NOT MEASUREMENT SENSITIVE

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DEPARTMENT OF DEFENSE
DESIGN CRITERIA STANDARD

U.S. NAVY SURFACE SHIP
MACHINERY ARRANGEMENTS

AMSC N/A FSC 20GP

FOREWORD

1. This 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. The purpose of this standard is to outline design practices and criteria for use during the development of machinery systems arrangements throughout Pre-Milestone B design activities. Pre-Milestone B design activities are defined as the engineering activities that take place during Exploratory Design, Pre-Analysis of Alternatives studies, Analysis of Alternatives studies, Pre-Preliminary, Preliminary, and Contract Design phases of non-nuclear surface ship new acquisitions and conversions. The content contained herein was developed from active naval shipbuilding specifications, past design experience, and insight into in-service maintenance issues across the fleet. This standard acts as a baseline for surface ship (non-nuclear) machinery systems arrangements designs prepared by or for the Naval Sea Systems Command unless written exception is granted.

3. The need for standardized machinery systems arrangements design methods and procedures has become apparent as the Navy continues to move toward providing more efficient and time-constrained design solutions for highly capable, cost-effective warships.

4. To ensure a shipboard machinery system can be successfully integrated into a total ship system, it is necessary to develop and evaluate the general configuration of the machinery system as a whole early in the design process. This can only be accomplished by identifying the physical relationships among key machinery components that drive ship system design considerations across most other design disciplines: naval architecture, topside integration, space arrangements, signatures, system survivability, and human systems. This standard provides a set of rules and requirements that will be used to develop and evaluate machinery systems arrangement designs early, often, and with increasing levels of fidelity as the design progresses. This standard is broad in scope and provides design direction on:

a. Aligning machinery arrangements design functional responsibilities to the current defense acquisition framework; establishing technical product and artifact standards for each ship design phase (Exploratory Design, Pre-Analysis of Alternatives studies, Analysis of Alternatives studies, Pre-Preliminary, Preliminary, and Contract Design phases); and ascertaining the appropriate level of fidelity required to ensure design feasibility.

b. Establishing design practices that focus on product standardization, concurrently maintaining configuration control of multiple machinery arrangements design baselines, and a seamless electronic data exchange.

5. Comments, suggestions, or questions on this document should be addressed to: Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to commandstandards@navy mil, with the subject line "Document Comment". Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

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1. SCOPE

1.1 Scope. This standard provides design practices and criteria for U.S. Navy surface ship machinery arrangements.

1.2 Applicability. This standard is applicable to Pre-Milestone B design activities (Exploratory Design, Pre-Analysis of Alternatives studies, Analysis of Alternatives studies, Pre-Preliminary, Preliminary, and Contract Design phases) for non-nuclear surface ship new acquisitions and conversions.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

FEDERAL SPECIFICATIONS

RR-C-901 - Cylinders, Compressed Gas: Seamless Shatterproof, High Pressure DOT 3AA Steel, and 3AL Aluminum

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-S-901 - Shock Tests. H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for

MIL-DTL-22606 - Flask and End Plugs, Compressed Gas - Air, Oxygen and Nitrogen

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-777 - Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships

(Copies of these documents are available online at https://assist.dla.mil/quicksearch/.)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

NAVAL SEA SYSTEMS COMMAND (NAVSEA) DESIGN DATA SHEETS

DDS 200-1 - Calculation of Surface Ship Endurance Fuel Requirements

(Copies of this document are available by email at commandstandards@navy.mil with the subject line “DDS request”.)

NAVAL SEA SYSTEMS COMMAND (NAVSEA) DRAWINGS

593-7556875	-	Food Waste Disposer Interface Drawing for Food Waste Disposers
803-2145807	-	Propulsion Shafting and Components
803-6983515	-	Format, Contract and Contract Guidance Drawings
810-1385887	-	Water Trap for Diesel Exhaust

(Copies of these documents are available from the applicable repositories listed in S0005-AE-PRO-010/EDM online at https://nll.ahf.nmci navy mil or from the Naval Ships Engineering Drawing Repository (NSEDR) online at https://199.208.213.105/webjedmics/index.jsp. To request an NSEDR account for drawing access, send an email to NNSY_JEDMICS_NSEDR_HELP_DESK@navy.mil.)

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

S9593-C6-IIN-010	-	Shipboard Solid Waste Processing Equipment Basic Ship Installation Integration Package for Pulpers, Solid Waste Shredders, and Plastics Processors

(Copies of this document are available online at https://nll.ahf.nmci.navy mil. This publication can be located by searching the Navy Publications Index for the TMIN without the suffix.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASME INTERNATIONAL

ASME Y14.100	-	Engineering Drawing Practices

(Copies of this document are available online at www.asme.org.)

ASTM INTERNATIONAL

ASTM A167	-	Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
ASTM A240/A240M	-	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM B443	-	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip
ASTM B444	-	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625 and UNS N06852) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Pipe and Tube
ASTM F1166	-	Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities

(Copies of these documents are available online at www.astm.org.)

NATIONAL FIRE PROTECTION ASSOCIATION

NFPA 30 - Flammable and Combustible Liquids Code

(Copies of this document are available at http://www nfpa.org.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS AND ABBREVIATIONS

3.1 Definitions.

3.1.1 Access. The system of passageways and openings that provides the capability for personnel movement throughout the interior and exterior portions of the ship; in a more restrictive sense, an opening in a deck, bulkhead, or other boundary that permits personnel to transit from one compartment or area of the ship to an adjacent one. When used in the latter sense, an access allows both ingress and egress.

3.1.2 Accessible location. Located within a space that is convenient for operation.

3.1.3 Athwartship(s). Moving along the beam of a ship.

3.1.4 Cell. A unit consisting of positive and negative plates, separators, cell covers, and electrolyte, properly assembled in a single jar or one compartment of a monoblock case.

3.1.5 Central control station. A compartment, remote from the machinery spaces, equipped with facilities for centralized operation of propulsion, electrical and independent auxiliary machinery, and for the coordination of damage control functions.

3.1.6 Centralized control. Control of multiple functions, processes, equipment, or systems from a central control location.

3.1.7 Chimney spaces. Chimney spaces are spaces that pose a fire risk to the vessel. Chimney spaces are multi-level, unmanned, and unmonitored spaces that are difficult to access. They are either ventilated or open to the atmosphere and have sufficient horizontal space for material stowage. Examples of chimney spaces that are of concern for machinery arrangements are uptake spaces, auxiliary boiler intake and ventilation or exhaust trunks, and incinerator exhaust routes. Access trunks and escape trunks are not considered as fire risk chimneys because they can be easily entered and inspected. Engine intakes, intake plenums, ventilation trunks, and stacks are not considered as fire risk chimneys because they do not have convenient room for stowage.

3.1.8 Combustible liquid. Any liquid that has a flash point at or above 100 °F as defined by NFPA 30. Class II liquids are any liquid that has a flash point at or above 100 °F and below 140 °F. Class IIIA liquids are any liquid that has a flash point at or above 140 °F and below 200 °F. Class IIIB liquids are any liquid that has a flash point at or above 200 °F.

3.1.9 Control. The action by which human operator or machine generated commands are implemented to regulate, govern, or direct the performance of machinery or systems. Control can be classified by type as either automatic or manual and by location as either remote or local.

3.1.10 Cylinder. A cylindrical container in accordance with RR-C-901 for use in storing compressed gases.

3.1.11 Emergency access. A route or opening intended to be used by personnel to escape or circumvent hazardous conditions or for damage control purposes. A normal access may also serve as an emergency access.

3.1.12 Enclosed operating station. An enclosed station located within a machinery space. An enclosed operating station (EOS) is equipped with facilities for centralized operation of propulsion, electrical, and independent auxiliary machinery located in that space and, to a limited extent, machinery located in other machinery spaces.

3.1.13 Firemain architecture. The overall arrangement of pumps, risers, mains, cross connections, and valves. A single main system may be provided for frigates and small ships; the single main will be located centrally in the ship for protection, and may transit through machinery space upper levels. The most common firemain architecture is the vertically offset loop, in which there are port and starboard mains offset by at least two decks. The lower main may transit through machinery space upper levels. In the vertically offset loop architecture, it is common for the pump risers to connect to an athwartship pipe in the space with the pumps, which in turn will connect to the port and starboard mains via risers. The athwartship pipe will often have two or three motor operated valves in it to permit the fire pumps to discharge to either side in combination or singly.

3.1.14 Flammable fluid. A liquid which has a flash point that does not exceed 100 °F, as defined by NFPA 30.

3.1.15 Flasks. A cylindrical container conforming to MIL-DTL-22606 for use in storing compressed gases. Generally, flasks are larger than cylinders.

3.1.16 Fuel service tanks. Fuel tanks that receive clean fuel from the fuel transfer system for delivery to the fuel service system.

3.1.17 Hot surface. A surface which can ignite fuel or create a personnel burn hazard. Surfaces which can ignite fuel are insulated and separated from fuel. Any hot surface should be insulated so the exterior temperature is limited to 52 °C (125 °F) to mitigate the personnel burn hazard.

3.1.18 Inconel. A Nickel-Chromium-Iron (Ni-Cr-Fe) alloy.

3.1.19 Local control. Control of equipment, machinery, or systems by manual or automatic means from a location near the machinery being controlled.

3.1.20 Locked space. Any space requiring a lock, excluding those spaces which are manned.

3.1.21 Loop system. Two single mains cross-connected at both ends, with maximum possible physical separation between mains.

3.1.22 Machinery plant. The propulsion plants, independent auxiliary plants, independent auxiliaries, and equipment with supporting piping, electrical, and control systems required for the ship.

3.1.23 Manned space. A space manned by watch standers during normal underway steaming.

3.1.24 Masker air system. A bleed air system that uses compressed air generated by propulsion and power generation gas turbine engines to attenuate vibration and noise transmissions from the hull. Bleed air passes through a masker air cooler to three masker air emitter rings (masker belts) on the hull. Small holes in the masker belts release the masker air into the sea, coating the hull with air bubbles to reduce (mask) the ship's noise signature.

3.1.25 Monitoring. Surveillance carried out by sensors for interpretation by watch standers or automatic systems, or both.

3.1.26 Normal access. A route or opening that provides a convenient means of access to a compartment or area of the ship and is intended to be used by personnel under normal conditions.

3.1.27 Oily waste holding tank. A holding tank that receives oily waste drainage from bilge wells and drain tanks via oily waste transfer pumps for processing by the oil water separators or off loading to shore facilities.

3.1.28 Passage. A compartment specifically dedicated to providing access.

3.1.29 Passageway. The volume within a passage or in the weather which must be kept clear of obstructions or protrusions to allow unrestricted access.

3.1.30 Prairie air system. A bleed air system that uses compressed air generated by propulsion and power generation gas turbine engines to disguise the noise signature radiated by the ship's propellers. Air from the bleed air manifold passes through prairie air coolers to a connection on the forward end of the propulsion shaft. This air passes through the propulsion shaft to the propeller, where it is emitted from small holes in the propeller blades.

3.1.31 Propulsion auxiliaries. Those auxiliaries directly associated with a propulsion plant, which perform functions essential to the operation of the propulsion plant.

3.1.32 Propulsion plant. The propulsion unit, propulsion auxiliaries, associated equipment, control systems, piping systems, and electrical systems that are required to drive one propeller.

3.1.33 Propulsion unit. The machinery and equipment that are mechanically, electrically, or hydraulically connected to a propulsion shaft.

3.1.34 Remote control. Control of equipment, machinery, or systems from a location remote from the operating machinery.

3.1.35 Sewage. The liquid waste discharge from water closets and urinals.

3.1.36 Stack. A casing external to the combustion exhaust systems above the weather deck which supports and protects them.

3.1.37 Subsystem. Any portion of a system that can be identified by special service or function.

3.1.38 System. All equipment, piping, and components described by and included on a fluid system diagram.

3.1.39 Tray. One or more cells assembled in a common container or monobloc case.

3.1.40 Uptake. The ductwork or piping of a system which conducts combustion exhaust gases from engines to the atmosphere.

3.1.41 Uptake space. The space which is separated from ship compartments and passageways by appropriate structure and which is reserved primarily for the run of uptakes between the machinery room and the base of the stack.

3.1.42 V-lines. The highest water levels that can be expected (including wave action and rolling effects) after resultant flooding from damage which the ship is required to be capable of surviving. There are two types of V-lines: FWL-I and FWL-II. FWL-I is the highest water level that can be expected on any particular main transverse watertight bulkhead when that bulkhead serves as a confining boundary to flooding which the ship is required to be capable of surviving. FWL-II is the highest water level that can be expected above the bulkhead deck at any particular watertight subdivision after flooding which the ship is required to be capable of surviving occurs anywhere outside that subdivision.

3.1.43 Ventilation. The movement of air from the weather into the ship or from the ship out to the weather by supply fans, exhaust fans, ductwork, or a combination thereof.

3.1.44 Vital spaces. Vital spaces are those in which continued operation is essential for maintaining ship control, propulsion, communications, seaworthiness, and primary mission capability. Primary mission capabilities for naval vessels are defined by the Naval Administration in the operational requirements documentation for each ship class. Vital spaces also achieve survivability requirements in accordance with survivability policies for U.S. Navy ships.

3.1.45 Vital system. A piping system or that portion thereof whose continual operation is essential for maintaining ships control, propulsion, communications, seaworthiness, and firefighting capability, or is required to meet Grade A shock capabilities as defined in MIL-S-901.

3.1.46 Watch station. A designated and preselected location where personnel are assigned on a regular basis to accomplish predetermined functions in an alert and attentive way.

3.1.47 Waste water. The liquid waste discharged from any plumbing system fixture or appurtenance which does not receive sewage, for example: sinks, lavatories, showers, laundries, galleys, and sculleries.

3.1.48 Workshops. Dedicated spaces or areas in which servicing, repairing, checking, and operational testing of ship's hull, mechanical and electrical (HM&E) and other systems and equipment are performed.

3.2 Abbreviations.

3.2.1 AFFF. Aqueous Film Forming Foam.

3.2.2 AMR. Auxiliary Machinery Room.

3.2.3 AR. Aspect Ratio.

3.2.4 CCS. Central Control Station.

3.2.5 CFM. Cubic Feet per Minute.

3.2.6 CHT. Collecting, Holding, and Transfer.

3.2.7 DDS. Design Data Sheets.

3.2.8 DFM. Diesel Fuel Marine (NATO designation: F-76).

3.2.9 EOS. Enclosed Operating Station.

3.2.10 FW. Fresh Water.

3.2.11 HFP. Heptafluoropropane.

3.2.12 HVAC. Heating, Ventilation, and Air Conditioning.

3.2.13 IRS. Infra-Red Suppression.

3.2.14 MGT. Marine Gas Turbine.

3.2.15 MMR. Main Machinery Room.

3.2.16 PKP. Purple Potassium Bicarbonate Powder.

3.2.17 PSI. Pounds per Square Inch.

3.2.18 ROM. Rough Order of Magnitude.

3.2.19 RR. Radius Ratio.

4. GENERAL REQUIREMENTS

4.1 General shipboard machinery arrangements design requirements. This section covers general aspects of machinery arrangements design.

