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MILITARY STANDARD

ENVIRONMENTS, WORKING, MINIMUM STANDARDS FOR

FSC MISC

DEPARTMENT OF DEFENSE
Washington, DC 20301

Environments, Working, Minimum Standards for

MIL-STD- 1695(AS)

1. This Military Standard is approved for use by the Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this standard should be addressed to the Naval Air Systems Command by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this standard, or by letter.

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FOREWORD

This standard has been prepared to define minimum standards for working environments for a broad range of hardware procurement, and is suitable for citation in request for proposals, invitation for bids, contracts and purchase orders, or governing specifications. The requirements contained herein are appropriate for all levels of procurement from a supplier (see 3.6). These provisions may be contractually modified as appropriate for specific types of hardware, or as appropriate to the hardware life cycle phase, after suitable coordination with the activity responsible for the technical requirements.

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1. SCOPE

1.1 Purpose. This standard defines the minimum standards for working environments applicable to suppliers of military hardware. The provisions of this standard are to be set forth in each procurement, either in total or in part, as appropriate to the hardware end item to be delivered and to the phase of the system acquisition cycle.

1.2 Source. Source data, supporting information, and the derivation of the individual standards are included as Appendix A in this standard.

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on the date of invitation for bids or request for proposal form a part of this standard to the extent specified herein.

STANDARDS

Federal

Fed-Std-209 - Clean Room and Work Station Requirements, Controlled Environment.

Military

MIL-STD-1313 - Microelectronic Terms and Definitions.

PUBLICATIONS

Department of Defense

DoD 4145.26M - DoD Contractors' Safety Manual for Ammunition, Explosives, and Related Dangerous Material.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

American Society of Heating, Refrigeration and Air-Conditioning Engineers, Incorporated (ASHRAE)

ASHRAE 52-76 - Method of Testing Air Cleaning Devices used in General Ventilation for Removing Particulate Matter.

(Application for copies should be addressed to the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Incorporated, 345 East 47th Street, New York, NY 10017.)

American National Standards Institute (ANSI)

ANSI S1.4-1971 - Specification for Sound Level Meters.

(Application for copies should be addressed to the American National Standards Institute, Incorporated, 1430 Broadway, New York, NY 10018.)

Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.

3. DEFINITIONS

3.1 General. For the purposes of this standard, definitions shall be in accordance with the notes to Table I and as defined herein.

3.2 Working environment. The term working environment refers to those environmental factors which may affect the operator's performance or quality of work, or may affect the quality characteristics of the work in process. Those factors include: cleanliness, lighting, air temperature, relative humidity, dust control, ventilation or exhaust, noise, and habitat.

3.3 Audit. An audit is a scheduled periodic inspection or evaluation to verify conformance to specified criteria.

3.4 Work station. A work station encompasses the specific area used to perform work. A work station, as an example, includes bench tops, bench mounted material and equipment shelves, drawers for tool storage, and all areas within reach of the operator. The definition of work station specifically excludes drawers and shelves designated for storage of personal material (lunch bags, purses, etc.).

3.5 Work area. A work area consists of a room or designated and segregated portion thereof which contains one or more work stations.

3.6 Supplier. A supplier is any private company or Government activity supplying systems, subsystems, components, or assemblies under contract or purchase order to any other company or Government activity for eventual inclusion as a part of an end item or system for delivery to the Government under a contract.

4. GENERAL STATEMENTS OF REQUIREMENTS

4.1 Working environments. Minimum standards for working environments shall be in accordance with Table I and the notes thereto.

5. DETAILED STATEMENTS OF REQUIREMENTS

5.1 Working environments. The supplier shall establish working environments in accordance with Table I and the notes thereto for all work stations and work areas where materials to be delivered under the contract or purchase order are fabricated, processed, assembled, tested, inspected, handled, and stored.

5.2 Environmental control plan. The supplier shall establish and implement an environmental control plan which defines in detail each applicable work area and work station, the environment to be maintained at each work area and work station, the permissible tolerance limits for each environmental factor of Table I, the methods of control (including the necessary instrumentation), and scheduled preventive maintenance, i.e., periodic air filter cleaning, light fixture cleaning and relamping, and clean-up requirements. The environmental control plan shall be made a part of the Quality Assurance Program Plan, Inspection Plan, or Internal Quality Procedures and shall be made available for review by the Government representive.

5.3 Audit. The supplier shall conduct scheduled audits of the controlled work areas and work stations to verify that the working environments are in accordance with the environmental control plan (see 5.2). Audit frequencies shall be adjusted by experience as required to assure continued conformance to the provisions of Table I.

TABLE I. Minimum Standards for Working Environments (See Note: 1)

Type of Work (Note 2)	Cleanliness (Note 3)	Lighting Footcandles (Lux) (Note 4)	Air Temperature °F(°C) (Note 5)	Relative Humidity (Note 6)	Dust Control (Note 7)	Ventilation or Exhaust (Note 8)	Noise dBA (Note 9)	Habitat (Note 10)
Work Area 1 Mechanical Fabrication								
Tolerance to 0.01 in (0.254 mm)	Class D	70 fc (750 lx)	Note 11	10-90%	Class D	Note 8	90 dBA	Class D
Tolerance to 0.001 in (25.4 µm)	Class C	100 fc (1100 lx)	Note 11	10-90%	Class D	Note 8	80 dBA	Class C
Tolerance to 0.0001 in (2.54 µm)	Class B	200 fc (2200 lx)	Note 12	30-70%	Class C	Note 8	80 dBA	Class C
Tolerance finer than 0.0001 in (2.54 µm)	Class BA	500 fc (5400 lx)	68-75.2°F (20-24°C)	35-55%	Class B	Note 8	75 dBA	Class B
Work Area 2 Foundry Operations								
Tolerance to 0.005 in (127 µm)	Class D	70 fc (750 lx)	Note 13	>10%	Class D	Note 8	90 dBA	Class D
Tolerance finer than 0.005 in (127 µm)	Class C	100 fc (1100 lx)	Note 13	>10%	Class C	Note 8	80 dBA	Class D
Work Area 3 Plastics Operations	Class B	100 fc (1100 lx)	Note 11	10-90%	Class C	Note 8	80 dBA	Class B
Work Area 4 Plating and Heat Treating	Class C	70 fc (750 lx)	Note 13	>10%	Class C	Note 8	90 dBA	Class C
Work Area 5 Electronic Parts	Class B	100 fc (1100 lx)	Note 12	30-70%	Class C	Note 8	75 dBA	Class B
Work Area 6 Hybrid Microcircuits	Class A	100 fc (1100 lx)	Note 12	30-70%	Class A	Note 8	70 dBA	Class A
Work Area 7 Mechanical Assembly								
Tolerance to 0.05 in (1.27 mm)	Class C	100 fc (1100 lx)	Note 11	10-90%	Class D	Note 8	75 dBA	Class D
Tolerance to 0.001 in (25.4 µm)	Class B	100 fc (1100 lx)	Note 11	10-90%	Class C	Note 8	75 dBA	Class C
Tolerance to 0.0001 in (2.54 µm)	Class BA	200 fc (2200 lx)	Note 12	30-70%	Class B	Note 8	75 dBA	Class B
Tolerance finer than 0.0001 in (2.54 µm)	Class A	500 fc (5400 lx)	68-75.2°F (20-24°C)	35-55%	Class A	Note 8	70 dBA	Class A
Work Area 8 Inspection Areas	At least equal to the type of work to be inspected							
Work Area 9 Inert Chemical Component Preparation and Assembly	Class B	100 fc (1100 lx)	Note 11	10-90%	Class C	Note 8	80 dBA	Class B
Work Area 10 Preparation, Mixing and Fabrication of Propellants, Pyrotechnics, and Explosives	Class BA	100 fc (1100 lx)	Note 12	30-70%	Class B	Note 8	80 dBA	Class B
Work Area 11 Ordnance Assembly								
Tolerance to 0.05 in (1.27 mm)	Class C	100 fc (1100 lx)	Note 11	10-90%	Class D	Note 8	75 dBA	Class D
Tolerance to 0.001 in (25.4 µm)	Class B	100 fc (1100 lx)	Note 11	10-90%	Class C	Note 8	75 dBA	Class C
Tolerance to 0.0001 in (2.54 µm)	Class BA	200 fc (2200 lx)	Note 12	30-70%	Class B	Note 8	75 dBA	Class B
Tolerance finer than 0.0001 in (2.54 µm)	Class A	500 fc (5400 lx)	68-75.2°F (20-24°C)	35-55%	Class A	Note 8	70 dBA	Class A
Work Area 12 Environmental Testing	Class C	100 fc (1100 lx)	Note 11	10-90%	Class D	Note 8	90 dBA	Class C
Work Area 13 Handling and Storage	Class D	70 fc (730 lx)	Note 13	>10%	Class C	Note 8	90 dBA	Class C

NOTES TO TABLE I

1. Reduced Environmental Limits

The requirements listed herein represent minimum requirements for normal manufacturing operations. Suppliers who are required to comply with the provisions herein and who may have special processes, such as X-Ray, video displays or light directed component insertion equipment, etc., may develop reduced environmental limits under the following conditions:

a. A valid engineering requirement exists for the reduced limit, and

b. The reduced limits are documented (including the reasons therefor) and subject to control and audit in the same manner as the remaining requirements listed herein, and

c. Such revised environmental limits, the reasons therefor, and the manner of control are subject to approval of the Government contracting officer.

2. Work Area Descriptions

a. Work Area 1: Mechanical Fabrication.

This work area includes machining and similar operations involving cutting, material removal, shaping, or joining metals and plastics. Typical operations include sawing, shearing, bending, punching, drawing, turning, boring, drilling, milling, grinding, welding, riveting, and similar operations.

b. Work Area 2: Foundry Operations.

This work area includes casting, extruding, rolling, and forging of metals and similar operations.

c. Work Area 3: Plastics Operations.

This work area includes the handling, mixing, potting, encapsulating, impregnating, spraying, and curing areas for chemicals, plastics, epoxies, paints, etc.

d. Work Area 4: Plating and Heat Treating.

This work area includes pickling, etching, plating, heat treating, and annealing operations.

Notes to Table I (Continued)

e. Work Area 5: Electronic Parts.

This work area includes handling, inspection, assembly and soldering or resistance welding of electronic parts, electronic assemblies, electromechanical devices and printed wiring boards.

f. Work Area 6: Hybrid Microcircuits.

This work area includes handling, inspection, assembly, bonding or soldering, adjustment or trimming, and sealing of hybrid microcircuits (see MIL-STD-1313).

g. Work Area 7: Mechanical Assembly.

This work area includes the joining of individual parts to form higher level assemblies.

h. Work Area 8: Inspection Areas.

An inspection area may be adjacent to, or removed from, the area in which the actual work is being done, such as a receiving inspection area. Inspection must be accomplished in a working environment at least equivalent to that in which the item to be inspected was fabricated, and, unless a subsequent cleaning operation is accomplished, the environment shall be equal to that required for the next assembly operation or processing step.

i. Work Areas 9, 10, and 11: Chemical, Propellant, Pyrotechnic, and Explosive Processing.

These areas are used exclusively for the manufacture, processing, and fabrication of propellants and related materials and devices. Some of the other work areas (1 through 7 in Table I) may be utilized to make up the entire assembly. However, areas 9 through 11 deal with the processes that make up the explosive subassembly itself, both live and inert. When these requirements conflict with safety considerations, the safety requirements shall take precedence. Unless otherwise specified, general safety requirements and definitions shall be in accordance with DoD publication 4145.26M. Work Area 8 (Inspection) applies to all types of work.

Notes to Table I (Continued)

j. Work Area 12: Environmental Test.

This work area is defined as being in the immediate vicinity of, or adjacent to, items under environmental test. A control station (e.g., a test console), whether remote from, in the immediate vicinity of, or adjacent to items under test, is considered a part of the environmental testing work area.

k. Work Area 13: Handling and Storage.

The environmental requirements for handling and storage of items in work shall at least equal the requirements for the type of work being accomplished except when items are covered or protected from contamination. Values listed in Table I apply to handling and storage of covered, bagged, or otherwise protected items.

3. Cleanliness Definitions

Class D - Daily Cleanup:

Removal of scrap, clean up all spilled oil, etc.

Class C - Prompt Cleanup:

Scrap, oil, and residue shall not be allowed to accumulate.

Class B - Prompt Cleanup:

Oil, residue, and spilled chemicals removed immediately. Floors, walls and work areas shall have easily cleaned surfaces. Cleanup of equipment and area shall be accomplished daily.

Class BA:

Oil, residue, spilled chemicals, and any foreign material which might develop in the area shall be cleaned immediately. Floors, walls, furniture, and work areas shall have hard, grease-resistant, easily cleaned surfaces. Materials and equipment shall be cleaned prior to acceptance into this area. In addition, parts and assemblies shall be kept in suitable covered containers when not in use. As a minimum, flushing or cutting fluids shall be filtered to remove contamination above 15.0 microns. Chips, particles, and dust generated during any and all mechanical operations shall be

Notes to Table I (Continued)

removed during the operation by vacuum. Clean, lint-free smocks are required for operators and inspectors. Complete cleaning and wipe-down of equipment, tools, fixtures, and the area shall be accomplished at the end of each 8 hours of operation or daily, whichever occurs first.

