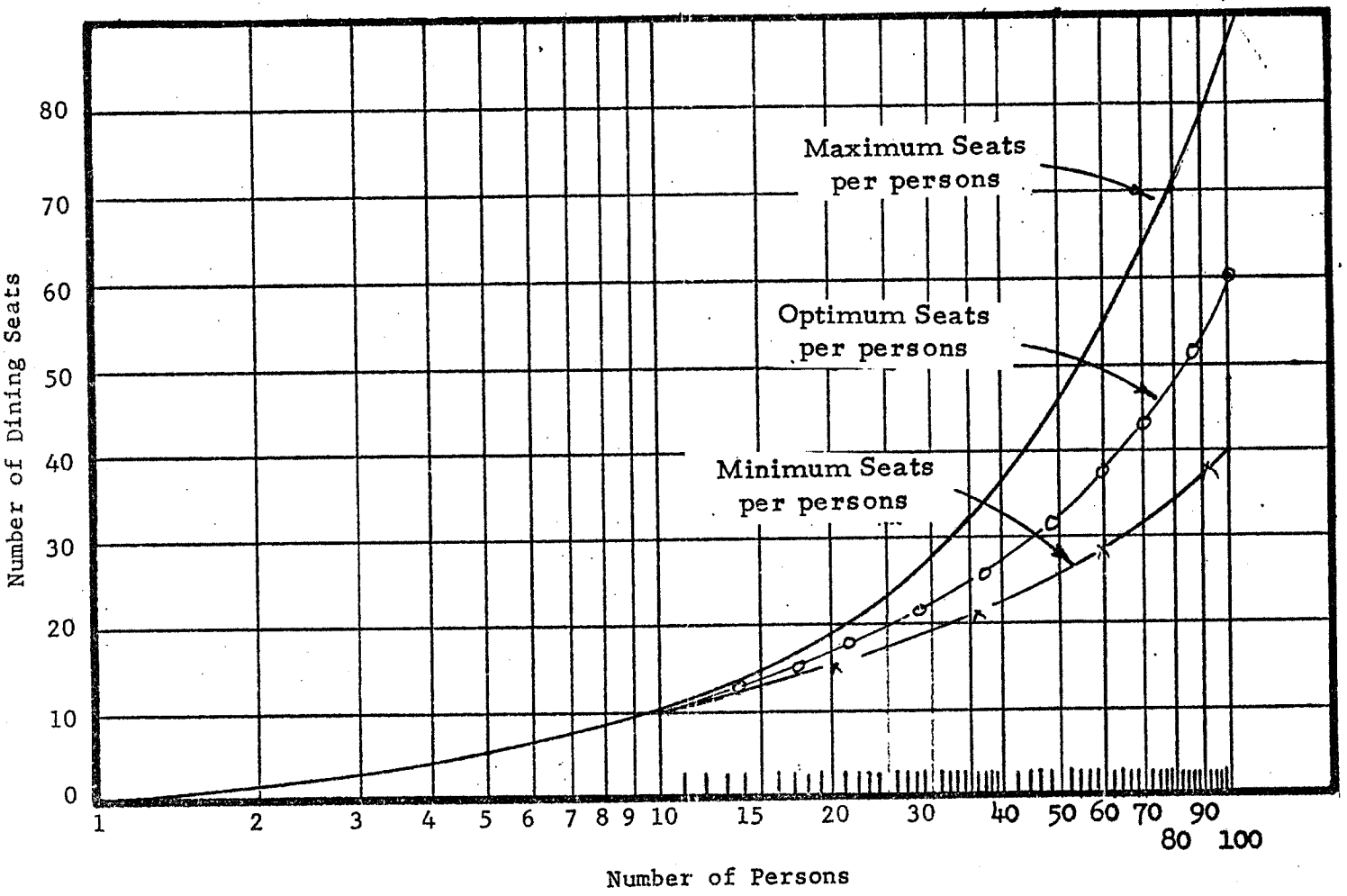


Figure II-G-10 Seating Use Ratio Chart #1

5.0 Design Example

A typical example of the use of hygiene data is presented in the following:

Requirement: Provide maximum number of water closets required in sleeping compartments that contain four men on a mission scheduled for six months duration.

Solution:

Step 1: Determine from Table II-G-1 which occupancy group A sleeping compartment is classified. Solution: Living Spaces.

Step 2: Enter Table II-G-4 at occupancy group - "Living Spaces". Proceed to column under water closets. Read: "See Figure II-G-5.

Step 3: From Figure II-G-5, enter number of persons at 4 and read vertically until in "maximum fixtures per person" area. Read across horizontally to "number of fixtures". Answer: 2.

Step 4: Determine maximum distance from living area to water closet from Figure II-G-1. Enter at 6 months duration and read vertically up to line. Answer: 75 feet. Maximum distance in floor levels is obtained from Figure II-G-2. Enter at 6 months duration and read vertically up to solid line. Answer: one floor maximum.

From the data, the maximum number of water closets to be provided would be 2. These water closets must be located not more than one level away and must not exceed a distance of 75 feet from the sleeping compartments.

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II-H DUAL ROOM USAGE

1.0 Introduction

The term dual room usage refers to the practice of providing facilities for two or more activities in one compartment. Specifically, for the purpose of this study, dual room usage refers to the combination of two or more active activities such as dining and lounging rather than combinations involving passive activities such as storage. The success of the mating of activities depends on the degree to which the activities are compatible, that is, how capable they are of functioning together harmoniously.

In attempting to establish parametric guidelines for compartmentalization levels* for specialized and combined activity compartments for extraterrestrial habitats, it has been necessary to rely entirely on extrapolated data from environmental simulation, historical presidence, and common sense. As a result of the non-scientific nature of the available data, it has not been possible to develop reliable systems for computing compartmentalization levels. A concept system format has been developed but is not considered accurate at this time.

As a general rule the advantages and disadvantages of dual room usage can be summarized as follows:

ADVANTAGES

Spatial efficiency is realized and larger open areas become practical when activities are combined.

*Compartmentalization levels refers to the number of compartment types required to house the various habitat activities. Separate compartments for dining and bathroom facilities represent two compartment types. Two separate bathrooms represent one compartment type. A combined activity compartment such as the theater/lounge/dining room represents one compartment type.

DISADVANTAGES

Compartmentalization level reduction results in a lower level of sensory stimulation along with scheduling and environmental (e. g. noise level) compromises.

Dual room usage is used as a means of making the most of limited space in all types of habitats, from efficiency apartments to submarines. An extreme example of this practice is seen in the Gemini space vehicles in which one compartment served as the dining room, bedroom, control room and bathroom for two men for periods of confinement of up to 14 days. Although this vehicle proved to be adequate for the mission and individuals it was designed to support, there is little doubt that it represented the extreme lower limits of habitability even though the crew was exceptionally highly motivated and trained.

As a general rule, a significant increase in crew size has resulted in a reduction in the effective level of dual room usage, and therefore, an increased level of compartmentalization. The need for the increased specialization can be attributed to both mechanical system and personnel needs.

In the case of the mechanical systems, as crew size is increased there is an attendant increase in the physical size of the station or habitat to the point that it is structively advantageous to subdivide the total volume into a number of compartments. Additionally, an increase in equipment size and degree of specialization (e. g. photography and repair facility) is to be expected with an increase in crew size and specialization level to the point that physical separation of activities is desirable.

In the area of personnel needs, an increase in crew size will result in additional conflicting activity schedules, an increase in personal stress created by sheer numbers, and an increased level of task specialization, all of which may be alleviated by an increased level of compartmentalization in public, private and work areas.

The effect of mission duration of compartment specialization is debatable depending on the degree of change and specific mission lengths considered. Generally speaking, however, it is known that the complaint of sameness or monotony in the environment has been common to practically all experimental and operational isolated missions as a result of the low level and non-changing nature of the sensory stimuli.

While insufficient data exist to develop accurate compartmentalization/mission duration relationship guidelines, it is probable that a relationship does exist for significa increases in mission duration, especially for missions from 0-60 days. As a general rule, therefore, because an increased level of compartmentalization will result in an increased level of visual stimuli and change, it is recommended that a significant increase in mission duration be accompanied by a reduction in the level of dual room usage.

While general recommendations have been developed, it was not the intent of this study, nor was it possible due to lack of relevant data, to establish precise standards for room combination priorities related to specific mission parameters. The recommendations presented herein, therefore, should be used as preliminary study guidelines only.

2.0 Definitions - N.A.

3.0 Factor Detail Discussion

3.1 Degree of Compatibility

Certain points on which activities are compared have a greater influence on compatibility than others.

An example of functionally uncompatible activities would be a dining room and an activity that required that the temperature be held at 87^{o} F $\pm$ 1 and the humidity be kept at 85-90%.

An example of an activity imposed requirement of a lesser nature is that of material limitations. For example, if a lounge area doubles as a distribution area for supplies during periods of resupply, high standards of material toughness would be imposed on the lounge fixtures exposed to the distribution activities. While these increased standards would decrease the choice of available materials, the area could still support lounging activities, if only a little less graciously.

3.2 Efficiency of Combination

The spatial efficiency realized in combining activities varies considerably depending on the nature of the activities involved in terms of layout and associated equipment or function.

The dining room and theater combination is an example of optimum efficiency achieved by combining two activities in that the space savings realized can be as high as 50% since the furniture in both areas is moveable and the schedules of usage do not overlap.

The supply room and shop, on the other hand, represent an inefficient combination of activities since both activities contain fixed, incompatible equipment, and the schedules of usage overlap.

The determination of the average efficiency to be expected when two or more activities are combined must be determined for all activity combinations to more thoroughly evaluate the relative merit of a specific activity combination.

4.0 Psychophysiological Effects

As a general rule, as the number of activities being combined increase and types of activities combined become more diversified, the stresses associated with trying to accomplish a task in this environment will increase.

5.0 Application

A system has been developed by which compartmentation levels may be approximated on the basis of the mission duration and crew size. As stated in paragraph 1.0, the system developed is not considered accurate at this time due to the lack of relevant data.

To utilize the system developed two steps are required.

5.1 Step 1

By referring to figure II-H-1, a mission compatibility rating figure can be determined for a specific mission. Five compatibility rating zones are defined, with the lower rating (1) representing a parametric area in which a high level of dual room usage and corresponding lower level of compartmentilization is practical. The high end of the scale (5) defines a parametric zone which requires a high level of compartmentilization. Missions with large crews and/or very long mission durations fall in this zone.

The crew size break off points are fairly arbitrary due to the lack of meaningful data in the sources reviewed pertaining to group dynamics pertaining to large crews.

The selection of the mission duration break off points was based on limited experience from operational and test data. It appears that stress build-up may parallel mission up to approximately 30 days at which time a degree of stabilization occurs. Following this, at approximately 60 days into a mission another stress build up tendency has been observed. Break off points beyond this are purely arbitrary.

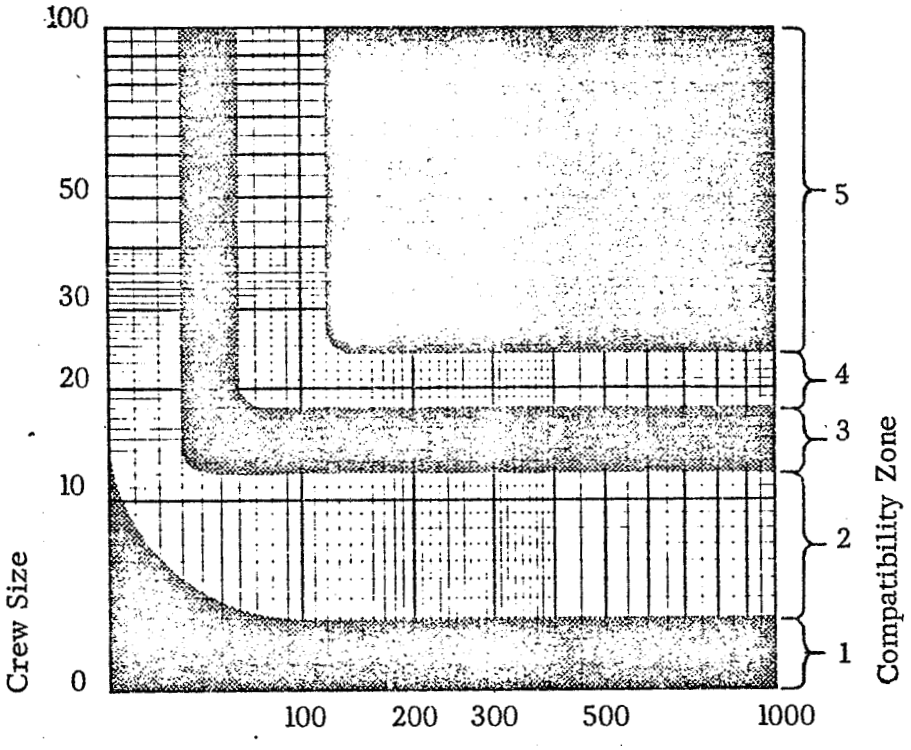
5.2 Step 2

Using a NASA-prepared list of 35 possible activity centers, five sets of possible dual room usage combinations have been developed respective to the mission compatibility

ratings of 1-5.* These combinations are shown on the following three pages with activity combinations appropriate to each compatibility zone listed accordingly.

Figure II-H-1
Compatibility Rating As a Function of Crew Size and Mission Duration

Rating:
1 = Most Effective
5 = Least Effective



* Only 34 activities appear on the activity combination lists. Recreation, one of the activities specified by NASA originally, will be supported by a number of activities centers (e.g. dining, lounge, gym, etc.) and is not considered to be an independent area.

5.2.1 Compatibility Level I

Personal Quarters	Communications
Study	Control
Locker room	Computer
Library	Storage
Lounge	Supply
Conference	
Briefing	Equipment
Chapel	Shop
Theater	Maintenance
Dining Room	
Gym	Office
	Laboratory
Passageway	Photography
Galley	Animal Housing
Snack Bar	Agricultural Study Area
Dispensary	Docking
Barber	Air Locks
Bathroom	
Laundry	Power

5.2.2 Compatibility Level II

Personal Quarters	Communications
Study	Control
Locker room	Computer
Library	Storage
Lounge	Supply
Conference Room	
Briefing Room	Equipment
Chapel	Shop
Theater	Maintenance
Dining Room	
	Office
Passageway	Laboratory
	Photography
Gym	
	Animal Housing

Bathroom	Agricultural Study Area
Galley	Docking
Snack Bar	Air Locks
Laundry	Power
Dispensary	
Barber	

5.2.3 Compatibility Level III

Personal Quarters	Communications
Study	Control
Locker Room	Computer
Library	Storage
Lounge	Supply
Conference Room	Equipment
Briefing Room	Shop
Chapel	Maintenance
Theater	
Dining Room	Office
Passageway	Laboratory
	Photography
Gym	
	Animal Housing
Bathroom	
	Agricultural Study Area
Galley	
Snack Bar	Docking
	Air Locks
Laundry	
	Power
Dispensary	
Barber	

5.2.4 Compatibility Level IV

Personal Quarters	Communications
Study	Control
	Computer

Library	Communications
Lounge	Control
	Computer
Conference Room	
Briefing Room	Storage
Chapel	Supply
Theater	
Dining Room	Equipment
	Shop
Gym	Maintenance
Locker Room	Office
Passageway	Laboratory
Bathroom	Photography
Galley	Animal Housing
Snack Bar	Agricultural Study Area
Laundry	Docking
	Air Locks

5.2.5- Compatibility Level V

Personal Quarters	Storage
Study	
	Supply
Library	
	Communications
Lounge	Control
Conference Room	Computer
Briefing Room	
Chapel	Equipment
Theater	Shop
Dining Room	Maintenance
Gym	Office

| Locker Room

| Passageway

| Bathroom

| Galley
| Snack Bar

| Laundry

| Dispensary

| Barber

| Laboratory

| Photography

| Animal Housing

| Agricultural Study Area

| Docking

| Air Locks

| Power

II-I GRAVITY

1.0 Introduction

Gravity, or the lack of it, will have a definite influence on spacecraft habitability. For manned space systems, two gravitation modes of operation are possible: weightlessness and artificially-induced gravity. Weightlessness is the "natural" state during space travel; artificial gravity requires rotation of the spacecraft about some spin axis during spaceflight.

Both modes of operation have inherent advantages and disadvantages from a habitability standpoint. Unfortunately, the preferred mode of operation for future space systems cannot be determined at the present time since only weightless environments have been used on previous space missions. These space missions have been of limited duration and they have not provided adequate data concerning man's response to protracted weightlessness.

Adverse, and possibly debilitating, physiological effects due to protracted weightlessness are a definite possibility and the effectiveness of proposed countermeasures remains questionable. If man experiences a time limitation on his ability to inhabit a weightless environment, artificial gravity induced by spacecraft rotation has the greatest apparent validity as a possible countermeasure. The habitability considerations of both weightlessness and artificial gravity are considered in the following sections.

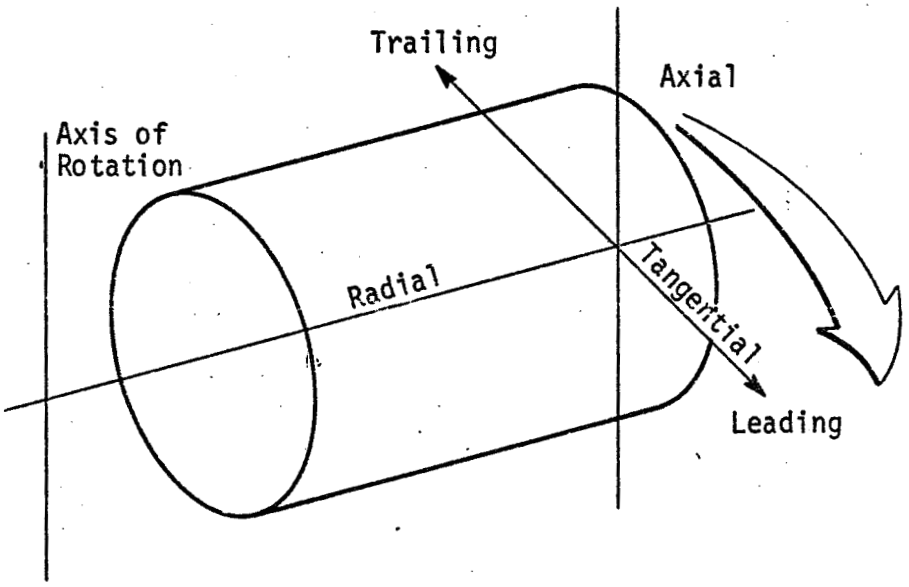
2.0 Definitions

2.1 Artificial Gravity

Apparent weight produced by centripetal acceleration in a rotating spacecraft.

2.2 Axes in Artificial Gravity

In the interest of clarity, the directions in which movements are made and external forces are applied will be indicated as axial, radial, or tangential with respect to the rotating spacecraft, as shown in the figure below. Tangential movements and forces may further be described as operating toward the leading edge or the trailing edge of the spacecraft. Thus, an astronaut climbing a ladder is translating radially, while an astronaut walking in the same direction the spacecraft is rotating is moving tangentially (toward the leading edge).



2.3 Coriolis Force

An apparent force resulting from linear movement with a rotating system.

2.4 Cross-Coupled Angular Acceleration

Angular acceleration produced by angular movement within a rotating system. Also known as gyroscopic precession. When, within a rotating spacecraft, an angular motion occurs about any axis not parallel to the axis of rotation, a torque is applied to the moving object about an axis perpendicular to the axes of motion of the spacecraft and the object.

2.5 Coriolis Stimulus

A highly unusual stimulus to the vestibular (motion sensing) system which results from cross-coupled angular acceleration produced by head movements in a rotating room or spacecraft.

2.6 Deafferentation

In a sensory system, loss of sensory input signals because of either mechanical or neural interference with normal operation.

2.7 Weightlessness

Absence of weight due to extreme distance from large astronomical bodies or (as in orbiting spacecraft) due to a cancelling centrifugal force.

2.8 Otolith Organs

Those receptors of the vestibular (motion sensing) system which are responsive to linear acceleration and gravity.

2.9 Semicircular Canals

Those receptors of the vestibular system which are responsive to angular acceleration.

3.0 Factors Detail Discussion

3.1 Zero Gravity

Past space missions have not exceeded 424 hours duration, and have not produced any major problems due to protracted weightlessness. However, protracted weightlessness has a number of known, and possibly adverse, physiological effects (Ref. I.1). In general, these effects have not been disabling in the short missions accomplished to date, but there exists a definite possibility that they will become more pronounced with longer missions. Whether man experiences a time limitation on his ability to inhabit a weightless environment will

depend on whether the deterioration is progressive, or reaches an acceptable asymptotic level with increasing exposure, and on the effectiveness of proposed countermeasures.

The stimulation and response of human sense organs to subgravity are presented in Table II-I-1. The physiological effects of weightlessness are shown in Table II-I-2, and the effects of zero-gravity on performance are shown in Table II-I-3. Zero gravity design considerations are given in Table II-I-4.

3.2 Artificial Gravity

While artificial gravity induced by spacecraft rotation has the greatest apparent validity as a procedure for preventing possible physiological deconditioning due to protracted weightlessness, it unfortunately involves a number of undesirable phenomena (Ref. I.4, I.17, I.5). Because of the unusual forces operating in such an environment, astronauts may anticipate a considerable degree of locomotor difficulty, spatial disorientation, and perhaps motion sickness. The degree to which these adverse effects will be experienced varies with the radius, angular velocity, and gravity level. In general, the degree of performance degradation which will occur is not known, since the conditions encountered in a rotating space station cannot be adequately simulated in a one-g environment (Ref. I.25, I.3, I.26).

The major effects of artificial gravity on astronaut performance are presented in Table II-I-5.

To summarize the information presented in Table II-I-5, the static effects of artificial gravity are not very serious, involving only a simple, constant visual-proprioceptive conflict regarding the vertical-horizontal frame of reference. During movement, however, and particularly radial or tangential translation and angular head movements, a number of serious abnormal mechanical and perceptual phenomena will occur. These phenomena may reasonably be expected to result in locomotor difficulty, illusions of spatial perception, motion sickness, and generally degraded performance. The degree to which

Table II-I-1 Stimulation and Response of Sense Organs (and Their Manner of Operation) to Subgravity

	Nerve Endings or Organs Responding to Differences in Pressure (e.g., those of touch or hearing)				Receptor Organ Sensitive to Light
	Those Responding Specifically to Gravitational Stimuli	Those not responding solely to gravitational stimuli but provide similar information to the brain			
	Motion and Position Sense	Muscle Sense giving body position and movement	Posture Sense	Pressure Sense	Optical Sense
Sense Organ	Otoliths (inner ear orientation organ)	Muscle Nerves	Sense Corpuscles along the course of nerves	Sense Corpuscles of touch	Eyes
Normal Stimulus	Acceleration and weight	Tension and weight	Tension	Pressure and weight	Light
Effect of Subgravity	Decreased Wt. & displacement of Otoliths ,	Decreased Wt. & muscle tension	No Effect	Decreased Pressure at contact point of body with support	No Effect
Effects of 0-g	Lack of Wt. & displacement of Otoliths	Lack of Physical Stress	No Effect	No feeling of pressure at body contact points	No Effect
Sensory Inputs during 0-g	None or 0-g Signal	No signal	No Effect	No signal	No Effect
Sensory Output during 0-g	None or 0-g	No signal	No Effect	No signal	No Effect
Sensation during 0-g	No Gravitational Vertical	Stress-Free Sensation	No Effect	Stress-Free Sensation	No Effect
Psychological & Physiological Results	Loss of Vertical orientation without visual reference	Disturbance of muscular coordination	No Effect	Loss of touch sensation	No Effect when visual cues available

(Ref. I.6)

Table II-I-2 Physiological Effects of Weightlessness

Function	Effects of Weightlessness
Cardiovascular Function	Spaceflight has been shown to disturb the homeostasis of the cardiovascular system of man. Decremental changes have been documented in compartmental fluid volumes (plasma volume, red-cell mass, blood volume), hydrostatic pressure (orthostatic hypotension), and related parameters. The extent to which they may adversely affect the performance of man remains to be determined as well as the effectiveness of preventive and/or remedial techniques.
Bone Decalcification	With protracted weightlessness, urinary excretion of calcium is increased to a point that calcium is lost from bone tissue in significant amounts with possible eventual brittleness. The amount of decalcification which might result from long exposure to weightlessness is not known.
Muscle Deconditioning	Weightlessness results in a greatly reduced requirement for skeletal muscle exertion since a very small amount of energy is required to accomplish desired locomotion movements. It is almost certain, however, that muscle deconditioning can be prevented by appropriate physical exercises.
Otholith Deconditioning	During weightlessness, the otholiths are deactivated or deafferented. Adaptation to this unstimulated state might be expected to result in overreaction to gravitational stimuli when reinstated and, more seriously, atrophy of the receptor tissue associated with the otoliths. The extent of otholith deconditioning which may result from protracted weightlessness is not known.
Respiration	Weightlessness and artificial atmospheres have major effects on the respiratory gas-exchange function of the body. These effects impose possible health hazards and limitations on man's performance limitations. The effects of prolonged exposure to weightlessness are not known.
Endocrine Function	Observations from past space flights are too sketchy to give a precise picture of how the endocrine system responds to the stress of spaceflight. Minimal information gained thus far indicates decreased endocrine activity during flight and increased activity after reentry.
Metabolism and Nutrition	Some changes related to metabolism and nutrition have been noted. These changes include reduction in body weight and loss of mineral material in the bones. Such effects may become progressively more serious to the extent of impairing the tolerance of bone structure, weakening of muscle mass, and possible formation of kidney stones.
Hematology	A pacuity of hematological data has been obtained to date; however, red-cell mass deficits have been consistently observed. More information is needed to determine the cause of this space-flight-related hemolysis. In addition, man's ability to combat infection and repair traumatized tissue under spaceflight conditions has not been established.

(Extracted from Ref. I.1, I.22)

Table II-I-3 Effects of a Zero-Gravity Environment on Performance

Performance Area	Performance Effects
Operational Behavior	From an operational viewpoint, all astronauts to date were capable of carrying out their functions and assigned duties satisfactorily, even under demanding situations. However, actual performance was never measured and it is entirely possible that some degradation actually occurred.
Emergency Behavior	Personnel can function correctly in an emergency situation.
Manual Work with a Tight Restraint	In general, with a tight restraint, personnel can perform as accurately and as quickly during zero-gravity as during normal gravity.
Manual Work with a Loose Restraint	Loose restraints require the use of one hand to hold onto any convenient solid apparatus to retain a position whil performing a task with other hand.
Locomotion by Free Floating	Easily accomplished if body's center of gravity and line of thrust are aligned pointed towards desired destination. If not aligned, tumble action takes place, however tumbling is easily controlled and can be stopped when contact is made with solid surface.
Hand Motions	Speed and accuracy appear to be about the same during zero-gravity as during normal gravity.
Orientation	When restrained and without tumbling, "up" stays up and "down" stays down. Tumbling produces complete disorientation.
Visual Functions	No degradation of visual skills have been reported on spaceflights to date. Illusions such as oculogyral, oculogravic and oculoagravic and diminished accuracy of the perception of the vertical have been demonstrated during zero-g phase of parabolic flight.
Knowledge and Control of Limb Position	Knowledge not generally impaired, but overshooting occurs in darkness. Bodily movements require less effort.
Body Resilience Motions	Bodies in passive state tend to leave surface. Restraint systems are required.
Walking	Propels individual away from surfaces. Handrails, handholes or foot grips are required.
Torque Operations	Applying torque induces uncontrolled motion in operator.
Package Handling	Requires use of restraints and locomotion aids.
Information Processing (cognitive functions)	No impairment has been reported on space missions to date. However, a human information-processing error of any magnitude could prove disastrous. Therefore, the conservative approach is to withhold conclusion until adequate data are obtained during long-term living in weightlessness.

(Extracted from Ref. I.1, I.15, I.22)

Table II-I-4 Zero-Gravity Design Considerations

Design Consideration	Group Type	Expected Motion	Design Rationale
Orientation	Large (dining rooms)	Static	Orientation for conventional "up and "down" to simulate earth-like environment and promote sense of security. This provides for face-to-face communications and readable facial expressions.
		Dynamic	Establish traffic patterns for large group movement so that plane of vision is constant to avoid collisions. In addition, establish traffic patterns to prevent psychological distractions; example: do not establish traffic flow patterns over dining tables or food serving counters.
	Small (bedrooms)	Static	Provide for easy orientation cues in different planes to provide a sense of change. This will provide crew personnel the opportunity to change to prevent monotony.
Lighting	Small (bedrooms)	Dynamic	Provide indirect or soft diffuse lighting so that any surface may be utilized. This will prevent glare.
		Static	Can be utilized as orientation cue.
Color	Large (passageway)	Dynamic	Use colors for directional cues for orientation of traffic patterns. Example: dark blue in passageway would lead to particular crew area which is also colored blue at entrance.
	Small (bedroom)	Static	Colors can be utilized as cues in rooms requiring definite floor/ceiling orientation.
Housekeeping	Large (lounge)	Dynamic	Provide easily cleanable material for locomotion aids such as handholes, rails, etc. In addition, place locomotion aids to reflect actual movement patterns. These will become dirty with use and will be psychologically displeasing if not easily cleanable.
	Both Large and Small	Static and Dynamic	Avoid sharp corners or protruding objects to prevent injury or damage. In addition, rounded surfaces are more easily cleanable.
Restraint	Large (dining rooms) Small (bedrooms)	Static	Prevent body drift but allow hands to be free. Restraint must allow for group visual orientation. Provide sleeping restraint to prevent body drifting including legs and arms. Also prevent extreme pressures that can cause numbness.