4.1.1 Vital machinery spaces. Vital spaces are those in which continued operation is essential for maintaining ship control, propulsion, communications, seaworthiness, and primary mission capability. Vital space boundaries shall provide protection from fumes, fire, and flooding in order to assure continued operation of equipment and protection of personnel. Vital spaces shall not be located adjacent to storerooms for hazardous materials.

4.1.1.1 Flooding water levels. Vital spaces entirely or partially below the flooding water levels (V-lines) shall have watertight boundaries. Vital spaces entirely above the V-lines shall have airtight boundaries, except where one or more boundaries are required to be watertight or oil-tight for other purposes.

4.1.1.2 Vital space staffing. Vital spaces, except fan rooms, and electronic cooling equipment rooms, are considered staffed.

4.1.1.3 Vital spaces. A partial list of vital spaces that shall be considered during machinery arrangements design development includes:

a. Air conditioning machinery rooms.

b. Auxiliary machinery rooms.

c. Central control station.

d. Cooling water machinery rooms.

e. Damage control central.

f. Degaussing control rooms.

g. Electronic control and electrical equipment rooms.

h. Emergency generator rooms.

i. Enclosed operating stations.

j. Fan rooms, air conditioning machinery rooms, cooling water machinery rooms, and other spaces containing ancillary equipment serving essential equipment in vital spaces.

k. IC and gyro rooms.

l. Main machinery rooms.

m. Other machinery spaces containing equipment that serves essential equipment in vital spaces.

n. Pump rooms.

o. Shaft alleys.

p. Steering gear rooms.

4.1.2 Access to equipment and machinery. Systems, equipment, and components shall be installed to facilitate accessibility for efficient operation, inspection, adjustment, maintenance repair, replacement, and removal.

4.1.2.1 Maintenance space. Work area and space shall be provided to enable the disassembly, repair, test, and checkout of systems and equipment to be repaired in place without dismantling other machinery, piping, or structure.

4.1.2.2 Access to equipment. Access to equipment shall permit maintenance and operation by a person within the female 5th through the male 95th percentile range of the anthropometric data as defined in ASTM F1166 and shall permit the movement and positioning of portable tools and test and support equipment required to perform maintenance and operational tasks.

4.1.2.3 Component accessibility. Pipes, ducts, wire ways, and other permanent fittings shall not be installed in the space that will be inaccessible behind deck-mounted front-serviced electric and electronic equipment mounted adjacent to bulkheads, or which prevents accessibility to equipment or its foundations.

4.1.2.4 Machinery space walkways. Walkways that interfere with such access shall be made portable. Permanent fittings and structures shall be kept clear of routes required for the removal of machinery and equipment.

4.1.2.5 Equipment and machinery location. For surface ships, handling and lifting gear for equipment and machinery shall be located so that onboard repair parts can be installed or removed without interference with the ship's structure or other machinery.

4.1.2.6 Underway maintenance. Maintenance that must be accomplished underway shall not require disassembly of other components of systems necessary for propulsion.

4.1.3 Machinery access routes. Access routes that identify prearranged paths of egress and ingress for movement of equipment shall be established.

4.1.3.1 Sizes of hatches and doors. Without exceeding the size limitations, hatches and doors affording access to machinery spaces, electronic spaces, electrical equipment rooms, and shops shall be large enough to permit the removal of the line replaceable units of shop equipment, electronic equipment, switchboard units, and machinery items. See 4.1.3.3 for shop equipment, electronic equipment, switchboard units, and machinery items that are difficult or impractical to disassemble.

4.1.3.2 Access routes. Where equipment is to pass through passages, plates, doors, or hatches, the removal route shall be arranged to be clear of structure, piping, wire ways, ducts, and other obstructions. Where interference is unavoidable, provisions shall be made for its rapid and convenient takedown to clear the access routes. Where the size of items or components to be shipped or unshipped exceeds acceptable door or hatch sizes, certain areas shall be arranged to be clear of piping, wire ways, ducts, and other obstructions so that structure can be readily removed and components can be shipped or unshipped.

4.1.3.3 Equipment removal plates. Equipment removal plates (patches) shall be provided along removal routes to permit passage of any equipment which cannot pass through hatches, doors, or arches. The size, quantity, and location of equipment removal plates along access routes shall be based on the equipment utilizing the removal route. The type of equipment removal plates located along the access routes shall be determined based on the frequency of repair (see table I).

TABLE I. Equipment removal plates.

Frequency of Access	Access Plate or Closure Type
Less than 2 years	Hatch or Door
2 to 6 years	Bolted Equipment Removal Plate (BERP)
Longer than 6 years	Welded Equipment Removal Plate (WERP)

4.1.3.4 Equipment removal and replacement duration. No item of equipment designated for removal, intact or in modules, through hatches or doors shall require more than 48 hours for removal and replacement. Items designated for removal through a BERP or WERP are allowed 80 hours for removal and replacement, exclusive of time required to prepare the WERP for use.

4.1.3.5 Gas turbine removal and replacement duration. For gas turbine propulsion and power generation applications, the gas generator and power turbine shall be removed and replaced from the ship (through the combustion air inlet duct if necessary) within 48 hours.

4.1.4 Bilge region. The design of machinery, systems, and equipment in machinery spaces shall be such that continued operation thereof will not be affected when the bilge regions are flooded. Machinery, equipment, or material which would be damaged by bilge water shall not be installed in such regions unless it can be suitably protected from the bilge water. The bilge region is defined as follows:

a. For surface ships, the term “bilge region” means the volume below the lowest level of floor plating in the main machinery rooms, auxiliary machinery rooms, and pump rooms, plus an additional volume. The additional volume is the volume, port, and starboard, bounded by the outer boundary, the lowest level of floor plating, and a plane extending upward and outward from the lowest level of floor plating, at a 45-degree angle, spanning the length of the space.

b. Measurements of plane: The plane begins at a variable distance inboard of the outboard boundary measured at the maximum space width at the lowest floor plating level. The distance shall be 915 millimeters (36 inches) when this width is less than 9144 millimeters (360 inches); 1220 millimeters (48 inches) where the width is 9144 millimeters (360 inches) or greater but less than 12192 millimeters (480 inches); 1524 millimeters (60 inches) where the width is 12192 millimeters (480 inches) or greater but less than 18288 millimeters (720 inches); and 2134 millimeters (84 inches) where the width is 18288 millimeters (720 inches) or greater.

c. Local recessed floor plating areas: In applying these criteria, local recessed floor plating areas constituting less than half of the area of the compartment shall be omitted in determining the level of the lowest floor plating.

d. Bilge height: The minimum height of the top of the bilge area shall be uniform throughout the compartment. The bilge region shall not extend above the next level above the lowest floor plating level.

4.1.5 Arrangement of rotating machinery. Rotating machinery shall be installed with the axis of rotation horizontal and parallel to the centerline of the ship as practicable unless the machinery is designed specifically for vertical or athwartship axis rotation.

4.1.6 Protection of personnel in machinery spaces. Protection of personnel against operating hazards shall be considered during machinery arrangements design development.

4.1.6.1 Safety guards. Space shall be allocated for guards that provide personnel protection around shafting, couplings, gears, flexible shafts, and similar items. Guards fitted on parts requiring frequent attention shall account for access provisions (door swings, cover pull envelopes, or other ready means for access).

4.1.7 Protection of machinery and equipment. During the development of a machinery arrangements design, provisions shall be made to protect equipment from the hazards of personnel brushing against or being thrown against the equipment (particularly under heavy sea conditions) and inadvertently causing damage to exposed components or the maladjustment of exposed functional controls. Protection of equipment shall be provided by equipment arrangement or by installation of enclosures, screens, or guardrails. The protective method chosen shall not hamper equipment access required for normal operation and maintenance.

4.1.8 Machinery space access. A familiarity with shipboard access requirements will help the machinery arrangements designer understand the overall ship system design considerations. Access requirements that are applicable to machinery arrangements are as follows (see 4.1.8.1 to 4.1.8.8).

4.1.8.1 Normal and emergency access. Each Main Machinery Room (MMR) and large Auxiliary Machinery Room (AMR) shall have at least one normal access route and at least one separate emergency access route. Large AMRs are those spanning multiple decks, extending the entire length of the major watertight subdivision that houses them, or are classed as vital spaces (see 4.1.1.3). Normal access shall be via a watertight access route from the damage control deck to the machinery space. Emergency access for machinery spaces shall be provided via a trunk leading from the floor plates at the lowest operating level of the space to an exit point above the FWL-II (see 3.1.42). The trunk shall be of fume-tight construction within the machinery space and of watertight construction outside it. The trunk shall be insulated from the machinery space with fire insulation, and the net interior dimensions shall be a minimum of 1.2 by 1.2 meters (48 by 48 inches) in size. A means for quick access to the emergency access location on the lowest operating level from the uppermost level of the machinery space shall be provided to facilitate evacuation of personnel in an emergency.

4.1.8.2 Vital machinery space access routes. For vital machinery spaces outside the watertight envelope, access routes shall be separated by construction that is at least fume-tight, or means shall be provided to prevent both routes from being blocked by smoke or toxic fumes from a single fire outside the space. For vital machinery spaces within the watertight envelope of the ship, the two means of escape shall, without compromising watertight integrity, access different routes separated by watertight construction.

4.1.8.3 Machinery space access. Each staffed vital machinery space partially or completely below the V-lines (FWL-I or FWL-II) shall be provided with a watertight access route to a location above the FWL-II (see 3.1.42). If this would require that a trunk be extended above the weather deck, the trunk shall be terminated at the weather deck. For surface ships built with side protective systems, the bulkhead deck shall be referenced in place of V-lines.

4.1.8.4 Single trunk. Several vital machinery spaces may be served by a single trunk unless a combined trunk is prohibited elsewhere.

4.1.8.5 Watertight trunk. Non-vital machinery spaces shall not be provided with access into watertight trunks serving vital spaces.

4.1.8.6 Vital machinery spaces below the bulkhead deck. Staffed vital machinery spaces directly below the bulkhead deck shall be provided with an access in the overhead.

4.1.8.7 Hangar access. Any machinery space staffed during normal operations with access from a hangar on non-aviation ships shall have a separate emergency access route to allow escape other than into the hangar.

4.1.8.8 Enclosed operating stations. Enclosed operating stations having normal access via a main machinery space shall be provided with an escape route that does not lead through the machinery space or is part of the machinery space's emergency access route.

4.1.8.9 Switchboard rooms. Switchboard rooms shall be provided with an emergency access to a deck other than the one on which the normal access is located.

4.1.8.10 Escape through joiner bulkheads. Where a secondary means of escape is required in joiner bulkheads but cannot otherwise be provided by a door, an escape panel shall be installed. Escape panels shall not be obstructed by furniture, fixtures, or other items.

4.1.8.11 Headroom. The unobstructed headroom in machinery space walking areas and access ways shall be not less than 1956 millimeters (77 inches). Headroom in walking and working areas shall permit normal operations required in the space without undue interference caused by striking objects overhead. Lighting fixtures, ventilation ducts, piping, and wiring shall be installed as close to the overhead as practicable.

4.1.8.12 Access way obstructions. Whenever possible, machinery, piping, operating rods, brackets, trolley tracks, and other items that restrict passage or are a source of danger to personnel shall be kept clear of normal routes of access.

4.1.8.13 Access way width. Access way width is measured as a maximum continued width that shall remain clear of any equipment obstructions. Access way allocations within machinery spaces shall be provided as follows:

a. The access way width required for normal two-way traffic within a machinery space or any means of egress that leads to an exit or entrance shall be at least 915 millimeters (36 inches).

b. All other access ways within machinery spaces shall be at least 610 millimeters (24 inches).

4.1.8.14 Minimum machinery space working clearances. The minimum machinery space working clearances shall be considered when determining the adequacy of equipment access space (see table II).

TABLE II. Minimum machinery space working clearances.

Maintenance Posture	Light Clothing	Bulky Clothing
	mm (inches)	mm (inches)
Minimum height allowance for standing	1960 (77)	1981 (78)
Minimum height allowance for crawling	788 (31)	864 (34)
Maximum depth of objects which must be reached into	584 (23)	534 (21)
Minimum width allowance for passing body	584 (23)	686 (27)
Minimum thickness allowance for passing body	330 (13)	410 (16)
Minimum height allowance for bending or kneeling	1220 (48)	1270 (50)

4.1.9 Protection of machinery from weapons effects. The survivability of machinery systems from weapons effects is determined by the functional design of the system and by the location of the system components. The functional design of the system components determines whether or not redundant portions of a system are vulnerable to a single weapon hit. For a system without any redundancy, the location of components determines the vulnerability, or target size, of the system.

4.1.9.1 Vital machinery systems. The following machinery systems are considered vital:

a. Mobility systems: propulsion, steering, and associated control systems.

b. Firefighting systems: the fire main and fire pumps, Aqueous Film Forming Foam (AFFF), magazine sprinkling, water mist, heptafluoropropane (HFP), and other installed firefighting systems.

c. Hull, mechanical, and electrical support systems: all systems required to support the combat systems, the mobility systems, and firefighting systems.

4.1.9.2 Functionally redundant systems. Where functionally redundant sources are installed in separate compartments, the system shall be installed such that the vital service can be supplied to the user after the loss of any sources located in a single compartment. Where functionally redundant distributive systems are installed, the system shall be installed such that the vital service can be supplied after the loss of a single redundant segment of the distributive system and shall not be interdependent.

4.1.9.3 Example of a functionally redundant system. An example of a functionally redundant system is as follows: one ship service switchboard and the power distribution system from that switchboard to a vital load would be “normal”; another ship service switchboard and the power distribution system from that switchboard to a vital load would be “alternate”. The “normal” and “alternate” systems are functionally redundant.

4.1.9.4 Distributive systems. Distributive systems shall be installed so that each functionally redundant segment is separated from other functionally redundant segments. The separation requirements are defined in 4.1.9.5.

4.1.9.5 Separation requirements. Where functionally redundant distributive system runs are installed in the fore and aft direction, they shall be separated athwartship and vertically. The athwartship separation shall be achieved by installing port and starboard runs. The runs shall be located at a distance not to exceed 1829 millimeters (72 inches) from the most outboard structure (2439 millimeters (96 inches) from curved structure) on the respective sides of the ship. Distance from the outboard structure shall be measured normal to the centerline and parallel to the baseline from the inboard side of the plating to the centerline of the pipe or cable.

4.1.9.6 Piping in electronic spaces. For water piping in electronic spaces, piping shall be inboard of and within 915 millimeters (36 inches) of the most outboard bulkhead that is the boundary between a heated portion of the ship and the unheated portion of the ship.

4.1.9.7 Separation of distributive systems. Vertical separation of distributive systems shall be achieved by separating the port and starboard runs by at least two decks. Where two deck separation is not possible due to ship geometry, a minimum of one deck separation shall be provided. When the lower runs pass through a machinery space, it is not necessary to change the height of the run to maintain the two deck separation. In such a case, the runs may stay at the same height as they are in adjacent spaces. Distributive systems routing through tanks should be avoided whenever possible due to the potential for cross-contamination following failures, complications with identifying the location of failures, and difficulty with making repairs. Fuel piping shall not be routed through tanks adjacent to the skin of the ship.