Class A:

Cleanliness shall be controlled in accordance with Fed-Std-209, Class 100,000 as a minimum, unless otherwise specified in the contract or purchase order.

4. Lighting

Indicated values are minimum light intensity values as measured at the work station using a light meter which is cosine and color corrected. Supplemental lighting shall be used when necessary to improve precision, minimize operator fatigue, and to provide illumination inside of cabinets and housings, but brightness ratios within the operator's field of view shall not exceed 10 to 1. Specialized equipment that requires a low ambient light level, i.e., TV displays, X-ray, etc., may require an exception to those levels specified in Table I (see Note 1, Reduced Environmental Limits).

5. Air Temperature

Designated temperature limits shown in Table I are dry bulb temperature measurements taken in proximity of the work stations during regular working hours. See Notes 11, 12, and 13 for those areas indicated in Table I.

6. Relative Humidity

Designated relative humidity shall be as measured at room ambient temperature in proximity to the work stations during regular working hours.

7. Dust Control Definitions

Class D - No dust control required.

Notes to Table I (Continued)

Class C - Outside and recirculated air shall be filtered to remove dust particles. Filter shall have a minimum arrestance of 65 percent in accordance with ASHRAE[1] Standard 52-76.

Class B - Outside and recirculated air shall be filtered to remove dust particles. Filter shall have a minimum efficiency of 60 percent in accordance with ASHRAE Standard 52-76.

Class A - Dust control shall be in accordance with Fed-Std-209, Class 100,000 as a minimum, unless otherwise specified in the contract or purchase order.

8. Ventilation or Exhaust

Air velocity at the work station shall be maintained at a velocity of less than 90 ft/minute (0.46 m/s) regardless of the season. Additionally, forced ventilation or exhaust shall be provided in areas where operations such as parts cleaning, vapor degreasing, and machine soldering are being accomplished. The maximum air velocity requirement shall not apply in these areas. Work areas for mechanical assembly of tolerances finer than 0.0001 in (2.54 μm) which utilize laminar flow benches shall maintain an air velocity of less than 110 ft/minute (0.56 m/s).

9. Noise

Noise is defined as the average sound level existing at the work station during normal operation when measured with a standard sound-level meter as specified in ANSI[2] S1.4-1971, Type 2, "A" weighted. Work stations for control of automatic equipment operations, which require operator loading and unloading only, may exceed the noise limits specified by 10 dBA but not exceed 90 dBA. Inspection and test work stations shall not exceed the values specified. Work areas for mechanical assembly of tolerances finer than 0.0001 in (2.54 μm) which utilize laminar flow benches may exceed by 5 dBA the value specified. For environmental testing, when the specified limit is exceeded, ear protection shall be provided.

[1] American Society of Heating, Refrigerating and Air-Conditioning Engineers.

[2] American National Standards Institute.

Notes to Table I (Continued)

10. Habitat

Class D - Uncontrolled

Class C - No food, drink, or personal grooming material is allowed at these work stations. No eating, drinking, or personal grooming is allowed in the work area. Drinking fountains are permissible.

Class B - No food, drink, personal grooming material, or smoking is allowed at these work stations. No eating, drinking, personal grooming, or smoking is allowed in the work area. Drinking fountains are permissible.

Class A - No food, drink, personal grooming material, or smoking material is allowed in these work areas. Drinking fountains are permissible.

11. Comfort Zone

The combination of air temperature and relative humidity shall not exceed the limits shown in the cross hatched area of Figure 1 for those areas specified in Table I.

12. Comfort Zone (Restricted)

The combination of air temperature and relative humidity shall not exceed the limits shown in the cross hatched area of Figure 2 for those areas specified in Table I.

13. Tolerance Zone

The combination of air temperature and relative humidity shall not exceed the limits shown in the cross hatched area of Figure 3 for those areas specified in Table I.

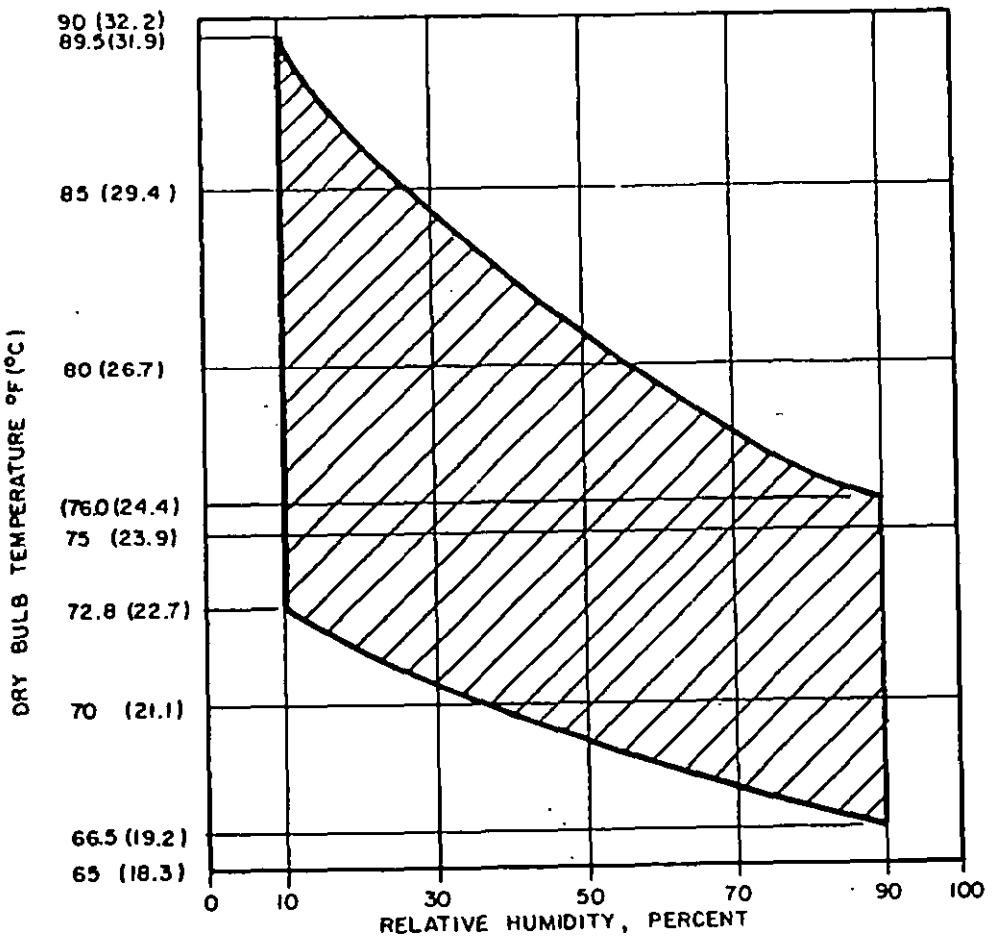


FIGURE 1. Personnel Comfort Limits
(MIL-STD-1472)

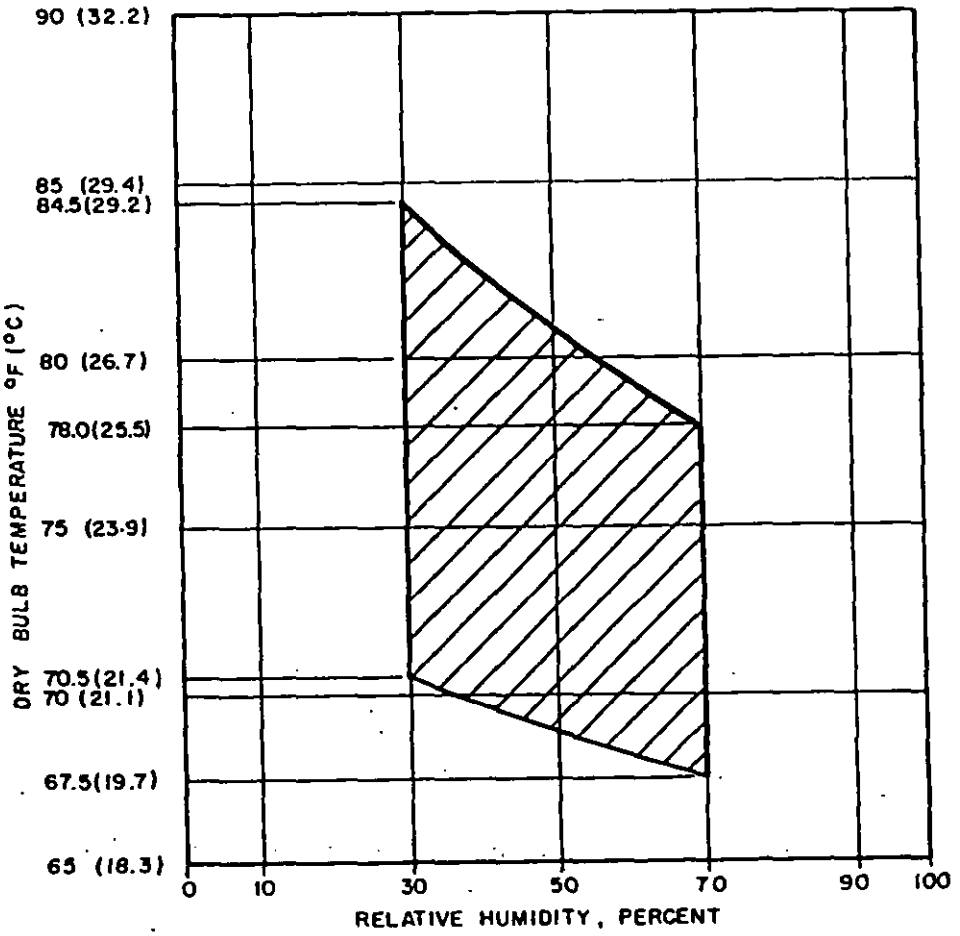


FIGURE 2. Personnel Comfort Limits
(Modified to Account for Humidity Effects on
Equipment and Work In-Process)

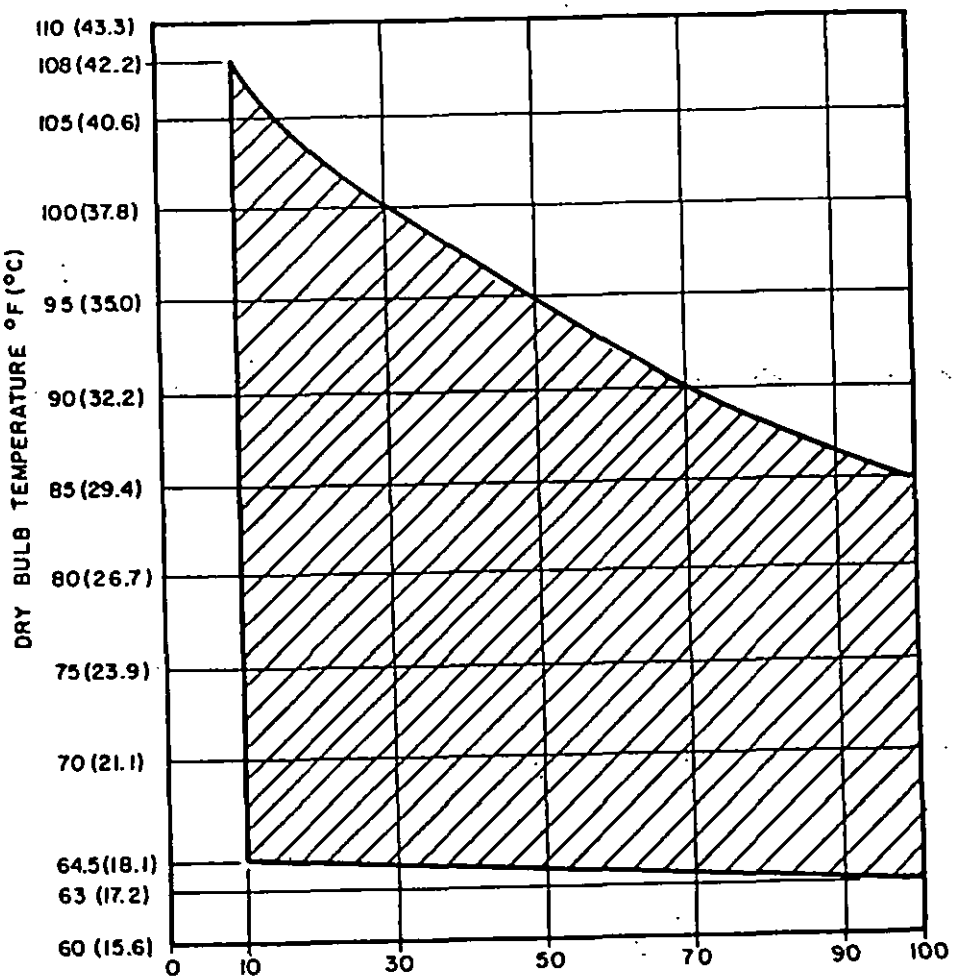


FIGURE 3. Tolerance Limits, Adapted From MIL-STD 1472

6. NOTES AND CONCLUDING MATERIAL Not applicable.

Preparing Activity
Navy-AS

(Project Misc NC-54)

APPENDIX A

The information contained within this Appendix is non-mandatory and delineates the historical background and justification for the development of the minimum standards for working environments.

