GUIDELINES FOR ENVIRONMENTAL FACTORS IN NATO SURFACE SHIPS

(ACOUSTICAL; CLIMATIC; VIBRATION; COLOUR; ILLUMINATION)

ANEP-25

This ANEP belongs to a series of ANEP's that were prepared by AC/141(IEG/6)SG/8 On the Influence of Human Factors on Ship Design. These ANEP's cover Human Factors/Ergonomics issues pertaining to manning, automation, maintenance, habitability, environment, work space design, etc.

February 1991

NORTH ATLANTIC TREATY ORGANIZATION

MILITARY AGENCY FOR STANDARDIZATION (MAS)

NATO LETTER OF PROMULGATION

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E. STAI
Major-General, NOAF
Chairman, MAS

RECORD OF NATIONAL RESERVATIONS

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RECORD OF NATIONAL RESERVATIONS (Cont)

NATION	SPECIFIC RESERVATIONS

RECORD OF CHANGES

CHANGE DATE	DATE ENTERED	EFFECTIVE DATE	BY WHOM ENTERED

PREFACE

1. The purpose of this document is to define the design criteria to be applied to NATO surface ships in order to provide a shipboard environment which shall ensure the effective performance, health and safety of personnel.

2. This Allied Naval Engineering Publication, ANEP-25, has been prepared by IEG/6 Sub-Group 8 ON THE INFLUENCE OF HUMAN FACTORS ON SHIP DESIGN.

3. Each nation is encouraged to use this ANEP in its own design in order to provide a basis for evaluation of its designs by other countries, e.g. for the purposes of procurement decisions.

4. This ANEP is part of the ANEP Series On Human Factors/Ergonomics In Ship Weapon System Life Cycle which includes issues related to WSLC management, personnel, planning, automation, selection and training, material design, shipboard organization and procedures. The covering document of the series, ANEP-20, HUMAN FACTORS/ERGONOMICS IN THE DEVELOPMENT AND ACQUISITION OF SHIP WEAPON SYSTEMS, describes the intention of the ANEP series and the interrelationships between the various issues, as well as providing a full list of the ANEP's, together with a summary of each.

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CHAPTER 1 - ACOUSTICAL ENVIRONMENT

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1.1 AIM

a. NATO surface ships shall be provided with and maintain, an adequate acoustical environment in order to prevent:

(1) loss of hearing and other damages to the health of personnel;

(2) interference with communications in operational and working spaces;

(3) reduction of efficiency of the crew;

(4) interference with the crew's recreation and sleep in accommodation spaces.

1.2 REQUIREMENTS

a. To achieve these objectives the acoustical environment, in terms of maximum noise levels (MNL), noise rating curves (NRC) and speech interference levels (SIL), shall be as specified in:

NATO STANDARDIZATION AGREEMENT STANAG 4293

GUIDELINES FOR THE ACOUSTICAL ENVIRONMENT IN NATO SURFACE SHIPS.

CHAPTER 2 - CLIMATIC ENVIRONMENT

CONTENTS PAGE NO.

2.1 GENERAL

a. The heating, ventilation and air-conditioning system shall, in all outside climatic conditions which the ship will encounter in its assigned operational area, and under all tactical situations, provide inside climatic environmental conditions which will maintain efficiency of the crew and the equipment.

b. For design purposes the outside climatic conditions should be considered within the following extremes:

(1) High temperature conditions: at least +32°C dry bulb temperature (DBT), at least 80% relative humidity, 30°C sea water temperature.

(2) Low temperature conditions: at least -12°C DBT, 30% relative humidity, -2°C sea water temperature.

2.2 DEFINITIONS

a. Air-conditioned spaces are spaces in which the room temperature and humidity is controlled automatically.

b. Normally ventilated spaces are spaces in which the room temperature primarily depends on the temperature of the incoming air which can be heated and sometimes cooled by devices operated manually by personnel.

2.3 CRITERIA

a. In order to fulfill the above requirements the living and working spaces (except for high heat producing spaces) shall be included, whenever possible, in the air-conditioning system. The criteria outlined in the subsequent paragraphs must be met.

b. For evaluation of the climatic environment Effective Temperature (ET) should be used. This measure represents the subjective reaction of humans to combinations of DBT, relative humidity and air velocity. The conversion of these factors into ET may be done using Figure 1 (for air velocities < 0.15m/s).

c. In all air-conditioned living and working spaces temperature, relative humidity and air velocity shall be maintained within the limits specified in Figure 1. The zone of optimum human performance applies to permanently occupied spaces, the acceptable zone to temporarily occupied spaces.
In high temperature conditions (see paragraph 2.1 b.(1)) the difference between external and internal temperature DBT shall be >10 K.

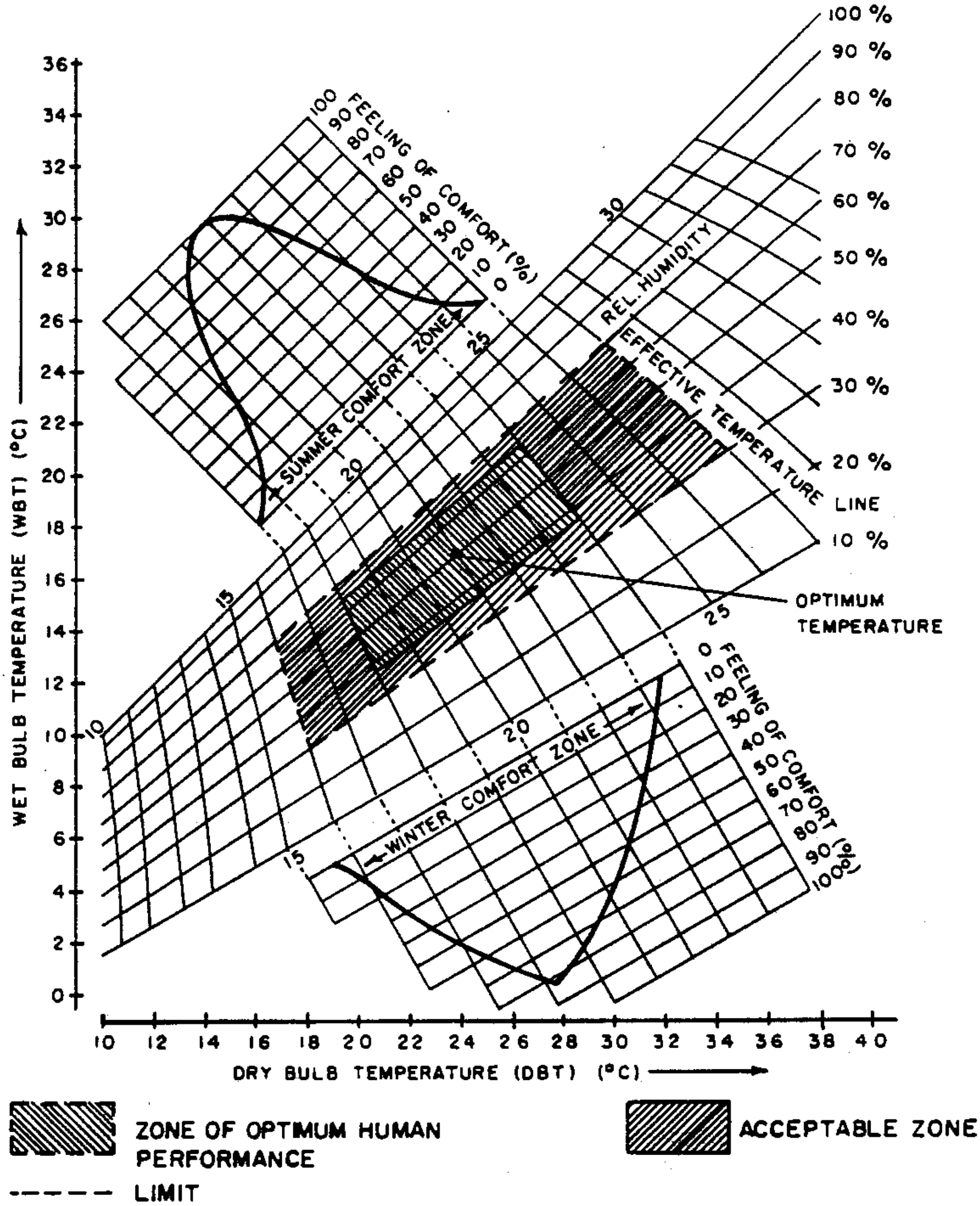

FIGURE 1

Temperature, Relative Humidity and Air Velocity for Air Conditioned Living and Working Spaces. Diagram for Determination of ET (Air Velocity: 0 - 0.15m/s)

d. In all normally ventilated spaces the temperature (DBT) shall be within the limits given in Table 1.

TABLE 1

Temperature Limits in Spaces Occupied By Personnel if not included in the Air-conditioning System

Name of Space	Upper Limit DBT (°C)	Lower Limit DBT (°C)
Machinery spaces (occupied by personnel)	40(1)	10
Workshops	35	15
Heads	36	15
Sanitary Spaces	30...36	24
Galleys	30...36	15
Pantries, Sculleries	30...36	15
Laundry	30...36	15
Store Room	36	10...15
Ship's Hospital (2)	28	20
Other Living and Working Spaces (2)	28	20

(1) Not manned continuously
(2) In cases when living and working spaces (except for high heat producing spaces) and the ship's hospital cannot be air-conditioned air cooling devices have to be provided

e. Air discharge must not be directed on personnel. At all places occupied by personnel the air velocity shall be in conformance with the limits given in paragraph 2.3 c. In spaces where the temperature exceeds 28 degrees centigrade the air velocity may be raised; the maximum is 0.33 m/sec.

f. In working spaces normally occupied by personnel (excluding machinery spaces and galleys) and in living spaces the difference in temperatures at the deck level and at the head level and the differences in temperatures at different places but same level should not be more than 3K.

2.4 FRESH AIR REQUIREMENTS

a. The amount of fresh air or - under closed down conditions - of decontaminated air introduced by the ventilation shall keep gases, vapours, dust and fumes within the limits specified in national regulations. The ventilation system must be designed so that gases which have been produced in the ship (e.g. narcotic gases in ship's hospital) and air coming from specific spaces can be carried off through the system.

b. The CO_2 concentration must not exceed the following limits:

(1) in combat-significant operational spaces 0.15%;

(2) in berthing and living spaces 0.15%;

(3) in messrooms 0.25%;

(4) in workshops, where heavy physical work is done for a short time, 0.5%.

c. The amount of fresh air necessary to meet the above specifications can be calculated for permanently closed down systems using the formula in Figure 2.

$$FAV = BAV \cdot n \cdot \frac{a}{b_2 - b_1} \quad [m^3]$$

BAV	= Breathing Air Volume		n	= Crew
Resting	= $0.50 m^3$/Person x h		a	= CO_2 generation during breathing = 4%
Light work	= 0.75 "	" "	b_1	= CO_2 content of fresh air = 0.03%
Work	= 1.25 "	" "	b_2	= CO_2 concentration in the space in %

b_2-limits:

In Combat - significant spaces =0.15%; in resting - compartments =0.15%; in messrooms =0.25%; in workshops, where heavy physical work is done for a short time = 0.5%

FIGURE 2
CALCULATION OF FILTERED AIR VOLUME (FAV)

CHAPTER 3 - SHIP VIBRATION

CONTENTS PAGE NO.

3.1 INTRODUCTION

a. Vibration has always been an integral part of ships and their operation. Through the years, advances in ship design and construction have tended to decrease overall hull stiffness and reduce energy dissipation by damping. At the same time large increases in propulsion machinery power have resulted in higher levels of vibration excitation. Another factor, unrelated to ship design, but one that has brought the study of vibration to the forefront, has been a general increase in the awareness of and concern for the environment in which people live and work.

b. Whenever vibration problems occur one question is always asked: "How much can human beings tolerate?" This cannot be answered categorically at this time because of the subjective nature of human response to vibration acceptability criteria. This is particularly true within the marine industry.

c. Ships present a special problem since they are in constant motion from wind and wave action. Those forces excite both rigid body motion and structural vibration. Machinery and propeller induced vibrations are superimposed on hull motions to give very complex responses. Any shipboard vibration guidelines, therefore, must represent a balance between the total environmental conditions and the pure biophysical reaction of human beings.

d. Because there are varied opinions on how vibration affect ship and crew reliability, the domain of acceptable vibration levels is very broad. Generally, however, vibration will cause physical annoyance to the crew before it adversely affects the ship structure, machinery or other equipment. Because of this the vibration guidelines are based primarily on human reactions.

e. The motion experienced by a person in a sea-going ship will depend on his location in the ship. Vibration in the 0-30 Hz range is the major source of problems to the man. In the range 0.1 - 0.63 Hz motion sickness can be caused, particularly around 0.25 Hz. Vibration above this range does not cause motion sickness.

f. It is well known that the human response data base for low frequency random motion is lacking in many areas. Nevertheless, there are many laboratory and field studies about motion sickness. Those studies have mainly investigated vertical motion (z-axis). The International Standard (ISO-2631/3,1985) which covers the effect of motion in the 0.1 to 0.63 Hz region, was drawn up from these results.

3.2 OBJECTIVE

a. This chapter establishes guidelines for evaluating the design of a ship with respect to the vibration environment it will impose upon crews. Zones are presented which estimate the reaction of a typical human being to different levels of vibration as a function of frequency. Such guidelines are necessary for the development of acceptable limits of vibration for different ship compartments and locations and to provide a set of criteria to which a ship design may be compared.

3.3 SOURCE

a. The vibration guidelines outlined in this chapter have been derived by Society of Naval Architects and Marine Engineers Panel HS-7 after an extensive review of various proposed criteria for human response, examination of actual shipboard noise and vibration performance data available to individual panel members, ISO-standards and lastly judgement as to the acceptability of ships in operation from which data were available.