4.1.9.8 Redundant distributive system runs. Redundant distributive system runs shall come together at the user that they supply. The distributive system runs to the user from the distributive system main shall meet the separation requirements (see 4.1.9.7 to 4.1.9.11) before the distributive runs travel a direct horizontal distance of 19 meters (60 feet) or a vertical distance of one deck level to the user, measured from the user.

4.1.9.9 Separation of functionally redundant distributive system runs. Where functionally redundant distributive system runs are installed in the vertical or athwartship direction, they shall be separated longitudinally by a distance of at least 20 meters (65 feet) in the hull and 13 meters (40 feet) in the superstructure.

4.1.9.10 Distributive subsystem enclaving. The distributive system runs for all of the subsystems that comprise one redundant segment of the total system shall be located together wherever practical. The word “together” is intended to mean physically located as close as practical and wherever possible distributive runs shall not be located in more watertight compartments than are absolutely necessary. The distributive system runs for all of the subsystems that comprise another redundant segment shall be located together wherever practical.

4.1.9.11 Vital component location. Where there is no redundancy in the system, vital components are non-redundant and each vital system component is required for the system to function. Vital components that are functionally non-redundant shall be located in the same compartment, whenever practical, and as close together as practical.

4.1.9.12 Power panel location. Power panels serving non-redundant, vital equipment shall be located in the same compartment as the equipment they service and as close as practical to the equipment they serve.

4.1.9.13 Vital component interconnections. All piping, cabling, or other interconnections between vital components that are functionally non-redundant shall be run in as direct an orthogonal route as practicable between the components.

4.1.9.14 Vital components located in the same compartment. Where vital components that are functionally non-redundant are located in the same compartment, the piping, cabling, or other interconnections between them shall be contained within the same compartment that contains the vital components.

4.1.9.15 Non-redundant, vital distributive system runs. Non-redundant, vital distributive system runs shall be within 3048 millimeters (120 inches) of the centerline of the ship and not closer than 3048 millimeters (120 inches) to the weather (except where the run must deviate from this to connect to equipment served).

4.1.9.16 Cable runs. The location of any power cable runs and control signal runs for remote operated valves or other remote operated actuators in vital systems shall be considered in determining the survivability of a complete vital system.

4.1.10 Shock considerations for machinery. Of importance to the machinery arrangements designer is the type of mounting system to be used for the various equipment, the excursions expected under shock conditions, and the impact of these items on the allowable locations and required space envelopes for the various components.

4.1.10.1 Design blast considerations. Under design blast criteria, the side shell may be expected to deform inward a certain estimated amount without structural failure. This will vary with each structural design. Examples of designs that account for this type of weapon effect include those with a peripheral Vertical Launch System (PVLS) or a system of tanks in layers is installed as part of a side protection system outboard of the machinery spaces. All machinery, vital piping, and equipment shall be kept clear of the deformation line estimated by the cognizant subsystem design team.

4.1.11 Noise and vibration. Of specific importance to the machinery arrangements designer is the impact of the noise and vibration reduction methods on the envelope required for the various systems and equipment. Space and weight allocation for airborne noise abatement concepts shall be accounted for as part of the machinery arrangements design effort.

4.1.12 Machinery systems arrangement and installation. Machinery arrangements shall provide the best military protection for all vital machinery and equipment and shall ensure that damage to, or flooding of, any watertight machinery space will cause the least interference with operation of machinery and equipment in any other machinery space.

4.1.12.1 Machinery plant access. Components of the machinery plant and piping shall be arranged and installed to permit ready accessibility for operation, inspection, and maintenance. In cases of questionable accessibility, the contractor shall demonstrate that accessibility is attainable.

4.1.12.2 Machinery interference. Removal of interferences (such as piping, floor plates, gratings, and air ducts) to accommodate maintenance shall be kept to a minimum. Maintenance that must be accomplished underway shall not require disassembly of other components of systems necessary for propulsion.

4.1.12.3 Surface temperature of machinery, piping, and equipment. Piping systems and equipment containing flammable or combustible liquids (Class II and Class IIIA, such as DFM and JP-5) and having a surface temperature under its insulation of 205 °C (400 °F) or higher shall be located at least 458 millimeters (18 inches) (measured from the extents of the insulated machinery and piping) from tanks containing flammable fluids (except lubricating oil). Piping systems and equipment containing combustible liquids (Class IIIB such as hydraulic fluid and lubricating oil) and having a surface temperature under its insulation of 343 °C (650 °F) or higher shall be located at least 458 millimeters (18 inches) (measured from the extents of the insulated machinery and piping) from tanks containing lubricating oil. They shall not be located at a level lower than tanks containing flammable or combustible liquids unless they are at least 3048 millimeters (120 inches) (measured horizontally) from the tank, or unless they are shielded from possible tank leakage. The hot surface of piping systems and equipment which pose a personnel burn hazard shall be insulated to maintain the exterior surface at 52 °C (125 °F) or lower. Machinery and equipment having surface temperatures of 650 °F or greater under their insulation spray shields shall be installed on flanged joints and flanged valve bonnets in piping containing flammable fluid.

4.1.12.4 Vapor losses from machinery. Vapor losses from piping, machinery, and equipment shall be minimized or eliminated where possible.

4.1.12.5 Location of components. Certain components may operate together to compose a system, and this may have a definite bearing on their proximity to one another (usually due to piping interconnections). Other items, by virtue of their duties, demand a certain relative location in the machinery space. Such demands cannot be usurped for purely geometrical reasons. It is essential that the designer familiarize himself/herself with the purpose and general construction of each component.

4.1.12.6 Innerbottom access. On larger naval vessels having an innerbottom, a height of 1220 millimeters (48 inches) between the tank top and the lower working level has been used frequently in the main machinery room and the auxiliary machinery room, and it has proven to be satisfactory. Where space is at a premium, or in secondary spaces such as pump rooms, etc., careful planning may allow for a reduction in height. A great deal depends upon the type of vessel and the quantity of piping systems which are to be installed below the lower floor plates. Because of the amount of foundation structure, piping systems, etc., the space below the floor level is usually crowded; therefore, a clear access route shall be provided to innerbottom manholes.

4.1.13 Lifting gear and special tools. Lifting gear and special tools necessary for ship overhaul of machinery components and piping systems shall include such equipment as heavy duty chain hoists, pad eyes, beam clamps, turnbuckles, shackles, pulleys, and wire rope. Where it is necessary to move disassembled parts for repair, inspection, or access, trolleys, or other suitable gear shall be provided.

4.1.13.1 Lifting gear placement. For multi-shaft ships, sufficient lifting gear shall be installed to permit opening the propulsion unit for inspection or repair of two shafts simultaneously. Lifting gear shall be fitted so that parts may be lifted and moved with a minimum disconnection of piping, cables, ventilation ducts, and other installed equipment.

4.1.14 General requirements for the electric plant. Electric machinery, equipment, and wiring shall be located to ensure adequate natural cooling and to avoid excessive heating. Insofar as practicable, electric wiring and equipment shall not be located in spaces above or adjacent to heat-producing apparatus, piping, ducts, or thermal insulating barriers where high, local ambient temperature may occur.

a. When practicable, electrical switchgear should be located in a separate room from the main propulsion machinery, or in a portion of the main machinery rooms that is not along a main access route.

b. When practicable, electrical switchgear should be oriented so that an arc flash explosion will not propel the front covers into personnel watch stander locations, or areas containing flammable and combustible fluids.

c. When practicable, equipment for electrical power conditioning, such as transformers, capacitors, and harmonic filters, should be in its own room.

d. Resiliently mounted, high voltage switchgear shall be located high enough above the deck to allow for power cable bend radii to enter from the bottom and prevent the relatively stiff cables from overly constraining equipment movement on the resilient mounts.

4.1.14.1 Protection from short circuits. In order to reduce the possibility of short circuits in electrical equipment caused by partial flooding of watertight spaces in which equipment is located and to protect equipment from mechanical injury, the requirements listed in 4.1.14.2 shall apply.

4.1.14.2 Location of transformers, motors, and controllers. Transformers, motors, and controllers (except those mounted at machinery room levels) shall be located with terminals or energized parts not lower than the access door sills in main boundary bulkheads or watertight spaces in which they are located; however, motors for the following or similar equipment may be mounted with terminals below the level of access door sills:

a. Blower for incinerator.

b. Drinking water coolers.

c. Refrigerator machinery.

d. Shop machinery.

4.1.14.3 Terminal connections. The lower terminals of control and distribution equipment shall not be lower than the terminals or energized parts of motors or other power consuming equipment connected thereto; however, the height above the deck need not be greater than 915 millimeters (36 inches).

4.1.14.4 Location of motors. Motors that drive auxiliaries located in lower level machinery spaces shall be installed as high above the bilges as practicable or shall be provided with watertight casings or cofferdams. Locations above bilges are preferred.

4.1.14.5 Equipment mounting. Equipment shall be mounted at a height that will avoid accidental mechanical injury.

5. DETAILED REQUIREMENTS

5.1 Hull structure. An understanding of the naval architectural constraints faced by the structural designer is necessary for the machinery arrangement designer to interface effectively with the structural designer and achieve an optimized machinery arrangements design.

5.1.1 Machinery space primary structure. Structure contributing to the longitudinal strength of the ship shall be continuous through transverse structure. Whenever practicable, structure shall be aligned to take advantage of continuity of design.

5.1.2 Stanchions in machinery spaces. Stanchions in machinery spaces shall be located vertically, one above another, or over structural bulkheads, insofar as practicable, to form continuous columns of support. Girders shall be used in lieu of stanchions only where interference caused by stanchions is unacceptable.

5.1.2.1 Stanchions in passageways. Stanchions shall not be located in passageways.

5.1.2.2 Stanchions in machinery spaces. In machinery spaces, stanchions shall be spaced to clear machinery installations and to permit the efficient operation, inspection, repair, and maintenance of the machinery.

5.1.2.3 Location of stanchions. Wherever practicable, stanchions shall be located to permit the removal of major items of equipment from the space without removal of the stanchions. In cases where this is unachievable, portable stanchions or angled stanchions are allowed where necessary to permit dismantling of machinery.

5.1.3 Structural bulkheads in machinery spaces. A minimum of 458 millimeters (18 inches) of maintenance clearance shall be maintained on each side of machinery space bulkheads.

5.1.3.1 Impact of deep stiffeners. The structural design of the machinery box may use deep stiffeners on the bounding bulkheads. This can impose limitations on the arrangement flexibility.

5.1.4 Machinery space deck and platform design. The structural design of the machinery box may use deep longitudinal or transverse main deck support structure. When both longitudinal and transverse deep members are used, the overall required height of the machinery box shall account for the unavailability to install items as cableways, piping runs, and ventilation ducting in the inter-frame spacing.

5.1.5 Machinery foundations. Machinery foundation design is done late in the design cycle. During the machinery arrangements design process, the machinery arrangement engineer shall ensure that adequate space under and around the machinery and equipment included in any of the machinery spaces is available to meet the following requirements (see 5.1.5.1 to 5.1.5.10).

5.1.5.1 Machinery foundation allowance. Adequate space around machinery foundations to install chocks and align and check the alignment of supported equipment shall be allocated during the machinery arrangement design.

5.1.5.2 Foundation access. Accessibility shall be provided for inspection and maintenance of equipment foundation structure and adjacent hull structure.

5.1.5.3 Construction of foundations. Foundations shall be constructed so as not to contain pockets which can retain liquids.

5.1.5.4 Equipment alignment. Provision shall be made for maintaining positive and accurate alignment where it is essential for satisfactory operation of the machinery or equipment.

5.1.5.5 Foundation and bedplate alignment. Foundations and bedplates shall be aligned so as to avoid distortion of the structure, the equipment, or resilient mounts.

5.1.5.6 Foundation and support structure rigidity. The rigidity of foundations and supporting structure shall be sufficient to prevent misalignment which would interfere with operation of the machinery and equipment and to preclude excessive vibratory motion or rocking on the foundation.

5.1.5.7 Foundation design. Foundations shall be designed to prevent misalignment or excessive strains due to thermal expansion, under any operating condition. Foundation design shall also accommodate for hull structure flexing in a seaway and structure-borne vibration (either imposed on, or generated by) of the foundated equipment.

5.1.5.8 Alignment critical machinery foundations. Large machinery components such as prime movers, transmissions, and generators which must be aligned with connected equipment, shall be installed on chocks or resilient mounts.

5.1.5.9 Mating equipment to foundations. Coamings, liners, gaskets, bolts, foundation blocks, and other material and fastenings shall be fitted, as required, for the attachment of machinery and equipment to foundations.

5.1.5.10 Welding of foundations. Non-rotating equipment which does not require removal for maintenance may be secured by welding. Equipment which contains rotating parts may be welded to foundations, provided that it is mounted on a sub-base which is used as the attached bolting member. Main propulsion machinery and generators shall not be welded to the foundation.

5.1.6 Chimney spaces. Machinery space design shall avoid the creation of chimney spaces (see 3.1.7). To discourage creating chimney spaces in combustion air uptake spaces, access via bolted manholes or panels shall be used lieu of doors, and the number and size of intermediate platforms shall be as small as possible. Intermediate platforms shall be constructed with grating instead of solid plate, because a solid plate can capture hot gases from a fire and will require a heat detector system to be installed. Similarly, large horizontal stiffening rings shall have lightening holes in the web to allow hot gases to pass through. Manhole covers for chimney spaces shall include a fire fighter’s access fitting.

5.2 Propulsion plant.

5.2.1 Internal combustion engines. Detailed machinery arrangements design requirements for propulsion and auxiliary diesel and gas turbine engines are as follows (see 5.2.1.1 to 5.2.3.13).

5.2.1.1 Engine control. Each propulsion and auxiliary internal combustion engine shall be capable of control at the engine or from each specified remote control station.

5.2.1.2 Remote shutdown devices. Mechanical operating gear shall be installed from the shutdown device on each propulsion and auxiliary internal combustion engine, including generator prime movers, to a station located outside the engine compartment and adjacent to its access.

5.2.2 Diesel engines.

5.2.2.1 Operating station considerations. Staffed operating stations, telephone hoods, log desks, hose reels, and ladders shall not be located in way of any crankcase explosion relief valves, fuel oil and lubricating oil pumps, and strainers and filters for flammable and combustible liquids.

5.2.2.2 Maintenance clearances. Unless vendor installation drawings are available for the diesel engines being considered, the following maintenance clearances shall be maintained throughout the machinery arrangement design development. For Contractor-Furnished Engine (CFE) situations, the largest, composite-sized, candidate engine shall be used in the arrangement to manage arrangements risk during the later design phases.

a. Allow 915 millimeters (36 inches) on the sides and one end of the equipment skid and 1220 millimeters (48 inches) on the opposite end.

b. For dual unit installations, maintain 1067 millimeters (42 inches) between units and 610 millimeters (24 inches) outboard of the units.

c. Diesel engines shall not be installed at angles greater than 5 degrees from the horizontal in any plane (longitudinally or athwartships).

d. The arrangements impacts associated with a wet sump (oil in attached oil pan) or dry sump (oil in a separate tank normally mounted in the foundation) shall be accounted for.

e. When a resilient mounting system is used to mitigate noise and vibration, the maximum expected equipment movement shall be considered.

5.2.2.3 Acoustic enclosure. Enclosures may be provided for noise control around main engines and auxiliary engines. Enclosures for fire containment shall be provided for auxiliary diesel engines, unless the engines are in spaces specifically designed to act as a fire containment. For any enclosure, the machinery arrangement design shall consider the associated size, weight, and supporting structural requirements.