10. INTRODUCTION

MIL-Q-9858A[1], Quality Program Requirements, Paragraph 6.2, requires that "The Contractor's quality program must assure that all machining, wiring, batching, shaping and all basic production operations of any type is accomplished under controlled conditions. Controlled conditions include documented work instructions, adequate production equipment, and any special working environment."

In order to establish a common definition of "special working environments," minimum standards for working environments have been defined which are required of suppliers and vendors supplying equipment to the Government. The purpose of this Appendix is to document the sources and derivation of the working environment standards.

20. SUMMARY

The *minimum standards for working environments* address the following areas:

Cleanliness

Lighting

Air Temperature

Relative Humidity

Dust Control

Ventilation or Exhaust

Noise

Habitat.

Various standards have been defined for thirteen generalized work areas which are considered representative of the type of work being performed for the Government. This Appendix addresses each environment, defines the applicability of each environmental standard to each work area, and provides the source and rationale for each standard imposed.

The various environmental levels defined have been imposed to accomplish the following:

a. Protect work in process from contamination,

b. Provide environmental standards commensurate with the precision of the required measurement,

c. Provide a working environment which is conducive to defect free workmanship, and

d. Focus attention on the worker as the key element in quality production.

30. SOURCE AND DERIVATION STANDARDS

30.1 Cleanliness.

a. Requirement summary. Various cleanliness levels have been established to provide increasingly severe cleanliness requirements from Class D, which represents the minimum cleanliness level required for personnel and plant safety, to Class A, which represents a clean room environment.

Cleanliness requirements have been assigned to various work areas based on engineering judgment and the potential for contamination of work in-process. Rough machining was assigned the lowest cleanliness requirement, and the requirements were made increasingly stringent as the required tolerance was tightened, since in general, the more precise the measurement, the greater the probability that contamination could cause measurement errors. At assembly, the more precise the assembly operation, the greater the probability that contamination could cause assembly problems (such as assembly errors, binding in completed assemblies, etc.).

b. Requirement source.

1. Fed-Std-209[2]

2. MIL-STD-1246[3]

c. Analysis. Tables A-I, A-II, and A-III provide an analysis of the requirements with regard to cleanliness and pertinent comments regarding the requirements.

TABLE A-I. Review of Notes in "Minimum Standards for Working Environments"

Note: 3, Title: Cleanliness

NOTE	COMMENTS AND JUSTIFICATION
Cleanliness Definitions	
Class D--Daily Cleanup:	
Removal of scrap, clean up all spilled oil, etc.	This represents the minimum standards for personnel and plant safety.
Class C--Prompt Cleanup:	
Scrap, oil and residue shall not be allowed to accumulate.	This represents good housekeeping practice.
Class B--Prompt Cleanup:	
Oil, residue, and spilled chemicals removed immediately. Floors, walls, and work areas shall have easily cleaned surfaces. Cleanup of equipment and area shall be accomplished daily.	This represents the next highest level of cleanliness in accordance with the analysis of Table A-II. To achieve this cleanliness level requires attention to facility design and proper cleanup and maintenance.
Class BA:	
Oil, residue, spilled chemicals, and any foreign material which might develop in the work area shall be cleaned immediately. Floors, walls, furniture, and work areas shall have hard, grease resistant, easily cleaned surfaces. Materials and equipment shall be cleaned prior to acceptance into this area. In addition, parts and assemblies shall be kept in suitable covered containers when not in use. As a minimum, flushing or cutting fluids shall be filtered to remove contamination above 15.0 microns. Chips, particles, and dust generated during any and all mechanical operations shall be removed during the operation by vacuum. Clean, lint free smocks are required for operators and inspectors. Complete cleaning and wipe-down of equipment, tools, fixtures and the area shall be accomplished at the end of each 8 hours of operation or daily, whichever occurs first.	Class BA represents the highest cleanliness level short of a clean room environment. Requirements agree with Table A-II, assuring cleanliness of both the area and material introduced into the area. Fluid filters should prevent any additional contamination: a filter rating of 10 percent of the maximum permissible particle size appears appropriate. Provisions are included to protect material in storage.
Class A:	
Cleanliness shall be controlled in accordance with Fed-Std-209, Class 100,000 as a minimum, unless otherwise specified in the contract or purchase order.	Product fabrication which requires a clean room atmosphere should be controlled in accordance with Fed-Std-209.

TABLE A-II. DERIVATION OF CLEANLINESS LEVELS [1/]

MIL-STD-1246					Applicable Cleanliness Levels of MIL-STD	
Cleanliness Level (Microns)	Maximum Number of Particles per Square Foot				Assembly [3/] Tolerance Range (inches)	Machining [4/] Tolerance Range (inches)
	2.5 micron (0.0001 inch)	25 micron (0.001 inch)	250 micron (0.01 inch)	1250 micron (0.05 inch)		
100	3600	70	0	0	Finer than 0.0001 (Class A)	-
150	15,000	350	0	0	0.001 to 0.0001 (Class BA)	Finer than 0.0001 (Class BA)
500	3×10^4	70,000	20	0	0.05 to 0.001 (Class B)	0.001 to 0.0001 (Class B)
2000	(9×10^4)	(2.3×10^5)	55,000	15	Coarser than 0.05 (Class C)	0.01 to 0.001 (Class C)
(5000) [2/]	(3.3×10^{13})	(7.2×10^{10})	(2.2×10^7)	(6150)	-	Coarser than 0.01 (Class D)

NOTES: [1/] For critical tolerance requirements, both Fed-Std-209 and MIL-STD-1246 provide recommended contamination levels for various types of operations. Fed-Std-209 defines the requirements in terms of the maximum number of 0.5 micron particles of contaminant per cubic foot of air. Fed-Std-209 also provides a graph which relates the number of 0.5 micron particles to the expected number of particles of larger sizes. MIL-STD-1246 defines cleanliness requirements in terms of the maximum particle size allowed per square foot of surface area. Although the two systems are thus not directly comparable, one parameter is common to both systems, the maximum particle size allowed.

Figure A-1 has been prepared to illustrate the relationship between the two methods of specifying cleanliness and contains data from Fed-Std-209 and MIL-STD-1246 plotted on a single graph. It can be seen that Fed-Std-209, Class 100,000 and MIL-STD-1246, Product Cleanliness Level 100, both permit a maximum particle size of 100 microns. This common reference point, which defines the minimum requirements for clean rooms, permits the establishment of cleanliness requirements for less critical applications. Table A-II has been prepared to provide a rational method of specifying cleanliness in relation to equipment tolerances. The maximum number of particles was calculated using the formula presented in MIL-STD-1246 since the formula provides improved precision over graphical techniques using Figure A-1.

The purpose of the cleanliness provisions is to provide a working environment which will permit the product cleanliness requirements to be achieved. Product cleanliness requirements may be either defined in the applicable product specification, or may be implied by the specified tolerances. One method of defining product cleanliness requirements, based on the specified tolerances, is illustrated in Table A-II. Work-in-process which is susceptible to assembly and measurement problems caused by particulate contamination must be protected from workplace induced contamination.

Particulate matter larger than 100-200 microns is usually visible to the naked eye. The environmental controls must protect susceptible product from contamination below the visible level. Based on the cleanliness classes defined in Table A-II, Classes A and BA require special controls to assure that the workspace does not contaminate the work-in-process. For Class A cleanliness, Fed-Std-209 provides guidance to assure that the working environment is compatible with the equipment tolerance range. Class BA should require cleaning for all material and equipment introduced into the work area to assure that the work area remains free of detrimental contamination which would not normally be visible.

2/ Numbers in parenthesis derived by interpolation or extrapolation of the specification requirements.

3/ Cleanliness limits selected to provide a low probability of occurrence at assembly of particles equal to or greater than the specified tolerance limit.

4/ Cleanliness requirements cannot be eliminated for the machining operations because of measurement problems, but may be relaxed one cleanliness level because of the subsequent cleaning operations.

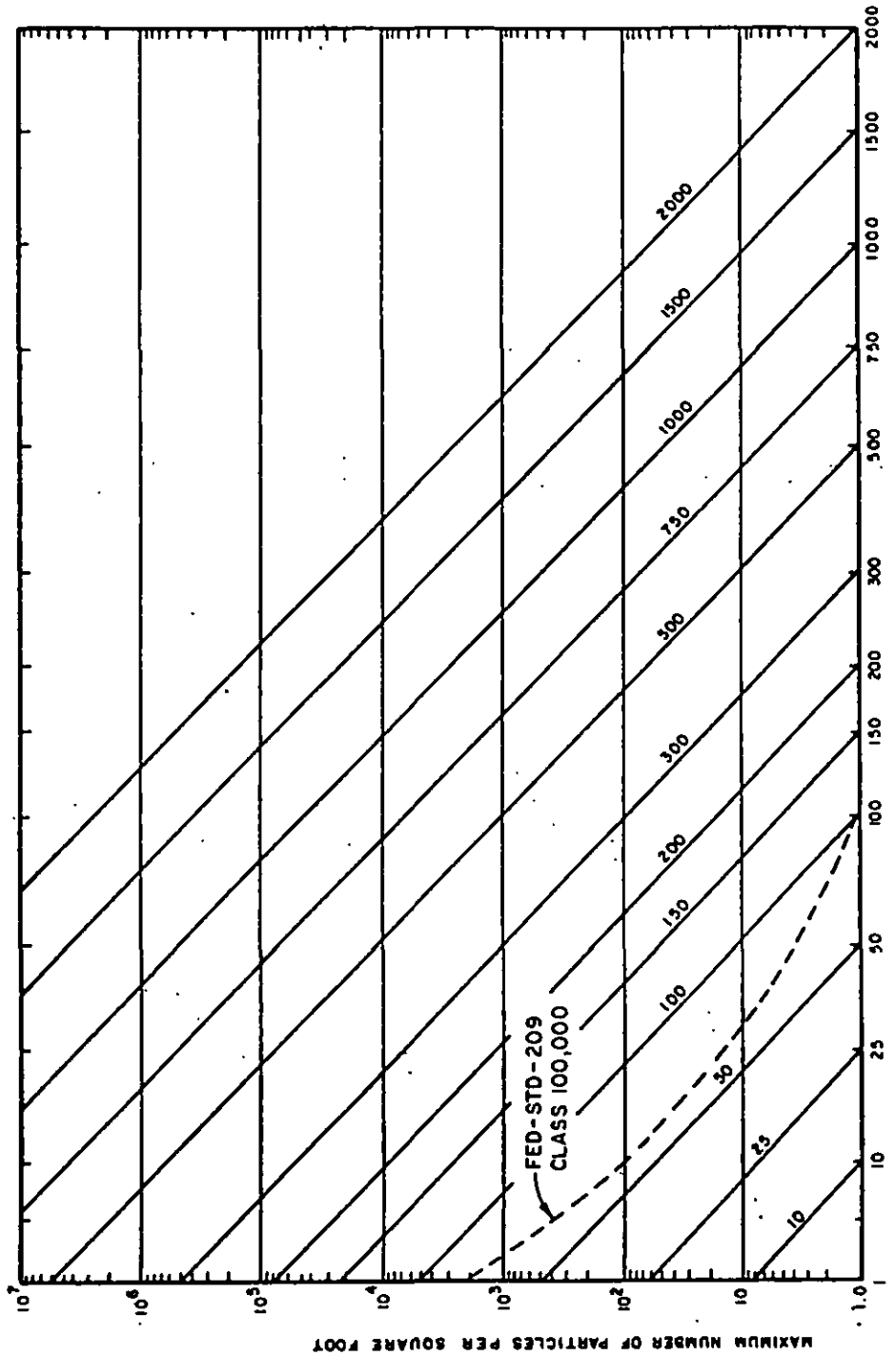


FIGURE A-1. Product Cleanliness Levels (From MIL-STD-1246)

TABLE A-III. Review of Provisions in "Minimum Standards for Working Environments"

Requirement: Cleanliness

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 1 Mechanical Fabrication		
Tolerance to 0.01 in (0.254 mm)	Class D	Cleanliness classes as established in Table A-II. Classes of cleanliness are proportional to the measurement precision required.
Tolerance to 0.001 in (25.4 µm)	Class C	
Tolerance to 0.0001 in (2.54 µm)	Class B	
Tolerance finer than 0.0001 in (2.54 µm)	Class BA	
Work Area 2 Foundry Operations		
Tolerance to 0.005 in (127 µm)	Class D	The type of work is inherently dirty, and not susceptible to contamination. Thus, only minimal controls are required. Good housekeeping controls appear to be all that can reasonably be expected of this type of operation.
Tolerance finer than 0.005 in (127 µm)	Class C	
Work Area 3 Plastics Operations	Class B	The type of work involves handling epoxies, potting, and encapsulating compounds, which must be cleaned immediately to prevent damage to floors, work benches, and fixtures. The Class B definition appears most appropriate.
Work Area 4 Plating and Heat Treating	Class C	These types of areas are not amenable to tight controls. As a result, most process requirements include cleaning operations. Good housekeeping practices appear to be all that can be practically imposed.
Work Area 5 Electronic Parts	Class B	Electronic assembly requires extensive cleanliness controls to prevent contamination of work in-process to preclude solderability problems.
Work Area 6 Hybrid Microcircuits	Class A	These devices are highly susceptible to contamination. The highest level of cleanliness is warranted.
Work Area 7 Mechanical Assembly		
Tolerance to 0.05 in (1.27 mm)	Class C	Cleanliness classes as established in Table A-II. Classes of cleanliness are proportional to the assembly precision required.
Tolerance to 0.001 in (25.4 µm)	Class B	
Tolerance to 0.0001 in (2.54 µm)	Class BA	
Tolerance finer than 0.0001 in (2.54 µm)	Class A	
Work Area 8 Inspection Area	Equal to the type of work to be inspected.	To prevent additional contamination of work, inspection areas must be controlled to at least the level under which the part was produced. In addition, controls must assure that the inspection operation does not contaminate the next assembly operation.
Work Area 9 Inert Chemical Component Preparation and Assembly	Class B	Cleanliness requirements will be similar to the requirements for Work Area 3, subject to the constraints of DoD 4145.26M [4/]
Work Area 10 Preparation, Mixing and Fabrication of Propellants, Pyrotechnics, and Explosives	Class BA	Mixing and handling of pyrotechnic and explosive chemicals is hazardous and susceptible to both humidity and contamination. Extreme cleanliness is required. Class BA appears to be the appropriate cleanliness level, subject to the constraints of DoD 4145.26M.