3.4 BASIC ELEMENTS

a. Vibration is characterized by the displacement of a mass over time and is defined by the amplitude and the frequency of the displacement. Subjectively, vibration is the shaking induced by a variety of agents such as modes of transport. In everyday language vibration means shaking, usually imposed by some mechanical agent.

b. A simple definition of the term vibration has been given by Crede (1957), who defines it as a number of reversals of velocity. This definition reminds us that both displacement and acceleration take place; for velocity is the rate of change of displacement, and acceleration is the rate of change of velocity, with respect to time. Angular (or rotational) vibration about a centre of rotation are frequently an important part of a vibration environment. For example, ships sailing in a rough sea, the pitching and rolling motions may be more disturbing than the rectilinear vibration up and down in a steady sea.

c. Frequency: The period of a vibration is the reciprocal of the frequency and is the duration in seconds of one complete cycle of motion. The international standard unit of frequency is the Hertz (Hz), which is one cycle per second.

d. Amplitude: Another important characteristic of a vibration is its intensity, which may be expressed in terms of the extent of the vibratory motions. If the vibration is a simple to-and-fro or sinusoidal oscillation about a position of rest or equilibrium, the amplitude is defined as the maximum value of the displacement from that position. It is properly measured in metres but, because in practice most vibrations of interest are of relatively small excursion, it is often expressed in centimetres or millimetres.

e. Intensity of Vibration: The magnitude of a vibration, that is, the acceleration (or, if quoted, the velocity or displacement), should be expressed as a root-mean-square (rms) value. By extension, the term "amplitude" is sometimes used when speaking of the maximum or rms value of a vibratory velocity or acceleration, quantities which are determined by the value of frequency and the displacement amplitude of the motion.

f. Direction of vibration: Direction of vibration affecting man has received standardized definitions in relation to the principle anatomical axes of the body. Rectilinear vibration transmitted to man should be measured in the appropriate direction of an orthogonal co-ordinate system having its origin at the location of the heart (see Fig. 1).

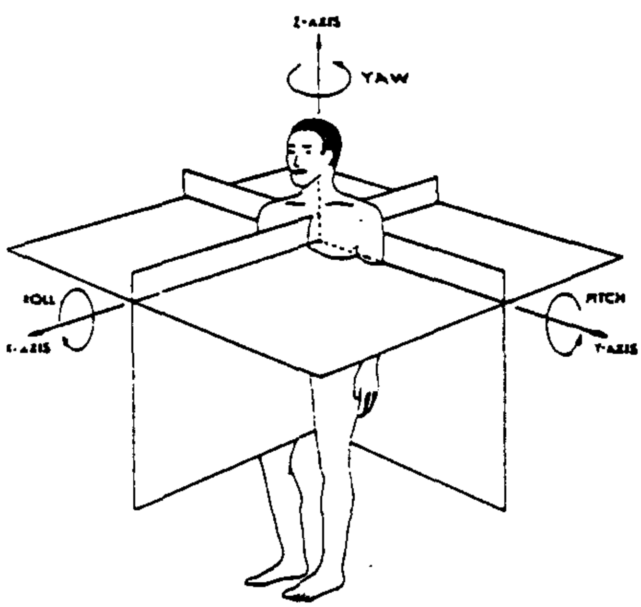

FIGURE 1

Axes for referring to the direction of vibrational and accelerating forces in man (Guignard, 1972).

3.5 EFFECTS OF SHIP MOTION

a. A ship at sea moves along the three translational axes and also rotates about the same three axes (roll, pitch and yaw). The accelerations are random in nature, being introduced by the random seaway in which the ship operates. The frequency range of the seaway induced motion and acceleration is essentially bounded at the lower end by zero frequency, and at the upper end by 5 Hz, with the major portion of the energy occurring below 1 Hz (Stark, 1980).

b. It would be impossible to investigate rigorously the effect of each of the nine different ship motions so there is a surprising lack of worthwhile data from laboratory and field studies which clearly link the main reaction with motion input. Ship motion below 1 Hz is a special problem associated with symptoms such as motion sickness which are of a character different from the effects of higher frequency vibration.

c. Most laboratory studies have mainly investigated vertical motion. This component of ship motion has long been considered as a primary factor in the etiology of motion sickness aboard ships (O'Hanlon, 1974).

3.6 CRITERIA AND RECOMMENDATIONS

a. A criterion of allowable human exposure to vibration is properly defined as an expression of the reason for limiting the vibration exposure of a specified population (e.g. seafarers, aircrew, or the travelling public) in a particular context. Three separate criteria of acceptable human vibration exposure are generally distinguished (Guignard, 1972), namely:

(1) a conservation of occupational health or safety against potentially hazardous levels of vibration;

(2) the conservation of working efficiency (or performance) against distracting or otherwise disturbing vibration; and

(3) the conservation of comfort or amenity, which intrusive vibration may spoil, for example, in passenger-carrying vehicles.

b. With reference to these criteria two evaluation methods have been established:

(1) ISO 2631-1985 "Evaluation of Human Exposure to Whole-Body Vibration" and;

(2) "Ship Vibration and Noise Guidelines" prepared by SNAME Panel HS-7 (Technical and Research Bulletin 2-25). The different evaluation methods which are used by different NATO nations are described below.

c. The recommended limits of exposure set according to these three criteria are defined graphically in the ISO guide for the evaluation of human exposure to whole body vibration (ISO-2631, 1985). This guide defines and gives numerical values for limits of exposure for vibration transmitted from solid surfaces to the human body in the frequency range 1 to 80 Hz. Figs. 2a and 2b show respectively in graphical form the vertical (a_z) acceleration limits as a function of frequency and exposure time: "equal fatigue-decreased proficiency boundary", and the vertical (a_z) acceleration limits as a function of exposure time and frequency (centre frequency of one-third octave band): "equal fatigue-decreased proficiency boundary" (after ISO-2631/1).

d. This frequency is considered to cover most conditions of passive motion normally regarded as "vibration" and it restricts the proposed recommendation to that part of the spectrum in which, on the basis of present knowledge, it is possible to draw continuous functions describing the human response to vibration with sufficient confidence for them to serve as standardized limits.

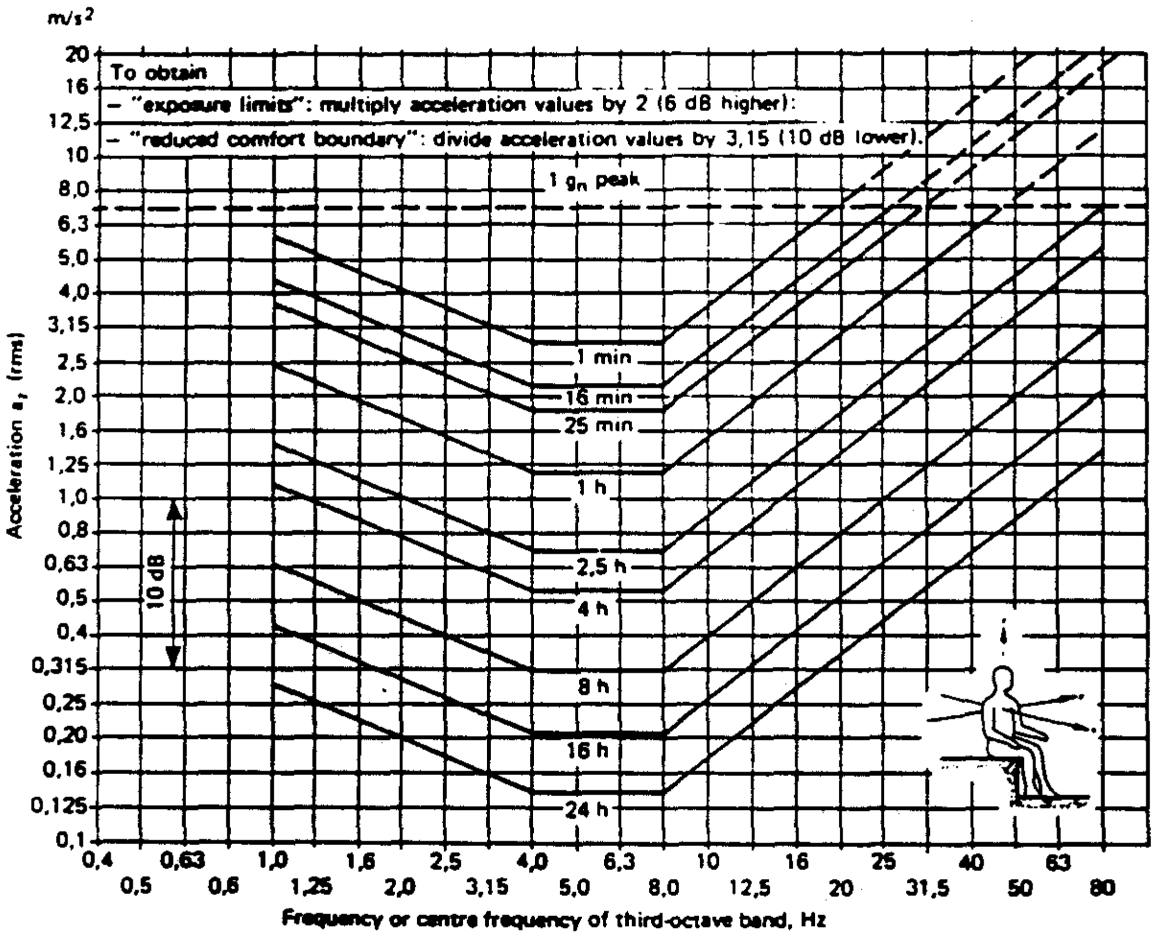

FIGURE 2a

Vertical (a_z) acceleration limits as a function of frequency and exposure time: "equal fatigue-decreased proficiency boundary".

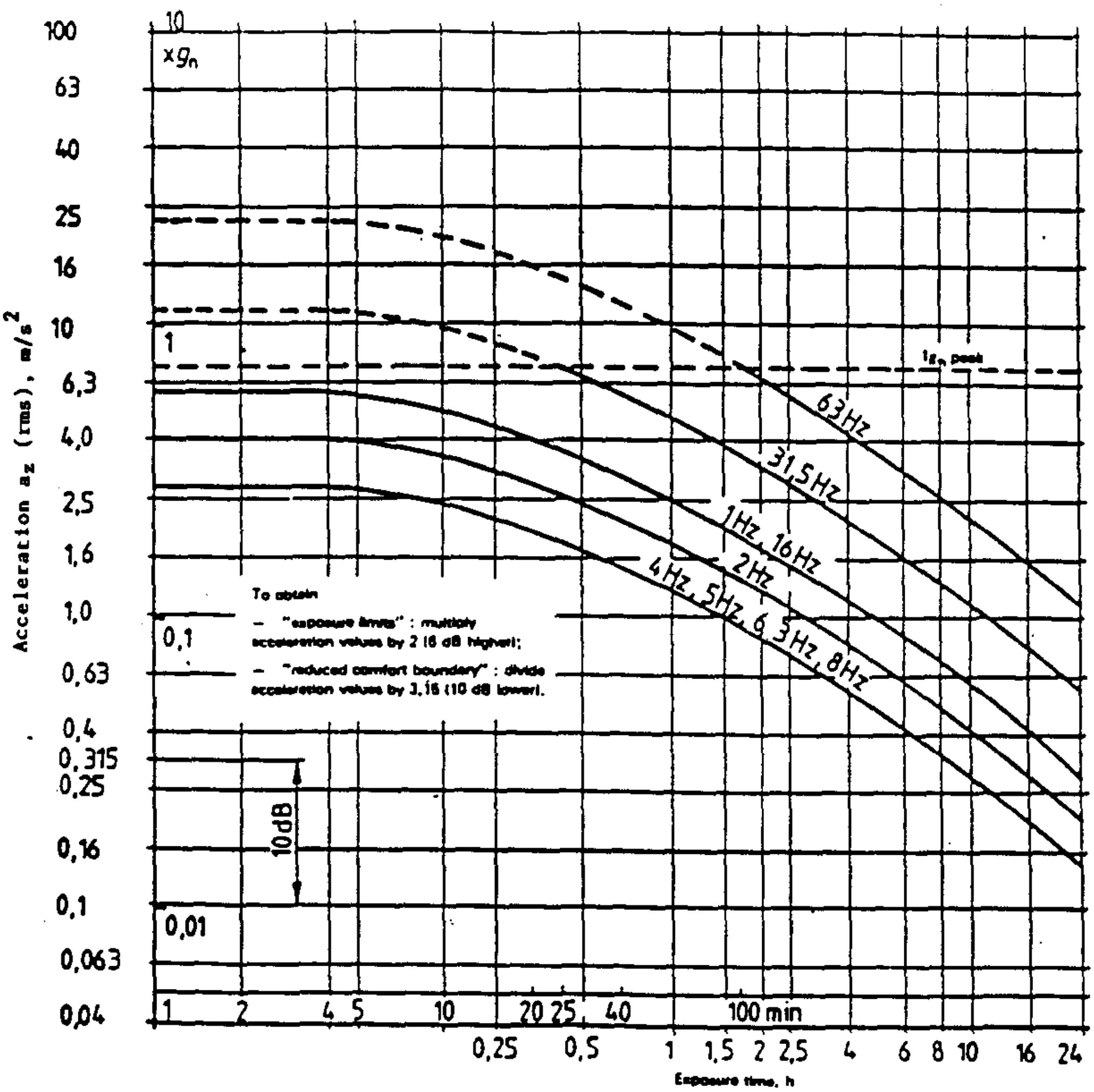

FIGURE 2b

Vertical (a_z) acceleration limits as a function of exposure time and frequency (centre frequency of one-third octave band): "equal fatigue-decreased proficiency boundary".

e. Vibration in the frequency range below about 1 Hz are a special problem, associated with symptoms such as motion sickness which are of a character different from the effects of higher frequency vibrations.

f. In ISO 2631/3, 1985, "evaluation of exposure to whole-body Z-axis vertical vibration in the frequency range 0.1 to 0.63 Hz," some information is given. (see also Figure 3). ISO 2631/3 covers vibration transmitted to the body in the frequency range 0.1 to 0.63 Hz, based on critical surveys and analyses of laboratory and field studies, which finally concentrated on some 25 investigations from 1947 to 1975. It applies especially to discrete frequency and narrow band vibration and provisionally to random or non-periodic vibrations within the specified frequency range.