5.2.2.4 In-place maintenance space. At a minimum, sufficient in-place maintenance space shall be allocated for the following diesel engine maintenance actions:

a. Diesel engine oil pan removal.

b. Diesel engine crankshaft removal: if required, lifting tools shall be accounted for in the maintenance space allocation for this action.

c. Diesel engine camshaft removal.

d. Diesel engine cylinder head and piston removal: if required, lifting tools shall be accounted for in the maintenance space allocation for this action.

e. Disassembly and removal of engine-mounted accessories such as fuel, lubricating, freshwater, and saltwater pumps, blowers, and starting motor located.

f. Access to the crankcase handhole covers.

g. Turbocharger removal: if required, lifting tools shall be accounted for in the maintenance space allocation for this action.

h. Fuel oil and lubricating oil strainers and filters.

i. Engine-mounted intercooler, aftercooler, oil and water coolers tube bundle removal.

5.2.2.5 Emergency combustion air inlets. In-space emergency combustion air inlets shall be free from obstructions and allow for the space required to remove and service air cleaners. Potential sources of fuel and oil contamination shall be kept from the vicinity of in-space diesel engine inlets.

5.2.3 Gas turbine engines.

5.2.3.1 Maintenance clearances. Unless vendor installation drawings are available for the gas turbine engines being considered, the following maintenance clearances shall be maintained throughout the machinery arrangement design development. For CFE situations, the largest, composite-sized, candidate engine shall be used in the arrangement to manage arrangements risk during the later design phases.

a. Allow 915 millimeters (36 inches) on the sides and one end of the equipment skid and 1220 millimeters (48 inches) on the opposite end.

b. For dual unit installations, maintain 1067 millimeters (42 inches) between units and 610 millimeters (24 inches) outboard of the units.

c. Gas turbine engines can be installed both with and without contractor-furnished enclosures. It is common practice for large propulsion gas turbine units and gas turbine generator sets to be installed in enclosures furnished by the gas turbine engine supplier. Gas turbine engines used on high-performance craft will not normally be installed in enclosures. Enclosures for fire containment shall be provided for gas turbine engines, unless the engines are in spaces specifically designed to act as a fire containment.

d. When available, installation drawings for the gas turbine engine as it is to be installed (i.e., with or without an enclosure) shall be used to determine the needed maintenance envelopes.

e. If an enclosure is to be used, the associated size, weight, and supporting structure requirements shall be reflected in the machinery arrangement design.

f. If an engine enclosure is to be used and no vendor information exists, a preliminary enclosure estimate shall be used based in information available for engines for a similar power rating.

5.2.3.2 Cooling ducts. Engines in enclosures shall utilize cooling ducts with enclosure interfaces independent from the combustion air inlet interface.

5.2.3.3 Flammable fluid spray. Fuel, oil, and other flammable piping, filters, and strainers shall be arranged to prevent drip or spray coming into contact with the hot surfaces of gas turbine engines that are not enclosed. Space needed for spray shields and guards shall be allocated in the machinery arrangement design.

5.2.3.4 Permanent trim. Gas turbine engines shall not be installed with a permanent trim greater than 5 degrees from the horizontal.

5.2.3.5 Off-skid accessories. All off-skid (detached) gas turbine engine accessories such as electronic control modules, external oil storage and conditioning assemblies, etc., shall be accounted for in the machinery arrangement.

5.2.3.6 Placement of off-skid accessories. The proximity of all off-skid engine accessories to the parent engine shall be considered.

5.2.3.7 Resilient mounting system. When a resilient mounting system is used to mitigate noise and vibration, the maximum expected equipment movement shall be considered.

5.2.3.8 In-place overhaul. No overhaul or extensive maintenance will be done on any gas turbine in place. The gas turbine engine will either be removed as a whole and replaced or will be broken down into major components or modules. This normally includes a complete gas generator and complete power turbine, or it may be broken down into modules, such as compressor section, combustor section, and high pressure turbine section.

5.2.3.9 Gas turbine removal. The gas turbine engine removal path shall be sized to accommodate the dimensions of the largest component to be removed, any clearances necessary to accomplish modular removal and replacement, lifting gear, and special tools.

5.2.3.10 Gas turbine removal via air inlet system. When gas turbine engines are to be removed and replaced via the air inlet system, work space shall be allocated at all openings to the engine enclosure and at various points along the inlet system to facilitate safe removal.

5.2.3.11 Modular replacement. Where a modular replacement of a gas turbine engine is employed, work space shall be allocated at all openings to the engine enclosure and all access points (hatches, doors, removal plates, etc.) along the removal path.

5.2.3.12 Removal routes. For gas turbine engines or engine modules that will not be removed through the air inlet system, removal routes shall be established that account for overhead cranes and other lifting aids necessary to remove the engine or its largest component.

5.2.3.13 Engine enclosure size. At a minimum the engine enclosure shall be sized sufficiently to perform the following routine preventive maintenance actions:

a. Fuel pump removal, inspection, and replacement.

b. Starting motor removal, inspection, and replacement.

c. Igniter, fuel injector, fuel manifolds, and fuel control removal, inspection, and replacement.

d. Internal borescope inspection.

5.2.4 Electric propulsion.

5.2.4.1 Location. The location of electric propulsion equipment shall be chosen to avoid ventilation supply and exhaust terminals, valves and flanges in piping systems, bilges, and similar moisture hazards to minimize the likelihood of fluid dripping or spraying on electric equipment under operating conditions.

5.2.4.2 Drip shields. When locating electric propulsion equipment away from possible sources of oil, water, or dirt is impracticable, drip shields shall be installed.

5.2.4.3 Baffles and water traps. When protecting electric propulsion equipment from rain or seawater entering through hatches or other weather openings, these openings shall have baffles and self-draining water traps.

5.2.4.4 Personnel protection. Personnel protection shall be provided as necessary to guard against hazardous voltages and other dangerous conditions.

5.2.4.5 Accessibility for inspection and servicing. Propulsion generators and motors shall be located so that commutators, collector rings, brushes, brush rigging, internal connections, drain plugs, and jacking and locking devices for shafts are accessible for inspection and servicing.

5.2.4.6 Drain lines. Drain lines from forced-lubricated bearings shall be installed in a manner which will ensure continuity of flow without flooding of propulsion motor or generator bearings and which will prevent trapping of air within the pipes under specified conditions of inclined operation.

5.2.4.7 Control equipment location. Electric propulsion control equipment shall be located to provide maximum safety and convenience to operating personnel and protection for the control equipment. If practicable, electric propulsion control equipment shall be located above the ship's full load design waterline.

5.2.4.8 Control equipment clearances. Adequate space shall be provided in front of and behind the electric propulsion control equipment for operation and servicing. A minimum clearance of 915 millimeters (36 inches) in front and 610 millimeters (24 inches) behind the control equipment shall be provided.

5.2.4.9 Control equipment and other switchboards. Electric propulsion control equipment shall be separated from other adjacent switchboards by at least 153 millimeters (6 inches). If exposed, an expanded metal enclosure shall be provided to restrict access to the rear of the equipment.

5.2.4.10 Excitation sets and auxiliaries. Electric propulsion excitation sets and electric propulsion auxiliaries (normal and standby units) shall be separated from each other and above the full load design waterline as far as practicable.

5.2.4.11 Remote stations. Remote stations for control of propulsion excitation sets and bearing lubricating oil pump motors shall be centrally located in an area convenient to operating personnel stationed at the propulsion control equipment.

5.2.4.12 Minimum maintenance allocations. At a minimum, sufficient in-place maintenance space shall be allocated for the following electric propulsion equipment maintenance actions:

a. Electric generator rotor removal (if required, lifting tools shall be accounted for in the maintenance space allocation for this action).

b. Condenser and heat exchanger tube bundle removal.

c. Fluid and air heaters.

d. Cooling system fans.

5.2.5 Propulsion reduction gear. During the machinery arrangement design process, space allocations for the following propulsion reduction gear considerations shall be maintained.

a. A minimum of 915 millimeters (36 inches) of unoccupied space shall be maintained between the gear casing and ship's structure.

b. A minimum of 610 millimeters (24 inches) and all of the volume directly below the propulsion reduction gear shall be reserved for its sump tank.

c. Clearance shall be maintained at the lowest point in the lubricating oil sump for oil to be drawn when the ship is on an even keel with no list.

d. Sump access openings and closures shall be located and provide sufficient clearance for removal of the cover and for cleaning of the sump.

e. Space for access openings and inspection clearance over the main pinion and gear meshes. Lifting gear may be required.

f. Clearance for removal and inspection over and around bearing caps.

g. If an integral thrust bearing is included, determine clearance shall be required to allow for the servicing of thrust shoes and installation of a thrust meter and account for them.

h. Clearances surrounding the attached lubricating oil pump(s), jacking gear, and propeller shaft locking device shall be provided for servicing.

i. Clearances shall be maintained in the proper locations for maintenance and installation personnel to check alignment with the propeller shaft.

5.2.6 Clutches and flexible couplings (propulsion).

5.2.6.1 Operating controls. Clutch operating controls shall be incorporated in the control stand or control board for the driving unit.

5.2.6.2 Couplings. Couplings shall be removable without removing the connected shafting.

5.2.6.3 Coupling housing guards. Coupling housing guards shall be arranged.

5.2.6.4 Emergency manual operation. Clutches equipped with a means for emergency manual operation shall include the clearance necessary for operation.

5.2.6.5 Air-cooled friction material. Where clutches or brakes use air-cooled friction material, the adjacent area shall be free of components that produce oily vapor.

5.2.6.6 Maintenance clearances. Provisions shall be made for maintenance clearances required for special tooling fit-up, including removing or sliding back housings, using power-operated tools, removing seals, servicing grease fittings, etc.

5.2.7 Shafting. A separate shafting arrangement drawing shall be prepared in accordance with 803-2145807. It shall consist of elevation and plan views of the completely assembled shafting system including shafts, clutches, motor shaft, low-speed gear shaft, couplings, sleeves, thrust shafts, resonance changers, torsion meters, all bearings, seals, bulkhead penetration, stern tubes, struts, rotating coupling covers, stationary fairwaters, rope guards, propellers, and hull lines and appendages in the vicinity of the outboard shafting and propellers.

5.2.7.1 Shaft unshipping. Shipping and unshipping of stern tube, intermediate, and propeller shafts shall be done outboard. The strut shall be large enough so that, with the removal of the strut bearing bushings, the shaft flanges will pass through the strut. In order to keep hull penetrations as small as possible, stern tubes are usually not made with openings large enough to pass a flange. Therefore, the stern tube shaft is made with a removable flange for the inboard coupling (see 803-2145807 for details).

5.2.7.2 Rudder clearance considerations. Clearance to pass these shafts with the propeller removed past the hull, rudder, and other appendages shall be illustrated on the drawing.

5.2.7.3 Initial shaft line arrangement rules. A distance equal to 25 percent of propeller diameter shall be established between the propeller and the hull when establishing the initial shaft line arrangement. A distance equal to 50 percent of propeller diameter shall be established between propellers on multi-shaft design configurations.

5.2.7.4 Initial shaft line arrangement rake and skew. The initial shaft line arrangement rake shall be less than 5 degrees. The initial shaft line arrangement skew shall be less than 3 degrees.

5.2.7.5 Mechanically connected shafts. Where two shafts of the shafting system are mechanically connected by parallel axis gears, they will have the same rake and no skew.

5.2.7.6 Clearance. Adequate clearance shall be available to service and maintain line shaft bearings, thrust bearings, and bulkhead and stern tube stuffing boxes and to check alignment.

5.2.8 Shaft bearings and seals.

5.2.8.1 Distance between stern tube and hull. The distance between the forward end of the stern tube and hull shall be no less than 305 millimeters (12 inches).

5.2.8.2 Placement of line shaft bearings. Whenever practical, line shaft bearings shall be located near main transverse watertight bulkheads to limit the relative motion of shafting in way of bulkhead seals during a shock event.

5.2.8.3 Maintenance, service, and cleaning clearances. Clearance shall be allocated in the machinery arrangement to maintain, service, and clean all thrust and line shaft bearings and seals.

5.2.8.4 Bearing replacement clearance. Clearance necessary for the replacement of bearing shells or bearings shall account for lifting gear and special tools.

5.2.8.5 Thrust meter clearance. Clearance for the installation and servicing of thrust bearing thrust meters shall be provided.

5.2.8.6 Bulkhead seal activation clearance. Clearance needed to activate a bulkhead seal in case of compartment flooding shall be provided on both sides of the installed bulkhead.

5.2.8.7 Stern tube clearance. Allocations for connections, servicing, and maintenance of the stern tube shaft and seal shall be provided.

5.2.8.8 Transmission shafting. Where transmission shafting connects driving and driven machinery on opposite sides of a watertight bulkhead, a floating type of stuffing box shall be installed at the bulkhead.

5.2.9 Propellers. The importance of the propeller on the machinery arrangement is its effect on the shaft line location.

5.2.9.1 Controllable pitch and cycloidal propellers. If controllable pitch or cycloidal propellers are used, consideration shall be given to the inboard elements for the pitch control system.

5.2.10 Propulsion control system. Control equipment shall be so arranged that maximum operational effectiveness of the control station can be obtained with minimum personnel.

5.2.10.1 Telephone stations. A log desk and telephone hood shall be installed in engine room control stations adjacent to the propulsion operating console. The telephone hood shall be of a design to permit intelligible speech communication under all noise conditions of plant operation. If space restrictions will not permit a separate telephone hood, a telephone booth with an integral log desk may be substituted.

5.2.10.2 Control panel protection. Local control panels shall be protected from any source of saltwater, freshwater, fuel, and lubricating oils that may drip, spray, or otherwise impinge on them.

5.2.10.3 Enclosed operating station. When arranging an Enclosed Operating Station (EOS), machinery space access shall not require passage through the EOS. The machinery arrangements shall consider that the boundary between the EOS and the machinery space will have an N-30 fire rating, and that an air lock may be required with the EOS.

5.2.10.4 Quality of view. The quality of view of the machinery room from the local operating station shall be considered. The view into the machinery space from EOS windows (if applicable) shall not be obstructed by switchboards, load centers, etc.

5.2.11 Circulating and cooling seawater system. Circulating and cooling seawater systems for the following machinery systems shall be arranged as follows (see 5.2.11.1 to 5.2.11.12).

5.2.11.1 Machinery seawater cooling. The following systems shall be installed:

a. Machinery seawater cooling: A system shall be installed to serve the reduction gear lubricating oil cooler and the controllable pitch propeller hydraulic oil cooler associated with each propulsion gas turbine unit. Two seawater-circulating pumps, a suction sea chest for each pump, and one overboard discharge in each machinery space are required.

b. Diesel engine and diesel generator cooling: A system shall be installed to serve the cooling water requirements for each propulsion diesel engine unit and diesel generator unit.

c. Air coolers and motors: A system shall be installed to serve the cooling-water requirements for air coolers of propulsion generators and motors in diesel-electric propelled ships.

d. Auxiliary machinery: A system shall be installed in each machinery space for supplying cooling water to various units of auxiliary machinery, such as turbine-driven pumps and forced-draft blowers. This system shall be served by one or more auxiliary machinery: cooling water pumps or from the firemain.

e. Air conditioning plant: A system shall be installed to serve each air conditioning plant.