Table II-I-5 Major Effects of Artificial Gravity

Effect	Remarks
1. Artificial gravity vector	Since artificial gravity is caused by centripetal acceleration, the artificial gravity vector at any point is radial so that, in general, a conflict exists between gravitational vertical and the vertical direction indicated by a flat floor (see Figure II-I-1). This will be the only unusual effect from the point of view of a stationary astronaut.
2. Coriolis Forces	An apparent force which is applied to an object translating within a rotating system.
a) tangential translation	Results in coriolis forces in a radial direction (see Figure II-I-1). An astronaut moving in the spacecraft's direction of rotation experiences an apparent weight increase while movement in the opposite direction produces an apparent weight decrease.
b) radial translation	Forces encountered will tend to pull the astronaut into or away from the ladder he is climbing or descending if the ladder's oriented radially. If the ladder rungs are oriented tangentially, the astronaut climbing or descending would be pulled away in a lateral direction (see Figure II-I-1).
3. Non-linear Motion of Dropped Objects	An object rotating with the spacecraft will, when released, continue to travel linearly in a tangential direction. Since the spacecraft continues rotating, the object appears to move in a non-linear fashion as shown in Figure II-I-1.
4. Cross-coupled Angular Acceleration (or gyroscopic precession)	Major effect will be on the semicircular canals. An angular head movement in any direction other than parallel to the spacecraft spin axis will result in a highly unusual stimulus to the vestibular system. Since the semicircular canals respond not only to the head movement actually made, but also to cross-coupled torque, the vestibular system provides information to the effect that a head movement has been made in a direction other than that actually accomplished (Ref. I.18). This information conflicts with all other visual and proprioceptive information and with the individual's knowledge of the movement attempted. This entire complex of conflicting sensory information, called a "Coriolis stimulation", is highly disabling, resulting in extreme spatial disorientation, undesirable compensatory motor responses, motion sickness, and general confusion.

these factors influence mission success will vary with, 1) the magnitudes of the phenomena (primarily a function of angular velocity), 2) the degree to which adaptation occurs, and 3) the degree to which appropriate equipment design and mission constraints are employed.

3.2.1 Habitability Design Criteria for Artificial Gravity

A number of basic design criteria, including optimum orientation, tilt, and layout of crew stations; control and display panels, and bunks; optimum direction of horizontal translation; floor layout; and optimum orientation during tangential translation, can be determined on the basis of an analysis of artificial gravity conditions. These analyses appear to be relatively straight-forward, and their results can be viewed with some confidence. The principal information which cannot be determined by analysis is the degree to which these criteria are critical. Artificial gravity experimentation will be required to determine the effects of deviations from orientations, equipment designs, etc. Some specific design guidelines are discussed in Table II-I-6.

Another consideration not mentioned in Table II-I-6 concerns habitability near the axis of rotation. Performance may be extremely degraded if mission planning requires translation through, or particularly, performance at, the axis of rotation. It is apparent that this environment combines all the disadvantages of weightlessness (the artificial gravity level is zero at the rotation axis) with all the disadvantages of artificial gravity (all the unusual forces resulting from rotation are still present), while benefiting little from the advantages of either. Until and unless it is demonstrated that acceptable levels of performance are possible under these conditions, mission planners would be wise to avoid requirements of astronaut performance at the spin axis wherever possible.

A counter-rotating hub has often been proposed for inclusion in artificial gravity spacecraft designs. The principal advantage of such a device is that it would allow zero-gravity and fixed-attitude experimentation while the spacecraft is rotating. A secondary advantage is the elimination of unusual rotational phenomena for astronauts

Table II-I-6 Habitability Design Considerations for Artificial Gravity

Crew Movement/Motion Requirements	Crew Area Design Requirements
1. Mode of locomotion must allow the crewman to remain oriented perpendicular to the spin axis.	1. All operable equipment, work stations, and data display consoles should be oriented in the design to operate perpendicular to the spin axis. It is necessary that controls and displays be laid out vertically, so that the required head movements are in fact confined to the plane of rotation. Note that the use of current predominantly horizontal displays would negate the benefit of correct display panel orientation.
2. All other stationary positioning must remain fixed in the above designated orientation.	2. All bunks should retain the above orientation. A slight head restraint should be used to restrain head movement while the crewman is in a sleep position. Extreme care should be used if bunks are stacked since Coriolis forces will be encountered during radial translation and since a (non-linear) fall from an upper bunk could be quite serious.
3. All head movements must be performed perpendicular to the spin axis in a reference of the forward vertical planes. Thus, an up or down head movement will not further aggrevate the vestibular situation. It should also be noted that all movements that are contrary to the above orientation must be executed very slowly.	3. All corridors and passageways should be designed to allow the crew members to retain the above orientation.
4. Movements parallel to the spin axis should involve a sideways shuffle and thus continue to allow the head to remain fixed in the proper orientation.	4. Ladders which provide for radial translation among levels must have the rungs oriented axially and with allowance for climbing one side and descending the other. Thus, Coriolis forces may always be made to press the astronaut into the ladder, rather than pulling him away. Ascent will be accomplished on the trailing side, descent on the leading side.

(Extracted in part from Ref. I.15)

operating at the spin axis. The ability of astronauts to make the transition from artificial gravity to weightlessness and back is entirely a question of adaptation. No experimental evidence bearing on this issue is available (Ref. I.24).

3.2.2 Adaptation

The vast majority of earth-based rotational studies have taken place in rooms rotated about their vertical axes. Under these circumstances, a normal perceptual-motor adaptation has been found to occur within about 24 hours at angular velocities at least as great as 6 rpm (Ref. I.7, I.12, I.9, I.13, I.19, I.20, I.21).

Since this angular velocity is greater than the maximum rotation rate proposed for early artificial gravity experimentation, and almost surely greater than that which may be used on later, larger space stations, it has frequently been assumed that adaptation will occur under the foreseen conditions of artificial gravity, particularly if the maximum rotation rate is approached gradually (Ref. I.8). It should be noted, however, that rotation in a space station differs in some significant details from rotation in an earthbased room (Ref. I.10). The intersensory discordances accompanying most movements in an earthbased rotating environment are consistent in the sense that any given movement has essentially the same effects on the subject regardless of his position within the room or the direction in which he is facing or (except for the direction of apparent gravity) moving. In a rotating space station, on the other hand, pitch and roll head movements (when standing), angular limb movements, and horizontal translation will have grossly different effects depending upon the orientation of the astronaut. Thus, the intersensory discordances which occur in artificial gravity are inconsistent. Since consistent intersensory discordance is a usual requirement for a normal perceptual-motor adaptation (Ref. I.14, I.16), adaptation may be expected to occur to a lesser degree (Ref. I.10, I.18) or in a different form in space than on earth.

A second form of adaptation which may occur to artificial gravity is a simple vestibular habitation or suppression of vestibular inputs (Ref. I.28). While this form of response change occurs primarily as a function of repeated stimulation and may not be affected by the presence of intersensory conflicts (Ref. I.23), it is nonetheless a mechanism whereby the adverse effects of artificial gravity on astronauts will probably be reduced.

A third form of adaptation which may occur in artificial gravity is a simple conditioned visual suppression of conflicting information. That is, the visual sense will become predominant, to the exclusion of conflicting information from vestibular and other proprioceptive sensors. While this form of response change has not been elicited specifically as a result of the kind of intersensory discordance present in artificial gravity, it is known to occur in humans (Ref. I.2). It is this "adaptive mechanism" which appears to be most adaptive in the presence of the inconsistent pattern of intersensory discordance present during spacecraft rotation (as opposed to rotation in an earthbased room).

While these considerations of adaptive mechanisms may seem to be of purely theoretical import, the degree and kind of adaptation which occurs bears significant implications for the proper design of spacecraft and for proper mission task planning. A normal perceptual-motor adaptation, for example, might well be highly radius-specific, so that an astronaut completely adapted to rotation at 33 feet might be unable to perform well at, say, 16 feet, where different responses are appropriate due to the change in radius and gravity level. Normal perceptual-motor adaptation also involves significant after-effects, so that a period of readaptation, in this case to a state of weightless non-rotation, is required. This period is often as long as that required for initial adaptation. Thus, an emergency despin following which critical tasks must be performed might pose insurmountable problems to an astronaut if adaptation takes this form. The other two forms of adaptation, however, would not be particularly radius-specific, nor would they require a significant period of readaptation after rotation. Of these two mechanisms, only that involving conditioned visual suppression

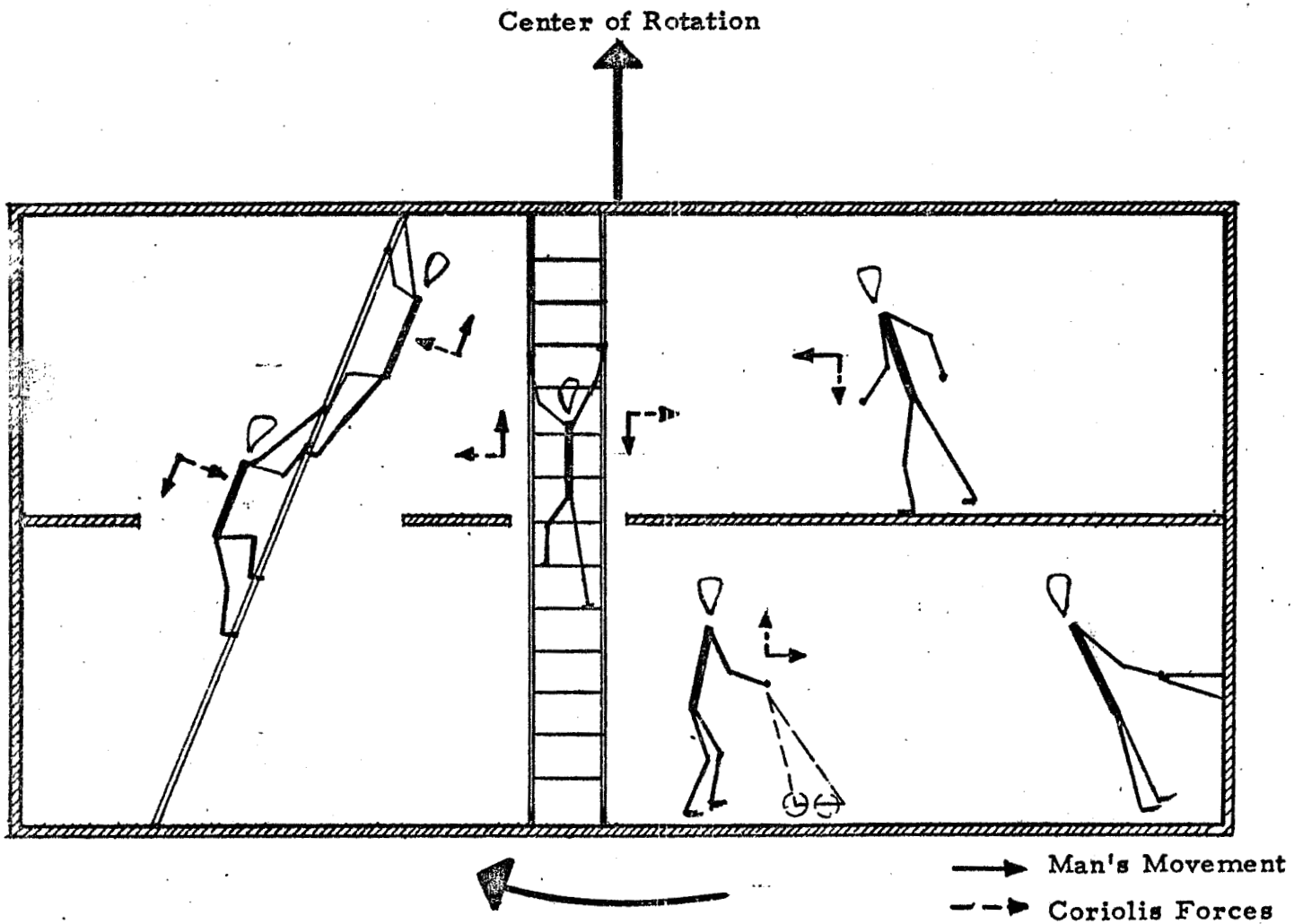


Figure II-I-1 Forces in Artificial Gravity

would fail completely in the absence of a structured visual field (Ref. I.2) as might occur, for example, in a power failure. Basically, each of these possible forms of adaptation would result in improved performance at the 33-foot level. While performance at other levels would be a significant clue to the type of adaptation occurring, the measurement of eye movements in conjunction with controlled head movements with and without a visual field is probably the only practical method of clearly determining the nature and degree of adaptive effects.

3.2.3 Artificial Gravity Design Envelope

Several investigators (Ref. I.4, I.17, I.26, I.27) have developed design envelopes for acceptable combinations of radius, angular velocity, and gravity level. Basically, the design envelopes are all bounded by some combination of the parameters: maximum angular velocity, minimum radius, maximum gravity level, minimum gravity level, and maximum level of Coriolis forces during translation. These parameters will be considered separately. The criteria used by each author for determination of design envelopes and the resulting design envelopes, shown as a function of radius and angular velocity, are presented in Figures II-I-2 through II-I-5. A composite design envelope is shown in Figure II-I-6.

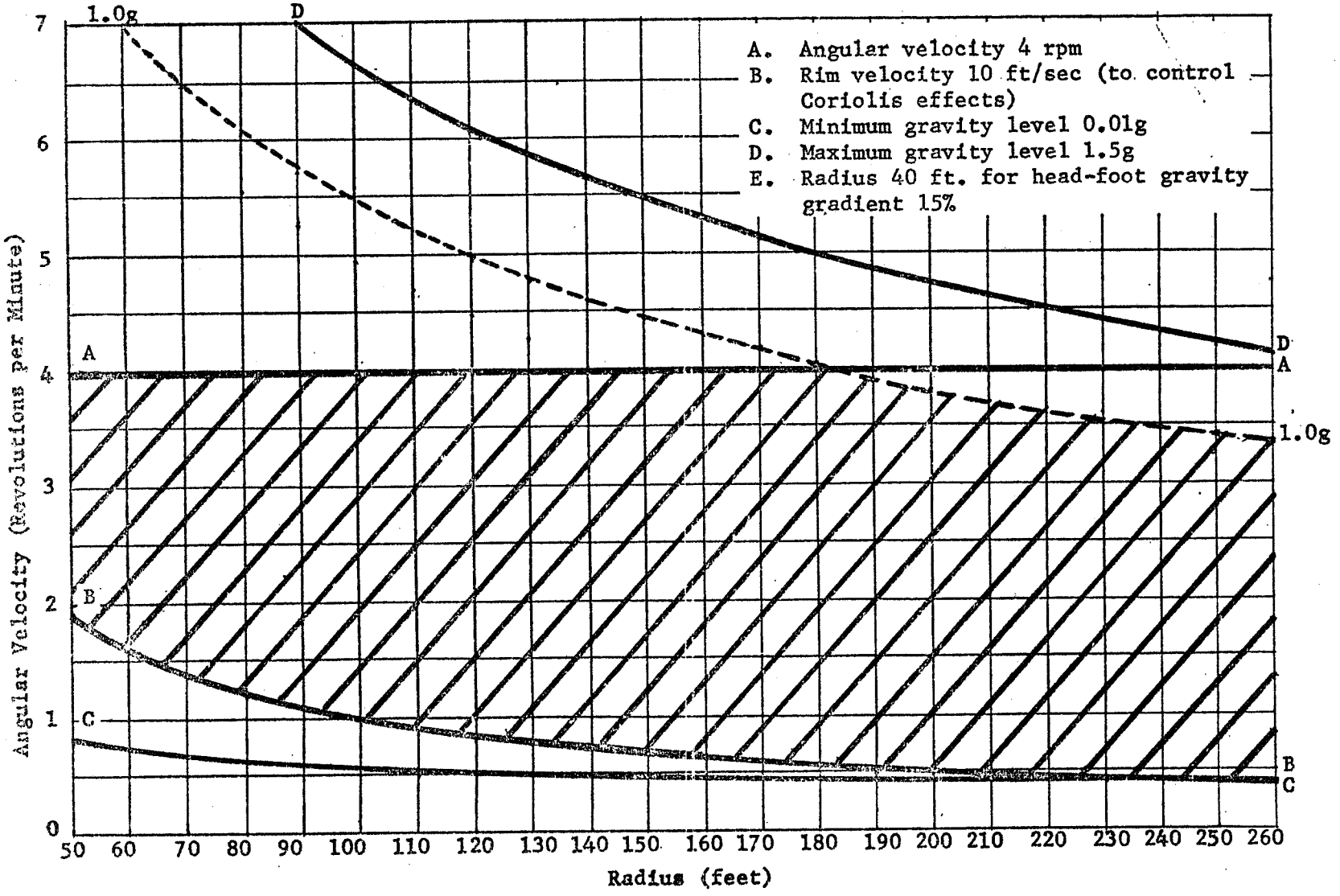


Figure II-I-2 Artificial Gravity Design Envelope (Ref. I.4)

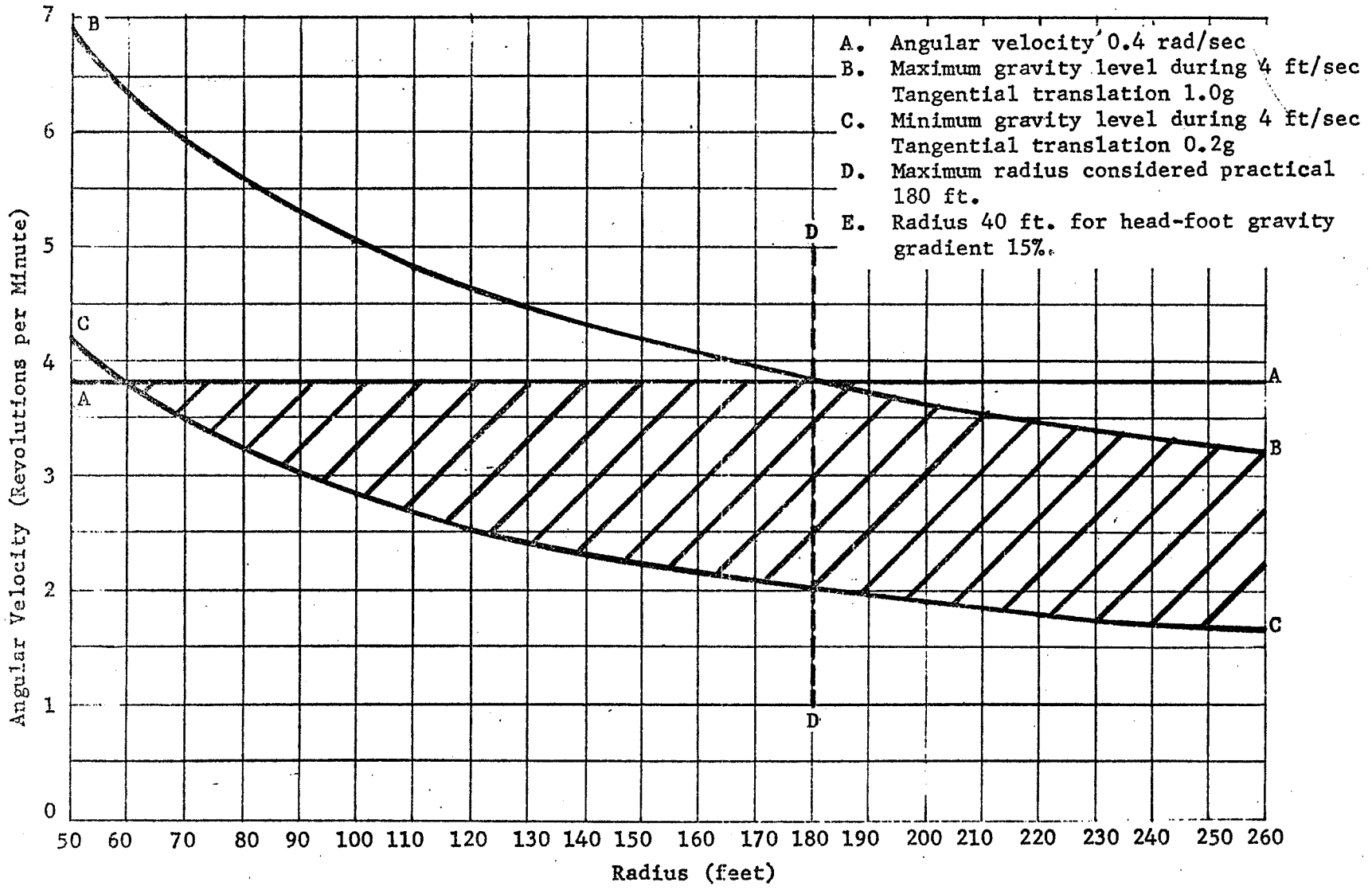


Figure II-I-3 Artificial Gravity Design Envelope (Ref. I.17)

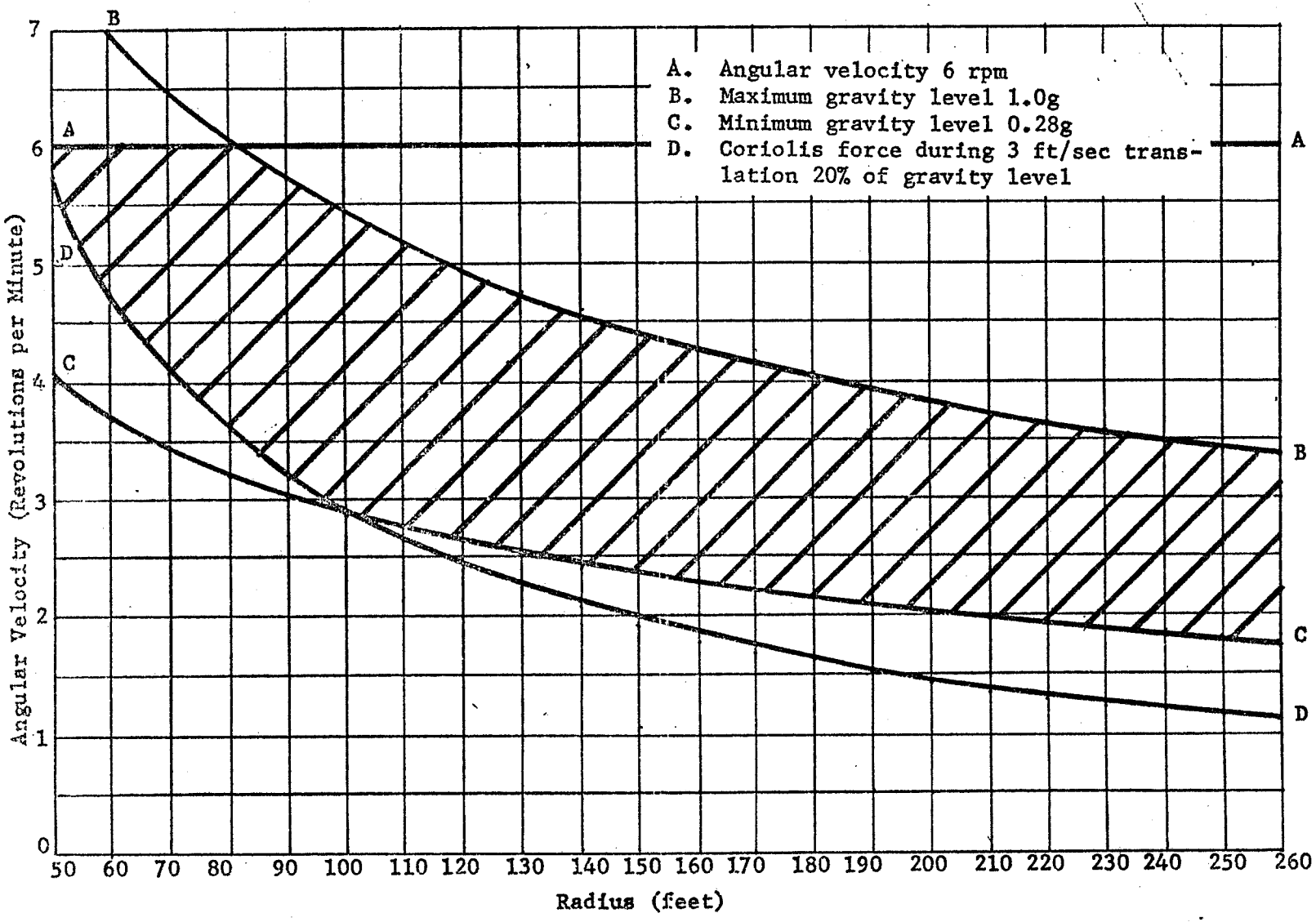


Figure II-I-4 Artificial Gravity Design Envelope (Ref. I.27)

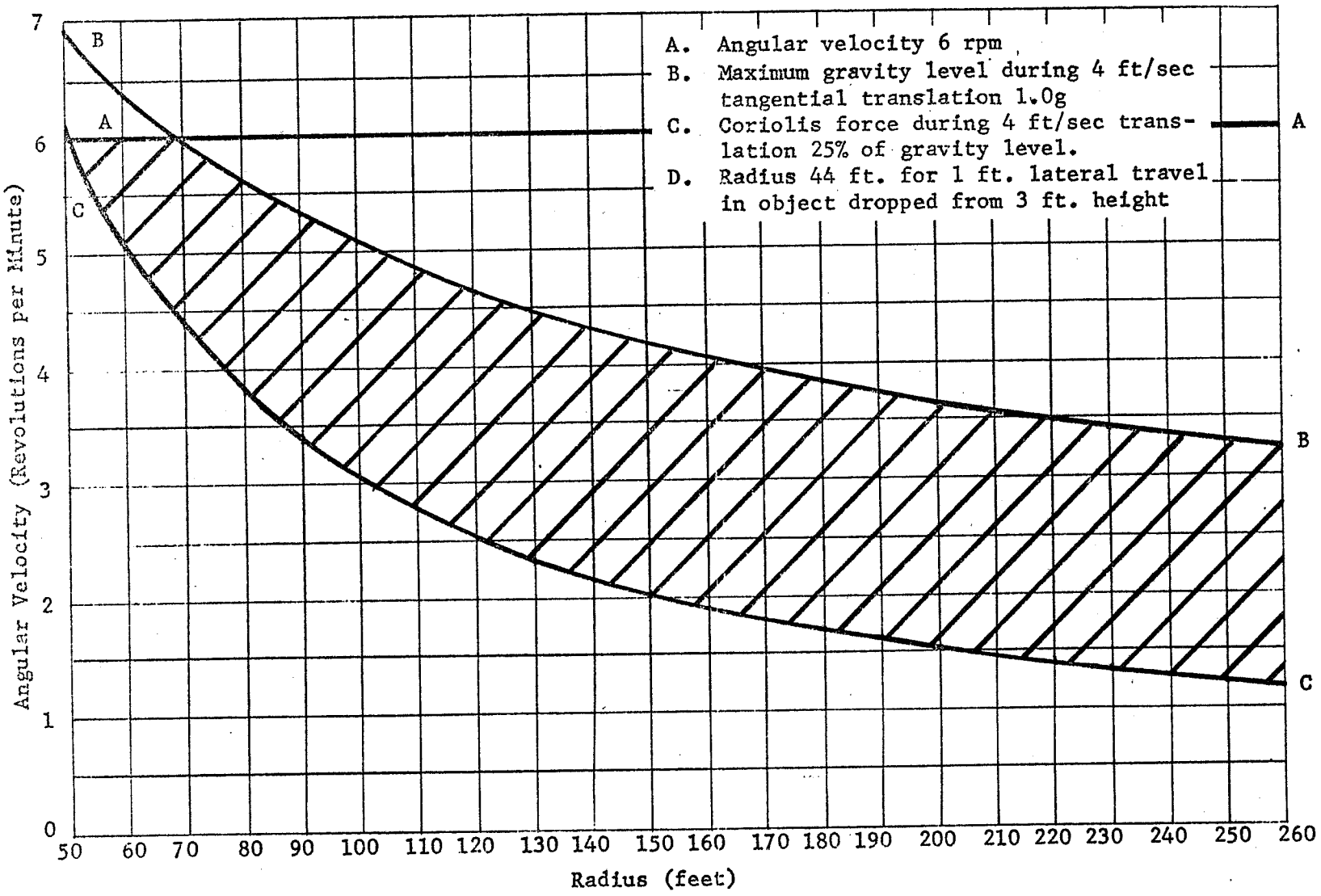


Figure II-I-5 Artificial Gravity Design Envelope (Ref. I.26)

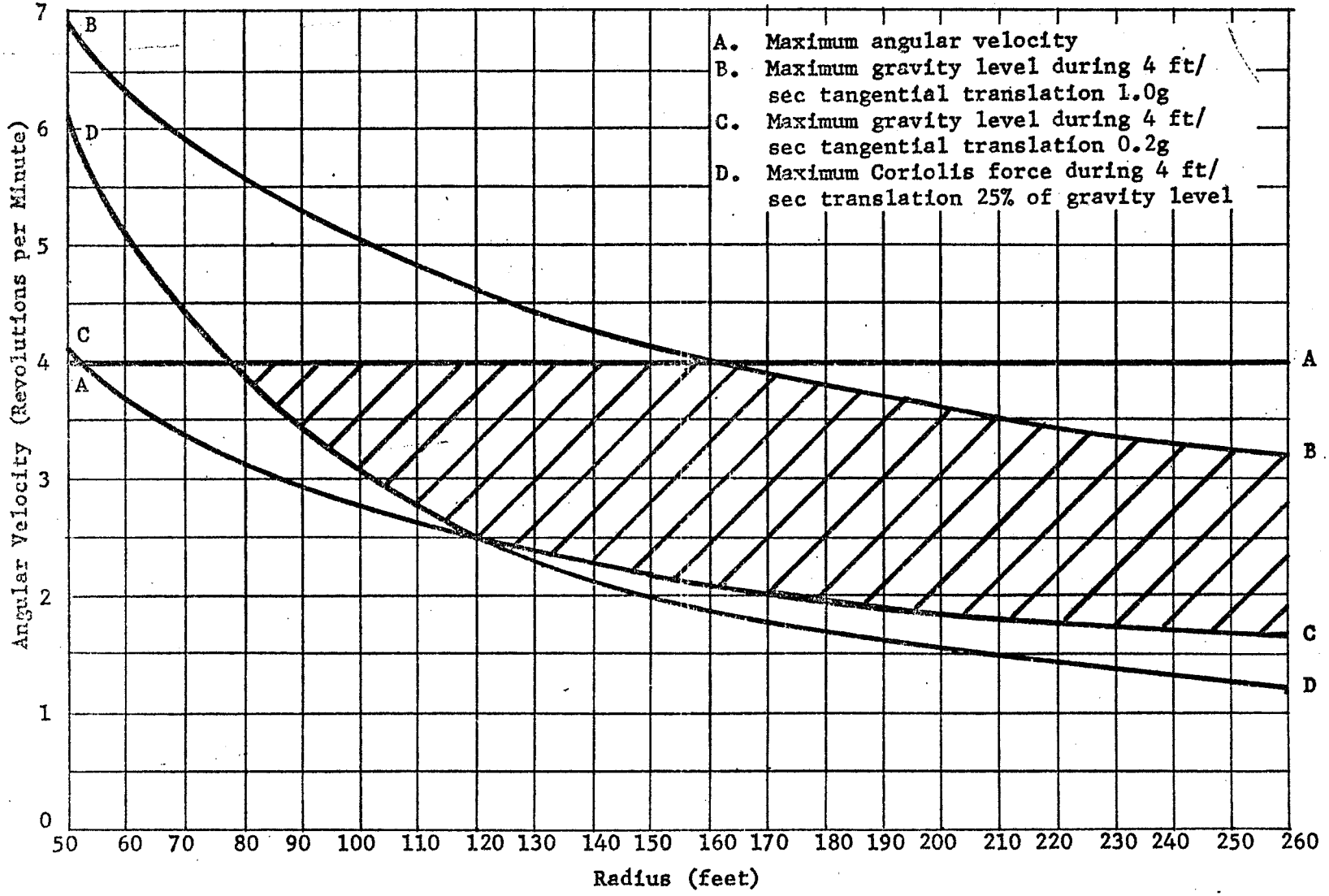


Figure II-I-6 Composite Artificial Gravity Design Envelope

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II-J INTERRELATED ENVIRONMENTS

1.0 Introduction

The problem of habitability is essentially one of interrelated environments. Habitability is a global concept involving the interplay of all factors related to man and his environment. Since man's environment includes not only the physical environment and physiological requirements, but also psychological and social requirements, the large number of possible interrelationships among habitability requirements makes the evaluation of habitability an extremely complex and difficult task.