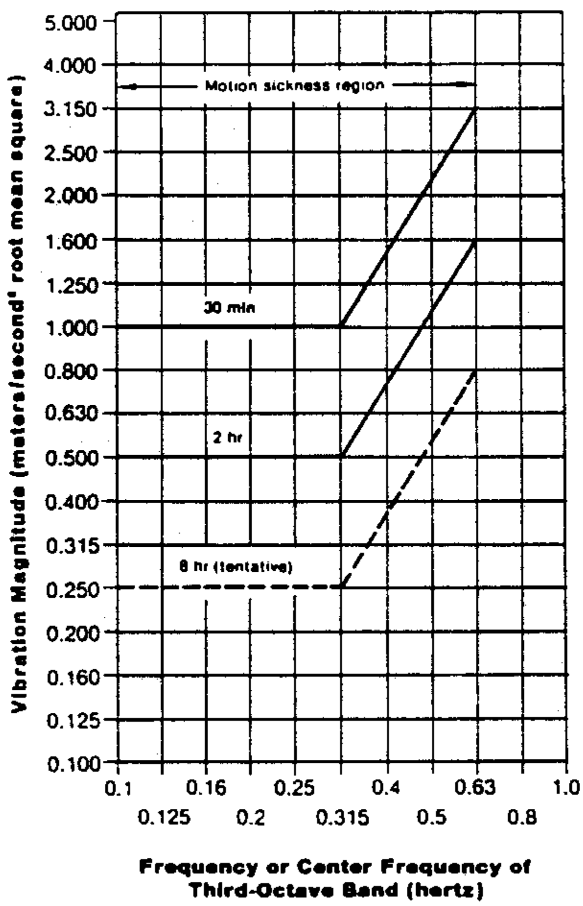

FIGURE 3

"Severe discomfort boundaries", 0.1 to 0.63 Hz for Z-axis (a_z) Vibration (ISO-2631/3, 1985).

g. The recommended guidelines for vibration are presented in both metric and English units in Figures 4a and 4b "Guidelines for Ship Vibration (Vertical and Horizontal)". It should be noted that all values are in rms. Each Zone in Figures 4a and 4b are:

<u>Zone 1</u> - Vibration levels in this zone are low enough so that adverse comments from personnel are generally unexpected.

<u>Zone 2</u> - Vibration levels in this zone indicate that vibration is noticeable, however, very few adverse comments would be expected.

<u>Zone 3</u> - In this zone vibration levels and human response increase rapidly in severity and adverse comments are generally expected.

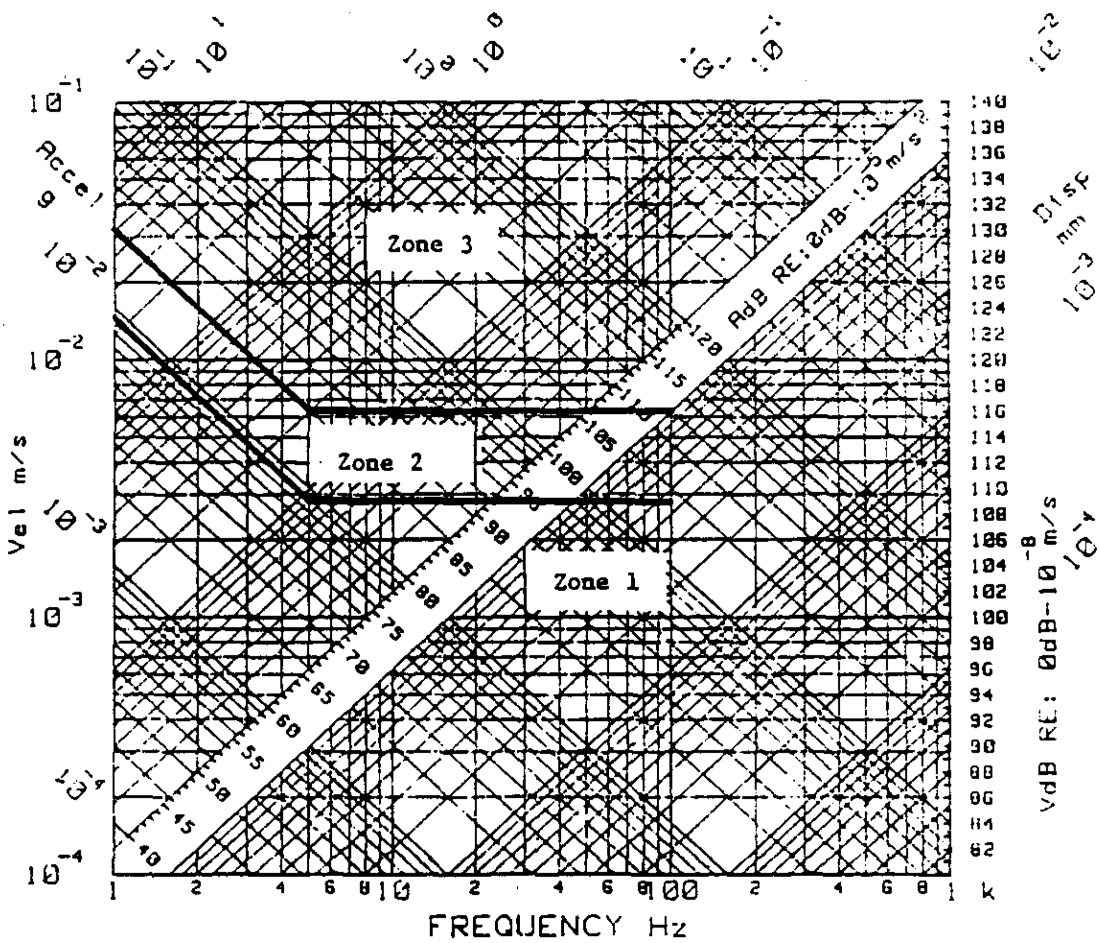

FIGURE 4a

Guidelines for Ship Vibration (Vertical and Horizontal, rms)

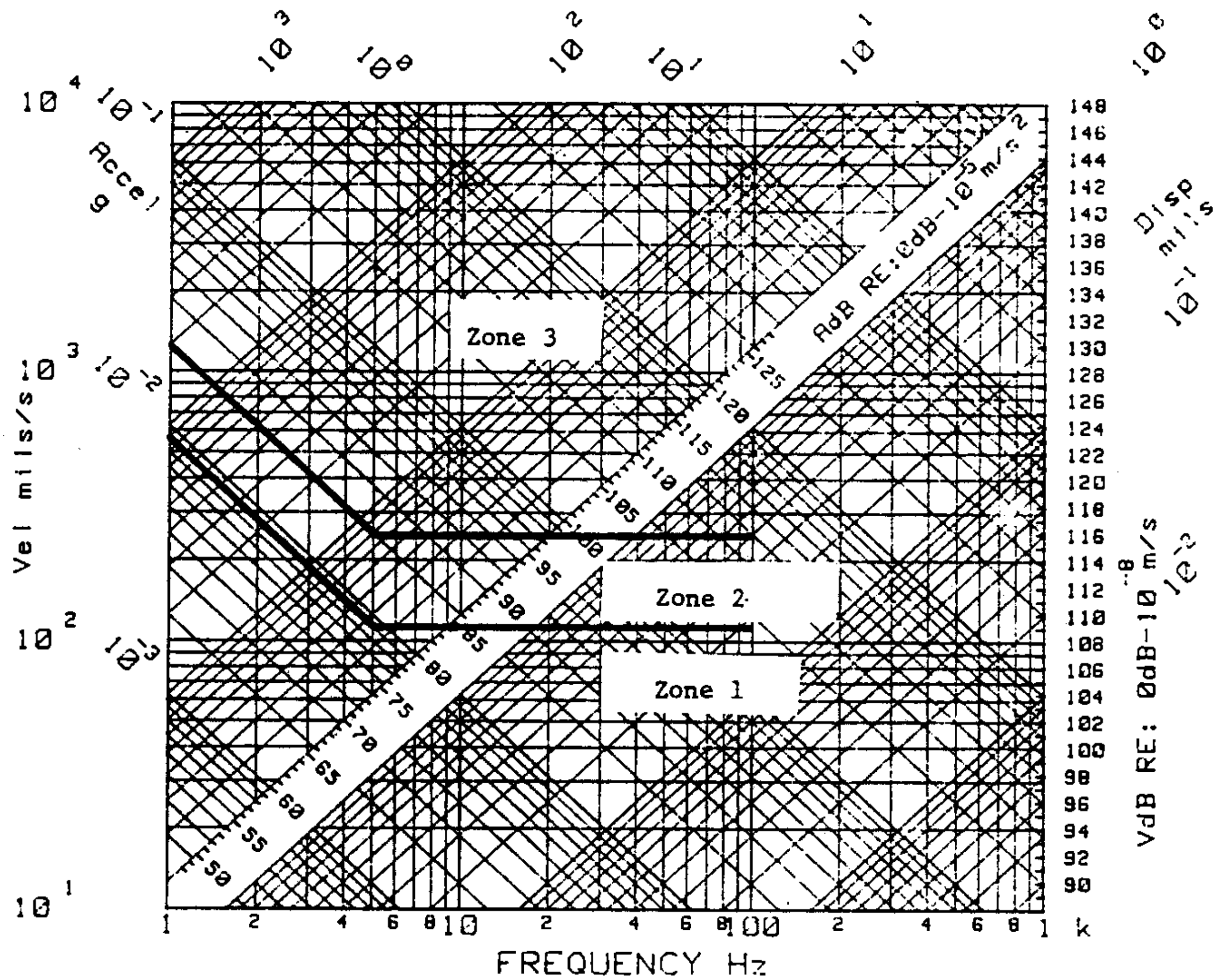

FIGURE 4b

Guidelines for Ship Vibration (Vertical and Horizontal, rms)

3.7 METHODS OF MEASUREMENT

a. The basic elements of vibration measuring equipment consists of the following parts: a vibration-detecting transducer or pick-up; a signal-processing amplifier (electrical, mechanical or optical), and an amplitude or level indicator or recorder.

b. Transducers: A transducer is a device which converts mechanical energy derived from the vibration into a proportional signal, usually electrical, which is transformed by the amplifier into a signal adequate to drive the recording or indicating device. The effective bandwidth (frequency range) varies from one type of transducer to another and it is accordingly important to select one suitable range of interest in any particular situation.

c. Accelerometer: Transducers yielding a signal directly proportional to the vibrational acceleration below a limiting cut-off frequency can be purchased, operating on one of a number of physical principles.

d. In the variable-inductance type, a seismically mounted mass, moved by the vibrating force, deflects a ferromagnetic core with respect to an electrically energized coil, thereby varying the current in it; while in the resistive strain-gauge type, mechanical deformation alters the electrical ohmic resistance of a bonded element which can be connected in a simple bridge circuit whose output provides the force-proportional signal.

e. Many transducers (including seismic accelerometers used above their resonant frequency) yield a signal proportional to vibrational velocity; and some direct-writing, non-electrical detecting instruments yield a measurement or recording of the displacement. In biodynamics capacitive transducers can be used to detect small displacements; and electrical devices are available which can be used to measure relatively large displacements up to several centimetres (e.g. potentiometers worked by mechanical linkages and, for more precise and noise-free operation, linear variable differential transformers).

f. For many applications, where it is not essential to rely solely upon on-the-spot determinations, the use of a suitable tape recording system to obtain representative records for subsequent analysis will be the method of choice. An rms - rectifying device may also be included for convenience, so that rms values may be read off or recorded directly.

g. Ship vibration data should be taken in accordance with some acceptable and consistent procedure such as the "Code for Ship-board Vibration Measurements, C-1", also see ISO-Documents 4867 and 4868.

3.8 DOCUMENTATION OF MEASUREMENTS

a. All vibration measurements taken should be documented by indicating:

i) all locations on the ship were measurements were made;

ii) the type of instrument used;

iii) check of instrument calibration;

iv) test condition;

v) reference to documentation of vibration measurements, if available (see 3.9 Related Documents 1, 3, 4 and 5).

3.9 RELATED DOCUMENTS

1. "Code of Shipboard Vibration Measurements", The Society of Naval Architects and Marine Engineers, Technical and Research Code C-1, 1975.

2. "Code of Hull Vibration Measurements on Naval Ships", Naval Research and Development Center Report 2781, 1968.

3. "Code C-4 Local Shipboard Structures and Machinery Vibration Measurements", the Society of Naval Architects and Marine Engineers Technical and Research Code C-4, 1976.

4. ISO-4867-84 "Code for the Measurement and Reporting of Shipboard Vibration Data".

5. ISO-4868-84 "Code for the Measurement and Reporting of Local Vibration Data of Ship Structures and Equipment".

6. ISO 6954-84 "Mechanical Vibration and Shock - Guidelines for the Overall Evaluation of Vibration in Merchant Ships".

7. "Shipboard Noise and Vibration from a Habitability Viewpoint" by A. Hagen and N.O. Hammer, Marine Technology, January 1969.

8. ISO-2631/1 "Evaluation of Human Exposure to Whole-Body Vibration - Part 1: General Requirements", (1st Edition, May 1985).

9. ISO-2631/3 "Evaluation of Human Exposure to Whole-Body Vibration - Part 3: Evaluation of Exposure to Whole-Body Z-Axis Vertical Vibration in the Frequency Range 0.1 to 0.63 Hz", (1st Edition, May 1985).