TABLE A-III. Review of Provisions in "Minimum Standards for Working Environments" (Continued)

Requirement; Cleanliness

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 11 Ordnance Assembly		
Tolerance to 0.05 in (1.27 mm)	Class C	Although separate requirements are appropriate for this work area because of stringent humidity requirements, cleanliness should be the same as for Work Area 7 (mechanical assembly) for the same considerations, subject to the constraints of DoD 4145.26M.
Tolerance to 0.001 in (25.4 µm)	Class B	
Tolerance to 0.0001 in (2.54 µm)	Class BA	
Tolerance finer than 0.0001 in (2.54 µm)	Class A	
Work Area 12 Environmental Testing	Class C	Since materials and assemblies undergoing environmental test are normally completely processed, no need for stringent process controls is evident. Class C represents a "good housekeeping" level of cleanliness.
Work Area 13 Handling and Storage	Class D	The requirement is applicable to items which are covered or otherwise protected from contamination, thus, only minimal cleanliness controls are required.

30.2 Lighting.

a. Requirement summary. Specified lighting values vary from 70 footcandles to 500 footcandles, with the provision for supplemental lighting where required. The lighting intensity has been found to affect productivity, error rate, and operator fatigue. Minimum light intensity values have been defined based primarily on the precision of the work and the size of the work.

b. Requirement source.

Illuminating Engineers Society Handbook[5]

c. Analysis. Tables A-IV and A-V provide an analysis of the requirements with regard to illumination and pertinent comments regarding the requirements.

TABLE A-IV. Review of Notes in "Minimum Standards for Working Environments"

Note: 4, Title: Lighting

NOTE	COMMENTS AND JUSTIFICATION
Lighting Indicated values are minimum light intensity values as measured at the work station using a light meter which is cosine and color corrected. Supplemental lighting shall be used when necessary to improve precision, minimize operator fatigue, and to provide illumination inside of cabinets and housings, but brightness ratios within the operator's field of view shall not exceed 10 to 1. Specialized equipment that requires a low ambient light level, i.e. TV displays, X-ray, etc., may require an exception to those levels specified in Table I (see Note 1, Reduced Environmental Limits).	The Illuminating Engineers Society (IES) Handbook recommends that measurements be made with a light meter which is cosine and color corrected. The requirement for maximum brightness ratios is adapted from Figure 14-2 of the IES Handbook. Figure 9-80 of the IES Lighting Handbook (5th Edition), while not addressing the specific work areas of concern, provides the following lighting - task relationship: 50-70 footcandles: Libraries, ordinary inspection, drilling, rough assembly, rough machining 100 footcandles: Reading, drafting, difficult inspection, medium assembly, coil winding, medium machining 200 footcandles: Cartography, highly difficult inspection 500 footcandles: Very difficult inspection, fine assembly, fine bench and machine work The amount of lighting directly affects productivity. Figure A-2 contains data from Figure 3-15 of the IES Handbook replotted to illustrate the relationship between illumination and the time required to detect an object. The time required is also a function of the contrast ratio between the object and the background. For any fixed object and background, it can be seen that the time required to detect the object decreases with increasing illumination. Figure A-3 contains similar data, replotted to illustrate that illumination must be increased as the object size decreases. Figures A-2 and A-3 thus provide the rationale for varying the required illumination in proportion to the required precision of the work. Several studies have been conducted in an effort to validate the IES recommendation, or to permit the reduction in lighting levels as an energy saving measure. References 6 and 7 report the results of several studies of clerical error rate, productivity, and attitude toward various levels of illumination. In each case, when lighting levels alone were considered, decreased illumination resulted in lower productivity, increased error rates, and increased worker dissatisfaction. Reference 8 reports measurements of eye fatigue which clearly indicate that reading at levels of 100 footcandles causes little or no eye fatigue, while levels of 10 and 1 footcandles cause considerable eye fatigue. Measurements reported in Reference 8 correlate well with the subjective data (worker's comments) reported in References 6 and 7.

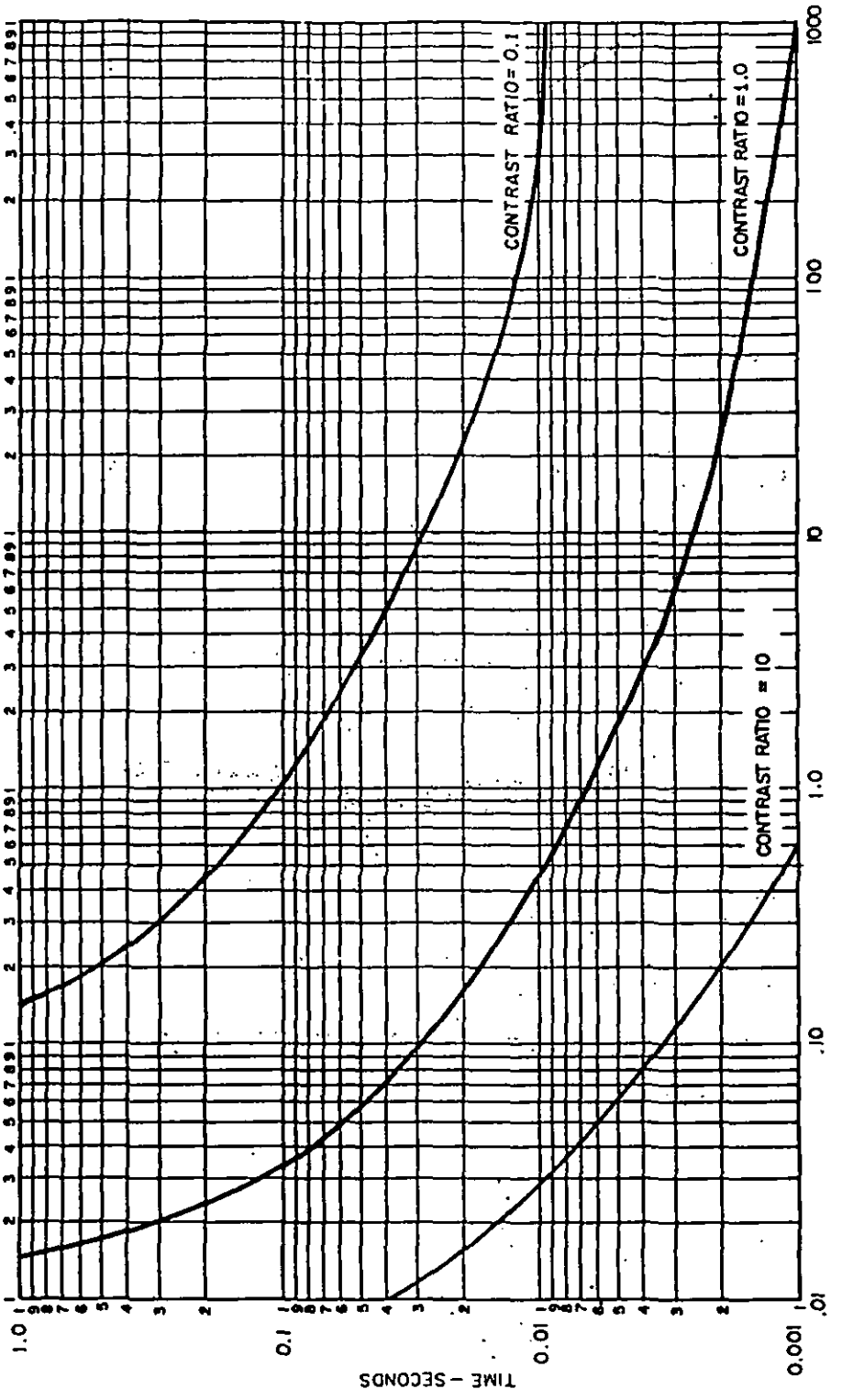


FIGURE A-2. Time Required to Detect Object vs Illumination (Based on 0.02" Spot)

NOTE: Luminance in Footlamberts is Equal to Illumination in Footcandles Times the Luminous Reflectance of the Surface.

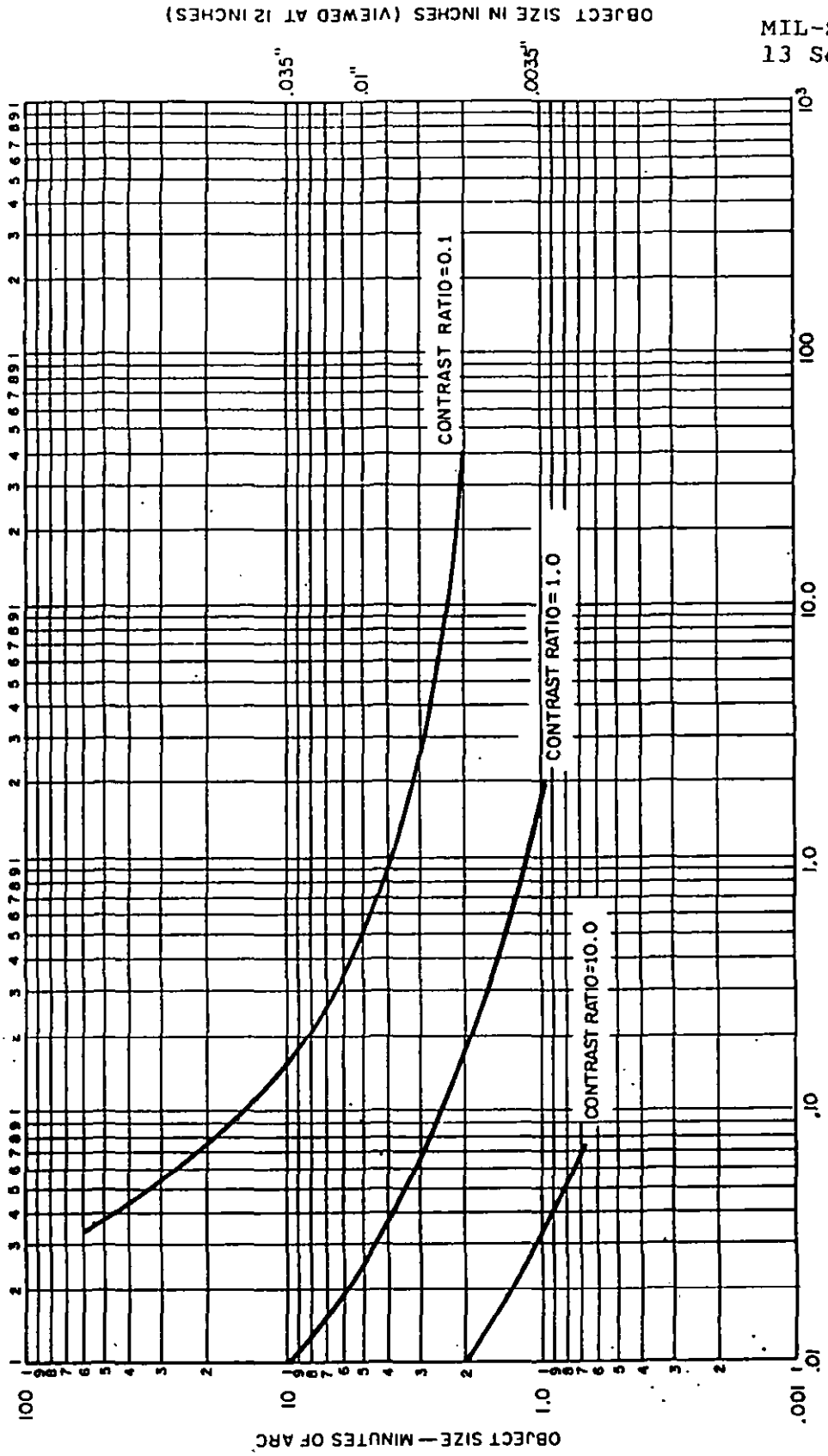


FIGURE A-3 REQUIRED ILLUMINATION vs OBJECT SIZE (BASED ON 0.4 SECOND DETECTION TIME)

NOTE: LUMINANCE IN FOOTLAMBERTS IS EQUAL TO THE ILLUMINATATION IN FOOTCANDLES TIMES THE LUMINOUS REFLECTANCE OF THE SURFACE.