5.2.11.2 Sea chests. For propulsion internal combustion engine cooling water systems, there shall be at least two sea chests in each propulsion engine room, one located on each side of the ship. The sea chests shall be cross-connected to permit circulating water for all propulsion engines in the same space to be taken from either or both sea chests. A separate seawater-cooling system that includes an emergency source of cooling water from the firemain, including the inlet cutout valve, strainer, and regulating valve, is required for diesel generator, seawater-cooling systems.

5.2.11.3 Sea chest suction and discharge piping. For ships designed to be beached, suction and discharge piping to ballast tanks that can be flooded shall be installed to provide cooling water to engines driving ship service generators.

5.2.11.4 Sea chest valves. Sea chest valves shall be provided with remote operation from the propulsion unit operating level. Valves 407 millimeters (16 inches) and above shall have electric motor power assist, with the motor and valve assist gear located at the propulsion unit operating level.

5.2.11.5 Main lubricating oil cooler. The location of the main lubricating oil cooler shall be located as near to the main reduction gear as practicable in order to minimize lubricating oil piping.

5.2.11.6 Seawater piping considerations. Machinery items shall be arranged so that the clearance needed to arrange seawater piping connections (including flexible connections, valves, and other piping components) close to the machinery items they provide is available.

5.2.11.7 General cooling system considerations. Certain auxiliary items, such as freshwater/seawater heat exchangers, lubricating oil coolers, and air coolers, shall be located in such a manner that there is adequate room for the piping connections and ensure that the piping will require the shortest possible route for the system. Adequate space shall be provided for tube withdrawal for all heat exchangers where tube withdrawal is required.

5.2.11.8 Location of pumps and inlet sea chests. Pumps and inlet sea chests shall be located to provide a minimum but adequate distance for the connecting piping, allowing for valves, strainers, and flexible piping.

5.2.11.9 Location of pumps, coolers, and compressor. Where several auxiliary machinery items are included in a machinery space, such as a seawater-cooled air conditioning plant, locate the pumps, coolers, and compressor unit in such a manner to ensure the shortest refrigerant and seawater piping and to require the least amount of space.

5.2.11.10 Location of motor controllers. Motor controllers for seawater-cooling pumps should be located in close proximity to the pumps.

5.2.11.11 Cooling water supply. Cooling water for propulsion motors and generators in diesel-electric-propelled ships can be from independent seawater-circulating pumps or from the propulsion internal combustion engine seawater-cooling system.

5.2.11.12 Cooling-water booster pump. A cooling-water booster pump and system shall be provided low in the ship for internal combustion engines located above the ship’s design light water line.

5.2.12 Internal combustion engine combustion air and exhaust systems. The interdependence of the design and arrangement of the combustion air intake ducting, combustion uptakes, and the stack is a major factor in the machinery arrangement. The ducting, both inlet and exhaust, shall provide a continuous air path from atmosphere to the equipment served or, in the case of exhaust, from the equipment to atmosphere. The routing path should be considered and established as early in the design process as possible since the ducting will penetrate compartments and spaces outside the machinery box and will impact the development of the topside arrangement.

5.2.12.1 Diesel engine combustion air. Diesel engine combustion air shall be ducted from the weather directly to the engine.

5.2.12.2 Small engine combustion air sourcing. For smaller engines, it is permissible to take air from the space in which unit resides. Doing so requires special design considerations for ventilation system.

5.2.12.3 Combustion air weather intake. The combustion air weather intake shall be designed and arranged to prevent its blockage by foreign objects. The weather inlet shall have a flow area not less than two times the cross-sectional area of the duct just downstream of the inlet.

5.2.12.4 Water trap or plenum chamber. If effective separation of entrained water cannot be accomplished by the duct arrangement, a water trap or plenum chamber with a drain shall be installed for this purpose.

5.2.12.5 Duct design. The system shall be designed to prevent the collapse of the ducting at maximum engine vacuum should the weather inlet become blocked.

5.2.12.6 Air supply alternatives. An alternative air supply shall be provided to permit continued, uninterrupted operation of the engine should the inlet become blocked. A vacuum breaker shall be installed between the air filter and the engine sized to supply combustion air sufficient for rated engine load. Alternative air can be drawn from the machinery space by separate ducts outfitted with sensors to alert personnel when the alternative air source is in use.

5.2.12.7 Gas turbine engines. Gas turbine engine requirements are in addition to those applicable from diesels (see 5.2.12).

5.2.12.7.1 Moisture separator. A moisture separator of a NAVSEA-approved type shall be installed in the intake ducting.

5.2.12.7.2 Emergency air inlet. An emergency air inlet shall be installed near the normal weather inlet. These "blow-in-doors" shall open automatically (by differential pressure) should normal inlets become blocked.

5.2.12.7.3 Weather intake openings. A 38-millimeter (1½-inch) mesh screen shall be installed in all weather intake openings.

5.2.12.7.4 Intake trunks. Intake trunks shall have a minimum of 458 millimeters (18 inches) of clear access on one side, 610 millimeters (24 inches) on the opposite side, and 762 millimeters (30 inches) on ends not integral with the ship's structure. Multiple intake trunks where not integral with the ship's structure shall have 610 millimeters (24 inches) clearance between the ducts.

5.2.12.7.5 Minimum intake duct. In addition to accommodating the necessary air flow, the minimum intake duct cross-sectional area shall be sized to remove any required equipment.

5.2.12.7.6 Removal hatches. If engine or equipment removal is to be done via the inlet duct, a removal hatch shall be required in the atmospheric intake compartment overhead and in every deck from there to the weather. Such deck cuts should be in a direct vertical line with the combustion air intake duct.

5.2.12.8 Diesel and gas turbine engine exhaust systems. Exhaust terminals shall be located where exhaust gases will not contaminate ventilation or combustion air intakes, interfere with operating crews, impinge on ship equipment, or create a fire hazard. They shall be designed to discharge gases clear of the ship to the maximum extent practicable.

5.2.12.9 Exhaust systems. Exhaust systems shall not be run through living spaces or other spaces where they will affect habitability unless specifically approved on a case basis. Where necessary to run the exhaust system through these spaces, adequate insulation shall be provided, and flanged joints shall not be installed in such spaces. Whenever practical, flat oval ducting should not be used for exhaust systems.

5.2.12.10 Water trap. Where a diesel engine exhausts out the side of a ship, a water trap, 810-1385887, and a locking-type gate valve, classified "W", shall be installed inboard and adjacent to the hull.

5.2.12.11 Uptake construction material. The material used in uptake construction shall be in accordance with MIL-STD-777, except that gas turbines material exposed to gases shall be Ni Cr Mo Cb (Inconel 625) in accordance with ASTM B443 or ASTM B444. For ships with a low magnetic requirement, the exhaust material shall be corrosion resistant steel (CRES), ASTM A240/A240M, Grade 316L (750 °F maximum) or 347, and intake material shall be CRES, ASTM A167, Type 304C.

5.2.12.12 Access to uptake ducts. Uptake ducts (where not integral with the ship's structure) shall have a minimum of 458 millimeters (18 inches) of clear access on one side, 610 millimeters (24 inches) on the opposite side, and 762 millimeters (30 inches) on the remaining sides. Multiple uptake ducts shall have 610 millimeters (24 inches) clearance between the ducts.

5.2.13 Lubricating oil systems. A complete and independent lubricating oil service system of the forced-feed type shall be installed for each propulsion unit as follows.

5.2.13.1 Strainers, thermometers, and sight flows. Strainers, thermometers, and sight flows for bearings shall be installed in readily visible and accessible locations.

5.2.13.2 Purifiers. A lubricating oil heater shall be installed for each purifier between the purifier suction pump discharge and the purifier bowl. It shall be sized to heat oil pumped at the rated capacity of the purifier from 40 to 160 °F. Where redundant purifiers are provided in a space, a single heater shall be provided to serve all the purifiers in the space and shall be sized for a flow rate equal to the combined flow rate of the maximum number of purifiers operated simultaneously.

5.2.13.3 Lubricating oil heater capability. A lubricating oil heater shall be installed capable of heating the oil in each propulsion reduction gear lubricating oil service system from 40 to 90 °F in 1 hour, taking into consideration heat losses through the sump tank and the system. Steam-propelled submarines carry the same requirement except the heaters shall be of the immersion type sized to heat the oil in 2 hours.

5.2.13.4 Electric immersion heaters. Where electric immersion heaters are specified, they shall be mounted as low as practicable in the sump and near the sump suction.

5.2.13.5 Drip pans. A pan with a perforated tray or wire screen shall be installed at each hand service connection, under each duplex strainer installed in the lubricating oil service system for the main propulsion system. The drip pan for the duplex strainer shall provide support for the strainer basket while it is cleaning. Means shall be provided for draining the pan to a portable container or the oily water drain collecting system.

5.2.13.6 Sample bottle racks. A lubricating oil sample bottle rack shall be arranged in each machinery space for storing samples of oil taken from main and auxiliary machinery. Bottle racks shall be installed near the primary watch station in each applicable space.

5.2.13.7 Facilities for rack stowage. Facilities shall be provided for the rack stowage of 1-quart containers of gas turbine lubricating oil in each space containing a gas turbine.

5.2.13.8 Oil stowage and settling tanks. Lubricating oil stowage and settling tanks in a machinery space may be combined into one structural unit, with an oil-tight division plate separating them.

5.2.13.9 Storage tanks for propulsion units and ship's service generators. One or more lubricating oil storage tanks shall be installed in each space in which one or more propulsion units or ship's service generators are installed. Minimum tank capacities are as follows (see 5.2.13.10 to 5.2.13.14).

5.2.13.10 Storage tank capacity for diesel propulsion systems. For diesel propulsion systems, the lubricating oil storage tank capacity shall be 1.1 times the capacity needed to fill all propulsion units, the controllable propeller pitch sump (if applicable), and ship's service generator sumps.

5.2.13.11 Storage tank capacity for gas turbine propulsion systems. For gas turbine propulsion systems, the lubricating oil storage tank capacity shall be 1.25 times the capacity needed to fill the main reduction gear sump and the controllable propeller pitch sump.

5.2.13.12 Storage tank capacity for ship service diesel generators. Where ship service diesel generators are installed, separate stowage for lubricating oil shall be provided. This tank shall have a minimum capacity to fill the diesel generator sumps in the space plus usage based on ship's endurance and an allowance for small boats.

5.2.13.13 Storage tank capacity for emergency generator. One lubricating oil tank shall be installed in each space in which an emergency generator is installed. The minimum tank capacity shall be sufficient to fill the generator sump tank three times, plus an allowance for small boats. The emergency diesel generator lubricating oil stowage tank overflow shall be led to the oily water drain collection system or to a used oil tank located in the same space, via a funnel.

5.2.13.14 Sump tank capacity. A sump tank shall be installed for each forced-fed lubricating oil service system where a sump tank is not integral with the unit. The capacity of each sump tank that serves an internal combustion engine and is not integral with the equipment shall be based on the engine manufacturer's requirements but not be less than a 2-minute supply at rated capacity of the engine pressure pump or the largest capacity lubricating oil service pumps for all other systems, plus allowance for oil drain back after shutdown and allowance for oil below the level of the suction tail pipe opening. In no case shall the sump tank contain less than 1 gallon for every 10 horsepower of the full power rating of the engine.

5.2.13.15 Location of lubricating oil sump tanks. Lubricating oil sump tanks shall be located as low as practicable to facilitate oil returning by gravity.

5.2.13.16 Lubricating oil settling tanks. Lubricating oil settling tank height shall be the largest tank dimension. The bottom of the surface of settling tanks shall be sloped no less than 20 degrees from the horizontal to facilitate contaminant drainage. For surface ships, one settling tank shall be installed in each space in which a propulsion unit is located. The minimum capacities of lubricating oil settling tanks for surface ships and for submarines (if provided) are as follows (see 5.2.13.17 to 5.2.13.21).

5.2.13.17 Settling tank capacity for diesel propulsion systems. For diesel propulsion systems, the lubricating oil settling tank capacity shall be equal to the combined oil capacity of one propulsion unit (propulsion engine, transmission combination) and one ship's service generator.

5.2.13.18 Settling tank capacity for gas turbine propulsion systems. For gas turbine propulsion systems, the lubricating oil settling tank capacity shall be equal to the capacity of one reduction gear sump plus a 10 percent allowance.

5.2.13.19 Lubricating oil tank capacity for diesel-propelled surface ships. For diesel-propelled surface ships, one or more used lubricating oil tanks shall be installed in the machinery spaces. The capacity of the tanks shall be equal to the total capacity of the diesel engine lubricating oil sumps, plus 10 percent. A used oil tank shall be installed in each space in which an emergency generator is located if the sump tank capacity exceeds 25 gallons.

5.2.13.20 Lubricating oil sludge tank. A lubricating oil sludge tank of no less than 25 gallons shall be installed in each space in which a lubricating oil purifier is located and an oily water drain collecting system is not installed.

5.2.13.21 General auxiliary servicing tank capacity. For surface ships, a tank for general auxiliary servicing shall be installed in each machinery space. The capacity shall be 10 gallons in propulsion machinery spaces and 5 gallons in auxiliary machinery spaces.

5.2.13.22 Lubricating oil duplex strainer. A lubricating oil duplex strainer servicing each propulsion system shall be located at the machinery space lower level at a height which permits gravity drainage to the sump tank.

5.2.13.23 Positive displacement lubricating oil service pumps. For single shaft ships, no less than two positive displacement lubricating oil service pumps shall be installed. For multi-shaft ships, three positive displacement lubricating oil service pumps shall be installed for each propulsion unit service system.

5.2.13.24 Lubricating oil service system. The lubricating oil service system for a propulsion diesel engine shall be separate from the service system for other propulsion unit components, such as propulsion reduction gears, hydraulic clutches, hydraulic couplings, etc. The diesel engine shall be supplied lubricating oil by a pressure pump. Each reduction gear shall be supplied lubricating oil by a gear-attached, positive displacement pump. Standby and emergency service, as applicable, shall be provided by electric, motor driven, positive displacement pumps installed to operate in parallel with the normal service pump.

5.2.13.25 Motor-driven, positive displacement pumps. For single shaft gas turbine propulsion systems, the reduction gear lubricating oil service system shall have three motor-driven, positive displacement pumps. Two of the pumps shall have two-speed electric motor drives, and the third shall have an air motor drive. The air motor-driven pump shall be designed as the coast-down pump. The motor shall be powered from air flasks with sufficient quantity to provide for one coast-down operation.

5.2.13.26 Positive displacement pumps. For multi-shaft ships, the reduction gear lubricating oil service system shall have three positive displacement pumps. One pump shall be attached to and driven from the reduction gear. The other two pumps shall have two-speed, electric motor drives.

5.2.13.27 Gas turbine units. The propulsion and generator gas turbine lubricating oil service systems should be furnished with the gas turbine units.

5.2.13.28 Hand pumps. For emergency diesel generator sets and diesel generators in gas turbine ships, a hand pump shall be installed and arranged to permit transferring oil from the stowage tank to the sump tank, from the sump tank to the used oil tank, and from the used oil tank to a deck discharge connection.