3.10 REFERENCES

1. Baranek, L.L. (1971) Noise and Vibration Control, McGraw-hill, New York.

2. Chinn, H.I. (1963) What is motion sickness? Report No. AMRL-TDR-63-25, Ohio.

3. Crede, C.M. (1957) Principle of vibration control. Handbook of noise control. Chapter 12. McGraw-hill, New York.

4. Guignard J.C., and King, P.F. (1972) Aeromedical Aspects of Vibration and Noise. Technical Editing and Reproduction Ltd., London.

5. Money, K.E. (1970) Motion Sickness. Physiological Review 50.

6. O'Hanlon, J.F., and McCauley, M.E. (1974) Motion Sickness incidence as a Function of the Frequency on Acceleration of Vertical Sinusoidal Motion. Aerospace Medicine, April.

7. Stark, D.R. (1980) Ride Quality in Marine Vehicles. Human Factor in Transport Research. Academic Press, London.

8. Yerges, C.F. (1969) Sound, Noise, and Vibration Control. Van Nostrand Reinhold Company, New York.

CHAPTER 4 - COLOUR SELECTION

CONTENTS PAGE NO.

4.1 INTRODUCTION

a. The design of any shipboard space is dependent on many different factors, one of which is the provision of an effective visual environment. Colour aboard plays an important role for habitability. Colour can cheer and depress, stimulate and tranquillize. Used unadvisedly, colour may cause strain and tension, but considered use of colour can enrich the environment, reduce boredom and prevent accidents. The length, width, height, depth of interior spaces aboard can be masked or accentuated with colour. Adverse colours make distant walls seem nearer and box large areas in, reducing their apparent size. Ceilings in very dark colours look weightier and lower; light colours have the reverse effect. Therefore proper selection and utilization of colours, as well as their proper illumination to achieve an effective visual environment, must not be overlooked in the design of shipboard spaces.

b. Two principle types of effect should be anticipated when considering the use of colour:

(1) psychophysical effects - primarily the influence of colour on the ability to see;

(2) psychological effects - mostly the effects of colour on the "feeling" or attitude of the user.

Of these the psychophysical effects are the most important and most reliable, because they can be related to the visual performance of personnel. The psychological effects are more difficult to define, or to demonstrate reliably, although they are a major consideration in the design of most living spaces.

4.2 BASIC ELEMENTS

a. The eye sees an object only by the light it reflects, so the wavelengths it reflects determine its colour. Some objects reflect and absorb light of all different wavelengths equally well. Black velvet absorbs nearly all the light that falls on it - the incident light; snow reflects nearly all the incident light. An object that absorbs some of each wavelength of incident light, and reflects the rest, appears grey, the actual shade of grey depending on the proportion reflected. The perceived object colour, the colour perceived as belonging to an object, is something perceived instantaneously. It is so common an experience that many persons find it hard to understand why colour is not simple to explain in a few easy lessons. But a colour perception results from the interaction of many highly complex factors. For a full discussion of the nature of colour, see "The Science Book of Color" (1953).

b. Three principle characteristics of colour must be distinguished when considering its use in working and living spaces. These are:

(1) hue - the characteristics which distinguish one colour from another, e.g. "red", "green" or "blue", dependent on the wavelength of the light emitted or reflected;

(2) luminosity - the intensity of the colour, or its ability to transmit or reflect a greater or lesser proportion of the incident light;

(3) saturation - the purity of the colour, on the extent to which it differs from a grey of the same luminosity.

4.3 IDENTIFYING AND MEASURING COLOURS

a. The founding father of practical modern colour order systems was Munsell. In his system there are three dimensions of colour: hue (determined by wavelength), value (lightness), and chroma (saturation), measured against an appropriate scale. These scales are made up by a collection of colour chips forming a book of colour charts, each chart with one of their variables held constant (Fig. 1).

b. The hue scale contains five Principal Hues Red (R), Yellow (Y), Green (G), Blue (B), Purple (P), and five Intermediate Hues YR, GY, BG, PB and RP, value, which is the lightness (or brightness of the hue, is indicated on a grey-scale ranging from 0 (black) to 10 (white). Chroma, the saturation of the colour - or conversely, its freedom from direction with white - is indicated by up to 16 or more steps from a given level of value. Thus, in the Munsell system, any colour can be specified by the use of three or four symbols. For example, a certain red with a value halfway up the grey-scale (5) and six steps in chroma away from neutral is written 5R5/6 the notation being written in order hue, value/chroma (Fig. 1). The ideal of such systems is to provide a colour language sufficiently standardized and detailed to meet the needs of science, to accommodate industry, and still be generally comprehensive to the amateur. There are different systems in West Germany, the DIN - Colour Chart; the British Standard Institute specification; the Natural Colour System of Sweden. All are used primarily in their country of origin, and none are interchangeable leading to great difficulties when, for example, an American company wants to have instrument panels manufactured and dyed in Germany or Italy.

MUNSELL BOOK OF COLOR
RED
(5.0R)

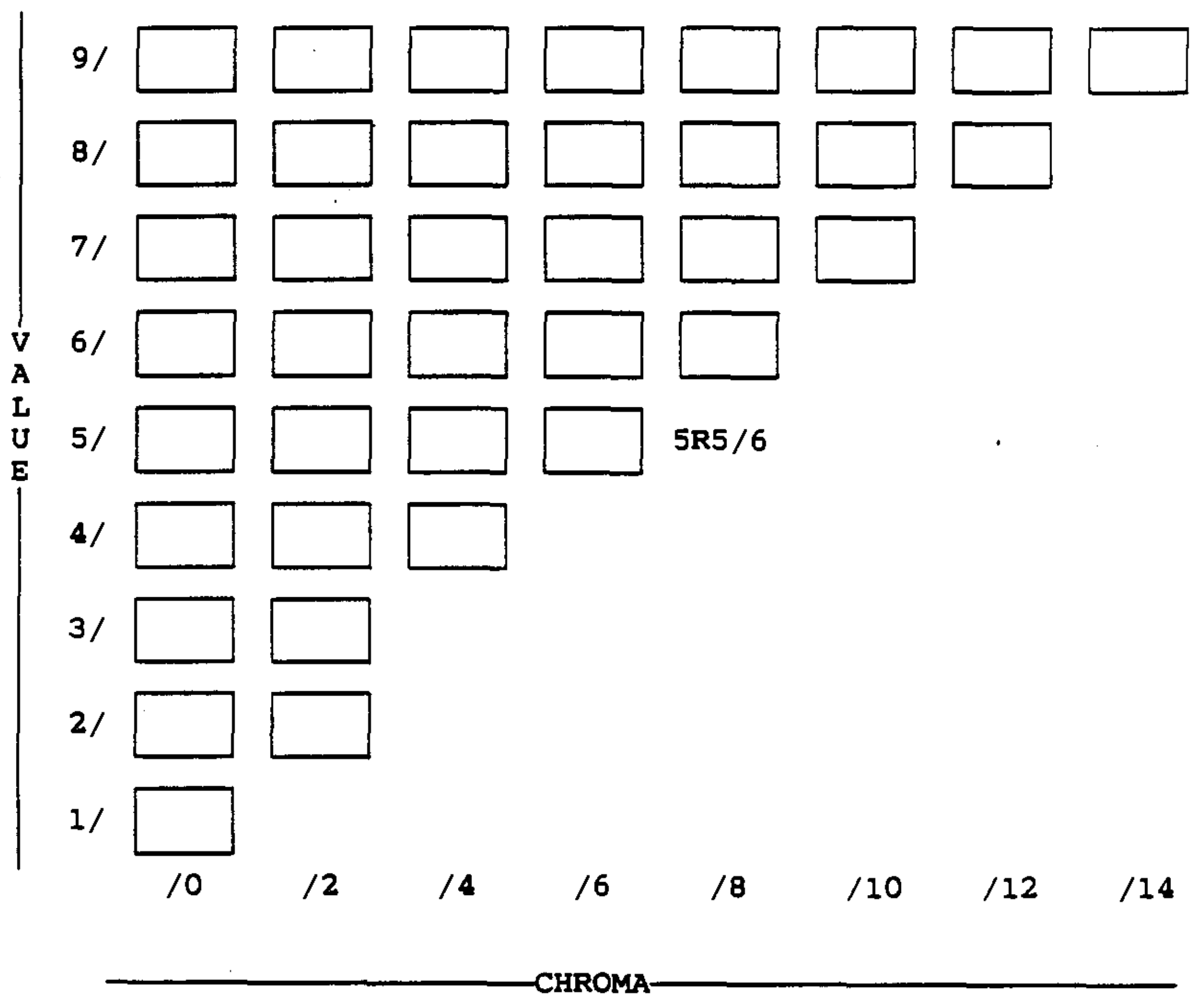

FIGURE 1

page of constant hue from the Munsell book of Colour showing location of colour chip 5R5/6.

c. The most advanced colour order systems are based not just on the appearance of colours - the matching of sample against chip - but on colorimetry, the identification and matching of colours by precise measurement. Colours can be matched by tristimulus colorimeters, machines based upon three coloured filters, the additive primaries; red, green and blue. They are mixed in different proportions until the resulting mixture matches the colour of a chip or swatch. Still more advanced is the spectrometer which measures the amount of light reflected or transmitted by a sample at each wavelength in turn throughout the visible spectrum. A curve plotted from the results can be converted to tristimulus values to show exactly how any given colour is built up in terms of its wavelength at measurements.

d. The Commission Internationale de l'Eclairage, an international body which specifies methods of measuring colour devised a colour order system based on spectrophotometric measurements of colour samples illuminated by specified types of lighting, and related to the visual response of a "standard observer". A sample may reflect green light, and look green under northern skylight, for example, yet under tungsten light it may appear slightly more yellow. But the C.I.E. specifications are presented in mathematical form; they do not show what colours look like, so reference has to be made to colour samples built up from the co-ordinates.

e. In publication C.I.E. No. 15(E-1.3.1) 1971, "Colorimetry", official recommendations on uniform colour spaces are given for international specifications and codes of practice.

f. So although the C.I.E. system is the last word in accuracy, it is of less day-to-day use than the system of coloured chips or patches with which a sample can be matched visually. To its credit, the redoubtable Munsell system affords both notation based on instrumental measurement (which can be cross-referenced with the C.I.E. co-ordinates) and samples in the Munsell Book of Colour. Other well-known visual reference systems include the Colour Harmony Manual, based on pioneering colour work by the German scientist, Wilhelm Ostwald, the Maerz and Pacel Dictionary of Colour and the Untied States' Government's Universal Color Language and Dictionary of Names, a book that attempts to unify all existing and filtered colour order systems (Varley, 1980).

4.4 THE PSYCHOPHYSICAL EFFECTS OF COLOUR

a. Colour effects the performance of visual tasks through its effect on brightness, on the perception of colour, and on the creation of visual after images.

b. The prime psychophysical consideration is to create a good level, and a good balance of the light needed to do the task. The luminosity of the colours is therefore of importance in controlling the brightness of the working or living space. Colour and lighting must therefore be considered as inter-related design factors.

c. In addition to light sources and lighting fixtures commonly used in compartment lighting, a large portion of the illumination on work planes is provided by light which has been reflected one or more times from overheads, bulkheads and decks. As a result, the reflectance of the compartment surfaces greatly affects the overall efficiency of the compartment in delivering light to the work. It should be noted that the higher the reflectance, the higher the utilization of light. In fact, a compartment in which all surfaces are flat white would produce the highest possible light utilization. But judged from a practical and psychological standpoint, this type of environment is seldom desirable.

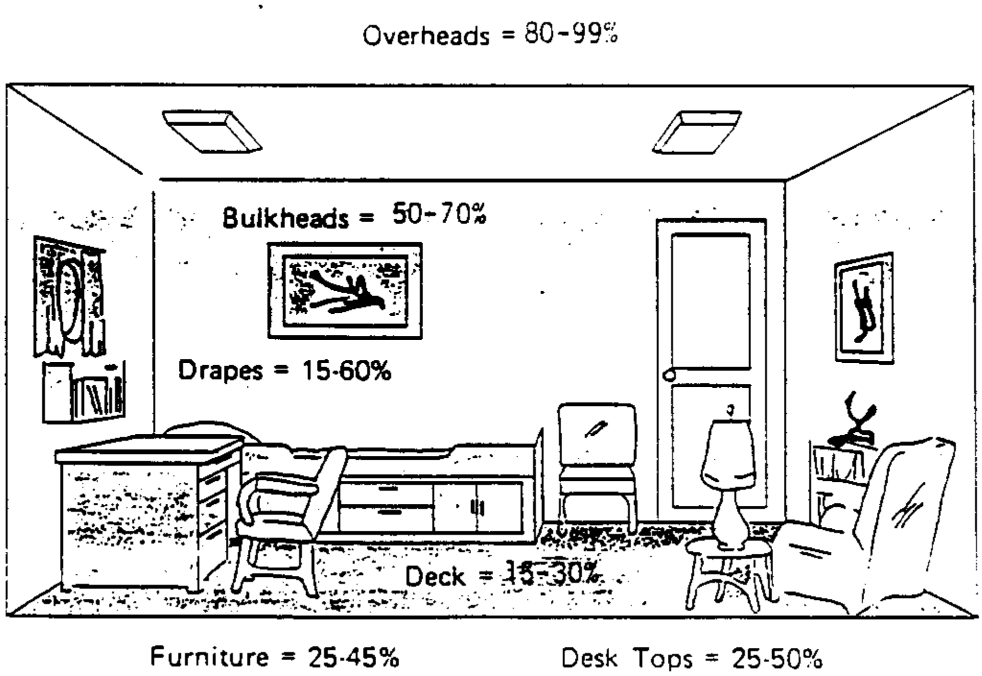

FIGURE 2

Recommended Reflectances for Interior Finishes

d. In general, as shown in Figure 2, maximum reflection values should be used on the ceiling; the reflectance must not be less than 80 per cent. This will be essential to the efficiency of indirect lighting systems. In direct systems, the clear colour overhead will reduce contrast between fixtures and their surroundings. Bulkheads should have a reflectance between 50 and 70 per cent, but not less than 50 per cent. Decks should have a reflectance factor between 15 and 30 per cent. Table 1 contains a percentage of reflected light for a variety of surface colours.

e. The reflection factors given in Figure 2 should not be used on the bridge or in the Operations Room, or in any other area where it is important to avoid reflections in windows or in CRTs. In those areas lower reflectances should be used for the ceiling, and higher values for the deck.

f. The reflectance of the colour is significantly affected by the choice of illumination, as discussed in a later section. When considering the brightness of a living or working space this must be taken into account. The selection of a blue or green hue, for example, will result in a very dark ship space under the red lighting conditions used for "darken ship" to preserve night vision. If the wavelength distribution of the light source is modified so that certain wavelengths are missing or considerably reduced (e.g., red light, yellow light, green light, etc.), the inherent colour characteristics of a surface reflect a different colour impression. Thus, as indicated in Table II, a yellow object will appear to be red-orange when viewed under red lights.