TABLE A-V. Review of Provisions in "Minimum Standards for Working Environments"

Requirement: Lighting

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 1 Mechanical Fabrication Tolerance to 0.01 in (0.254 mm) Tolerance to 0.001 in (25.4 µm) Tolerance to 0.0001 in (2.54 µm) Tolerance finer than 0.0001 in (2.54 µm)	70 fc (750 lx) 100 fc (1100 lx) 200 fc (2200 lx) 500 fc (5400 lx)	Using 100 footcandles as the reference for reading and medium assembly and assuming that this is applicable to tolerances of 0.001 inch, the remaining requirements are derived by scaling the reference value up and down.
Work Area 2 Foundry Operations Tolerance to 0.005 in (127 µm) Tolerance finer than 0.005 in (127 µm)	70 fc (750 lx) 100 fc (1100 lx)	These operations do not depend on operator visual acuity, therefore minimum lighting levels are adequate. Although these operations do not depend on operator visual acuity, increased lighting is required because of the higher precision of the work and the type of equipment and tooling being used.
Work Area 3 Plastics Operations	100 fc (1100 lx)	Plastics operations areas require lighting level equivalent to the reference level of 100 footcandles.
Work Area 4 Plating and Heat Treating	70 fc (750 lx)	Plating and heat treating operations depend more on process controls and timing than on visual observation by the operator. As such, only the minimum lighting level of 70 footcandles is required.
Work Area 5 Electronic Parts	100 fc (1100 lx)	Electronic assembly is a semi-precision operation, but tight tolerances are not required to be observed by the operator. The reference lighting level of 100 footcandles appears to be the appropriate requirement.
Work Area 6 Hybrid Microcircuits,	100 fc (1100 lx)	Hybrid microcircuits are normally fabricated and assembled with optical aids, which require supplementary lighting. As a result, high ambient light levels are not warranted.
Work Area 7 Mechanical Assembly Tolerance to 0.05 in (1.27 mm) Tolerance to 0.001 in (25.4 µm) Tolerance to 0.0001 in (2.54 µm) Tolerance finer than 0.0001 in (2.54 µm)	100 fc (1100 lx) 100 fc (1100 lx) 200 fc (2200 lx) 500 fc (5400 lx)	Requirements are derived by scaling the reference lighting level up to account for the precision required for the tighter tolerances. To facilitate the assembly process, the minimum level has been established at 100 footcandles.
Work Area 8 Inspection Areas	Equal to type of work to be inspected	Visual acuity requirements for inspection are equal to, or more severe than, those required for fabrication and assembly. Thus, lighting must be at least equal to the requirements during the fabrication or assembly operation.
Work Area 9 Inert Chemical Component Preparation and Assembly	100 fc (1100 lx)	This work area involves mixing and processing of chemicals, similar to the requirements for Work Area 3 (reference level of 100 footcandles).
Work Area 10 Preparation, Mixing and Fabrication of Propellants, Pyrotechnics, and Explosives	100 fc (1100 lx)	This work area involves mixing and processing of chemicals, similar to the requirements for Work Area 3 (reference level of 100 footcandles).

TABLE A-V. Review of Provisions in "Minimum Standards for Working Environments" (Continued)

Requirement: Lighting

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 11 Ordnance Assembly Tolerance to 0.05 in (1.27 mm) Tolerance to 0.001 in (25.4 µm) Tolerance to 0.0001 in (2.54 µm) Tolerance finer than 0.0001 in (2.54 µm)	100 fc (1100 lx) 100 fc (1100 lx) 200 fc (2200 lx) 500 fc (5400 lx)	Ordnance assembly requirements are the same as for mechanical assembly as regards visual requirements for the operator. Lighting requirements are therefore the same as for Work Area 7.
Work Area 1 Environmental Testing	100 fc (1100 lx)	This work area involves medium assembly requirements, meter reading, and similar activities. The reference level of 100 footcandles appears appropriate.
Work Area 13 Handling and Storage	70 fc (750 lx)	Handling and storage of covered or packaged items does not require high visual acuity, therefore the minimum lighting requirements are appropriate.

30.3 Air temperature.

a. Requirement summary. Air temperature requirements vary from established limits for human tolerance, which are applicable in areas where process controls establish product quality, to highly restricted temperature limits which are required to assure measurement precision. Intermediate values, applicable to operations where the operator exerts a direct influence on product quality, have been defined based on consideration of operator comfort, static electricity, and potential for corrosion.

b. Requirement source.

1. MIL-STD-1472[9]

2. MIL-HDBK-52[10]

3. Fed-Std-209

4. ASHRAE Standard 55-74[11]

c. Analysis. Tables A-VI and A-VII provide an analysis of the requirements with regard to air temperature and pertinent comments regarding the requirements.

TABLE A-VI. Review of Notes in "Minimum Standards for Working Environments"

Note: 5, Title: Air Temperature

NOTE	COMMENTS AND JUSTIFICATION
Air Temperature Designated temperature limits shown in Table I are dry bulb temperature measurements taken in proximity of the work stations during regular working hours. See Notes 11, 12, and 13 for those areas indicated in Table I.	MIL-STD-1472 defines both personnel comfort zones and personnel tolerance limits, while MIL-HDBK-52 provides guidance regarding environmental requirements for precision measurements. Figure A-4, derived from MIL-STD-1472, defines personnel tolerance limits, and is based on 12-hour exposure with lightweight clothing at air velocities equal to 200-feet per minute. Figure A-4 defines the worst case limits which should be allowed under any conditions. Figure A-5, derived from MIL-STD-1472, defines personnel comfort limits. Figure A-5 represents the worst case limits for effective personnel performance. For information, Figure A-5 also includes the comfort limits defined in ASHRAE Standard 55-74. Figure A-5 however, permits relative humidity to vary between 10 and 90 percent. Such levels are normally not acceptable for fabrication of military equipment. High humidity causes corrosion of unprotected metals, and can affect chemical processes. Low humidity facilitates the generation of static electricity, can affect chemical processes, can damage electronic components, and can cause measurement and assembly problems resulting from the attraction of charged particles to work in process. As a result of these considerations, Figure A-6 has been prepared, which further restricts the permissible relative humidity range to between 30 and 70 percent. Figure A-6 also includes the restricted levels recommended in MIL-HDBK-52 for precision measurement. A discrepancy exists between the recommendations of MIL-HDBK-52 and Fed-Std-209. The accepted reference temperature for dimensional calibrations is 20°C (68°F). MIL-HDBK-52 includes 68°F as the recommended lower temperature limit for areas used for performing mechanical calibrations. Fed-Std-209, however, recommends a nominal temperature of 73°F. Any departure from 68°F will require that precision measurements be adjusted to account for the thermal coefficient of expansion of the materials involved. Since adjustments will be necessary, it appears that the recommended limits defined in MIL-HDBK-52 can be relaxed to permit compatibility with Fed-Std-209. An arbitrary recommendation is to permit temperature variations between 68°F and 75°F for clean room operations.

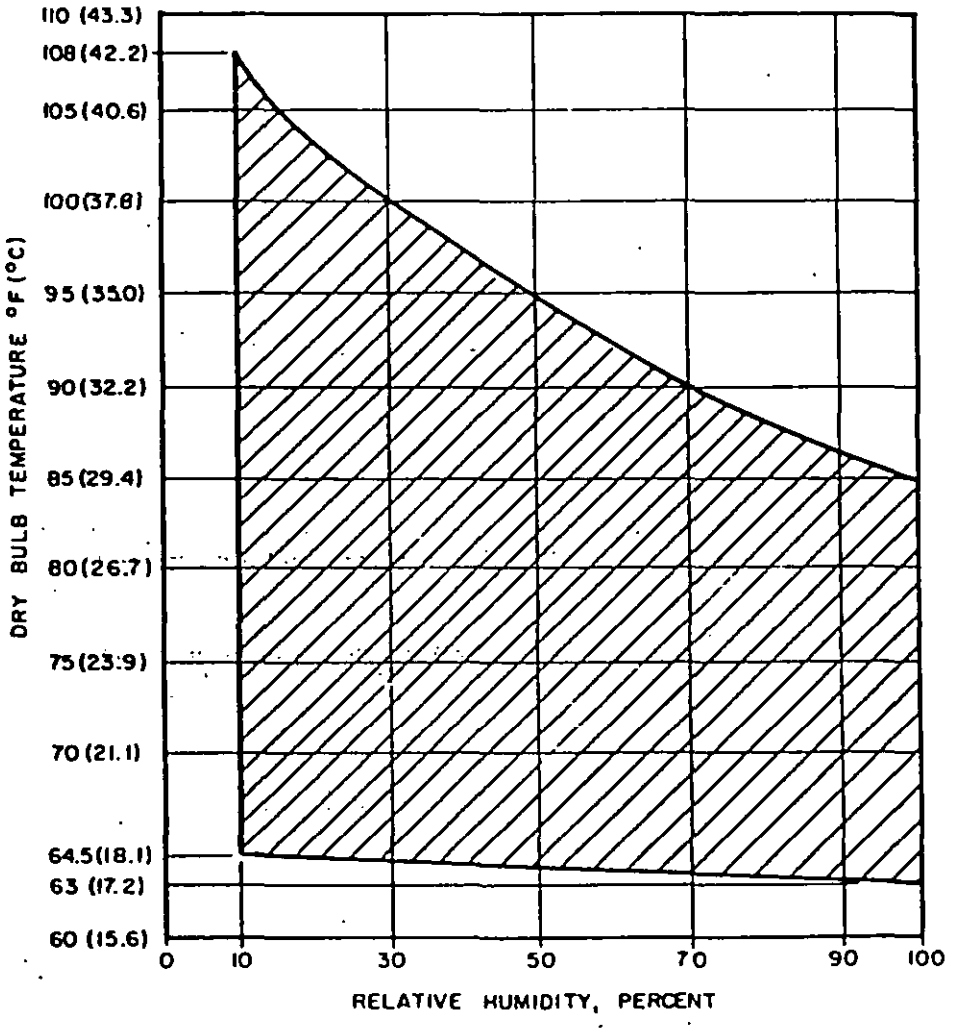


FIGURE A-4. Tolerance Limits, Adapted From MIL-STD-1472

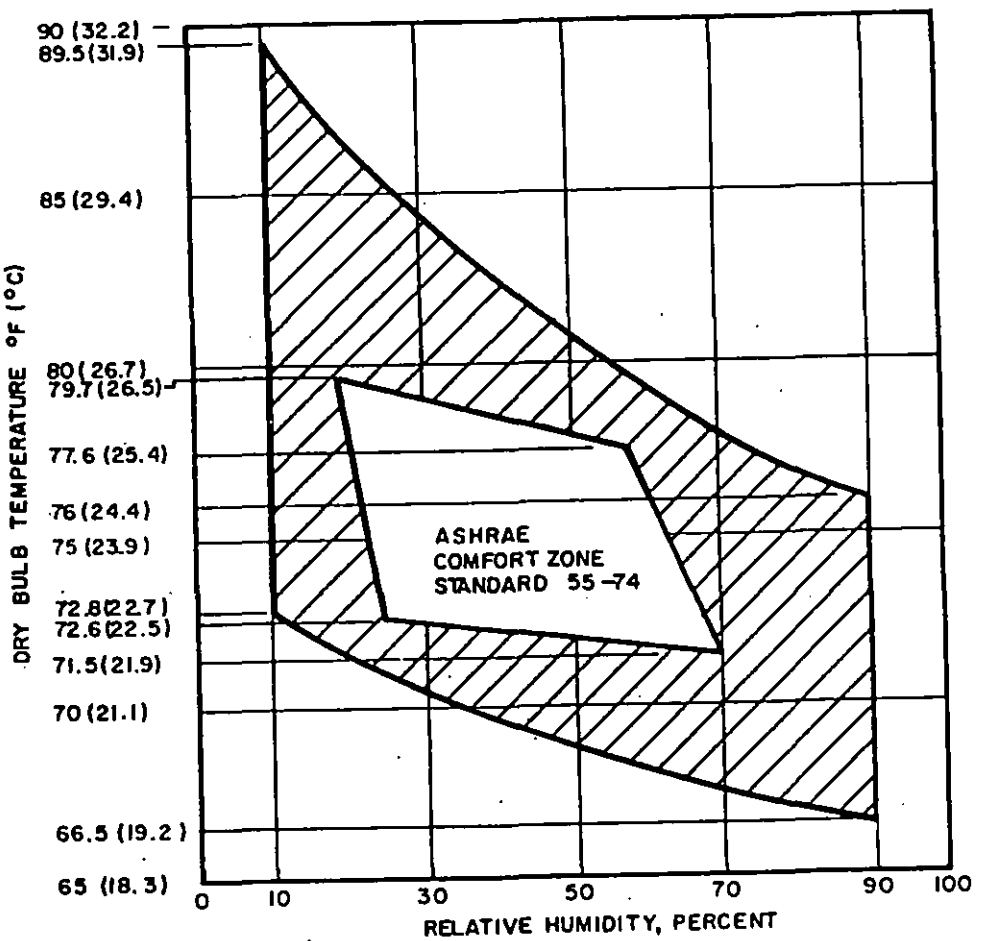


FIGURE A-5. Personnel Comfort Limits
(MIL-STD-1472)