The assessment of habitability is complicated not only by the large number of possible interrelationships among habitability requirements, but also by the interrelation of habitability requirements and individual differences. That is, habitability is a relative as well as a global concept; optimum habitability for one person may not be optimum habitability for another person. For example, studies of visual comfort and visibility have shown that persons vary considerably. Some are very sensitive to brightness and find that what may be a comfortable situation for others is considerably annoying and uncomfortable to themselves. In one particular study (Ref. J.5), observers were required to select brightnesses which were at the borderline of comfort and discomfort. The percent of observers selecting borderlines falling within different brightness ranges is shown in Figure II-J-1. The average brightness selected was 890 foot lamberts. However, if this value were used as the basis for determining brightness limitations, 50 percent of the observers would be uncomfortable. In other words, a much lower brightness must be used if all observers are to be comfortable. Another example of the problem of individual differences in habitability concerns the use of color in living areas. Generally speaking, most people prefer either warm or cool colors. Personal preference depends on such factors as the individual's familiarity

with certain colors and color schemes and the emotional connotations, either conscious or unconscious, that they may have for him. It is generally assumed that emotionally responsive persons will react freely to color, inhibited individuals will feel uneasy with an actively colored environment, and restricted or detached types may be unaffected (Ref. J.4).

The problem of individual differences in habitability is traditionally handled by establishing comfort ranges and tolerance limits for the various indices. Unfortunately, the specification of tolerance limits and comfort zones for various factors is complicated by a third type of interrelationship, the interrelationship of time and multiple stresses on behavioral efficiency. The reliability of established end-points of tolerance and comfort zones is always questionable; however, the reliability is especially suspect when other stressors are operative in the environment. In addition to the usually unknown effects of multiple stresses on tolerance limits, there is the problem of the convergence or divergence of the end points as a function of time. Very few studies

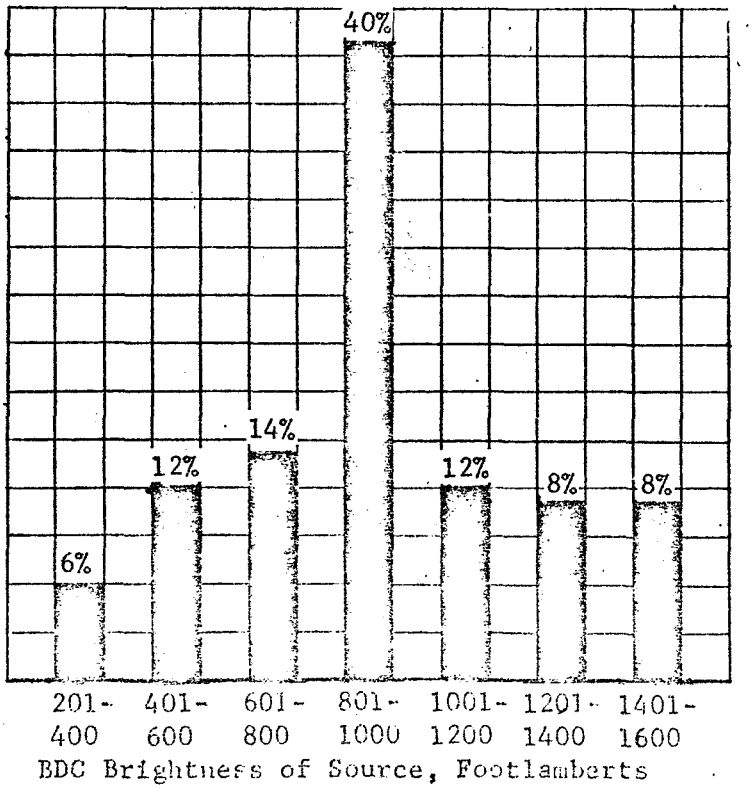


Figure II-J-1 The Brightness Judged to be at the Borderline Between Comfort and Discomfort, as Selected by Each of a Group of Observers

have been performed to evaluate multiple stresses and time relationships. The limited data that are available indicate that whether combinations of stresses produce additive or less than additive effects depends entirely on what effect is measured. For example, the data in Table II-J-1 were taken from a study (Ref. J. 7) in which three separate stressors (heat, 105°F; noise 110 db; and hypoxia, 12,000 ft. equivalent) were paired or used together while performance was measured by a primary tracking task and a secondary monitoring task and three physiological measures were monitored, heart rate, respiration rate, and rectal temperature.

Table II-J-1 Effects of Multiple Stresses

Stresses	Effects		
	Primary Task	Physiological Measures	Secondary Task
Hypoxia heat & noise	< additive	additive	additive
Hypoxia and noise	additive	additive	additive
Hypoxia and heat	additive	additive	> additive
Noise and heat	< additive	additive	additive

Note that only the physiological measures showed consistent additive effects, the primary behavioral task showed additive or less than additive effects, and the secondary task showed additive or more than additive effects.

To conclude, the problem of interrelationships is crucial to the overall problem of habitability. Some of the interrelationships are possible to express in quantitative or qualitative terms; others are impossible to express, either quantitatively or qualitatively. The major interacting influences on temperature, illumination and acoustics are presented in the appropriate chapters. However, certain interrelationships stand somewhat alone and are difficult to place in other chapters. The major conclusions concerning these are presented next.

2.0 Interrelated Environments

2.1 Interrelationships of Interiors

Interrelationships among colors, illumination, shade, and the subjective impressions of time, size, weight, and volume are given in Tables II-J-2 through II-J-6.

Table II-J-2 Color Effects on Perceptions of Time, Size, Weight, and Volume

Color	Perception of Time	Size	Weight	Volume*
"Warm" red yellow pink ivory cream peach lemon coral rose wine	time is over-estimated. Use warm colors for areas where time in apparent "slow motion" might be more pleasurable (eating, recreation).	things seem longer and bigger.	weights seem heavier.	decreases apparent size of rooms.
"Cool" green violet blue bluish-green turquoise lilac lime jade aqua	time is under-estimated. Use cool colors for areas where routine or monotonous tasks are performed.	things seem shorter and smaller.	weights seem lighter. (Use on boxes & containers which must be carried about.)	increases apparent size of rooms.

(Extracted from Ref. J.2, J.4)

*The conditions of brightness, color saturation and level of illumination required to either enlarge or close-in a living area are presented in Table II-J-3.

Table II-J-3 Brightness, Color Saturation, and Illumination Level Effects on Perception of Volume

Volume (roominess)	Brightness*	Color Saturation	Illumination Level
enlarge**	Areas will be enlarged by lightness and small paper patterns. (Use to alleviate feelings of oppression or "closed-in".)	Pale or desaturated colors "recede". In situations where equipment projects into a room and tend to make it appear smaller than it actually is, paint projections the same color as the ceiling or wall-a very light shade-to make them appear to recede into ceiling or wall.	High
Close-in	Areas will be closed-in by darkness and large paper patterns.	Dark or saturated hues "protrude".	Low

(Extracted from Ref. J.2, J.4, J.8)

*Brightness is a function of reflectance. Table II-J-4 and II-J-5 give reflectance factors for typical paint, paper, and wood finishes and Federal Color Standards. Table II-J-6 presents the Illuminating Engineering Society's recommendations for reflectance ranges of interior surfaces (Ref. J.6).

**Note: In establishing space relationships in interiors there is a wholly natural sequence of perspective, white, black, pure hues, and deep shades will appear near the eye. In what is called aerial perspectives, as colors shift or fall back into the distance that which is dark increases in value; that which is light in value softens and all colors eventually fade into medium gray. Color schemes can be planned to feature this phenomenon by using strong contrasts for near elements and grayish or weak contrast for far elements (Ref. J.2).

Table II-J-4 Reflectance Factors for Federal Color Standards (No. 595)

In the table of Federal Color Standards at the right, the first digit of the Federal color number indicates the gloss range of the color (1, gloss; 2, semi-gloss; 3, lusterless). Where a color appears in more than one gloss range, the last four digits are the same. The Federal color numbers listed are gloss colors. Federal Standard: Colors, NO 595, includes these colors in semi-gloss and lusterless when required for Shore Establishment use. (Ref. J.8)

Color	Federal Color Number	Reflectance Percent
Light ivory	13711	75
Soft yellow	13695	72
Peach	12648	64
Sun tan	13613	60
Light green	14516	55
Highlight buff	13578	55
Brilliant yellow	13538	55
Light blue	15526	50
Pearl grey	16492	46
Light Navy gray	16251	29
Bright green	14260	26
Medium green	14277	25
Vivid orange	12246	23
Medium tan	10219	21
Terra cotta	10233	20
Clear blue	15177	19
Spruce green	14159	15
International orange	12197	15
Radiation purple	17142	15
Med. Navy gray	16187	14
Deep green	14158	14
Fire red	11105	7
Deep Navy gray	16087	7
Passive green	14077	7
Passive maroon	10075	7
Marine Corps green	14052	4

Table II-J-5 General Reflectance Factors of Paint, Paper, and Wood

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

(Ref. J.8)

Table II-J-6 Reflectance Range for Interior Surfaces

Ceilings	60 to 85 percent (white or pale tint)*
Walls	35 to 60 percent#
Window or Glass Wall	Fabric treatment: Wide expanse or backgrounds. 45 to 85 percent Limited areas of decorative design on light background or side draperies 15 to 45 percent
Floors	15 to 35 percent (25 to 35 percent preferred)+ (Values of high end of range recommended for use in rooms where lighting efficiency is a major consideration: kitchen, bathrooms, utility rooms)

* 70 percent or more is required for effective performance of indirect lighting methods.

\# Appreciably higher than 50 percent creates brightness problems when portable luminaires are placed near walls and when extensive wall lighting methods are used. According to paint manufacturers, the public prefers 45 percent.

\+ Middle to high values preferred because of their predominance within the 60-degree cone of vision when performing many visual activities.

2.2 Interrelationships in Living Areas

Interrelationships among colors, temperature, sound, and overall subjective impression in living areas are presented below.

Color	Sound	Temperature	Subjective Impression in Living Area
"Warm" red yellow lemon pink ivory cream peach coral rose wine	Noise induces a hazier perception of warm colors Brightness, loudness, stimulation of senses in general are associated with the most active effect of warm colors.	"warmness" Use to soften up chilly or vaulty spaces.	Centrifugal action - with high levels of illumination, warm and luminous colors, the person tends to direct attention outward. There is increased activation in general, alertness, outward orientation. Such an environment is conducive to muscular effort, action, and cheerfulness.
"cool" green blue violet lilac bluish-green turquoise lime jade aqua	Noise increases sensitivity for cool colors. Dimness, quietness and sedation of the senses in general are associated with the most active effect of cool colors.	"coolness" Use where working conditions expose person to warm temperatures.	Centripetal action - with softer surroundings, color hues, and lower levels of illumination, there is less distraction and a person's ability to concentrate on difficult visual and mental tasks is enhanced. Good inward orientation is furthered.

(Extracted from Ref. J.2, J.3, J.4)

2.3 Interrelationships of Colors, Odors and Taste

Interrelationship among colors, odors, and taste are shown below:

	Odor	Taste
These colors have pleasant associations with odors and taste. Their use in food service areas has been shown to facilitate appetite appeal.	pink lavender pale yellow green	coral peach soft yellow light green — tints vermillion flamingo pumpkin turquoise — richer colors
Avoid these colors in food service areas as they have unpleasant associations with odors and taste.	gray brown black deep shades in general	yellow-orange yellow-green purples violet greenish yellow gray blue olive

(Extracted from Ref. J.2, J.4)

2.4 Interrelations Between Color and Type of Illumination

In the field of interior color, the expression "true color" has no meaning. Light modifies colors in an almost infinite number of ways (Ref. J.6). The effects of artificial illuminants on the perception of color is of particular interest in establishing habitability illumination requirements; therefore, the effects of white fluorescent lamps and mercury and filament lamps on the perception of colors are given in Tables II-J-7 and II-J-8.

Table II-J-7 Color Effects of White Fluorescent Lamps

	Cool White	Deluxe* Cool White	Warm+ White	Deluxe+ Warm White	Daylight	White	Soft White Natural
Lamp appearance; effect on neutral surfaces.	White	White	Yellowish White	Yellowish White	Bluish White	Pale Yellowish	Pinkish White
Effect on "atmosphere"	Neutral to moderately cool	Neutral to moderately cool	Warm	Warm	Very Cool	Moderately warm	Warm, pinkish
Colors strengthened	Orange, yellow, blue	All nearly equal	Orange, yellow	Red, orange, yellow, green	Green blue	Orange, yellow	Red, orange
Colors grayed	Red	None appreciably	Red, green, blue	Blue	Red, orange	Red, green, blue	Green, blue
Effect on complexions	Pale Pink	Most natural	Sallow	Ruddy	Greyed	Pale	Ruddy Pink
Remarks	Blends with natural daylight.	Best overall color rendition; simulates natural daylight.	Blends with incandescent light.	Excellent color rendition; simulates incandescent light.	Usually replaceable with CW.	Usually replaceable with CW or WW.	Usually replaceable with CWX or WWX.

* Greater preference at higher levels.

\+ Greater preference at lower levels.

Source: General Electric Company

Table II-J-8 Color Effects of Mercury and Filament Lamps

Incandescent			High Intensity Discharge Lamps			
Lamp Names	Filament**	Clear Mercury	White Mercury	Deluxe White Mercury	Multi-Vapor*	Lucalox**
Lamp appearance effect on neutral surfaces	Yellowish white	Greenish blue-white	Greenish white	Purplish white	Greenish white	Yellowish
Effect on "atmosphere"	Warm	Very cool, Greenish	Moderately cool, Greenish	Warm, Purplish	Moderately cool, Greenish	Warm, Yellowish
Colors strengthened	Red Orange Yellow	Yellow Green Blue	Yellow Green Blue	Red Yellow Blue	Yellow Green Blue	Yellow Orange Green
Colors greyed	Blue	Red, Orange	Red, Orange	Green	Red	Red, Blue
Effect on complexions	Ruddiest	Greenish	Very pale	Ruddy	Greyed	Yellowish
Remarks	Good color rendering	Very poor color rendering	Moderate color rendering	Color acceptance similar to CW fluorescent	Color acceptance similar to CW fluorescent	Color acceptance approaches that of WW fluorescent

* Greater preference at higher levels.
** Greater preference at lower levels.

A related problem concerns the "normal" appearance of object colors; for example, the normal appearance of human flesh. It has been demonstrated by A. A. Kruithof (Ref. J.2) that the normal appearance for object colors will require different tints in a light source, depending on the degree of illumination intensity. Colors of objects and surfaces will have a pleasing and natural appearance only if the color tint of the light source is warm (pink, orange) at low levels of intensity and whiter and cooler at high levels of intensity. Figure II-J-2 demonstrates Kruithof's principle; the region of natural appearance for object colors in relation to the tint of light source and level of illumination lies within the crosshatched area. Note that for good and flattering human appearance, warm light is required at low levels of illumination and whiter (cooler) light is required at higher levels of illumination.

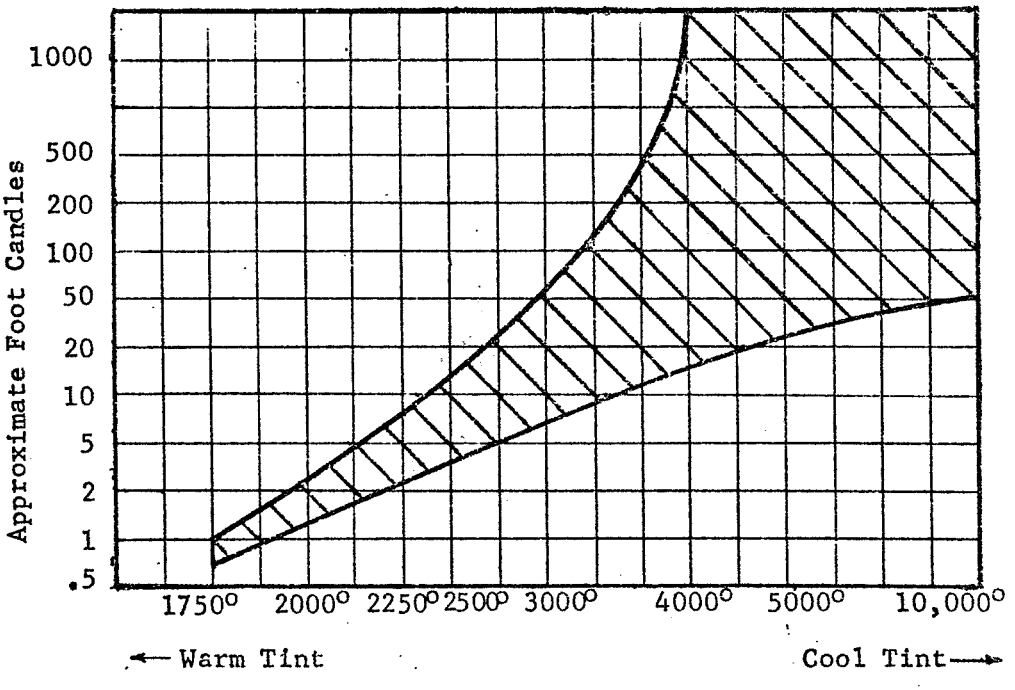


Figure II-J-2 Kruithof's Principle (Ref. J.2)

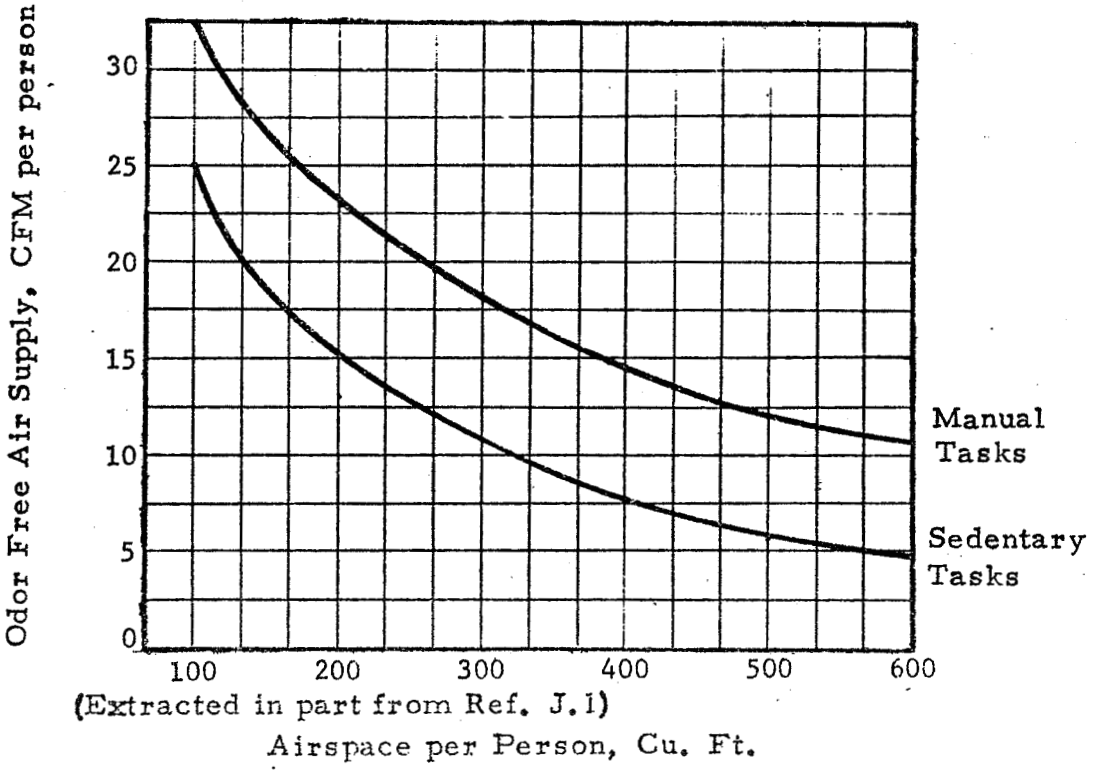
Table II-J-9 Kelvin Color Temperatures of White Fluorescent Lamps

Lamp Color Name	Color Temperature
Warm White	3000 K
Deluxe Warm White	2900 K
White	3500 K
Cool White	4200 K
Deluxe Cool White	4200 K
Sign White	5200 K
Daylight	7000 K

Source: General Electric Company

2.5 Interrelationship of Volume and Ventilation Requirements

Often the production of body odors in an enclosed space requires ventilation. The data plotted in Figure II-J-3 below are the minimum odor-free air requirements to remove objectionable body odors under laboratory conditions for sedentary adults and for adults engaged in manual tasks.



(Extracted in part from Ref. J.1)

Figure II-J-3 Minimum Odor-Free Requirements to Remove Objectionable Body Odors

REFERENCES

J.1 ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 345 East 47th Street, New York, New York, 1967.

J.2 Birren, Faber: Light, Color and Environment, Van Nostrand Reinhold Company, New York, 1969.

J.3 Birren, Faber; Principles of Color, Van Nostrand Reinhold Company, New York, New York, 1969.

J.4 Birren, Faber, Color Psychology and Color Therapy, University Books, Inc., New Hyde Park, N.Y., 1961.

J.5 Guth, S.K., BCD Brightness Ratings in Lighting Practice, Illum. Eng., 47, 184, 1952.

J.6 Halse, A.O.: The Use of Color in Interiors, McGraw-Hill Book Company, New York, N.Y., 1968.

J.7 Webb, Paul (Editor): Bioastronautics Data Book, Scientific and Technical Information Division, National Aeronautics and Space Administration, Washington, D.C., 1964.

J.8 Woodson, Wesley E., D. W. Conover: Human Engineering Guide for Equipment Designers, Second Edition, University of California Press, Berkeley, California, 1964.

III CREW AREA CRITERIA

1.0 Introduction

Habitability criteria standards are presented in this section by crew area for a broad range of mission parameters. Data relating to the following crew areas are presented for each area by the groups listed below. The four groups are further broken down by specific areas. The description of each area, to a great extent, determined the various standards and concepts. The activity of the crew areas determines the metabolic rate for temperature considerations and lighting requirements and is listed as either high, moderate, or low. The mood to be created in the room determined such factors as temperature, color, lighting, and acoustics. Therefore, the mood characteristics are either restful, mental concentration, or physical activity. The social factor determined such items as hygiene and mess requirements, volumetric requirements, and dual room usage. For each standard and concept, all of the descriptive terms must be combined to achieve the optimum standard or concept.

2.0 Personal Areas

1. Crew Compartments, Bedroom

3.0 Public Areas

1. Dining Room
2. Lounge
3. Recreation
4. Library
5. Study
6. Conference
7. Passageway
8. Chapel
9. Gym
10. Locker Room

11. Theater
12. Briefing Room

4.0 Service Areas

1. Galley
2. Snack Bar
3. Bathroom
4. Dispensary
5. Laundry
6. Barber Shop

5.0 Work Areas

1. Equipment
2. Maintenance
3. Power
4. Storage, Food
5. Supply
6. Control
7. Communications
8. Computer
9. Shop
10. Offices
11. Laboratories
12. Docking
13. Photography
14. Animal Housing
15. Agricultural Study Area
16. Air Locks

III-2.1

AREA: Crew Compartments (bedroom)

DESCRIPTION

ACTIVITY: Low

MOOD: Restful, Mental Concentration

SOCIAL FACTOR: Private with ability to have one or two guests.

LIGHTING

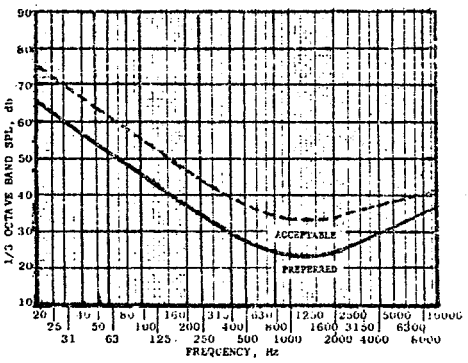
Light Source: Incandescent and Fluorescent

Light Level, Foot Candles		
Maximum	Desirable	Minimum
30	10-30	3

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	20-50	15
Floors	40	15-35	10
Furniture	50	20-40	10
Draperies	60	15-60	15

REMARKS: Individual reading lamps at head of each bed for personal use essential. General lighting level controllable (high-low) to adequately meet needs but not interfer with functions of other occupants. Atmosphere should be cool and relaxing.

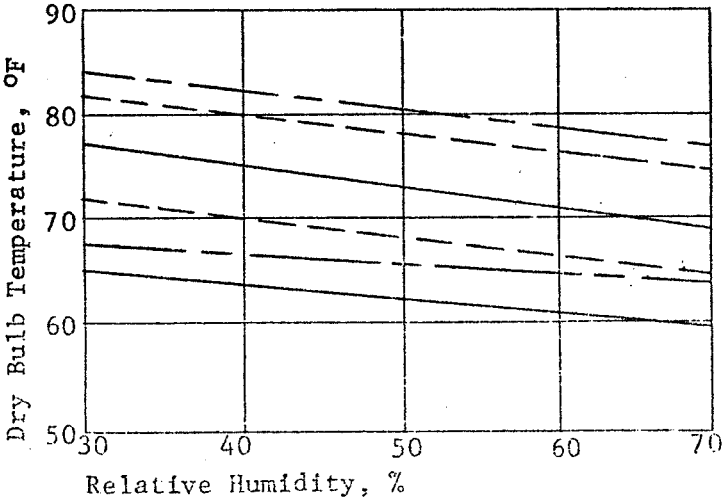
ACOUSTICS



REMARKS: Relaxation must be promoted, therefore intermittent and high-pitched noise sources must be eliminated. Thick carpets, drapes, and padded cloth furniture can be used to help trap noises.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - — - —

Air Flow Rate: 50 fpm
Metabolic Rate: 300 BTU/hr
Clo Factor: 0 to 1.0
Occupancy Time/Day: 9 Hours

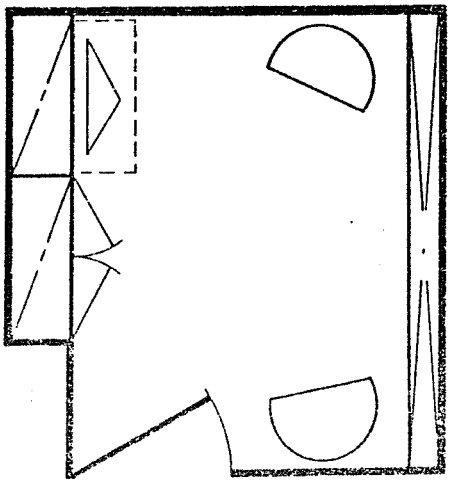
EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
3ba	2dc	14ne	13fe	13ne	2ic
		14pc	15fe	13pc	2ne
		14pl		13pl	2pc
				15ne	
				15pl	

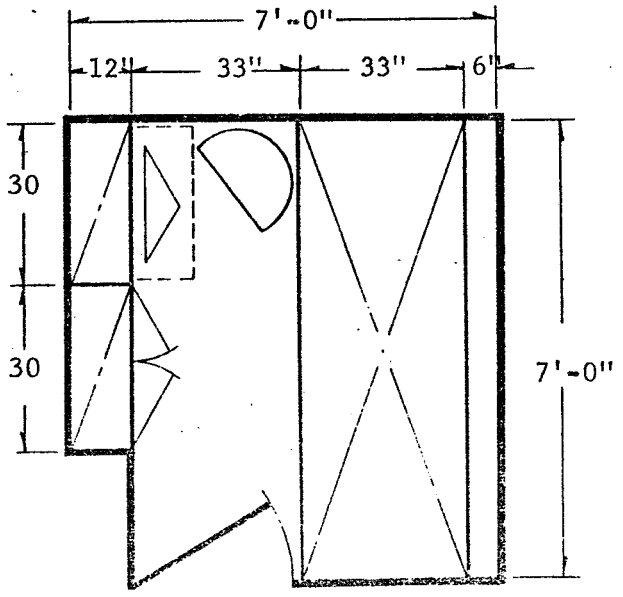
REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Both warm and cool schemes are recommended to allow for personal taste and provide for change. Provisions should be made for personal involvement if desired by occupant.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. It is recommended that all personnel be provided with a private room. The following area guidelines apply. (square feet): Gross: 45-50, Visual: 38, Net: 20-38 (fold up bed). Ceiling Height= 6'6"



BED STOWED



BED DEPLOYED

EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
3ba	2dc	17nc 171g 17pl	3dc	15nc 151a 15pl 181g 18pl	2nc 2ng

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Both warm and cool schemes are recommended to allow for personal taste and provide for change. Provisions should be made for personal involvement if desired by occupant.