	PERCENT OF REFLECTED LIGHT		
COLOUR	LIGHT	MEDIUM	DARK
White	85	-	-
Ivory	75	60	40
Gray	75	50	20
Yellow	75	65	35
Buff	70	63	30
Green	65	40	10
Blue	55	35	8
Red	-	-	13
Brown	-	-	10
WOOD FINISH			
Maple	42		
Satin Wood	34		
English Oak	17		
Walnut	16		
Mahogany	12		

TABLE I. Reflectance Factors

EFFECT OF COLORED LIGHT ON COLORED OBJECTS				
Object Color	Red Light	Blue Light	Green Light	Yellow Light
White	Light Pink	Very Light Blue	Very Light Green	Very Light Yellow
Black	Reddish Black	Blue Black	Greenish Black	Orange Black
Red	Brilliant Red	Dark Bluish Red	Yellowish Red	Bright Red
Light Blue	Reddish Blue	Bright Blue	Greenish Blue	Light Reddish Blue
Dark Blue	Dark Reddish Purple	Brilliant Blue	Dark Greenish Blue	Light Reddish Purple
Green	Olive Green	Green Blue	Brilliant Green	Yellow Green
Yellow	Red Orange	Light Reddish Brown	Light Greenish Yellow	Brilliant Light Orange
Brown	Brown Red	Bluish Brown	Dark Olive Brown	Brownish Orange

TABLE II.

g. The perception of colour and the creation of visual after images are inter-related. For example in a sick bay the surgeon works under very high light levels, which will produce green hued after images of flesh and blood, since green is the complementary colour of red. Green is therefore a very functional colour for use in operating rooms, or sick bays, because it makes the after images less opponent, and thus less distracting to the surgeon. Conversely, if the wrong hue - one biased towards red, is used in messes, the after images can make food appear less palatable.

h. When a surface is very hard and glossy, light rays concentrate, making the intensity of the light and apparent brightness of one part of a surface much higher than that of another. This results in a variation in the apparent colour of one part of the surface versus another. If source intensity is high enough it is possible to obliterate the colour impression altogether, so that the source itself is reflected as "glare". See Figure 3.

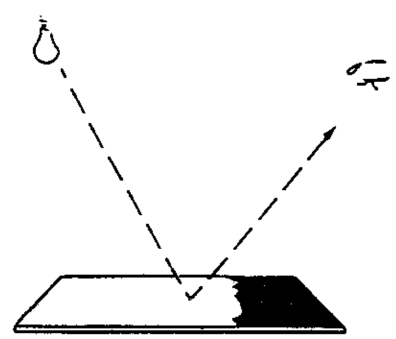

FIGURE 3

j. Rough textured surfaces make any colour appear darker and less bright because more of the light falling on the surface is absorbed. Conversely a smooth, glossy surface reflects more light, making the colour appear brighter. Take a stone, for instance, and wash it off. While it is wet, several colours will be apparent; when it dries, it may appear simply as a flat monotone. See Figure 4.

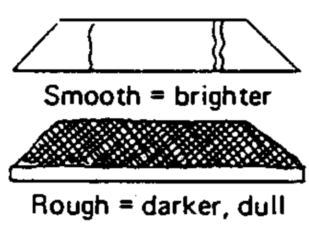

FIGURE 4

k. If the surface of an object is roughened it will scatter light falling upon it, causing apparent brightness across the surface to appear more equal, making all parts of the surface appear similar in colour. See Figure 5.

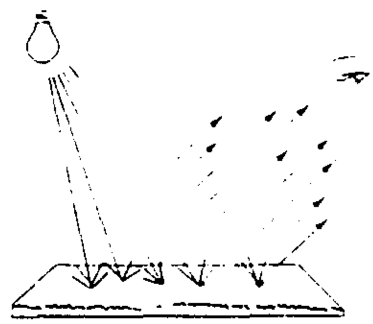

FIGURE 5

m. If the rays from a light source arrive at a surface essentially from only one direction, deep shadows will occur on the surfaces of an object that are not facing the source. Because of the brightness difference between the surfaces facing the source and those surfaces in shadow, the apparent colour of the two surfaces will be different, although the inherent colour is the same. Thus, in practice we attempt to diffuse the light from the source and/or try to provide secondary reflections from adjacent surfaces in order to equalize the brightness of various object surfaces, making them all recognizable as the same. Adjacent surface colours, on the other hand, if sufficiently vivid (saturated) may alter the colour of the secondary light reflections and thus impart their own particular colour to the surface of the object facing the secondary surface reflection. See Figure 6.

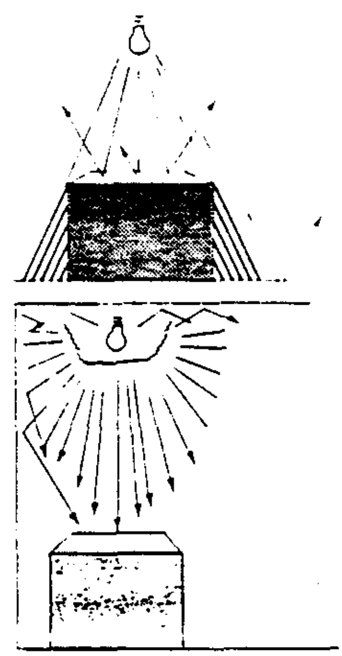

FIGURE 6

4.5 THE PSYCHOLOGICAL EFFECTS OF COLOUR

a. Although colour researchers have not always been able to quantify the precise effects of various colours or light levels on humans, their research and experience seem to indicate that certain colours and light conditions often elicit typical repeatable reactions. Illumination level and quality do contribute to impressions of compartment size, atmosphere of warmth or coolness, or generate moods or feelings of repose, pleasantness, excitement, boredom or depression. Colour can have considerable bearing on the appetizing appearance of food and on the naturalness of one's skin appearance.

b. The following four basic psychological response characteristics are perhaps most important to the development of appropriate colour and lighting schemes aboard ship:

(1) Certain colours make a space appear larger than it actually is, while others cause the space to "close - in" on the observer;

(2) Certain colours cause a space to seem warm, while others make it seem cooler;

(3) Some colours appear to have a definite effect on the mood of the observer, i.e., some colours may be stimulating, others calming;

(4) Some colours seem to clash with each other and therefore produce a feeling of irritation to observers especially sensitive to colour incompatibilities.

c. The average observer perceives dark and/or saturated colours as advancing toward him, light and/or desaturated colours as receding from him. If we wish to make a compartment appear less crowded, then our colours should be light and unsaturated. Any structure or furniture that is dark in colour will make a space appear crowded. The level of illumination contributes to this appearance of being crowded in that a dimly-lit space generally appears smaller than one that has a higher, more evenly-distributed level of light. Therefore aboard ship, with few exceptions, good illumination and lighter colours are desirable.

d. So-called cool colours (e.g. blues and greens) make a space seem cooler, while so-called warm colours (such as reds, browns, oranges) make a space seem warmer. Although there has been little quantitative evidence of any direct correlation between cool or warm colours and actual physiological temperature variation, cool colours usually are preferred for facilities located in hot climates, and warmer colours for facilities located in cold climates. However, since many colours considered cool or warm also have other mood-generating characteristics, it is important not to let these temperature related characteristics become over-emphasized. Thus a warm colour may be more important in terms of its ability to generate comfort or relaxing moods, especially if compartments are well air-conditioned and therefore do not need "cooling off" by means of colour.

e. Because of their personal experiences with natures's own colour schemes, most individuals tend to associate various "artificial" colours with those experiences. Table III provides a fairly complete list of known colour-mood associations as well as food, odour and other psychological responses. Perhaps most important to shipboard colour scheme selection is avoidance of the traditional institutional grey and white. A variety of colours helps to liven the environment and provide relief from the boredom of neutral colours. Some generalizations are possible. For example, some hues, greens, blues and certain browns, are generally considered restful, and should therefore be used for such spaces as wardrooms, officers' cabins, etc. More saturated hues which tend to stimulate are recommended for working areas. Certain colours lend "warmth" to a room, whereas others create a feeling of "coolness". Reds, yellows, and browns are considered warm colours; blues and greens give the impression of coolness. Dark colours or saturated hues "protrude" and pale or desaturated colours "recede". This principle should be applied in areas where pipes, ventilation systems and other devices project into a room and tend to make it appear smaller than it really is. Paint these projections the same colour as the ceiling or bulkhead, preferably a very light shade to make them appear to recede into the ceiling or bulkhead.

TABLE III. Typical Colours and Their Effect on Humans

DESCRIPTION	RESPONSE
Pale Pink	Slightly warm feeling, pleasing when associated with odours
Pink	Warm, soft, pleasing when associated with odours and taste
Reddish Pink	Warm feeling, slightly stimulating, pleasing association with taste
Scarlet	Very warm feeling, stimulating and exciting
RED	Warm feeling, stimulating, generally exciting, but calm to the extent of indicating a protective quality, pleasing to the appetite, associated with danger
Reddish Orange	Warm, stimulating, exciting, cheerful, pleasing association with taste
ORANGE	Warm, stimulating exciting, cheerful, pleasing association with taste
Any of the above reflect light that is flattering to the skin and complexion thus making people appear healthy and normal (as opposed to cool colours which create an appearance of being pale). Scarlet through ORANGE colours advance slightly toward the observer.	
Yellowish-Orange	Warm, somewhat exciting, cheerful, express a feeling of comfort, associated with pleasing taste
YELLOW	Warm, somewhat exciting, cheerful, comfortable, associated with pleasing taste
Pale Yellow	Warm, cheerful, associated with pleasing odour and taste, softness and comfort
Greenish-Yellow	May be associated with feeling of slight warmth or coolness depending on other colours used; <u>not</u> associated with good taste

TABLE III. Typical Colours and Their Effect on Humans (CONTINUED)

Yellowish-Green	May be associated with feeling of slight warmth or coolness depending on other colours used; calming, somewhat neutral, may or may not be associated with good taste
GREEN	Generally cool, slightly cheerful, comfortable, calming, associated with pleasing refreshing odour
Bluish-Green	Cool, calming, associated with good taste
BLUE	Cool, comfort, protective, calming, although may be slightly depressing if other colours are dark, associated with bad taste
GREEN through BLUE will advance toward observer if dark shades are used	
Pale Blue	Cool, soft, calming, tends to neutralize if other colours are pale, reflected light makes skin appear pale
Lavender	Slightly cool, calming, soft, associated with pleasing odour, but with bad taste
Violet	Slightly warm, calming, associated with bad taste
Royal Blue	Rich, substantial, may be slightly depressing if used with other dark colours, associated with bad taste
Purple	Rich, protective, calming, may be depressing, associated with pleasing odour, but bad taste
Violet through Purple will advance toward observer, creates a feeling of heaviness	

TABLE III. Typical Colours and Their Effect on Humans (CONTINUED)

Hot Pink (a yellowish cast)	Very warm, stimulating, exciting, cheerful
Rose (a bluish cast in pink range)	Neutral relative to warmth, comfortable, calm, associated with pleasing odour
Fluorescent Orange	Warm, stimulating, exciting, cheerful, extremely conspicuous
Fluorescent Red	Warm, stimulating, exciting, cheerful, extremely conspicuous
Fluorescent Yellow	Warm, stimulating, slightly irritating but cheerful
Chartreuse	Slightly warm cheerful, associated with bad taste
Olive	Warm, comfortable, slightly depressing, associated with bad taste
Cream	Slightly warm, comfortable, clean, reflected light enhances skin tone
Buff	Warm, comfortable, calm, soft; good blend with other colours
Tan	Warm, very comfortable; good blend with other colours
Reddish-Brown	Warm, comfortable, cheerful, slightly stimulating, cheerful
Brown	Warm, comfortable, rich, substantial protective, may be slightly depressing
Fluorescent Orange and Red, Olive, Reddish-Brown and Browns advance toward Observer	
WHITE	Neutral, sterile, clean, fresh, stark crisp; may appear hard or soft depending on lighting colour; may appear harsh, glaring

TABLE III. Typical Colours and Their Effect on Humans (CONTINUED)

Off-White	Neutral, clean, fresh
Light Grey	Neutral, clean, fresh, calming, soft comfortable; critical that the tint is compatible with other colours (e.g. bluish, pinkish, yellowish, etc)
GREY	Neutral, comfortable calming, slightly hard; critical that the tint is compatible with other colours (e.g., bluish, pinkish, yellowish, etc.)
Dark Grey	Neutral, comfortable, may be depressing critical that the tint is compatible with other colours used (e.g., bluish, pinkish, yellowish, etc.); substantial heavy, advances toward the observer
Flat Black	Solid, heavy, comfortable, generally neutral, advances toward the observer, gives the impression of being dirty, vagueness, recedes
Deep Black	Protective, depressing, heavy, substantial advances toward observer in small amounts, but may recede in large amounts (e.g., painting a ceiling black)
Gold/Brass	Rich, comfortable, warm (tint important for compatibility with other colours); slightly advancing
Silver/Aluminum	Neutral, cold, hard, clean, stiff and uncomfortable, sterile, lifeless, recedes.
Light Wood Grain	Warm, comfortable, quiet.
Dark Wood Grain	Warm, comfortable, quiet, protective, slightly depressing.
Light Leather Grain	Warm, comfortable, cheerful, soft.
Dark Leather Grain	Warm, comfortable, protective, soft, slightly depressing, advancing.