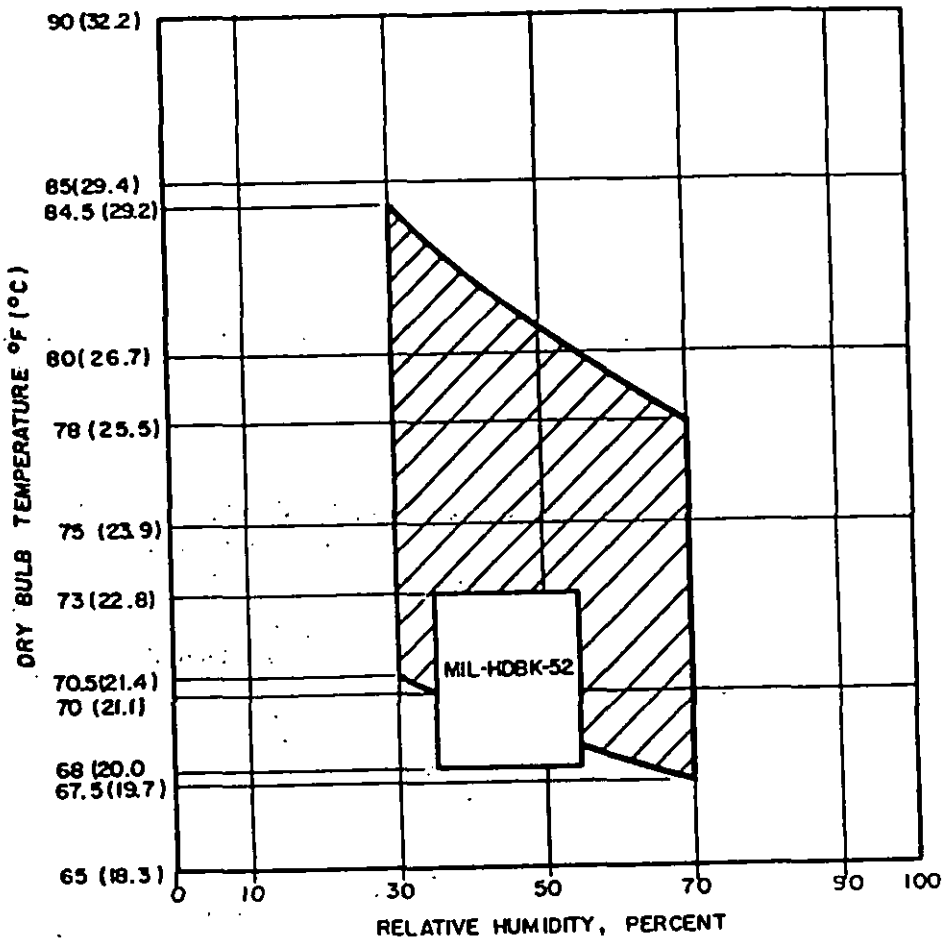


FIGURE A-6. Personnel Comfort Limits

(Modified to Account for Humidity Effects on Equipment and Work In-Process)

TABLE A-VII. Review of Provisions in "Minimum Standards for Working Environments"

Requirement: Air Temperature

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 1 Mechanical Fabrication		
Tolerance to 0.01 in (0.254 mm)	Note 11	a. Tolerance to 0.01 inch: This should be restricted to the comfort zone defined by Figure A-5.
Tolerance to 0.001 in (25.4 um)	Note 11	
Tolerance to 0.0001 in (2.54 um)	Note 12	b. Tolerance to 0.001 inch: This should be restricted to the comfort zone defined by Figure A-5.
Tolerance finer than 0.0001 in (2.54 um)	68-75.2°F (20-24°C)	c. Tolerance to 0.0001 inch. Humidity and static electricity can become problems at these tolerance limits. Air temperature should be restricted to the limits defined by Figure A-6.
		d. Tolerances finer than 0.0001 inch. For compatibility with both MIL-HDBK-52 and Fed-Std-209, the appropriate limits appear to be 68 to 75°F.
		e. Referenced Notes: Note 11 invokes Figure A-5, Note 12 invokes Figure A-6, Note 13 invokes Figure A-4 (applicable to Work Areas 2, 4, and 13).
Work Area 2 Foundry Operations		
Tolerance to 0.005 in (127 um)	Note 13	The type of work precludes rigid temperature controls.
Tolerance finer than 0.005 in (127 um)	Note 13	
Work Area 3 Plastics Operations	Note 11	Figure A-5, invoked by Note 11, represents the minimum requirements for areas where workmanship is a factor.
Work Are 4 Plating and Heat Treating	Note 13	The nature of the operations conducted in Work Area 4 do not require precise operator comfort, and normally preclude close temperature and humidity control. Work Area 4 is controlled in accordance with Figure A-4 by incorporating Note 13.
Work Area 5 Electronic Parts	Note 12	Electronic parts handling and assembly requires both operator comfort and restricted humidity limits. Note 12 invokes Figure A-6, which is appropriate.
Work Area 6 Hybrid Microcircuits	Note 12	Electronic parts handling and assembly requires both operator comfort and restricted humidity limits. Note 12 invokes Figure A-6, which is appropriate.
Work Area 7 Mechanical Assembly		
Tolerance to 0.05 in (1.27 mm)	Note 11	This work area is controlled to the same limits as Work Area 1.
Tolerance to 0.001 in (25.4 um)	Note 11	
Tolerance to 0.0001 in (2.54 um)	Note 12	
Tolerance finer than 0.0001 in (2.54 um)	68-75.2°F (20-24°C)	
Work Area 8 Inspection Areas	Equal to the type of work to be inspected.	Measurement requirements at inspection stations are equal to, or more stringent than, the requirements for fabrication or assembly operations. It is thus logical to require equivalent environmental requirements.
Work Area 9. Inert Chemical Component Preparation and Assembly	Note 11	Chemical processing is controlled to the same limits as Work Area 3.

TABLE A-VII. Review of Provisions in "Minimum Standards for Working Environments" (Continued)

Requirement: Air Temperature

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 10 Preparation, Mixing and Fabrication of Propellants, Pyrotechnics, and Explosives	Note 12	Pyrotechnics and explosives normally require close humidity control during mixing and processing. Thus, Figure A-6 invoked by Note 12, is most appropriate.
Work Area 11 Ordnance Assembly		
Tolerance to 0.05 in (1.27 mm)	Note 11	Personnel comfort and measurement precision are the same as for other mechanical assemblies, therefore the temperature requirements for Work Area 11 are the same as for Work Area 1.
Tolerance to 0.001 in (25.4 µm)	Note 11	
Tolerance to 0.0001 in (2.54 µm)	Note 12	
Tolerance finer than 0.0001 in (2.54 µm)	68-75.2°F (20-24°C)	
Work Area 12 Environmental Testing	Note 11	Close humidity control of completed assemblies is not normally required, therefore the comfort zone of Figure A-5, invoked by Note 11, is appropriate.
Work Area 13 Handling and Storage	Note 13	Handling and storage of properly covered and protected items is not subject to operator induced workmanship problems or to static electricity. Therefore, the requirements of Figure A-4, invoked by Note 13, appear most appropriate.

30.4 Relative humidity.

a. Requirement summary. Relative humidity requirements are based on the MIL-STD-1472 recommendations. For critical applications, where corrosion or static electricity can be a problem, the limits have been revised downward to 30 to 70 percent. Clean room humidity limits are based on MIL-HDBK-52 and Fed-Std-209 recommendations, while ordnance manufacturing requirements are based on the requirements of DoD 4145.26M.

b. Requirement source.

1. MIL-STD-1472

2. MIL-HDBK-52

3. Fed-Std-209

4. DoD 4145.26M

c. Analysis. Tables A-VIII and A-IX provide an analysis of the requirements with regard to humidity and pertinent comments regarding the requirements.

TABLE A-VIII. Review of Notes in "Minimum Standards for Working Environments"

Note: 6, Title: Relative Humidity

NOTE	COMMENTS AND JUSTIFICATION
Relative Humidity Designated relative humidity shall be as measured at room ambient temperature in proximity to the work stations during regular working hours.	Humidity controls are required for a variety of reasons (*References 2* and 12): a. Relative humidity directly affects operator comfort (see Figure A-5 for a definition of the "comfortable" temperature - humidity relationship). b. Rusting of parts can occur and become a serious problem at relative humidities above 50 percent. Hygroscopic particles that collect on surfaces can absorb enough moisture from the air to become starting points for corrosion pits and will adhere to surfaces more tenaciously than particles in low humidity environments. c. Electrical static charges on dielectric materials or parts can cause problems due to particle attraction at low relative humidities. Static charges can cause damage to a variety of electronic components. d. Low humidity dries the operator's skin, increasing the amount of skin scaling, flaking, and similar contamination generated by the operator. Although "high" and "low" are subjective terms when referring to relative humidity, References 13 and 14 provide data which indicate that static electricity generation becomes a consideration at relative humidities below 50 percent, and a major problem when handling many electronic components at relative humidities below 30 percent.

TABLE A-IX. Review of Provisions in "Minimum Standards for Working Environments"

Requirement: Relative Humidity

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 1 Mechanical Fabrication Tolerance to 0.01 in (0.254 mm)	10-90%	Humidity is controlled in accordance with Figures A-5, A-6, and MIL-HDBK-52.
Tolerance to 0.001 in (25.4 µm)	10-90%	
Tolerance to 0.0001 in (2.54 µm)	30-70%	
Tolerance finer than 0.0001 in (2.54 µm)	35-55%	
Work Area 2 Foundry Operations Tolerance to 0.005 in (127 µm)	>10%	Humidity controls do not appear to be applicable to this type of work. Humidity is controlled in accordance with Figure A-4.
Tolerance finer than 0.005 in (127 µm)	>10%	
Work Area 3 Plastics Operations	10-90%	Humidity is controlled in accordance with Figure A-5. Isolated cases where humidity is a consideration (such as use of RTV silicones) should be covered by process controls (see Note 1).
Work Area 4 Plating and Heat Treating	>10%	Humidity controls do not appear to be applicable to this type of work. Humidity is controlled in accordance with Figure A-4.
Work Area 5 Electronic Parts	30-70%	Electronic parts handling and assembly require humidity controls in accordance with Figure A-6 on the basis of both static electricity protection and protection from humidity caused corrosion.
Work Area 6 Hybrid Microcircuits	30-70%	Electronic parts handling and assembly require humidity controls in accordance with Figure A-6 on the basis of both static electricity protection and protection from humidity caused corrosion.
Work Area 7 Mechanical Assembly Tolerance to 0.05 in (1.27 mm)	10-90%	Requirements are the same as for Work Area 1.
Tolerance to 0.001 in (25.4 µm)	10-90%	
Tolerance to 0.0001 in (2.54 µm)	30-70%	
Tolerance finer than 0.0001 in (2.54 µm)	35-55%	
Work Area 8 Inspection Areas	Equal to the type of work to be inspected.	To prevent measurement errors, contamination, and resulting degradation, environmental requirements are equal to those required for the fabrication or assembly of the product.
Work Area 9 Inert Chemical Component Preparation and Assembly	10-90%	Requirements are the same as for Work Area 3.
Work Area 10 Preparation, Mixing and Fabrication of Propellants, Pyrotechnics, and Explosives	30-70%	Figure A-6, which is the applicable type of temperature control, permits relative humidity of 30 to 70%. Isolated cases where humidity should be controlled to tighter limits should be covered by process instructions (see Note 1).

TABLE A-IX. Review of Provisions in "Minimum Standards for Working Environments" (Continued)

Requirement: Relative Humidity

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 11		
Ordnance Assembly		
Tolerance to 0.05 in (1.27 mm)	10-90%	Temperature limits are in agreement with Work Area 1. The higher humidity levels effectively minimize the effects of static electricity. Grounding requirements prescribed by DoD 4145.26M minimize hazards from static electricity at low humidity levels. Isolated cases where humidity levels should be controlled to tighter limits should be covered by process instructions (see Note 1).
Tolerance to 0.001 in (25.4 µm)	10-90%	
Tolerance to 0.0001 in (2.54 µm)	30-70%	
Tolerance finer than 0.0001 in (2.54 µm)	35-55%	
Work Area 12		
Environmental Testing	10-90%	Requirement is in accordance with Figure A-5.
Work Area 13		
Handling and Storage	>10%	Requirement is in accordance with Figure A-4.

30.5 Dust control.

a. Requirement summary. Dust control is a companion requirement to cleanliness (see 30.1). Dust control requirements vary from no control for Class D cleanliness levels to clean room dust control requirements for Class A cleanliness levels. Dust control requirements for intermediate cleanliness levels have been selected to control airborne particulate matter in direct relation to the allowable product cleanliness classes.

b. Requirement source.

1. ASHRAE Standard 52-76[15]

2. Fed-Std-209

c. Analysis. Tables A-X, A-XI, A-XII and A-XIII provide an analysis of the requirements with regard to dust control and pertinent comments regarding the requirements.