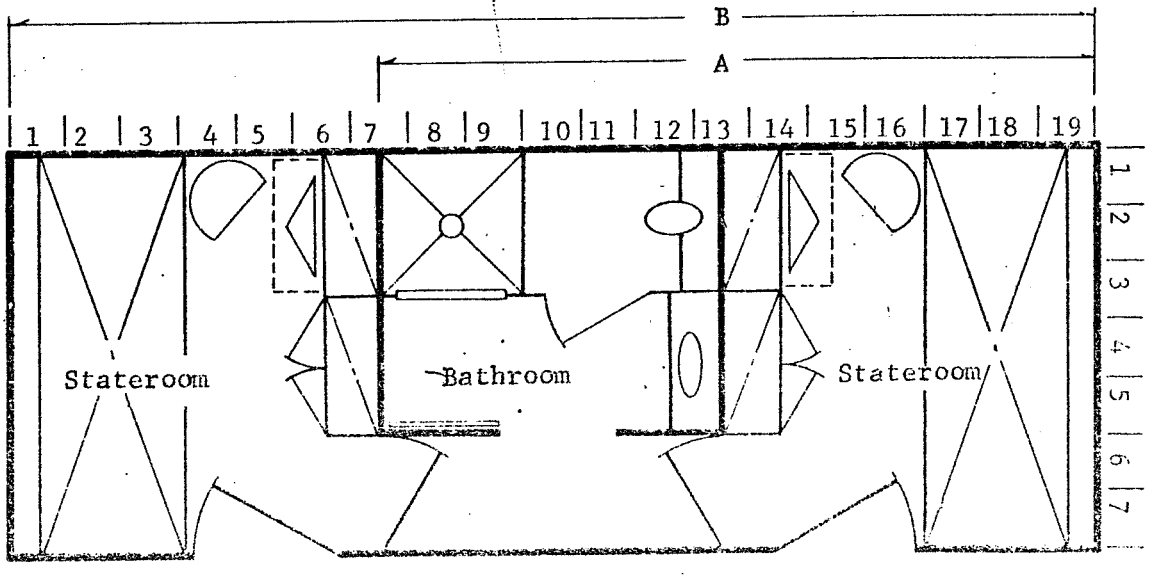
VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment.

A: Suitable for deputy commander, crews 50 - 100. Gross area/man= 80 sq. ft.

B: Suitable for deputy commander, crews 15 - 50, and management personnel, crews 50 - 100. Gross area/man= 70 sq. ft.

Ceiling Height= 6'6".



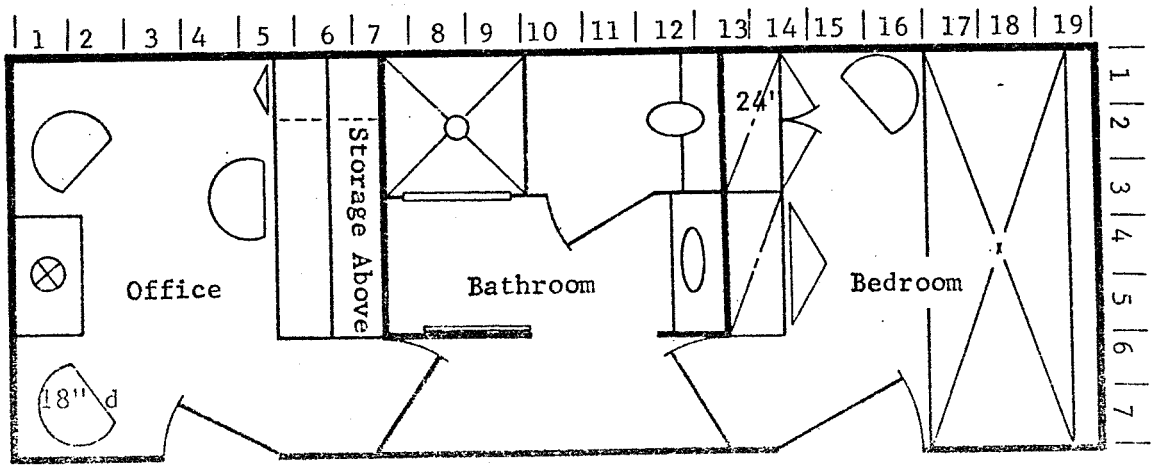
EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
3ba	2dc	2ne	1dc	1ne	14ne
		2pc		1pc	14pc
		2pl		1pl	
				3ne	
				3pl	

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Both warm and cool schemes are recommended to allow for personal taste and provide for change Provisions should be made for personal involvemen' if desired by occupant.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. The bedroom and bathroom sizes are constant for all missions; the office varies according to crew size. Gross area/crew size- 125.5 sq. ft./6-30 crew; 133.5 sq. ft./31-60 crew; 159.5 sq. ft./61-100 crew. Ceiling height=6'-6".



III-3.1

AREA: Dining Room

DESCRIPTION

ACTIVITY: Moderate to Low

MOOD: Restful

SOCIAL FACTOR: Public

LIGHTING

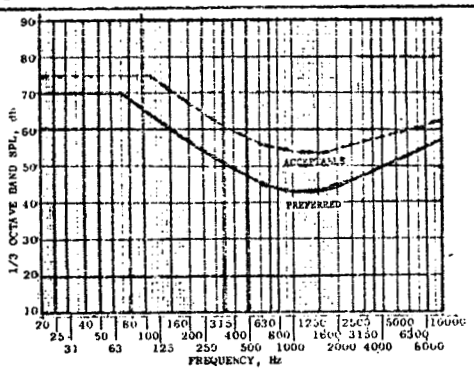
Light Source: Incandescent and Fluorescent

Light Level, Foot Candles		
Maximum	Desirable	Minimum
30	15-30	10

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	35-60	35
Floors	35	15-35	10
Furniture	45	15-45	15
Draperies	60	15-60	15
Machines		-	
Control Panel		-	
Instruments		-	

REMARKS: Two levels provided to suit the individual conditions: higher level for expediting meal serving time, lower level for subdued, relaxed dining. Higher level for maintenance program. Environment warm and inviting. Use of incandescent appropriate.

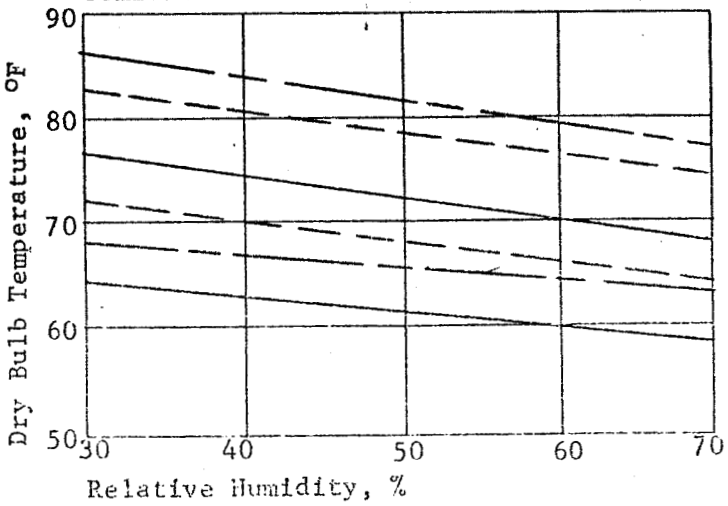
ACOUSTICS



REMARKS: High pitched noise sources must be particularly avoided to preclude crew annoyance. Unlocalized noise sources are more annoying than noise sources that can be localized. From standpoint of noise control, ideal wall, ceiling and floor should be massive and porous. SIL levels below 60 db should be maintained.

TEMPERATURE

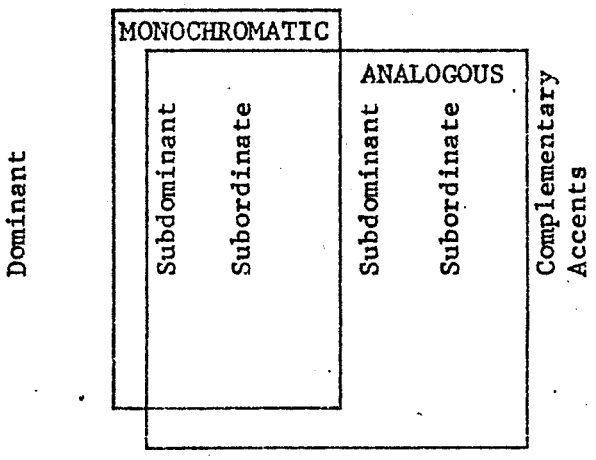
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 60 fpm
Metabolic Rate: 400 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 2 Hours

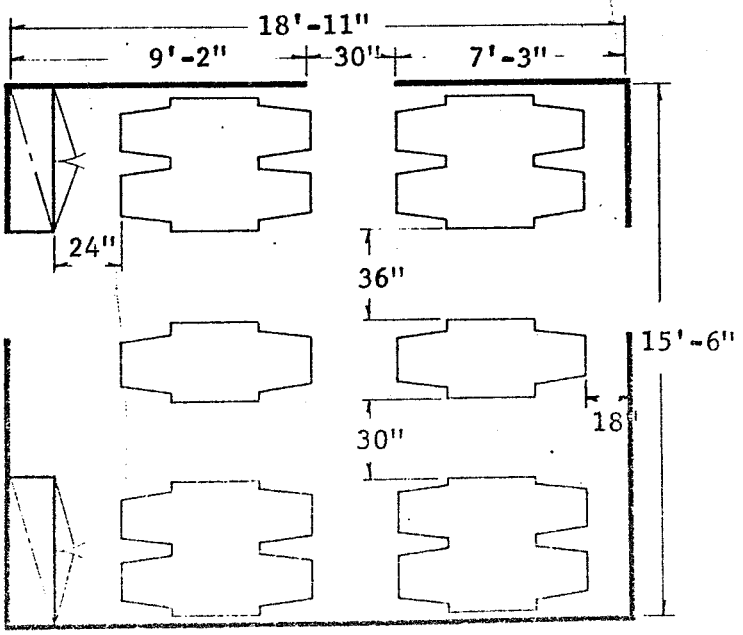
EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Warm colors are used to enhance feelings of relaxation and aid the senses of taste and odor.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Gross area/man = 15 sq. ft. Ceiling height = 7'-0" for up to 300 sq. ft. gross area, 7'-6" 300-500 sq. ft. gross area. Seating provision recommendations are as follows: crews 6-20 = 100% of crew. For crews in excess of 20 it is recommended that seating be provided for a minimum of 50% of the crew. More than two settings per meal should be avoided. It should be kept in mind that this will likely be the largest visual area in the habitat.



III-3.2

AREA: Lounge

DESCRIPTION

ACTIVITY: Low

MOOD: Restful

SOCIAL FACTOR: Public

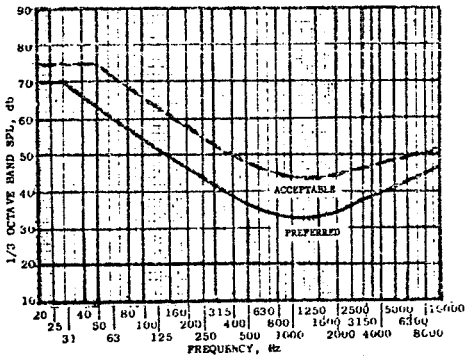
LIGHTING

Light Source: Incandescent and Fluorescent

Item	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	30	20-30	10
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	35-60	30
Floors	35	15-35	10
Furniture	45	20-40	15
Draperies	60	15-60	15

REMARKS: Lighting should be designed primarily for comfort and relaxation. Emphasis should be placed on creating variations within the room with 30 fc in reading areas. Provide adequate visual rest centers. Friendly, warm sources desirable.

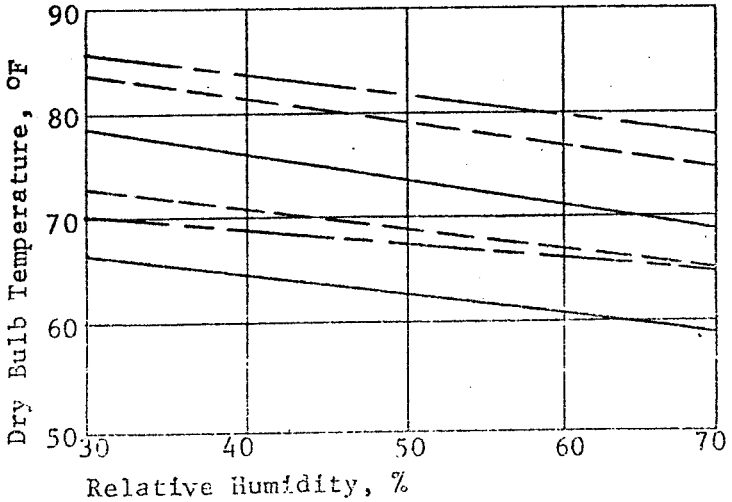
ACOUSTICS



REMARKS: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————
10 PSIA — — — —
14.7 PSIA — - — -

Air Flow Rate: 50 fpm
Metabolic Rate: 450 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 2.5 Hours

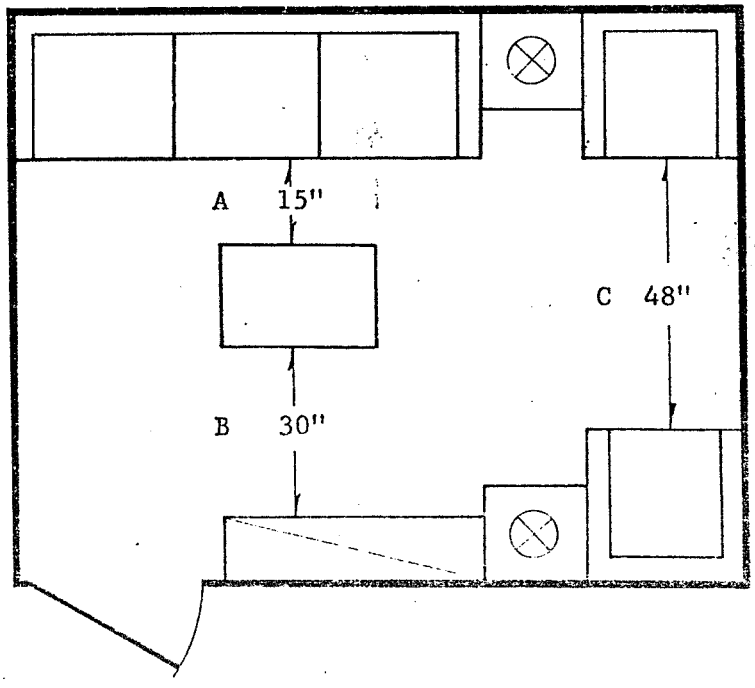
EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
1ba	1ic	1ng 1ni	2db	2ng 2ni 24ng 24½pl	15lg 15fe

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Warm colors with low intensities and subtle value changes supplement a relaxed attitude and add a note of cheerfulness.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Provide lounge seats based on 20% of crew sizes from 6 - 50. Minimum 4 seats. For crew sizes from 50 - 100 provide lounge seats based on 15% of crew size over 50, plus 10. Gross area/seat= 16 sq. ft. Ceiling height = 7'0".



III-3.3

AREA: Recreation

DESCRIPTION

ACTIVITY: Moderate to High

MOOD: Mental Concentration* & Physical Activity

SOCIAL FACTOR: Public

LIGHTING

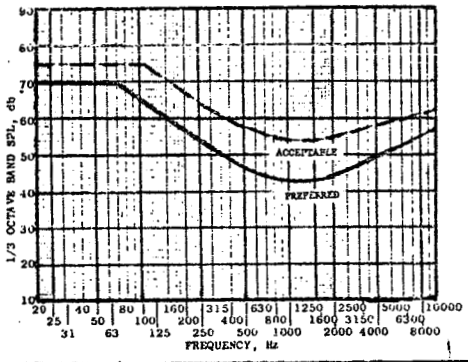
Light Source: Incandescent and Fluorescent

Light Level, Foot Candles		
Maximum	Desirable	Minimum
30	20-30	10

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	70	40-60	35
Floors	50	15-35	15
Furniture	45	25-45	20
Draperies	60	15-60	15

REMARKS: Lighting should be general to allow maximum use of area for active recreation. Colors should be cool. Individual game areas should be highlighted. Relaxing as in lounge.

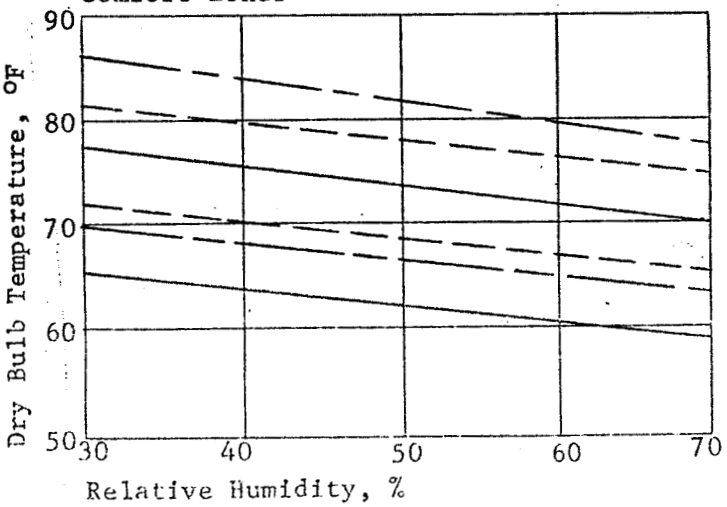
ACOUSTICS



REMARKS: SIL level below 60 db must be maintained. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

Comfort Zones

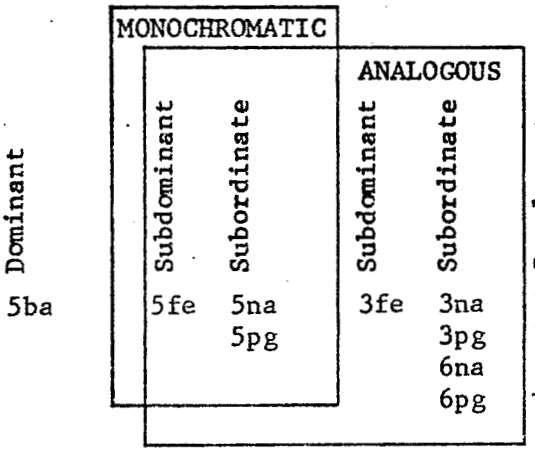


Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 70 fpm
Metabolic Rate: 450 to 700 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 2 Hours

*Card Games

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Warm colors with high intensities enhance feelings of excitement and low responsibility.

VOLUME

REMARKS: Gym, theatre, dining area and crew compartment areas are utilized for recreation activities.

III-3.4

AREA: Library

DESCRIPTION

ACTIVITY: Low

MOOD: Restful and Mental Concentration

SOCIAL FACTOR: Public

LIGHTING

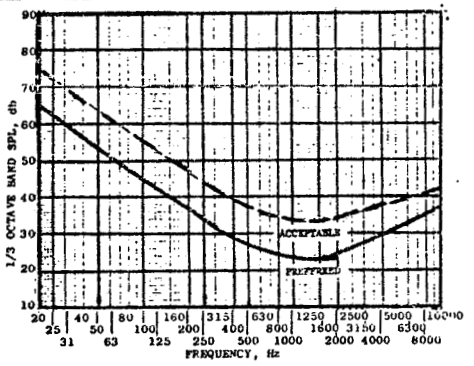
Light Source: Incandescent-Halogen Cycle, Fluorescent

Light Level, Foot Candles		
Maximum	Desirable	Minimum
30	20-30	10

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	70	40-70	35
Floors	40	15-35	10
Furniture	50	35-50	20
Draperies	60	15-60	15

REMARKS: Lighting should be suitable for reading, either at a table or in a chair. Relaxing.

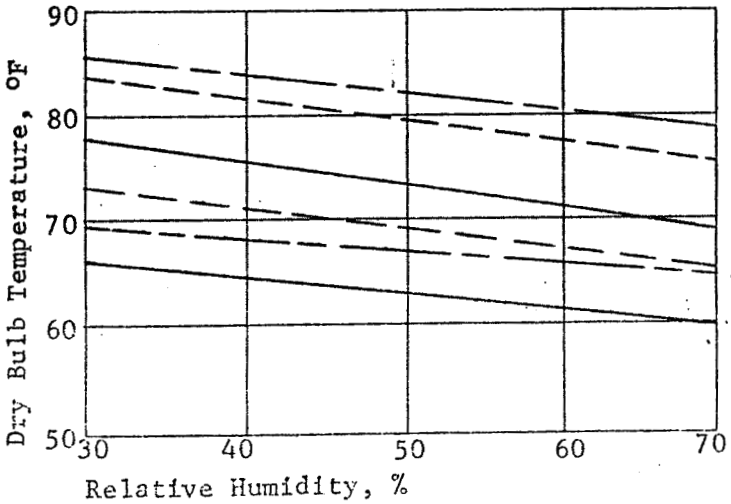
ACOUSTICS



REMARKS: SIL levels below 50 db must be maintained. Intermittent and high-pitched noise sources must be avoided to promote restful atmosphere and facilitate mental concentration. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

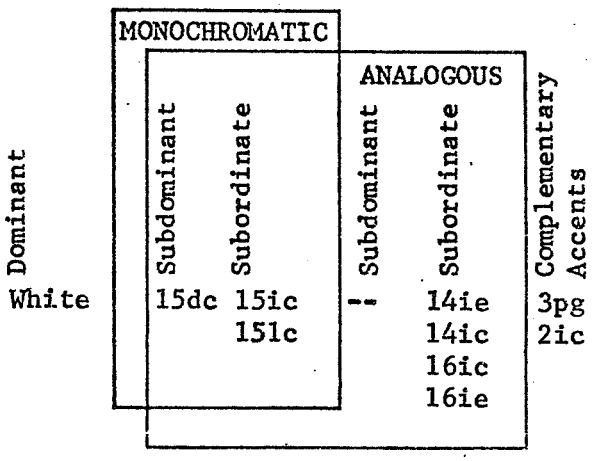
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 50 fpm
Metabolic Rate: 450 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 1 Hour

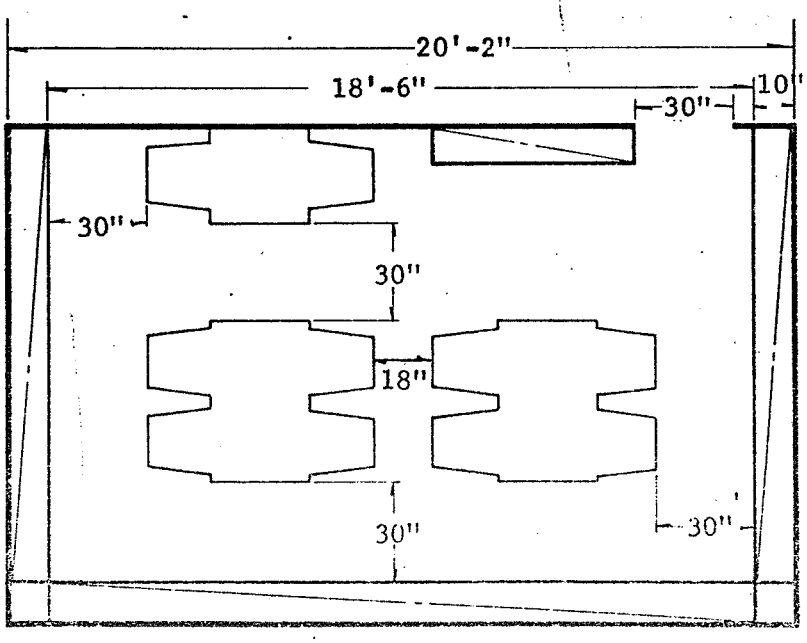
EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Colors provide adequate illumination levels for sight tasks and cool hues evoke an atmosphere of relaxed restraint and high responsibility.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Mission 30-60 days=.5 lin. ft. of shelves/man; 60-120= 1.0'/man; 120-1040= 2.0'/man. Minimum books/mission= mission duration (days). One lin. ft. of wall space= 6 lin. ft. of shelf space. One lin. ft. of shelf space= 7 books. Lin. ft. of books= approximately one square of gross area required for library. Ceiling height= 7'-0". Key passageway dimensions shown in schematic layout.



III-3.5

AREA: Study

DESCRIPTION

ACTIVITY: Low

MOOD: Restful and Mental Concentration

SOCIAL FACTOR: Public

LIGHTING

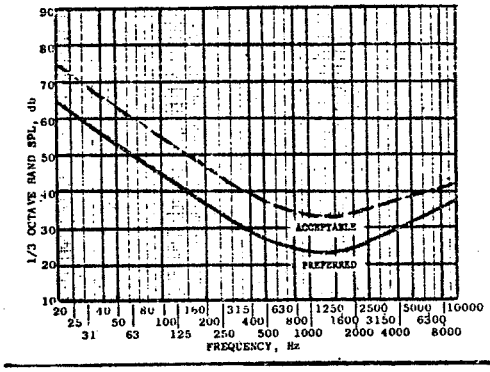
Light Source: Incandescent-Halogen Cycle, Fluorescent

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	30	20-30	10

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	70	40-70	35
Floors	40	15-35	10
Furniture	50	35-50	20
Draperies	60	15-60	15

REMARKS: Lighting should be suitable for reading, either at a table or in a chair. Relaxing.

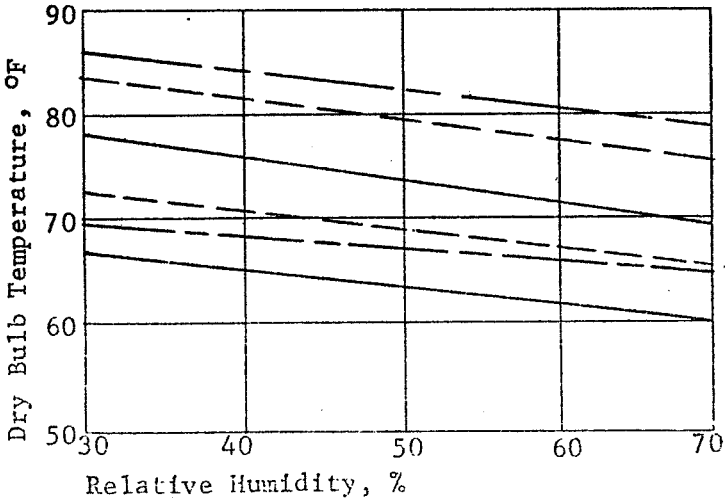
ACOUSTICS



REMARKS: SIL levels below 50 db must be maintained. Intermittent and high-pitched noise sources must be avoided to promote restful atmosphere and facilitate mental concentration. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

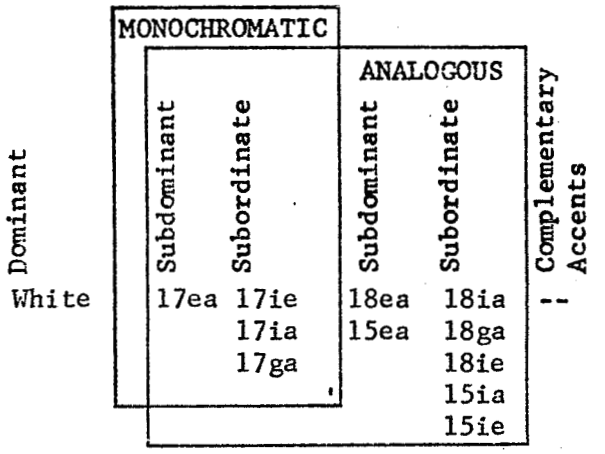
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 50 fpm
Metabolic Rate: 450 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 1 Hour

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Colors provide adequate illumination for sight tasks and cool hues evoke an atmosphere of relaxed restraint and high responsibility.

VOLUME

REMARKS: Not independent area. Provisions for study exist in crew compartment and Library.

III-3.6

AREA: Conference

DESCRIPTION

ACTIVITY: Moderate to Low

MOOD: Mental Concentration

SOCIAL FACTOR: Public

LIGHTING

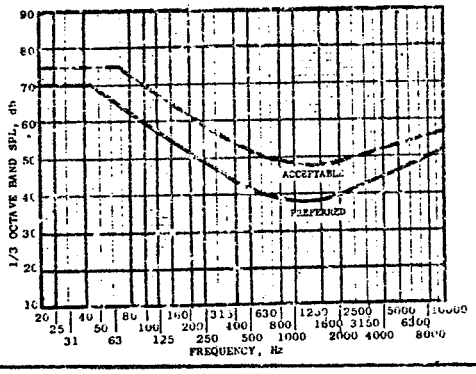
Light Source: Fluorescent and Metal Halide

Light Level, Foot Candles		
Maximum	Desirable	Minimum
70	50-70	20

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	40-60	40
Floors	35	15-35	15
Furniture	45	20-45	20
Machines	45	25-45	20

REMARKS: Lighting should be efficient and functional. Colors should be cool but stimulating.

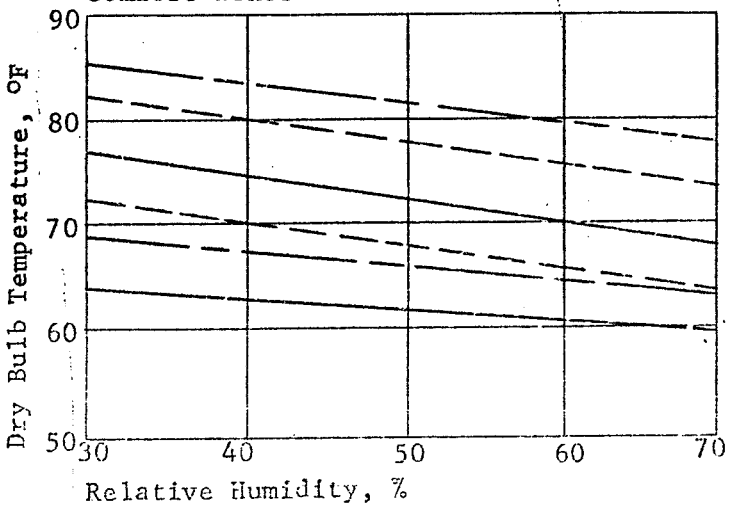
ACOUSTICS



REMARKS: SIL levels below 60 db must be maintained to promote face-to-face communication. Avoid intermittent, high-pitched and unlocalized noise sources, thick carpets, drapes, and padded cloth furniture can be used to help trap noise.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - — - —

Air Flow Rate: 60 fpm
Metabolic Rate: 500 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 2 Hours

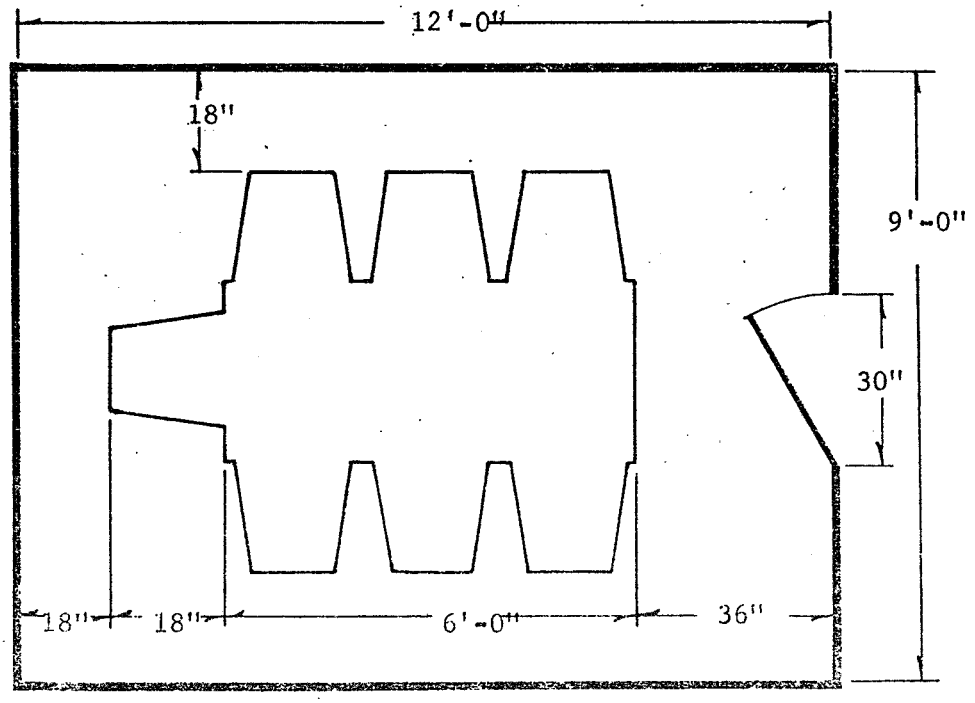
EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
3ba	4ge	4ni	3ne	3pl	
		4pn		3nl	
		5pl		3pl	

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Warm colors add to stimulating atmosphere which lends itself to discussion and the exchange of points of view.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Sufficient seating should be provided for the commander and 100% of department heads plus two seats. Interior dimensions shown represent acceptable minimum passageway clearances. Gross area/man= 15 sq. ft. Ceiling height= 7'0".