4.6 COLOUR COMBINATIONS

a. Putting colours together is the thing people find most difficult about managing colour - perhaps because there are so many colours. Some hues and shades of colour seem to go together while others appear to clash. The more saturated the colours, the more the incompatibilities or "clashes" become apparent.

b. It is not desirable to use saturated hues of any colour family except for "accent". Thus a Blue Family probably would consist of lighter shades of blues, namely, medium to light blue for bulkhead plus an extremely pale blue or off-white for overhead, plus a medium blue for the deck. The bulkhead could be a pure blue or it would consist of a pure blue for the lower half of the wall with a slightly greenish blue for the upper half. The deck could then also have a slightly greenish cast created by green fibres woven into carpet or imbedded in a tile pattern. For accent colour in upholstery or drapes the complementary colours yellow and orange would be appropriate since they are opposite the blue-green.

c. In picking a basic colour scheme represented by several analogous hues, one should always pick a series of hues from only one side of a primary. Typical compatible colour families might be as follows:

(1) Blue Family:	Blue with Royal Blue, or Blue with Greenish Blue
(2) Brown Family:	Brown with Reddish-Brown, or Brown with Yellowish -Brown
(3) Yellow Family:	Yellow with Orangish-Yellow, or Yellow with Greenish-Yellow
(4) Red Family:	Red with Yellowish-Red, or Red with Purplish-Red

4.7. APPLICATION GUIDELINES

a. A proper combination of colour and light is necessary in order to see well. Lighter colours provide good seeing conditions without requiring high levels of illumination. When darker colours are used it is necessary to provide higher levels of illumination. Even distribution of illumination and reduction of shadow are primary objectives. These are accomplished by proper diffusion of the primary light sources, increase in secondary light reflection by use of lighter surface colours, and minimization of spectral reflection (glare) caused by glossy surfaces. Satisfactory colour selection can be made only if it is done under the proper illumination conditions. Colours selected under an incandescent light will not appear the same if they are inspected under a fluorescent luminaire. Appearance rating of colours under artificial light sources are shown in Table IV.

Colour	Standard Cool White	De Luxe Cool White	Standard Warm White	De Luxe Warm White	Incandescent Lamps
Red	dull	dull	fair	good	good
Brown	fair	good	good	fair	good
Yellow	fair	good	good	dull	fair
Green	good	good	fair	dull	dull
Blue	fair	dull	dull	dull	dull
Grey	good	fair	soft	soft	dull

TABLE IV. Rating of Colours

b. Although certain colour-mood objectives are quite clear, many compartments require the consideration of conflicting objectives. When conflicts appear, utilize colour schemes that are neutralizing as opposed to mixing to many colour elements to emphasize several specific moods. Table V provides a general guide for creating specific moods for typical living and work-space compartments. Since most shipboard compartments are of marginal size, use colours that make the space appear larger and, cause projecting structure and furnishings to recede into the background.

COMPARTMENT	DESIRED MOODS
BERTHING	Restful, comfortable, quiet, private secure. Use colours that will enhance appearance of skin, provide touch of cheerfulness and minimize institutional look.
SANITARY	Clean, sanitary, cheerful. Use colours that enhance appearance of skin, de-emphasize distasteful odours, effects of heat and humidity.
MESSING	Cheerful, comfortable, socially stimulating. Choose colours that enhance appearance of skin and food.
LOUNGE & RECREATION	Active Recreation: cheerful, bright, socially stimulating. Use colours that maximize visibility. Sedentary Activities: warm, cheerful, comfortable. Choose colours that stimulate medium level of sociability but do not emphasize confusion, or institutional look. Consider activity mix carefully and provide logical identifications of areas that have differing mood requirements, e.g. T.V., stero listening, games, casual reading.
MISCELLANEOUS AREAS	Barbershop: efficiency, cleanliness, visual performance effectiveness. Choose colours that enhance skin appearance and maximize visibility. Training Area: cheerfulness, alertness, motivation, efficiency. Choose colours that increase visual performance efficiency.

TABLE V. Suggested Mood Objectives for Standard Spaces

c. In addition to the requirement for good visibility necessary to inspect and remove dirt, soil, etc., consider the following:

(1) select paints that are easy to clean;

(2) select materials that are easy to clean;

(3) select paints and materials that resist damage;

(4) apply paints and materials in a manner that does not require extreme care or skill to refurbish, i.e., minimize the amount of masking before paint is applied, consider the ease of upholstery replacement, etc.;

(5) avoid the use of too many colours of paint, material or fabrics which increase logistic problems, require too many different cleaning materials or procedures, or require special tools to clean or refurbish compartments or components.

NOTE: Previous philosophies of using dark colours because they do not show dirt or soil are not necessarily valid. Dirt, soil, or damage should be sufficiently obvious that these needs are not overlooked. New paints and materials are available that have inherent resistance to discolouration or damage and that are easy to clean or replace; select these rather than destroy an otherwise effective colour scheme/material concept. However, be sure to use only NATO-approved materials. (See ANEP-24 GUIDELINES FOR SHIPBOARD HABITABILITY REQUIREMENTS FOR COMBATANT SURFACE SHIPS, Chapter 5). In selecting colours for interior finishes, it is important to preserve sufficient reflectance to maintain adequate light distribution throughout the space. Figure 2 shows the general surface reflectance values that should be maintained for overhead, bulkhead, deck and furnishings.

d. Specific guidelines for compartment/component colour selection are listed below:

(1) BULKHEADS:

a) A single-colour paint scheme should be used for most bulkhead treatments in order to provide a feeling of expanse. Use a light shade of the basic colour family that has been selected. The same colour and shade should be used on doors and door frames.

b) If pre-coloured bulkhead coverings are used in lieu of paint, they too should be of a single colour.

c) In larger compartments, one bulkhead may be of a slightly different shade of the basic colour family and/or woodgrain or other patterned panelling may be used to add interest to the visual environment. Avoid use of very dark woodgrain panels with light painted surface treatments.

(2) OVERHEADS:

a) Compartment overheads should be painted an off-white blended to match the basic colour family represented by bulkhead colour. If overheads are not sheathed over, all structural elements, piping, ceiling-mounted ducting, etc. should be painted the same colour as the basic overhead in order to camouflage such elements, i.e., make them less apparent.

(3) DECKS:

a) Deck colours should be a medium shade from the same colour family as used on the bulkheads

b) If tile is used, fine-grained patterns may be selected (avoid large, bizarre patterns, e.g., large high contrast checkerboard, stripes, etc., or dark to saturated solid colours).

c) If carpet is used, fine-grained patterns and/or solid colours should be selected (avoid large, prominent patterns).

d) If tile is used on one part of the compartment together with carpet on another part, make sure that the two are colour and pattern compatible, i.e., if a repeated geometric pattern is used on one, the other should consist of a random and much finer-grained patterns. Above all avoid deck covering patterns that appear "busy", e.g. that attract too much attention.

(4) BUILT-IN CABINETS:

a) Built-in cabinets should be treated with a colour or with a woodgrain of colour and shade that cause them to remain neutral or recede with respect to their appearing to reduce the size of the compartment space. The larger the visual area represented by cabinets the lighter the colour or shade should be.

b) The colour and shade of painted cabinets either should be the same as bulkheads or slightly darker, but compatible with basic bulkhead colour family characteristics.

(5) FURNISHINGS:

a) The basic structure of furniture should be of the same or similar colour and shade as any cabinetry within the compartment. Desk tops should be of a light shade in order to minimize the brightness contrast between the top and any printed or writing material that may be used on them.

b) A single colour scheme may be used with compartments having woodgrain finish on a bulkhead or on built-in cabinets. Woodgrain furniture should match and/or blend with bulkhead or cabinet woodgrain (avoid use of two or more highly textured grains).

c) Furniture upholstery may be of an analogous colour whose hue and shade are compatible with the basic colour family chosen (the upholstery may be either lighter or darker than the bulkhead colour/shade, or the upholstery may be of a contrasting complementary colour/shade to provide accent to the general decor, either solid or patterned colours may be used. Small, fine grained patterns should be selected as opposed to large, bizarre patterns with highly saturated hues. If solid colours are selected, no more than two different colours should be used within the same compartment.

(6) ACCESSORIES:

a) Curtains or drapes may be either of a solid colour or a patterned design. In the latter case, the pattern should be small and fine-grained (avoid use of large, exotic patterns).

b) The colour and shade of curtains or drapes may be selected from an analogous or complementary hue. If the curtains or drapes occupy a large visual area, analogous colour/shade selections are desirable. If the visual area covered is small, complementary colours may be used to provide accent and visual interest.

c) Other accessory items such as ash trays, table lamps, waste baskets, etc. should possess colours that are compatible with the basic colour family chosen. Ash trays and lamps are of interest and may be of a complementary colour while the waste basket, being of less interest, should be of an analogous colour and/or of the same woodgrain as any other woodgrain selected for the compartment.

d) When metal is used for sheathing trim, for cabinet handles, etc., the colour of the metal should be compatible with the basic colour family, i.e., brass or gold with warm colours, aluminum or silver with cooler colours. Highly polished metal trim should be avoided, i.e., use antiqued or satin finish. Large amounts of metal surface or trim should not be used in any compartment since it tends to create an institutional appearance. Exceptions include serving tables in the messing area, shelving and dispensers in the sanitary spaces.

4.8 REFERENCES

1. Optical society of America, Report on Colorimetry. The Science Book of Color. New York; Crowell 1953.

2. Munsell, A.H. Munsell Book of Color. Baltimore, Md: Munsell Color Company, Inc., 1929.

3. International Commission on Illumination, Report of the Commission. Commission Internationale de l'Eclairage. Publication C.I.E. No. 13.2, Paris: Bureau de la C.I.E., 1974.

4. International Commission on Illumination, "Colorimetry". Commission Internationale de l'Eclairage. Publication C.I.E. No. 15, Paris: Bureau de la C.I.E., 1971.

5. International Organization for Standardization (ISO). "Colours of signal lights on board ships", ISO 2412-1992.

6. International Organization for Standardization (ISO). "Safety Colours". ISO/R 408-1964.

7. International Organization for Standardization (ISO). "Identification colours for pipes conveying fluids in liquid or gaseous condition in land installations and on board ships". ISO/R 508-1966.

8. Jacobson, Egbert. Color Harmony Manual. Chicago: Container Corp of America, 1978. (Discussion of the practices of Wilhelm Ostwald).

9. Maerz, Aloys John. Dictionary of color. New York: McGraw-Hill, 1950.

*10. National Bureau of Standards. A Universal Color Language. By Kenneth Kelly and Deane Judd, Washington DC: U.S. Govt Printing Office, 1976.

*11. National Bureau of Standards. Dictionary of Names. By Kenneth Kelly, Washington DC: U.S. Govt Printing Office, 1976.

12. U.S. Maritime Administration. Section 25, Standard Specification for Merchant Ship Construction. PB-290-400 Washington DC.

13. U.S. Maritime Administration, Office of Ship Construction. Officer and Crew Standard Furniture Feb. 1981. Washington DC, 1981.

14. U.S. Navy. Shipboard Color Co-ordination Guidance Manual. NAVSEA 0929-002-7010.

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* Originally two publications, have since been combined to form: National Bureau of Standards. Universal Color Language and Dictionary of Names. NBS special publication #440, Washington DC: U.S. Govt Printing Office, 1976.

CHAPTER 5 - STANDARD OF ILLUMINATION

CONTENTS PAGE NO.

5.1 **AIM**

a. The aim of this chapter is to establish a Standard of Illumination for NATO Naval Surface Ships setting forth illumination standards in various compartments.

b. The CIC is excluded from this guideline, because here the lighting is strongly dependent on the physical characteristics of the displays.

5.2 **GENERAL**

a. The purpose of the lighting installations on board is to:

(1) Provide conditions for optimum visual performance, particularly in the sphere of work;

(2) Facilitate work in order to achieve optimum performance;

(3) Aid the avoidance of lapses in performance;

(4) Contribute to the prevention of accidents;

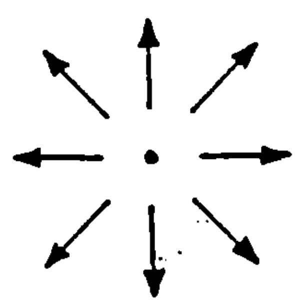
(5) Increase the safety of the ship;

(6) Sustain and promote the general well-being of all those on board, both in their work and their recreation.

5.3 **DEFINITIONS**

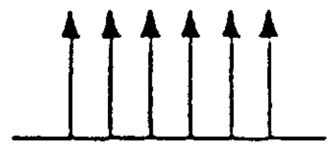
a. The following definitions apply:

(1) Luminous flux (Φ) (unit:lm)
The light emitted by a source, or received by a surface. The quantity is derived from radiant flux by evaluating the radiation in accordance with the spectral sensitivity of the standard human eye as described by the CIE Standard Photometric Observer.



(2) Luminous intensity (I) (unit: cd)
A quantity which describes the power of a source or illuminated surface to emit light in a given direction. It is the luminous flux emitted in a very narrow cone containing the given direction divided by the solid angle of the cone: the result is expressed in candelas.