TABLE A-X. Review of Notes in "Minimum Standards for Working Environments"

Note: 7, Title: Dust Control

NOTE	COMMENTS AND JUSTIFICATION
Dust Control Definition Class D - No dust control required. Class C - Outside and recirculated air shall be filtered to remove dust particles. Filter shall have a minimum arrestance of 65 percent in accordance with ASHRAE[1] Standard 52-76. Class B - Outside and recirculated air shall be filtered to remove dust particles. Filter shall have a minimum efficiency of 60 percent in accordance with ASHRAE Standard 52-76. Class A - Dust control shall be in accordance with Fed-Std-209, Class 100,000 as a minimum, unless otherwise specified in the contract or purchase order. [1]American Society of Heating, Refrigerating and Air-Conditioning Engineers.	Dust control is accomplished by filtering recirculated and make-up air to remove airborne particulate matter. Dust filters are grouped into five broad categories: Viscous fiber (common furnace filter) Viscous metal Dry (medium efficiency) Dry (high efficiency) High Efficiency Particulate Air (HEPA) Filters are evaluated through a variety of tests, primarily on the basis of the amount of particulate matter removed from an airstream. The more common tests are the synthetic dust test (ASHRAE Standard 52-76), the atmospheric dust test (ASHRAE Standard 52-76), and the DOP (dioctyl-phthalate) smoke test (MIL-STD-282, Method 102.9.1[16]). The matrix of Table A-XI illustrates typical performance of the various filters when evaluated by the three test methods (from Reference 17). In generalities, the synthetic dust test measures the ability of a filter to remove large particulate matter from the airstream (greater than 10 microns), the atmospheric dust test measures the ability to remove matter in the 1 to 10 micron range, and the DOP test measures the filter efficiency for removing particles of 0.3 micron diameter. Section 30.1 provides standards of cleanliness for various areas of a manufacturing facility. Dust control is intimately related to cleanliness. Referring to Figure A-1, and using MIL-STD-1246, Level 100 and Fed-Std-209, Class 100,000 (which requires a HEPA filter) as the clean room reference, filter requirements can be decreased as summarized in Table A-XII.

TABLE A-XI. Filter Performance

Type of Filter	Percentage of Particulate Matter Removed from Airstream		
	Arrestance (Synthetic Dust)	Efficiency (Atmospheric Dust)	Efficiency (DOP Smoke)
Viscous fiber	65–75	5–10	0–2
Viscous metal	70–75	3–8	0–2
Dry (med eff.)	100	60–70	50–60
Dry (high eff.)	100	78–88	70–85
HEPA	100	100	99.97 min

TABLE A-XII. Filter Ratings

MIL-STD-1246 Product Cleanliness Level	Table I Cleanliness Class	Assembly Tolerance Range (inches)	Machining Tolerance Range (inches)	Filter Type	Filter Rating (Minimum)	Applicable Dust Control Class
100	A	<0.0001	-	HEPA	99.97% (DOP Test)	A
150	BA	0.001 to 0.0001	<0.0001	Dry	60% (Efficiency)	B
500	B	0.05 to 0.001	0.001 to 0.0001	Viscous	65% (Arrestance)	C
2000	C	>0.05	>0.001	-	-	D

TABLE A-XIII. Review of Provisions in "Minimum Standards for Working Environments"

Requirement: Dust Control

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 1 Mechanical Fabrication		
Tolerance to 0.01 in (0.254 mm)	Class D	Dust control requirements selected in accordance with Table A-XII.
Tolerance to 0.001 in (25.4 µm)	Class D	
Tolerance to 0.0001 in (2.54 µm)	Class C	
Tolerance finer than 0.0001 in (2.54 µm)	Class B	
Work Area 2 Foundry Operations		
Tolerance to 0.005 in (127 µm)	Class D	Dust control requirements do not appear feasible for this work area.
Tolerance finer than 0.005 in (127 µm)	Class C	Because of the tolerances involved, minimal dust control is required. Class C requires air filtration, which is appropriate.
Work Area 3 Plastics Operations	Class C	Class B cleanliness requirements require Class C dust control (see Table A-XII).
Work Area 4 Plating and Heat Treating	Class C	Class C cleanliness requirements would normally require no dust control; however, since dust can severely degrade plating baths, minimum dust control is provided.
Work Area 5 Electronic Parts	Class C	Class B cleanliness requirements require Class C dust control (see Table A-XII).
Work Area 6 Hybrid Microcircuits	Class A	Hybrid microcircuits are highly susceptible to contamination during the fabrication process. Class A dust control is thus appropriate.
Work Area 7 Mechanical Assembly		
Tolerance to 0.05 in (1.27 mm)	Class D	Dust control requirements selected in accordance with Table A-XII.
Tolerance to 0.001 in (25.4 µm)	Class C	
Tolerance to 0.0001 in (2.54 µm)	Class B	
Tolerance finer than 0.0001 in (2.54 µm)	Class A	
Work Area 8 Inspection Areas	Equal to the type of work to be inspected.	To prevent contamination, inspection must be accomplished in an environment equal to or better than that required for the previous process or assembly step.
Work Area 9 Inert Chemical Component Preparation and Assembly	Class C	Requirements are similar to those for Work Area 3.
Work Area 10 Preparation, Mixing and Fabrication of Propellants, Pyrotechnics, and Explosives	Class B	Class BA cleanliness requirements require Class B dust control (see Table A-XII).
Work Area 11 Ordnance Assembly		
Tolerance to 0.05 in (1.27 mm)	Class D	Ordnance assembly is similar to mechanical assembly. Thus, the requirements for Work Area 11 are the same as for Work Area 7.
Tolerance to 0.001 in (25.4 µm)	Class C	
Tolerance to 0.0001 in (2.54 µm)	Class B	
Tolerance to 0.0001 in (2.54 µm)	Class A	

TABLE A-XIII. Review of Provisions in "Minimum Standards for Working Environments" (Continued)

Requirement: Dust Control

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 12 Environmental Testing	Class D	Class C requirements require no dust control (see Table A-XII).
Work Area 13 Handling and Storage	Class C	Class D cleanliness requirements would normally require no dust control, however to prevent transfer of dirt into clean areas, material being handled and stored should be protected from gross contamination. Class C dust control appears adequate.

30.6 Ventilation or exhaust.

a. Requirement summary. Ventilation requirements control air movement only to the extent that drafts are prevented and noxious or toxic fumes are exhausted. Compliance with the air temperature requirements provides an adequate level of ventilation.

b. Requirement source.

1. MIL-STD-1472

2. 1976 ASHRAE Systems Handbook[18]

c. Analysis. Tables A-XIV and A-XV provide an analysis of the requirements with regard to ventilation or exhaust and pertinent comments regarding the requirements.

TABLE A-XIV. Review of Notes in "Minimum Standards for Working Environments"

Note: 8, Title: Ventilation or Exhaust

NOTE	COMMENTS AND JUSTIFICATION
Ventilation or Exhaust Air velocity at the work station shall be maintained at a velocity of less than 90 ft/minute (0.46 m/s) regardless of the season. Additionally, forced ventilation or exhaust shall be provided in areas where operations such as parts cleaning, vapor degreasing, and machine soldering are being accomplished. The maximum air velocity requirement shall not apply in these areas. Work areas for mechanical assembly of tolerances finer than 0.0001 in (2.54 um) which utilize laminar flow benches shall maintain an air velocity of less than 110 ft/minute (0.56 m/s).	Ventilation is used to control levels of temperature, humidity, odor, and air motion to promote human comfort and to prevent hazardous conditions. Human comfort is defined in Figures A-5 and A-6. Ventilation requirements are automatically defined and controlled when the temperature and humidity requirements of Figures A-5 and A-6 are met. The only additional consideration is one of drafts. Personnel tolerance to drafts varies, both from person to person, and also as a function of the temperature differential between the impinging air and the average room temperature. MIL-STD-1472 recommends 65 fpm as a maximum, which agrees with the ASHRAE Systems Handbook recommendations for light work (50-75 fpm). These values have been relaxed to 90 ft/minute maximum to agree with the recommendations contained in Fed-Std-209. Forced ventilation or exhaust can cause this value to be exceeded; however, the safety aspects and improved comfort resulting from removal of the fumes appear to be an overriding consideration.

TABLE A-XV. Review of Provisions in "Minimum Standards for Working Environments"

Requirement: Ventilation or Exhaust

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
All	Note 8	Ventilation criteria, as defined in Note 8, are considered to be applicable for all inhabited work areas.

30.7 Noise.

a. Requirement summary. Noise limits have been established for all work areas. The least critical areas have been specified to agree with OSHA limits [19] (90 dBA). Permissible noise levels are reduced as required operator concentration and skill requirements are increased.

b. Requirement source.

Occupational Safety and Health Act.

c. Analysis. Tables A-XVI and A-XVII provide an analysis of the requirements with regard to noise and pertinent comments regarding the requirement.

TABLE A-XVI. Review of Notes in "Minimum Standards for Working Environments"

Note: 9, Title: Noise

NOTE	COMMENTS AND JUSTIFICATION
Noise Noise is defined as the average sound level existing at the work station during normal operation when measured with a standard sound-level meter as specified in ANSI[1] S1.4-1971, Type 2, "A" weighted. Work stations for control of automatic equipment operations, which require operator loading and unloading only, may exceed the noise limits specified by 10 dBA but not exceed 90 dBA. Inspection and test work stations shall not exceed the values specified. Work areas for mechanical assembly of tolerances finer than 0.0001 in (2.54 μm) which utilize laminar flow benches may exceed by 5 dBA the value specified. For environmental testing, when the specified limit is exceeded, ear protection shall be provided. [1]American National Standards Institute.	Noise control is required for personnel protection from hearing loss, from noise induced stress, and to increase productivity and decrease the error rate. Regulations regarding hearing conservation are defined in OSHA regulations (90 dBA for 8 hours exposure). Although not quantified through statistically validated test programs, the following benefits have been observed when noise has been controlled below the OSHA requirements: . Reduced error rate . Improved morale . Reduced incidences of physical and psychological disorder . Increased worker performance . Reduced accident rates . Reduced absenteeism . Reduced labor turnover Most of the studies have compared levels of approximately 80 dBA to levels above 90 dBA. A few have attempted to evaluate performance at levels below 80 dBA. Figures A-7 and A-8 illustrate results of two of the studies (References 20 and 21) which relate performance (in terms of error rate) with white noise levels from 50 to 90 dB. White noise levels (in dB) are numerically higher than the same noise measured in dBA, therefore, Figures A-7 and A-8 illustrate the effect of noise in the region of interest (levels below 90 dBA). One factor which appears to be most prevalent is the fact that random impulse type noise is more conducive to errors and reduced production than steady state noise. Unfortunately, no agreed-upon method for defining this type noise is available, nor are sufficient data available to define the intensity (above a steady state background) where the deleterious effects become evident. One quirk of human nature has become evident. Whereas an impulse of noise unrelated to the particular task is distracting, a task-related noise of the same intensity is not. A frequently cited example is that of the vacuum cleaner manufacturer who produced an essentially silent vacuum cleaner which he could not sell. Operators feel more confident and perform more efficiently when they can hear that their machine is performing properly. This brief discussion is essentially in agreement with a review of the available literature and an analysis of the alternatives and potential benefits of noise control below the OSHA requirements presented in Reference 22.