5.2.13.29 Lubricating oil purifiers. For gas turbine-propelled ships, one lubricating oil purifier shall be installed in each machinery space. For diesel-propelled ships, the number of lubricating oil purifiers and their arrangement shall be as specified for the particular installation.

5.2.13.30 Sump tank configuration. The configuration of the propulsion system sump tank shall be such that the working level will be a minimum of 153 millimeters (6 inches) below the lowest point of the bull gear at both the angle of heel and at maximum specified angles of roll. Sump tanks may extend to the shell on ships without innerbottoms. On ships that include innerbottoms, the innerbottom shall form the lower boundary of the sump tank.

5.2.13.31 Working level permissions. In some cases, the limiting deck height, in conjunction with the size of the bull gear, does not permit a working oil level below the bull gear. In these cases, a working level at or slightly above [not exceeding 77 millimeters (3 inches)] the bottom of the bull gear is permitted, provided that a splash pan is fitted over the bull gear.

5.2.13.32 Feasibility studies. During feasibility studies, the total volume of lubricating oil tanks shall include allowances for internal tank structure (3 percent), expansion (5 percent), and possibly other operational constraints.

5.2.13.33 Water settling and gravity feed. Determine whether the lubricating oil storage and service tanks may be required to be located at a minimum height to facilitate water settling or gravity feed.

5.2.13.34 Valve accessibility. All valves, including vent and drain valves on the strainers, filters, and purifiers, shall be kept accessible.

5.2.13.35 Tank access covers and handholes. All tanks shall have tank access covers or handholes. Space shall be allocated to facilitate internal tank cleaning.

5.2.13.36 Location of lubricating oil pumps. All lubricating oil pumps shall be located adjacent to the sump tank and low in the hull to obtain submergence of the pump suction. Since the sump tank is usually built into the main unit foundation, with the ship's innerbottom forming the bottom of the tank, the lubricating pumps are generally located at the after-end of the main machinery room, with the base of the pump no more than 153 millimeters (6 inches) above the innerbottom to ensure optimum submergence.

5.3 Electric plant. Continuity of the electric power supply shall be the primary aim of electric plant design and arrangement. To ensure continuity of service, quantity and location of generators and switchboards should be considered.

5.3.1 Space flooding. Flooding of equipment shall be minimized by locating electric machinery as far away from the bilge as practicable.

5.3.2 Electrical equipment and machinery clearances. Clearances shall be provided in the immediate vicinity of electrical equipment and machinery to permit complete accessibility for operation and maintenance. Electrical distribution and electrical control equipment shall be installed so that the tops of enclosures are not more than 2134 millimeters (84 inches) above the deck.

5.3.3 Ship's service and emergency generator sets.

5.3.3.1 Installation arrangement. The arrangement of the complete installation shall include clearances for dismantling within the space limitations of the selected locations on the ship. Generator sets shall be readily accessible for routine cleaning, inspection, maintenance, and repair.

5.3.3.2 Remote shutdown device. A remote shutdown device shall be installed for each ship's service and emergency diesel or gas turbine generator (see 5.2.1.2).

5.3.3.3 Location of starting batteries and air tanks. Starting batteries or air tanks for diesel or gas turbine engine starting systems shall be located as near as practicable to the diesel or gas turbine engine.

5.3.3.4 Location of service generators. For combatant ships (except patrol combatant ships), ship service generators are so located with respect to the damage length, as defined for the ship, that at least half of the electric plant is available subsequent to a major, survivable casualty.

5.3.3.5 Location of generator switchgear unit. The associated generator switchgear unit shall be located in the same space and as close to the generator as practicable.

5.3.3.6 Maintenance clearances. When arranging ship's service generators, the following maintenance clearances shall be maintained:

a. Allocate 915 millimeters (36 inches) from the furthest physical extent on the sides and one end of the units.

b. Allocate 1220 millimeters (48 inches) between a unit and its switchboard plus 610 millimeters (24 inches) behind the switchboard.

c. Allocate 1220 millimeters (48 inches) between two generator units in the same space.

d. Sufficient space shall be available to permit generator rotor removal and maintenance access.

5.3.3.7 Generator sets. Generator sets shall be mounted parallel to the fore and aft ship axis.

5.3.3.8 Location of emergency generators. Emergency generators shall be located such that:

a. Units are located above the design water line and V-line.

b. Separation between each emergency unit and the ship's service generators is at least two watertight bulkheads.

c. When two emergency generators are provided, one is installed forward, and one is installed aft of the machinery spaces.

5.3.3.9 Requirements for emergency generators. Emergency generator(s) are not required for ships provided with diesel or gas turbine-driven ship service generators, provided that all generators are arranged for automatic start. However, if the ship service generators are not separated and not above the design waterline and V-line, an emergency generator in a separate space may be required.

5.3.3.10 Ship service generators. For single machinery box (one space or adjoining spaces) ships, one or more ship service generators shall be located remotely from the machinery spaces and provided with automatic starting features unless an emergency generator is provided.

5.3.4 Storage batteries and servicing facilities. Racks for engine starting batteries shall be located as close as practicable to the starting motor and as far as practicable from the generator (if used).

5.3.5 Electric power supply conversion equipment. The installation of conversion equipment shall include space and clearances for dismantling within the ship. Conversion equipment shall be located insofar as practicable with terminals and live parts not lower than the access door sills in the main boundary bulkheads of the watertight area in which it is located.

5.3.5.1 Requirements for metallic rectifiers. Installation of rectifier power supplies or other equipment containing metallic rectifiers shall be in accordance with the following requirements:

a. Equipment containing metallic rectifiers shall be located in the coolest available areas close to their consuming equipment, and downstream from other equipment dissipating appreciable heat. Stagnant air spaces or spaces in which there will be immediate recirculation of the heated discharge air shall be avoided when possible.

b. Fan-cooled and ventilated equipment shall be oriented such that the intake air comes from the cooler region and the discharge is toward the warmer region and exhaust from the space.

c. Equipment shall be installed in a manner which permits free circulation of cooling air.

d. When arranging motor generator sets, the following maintenance clearances shall be maintained:

(1) Allocate 610 millimeters (24 inches) on the sides and one end of the unit.

(2) Allocate the space required to perform an in-space rotor pull plus 305 millimeters (12 inches) on the opposite end.

(3) Allocate 1220 millimeters (48 inches) between dual units.

5.3.6 Switchboards and electric power panels. Switchboards and power panels shall be located with respect to adjacent machinery, accesses, ventilation ducts, and piping to provide the maximum safety to personnel and protection to the switchboard equipment. Athwart ship arrangement of switchboards is preferred.

5.3.6.1 Switchboard clearances. The operating space in front of the switchboard guardrails shall be a minimum of 1067 millimeters (42 inches). A minimum of 610 millimeters (24 inches) of clearance shall be provided between the rear of the switchboard and the adjacent ship's structure. When applicable, clearance between the rear of the switchboard and the adjacent ship's structure shall be sized sufficiently for servicing circuit breaker support components, fans, arc chutes, and bus bars. One end of the switchboard shall have a minimum clearance of 610 millimeters (24 inches), and the other end shall have a minimum clearance of 153 millimeters (6 inches) from the ship's structure.

5.3.6.2 Structural members. In no case shall the sections of switchboards be directly connected by structural members, except at the base.

5.3.6.3 Location of switchboards. Switchboards shall be located so that the base of the units can be bolted directly to the deck stiffeners (not bolted to a thin deck plate).

5.3.6.4 Protective measures against flooding. To reduce the possibility of a power failure caused by partial flooding of switchboards, or as a result of water on the deck plates splashing on them, ship service and emergency switchboards shall be protected against such conditions insofar as practicable. Examples of possible protective measures are:

5.3.6.5 Design and mounting of switchboards. The design and placement of switchboard louvers and live parts shall ensure they are located above the level of watertight door sills located in the compartment's main boundary bulkhead.

5.3.6.6 Watertight barrier. The lower portion of the switchboard shall be protected by a watertight barrier or enclosure. If the barrier is not integral with the switchboard, it shall be provided with quick-opening drains.

5.3.6.7 Avoidance of excessive weight and height. Judgment shall be exercised in accomplishing the required protection to avoid excessive weight and height of the electrical installation caused by barriers and high foundations.

5.3.6.8 Emergency switchboard. An emergency switchboard shall be provided for each emergency generator. The emergency switchboards shall be located near the centerline of the ship, above the water line, with the minimum separation from the ship service switchboards.

5.3.6.9 Nonskid rubber matting. Nonskid, non-conductive rubber matting shall be applied over floor plating, in the front and rear of all switchboards, in way of the operating and maintenance areas.

5.4 Electronic systems.

5.4.1 Telephone systems. Soundproof booths shall be installed for dial telephone and sound-powered telephone handsets in spaces where higher ambient noise levels are expected and where deafness avoidance is a greater consideration than intelligible speech communication. Solid decking shall be installed on the deck area under the booth.

5.4.1.1 Installation of telephone amplifiers and speakers. Sound-powered telephone amplifiers and speakers shall be installed in main and auxiliary machinery rooms, emergency generator rooms, and other large, noisy spaces.

5.4.2 Degaussing systems. Degaussing power supplies and switchboards shall be co-located with the ship's main switchboards. The degaussing control units shall be located on the bridge, in the Central Control Station (CCS), and at the EOS (when applicable).

5.4.2.1 Degaussing system equipment to be considered. The degaussing system equipment that should be considered during machinery arrangement design development includes:

a. Degaussing coils.

b. Degaussing switchboards.

c. Degaussing power supplies.

d. Degaussing control units.

5.5 Auxiliary systems.

5.5.1 Pumps. The location of pumps shall provide the highest practicable net positive suction head. Centrifugal pumps for seawater service shall be located where they will have positive static submergence head of at least 915 millimeters (36 inches) under all conditions of draft and list up to 15 degrees.

5.5.1.1 Operating space. The operating space along the sides of pumps shall be a minimum of 762 millimeters (30 inches). No less than 915 millimeters (36 inches) of clearance shall be provided at one end of the pump. For multiple units, 1220 millimeters (48 inches) of operating space shall be allocated between the pumps.

5.5.2 Sea chests and piping systems.

5.5.2.1 Sea chests. Sea chests do not generally appear on the machinery arrangement since they are usually located within the innerbottom. They can, however, impact the arrangement indirectly, and the designer should be aware of this. It is preferable that each fire pump have its own sea chest to improve reliability. The ship's roll limits, together with the roundness of the bottom and the necessity to keep the suction sea chests under water, will limit the area available for sea chest locations, particularly for small ships. It is desirable to keep pumps close to the sea chests that service them in order to limit piping runs; as a result pump locations may also be indirectly limited. Ships designed for operation in shallow areas may require both high and low sea chests. Sea chests shall be located and designed to avoid the following:

a. The pickup of fluid discharged from another ship source: fluid which exits the hull through an overboard discharge and follows the path of the flow lines about the hull.

b. High entrance losses or suction difficulties with the ship underway.

c. The intake of air under any design operating condition including:

(1) Light ship displacement conditions.

(2) Astern power operation.

(3) Operation of Prairie/Masker systems.

(4) Pickup of debris from the sea bed.

5.5.2.2 Sand traps. On ships designed to be beached, sea connections shall incorporate sand traps.

5.5.2.3 Air in seawater systems. Seawater systems shall be, to the extent practicable, designed to permit air to pass through the system without becoming entrapped or adversely affecting system performance.

5.5.2.4 Overboard discharges. Overboard discharges shall be combined to the maximum extent practicable to minimize the number of shell penetrations.

5.5.2.5 Design and location of overboard discharges. Overboard discharges shall be designed and located to avoid the following:

a. Detrimental effects on underwater transducers.

b. Discharging into the path of the flow lines about the hull, which will cause the discharge to flow into suction sea chests.

c. Areas for boat handling and accommodation ladders.

5.5.2.6 Piping arrangement. Piping arrangement rarely affects machinery arrangement. However, careless machinery layout can cause unnecessary difficulties for the piping designer. Thus, the machinery arrangement engineer should avoid piping inefficiencies and interferences.

a. Seawater piping shall not be located above switchgear and generators.

b. Suction piping to fire pumps shall have a straight section equivalent to 5 times the pipe diameter before entering the pump eye, and all fire pump suction piping bends shall have a minimum radius of 5 times the pipe diameter.

5.5.3 Overflows, air escapes, and sounding arrangements. Sounding tubes for tanks containing flammable and combustible liquids shall terminate outside of machinery spaces.

5.5.4 Thermal insulation for machinery and piping. Consideration shall be given to machinery box insulation requirements (thickness) when initially locating equipments near bulkheads so covered. Care shall be exercised to ensure that insulation does not encroach upon clear maintenance volumes.

5.5.5 Ventilation systems. The impact of the ventilation system on machinery arrangements, including HVAC, can include equipment, ducting, fans, and spot coolers. Air conditioning machinery is customarily located outside the main machinery rooms in spaces designated as air conditioning and refrigeration machinery rooms or auxiliary machinery rooms.

5.5.5.1 Installation. Installation of duct sections, cooling coils, unit coolers, and steam heaters over the following equipment (and similar equipment) shall be avoided if at all possible:

a. Computers.

b. Control panels.

c. Electronic equipment.

d. Generators.

e. Generator terminals.

f. Load center and power distribution panels.

g. Switchboards.

h. Transformer terminals.

5.5.5.2 Fire zones. Air conditioning systems shall serve only one fire zone and shall penetrate no fire zone bulkheads. Ventilation systems shall serve only one fire zone. Where lack of superstructure prevents weather openings for a particular fire zone, fire zone bulkheads may be penetrated to serve that zone, provided the ducts are carried individually watertight from the weather to the fire zone served.

5.5.5.3 Ventilation duct arrangement. The details of the ventilation duct arrangement are usually developed late in the design. The machinery arrangements designer should anticipate the impact on space, particularly in the overhead, made by the ventilation ducting, heaters, and cooling coils.

5.5.5.4 Ventilation design data. The following ventilation information shall be considered when scoping machinery box impact caused by the space's support system (see 5.5.5.5 to 5.5.5.9).

5.5.5.5 Minimum number of air supply systems. Based on total compartment mechanical supply air quantity, the minimum number of supply air systems for machinery spaces are:

a. Under 10,000 CFM: one supply air system.

b. 10,000 CFM and over: two supply air systems.

5.5.5.6 Watch stations. The machinery spaces require special attention to ensure that an adequate number, type, and location of mechanical supply terminals are provided to meet at least the minimum ventilation requirements for a 4-hour watch. Examples of watch stations include:

a. Main switchboards.

b. Local operating consoles.

c. Oil distribution box.

5.5.5.7 Watch station operator terminals. Each operator at each watch station shall be provided with one terminal sized for a minimum of 2500 CFM. Where this is not possible because of interferences with one large terminal (and ducting), two smaller terminals, each sized for 1250 CFM, may be used for each operator.

5.5.5.8 Mechanical ventilation. All walking areas and areas where personnel can position themselves to work on equipment (installed or otherwise) shall have mechanical ventilation.

5.5.5.9 Terminals serving air compressors. Terminals serving air compressors shall provide 150 percent of the air compressor intake requirements. The terminus of the supply duct shall be located 153 to 229 millimeters (6 to 9 inches) from the air compressor intake opening. The terminal shall direct air into that opening.