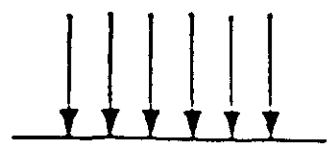
(3) Luminance (L) (unit: cd/m^2)
The physical measure of the stimulus which produces the sensation of brightness measured by the luminous intensity of the light emitted or reflected in a given direction from a surface element, divided by the area of the element in the same direction. The SI unit of luminance is the candela per square metre, the relationship between luminance and illuminance is given by the equation



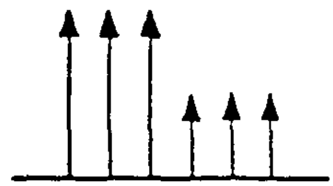
$$\text{Luminance} = \frac{\text{Illuminance x reflectance}}{\pi}$$

This equation applies to a matt surface.

(4) Illuminance (at a point of a surface) (E) (unit: lm/m^2, lux)
Quotient of the luminous flux incident on an element of the surface containing the point, and the area of that element.



(5) Contrast (C)
A term that is used subjectively and objectively. Subjectively, it describes the difference in appearance of two parts of a visual field seen simultaneously or successively. The difference may be one of brightness or colour or both. Objectively, the term expresses the luminance difference between the two parts of the field. The relationships used are:



$$\text{contrast} = \left| \frac{L - L_1}{L_1} \right| \qquad (1)$$

Quantitatively, the sign of the contrast is ignored. L_1 is the dominate of background luminance. L is the task luminance.

$$\text{contrast} = \frac{L}{L_1} \text{ if } L > L_1 \text{ or } \frac{L_1}{L} \text{ if } L < L_1 \qquad (2)$$

In this document relationship (2), better known as luminance ratio, is used.

(6) Reflectance (R)
The ratio of the luminous flux reflected from a surface to the luminous flux incident on it. Except for matt surfaces, reflectance depends on how the surface is illuminated but especially on the direction of the incident light and its spectral distribution. The value is always less than unity and is expressed as either a decimal or as a percentage.

(7) Diffuse reflection
Reflection in which the reflected light is diffused and there is no significant specular reflection, as from a matt paint.

(8) Specular reflection
Reflection without diffusion in accordance with the laws of optical reflection as in a mirror.

(9) Apparent colour
Of a light source; the degree of warmth associated with the source colour. Lamps of low colour temperatures are usually described as having a warm apparent colour, and lamps of high colour temperature as having a cold apparent colour.

(10) Colour temperature (CT) (unit: K)
A measure of the apparent colour of a light source.

CT ≤ 3300 K	warm
3300 K < CT ≤ 5300 K	neutral
5300 K < CT	cold

(11) Colour rendering
A general expression for the appearance of surface colours when illuminated by light from a given source. "Good colour rendering" implies similarity of appearance to that under an acceptable light source, such as daylight.

(12) Colour rendering index (Ra)
A measure of the degree to which the colours of surfaces illuminated by a given light source are rendered accurately. This index is based on the accuracy with which a set of test colours are reproduced by the light source of interest relative to how they are reproduced by an appropriate standard light source. Perfect agreement is given a value of 100.

(13) Glare
The discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the general surroundings.

(14) Discomfort glare
Glare which causes visual discomfort.

(15) Contrast rendering factor(CRF)
The ratio of the contrast of a task under a given lighting installation to its contrast under reference lighting conditions, that is perfectly diffuse and unpolarised lighting.

(16) Visual task
The visual element of the work being done.

(17) Working plane
The plane at which work is usually done. In general, it is assumed to be a horizonal plane limited by the bulkheads of the interior at a height above the deck of 0.90m for standing workers and of 0.75m for those who are seated.

(18) Reference surface (plane of interest)
The reference surface will usually be the working plane. However, the reference surface can be limited to the area(s) of the working zone(s) or to the task area(s) when the task locations are known and clearly specified. When the task is not in a horizontal plane or in a different height, the reference surface has to be determined accordingly, at a specific angle or height, e.g. vertical front panels in machinery control rooms.

(19) Service illuminance (E)
The illuminance used in the lighting specifications of this document. The service illuminance is the mean illuminance throughout the maintenance cycle of the installation and averaged over the reference surface.

(20) Mean illuminance ($\bar{E}$)
The quotient of the luminous flux received by a surface and the area of that surface. The mean illuminance can be approximated by the arithmic mean of the illuminances in a number of points on the surface.

(21) Uniformity ratio (UR)
In working and living areas: the ratio of the minimum illuminance to the average illuminance. The ratio applies to values on the reference surface.

$$UR_1 = E_{min} / \bar{E}$$

In passageways the ratio of the minimum illuminance to the maximum illuminance. The ratio applies to values on the plane at 0.2m above the deck.

$$UR_2 = E_{min} / E_{max}$$

(22) Maintenance factor (MF)/Light loss factor (LLF)
The ratio of illuminance provided by an installation in the average condition of dirtiness expected in service, to the illuminance from the same installation when new. The maintenance factor is always less than unity.

(23) General lighting
Lighting designed to illuminate the whole of the reference surface without provision for special local requirements.

(24) General surround lighting
Lighting designed to illuminate the non-working parts of a working interior.

(25) Local lighting
Lighting designed to illuminate a particular small area of the reference surface which usually does not extend far beyond the visual task, e.g. a desk light.

(26) Back-up lighting
(emergency lighting, substitute lighting, auxiliary lighting). Lighting provided for use when the main lighting installation fails in areas in which illumination is needed. The electrical power for back-up lighting may be provided through a secondary power supply system or by batteries. Provisions for immediate activation on failure of the main system have to be made.

(27) Orientation lighting
Lighting provided to ensure that one can find his way and perceive other persons in the almost dark.

(28) Red lighting
Lighting designed to minimize interference with vision in dark-adapted conditions. Wavelengths between 625 - 635 nm dominate while wavelengths smaller than 600 nm must be excluded from the light emitted by the source. Applicable with darkened ship operation and in berthing areas for safety and sleeping comfort.

(29) White lighting
In some cases locally white lighting at low intensity from fluorescent (filtered: blue excluded) or incandescent (dimmed) lamps may be applied if colour perception is important and interference with dark adaptation must be minimized.

(30) Darkened ship
The ship's material conditions established to ensure light security. These conditions are operated by providing light traps, door operated switches, darkened ship control circuits, and material classifications assigned to certain doors and hatches.

(31) Adaptation
The process which takes place as the visual system adjusts itself to the brightness or the colour of the visual field. The term is also used, usually qualified, to denote the final state of this process. For example "dark adaptation" denotes the state of the visual system when it has become adapted to a very low luminance (below some hundreds of a candela per square meter). "Light adaptation" refers to luminances of at least several candelas per square meter.

(32) Luminaire
An apparatus which controls the distribution and if necessary the spectral properties of light given by a lamp or lamps and which includes all the components necessary for fixing and protecting the lamps and for connecting them to the supply circuit.

5.4 SCOPE

a. This document covers general requirements for the lighting on NATO surface naval ships. Specially discussed are:

(1) Visual requirements;
(2) Lighting criteria;
(3) Measurement;
(4) Recommendations (or standards);
(5) Lighting systems;
(6) Additional considerations on visibility and well-being;
(7) Tables of service illuminances.

5.5 VISUAL REQUIREMENTS

a. The visual requirements for a given compartment are dependent on the types of operation to be performed in that compartment. Especially on ships it may occur that different operations must be performed in the same space simultaneously by different persons or subsequently or intermittently by one person. These circumstances can result in conflicting visual requirements. Careful analysis of these requirements is needed in order to find the best possible compromise.

b. The lighting benefits mentioned in sub-paragraphs 5.2.a.(1),(2),(3) and (6) will only be obtained if additional considerations concerning visibility and well-being are met. These two issues therefore will be considered in some detail in paragraph 5.10.

5.6 LIGHTING CRITERIA

a. Important criteria for lighting are:

(1) Illuminance;
(2) Luminance ratios in the visual field;
(3) Limitation of direct and indirect glare;
(4) Apparent colour and colour rendering index of the light source.

b. Detailed information on these criteria is given in paragraph 5.8.

5.7 MEASUREMENT

a. Instrument:

(1) Most field measurements of lighting are undertaken with a illuminance meter.

(2) A good illuminance meter shall be colour and cosine corrected, shall be linear in response and insensitive to ambient temperature variations. It must meet the specifications of CIE 18.2.

(3) Therefore:

(i) The spectral response of the photocell must be corrected to that of the human photopic visual system. When filters are used the instrument is described as colour corrected, or $V(\lambda)$ corrected.

(ii) The response of the illuminance meter to light incident at an angle φ from the normal n must follow the equation $E - E_n.\cos\varphi$. Most illuminance meters are cosine corrected by means of transparent hemispheres or diffusing covers.

(iii) Errors of measurement of ±5% are permitted.

(4) Since the sensitivity of illuminance meters varies with time, the meters should be recelebrated at least once a year.

b. Method:

(1) Field measurements are undertaken to establish whether:

(i) a new installation has achieved the design specifications;

(ii) an installation (still) meets a desired criterion.

(2) For both reasons it is usually sufficient to measure the illuminances.

(i) Measurements of the mean illuminance $\bar{E}$ have to be taken at the pertinent reference surface. For general lighting in rooms, spaces and passageways measuring positions usually are at a height above the deck of 0.85 m (according to CIE) or as specified in national regulations, e.g. U.S. 0.76 m. Measuring positions have to be distributed uniformly across the room, e.g. by applying a grid net with edge lengths of 1...2 m and measuring positions in the centres. From the measurements of all the room's measuring positions that mean value is computed, which approximates the mean illuminance $\bar{E}$. If the reference surface comprises a small area, e.g. a desk, a panel, etc., the edge lengths of the grid shall be determined accordingly.

(ii) Measurements on the weatherdeck have to be taken in centreline of passageways at a height above the deck of 0.20 m at each luminaire position projected on this line and between each two luminaire positions.

c. Conditions:

(1) Before starting measurements it is necessary to:

(i) Stabilise the performance of the lamps and luminaires. Installations using discharge lamps, including fluorescent, should be lit for at least 20 minutes. Installations using incandescent lamps for at least 10 minutes. New installations have first to be operated for an appropriate time at the design supply voltage. For discharge lamps this time is 100 hours, for incandescent lamps 10 hours will be sufficient.

(ii) Exclude daylight from the interior when measurements of the electric lighting installation alone are required.

(2) The measurements have to be taken under the following conditions:

(i) Design supply voltage;
(ii) Normal ambient temperatures at measuring locations.

d. Record:

(1) It is essential to keep a complete and accurate record of the circumstances at the time the measurements are made. The record should contain:

(i) Description of the illuminance meter used;
(ii) Lamp type;
(iii) Level and stability of the supply voltage;
(iv) Luminaire type and lay-out;
(v) Conditions as specified in Para 5.7.c.;
(vi) Points of measurement (reference surface, position).

5.8 RECOMMENDATIONS

a. Illuminance:

(1) Table I gives the range of recommended service illuminances for different applications of lighting. Tables II and III (5.11) provide more detailed recommendations.

TABLE I

Ranges of recommended service illuminances for different applications of lighting

RANGE OF RECOMMENDED SERVICE ILLUMINANCES (lx)	APPLICATION
10 - 200	Lighting for orientation. Applicable in areas where the visual task is not critical and mostly confined to movement. In general it is needed to add locally normal lighting for reading printed matter or tasks with comparable details and contrasts.
200 - 800	Normal lighting. Most visual tasks can be carried out in this range of illuminances, in which performance is only slightly affected by the illuminance.
800 - 3000	Special Lighting. This lighting is sometimes wished locally for special situations. These situations arise with: weak contrasts with small reflection factors, very accurate colour judgement, avoidance or stimulation of effects of of gloss or shadow. Not rarely these illuminances can be avoided by taking other (ergonomic) measures.

The lower values of the ranges represent the minimum requirements, the higher values the optimum requirements. The latter should always be the target values.

(2) For the design of the lighting installation the appropriate service illuminance has to be multiplied by a design factor of at least 1.25 to take into account ageing and pollution. The design factor is defined as the reciprocal of the maintenance factor MF (5.8.a.(6)).

(3) The mean illuminance may never, not even at the end of the maintenance cycle, be less than 0.8 time the service illuminance. The illuminance on the place on which the visual task is carried out may never be less than 0.6 time the service illuminance. This factor is defined as the maintenance factor MF (5.8.a.(6)) multiplied by the uniformity ratio UR (5.8.a.(5)).

(4) Uniformity of illuminance:

(i) For the reference surface uniformity of illuminance is important. Sudden changes of illuminance in this region are likely to cause distraction and dissatisfaction and may affect task performance.

(ii) The following uniformity ratios (UR) apply:

1) for all spaces including living, recreational and sanitary spaces:- $UR_1 \geq 0.4$

2) for desks and vertical front panels in machinery control rooms:- $UR_1 \geq 0.7$

3) for passageways:- $UR_2 \geq 0.1$

(iii) It should be noted that, in particular in living and recreational spaces, it may be neither necessary nor desirable for illuminance to be uniform throughout the whole interior. Therefore it may be appropriate to divide large spaces into different illuminance zones taking into account the various tasks/activities to be fulfilled in these zones. The mean illuminances in adjacent rooms should not vary from each other by a ratio exceeding 5.

(5) Maintenance:

(i) The illuminance levels resulting from a lighting installation decreases during use due to the fall in lamp lumen output and accumulation of dirt on lamps, luminaires and room surfaces.

(ii) The design of a lighting installation must make allowance for this by initially providing an illuminance which is higher than recommended. This is done by including a suitable maintenance factor in the lighting calculations. The magnitude of this factor depends on:

1) Dirtiness of the conditions;
2) Maintenance schedule (renewal lamps, cleaning luminaires and room surfaces);
3) Type of luminaire (open or closed).

(iii) The maintenance factor (MF) shall preferably not be less than 0.8.

b. Luminance ratios in the visual field:

(1) Luminance ratios in the visual field of the working person should not be too high. The luminance ratio between the area of the visual task and other areas should not exceed the ratio of 10. Above this ratios may work obtrusive or cause distraction and may affect task performance. Between the area of the visual task and its immediate surround a ratio of 3 is generally preferred.