III-3.7

AREA: Passageway

DESCRIPTION

ACTIVITY: Moderate

MOOD: Physical Activity

SOCIAL FACTOR: Public

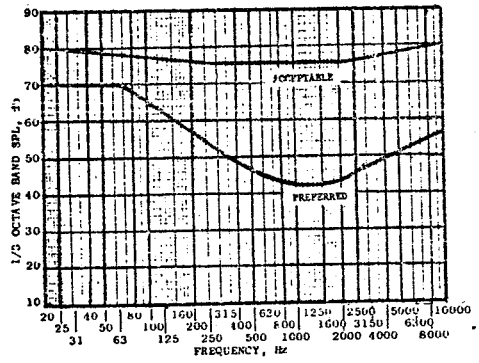
LIGHTING

Light Source: Incandescent-Halogen Cycle

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	20	5-20	1
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	40-80	40
Walls	50	20-45	20
Floors	50	15-35	15

REMARKS: Lighting generally should be adequate to observe any obstacles. Hallways provide transition between lighted areas; consequently, lighting and color should meet transition function. Lighting level should be no greater than 1/5th of adjacent areas.

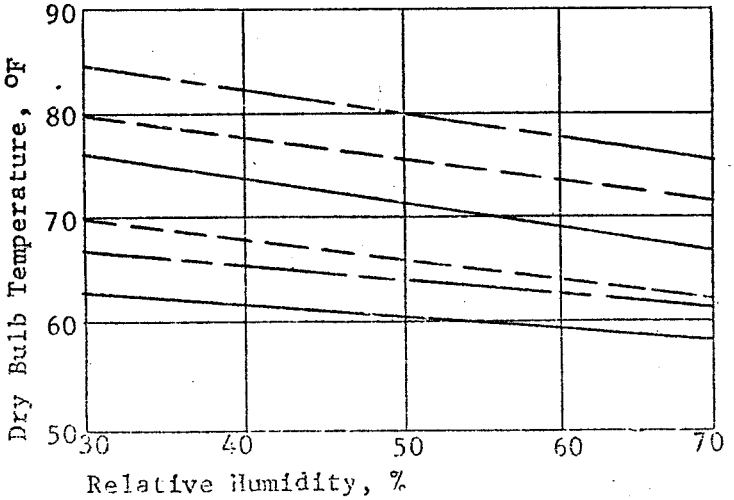
ACOUSTICS



REMARKS: SIL levels below 70 db should be maintained so as not to interfere with loudspeaker communication. Floors made of bare woods magnify impact noises, particularly in long corridors. Carpet with proper padding will absorb airborne sounds.

TEMPERATURE

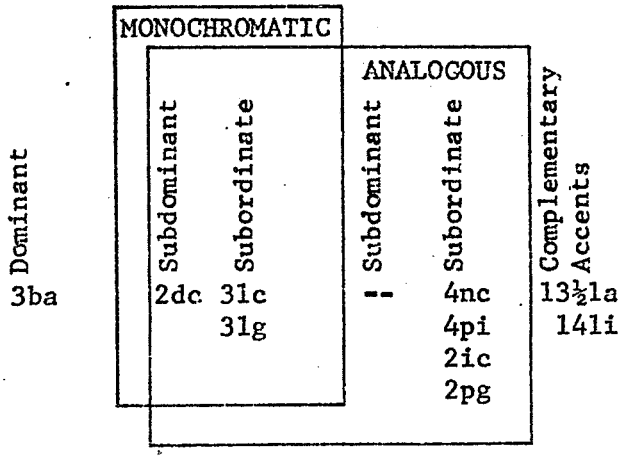
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 60 fpm
Metabolic Rate: 400 to 750 BTU/hr
Clo Factor: .75 to 1.2
Occupancy Time/Day: .5 Hour

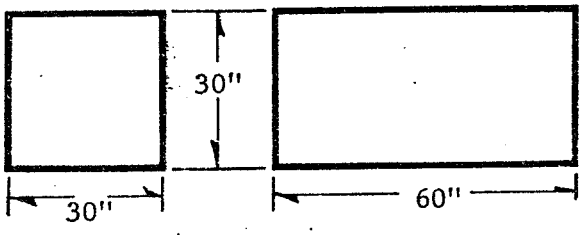
EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Neutral scheme creates an expansiveness in narrow areas and allows for good transition into areas which will be of different color schemes.

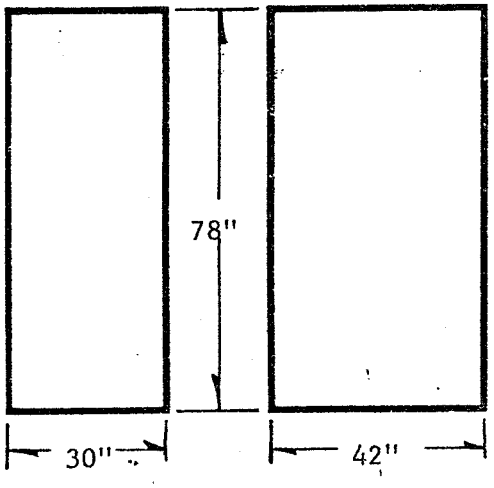
VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Zero-Gravity passageways based on limited data.



Minor Major

Zero Gravity



Minor Major

Artificial Gravity

III-3.8

AREA: Chapel

DESCRIPTION

ACTIVITY: Low

MOOD: Restful and Spiritual Concentration

SOCIAL FACTOR: Public

LIGHTING

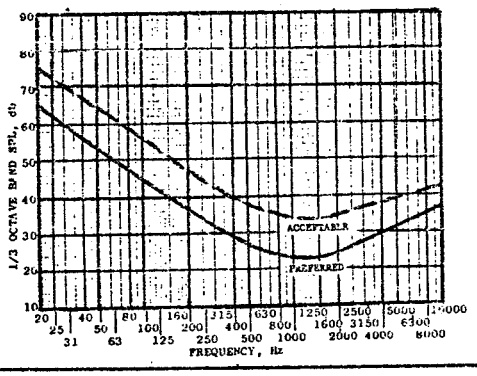
Light Source: Incandescent-Halogen Cycle

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	20	5-20	2

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	85	50-80	50
Walls	50	20-50	20
Floors	35	15-35	10
Furniture	40	15-40	10

REMARKS: Lower subdued atmosphere for meditation; higher lighting levels for active worship. Specific highlighting of alter for focus of attention. Colors subdued.

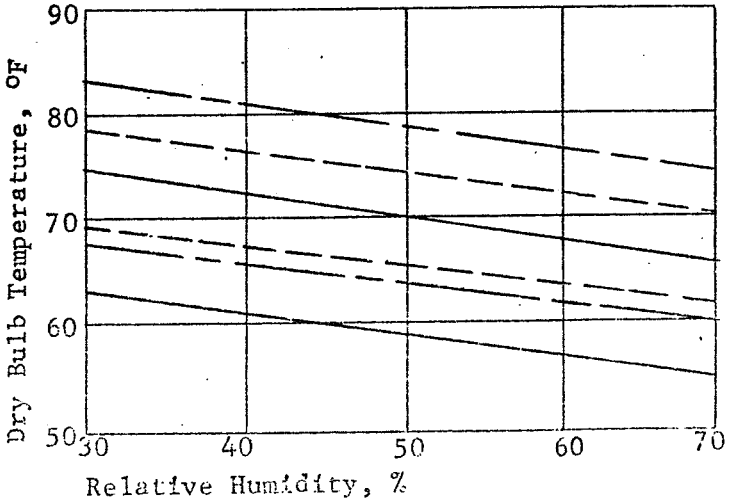
ACOUSTICS



REMARKS: SIL levels below 50 db must be maintained. Intermittent and high-pitched noise sources must be avoided to promote restful atmosphere and facilitate mental concentration. Thick carpets, drapes, and padded cloth furniture help to trap noise.

TEMPERATURE

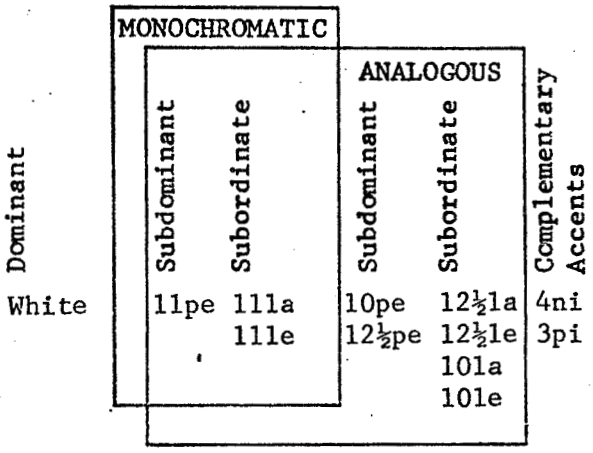
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — — ——— —

Air Flow Rate: 60 fpm
Metabolic Rate: 400 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 1 Hour

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Colors used are those associated with religious signifigance.

VOLUME

REMARKS: See Theater

III-3.9

AREA: Gym

DESCRIPTION

ACTIVITY: High

MOOD: Physical Activity

SOCIAL FACTOR: Public

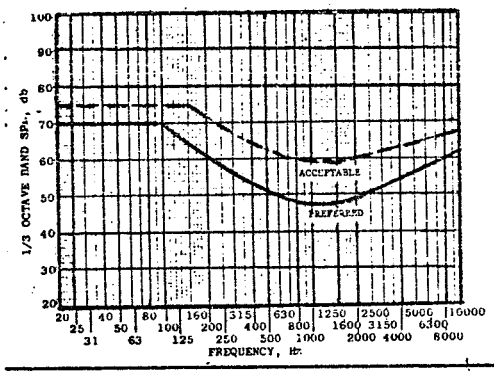
LIGHTING

Light Source: Fluorescent, Mercury Vapor, Metal Halide

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	30	20-30	15
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	70-90	60
Walls	70	40-60	35
Floors	35	15-35	15

REMARKS: General lighting for maximum use of area. Cool colors.

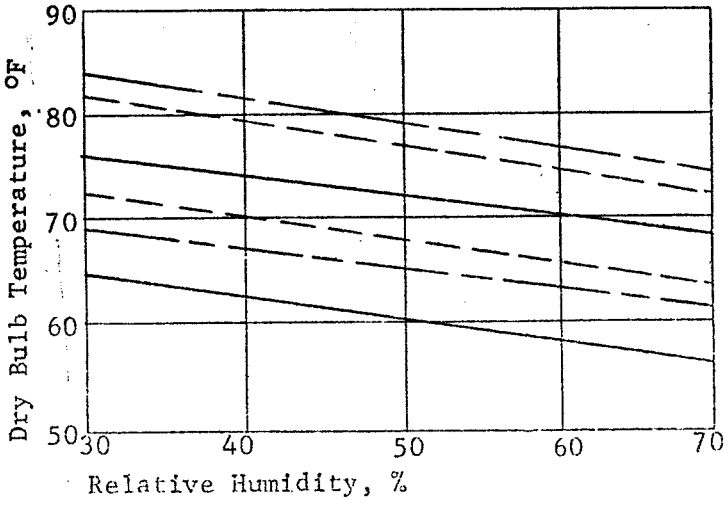
ACOUSTICS



REMARKS: None

TEMPERATURE

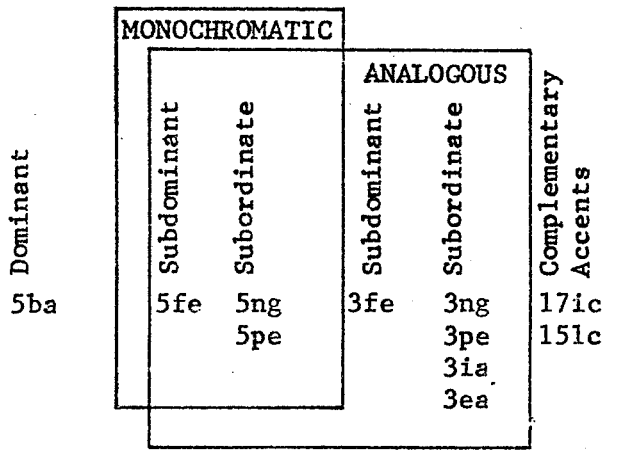
Comfort Zones



Legend:
5 PSIA ————
10 PSIA — — — —
14.7 PSIA — - ——-

Air Flow Rate: 80 fpm
Metabolic Rate: 750 to 1800 BTU/hr
Clo Factor: .5 to 1.3
Occupancy Time/Day: 1.5 Hour

EXAMPLE COLOR SCHEME

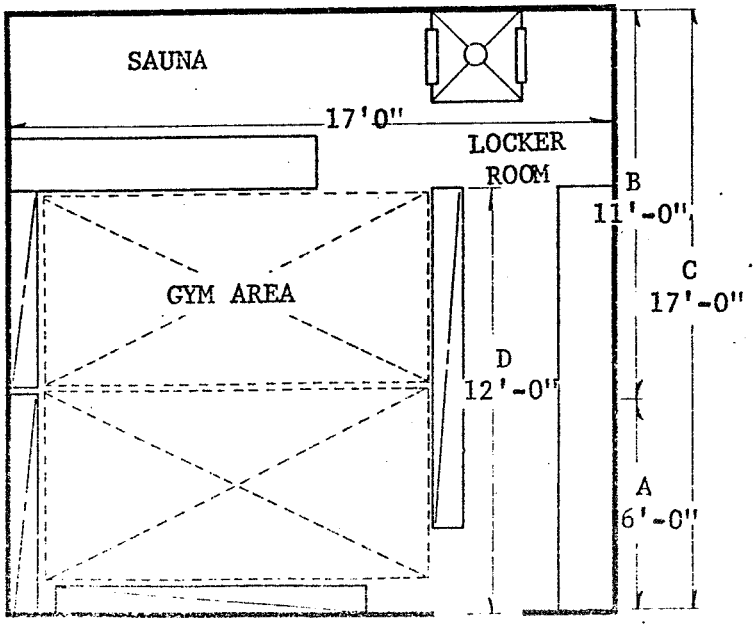


REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Feelings of excitement and stimulation are accented by warm hues.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment.

A- size for crews of 6-50 men on missions of 30-180 days 102 sq. ft. gross
B- size for crews of 6-50 men on missions of 180-1040 days 187 sq. ft. gross
C- size for crews of 50-100 men on missions of 180-1040 days 289 sq. ft. gross
D- size for crews of 50-100 men on missions of 30-180 days 204 sq. ft. gross
Ceiling Height= 7'0".



III-3.10

AREA: Locker Room

DESCRIPTION

ACTIVITY: Moderate

MOOD: Physical Activity

SOCIAL FACTOR: Public

LIGHTING

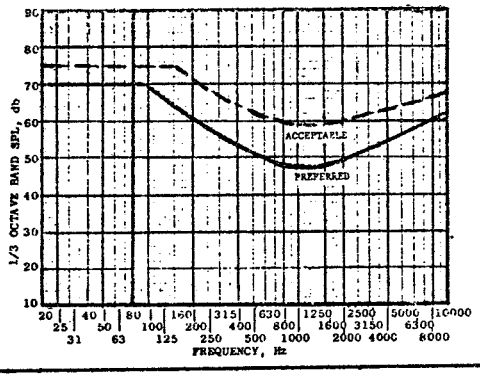
Light Source: Fluorescent

Light Level, Foot Candles		
Maximum	Desirable	Minimum
30	20-30	10

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	50	20-50	20
Floors	35	15-35	15

REMARKS: General lighting for maximum use of area. Cool colors.

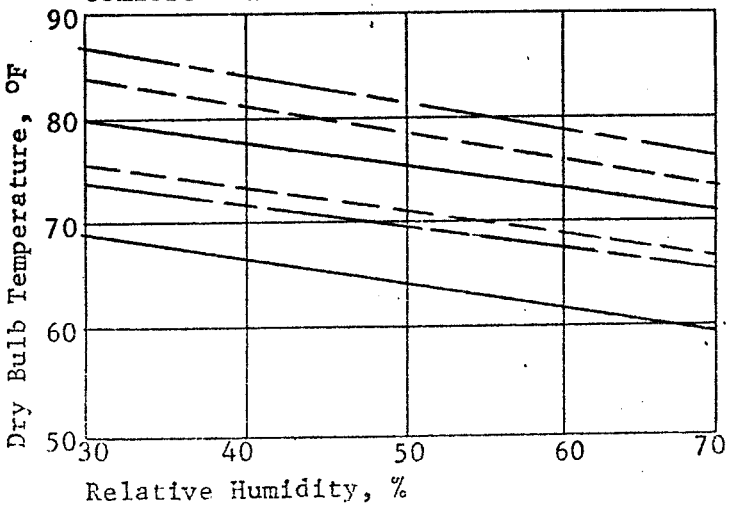
ACOUSTICS



REMARKS: None

TEMPERATURE

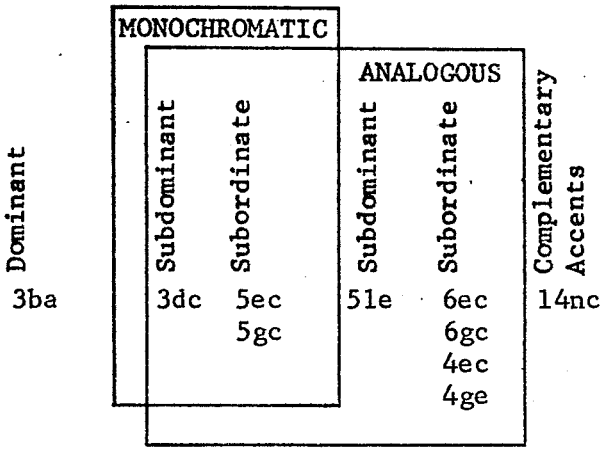
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 70 fpm
Metabolic Rate: 600 BTU/hr
Clo Factor: 0 to 1.3
Occupancy Time/Day: .75 Hour

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Color should be of warm hues which enhance skin tones.

VOLUME

REMARKS: See Gym

III-3.11

AREA: Theatre

DESCRIPTION

ACTIVITY: Low

MOOD: Restful

SOCIAL FACTOR: Public

LIGHTING

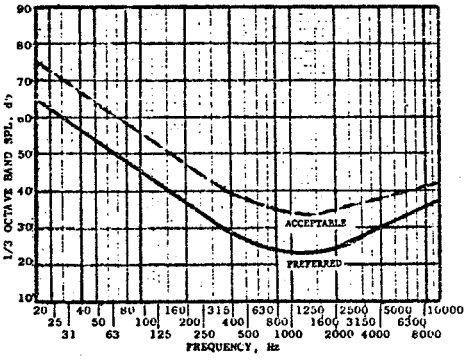
Light Source: Incandescent and Fluorescent

Light Level, Foot Candles		
Maximum	Desirable	Minimum
25	5-20	2

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	35-60	30
Floors	35	15-35	10
Furniture	45	20-40	15
Draperies	60	15-60	15

REMARKS: General lighting controllable from high to off to meet needs of film projection. Very low intensity lighting as required to maintain safety when general lighting is off. Relaxing colors.

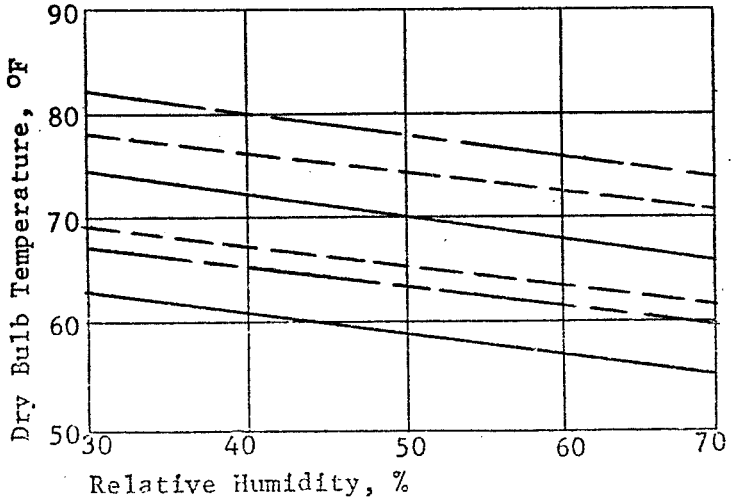
ACOUSTICS



REMARKS: None

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 60 fpm
Metabolic Rate: 450 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 2 Hours

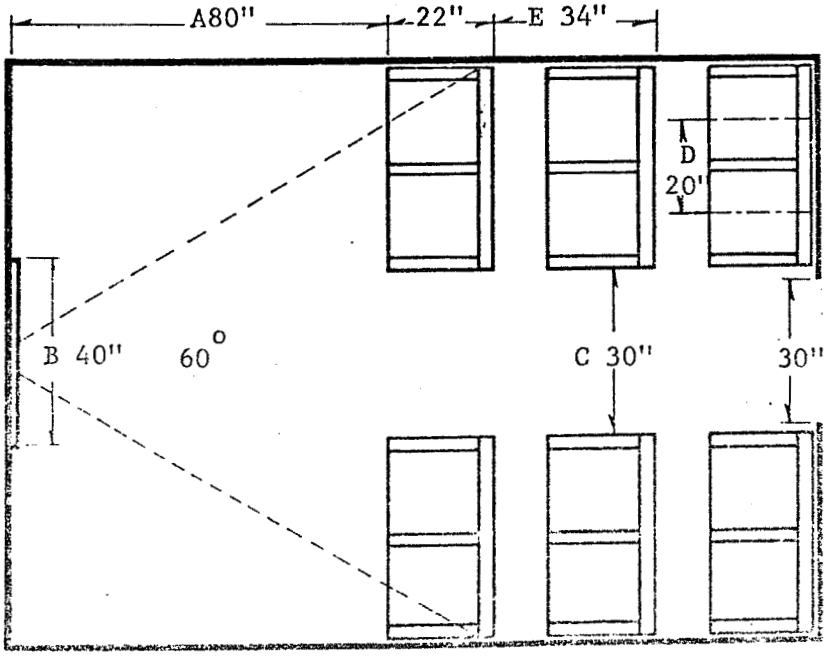
EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
5ba	5fe	5na 5pg	3fe	3na 3pg 6na 6pg	15na 13½la

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Warm colors with high intensities enhance feelings of excitement and low responsibility.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Sufficient seating should be provided for 50% of the crew. Gross area/man = 10-12 sq. ft. Ceiling Height: 7'0"= 100-300 sq. ft., 7'6"= 300-500 sq. ft. Key dimensions shown are: A-Minimum viewing distance; B-Minimum screen size, C-Major through passage, D-Seats (Center to center), E-Seats (Back to back).



III-3.12

AREA: Briefing Room

DESCRIPTION

ACTIVITY: Moderate

MOOD: Mental Concentration

SOCIAL FACTOR: Public

LIGHTING

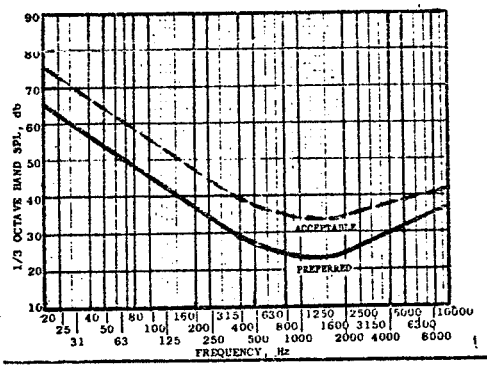
Light Source: Fluorescent and Metal Halide

Light Level, Foot Candles		
Maximum	Desirable	Minimum
70	50-70	20

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	70	50-70	50
Floors	35	15-35	15
Furniture	45	25-45	15

REMARKS: Lighting should be efficient and functional with emphasis in some areas. Projection type lighting may be required.

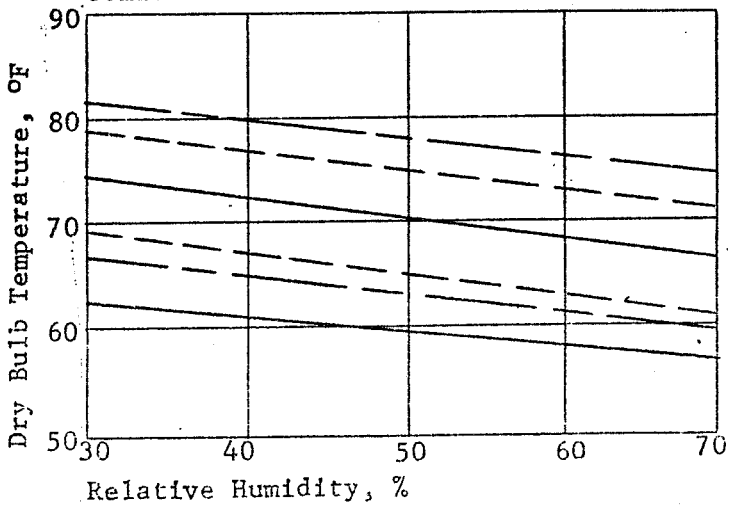
ACOUSTICS



REMARKS: SIL levels below 40 db must be maintained to promote effective communication. Avoid intermittent high-pitched and unlocalized noise sources. Thick carpets, drapes, and padded cloth furniture can be used to help trap noise.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 60 fpm
Metabolic Rate: 500 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 1 Hour

EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
White	15dc	15ic	--	14ie	2 ea
		15ic		14ic	
				16ic	
				16ie	

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Cool colors recommended with low contrast and intensity to cause the least amount of distraction.

VOLUME

REMARKS: See conference room

III-4.1

AREA: Galley

DESCRIPTION

ACTIVITY: Moderate

MOOD: Physical Activity

SOCIAL FACTOR: Public

LIGHTING

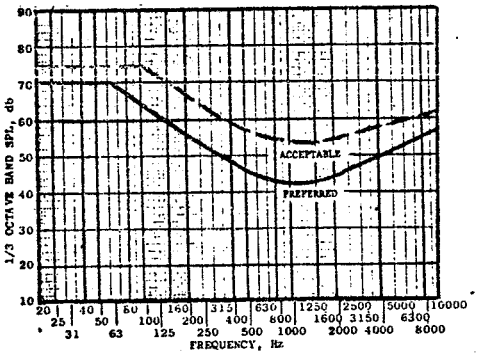
Light Source: Incandescent-Halogen Cycle, Fluorescent

Light Level, Foot Candles		
Maximum	Desirable	Minimum
50	20-50	10

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	70-90	60
Walls	70	40-70	35
Floors	40	20-40	20
Furniture	95	60-80	50

REMARKS: For maintenance purposes area must be clean and bright. Lighting should be crisp and efficient with emphasis over work areas. Light surfaces will facilitate utilization of light in reaching cupboards, under counters, etc. Localized lighting over dish washing area for high degree of performance in inspecting clean dishes. Serving area should have deluxe color lamps to enhance appearance of food. Source equipment must be easily maintained and cleaned with minimum of dirt holding crevices or attachments.

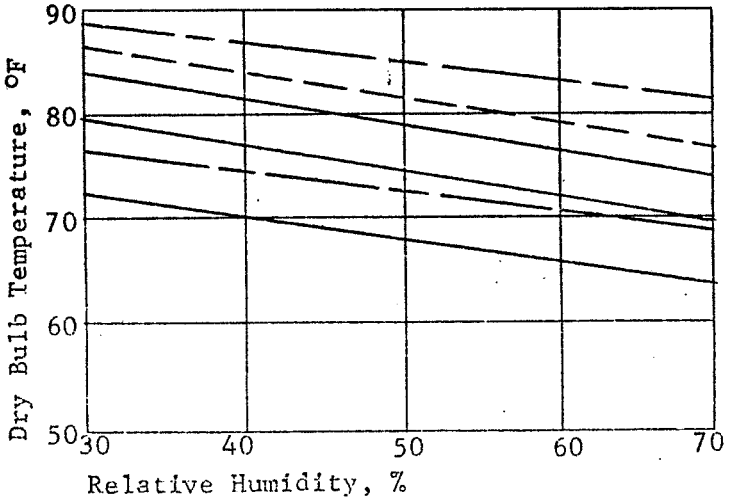
ACOUSTICS



REMARKS: High-pitched noise sources interfere most with work. Contiuous high-pitched noise levels above 90 db must be particularly avoided.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 80 fpm
Metabolic Rate: 700 BTU/hr
Clo Factor: 1.0
Occupancy Time/Day: 1.5 Hours

EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents	REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. A feeling of cheer is created with warm colors while maintaining high light levels.
	Subdominant	Subordinate	Subdominant	Subordinate		
2ba	White	2hb	--	1½hb	14gc	
		2gc		1½gc	14ea	
		2ea		1½ea		
				3gc		
				3ea		

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-4.2

AREA: Snack Bar

DESCRIPTION

ACTIVITY: Moderate

MOOD: Restful

SOCIAL FACTOR: Public

LIGHTING

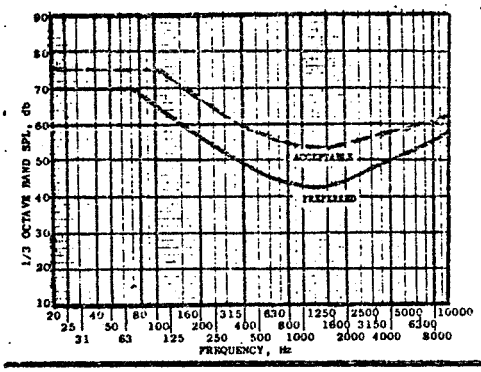
Light Source: Incandescent-Halogen Cycle, Fluorescent

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	30	10-30	10

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	35-60	35
Floors	35	15-35	15
Furniture	45	15-45	15
Draperies	60	15-60	15

REMARKS: Lighting should be festive and engaging. Color should be flattering and relaxing. Higher levels for maintenance and movement of people.