5.5.6 Refrigeration systems. Refrigeration systems shall not be located in main machinery spaces.

5.5.6.1 Service openings. Service openings of refrigeration equipment shall be accessible. Clearances shall permit removal of compressor parts through cylinder leads and crankcase ends. Maintenance provisions shall be made for withdrawing condenser and chiller tubes.

5.5.6.2 Air-cooled condensers. Enough space shall be allowed for air-cooled condensers to permit free air flow through the condenser.

5.5.6.3 Maintenance and operating space. The clear maintenance and operating space allocated for refrigeration and air conditioning equipment shall be no less than 915 millimeters (36 inches) on one side and one end, and 610 millimeters (24 inches) on the opposite side and end.

5.5.6.4 Clear space for pumps. A minimum clear space of 610 millimeters (24 inches) shall be provided on all sides of refrigeration and air conditioning pumps.

5.5.6.5 Remotely located chillers, condensers, and receivers. All remotely located chillers, condensers, and receivers shall be mounted at least 305 millimeters (12 inches) off structure on all sides. A tube removal allowance plus 305 millimeters (12 inches) shall be provided on one end and 610 millimeters (24 inches) front clearance shall be reserved.

5.5.7 Waste heat recovery systems. Waste heat systems addressed in this section utilize gas turbine engine exhaust or diesel engine jacket water to provide steam or hot fresh water for hotel services such as de-icing, lubricating, and fuel oil heating.

5.5.7.1 Gas turbine exhaust gas waste heat boiler system. The boiler and its ancillaries shall be located in a dedicated space directly above the gas turbine [usually a ship's service gas turbine generator (SSGTG)] to provide a short, direct path for exhaust ducting. Feed and drain tanks and the feed pump are located in the machinery space below the boiler to facilitate drain back from the steam users.

5.5.7.2 Major components. The major components of a gas turbine exhaust gas waste heat boiler system are:

a. A waste heat boiler.

b. Feed water and reserve feed water tanks.

c. A feed pump.

d. A condensate drain cooler.

e. A contaminated drain tank.

f. A boiler control condenser.

5.5.7.3 Diesel engine jacket water waste heat system. The basic system consists of a jacket-water-to-hot-water heat exchanger and a circulating pump for each engine with one compression tank (approximately 50 to 100 gallon capacity) for the system. Ship's service diesel generators are usually the source of waste heat; however, small vessels sometimes use the propulsion engine jacket water. The heat exchanger shall be co-located with the engine; the circulating pump, compression tank, and hot water users need not be close to the engine.

5.5.8 Seawater service systems.

5.5.8.1 Separation of fire pumps. Fire pumps shall be separated to reduce the possibility of losing all fire pumps as a result of a single casualty. No more than 25 percent of the total number of fire pumps shall be located in any one fire zone, unless otherwise determined to be acceptable by a firemain system survivability study.

5.5.8.2 Number of fire pumps. The number of fire pumps to be installed is a function of the total firemain capacity required, the type of driver employed, and other factors. A minimum of two fire pumps located in two different fire zones shall be arranged on all ship designs.

5.5.8.3 Installation of fire pumps. Diesel-driven or gas turbine-driven fire pumps, if used, shall be installed outside the main and auxiliary machinery spaces.

5.5.8.4 Sea chest and isolation valving. Each fire pump or group of fire pumps shall require a sea chest and isolation valving.

5.5.8.5 Sea chests on ships designed for beaching. On ships designed for beaching, two widely spaced sea chests may be required in each machinery space with cross-connect piping and valves so that any fire pump in the space can take suction from either sea chest.

5.5.8.6 Location of fire pumps. Fire pumps shall be located with at least one per fire zone, insofar as practicable. At least one fire pump shall be located in the forward fire zone.

5.5.8.7 Firemain piping. In ships with a vertically offset firemain architecture, a composite firemain architecture, or a single main, one of the mains may run fore and aft through the machinery spaces. Some ships may incorporate athwartship piping, with port and starboard risers to the mains. All main piping is likely to have a nominal diameter (DN) of 200 to 300 (8 to 12 inches) and include motor operated valves. In spaces with only a single riser to a main, a 4-valve hose manifold may be located in the machinery space. In order to minimize pipe bends and interferences, the machinery arranger should consult with the firemain designer early to get an understanding of the number of fire pumps required, the placement of major valves and hose manifolds, and the firemain architecture.

5.5.8.8 Motor-driven fire pumps. Each motor-driven fire pump shall require independent motor controllers, independent sea chest valves remotely operable from at least one deck above, and pump suction and discharge valves for each pump, which may be manually operated or powered.

5.5.8.9 Vertical fire pumps. Vertical fire pumps shall be utilized only if the machinery arrangement cannot support horizontal pumps.

5.5.8.10 Emergency fire pumps. Where emergency fire pumps are provisioned, their controls shall be located above the design water line and V-line.

5.5.9 Auxiliary seawater systems. The composition and purpose of auxiliary seawater systems can vary widely among different ship types. In general, this system differs from the seawater service system in that it is dedicated to one piece of equipment requiring seawater.

5.5.9.1 Use of auxiliary seawater systems. Auxiliary seawater systems shall have dedicated and co-located sea chests, pumps, strainers, and piping. When needed, auxiliary seawater systems shall be used for the following systems:

a. Air compressor heat exchangers.

b. Ship's service turbo generator (SSTG) lubricating oil heat exchangers.

c. Diesel engine cooling (propulsion or generator).

d. Refrigeration heat exchangers.

5.5.10 Drainage and ballasting systems. The scope of this discussion shall be limited to those drainage and ballast systems with equipments located within the main and auxiliary machinery spaces. These systems include main drainage, ballast/deballasting systems (where main drainage pumping equipment is used), and the oily waste water drainage system.

5.5.10.1 Main drainage system. The main drainage system shall consist of piping installed low in the ship with suction branches to spaces to be drained and with direct connections to eductors and drain pumps.

5.5.10.2 Eductors. Eductors shall discharge overboard through a sea valve located below the waterline.

5.5.10.3 Drain pumps. The drain pumps shall take suction from the drain main, fuel stripping system, and oily waste holding tanks via a simplex strainer and shall discharge overboard, to the oily waste holding tanks via an oily-water separator as well as to port and starboard weather deck discharge connections.

5.5.10.4 Looped main drainage. In a looped main drainage system, the two mains shall be cross-connected at each pump or eductor.

5.5.10.5 Suction connections. In addition to bilge suctions installed at the forward and aft ends of each main machinery space, suction connections are required from an oily waste holding tank, a fuel drain tank, and a waste water drain tank.

5.5.10.6 Strainers. Strainers, required on the suction tailpipes, shall extend up to the level of the lower grating.

5.5.10.7 Removal of oily waste water. Either the main drainage system or an independent oily waste water suction main shall be used to remove oily waste water. If an independent system is used, two oily waste water pumps, oily water separators, and an oily water polisher (if required) shall be required and located on the space's lower level.

5.5.10.8 Main drainage system. Either eductors driven by the firemain or separate pumps shall be used to operate the main drainage system. If eductors are used, they shall be located below the lower level floor plates.

5.5.10.9 Ballasting/deballasting requirements. Unless ballasting/deballasting requirements are large, the main drainage eductors can serve this system. Where ballast/deballast requirements are large, separate pumps shall be used and can be installed in one or more compartments outside the machinery spaces.

5.5.10.10 Electric or oil-hydraulic valve operators. Where staffing requirements dictate remote control of the systems, space allowances shall be made for electric or oil-hydraulic valve operators.

5.5.11 Distilling plants. Each distilling unit shall be complete with no component serving more than one unit.

5.5.11.1 Location of pumps. Pumps shall be located at a sufficiently low level to ensure a positive suction head under all distiller and ship operating conditions.

5.5.11.2 Lifting gear. Lifting gear shall be provided, including tracks and hoists.

5.5.11.3 Distilling plants. The number of distilling plants installed is usually equal to the number of shafts, but in no case shall be less than two plants.

5.5.11.4 Clear maintenance and operating space. The clear maintenance and operating space allocated for distilling plants shall be no less than 610 millimeters (24 inches) on the back and sides. The clear maintenance and operating space allocated for the front of distilling plants shall be no less than the space required for heat exchanger tube removal plus 305 millimeters (12 inches).

5.5.12 Freshwater service systems. This section contains requirements for freshwater service systems except those which use a freshwater/ seawater heat exchanger for cooling the freshwater. The systems included are potable water, diesel generator waste heat, chilled water, distilled water, and the gas turbine wash down system.

5.5.12.1 Cold potable water system. The cold potable water system shall be as follows:

a. The system shall be arranged to provide for recirculation of the potable water in any potable water stowage tank via a recirculation brominator.

b. The cold potable water system shall have pumps, potable water tanks, and filling and suction manifolds. These components shall be grouped where practicable. More than one manifold may be installed to obtain better suction piping arrangement. Pumps shall be located at low levels in the ship and as centrally as practicable with respect to the stowage tanks.

c. A system shall be installed for the purpose of disinfecting both a ship's distilled water and freshwater from shore sources, utilizing bromine as the disinfecting agent. The system shall have proportioning bromine feeder units, potable water recirculation pumps, and suction and return lines from each potable water stowage tank. These components shall be grouped where practicable and located at low levels in the ship and as centrally as practicable with respect to the stowage tanks. Distiller brominators shall be installed in the discharge lines from the distillate transfer pumps upstream of the filling and suction manifolds for the purpose of introducing bromine into the distillate prior to entering the potable water stowage tanks.

d. Recirculation brominators shall be installed to disinfect water recirculated from the ship's potable water stowage tanks. Suction lines from each potable water stowage tank shall be led to the selector valve on the inlet side of the brominator.

e. Priming pumps shall be provided for service pumps and bromine recirculation pumps which do not have positive suction head under all conditions.

f. Potable water tanks shall be of the following types:

(1) Compression tanks for pressure sets.

(2) Distilled water collecting tanks.

(3) Gravity tanks.

(4) Small supply tanks.

(5) Ship tanks.

g. In general, ship tanks shall be built-in tanks formed by the ship structure. Gravity tanks, distilled water collecting tanks, and small supply tanks shall in general be independent of the ship structure.

5.5.12.2 Hot water circulating system (diesel generator waste heat). A hot water circulating system (diesel generator waste heat) shall be as follows:

a. A hot water circulating system shall be installed to provide heating water to the following services: fuel service and transfer heaters; the lubricating oil purifier heater; lubricating oil settling tank heating coils; the hot potable water heater; distilling plants; and the guided missile launcher anti-icing system heat exchanger (if applicable).

b. Heat exchangers shall be installed in the diesel engine jacket water cooling system of each ship service diesel-generator upstream of the jacket water cooler temperature-regulating valve.

c. A compression tank shall be installed to serve the hot water-circulating system return main. The tank shall be sized to hold twice the total volume increase of the system when the water is heated from 50 to 170 °F. The compression tank shall be charged with air to maintain a minimum of 5 psi throughout the hot water-circulating system under all conditions.

5.5.12.3 Chilled water system. A chilled water system shall be as follows:

a. Each chilled water expansion tank shall be sized to accommodate the thermal expansion of the total volume of coolant in its system through a temperature gradient from 32 to 120 °F. In general, two or more complete, two-pipe, forced-circulation loops shall be installed. One supply and one return main shall be installed under the main deck.

5.5.12.4 Gas turbine wash down system. A gas turbine wash down system shall be as follows:

a. A gas turbine wash down system shall be provided for the propulsion gas turbines. The system shall consist of a wash water tank, rinse water tank, injection pump, and distribution piping.

b. The wash water tank capacity shall be based on the size and flow needs of the serviced gas turbines. Capacities between 50 and 90 gallons are typical. Filling of the tanks shall be directly from the distilled water system.

5.5.13 Auxiliary freshwater cooling. This element covers freshwater cooling systems for machinery and equipments where the cooling interface for the freshwater to be cooled is a freshwater/seawater heat exchanger. The source of the seawater is the circulating and cooling seawater system. The systems requiring cooling are the electronic and auxiliary freshwater cooling systems, diesel engine cooling systems, and the auxiliary freshwater-cooling systems.

5.5.13.1 Diesel engine freshwater cooling systems.

5.5.13.2 Freshwater cooling system requirements. Freshwater cooling systems shall be closed-loop, shall be self-contained, and shall provide cooling water to the diesel engine water jacket and to the lubricating oil cooler.

5.5.13.3 Seawater service system. Freshwater shall be cooled by the seawater service system.

5.5.13.4 System fill and makeup water. System fill and makeup water shall be from the cold potable water system, via an air gap, to the cooling water system expansion tank.

5.5.13.5 Freshwater-circulating pump. The freshwater-circulating pump usually is procured with and attached to the engine. Some foreign engines may have separate pumps which may or may not be procured with the engine.

5.5.13.6 Locations. Locations are required for the freshwater/seawater heat exchanger, lubricating oil cooler, freshwater treatment tank, and a 10 to 20 gallon expansion tank. A temperature control/bypass valve shall be located and piped to pass heated jacket water to either the heat exchanger or the lubricating oil cooler. In surface ships, a freshwater/waste heat circulation heat exchanger and a booster circulation pump may be installed.

5.5.13.7 Electronic and auxiliary freshwater cooling system.

5.5.13.7.1 Electronic and auxiliary freshwater equipments. The Electronic and Auxiliary Freshwater (EAFW) shall be a closed-loop system comprised of the following equipments:

a. Two electric motor-driven, sound isolated, centrifugal circulation pumps.

b. Two seawater/freshwater heat exchangers.

c. A pressurized expansion tank and air trap.

d. A mixed-bed ion exchanger and ancillary equipment.

e. A demineralizer system (demineralizer, demineralized water storage tank, ion exchanger, hose connections, piping, and valves).

f. Necessary piping, valves, alarms, and controls.

5.5.13.7.2 Electronic equipment requiring cooling. The EAFW system may cool some equipment, such as air compressors, located in the engine room or auxiliary engine rooms.

5.5.14 Ship fuel and fuel compensating systems. Each space containing diesel engines or gas turbines for propulsion shall have two fuel service tanks. Fuel service tanks shall not be located forward of the machinery box.

5.5.14.1 Fuel tank vents. Fuel tank vents shall not terminate in living spaces.

5.5.14.2 Separate service tanks. For combatant type ships, auxiliary engines shall have separate fuel service tanks in the same space as the engines.

5.5.14.3 Servicing auxiliary engines and boilers. For auxiliary type ships, auxiliary engines and boilers may be serviced from the fuel service tanks in the main machinery space.

5.5.14.4 Diesel or gas turbine generator sets. Emergency diesel or gas turbine generator sets shall have a separate fuel service tank in the same space as the unit.

5.5.14.5 Emergency gravity tank. Propulsion gas turbines shall have an emergency gravity tank in the same space to provide fuel for a specified period when all electric power is lost.

5.5.14.6 Fuel service tank stowage. Fuel service tanks shall each stow fuel for 8 hours of operation at the full load capacity of the units being served. Gas turbines may be sized for 6 hours if the volume of the tank is deemed excessive.

5.5.14.7 Contaminated fuel settling tank. Each space containing boilers, diesel engines, or gas turbines shall contain a contaminated fuel settling tank. Total capacity of these tanks shall be one percent of the ship's endurance fuel capacity, per DDS 200-1.