(2) Because of the relationship between illuminances and reflection characteristics of (matt) surfaces in causing luminances some design recommendations on (diffuse) reflectances can be given:

(i) Working planes	0.2 ..... 0.5
(ii) Ceilings	0.7
(iii) Bulkheads	0.5
(iv) Decks	0.2

c. Limitation of indirect and direct glare:

(1) Limitation of indirect glare (veiling reflections):

(i) Contrast in the visual task can be reduced by veiling reflections. This occurs when a high luminance is reflected by the task towards the worker's eye and thus veils, or interferes with the perception of the visual task.

(ii) In particular, reflections of light sources (luminaires, windows) in specular or semi-specular visual tasks (printed matter, vdu-screens, glass panels) can result in substantial losses of contrast.

(iii) The most effective method of dealing with indirect glare is to locate the worker or the light source in such a way that reflections of the latter are directed away instead of into the worker's eye. If this is not possible the luminance of the light sources must be reduced. A complementary way is to reduce the glossiness of the materials used.

(2) Limitation of direct glare (discomfort):

(i) Glare is experienced if the luminance of luminaires or windows is excessive compared with the general brightness in the interior. In interiors discomfort glare is likely to be more a problem than disability glare.

(ii) The discomfort is greater the higher the luminance of the sources, the greater the solid angle they subtend, and the greater their number within the visual field. It is lower the greater the angle formed by the direction of the source and the visual axis, and the higher the luminance of the background.

(iii) Discomfort glare must be limited through restriction of the parameters mentioned. This means among others that luminaires of which the lamp is not directly or indirectly (that is reflected from specular luminaire surfaces) visible should be used.

d. Apparent colour and colour rendering index of the light Source:

(1) The choice of an appropriate apparent colour of light source for a compartment is determined by the function of the compartment.

(i) For working interiors in general a neutral white light source colour should be used; colour temperature $3300\ K \le CT \le 5300\ K$.

(ii) For recreational interiors in general a warm light source colour should be used; colour temperature $CT \le 3300\ K$.

(iii) For special applications, such as on the bridge during the night, light with a specific spectral composition should be used.

(2) Five colour rendering groups are distinguished:

Group 1 with colour rendering index
$Ra \ge 90$ = good;

Group 2 with colour rendering index
$90 > Ra \ge 80$ = sufficient;

Group 3 with colour rendering index
$80 > Ra \ge 60$ = doubtful or moderate;

Group 4 with colour rendering index
$60 > Ra \ge 40$ = poor;

Group 5 with colour rendering index
$40 > Ra \ge 20$ = very poor.

(3) For tasks involving accurate colour judgement light of colour rendering group 1 should be used. For recreational interiors and in general for working interiors light of colour rendering group 1 or 2 should be used. For work indoors where colour rendering is of no importance, light of colour rendering group 3 may be used. For lighting applications where safety or security are the major requirements, light of colour rendering group 4 or 5 may be used, provided that safety colours can be perceived.

5.9 LIGHTING SYSTEMS

a. Ship service lighting system:

(1) A ship service lighting system should be installed. This system should meet the requirements as specified in this document.

(2) The system includes luminaires which should meet the CIE and CEE specifications as applicable for the circumstances under which they will be used.

(3) The system includes the installation of luminaires which are permanently installed and the assembling of luminaires, cables and plugs for portable luminaires.

(4) The system includes the wiring, outlet boxes and sockets.

b. Lighting, dark adaptation:

(1) Adaptation to low luminances (dark adaptation) requires more time than the adjustment of the visual system to relatively high luminances.

(2) The greater the luminance ratio's the longer the time required. On transition from daylight to a very dark environment for example, some initial adaptation occurs very quickly during the first five minutes, after which the rate of further adaptation greatly decreases. Complete adaptation may only be reached after an hour, 90% being obtained in about 30 minutes.

(3) Dark adaptation is disturbed when the eye is exposed to higher luminances. Red lighting reduces this interference to dark adapted vision. Where high demands on night vision exist, as on the bridge and rooms, passageways directly adjacent to the bridge, red lighting at low intensity is preferred.

(4) Some national regulations require also red lighting in mess decks, wash rooms, heads, passageways, hangars and special compartments to facilitate safe and rapid movement of personnel while maintaining night vision.

(5) Red lighting disturbs colour perception and supports long sightedness. That is why another additional lighting is used when perception of colour is important, providing locally a fluorescent (filtered: blue excluded) or incandescent (dimmed) white light at very low level in order to limit the disturbance of dark adaptation.

c. Back-up lighting (emergency lighting, substitute lighting, auxiliary lighting):

(1) Back-up lighting should be provided in areas in which illumination is critical for personnel escape, or in which uninterrupted illumination is critical.

(2) It should be provided through a secondary power supply system which is independent of the main power system (e.g. auxiliary power supply, batteries). It should be secured that the back-up lighting is available immediately after loss of vital lighting.

(3) The level of illumination should be sufficient to direct the immediate task. Illumination for perceiving detail should be provided in engine starting areas, in hangars, on catwalks, in machinery spaces, on faces of machinery control and switchboards or consoles and on operating tables. In addition to the second lighting, portable rechargeable battery lights, hat lights and flashlights which give sufficient illumination for damage control operations should be provided.

5.10 ADDITIONAL CONSIDERATIONS ON VISIBILITY AND WELL-BEING

a. Visibility:

(1) The visibility of an object is a measure of the ease, speed and accuracy with which the object can be detected or recognized visually.

(2) Visibility is dependent on many factors of which the most important are:

(i) The apparent size of the critical detail.
The apparent size of a detail is usually expressed in minutes of arc of the angle subtended by the detail at the observer's eye. The critical detail of the object is the detail with the lowest visibility that must be seen in order to detect and recognize the object visually. The smaller the apparent size the more it is determinative for visibility. The visibility of a detail of 2 minutes of arc and a good contrast with its background can be perceived by almost all men. In general a detail of 1 minute of arc is the smallest that can be perceived.

(ii) The luminance contrast in the visual task.
For the luminance contrast in the visual task the ratio of the luminance of the detail to the background luminance is used. The smaller the luminance contrast the more it is determinative for visibility. Luminance contrasts should range between 3 and 10.

(iii) The adaptation luminance.
The adaptation luminance is a measure for the state of the visual system when it has become adapted. For central vision it is the average luminance of the central part of the visual field. As adaptation luminance increases from very low level up to about 30 cd/m^2 there is a steady improvement in the detail and threshold contrast that can be resolved, the colour discrimination that is possible and other visual capabilities. Above 30 cd/m^2 no further improvement of practical importance can be expected. Changes in the adaptation luminance can occur for instance when an observer is moving from one place to another or when he is changing his viewing direction or when the lighting is switched on or off.

(iv) The available observation time.
The smaller (< 1 sec) the available observation time the more it is determinative for visibility.

(v) Colours and colour contrasts.
In general only luminance contrasts contribute to visibility. Colour contrasts alone have approximately 5 times poorer visibility.

(vi) Location of the object in the visual field.
The further the critical detail is seated away from the line of sight the lower will be its visibility.

(vii) The amount of information to be processed.
The smaller the amount of information to be processed the easier and the faster the process of detection or recognition will be terminated and consequently the greater will be the visibility. For instance when the detail to be seen is one surrounded by many others, especially when these are similar ones, visibility is less than when it would be surrounded by a uniform field. When the location of the detail to be seen in the visual field is unknown its visibility is less than when the location of its appearance is known. When a person has built up great experience in perception of a specific detail his level of visibility will be greater than that of an unexperienced person.

b. General well-being:

(1) Just like other factors of man's environment such as temperature, sound, moisture, etc. light affects general well-being. For example: lamps of high colour temperature produce light that is associated with a cool climate, lamps of low colour temperature cause impressions of warmth and relaxation.

(2) Another aspect of the luminous environment that may affect general well-being is the luminance contrasts in the compartment. If these are too small, a feeling of dullness may result due to lack of stimulation, which might affect performance adversely after some time. If on the other hand the luminance

ratios are too great, adaptation of the visual system will be adversely affected leading to undue fatigue, decreasing task visibility or causing a feeling of discomfort.

(3) The last aspect of the luminous environment that will be considered here is the colour rendering of surface colours. Depending on the spectral properties of the source of illumination the colours of people, objects and room surfaces will appear more or less distorted. The colour rendering index of a light source is used as a measure for the degree to which colours when illuminated by that source appear accurately. When the colour rendering especially of the human skin and of organic products is poor, people will in general be dissatisfied.

5.11 TABLES OF SERVICE ILLUMINANCES

TABLE II

Recommended service illuminances (E) for different visual task characteristics

APPLICATION OF LIGHTING	CLASS	CHARACTERISTICS OF THE VISUAL TASK	E (lx)
Lighting for Orientation	1.	Visual tasks confined to movement and casual seeing calling for only limited perception of big objects.	10 - 100
	2.	Visual tasks especially confined to movement, requiring some perception of (very large) detail and recognition of persons.	100 - 200
Normal Lighting	3.	Reading and writing and visual tasks with comparable details and contrasts.	200 - 400
	4.	Perception of smaller details and lower contrasts as with 3.	400 - 800
Special Lighting	5.	Perception of low contrast on dark background; also accurate colour judgement.	800 -1600
	6.	Perception at the limit of vision.	1600-3000

The lower values of the ranges represent the minimum requirements, the higher values the optimum requirements. The latter should always be the target values.

TABLE III

Compartment illumination requirements (service illuminances)
(See also Tables I and II)

GENERAL LIGHTING RECOMMENDATIONS		LOCAL LIGHTING RECOMMENDATIONS	
FUNCTIONAL GROUP	CLASS	EQUIPMENT OR FURNITURE	CLASS
hangar and air control and associated spaces, except:	2		
flight deck crew shelter	1		
flight crew ready room	1	status board	2
living and recreation spaces, except:	2		
staterooms	1	berths (reading)	3
berthing areas	1	mirror, toilet cases	2
recreation areas	2	reading and writing areas	3
library without local lighting	3	secretary-bureau	3
library with local lighting	2		
commissary and messing spaces	2	food preparation counter	3
		range tops	2
		serving lines	2
damage control spaces, except:	2	diagram boards	3
		diagram with lamps	2
repair stations	1		
unit patrol stations	1		
foam injection station	1		
electronics spaces	1	desk, radio receiver	2
machinery spaces	1	gage and control boards	2
		switchboards (except weapons control)	2
		log desk	2
		switchboards, weapons control	2
		enclosed operation station	2
		machine tools (rough task)	2

TABLE III

Compartment illumination requirements (service illuminances)(continued)

GENERAL LIGHTING RECOMMENDATIONS		LOCAL LIGHTING RECOMMENDATIONS	
FUNCTIONAL GROUP	CLASS	EQUIPMENT OR FURNITURE	CLASS
ordnance spaces (enclosed)		Control rooms	2
and weapons	1		
control spaces	1	panels and instruments	
gunnery spaces ammunition		(bulkhead mounted)	2
handling spaces, and		computers (requiring	
magazines	1	illumination)	2
		range keepers	2
		stable elements	2
flag spaces (except galley)	1		
medical and dental spaces,			
except:	2	dental bracket table	3
laboratories	3	dental operating chair	
medical treatment room	3	(dental vision)	5
surgical dressing room	2	dental prosthetic	
pharmacy	4	laboratory unit	5
X-ray viewing and examining		dental instrument	
room (dental)	2	cabinet	3
battle dressing stations	2	medical training room	
		and technical	
		professional library	
		(reading position)	3
		operating table	6
offices	2	desks	3
		tables	3
		desk, typewriter	3
		teletypewriters	3

TABLE III

Compartment illumination requirements (service illuminances)(continued)

GENERAL LIGHTING RECOMMENDATIONS		LOCAL LIGHTING RECOMMENDATIONS	
FUNCTIONAL GROUP	CLASS	EQUIPMENT OR FURNITURE	CLASS
for in-port use only other ship control and weapons control spaces except CIC (for example: enclosed lookout stations, secondary conning station, pilot house)	1	chart table	3
workshops	2	workbench, general workbench, fine work, such as instrument and typewriter repair, etc machine tools	3 4 3
store rooms dental store rooms issue rooms	1 1 1	issue counters bins and drawer areas	1 2
utility spaces	1	sewing machines barber shop chair iron board and press	3 2 2
sanitary spaces, except shower areas	1 1	mirror areas	1
moving stairways, passage-ways, companionways, ladders and vestibules scuttles, hoists, unattended equipment spaces, unassigned spaces, reserved spaces, and cargo spaces passageways (used as medical waiting rooms) photographic spaces	1 1 2 2	bulletin boards elevator controls sink (photographic)	1 1 1

5.12 RELATED DOCUMENTS

1.	ANEP-24	Guidelines for Shipboard Habitability Requirements for Combatant Surface Ships
2.	ANEP-25	Guidelines for Environmental Factors in NATO Surface Ships (Chapter 4 - Colour Selection).

5.13 REFERENCES

1. "Bauvorschrift für Schiffe des Bundeswehr"(BV), Heft 35, "Lighting Equipment", dated 2/82.

2. BBC Pre-stage Units and Circuits for Low Voltage Discharging Lamps, C.H. Sturm, Giradet, Essen, 4.Edition.

3. "Electrical Generation and Distribution Systems", Part 10 "Lighting", dated 6/76, of the Royal Norwegian Navy (RNON).

4. Guide on Interior Lighting, second edition, Publication CIE No. 29(2), 1986, Vienna.

5. CIBS code for Interior Lighting, 1984, Chartered Institution of Building Services, London.

6. IES Lighting Handbook, 1981, Illuminating Engineering Society of North America, New York.

7. International Lighting Vocabulary, 4th Edition, Publ. CIE no. 17.4, 1987, Vienna.

8. Principles of visual ergonomics to be applied to the lighting of work systems draft by ISO/TC159/SC5/WG2.

9. "Supervision of Lighting Systems", Norwegian Working Paper AC/141(IEG/6)SG/4, prepared by: Norway.