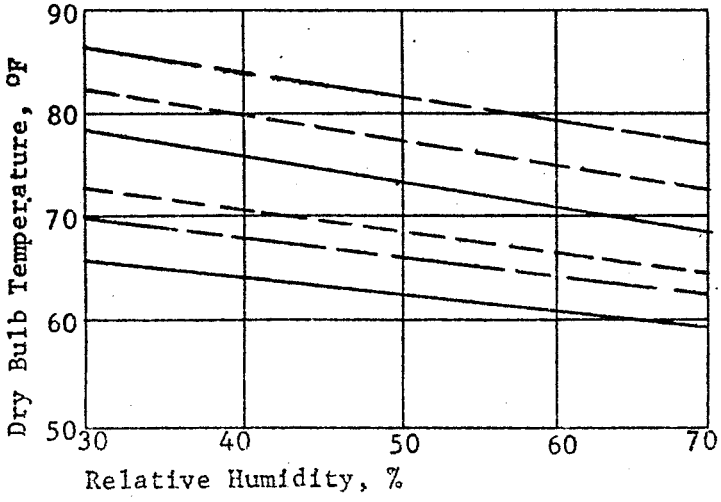
ACOUSTICS



REMARKS: High-pitched noise sources must be particularly avoided to preclude crew annoyance. Unlocalized noise sources are more annoying than noise sources that can be localized. From standpoint of noise control, ideal wall, ceiling, and floor should be massive, and porous. SIL levels below 60 db should be maintained.

TEMPERATURE

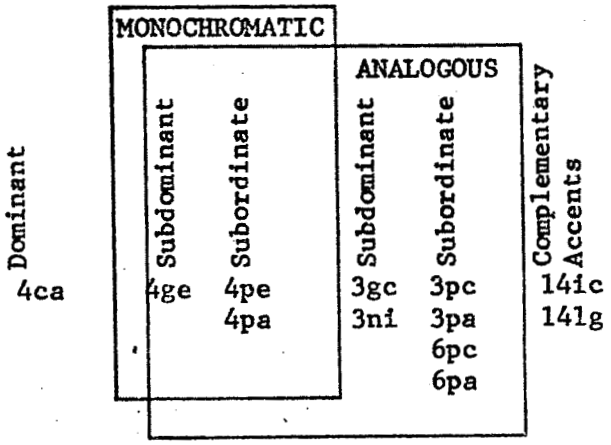
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - — - —

Air Flow Rate: 70 fpm
Metabolic Rate: 500 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: 1 Hour

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only.

VOLUME

REMARK: Not independent area. Utilizes dining facilities, food and beverage dispensers and dining tables during non meal hours.

III-4.3

AREA: Bathroom

DESCRIPTION

ACTIVITY: Low

MOOD: Restful

SOCIAL FACTOR: Private*

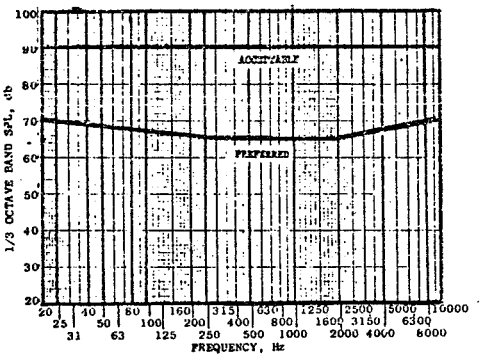
LIGHTING

Light Source: Incandescent-Halogen Cycle, Fluorescent

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	30	10-30	5
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	70	40-70	35
Floors	40	20-40	20
Furniture	99	60-90	60

REMARKS: Definite use of deluxe colors for flattering appraisal of complexion and skin tones. Light specifically over lavatory area to provide adequate illumination for cleaning and shaving functions. Care should be taken to insure light reaching underside of chin. Lower lighting levels sufficient in other bathroom areas.

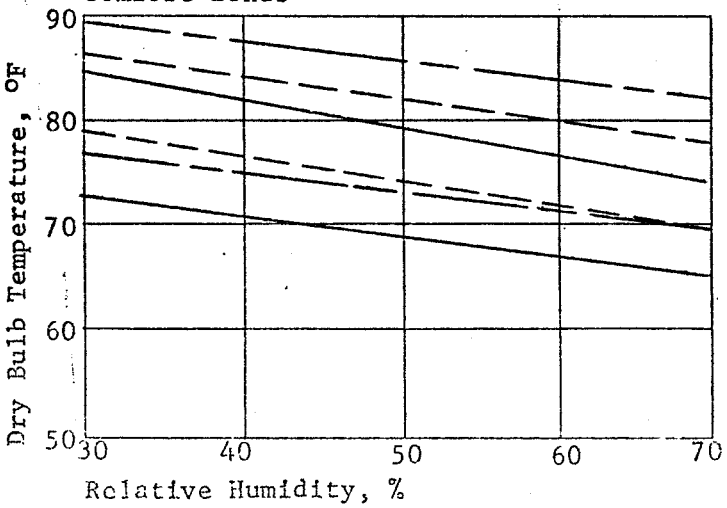
ACOUSTICS



REMARKS: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 40 to 80 fpm
Metabolic Rate: 500 BTU/hr
Clo Factor: 0 to 1.0
Occupancy Time/Day: .5 Hour

*Private without compromise

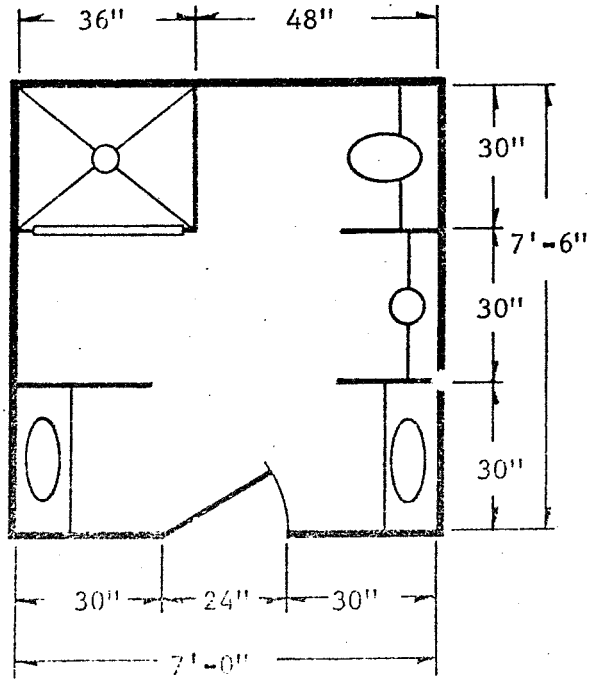
EXAMPLE COLOR SCHEME

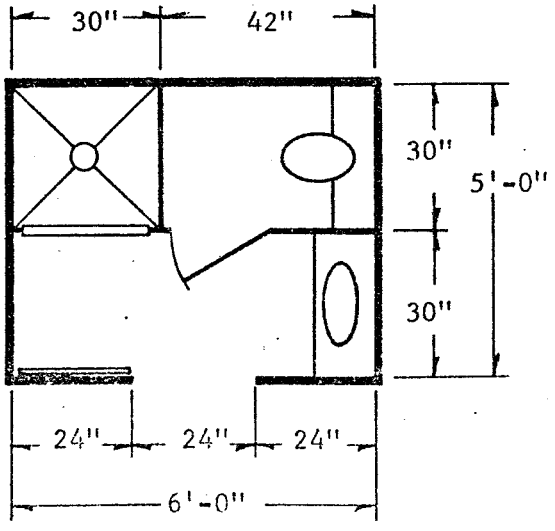
Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
3ba	3dc	5ec 5gc	5pe	6ec 6gc 4ec 4ge	13 ½la 14 pc

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Warm hues used enhance skin tones to generate feelings of health and well-being.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. The example layouts shown were developed from size and clearance figures presented in Section II-E and fixture requirement recommendations presented in section II-G. Ceiling Height= 6'6".





III-4.4

AREA: Dispensary

DESCRIPTION

ACTIVITY: Low

MOOD: Restful

SOCIAL FACTOR: Public

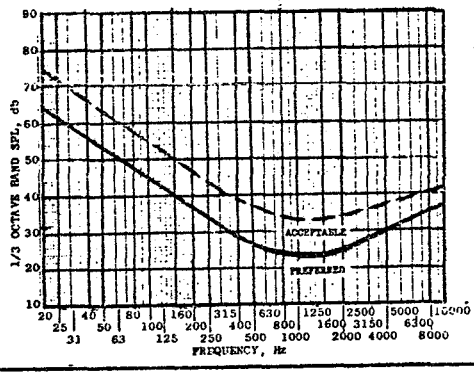
LIGHTING

Light Source: Incandescent-Halogen Cycle, Fluorescent

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	100	50-100	30
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	70-90	60
Walls	80	50-70	50
Floors	40	20-40	15
Furniture	85	45-80	35

REMARKS: Atmosphere should be clean and sterile. Localized examination lights should be color-corrected and provide proper amounts of light on specific areas being studied. Provisions should be made for providing 500-100 fc for short duration operations and other emergency practices. Deluxe color general lighting essential.

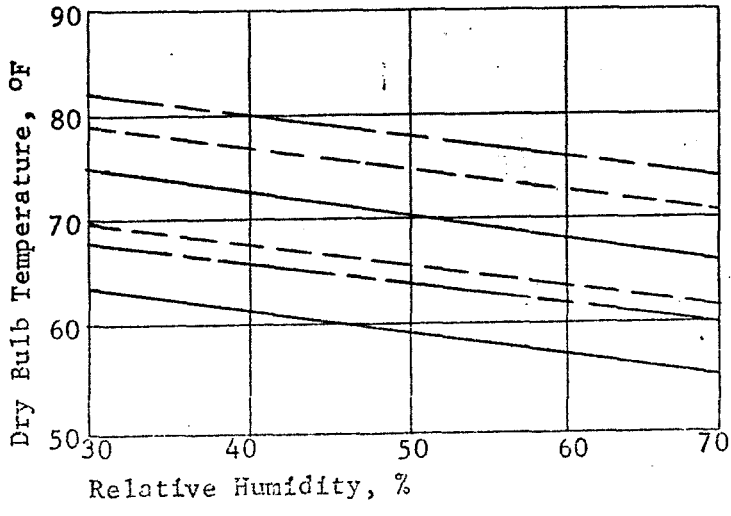
ACOUSTICS



REMARKS: SIL levels should be maintained below 50 db. Annoying noise sources (intermittent, high-pitched, unlocalized) should be especially avoided.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — — ——— —

Air Flow Rate: 60 fpm
Metabolic Rate: 600 BTU/hr
Clo Factor: 0 to 1.0
Occupancy Time/Day: 2 Hours

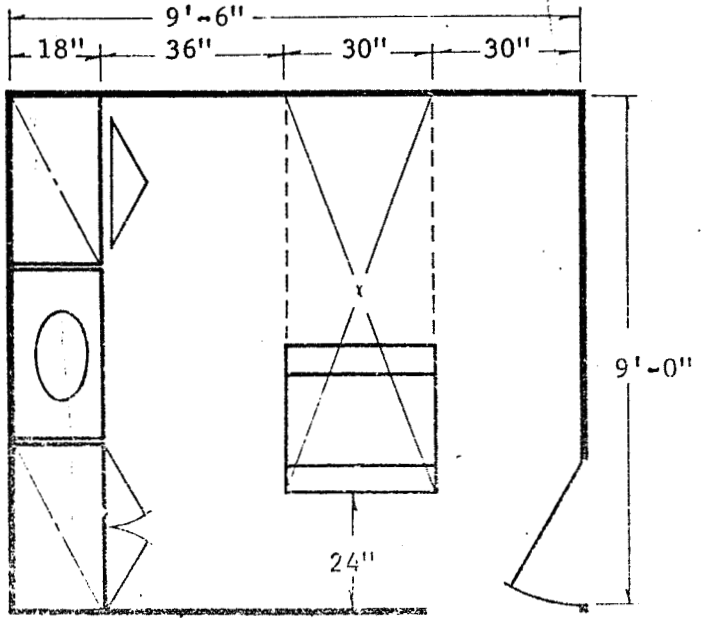
EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
Iba	1gc	11c 11g	2gc 24gc	21c 21g 241c 241g	15na

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Colors are those generally accepted in hospitals which tend to sublimate feelings of depression.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. For missions which require a dispensary, direct access should be provided to a bath room and medical records, file or office. To make maximum utilization of the area it may be possible to have its function as a barber shop since the physical layout and wet-space requirements are similar and the frequency of usage for both would probably be low. Ceiling height is 6'-6".
Gross Area= 85.5 sq. ft.



III-4.5

AREA: Laundry

DESCRIPTION

ACTIVITY: Moderate to High

MOOD: Physical Activity

SOCIAL FACTOR: Public

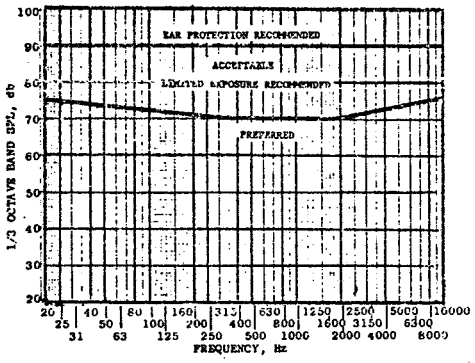
LIGHTING

Light Source: Incandescent-Halogen Cycle, Fluorescent, Mercury Vapor

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	30	20-30	15
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	70	40-65	35
Floors	35	15-35	15
Furniture	90	60-80	50

REMARKS: General lighting should be uniform and adequate for the tasks. Inspection or mending area should be provided with higher level for work performance.

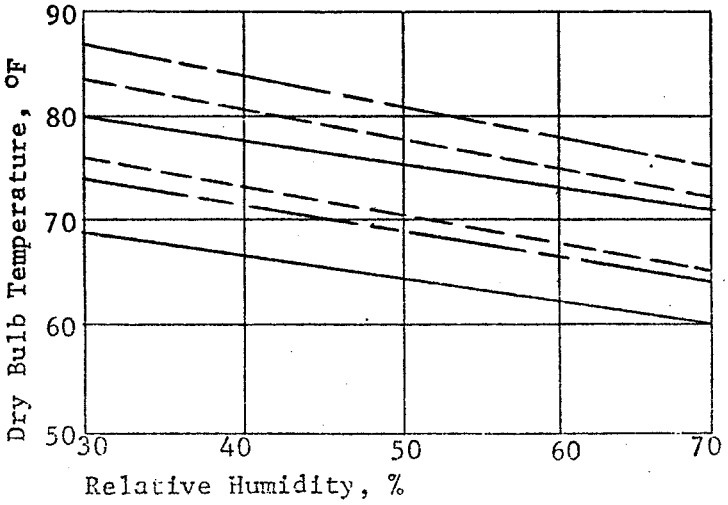
ACOUSTICS



REMARKS: None

TEMPERATURE

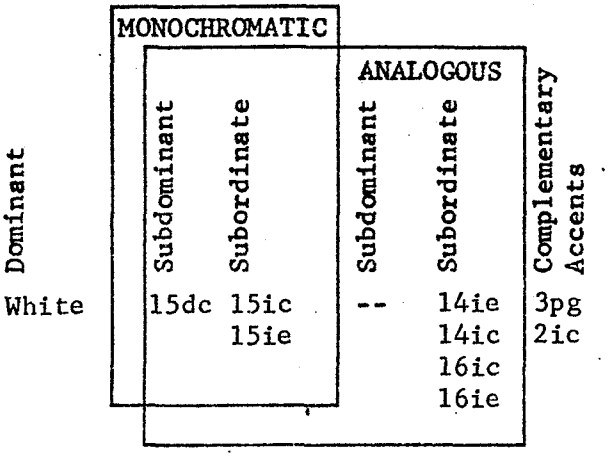
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 80 fpm
Metabolic Rate: 1000 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: .5 Hour

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for this activity mood; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only.
Adquate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-4.6

AREA: Barber Shop

DESCRIPTION

ACTIVITY: Moderate to Low

MOOD: Restful

SOCIAL FACTOR: Public

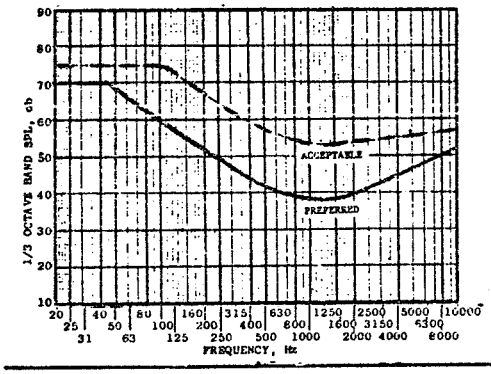
LIGHTING

Light Source: Fluorescent-Deluxe Colors

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	30	20-30	15
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	70-90	60
Walls	80	50-70	50
Floors	40	20-40	15
Furniture	80	30-60	30

REMARKS: Deluxe color lamps over barber chair positioned for adequate observation and work.

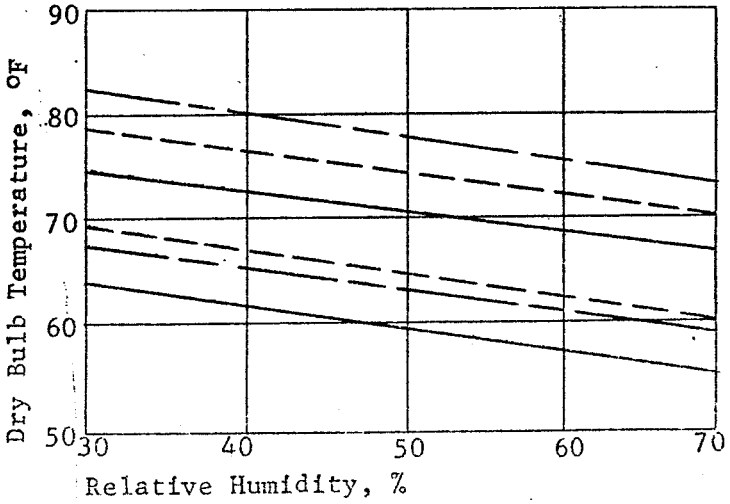
ACOUSTICS



REMARKS: High-pitched noise sources must be particularly avoided to preclude crew annoyance. Unlocalized noise sources are more annoying than noise sources that can be localized. From standpoint of noise control, ideal wall, ceiling, and floor should be massive and porous. SIL levels below 60 db should be maintained.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - — - —

Air Flow Rate: 60 fpm
Metabolic Rate: 600 BTU/hr
Clo Factor: .75 to 1.0
Occupancy Time/Day: .5 Hour

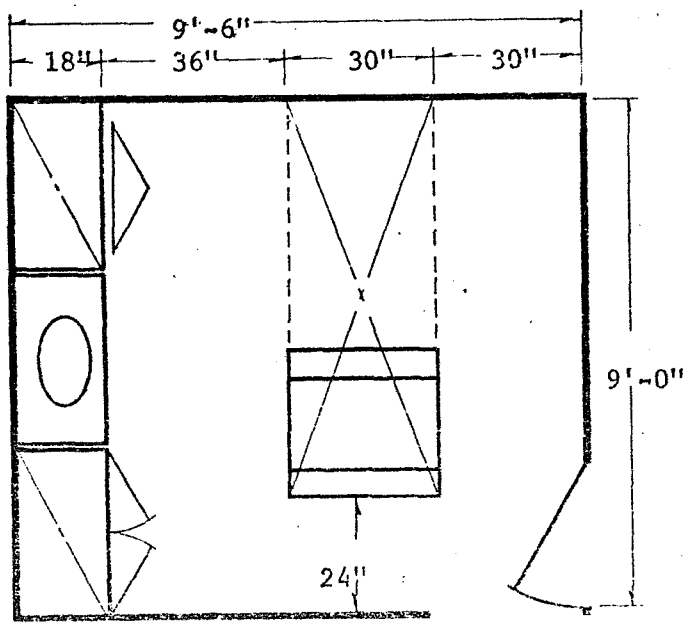
EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
1ba	1gc	11c 11g	2gc 24gc	21c 21g 241c 241g	15na

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Colors selected are based on those generally accepted in hospitals since this area might serve as a dispensary.

VOLUME

REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. To make maximum utilization of the area it may be possible to have it function as a dispensary since the physical layout and net space requirements are similar and the frequency of usage of both would probably be low. Gross Area = 85.5 sq. ft. Ceiling height is 6'6".



III-5.1

AREA:Equipment

DESCRIPTION

ACTIVITY:Moderate

MOOD:Physical Activity

SOCIAL FACTOR:Public

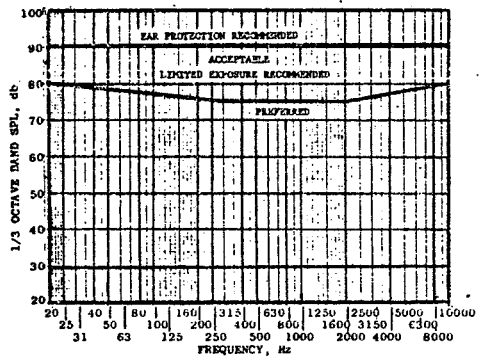
LIGHTING

Light Source:
Incandescent-Halogen Cycle, Fluorescent, Mercury Vapor

Item	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	20	10-20	10
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	40-60	40
Floors	40	20-40	15
Machines	45	25-45	20
Control Panel	40	20-40	20
Instruments	45	25-45	20

REMARKS:General, low maintenance lighting equipment should be provided. For emergency purposes lighting should have a secondary backup power source. Discharge types of sources may create stroboscopic effects in rotating equipment which might be dangerous. Instrument panels should be self-lighted or designed to minimize reflections in the panels from the overhead lighting. Equipment colors should be coded to reflect their use or danger.

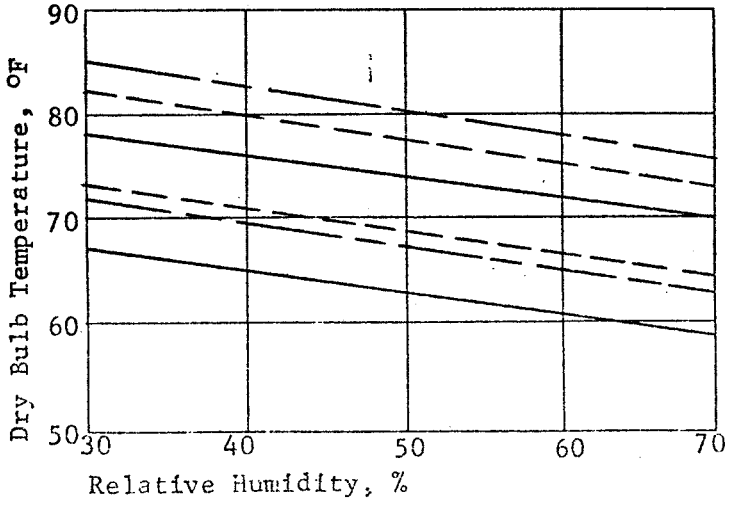
ACOUSTICS



REMARKS:None

TEMPERATURE

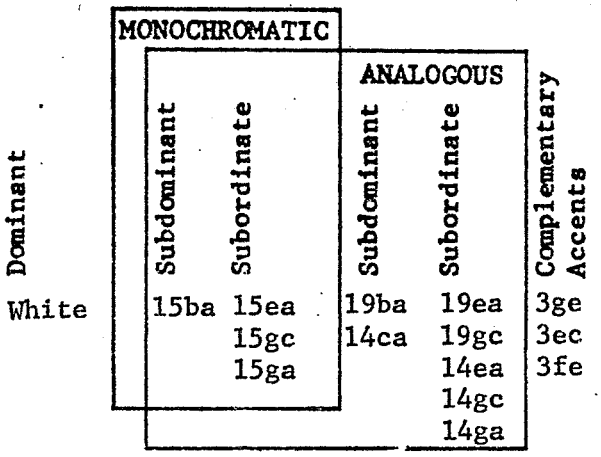
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 80 fpm
Metabolic Rate: 800 to 1600 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 2 Hours

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.2

AREA: Maintenance

DESCRIPTION

ACTIVITY: Moderate

MOOD: Physical Activity

SOCIAL FACTOR: Public

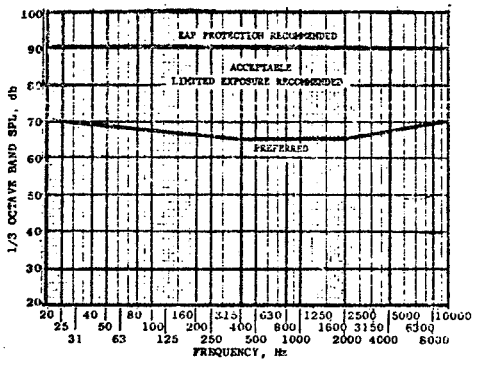
LIGHTING

Light Source: Incandescent-Halogen Cycle, Fluorescent, Mercury Vapor

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	100	50-100	30
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	40-90	40
Walls	60	40-60	40
Floors	40	20-40	15
Machines	45	25-45	20
Control Panel	40	20-40	20
Instruments	45	25-45	20

REMARKS: Localized higher lighting levels are necessary over machining operations and areas of fine detail work. Care should be given to reflect glare present in attempting to read specular metal machine tools.

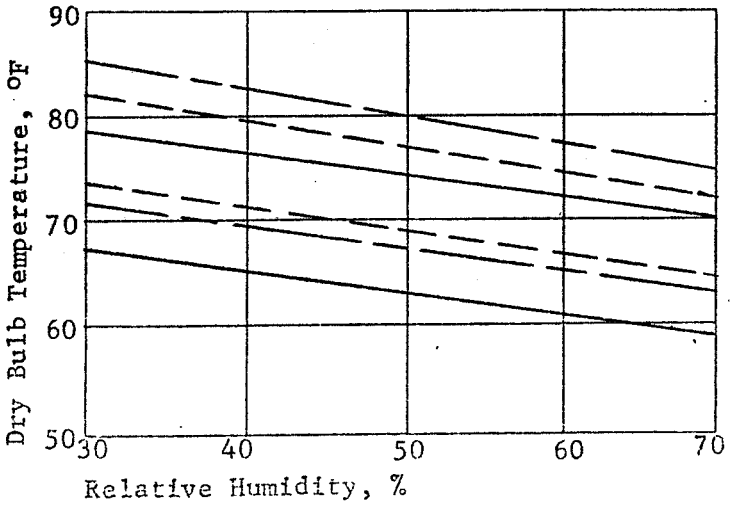
ACOUSTICS



REMARKS: None

TEMPERATURE

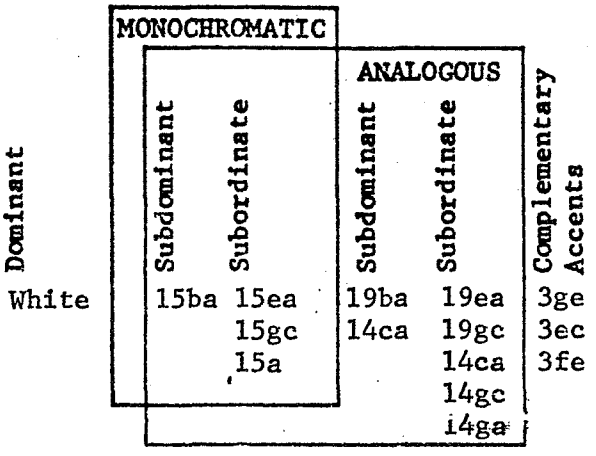
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ———— -

Air Flow Rate: 80 fpm
Metabolic Rate: 800 to 1600 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 2.5 Hours

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.3

AREA: Power

DESCRIPTION

ACTIVITY: Moderate

MOOD: Physical Activity

SOCIAL FACTOR: Public

LIGHTING

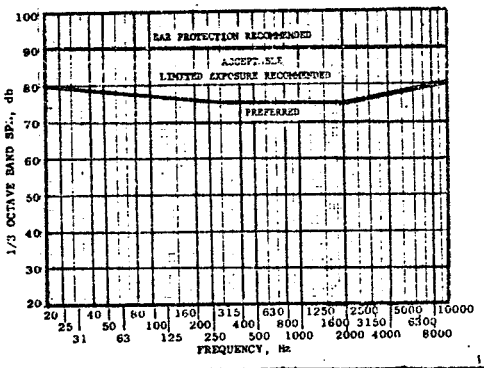
Light Source: Incandescent-Halogen Cycle, Fluorescent, Mercury Vapor

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	20	10-20	10

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	40-60	40
Floors	40	15-35	15
Machines	45	25-45	20
Control Panel	40	20-40	20
Instruments	45	25-45	20

REMARKS: General, low maintenance lighting equipment should be provided. For emergency purposes lighting should have a secondary backup power source. Discharge types of sources may create stroboscopic effects in rotating equipment which might be dangerous. Instrument panels should be self-lighted or designed to minimize reflections in the panels from the overhead lighting. Equipment colors should be coded to reflect their use or danger.