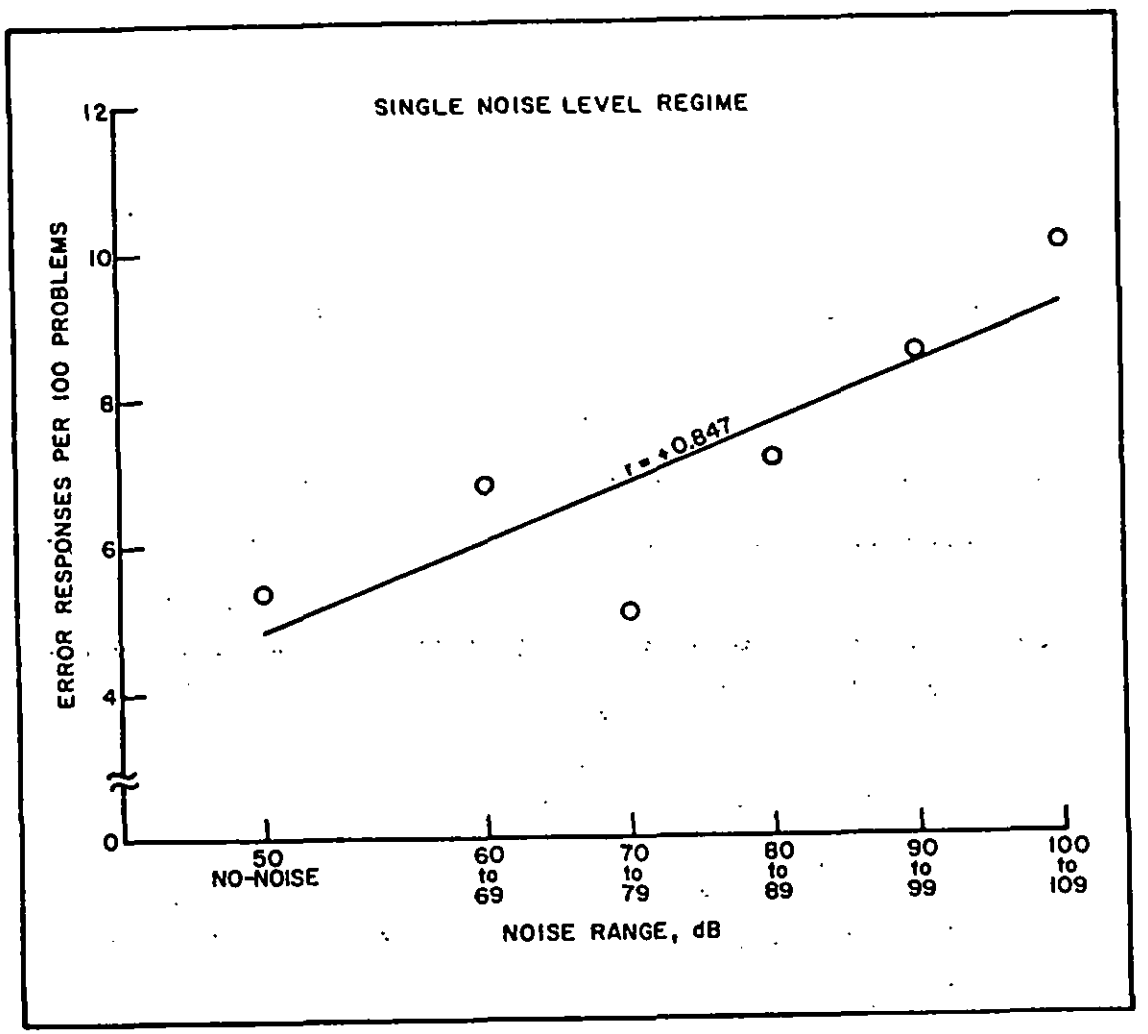
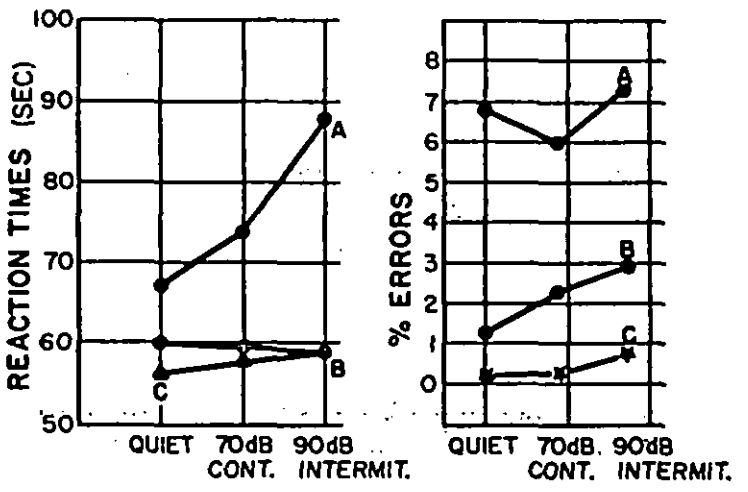


FIGURE A-7. Single Regression Analysis of Error Responses by Range of Noise Level



A-AN AUDITORY VIGILANCE TASK - THE MOST DIFFICULT ONE. S DISCRIMINATED A PURE TONE (400 Hz) AMONG 4 DIFFERENT TONES.

B-A WORD RECOGNITION TASK OF MEDIUM DIFFICULTY. S REACTED TO ONE TRIGRAM (DOC) AMONG 4 DIFFERENT TRIGRAMS.

C-AN EASY VISUAL AND AUDITORY REACTION TIME TASK. S REACTED TO A VISUAL AND AN AUDITORY STIMULUS AND DISCARDED ANOTHER VISUAL AND AUDITORY STIMULUS.

THE NOISE WAS THE SAME IN ALL 3 EXPERIMENTS: 70dB WHITE CONTINUOUS NOISE AND 90dB VARIED INTERMITTENT NOISE.

FIGURE A-8. Effects of Noise on Performance Level as a Function of Task Difficulty

TABLE A-XVII. Review of Provisions in "Minimum Standards for Working Environments"

Requirement: Noise

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 1 Mechanical Fabrication		
Tolerance to 0.01 in (0.254 mm)	90 dBA	Values have been selected, based on engineering judgements, to establish noise levels based on feasibility and potential for reducing operator errors.
Tolerance to 0.001 in (25.4 µm)	80 dBA	
Tolerance to 0.0001 in (2.54 µm)	80 dBA	
Tolerance finer than 0.0001 in (2.54 µm)	75 dBA	
Work Area 2 Foundry Operations		
Tolerance to 0.005 in (127 µm)	90 dBA	This work area judged to have little or no susceptibility to noise induced operator errors.
Tolerance finer than 0.005 in (127 µm)	80 dBA	This work area judged to be only partially susceptible to noise induced operator errors.
Work Area 3 Plastics Operations	80 dBA	Work Area 3 judged to be only partially susceptible to noise induced operator errors.
Work Area 4 Plating and Heat Treating	90 dBA	Work Area 4 judged to have little or no susceptibility to noise induced operator errors.
Work Area 5 Electronic Parts	75 dBA	Work Area 5 judged to be very susceptible to noise induced operator errors.
Work Area 6 Hybrid Microcircuits	70 dBA	Work Area 6 judged to be highly susceptible to noise induced operator errors.
Work Area 7 Mechanical Assembly		
Tolerance to 0.05 in (1.27 mm)	75 dBA	Work Area 7 judged to be more susceptible to noise induced operator errors than Work Area 1. An arbitrary reduction of 5 dB from the Work Area 1 levels has been specified. The maximum permitted has been limited to 75 dBA to permit adequate communication (from MIL-STD-1472).
Tolerance to 0.001 in (25.4 µm)	75 dBA	
Tolerance to 0.0001 in (2.54 µm)	75 dBA	
Tolerance finer than 0.0001 in (2.54 µm)	70 dBA	
Work Area 8 Inspection Areas	Equal to the type of work to be inspected.	Inspection judged to be equal in susceptibility to noise induced operator errors as the associated process or assembly operation.
Work Area 9 Inert Chemical Component Preparation and Assembly	80 dBA	Work Area 9 judged to be equivalent to Work Area 3.
Work Area 10 Preparation, Mixing and Fabrication of Propellants, Pyrotechnics, and Explosives	80 dBA	Work Area 10 judged to be equivalent to Work Area 3.

TABLE A-XVII. Review of Provisions in "Minimum Standards for Working Environments" (Continued)

Requirement: Noise

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 11 Ordnance Assembly		
Tolerance to 0.05 in (1.27 mm)	75 dBA	Work Area 11 judged to be equivalent to Work Area 7.
Tolerance to 0.001 in (25.4 μm)	75 dBA	
Tolerance to 0.0001 in (2.54 μm)	75 dBA	
Tolerance finer than 0.0001 in (2.54 μm)	70 dBA	
Work Area 12 Environmental Testing	90 dBA	Because of the nature of the work involved, more stringent controls are not feasible.
Work Area 13 Handling and Storage	90 dBA	Handling and storage of items in work judged to have little or no susceptibility to noise induced operator errors.

30.8 Habitat.

a. Requirement summary. Three levels of habitat are defined. The first is where no food, drink, or personal grooming are allowed: the second is where no food, drink, personal grooming, or smoking are allowed; and the third precludes the introduction of food, cosmetics, or smoking materials into the work area. Selection of the appropriate level is based on engineering judgments regarding the potential for contaminating work in-process.

b. Requirement source.

Fed-Std-209

c. Analysis. Tables A-XVIII and A-XIX provide an analysis of the requirements with regard to habitat and provide comments regarding the requirements.

TABLE A-XVIII. Review of Notes in "Minimum Standards for Working Environments"

NOTE: 10, Title: Habitat

NOTE	COMMENTS AND JUSTIFICATION
Habitat Class D - Uncontrolled Class C - No food, drink, or personal grooming material is allowed at these work stations. No eating, drinking, or personal grooming is allowed in the work area. Drinking fountains are permissible. Class B - No food, drink, personal grooming material, or smoking is allowed at these work stations. No eating, drinking, personal grooming or smoking is allowed in the work area. Drinking fountains are permissible. Class A - No food, drink, personal grooming material, or smoking material is allowed in these work areas. Drinking fountains are permissible.	Potential sources of contamination were reviewed to identify those likely to be encountered in an industrial environment, and which could be controlled by the operator. This was supplemented by on-site observation at a number of manufacturing facilities. These studies resulted in identifying food, drink, grooming, and smoking as the principal causes of operator induced contamination outside of a clean room environment. (In a clean room environment, bacteria, sneezing and coughing, skin flakes, etc., are also major causes of contamination.)

TABLE A-XIX. Review of Provisions in "Minimum Standards for Working Environments"

Requirement: Habitat

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 1 Mechanical Fabrication		
Tolerance to 0.01 in (0.254 mm)	Class D	Little possibility of detrimental contamination is anticipated at the rough machining operation.
Tolerance to 0.001 in (25.4 µm)	Class C	The remaining categories are increasingly more susceptible to contaminants; however, the machining operation is normally followed by a cleaning operation, thus Class A requirements are not justified.
Tolerance to 0.0001 in (2.54 µm)	Class C	
Tolerance finer than 0.0001 in (2.54 µm)	Class B	
Work Area 2 Foundry Operations		
Tolerance to 0.005 in (127 µm)	Class D	Little possibility of detrimental contamination is anticipated in these work areas.
Tolerance finer than 0.005 in (127 µm)	Class D	
Work Area 3 Plastics Operations	Class B	Employee safety requirements preclude eating, drinking, grooming, or smoking in the work area.
Work Area 4 Plating and Heat Treating	Class C	Employee safety requirements preclude eating, drinking, or grooming in the work area.
Work Area 5 Electronic Parts	Class B	Electronic parts and assemblies are susceptible to contamination from food and tobacco smoke; therefore, Class B requirements are appropriate.
Work Area 6 Hybrid Microcircuits	Class A	The extreme cleanliness requirements for this work area preclude the introduction of any unnecessary contaminants into the work area.
Work Area 7 Mechanical Assembly		
Tolerance to 0.05 in (1.27 mm)	Class D	As with Work Area 1, little possibility of detrimental contamination can be seen for the coarse assembly operation. The remaining categories are increasingly more susceptible to contamination and the assemblies will not necessarily be cleaned and degreased after assembly.
Tolerance to 0.001 in (25.4 µm)	Class C	
Tolerance to 0.0001 in (2.54 µm)	Class B	
Tolerance finer than 0.0001 in (2.54 µm)	Class A	
Work Area 8 Inspection Areas	Equal to the type of work to be inspected	Inspection operations judged to be equivalent in susceptibility to the process or assembly operation preceding the inspection operation.
Work Area 9 Inert Chemical Component Preparation and Assembly	Class B	Requirements judged to be the same as required for Work Area 3.
Work Area 10 Preparation, Mixing and Fabrication of Propellants, Pyrotechnics, and Explosives	Class B	Requirements judged to be the same as required for Work Area 3.

TABLE A-XIX. Review of Provisions in "Minimum Standards for Working Environments" (Continued)

Requirement: Habitat

WORK AREA	REQUIREMENT	COMMENTS AND JUSTIFICATION
Work Area 11 Ordnance Assembly		
Tolerance to 0.05 in (1.27 mm)	Class D	Requirements judged to be the same as required for Work Area 7. Smoking materials are prohibited at all times by DoD 4145.26M.
Tolerance to 0.001 in (25.4 µm)	Class C	
Tolerance to 0.0001 in (2.54 µm)	Class B	
Tolerance finer than 0.0001 in (2.54 µm)	Class A	
Work Area 12 Environmental Testing	Class C	Environmental testing usually involves end item testing or testing of units which will not be used in subsequent assembly. Thus, only minimal habitat requirements are appropriate.
Work Area 13 Handling and Storage	Class C	Handing and storage of items in work which are properly covered or protected normally would not require habitat restriction. However, to prevent the introduction of contaminants to clean areas, minimal controls are required. Class C habitat appears appropriate.

30.9 Additional considerations.

30.9.1 Reduced environmental limits. A number of instances can be envisioned where the provisions derived herein are not applicable, such as a need for reduced ambient lighting levels when using optical comparators, when using light-directed component insertion equipment, and when viewing TV monitors or X-ray films, and a need for restricted humidity levels when assembling thermal batteries. Some provision must be made to permit the supplier the freedom to develop alternate environmental limits when warranted for valid engineering reasons. Note 1 has thus been included, which reads as follows:

Note 1. "The requirements listed herein represent minimum requirements for normal manufacturing operations. Suppliers who are required to comply with the provisions herein and who may have special processes, such as X-ray, video displays or light directed component insertion equipment, etc., may develop reduced environmental limits under the following conditions:

a. A valid engineering requirement exists for the reduced limit, and

b. The reduced limits are documented (including the reasons therefor) and subject to control and audit in the same manner as the remaining requirements listed herein, and

c. Such revised environmental limits, the reasons therefor, and the manner of control are subject to approval of the Government contracting officer."

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