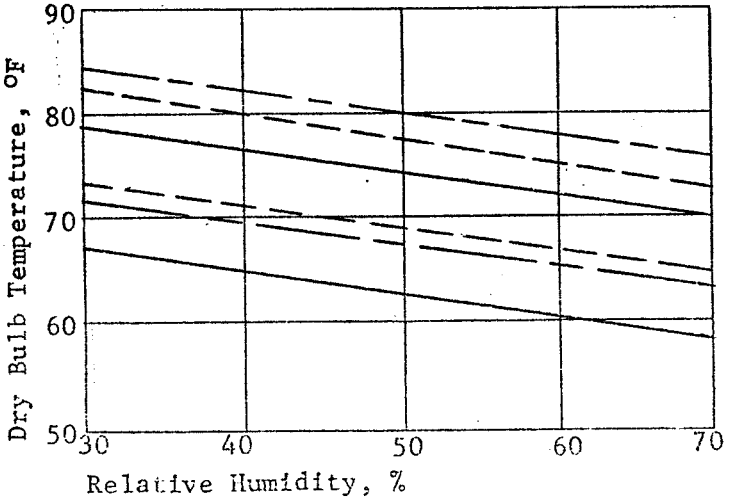
ACOUSTICS



REMARKS: None

TEMPERATURE

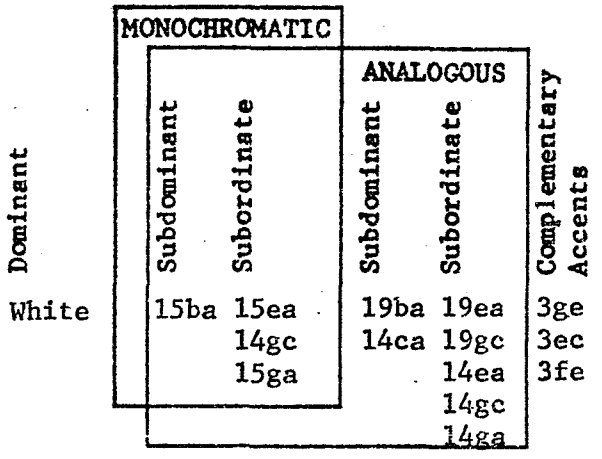
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - — - —

Air Flow Rate: 80 fpm
Metabolic Rate: 800 to 1500 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 1 Hour

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.4

AREA: Storage, Food

DESCRIPTION

ACTIVITY: Moderate

MOOD: Physical Activity

SOCIAL FACTOR: Public

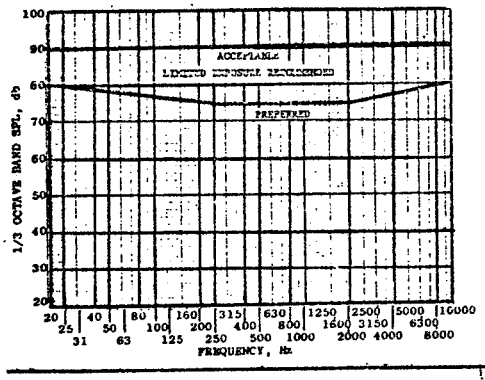
LIGHTING

Light Source: Incandescent-Halogen Cycle

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	10	5-10	5
Item	**Surface Reflectance, %**		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	35-60	35
Floors	35	15-35	15

REMARKS: Lighting should be adequate for proper identification of products. Shelves should be shallow for ease of seeing products located on rear of shelf. Lighting should be utilitarian in nature.

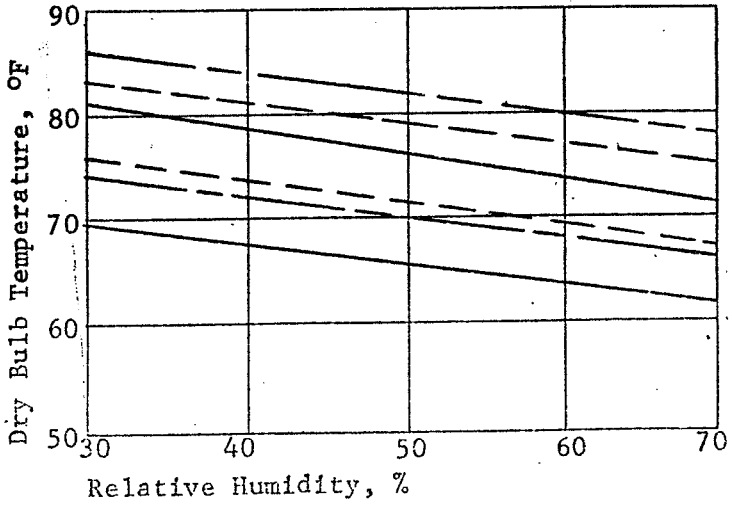
ACOUSTICS



REMARKS: None

TEMPERATURE

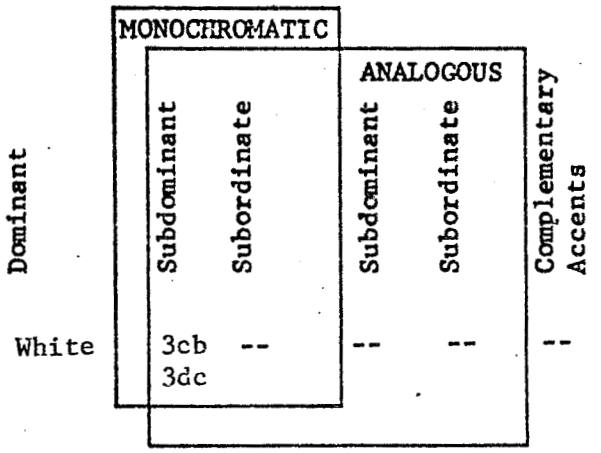
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - — - —

Air Flow Rate: 80 fpm
Metabolic Rate: 750 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: .5 Hour

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Adequate light is provided
Neutral colors are recommended for storage areas.

VOLUME

REMARKS: Physical description of activity is mission dependent.

III-5.5

AREA: Supply

DESCRIPTION

ACTIVITY: Moderate

MOOD: Physical Activity

SOCIAL FACTOR: Public

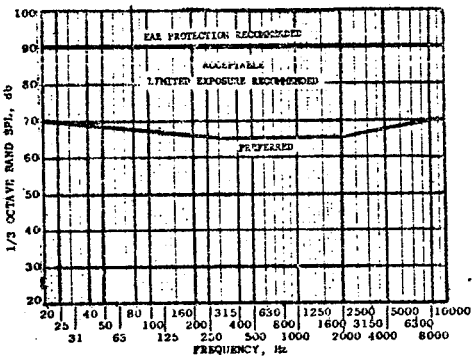
LIGHTING

Light Source: Incandescent-Halogen Cycle, Fluorescent, Mercury Vapor

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	20	15-20	5
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	70	40-60	40
Floors	40	20-40	15

REMARKS: Lighting should be adequate to provide illumination of storage and dispensing areas to insure proper product identification. If color identification is important, color of sources should have high color rendering index.

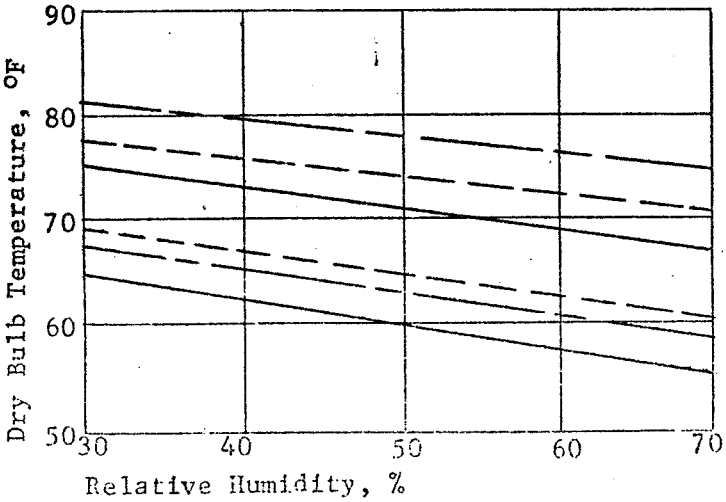
ACOUSTICS



REMARKS: None

TEMPERATURE

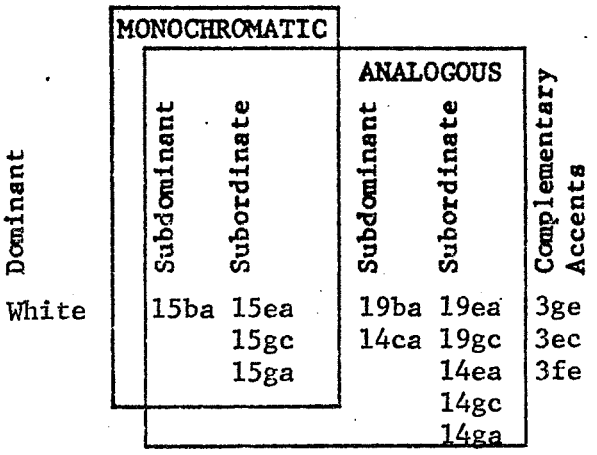
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 70 fpm
Metabolic Rate: 1000 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 1 Hour

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.6

AREA: Control Room

DESCRIPTION

ACTIVITY: Moderate to Low

MOOD: Mental Concentration

SOCIAL FACTOR: Public

LIGHTING

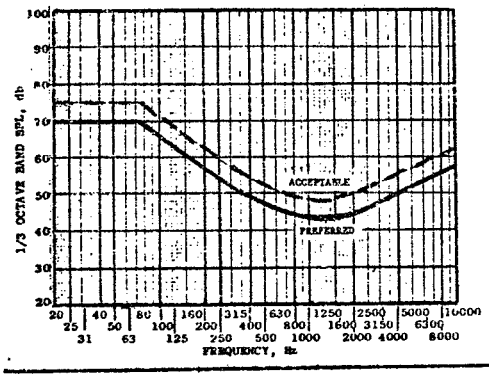
Light Source: Fluorescent-Deluxe Colors, Metal Halide

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	70	50-70	20

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	40-60	40
Floors	35	15-35	15
Machines	45	25-45	20
Control Panel	40	20-40	20
Instruments	45	25-45	20

REMARKS: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed, e.g., navigational, chart reading, etc. Colors should be cool but stimulating.

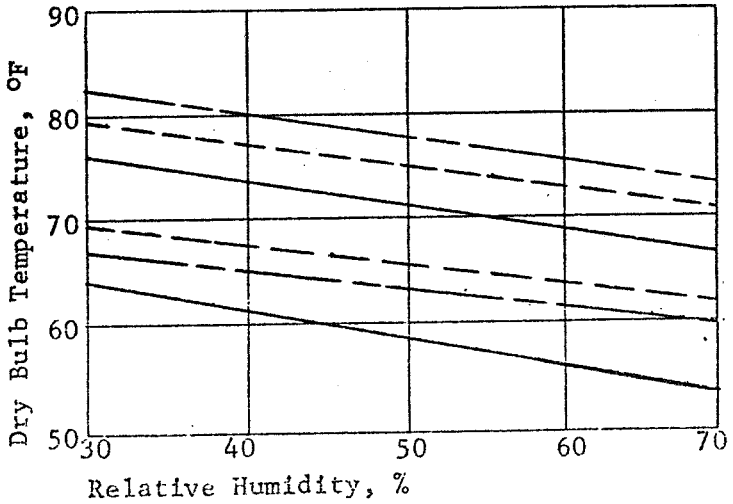
ACOUSTICS



REMARKS: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks, SIL levels below 60 db must be maintained to promote close face-to-face communication. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface.

TEMPERATURE

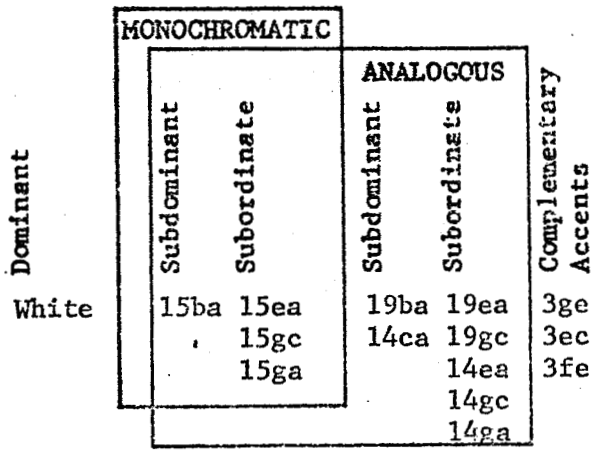
Comfort Zones



Legend:
5 PSIA ————
10 PSIA — — — —
14.7 PSIA — - ——

Air Flow Rate: 60 fpm
Metabolic Rate: 750 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 8 Hours

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.7

AREA: Communications

DESCRIPTION

ACTIVITY: Moderate to Low

MOOD: Mental Concentration

SOCIAL FACTOR: Public

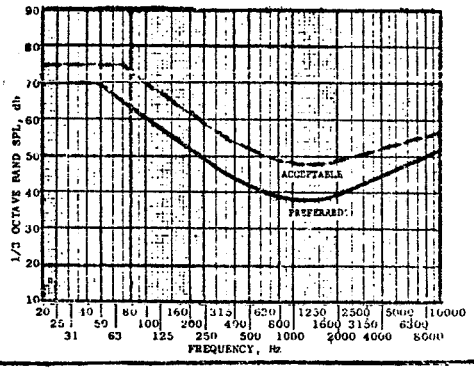
LIGHTING

Light Source: Fluorescent-Deluxe Colors, Metal Halide

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	70	50-70	20
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	40-60	40
Floors	35	15-35	15
Machines	45	25-45	20
Control Panel	40	20-40	20
Instruments	45	25-45	20

REMARKS: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed; e.g., navigational, chart reading, etc. Colors should be cool but stimulating.

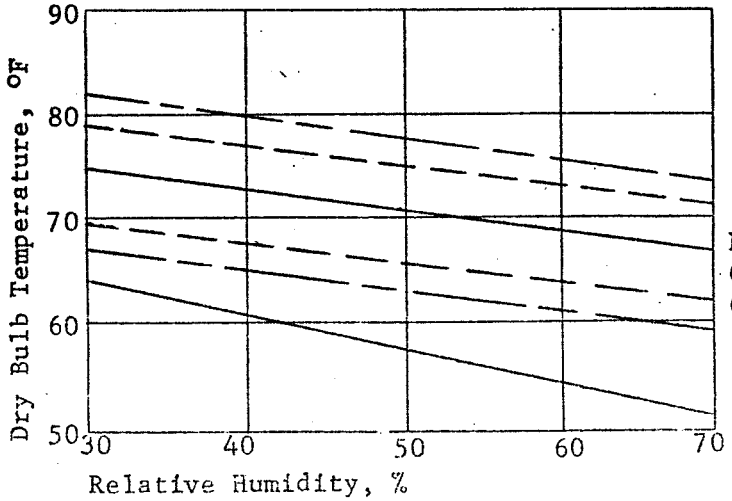
ACOUSTICS



REMARKS: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks. SIL levels below 60 db must be maintained to promote close face-to-face communication. From the standpoint of noise control, ideal wall, ceiling and floor should be massive with rough porous surface.

TEMPERATURE

Comfort Zones

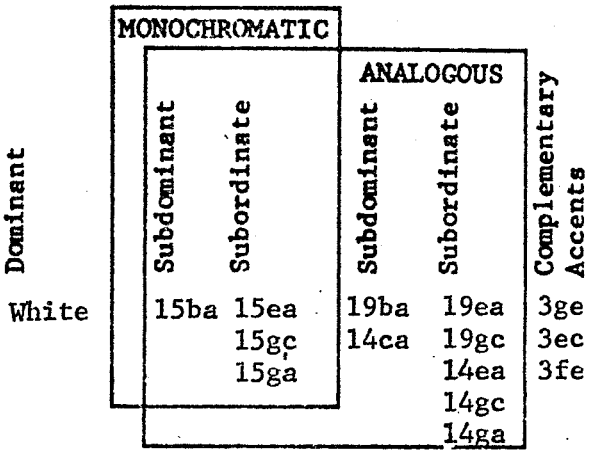


Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 60 fpm
Metabolic Rate: 800 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 8 Hours

NOT REPRODUCIBLE

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.8

AREA: Computer

DESCRIPTION

ACTIVITY: Moderate to Low

MOOD: Mental Concentration

SOCIAL FACTOR: Public

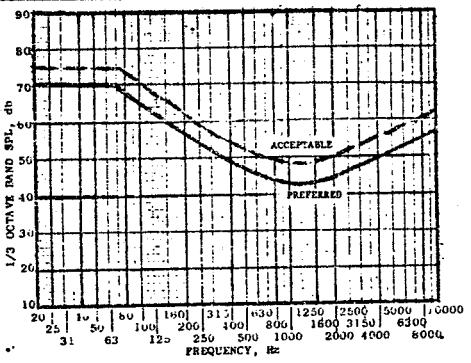
LIGHTING

Light Source: Fluorescent, Metal Halide

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	70	50-70	20
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	40-60	40
Floors	35	15-35	15
Machines	45	25-45	20
Control Panel	40	20-40	20

REMARKS: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed; e.g., navigational, chart reading, etc. Colors should be cool but stimulating.

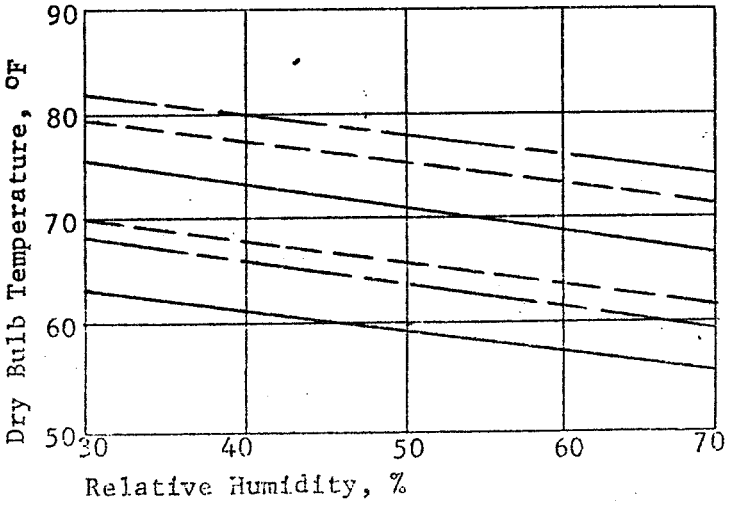
ACOUSTICS



REMARKS: None

TEMPERATURE

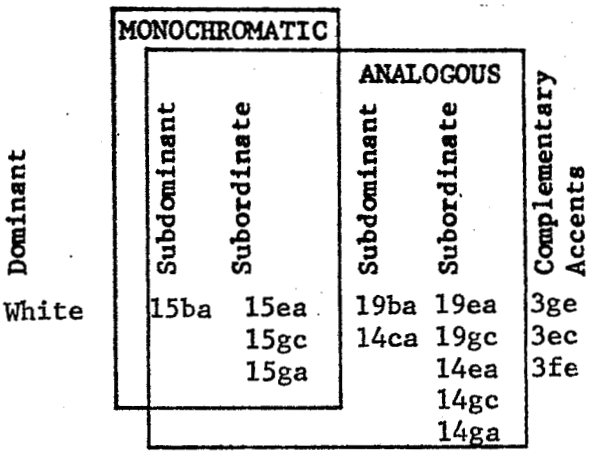
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - — - —

Air Flow Rate: 60 fpm
Metabolic Rate: 700 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 8 Hours

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.9

AREA: Shop

DESCRIPTION

ACTIVITY: Moderate to High

MOOD: Physical Activity

SOCIAL FACTOR: Public

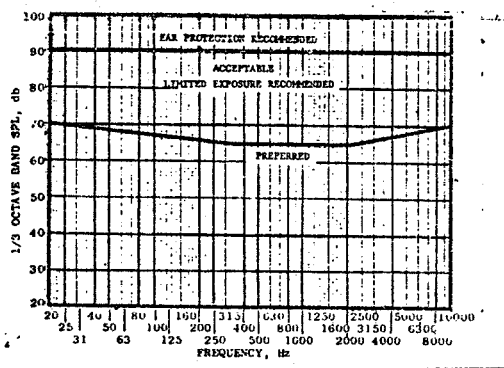
LIGHTING

Light Source: Incandescent-Halogen Cycle, Fluorescent, Mercury Vapor

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	70	50-70	20
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	65-90	60
Walls	60	40-60	40
Floors	50	20-50	20
Machines	45	25-45	20
Control Panel	40	20-40	20

REMARKS: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed; e.g., navigational, chart reading, etc. Colors should be cool but stimulating

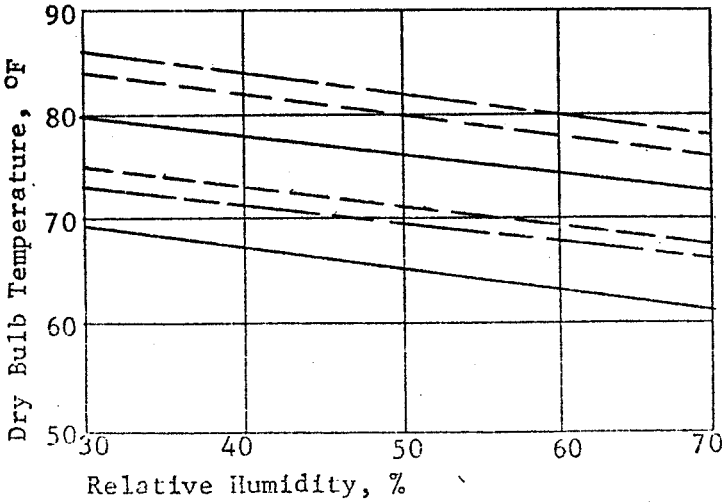
ACOUSTICS



REMARKS: None

TEMPERATURE

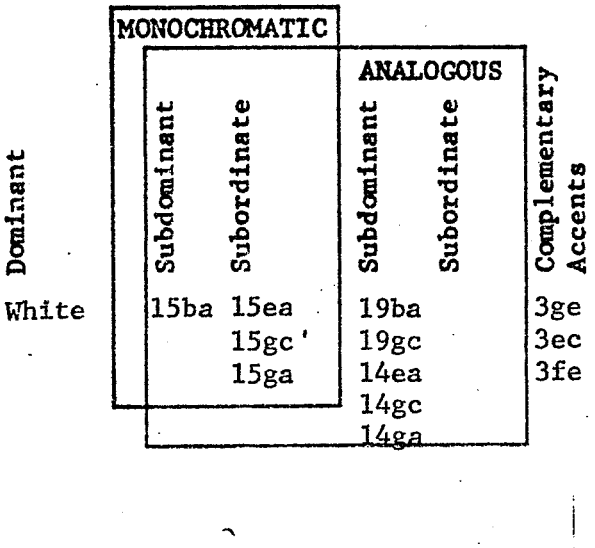
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - — - —

Air Flow Rate: 80 fpm
Metabolic Rate: 1250 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 6 Hours

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.10

AREA: Offices

DESCRIPTION

ACTIVITY: Moderate

MOOD: Mental Concentration

SOCIAL FACTOR: Public

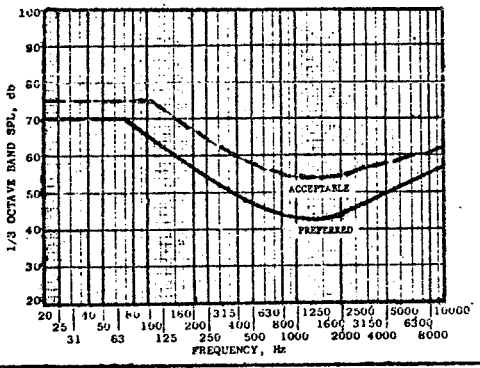
LIGHTING

Light Source: Fluorescent, Metal Halide

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	70	50-70	20
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	40-60	40
Floors	35	15-35	15
Furniture	45	20-45	20
Machines	45	25-45	20

REMARKS: Lighting should be efficient and functional with emphasis over specific working areas. Higher levels should be provided over areas where specific detailed work is being performed; e.g., navigational, chart reading, etc. Colors should be cool but stimulating.

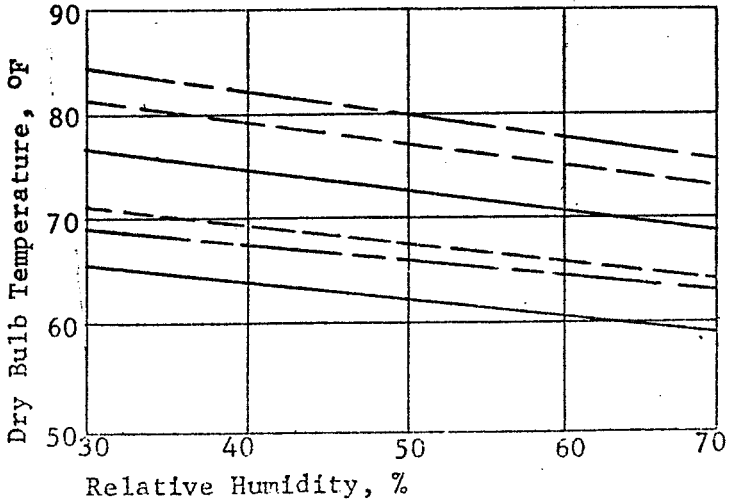
ACOUSTICS



REMARKS: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks. SIL levels below 60 db must be maintained to promote close face-to-face communication. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ———

Air Flow Rate: 60 fpm
Metabolic Rate: 700 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 8 Hours

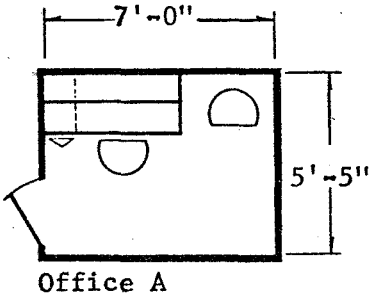
EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
White	15ba	15ea	19ba	19ea	3ge
		15gc	14ca	19gc	3ec
		15ga		14ea	3fe
				14ga	

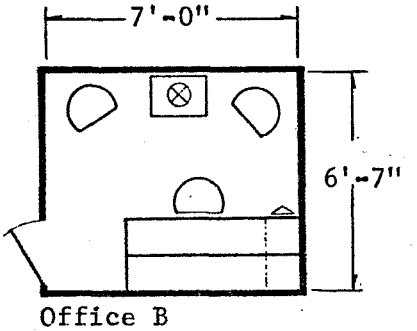
REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate light is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness and responsibility. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

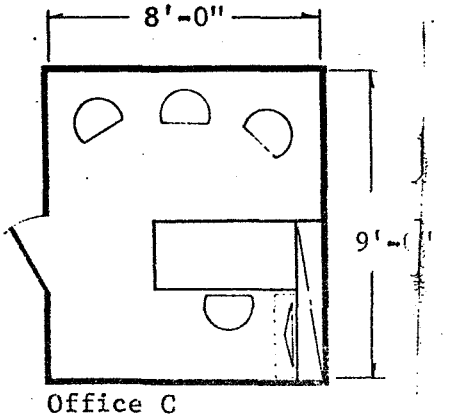
REMARKS: The following recommendations are to be used for general guidance only; unless otherwise noted, the area recommendations pertain to an artificial gravity environment. Office area requirement must be determined on an individual basis once the associated equipment and the task of the occupant(s) are defined. The three example layouts shown represent guideline sizes for a station commander for missions with the following crew sizes: A=6-30, B=31-60, C=61-100
Ceiling Height-6'-6"



Office A
38 Sq. Ft.



Office B
46 Sq. Ft.



Office C
72 Sq. Ft.

III-5.11

AREA: Laboratories

DESCRIPTION

ACTIVITY: Moderate

MOOD: Mental Concentration

SOCIAL FACTOR: Public

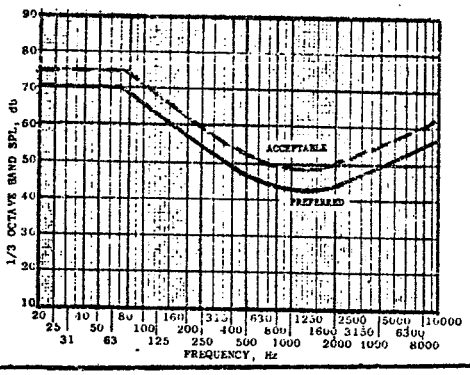
LIGHTING

Light Source: Incandescent-Halogen Cycle Fluorescent, Mercury Vapor

Item	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	70	50-70	20
	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	70-90	65
Walls	70	50-70	50
Floors	40	20-40	20
Furniture	85	45-80	35
Machines	45	25-45	20

REMARKS: Lighting similar to office areas, being efficient and functional with emphasis over work benches. If color is essential in making identifications, sources with high color rendering index are necessary. Adequate lighting of exhaust hoods and climate chambers should be provided for proper observation of experiments.

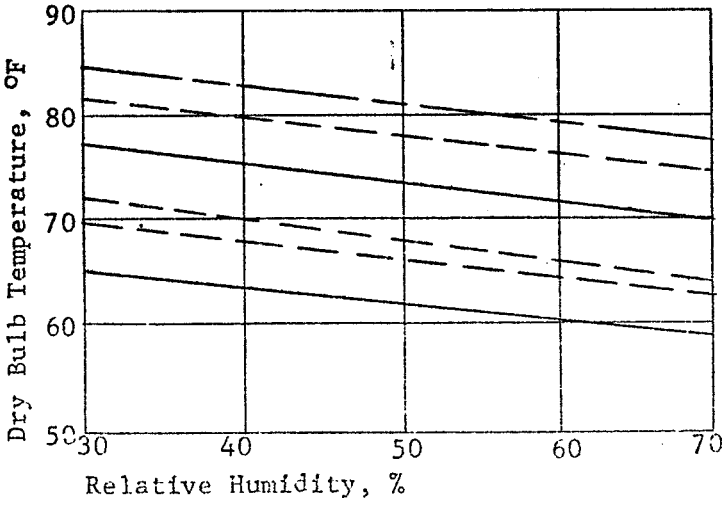
ACOUSTICS



REMARKS: Annoying noise sources, (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks. SIL levels below 60 db must be maintained to promote close face-to-face communication. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface.

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————
10 PSIA — — — —
14.7 PSIA — - — - —

Air Flow Rate: 70 fpm
Metabolic Rate: 1000 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 6 Hours

EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
White	15ba	15ea	19ba	19ea	3ge
		15gc	14ca	19gc	3ec
		15ga		14ea	3fe
				14gc	
				14ga	

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.12

AREA: Docking

DESCRIPTION

ACTIVITY: Moderate to High

MOOD: Physical Activity

SOCIAL FACTOR: Public

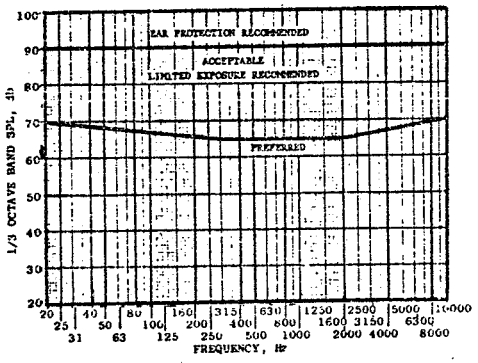
LIGHTING

Light Source: Incandescent-Halogen Cycle, Fluorescent, Mercury Vapor

Item	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	30	10-30	10
Item	**Surface Reflectance, %**		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	40-60	40
Floors	35	15-35	15

REMARKS: Lighting should be adequate for general safety, identification of products, movement of materials, and storage. Color coding would be useful in identifying and handling.

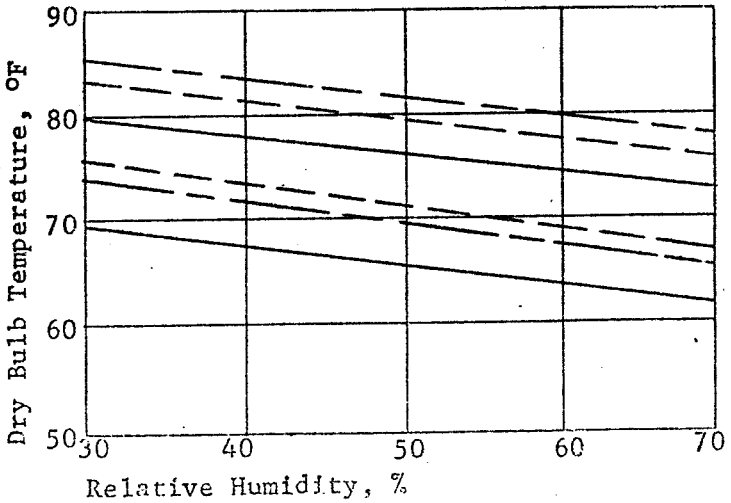
ACOUSTICS



REMARKS: None

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ——— -

Air Flow Rate: 80 fpm
Metabolic Rate: 800 to 1500 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 3 Hours

EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
White	3cb 3dc	--	--	--	--

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Adequate light is provided
Neutral colors are used in this area because it is an area of transition.

VOLUME

REMARKS: Physical description of activity is mission dependent.

III-5.13

AREA: Photographic Support

DESCRIPTION

ACTIVITY: Low

MOOD: Mental Concentration

SOCIAL FACTOR: Public

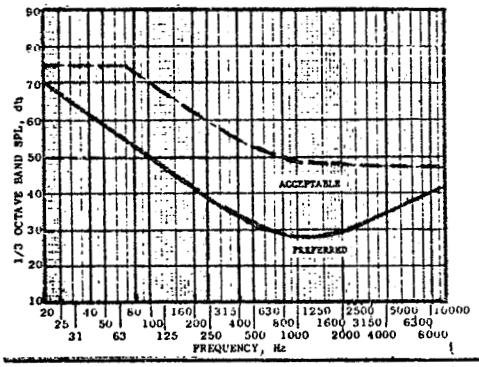
LIGHTING

Light Source: Incandescent-Halogen Cycle

	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	30	0-30	0
Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	40-60	40
Floors	35	15-35	15
Machines	45	25-45	20

REMARKS: Lighting must be capable of being reduced below the sensitivity requirements of the films and other photographic products being used. Adequate safety lights should be provided for the dark adapted environment.

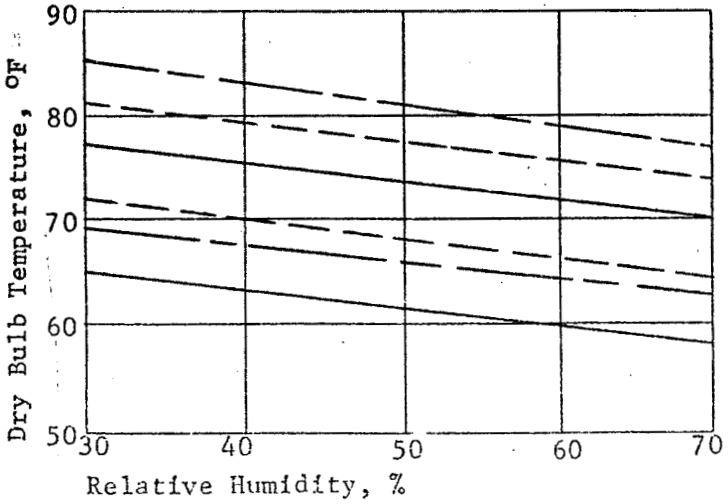
ACOUSTICS



REMARKS: Annoying noise sources (intermittent, high-pitched, unlocalized) must be avoided to preclude interference with mental tasks. SIL levels below 60 db must be maintained to promote close face-to-face communication. From standpoint of noise control, ideal wall, ceiling, and floor should be massive with rough porous surface.

TEMPERATURE

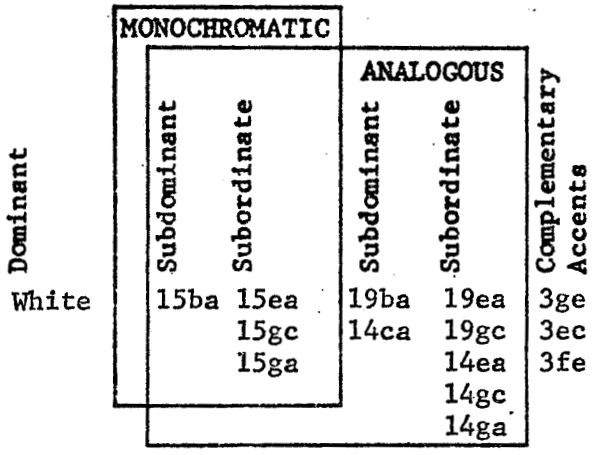
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - ———-

Air Flow Rate: 70 fpm
Metabolic Rate: 700 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 4 Hours

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a baseline reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.14

AREA: Animal Housing

DESCRIPTION

ACTIVITY: Moderate

MOOD: Physical Activity

SOCIAL FACTOR: Public

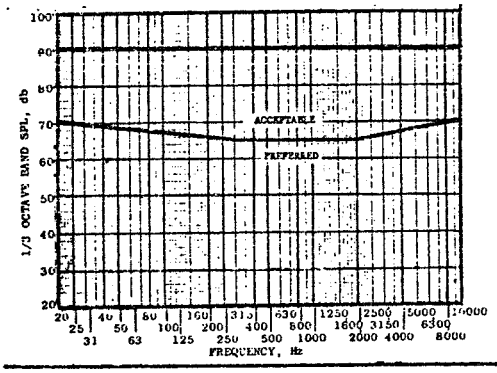
LIGHTING

Light Source: Incandescent-Halogen Cycle, Fluorescent, Mercury Vapor

Item	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	50	5-50	1
	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	35-60	35
Floors	35	15-35	15
Machines	45	25-45	20

REMARKS: Lighting should be sufficient for general hygiene purposes. Close inspection of animals could be achieved with localized lighting. Control of the lighting levels and spectral composition may be desirable for investigation and/or control of animal and plant growing cycles.

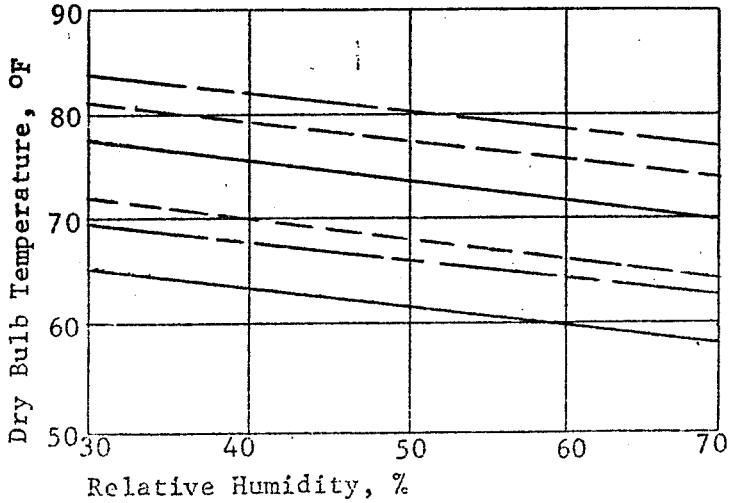
ACOUSTICS



REMARKS: None

TEMPERATURE

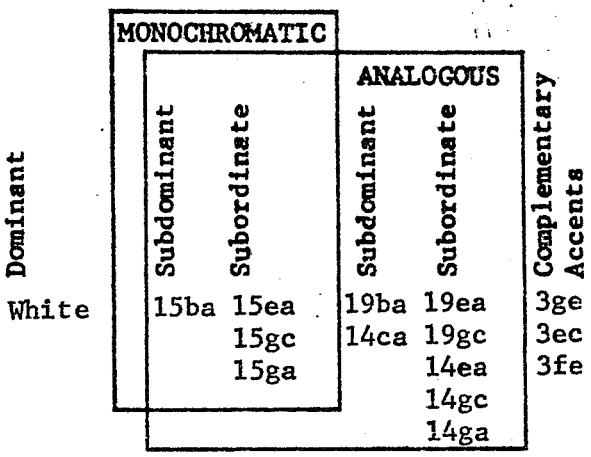
Comfort Zones



Legend:
5 PSIA ————
10 PSIA — — — —
14.7 PSIA — - ——

Air Flow Rate: 70 fpm
Metabolic Rate: 800 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 3 Hours

EXAMPLE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

VOLUME

REMARKS: Area requirement of activity is mission equipment dependent.

III-5.15

AREA: Agricultural Study Area

DESCRIPTION

ACTIVITY: Moderate

MOOD: Physical Activity

SOCIAL FACTOR: Public

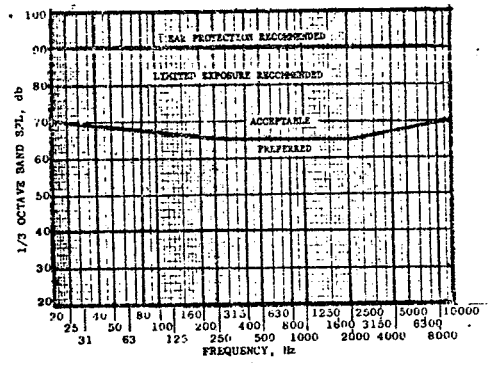
LIGHTING

Light Source: Incandescent-Halogen Cycle, Fluorescent, Mercury Vapor

Item	Light Level, Foot Candles		
	Maximum	Desirable	Minimum
	50	5-50	1
	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	60-90	60
Walls	60	35-60	35
Floors	35	15-35	15
Machines	45	25-45	20

REMARKS: Lighting should be sufficient for general hygiene purposes. Close inspection of animals could be achieved with localized lighting. Control of the lighting levels and spectral composition may be desirable for investigation and/or control of animal and plant growing cycles.

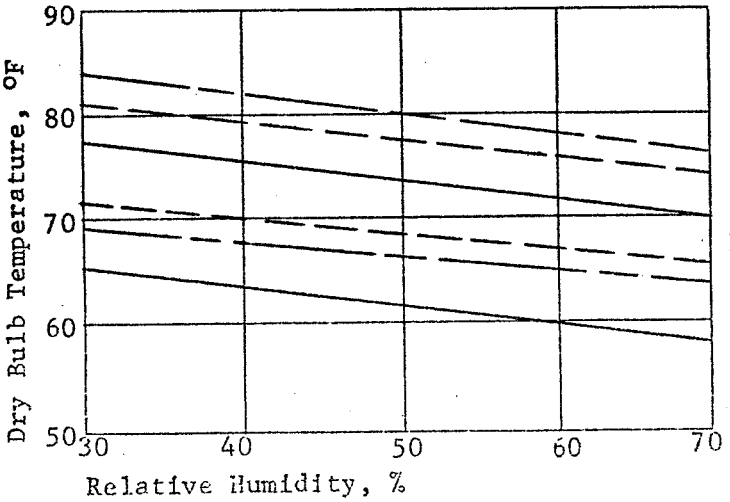
ACOUSTICS



REMARKS: None

TEMPERATURE

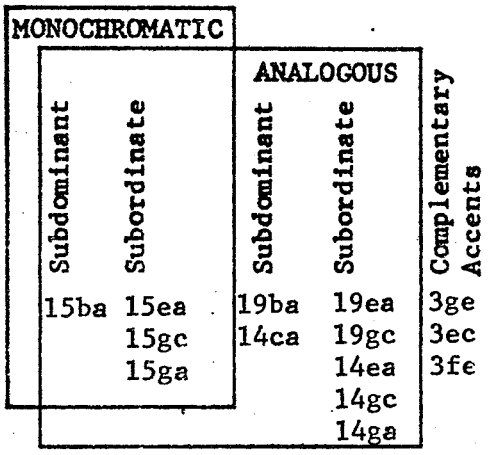
Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — - — - —

Air Flow Rate: 70 fpm
Metabolic Rate: 800 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 6 Hours

LE COLOR SCHEME



REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Adequate lighting is provided for sight tasks. Basic cool hues are conducive to feelings of spaciousness, responsibility, and tend to make time pass more rapidly. Low color intensity and value contrasts serve to compliment attentiveness.

E

KS: Area requirement of activity is mission equipment
dent.

III-5.16

AREA: Air Locks

DESCRIPTION

ACTIVITY: Moderate to High

MOOD: Physical Activity

SOCIAL FACTOR: Public

LIGHTING

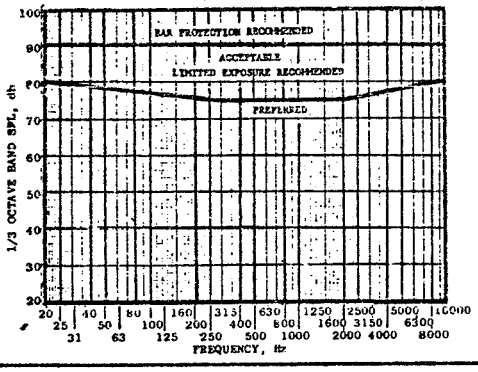
Light Source: Incandescent, Fluorescent, Mercury Vapor

Light Level, Foot Candles		
Maximum	Desirable	Minimum
10	5-10	1

Item	Surface Reflectance, %		
	Maximum	Desirable	Minimum
Ceiling	90	70-90	70
Walls	70	50-70	50
Floors	40	20-40	20
Control Panel	40	20-40	20
Instruments	45	25-45	20

REMARKS: Same considerations as for hallways. Lighting should be designed for transition aspects of area.

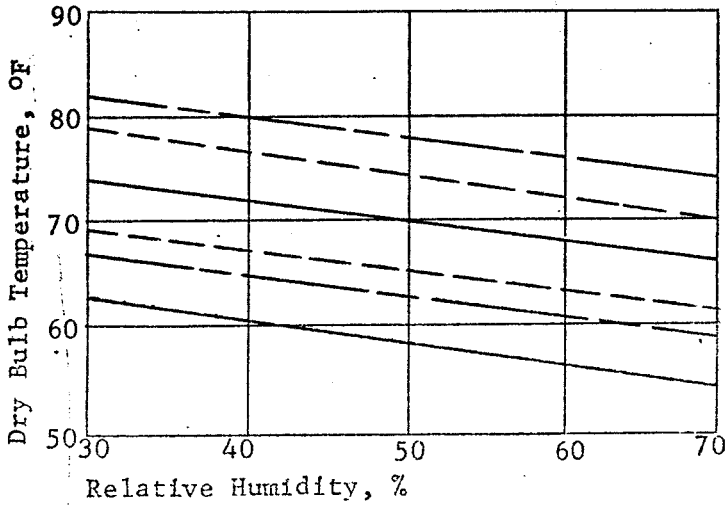
ACOUSTICS



REMARKS: None

TEMPERATURE

Comfort Zones



Legend:
5 PSIA ————————
10 PSIA — — — — —
14.7 PSIA — — ———

Air Flow Rate: 60 fpm
Metabolic Rate: 850 BTU/hr
Clo Factor: .8 to 1.0
Occupancy Time/Day: 1 Hour

EXAMPLE COLOR SCHEME

Dominant	MONOCHROMATIC		ANALOGOUS		Complementary Accents
	Subdominant	Subordinate	Subdominant	Subordinate	
White	3cb 3dc	--	--	--	--

REMARKS: The example shown here is an acceptable color scheme for the defined mood and activity level of this area; however it should not be construed as the sole solution. The Ostwald Color System is employed as a base-line reference only. Adequate light is provided
Neutral colors are used in this area because it is an area of transition.

VOLUME

REMARKS: Physical description of activity is mission dependent.

IV UTILIZATION OF HANDBOOK

1.0 Introduction

The handbook may be used as a reference source for background data and concepts regarding the nature and importance of various elements of habitability, Section II, and for general guidance as to how the elements of habitability may be applied to specific mission activities and combinations thereof, Sections III and IV respectively.

Section II, General Design Criteria, may be used to gain a basic understanding of the nature and importance of the habitability elements discussed herein. These elements are:

A. Lighting
B. Acoustics
C. Temperature
D. Color
E. Volume
F. Texture and Design
G. Hygiene
H. Dual Room Usage
I. Gravity
J. Interrelated Environments

An understanding of these elements is an ingredient essential to making decisions regarding the application of concepts and guidelines presented in this handbook to actual mission design situations.

Section III, Crew Area Criteria, contains general guidelines and examples pertaining to the application of the data and concepts presented in Section II to specific activity areas. It is emphasized that these guidelines are general in nature and must be used with discretion.

Section IV, Paragraph 4.0, presents a system for applying the concepts and guidelines presented in Sections II and III to the development of rough mission models. The limitations of this system reflect the general nature of the handbook as well as the state of the art relating to man's understanding of habitability.

2.0 Limitations of Study

For a number of the habitability elements researched, meaningful data, essential to the establishment of minimum desirable standards, do not exist. This is due both to the state of the art of identifying and quantifying the elements of habitability, the lack of terrestrial models relevant to space flight conditions, and to the intangible nature of many of the elements considered. An excellent example of an element for which very little data exist is 'dual room usage' and the effect of specific variations in the level or type of dual room usage on habitability. T. M. Fraser refers to these elements as the 'Intangibles of Habitability' in his 1968 study for NASA of the same title. As he states in conclusion, "the intangible will tend to remain intangible and in fact the problems they create may never be defined but progressively succumb to the evolutionary development of long-ranged spacecraft." Elements which have classically been considered to be the exclusive domain of the arts: e. g. configuration and interrelationships of space, and the effects of lighting and surface treatment such as color, texture and pattern on the interpretation of these spaces have relied strictly on subjective type data for guidance. For these elements there is no absolute or ultimate combination which will ensure the habitability of a habitat. A single or fixed solution in fact would be self-defeating in that it would most likely add to the monotony of the environment.

3.0 Reliability of Guidelines

Due to the limited amount of meaningful data pertaining to the effects of extended mission durations on man, various intangible habitability elements and interrelationships of same, as well as the reactions of average men to confined situations, the guidelines contained herein should be used for general guidance only. It is expected that these guidelines may well undergo considerable change as man's exposure to long duration extraterrestrial missions increases.

4.0 Mission Model Development

4.1 General

As discussed in paragraph IV-3.0, it is not possible to develop an accurate mission model for all combinations of mission parameters since insufficient data exist in the areas of activity, volumetric requirements and dual room usage to compute accurate figures. The following example therefore, illustrates only a systematic approach to this problem which, with accurate environmental data input, should provide a quick method of computing approximate habitability needs.

4.2 Procedure

To utilize the handbook to develop an approximate model for a specific mission the following six steps are used:

1. Determine the mission compatibility rating.
2. Determine the acceptable compartmentation level and suitable activity combinations.
3. Figure the area requirements for the individual activities.
4. Apply the efficiency factor to activity area requirements.
5. Figure the area requirements for combined activities.
6. Determine which activities in each activity combination has the most stringent habitability standards for lighting, acoustics, temperature and color.

4.3 Sample Calculation

Example mission parameters:

Crew size - 12
Mission duration - 90 days per crew
Gravity level - zero

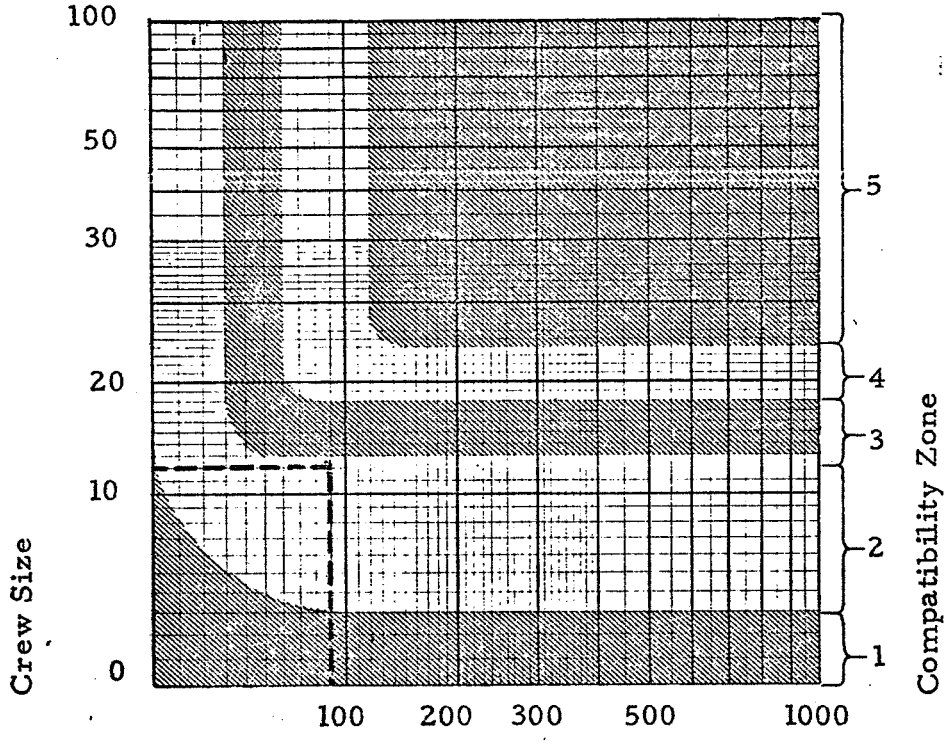
Atmosphere - 14.7 psia O_2-N_2
Station Life - 10 years

4.3.1 Step 1: Mission Compatibility Rating

Refer to figure II-H-1 to determine the mission compatibility rating. As shown by the dotted lines in figure IV-1, the mission compatibility rating for the sample mission is 2.

Figure IV-I
Compatibility Rating As a Function of Crew Size and Mission Duration

Rating:
1 = Most Effective
5 = Least Effective



4.3.2 Step 2: Work Sheet Selection

Select the work sheet appropriate to the mission compatibility level. Work sheets for computing approximate volumetric requirements and for noting dominant lighting, acoustic, temperature and color standards for each area are provided on pages 4-8 to 4-12. Each of the five work sheets is laid out to reflect the compartmentation recommendations for a specific compatibility level as established in Section II-H, Dual Room Usage. For the sample mission, a compatibility level II chart is shown in Figure IV-2 filled in with data derived from Section III of the Handbook.

4.3.3 Step 3: Apparent Area

The area requirements for the individual activities are recorded by the user in the left hand column. These figures are determined by referring to the appropriate crew areas in Section III. Because of the general nature of the handbook, area figures are provided for only those areas in which furniture units were not mission dependent (unknown machinery, etc.)

4.3.4 Step 4: Actual Area

By multiplying the apparent area need for each activity by the efficiency figure listed in the second column from the left, the actual area need for that activity are determined.

4.3.5 Step 5: Total Area

The actual area needs are now combined to determine the total area needs for each activity combination. These figures are added together and multiplied by the average floor to ceiling height to determine a rough volumetric requirements for all of the activities considered.

4.3.6 Step 6: Dominant Environmental Standards

Refer to Section III to determine those areas within each activity combination which have the most stringent

standards for lighting, acoustics and temperature. The activity having the dominant standard in each area should be checked in the appropriate column.

The dominant activity in each activity combination is listed first on the worksheet within each activity group.

The color scheme for a combined activity area is generally selected to complement the character of the dominant activity in the area.

Figure IV-2
Example Mission Worksheet

MISSION WORKSHEET - II (Example)

MISSION PARAMETERS:
Crew Size: 12 Gravity Level: 0
Mission Duration: 90 DAYS/CREW 10YR TOTAL Atmosphere: 14.7 PSI

ACTIVITY COMBINATIONS	Apparent Area	Efficiency Factor	Actual Area	Total Area	Dominant Environmental Standards		
					Lighting	Acoustics	Temp.
Personal Quarters	558	1.0	558		X	X	X
Study	—	.0	—				
Locker	—	.0	—				
Dining Room	180	1.0	180				
Recreation*	—		—				
Theater	—	.0	—				X
Conference Room	—	.0	—				
Briefing Room	—	.0	—				
Chapel	—	.0	—				
Library	12	.35	4.2		X	X	
Lounge	64	.5	32				
Gym	96	1.0	96				
Passageway	—	1.0					
Galley	—	1.0	X		X	X	
Snack Bar	—	.0	X				X
Laundry	—	1.0	X				
Dispensary	76	1.0	76		X	X	X
Barber		.0					
Bathroom	157.5	1.0	157.5				
Storage	—	-	X			X	
Supply	—	-	X		X		X
Communications		-	X		X	X	X
Control		-	X				
Computer		-	X				
Equipment		-	X				X
Shop		-	X			X	
Maintenance		-	X		X		
Office		-	X				X
Laboratory		-	X		X		
Photography		-	X			X	
Animal Housing		-	X				
Agricultural Study Area		-					
Docking		-			X	X	
Air Locks		-					X
Power		-					

MISSION WORKSHEET - I

MISSION PARAMETERS:

Crew Size:_____ Gravity Level:_____

Mission Duration:_____ Atmosphere:_____

ACTIVITY COMBINATIONS	Apparent Area	Efficiency Factor	Actual Area	Total Area	Dominant Environmental Standards		
					Lighting	Acoustics	Temp.
Personal Quarters		1.0					
Study		.0					
Locker Room		.0					
Dining Room		1.0					
Recreation*							
Theater		.0					
Conference Room		.0					
Briefing Room		.0					
Chapel		.0					
Library		.35					
Lounge		.5					
Gym		.2					
Passageway		1.0					
Galley		1.0					
Snack Bar		.0					
Laundry		1.0					
Dispensary		-					
Barber		-					
Bathroom		-					
Storage		-					
Supply		-					
Communications		-					
Control		-					
Computer		-					
Equipment		-					
Shop		-					
Maintenance		-					
Office		-					
Laboratory		-					
Photography		-					
Animal Housing		-					
Agricultural Study Area		-					
Docking		-					
Air Locks		-					
Power		-					

MISSION WORKSHEET - II

MISSION PARAMETERS:

Crew Size:_____ Gravity Level:_____

Mission Duration:_____ Atmosphere:_____

ACTIVITY COMBINATIONS	Apparent Area	Efficiency Factor	Actual Area	Total Area	Dominant Environmental Standards		
					Lighting	Acoustics	Temp.
Personal Quarters		1.0					
Study		.0					
Locker Room		.0					
Dining Room		1.0					
Recreation*							
Theater		.0					
Conference Room		.0					
Briefing Room		.0					
Chapel		.0					
Library		.35					
Lounge		.5					
Gym		1.0					
Passageway		1.0					
Galley		1.0					
Snack Bar		.0					
Laundry		1.0					
Dispensary		1.0					
Barber		.0					
Bathroom		-					
Storage		-					
Supply		-					
Communications		-					
Control		-					
Computer		-					
Equipment		-					
Shop		-					
Maintenance		-					
Office		-					
Laboratory		-					
Photography		-					
Animal Housing		-					
Agricultural Study Area		-					
Docking		-					
Air Locks		-					
Power		-					

MISSION WORKSHEET - III

MISSION PARAMETERS:

Crew Size:_____ Gravity Level:_____

Mission Duration:_____ Atmosphere:_____

ACTIVITY COMBINATIONS	Apparent Area	Efficiency Factor	Actual Area	Total Area	Dominant Environmental Standards		
					Lighting	Acoustics	Temp.
Personal Quarters		1.0					
Study		.0					
Locker Room		.0					
Dining Room		1.0					
Recreation*							
Theater		.0					
Conference Room		.0					
Briefing Room		.0					
Chapel		.0					
Library		.35					
Lounge		1.0					
Gym		1.0					
Passageway		1.0					
Galley		1.0					
Snack Bar		.0					
Laundry		1.0					
Dispensary		1.0					
Barber		1.0					
Bathroom		1.0					
Storage		-					
Supply		-					
Communications		-					
Control		-					
Computer		-					
Equipment		-					
Shop		-					
Maintenance		-					
Office		-					
Laboratory		-					
Photography		-					
Animal Housing		-					
Agricultural Study Area		-					
Docking		-					
Air Locks		-					
Power		-					

MISSION WORKSHEET - IV

MISSION PARAMETERS:

Crew Size:_____ Gravity Level:_____

Mission Duration:_____ Atmosphere:_____

ACTIVITY COMBINATIONS	Apparent Area	Efficiency Factor	Actual Area	Total Area	Dominant Environmental Standards		
					Lighting	Acoustics	Temp.
Personal Quarters		1.0					
Study		.0					
Locker Room		.0					
Dining Room		1.0					
Recreation*							
Theater		.0					
Conference Room		.0					
Briefing Room		.0					
Chapel		.0					
Library		.35					
Lounge		1.0					
Gym		.2					
Passageway		1.0					
Galley		1.0					
Snack Bar		.0					
Laundry		1.0					
Dispensary		1.0					
Barber		1.0					
Bathroom		1.0					
Storage		-					
Supply		-					
Communications		-					
Control		-					
Computer		-					
Equipment		-					
Shop		-					
Maintenance		-					
Office		-					
Laboratory		-					
Photography		-					
Animal Housing		-					
Agricultural Study Area		-					
Docking		-					
Air Locks		-					
Power		-					

MISSION WORKSHEET - V

MISSION PARAMETERS:

Crew Size:_____ Gravity Level:_____

Mission Duration:_____ Atmosphere:_____

ACTIVITY COMBINATIONS	Apparent Area	Efficiency Factor	Actual Area	Total Area	Dominant Environmental Standards		
					Lighting	Acoustics	Temp.
Personal Quarters		1.0					
Study		.0					
Locker Room		.0					
Dining Room		1.0					
Recreation*							
Theater		.0					
Conference Room		.0					
Briefing		.0					
Chapel		.0					
Library		1.0					
Lounge		1.0					
Gym		1.0					
Passageway		1.0					
Galley		1.0					
Snack Bar		.0					
Laundry		1.0					
Dispensary		1.0					
Barber		1.0					
Bathroom		1.0					
Storage		-					
Supply		-					
Communications		-					
Control		-					
Computer		-					
Equipment		-					
Shop		-					
Maintenance		-					
Office		-					
Laboratory		-					
Photography		-					
Animal Housing		-					
Agricultural Study Area		-					
Docking		-					
Air Locks		-					
Power		-					