5.5.14.8 Piping restrictions. Although most piping will not be shown on machinery arrangement drawings, it is important to keep these restrictions in mind when installing components which will be served by fuel piping.

5.5.14.9 Fuel duplex strainers. Fuel duplex strainers subject to pump discharge pressure shall be provided with safety shields and spray tight enclosures. They shall not be located beneath distributive system piping systems servicing high temperature fluid systems.

5.5.14.10 Tank and tail pipe volume. Total volume of each tank shall include allowances for internal tank structure (three percent), expansion (five percent) and for unavailable fuel below the suction tail pipe. Tail pipe allowance shall be eight percent when tail pipe height is 610 millimeters (24 inches).

5.5.14.11 Fuel transfer pumps. Fuel transfer pumps take their suction from wing and bottom tanks. They should therefore be kept low in the ship.

5.5.14.12 Centrifugal purifiers. Purifier maintenance allowances for using hand-operated chain hoists mounted on monorail tracks directly over the bowl shall be provided.

5.5.14.13 Tank access covers. All tanks shall have tank access covers. Keep space available for this function.

5.5.14.14 Space and access for piping. Fuel systems will have considerable piping, including cross connections between service systems, tank manifolds, test connections, and liquid level-indicating systems in addition to those items on the equipment list which will be shown on the drawing. Arrangements shall leave space and access for these functions.

5.5.14.15 Fuel flow meters. Fuel flow meters serving each main engine and ship service generator shall be provided.

5.5.15 Gasoline and aviation fuel (JP-5) systems. The arrangement of gasoline and JP-5 equipment and piping rarely impacts propulsion machinery spaces, and there are usually no arrangement difficulties when locating the equipment in AMRs or dedicated pump rooms. The existence and operation of aviation fuel (JP-5) systems on board the ship, such as fire hazards, fuel contamination, and toxicity hazards to ship personnel, generate some conditions which should be considered in their design arrangement. In addition, gasoline's extreme volatility requires consideration over and above those for JP-5 piping and equipment.

5.5.15.1 Gasoline pump room separation. Gasoline pump motors and seawater compensating pumps that are located in the gasoline pump room shall be installed in an adjacent compartment separated from the pump room by an airtight (fume-tight) bulkhead. Where the motor shafts extend through this bulkhead, airtight stuffing boxes shall be used on that bulkhead.

5.5.15.2 Gasoline stowage and pumping. Gasoline stowage and pumping are becoming increasingly rare on naval vessels other than petroleum transport tankers. Aviation gasoline is rarely carried on board combatants, and motor gas for use in United States Marine Corps (USMC) vehicles and generators is seeing less use as USMC switches to diesel power.

5.5.15.3 Gasoline double-walled piping. Gasoline double-walled piping is required in spaces other than gasoline tanks and pump rooms; this pipe is, in turn, run in trunks through the ship to fueling stations. The pipe annulus (space between inner and outer pipes) is filled with inert N_2 or CO_2 Thus, N_2 generators, N_2 cylinders, and CO_2 cylinders shall be co-located with the pump room.

5.5.16 Compressed air systems.

5.5.16.1 Air receivers. Air receivers used in systems where pressures are less than 600 psi shall be fitted with pressure gauges and relief valves. Where practicable, the relief valves shall discharge outside the machinery space. Where permitted, a manhole or multiple hand holes shall be provided for interior cleaning. Orientation of receivers shall ensure clear access to these accesses.

5.5.16.2 Air flasks. Flasks used for air compressor systems of 600 psi or more shall not be mounted directly on bulkheads or rest on deck beams. They shall be placed in a vertical position with their air intakes and outlets on the top and their drains on the bottom. Drain piping can be combined from multiple air flasks.

5.5.17 Fire extinguishing systems. The following firefighting requirements are relative to machinery arrangements:

a. Fire protection systems for machinery spaces will be determined by NAVSEA based on a hazard analysis. The system selection guidance in this section may be used for early stage design, before a hazard analysis has been conducted. All fixed fire extinguishing systems that are intended for a machinery space, either as the primary or secondary system, shall be located outside the machinery space except for the distribution piping, nozzles, and local controls associated with water mist, HFP and AFFF sprinkling, and AFFF and seawater hose stations. HFP cylinders for engine enclosures may be in the machinery space that contains the enclosure. A fixed CO_2 total flooding fire extinguishing system shall not be provided for any machinery space.

b. Machinery spaces and engine enclosures that contain both pressurized fuel and ignition sources shall be provided with a water mist or HFP fixed fire extinguishing system suitable for three-dimensional fires and with AFFF sprinkling for the bilge or lowest deck if there is no bilge. AFFF sprinkling shall also be provided for the top and sides of diesel engines. Incinerator spaces shall be provided with AFFF overhead sprinkling. HFP systems provided for main engine enclosures shall include primary and reserve systems. Typical ignition sources include engines, engine exhaust ducts, bleed air piping, motor driven centrifugal fuel purifiers, and air compressors. AFFF hose reels shall be provided in the space and for reentry, as described in this section. Seawater fire hose stations shall be provided as described in this section. Portable fire extinguishers shall be provided as described in this section.

c. Machinery spaces that contain pressurized fuel without ignition sources shall be provided with AFFF overhead sprinkling. AFFF hose reels shall be provided in the space and for reentry, as described in this section. Seawater fire hose stations shall be provided as described in this section. Portable fire extinguishers shall be provided as described in this section.

d. Seawater fire hose stations shall be provided in machinery spaces that contain pressurized fuel to facilitate bulkhead cooling. Bulkhead cooling is not required for bulkheads where the far side is a void or a tank for water, or the side shell below the waterline. At least two fire hose stations, each with 15 meters (50 feet) of hose, shall be located on each level. Each hose shall be considered to provide bulkhead cooling only for the level on which it is located, and shall be limited to cooling 18 meters (60 feet) of bulkhead length. The arrangement of seawater hose stations shall consider that the hose lay must be on a route that personnel can travel, shall consider the rigidity of the hose when pressurized, and may include an allowance for 3 meters (10 feet) of stream reach.

e. Seawater fire hose stations shall be provided for general purpose firefighting in machinery spaces that do not contain pressurized fuel. Seawater hose fire stations for steering gear spaces shall be outside the machinery space. Seawater hose stations shall be arranged to provide two-hose coverage of any point in the space with 15 meters (50 feet) of hose and an allowance for 3 meters (10 feet) of stream reach. Hoses for steering gear spaces shall be 30 meters (100 feet) in length. Seawater hose stations on one level shall not be considered to provide coverage on another level. The arrangement of seawater hose stations shall consider that the hose lay must be on a route that personnel can travel, and shall consider the rigidity of the hose when pressurized.

f. AFFF hose reels with 15 meters (50 feet) of hose shall be provided on each level in sufficient quantity so that each point in the space can be reached with at least one hose. Reentry AFFF hose reels shall be provided outside the machinery space at the main access and at the escape trunk with sufficient hose length to reach any point in the space. The arrangement of AFFF hose reels shall consider that the hose lay must be on a route that personnel can travel, shall consider the rigidity of the hose when pressurized, and may include an allowance for 3 meters (10 feet) of stream reach. AFFF hose reels shall be arranged so the hose will unwind along the direction of travel.

g. At least one portable CO_2 fire extinguisher shall be provided within a 9-meter (30-foot) horizontal travel distance for major electrical and electronic equipment. Examples of major electrical and electronic equipment include electrical generators, motors, switchboards, static conversion power supplies, storage batteries, electronic equipment, and major control equipment. For main switchboards and load centers, and where more than one generator is collocated, two CO_2 portable fire extinguishers shall be provided. Each CO_2 portable fire extinguisher can provide coverage for more than one piece of electrical equipment. Preferred locations are near areas normally occupied by personnel on watch, near specific hazards, and in the vicinity of accesses. CO_2 portable fire extinguishers shall not be located in spaces in which the design temperature can exceed 55 °C (130 °F). Portable dry chemical PKP fire extinguishers shall be provided in machinery spaces that contain flammable liquids, and in O_2N_2 compressor rooms. At least one PKP portable fire extinguisher shall be provided for each level of the space. PKP fire extinguishers shall be 18 pound capacity unless otherwise noted. One PKP portable fire extinguisher shall be located within a 9-meter (30-foot) horizontal travel distance from potential leak or spill points, except that extinguishers for engines in enclosures shall be located at each enclosure access door, and in spaces with AFFF hose reels one 27-pound PKP portable fire extinguisher shall be provided at each hose reel. One PKP portable fire extinguisher shall be provided within a 9-meter (30-foot) travel distance to each flammable and combustible material cabinet, but not closer than 2.4 meters (8 feet). A PKP portable fire extinguisher can provide coverage for more than one hazard.

5.5.18 Fluid storage and supply tanks. Reserve fluid storage tanks and pressurized supply tanks shall be constructed to allow visual inspection and cleaning of the tank interior and draining of water collected at the low point in each bay of the tank.

5.5.18.1 Fluid storage and supply tank connections. The location of fluid supply tank fill and vent connections shall prevent spillage under the maximum roll and pitch conditions specified in the shipbuilding specifications. Tank vents shall be terminated as close to exhaust ventilation terminals as practicable. Tank return lines shall terminate below the fluid level. Return lines shall terminate separate from pump suction lines to prevent fluid flowing from the return lines from going directly back to pump suction.

5.5.18.2 Filters. Filters shall be provided for hydraulic systems as specified for the equipment. Filters shall be readily accessible, and all filter elements shall be removable for service and inspection without disconnecting the attached pipe or dismounting the filter housing. Filters used within control valves or components shall be accessible for removal without removing the valve or component.

5.5.18.3 Accumulators. Accumulators shall be arranged in the vertical axis such that wear to internal dynamic seal or diaphragm is minimized.

5.5.18.4 Supplemental system cooling. If supplemental system cooling is required, a heat exchanger shall be provided to maintain the hydraulic fluid's temperature within acceptable operating limits. Installation shall provide for isolation of the heat exchanger with bypass included.

5.5.18.5 Reserve oil storage tank. A reserve oil storage tank shall be provided for each hydraulic fluid used in the ship's hydraulic service systems. Each tank shall have a capacity at least equal to the capacity of those systems using the hydraulic fluid.

5.5.18.6 Single supply tank. When practical, a dedicated supply tank shall be provided for each hydraulic pump that operates steering gear. For purposes of system separation and reliability, a bay shall be provided in the lower area of the tank for each pump. Supply tanks shall be located at a height above the pumps sufficient to ensure complete flooding of pumps by hydraulic fluid in the event of loss of tank air pressure.

5.5.19 Fin stabilizers and machinery. Fin stabilizer-operating and control equipment arrangement is not normally under the cognizance of the Machinery Arranger. Should the stabilizer equipment be located in a machinery space (MMR or AMR), the machinery arrangements engineer must be prepared to allocate the necessary space for this equipment. The following points shall be considered:

a. The priority area for fin stabilizers is approximately amidships at the turn of the bilge (port and starboard).

b. Fin stabilizer-operating and control equipment consists of hydraulic power units (with oil reservoir) and remote and local control units.

c. Adequate access, maintenance, and pull space around the stabilizer unit shall be provided.

5.5.20 Environmental pollution control systems. The arrangement and location of sewage holding tanks, pumps, monitoring sensors (temperature, hydrogen sulfide, flooding, etc.), and processing equipment shall prevent leakage from these components from contaminating bilges and adjacent spaces.

5.5.20.1 Dedicated space. A dedicated space apart from any continuously manned space shall be provided for these components. The space shall be capable of containing any leakage or spills from these components during maintenance or malfunction. The space shall incorporate a sump and an eductor. The sump shall be located in the lowest point in the space.

5.5.20.2 Potable water tanks. Potable water tanks shall not be located below the level of the sewage equipment space.

5.5.20.3 CHT tank and potable water tank. CHT tank and potable water tanks shall not share a common or integral boundary. The sewage equipment space shall not be located adjacent to living spaces, food storage spaces, or continuously manned spaces.

5.5.20.4 Access. Access to the space shall not be through living or messing areas.

5.5.21 Ladders, handrails, floor plates, staging, and gratings.

5.5.21.1 Attachments. Attachments to structure or equipment (such as electrical panels or machinery) shall be made only where the structure or equipment is specifically designed or reinforced for such purposes and where equipment is neither sound isolated nor resiliently mounted.

5.5.21.2 Ladders. Ladders shall be installed as necessary to provide access to all compartments, all duty station passages, all walkways, and all important operating parts of machinery and systems. All ladders and handrails shall be located so as not to interfere with the opening and closing of hatches, doors, gratings, or manholes. Inclined ladders shall be installed as the main access to all machinery compartments, except where the access location or the machinery arrangement precludes their installation. Ladders and handrails shall be of steel construction. Standing areas at the top and bottom of ladders shall be steel.

5.5.21.3 Ladder access. Access ladders shall be securely fixed in place but shall be removable where necessary under service conditions. Where removal is not required, ladders may be built or fixed in place.

5.5.21.4 Treads. Top treads of inclined ladders shall be 229 millimeters (9 inches) deep. The distance from the edge of the top tread to the bulkhead or hatch coaming shall not exceed 51 millimeters (2 inches). If necessary, the depth of the top tread shall be increased to suit. All other treads shall be 153 millimeters (6 inches) deep for inclined ladders installed at angles of 50 to 60 degrees with the deck and 102 millimeters (4 inches) deep for inclined ladders installed at angles greater than 60 degrees.

5.5.21.5 Inclined ladders. Wherever practicable, interior inclined ladders shall be installed at an angle of 50 to 60 degrees with the deck, and exterior inclined ladders, at an angle of 50 degrees with the deck. Headroom shall be at least 1905 millimeters (75 inches) between the leading edge of the tread and the ship's structure or installed system.

5.5.21.6 Unguarded openings. Unguarded openings between the upper end of handrails, chains, or ropes of inclined ladders and adjacent rails or structures of the upper level shall be kept to a minimum, and in no case, shall they be greater than 127 millimeters (5 inches).

5.5.21.7 Sheet metal shields. Sheet metal shields shall be fitted on the underside of ladders over machinery and equipment and in quarters. Shields shall be of the same material as the ladders to which they are fitted. The shields shall be securely fastened to prevent vibration but shall be readily removable for cleaning and preservation.

5.5.21.8 Floor plates and gratings. Steel floor plates and gratings shall be installed for access to all machinery and equipment. Unnecessary weight and complication shall be avoided, but the load to be supported, including machinery overhaul tools and parts, shall be considered in determining the length of span. Extra support shall be provided at all points where heavy weight or particularly rough usage is expected. Plates or gratings shall not be attached to or supported from boiler casings.

5.5.21.9 Portable or hinged sections of floor plates. Portable or hinged sections of floor plates or gratings shall be fitted in areas where access is required below them for periodic inspection of equipment, maintenance, and cleaning. Where access is required for operation of valves or other controls, hinged sections shall be used. A means of preventing personnel from falling through open grating shall be provided.

5.5.21.10 Nonskid floor plates. Floor plates of a nonskid type shall be installed in the lower levels of machinery rooms and shaft alleys (except in areas specified under gratings). Floor plates shall be installed on the upper levels of machinery rooms in way of switchboards.

5.5.21.11 Gratings. In machinery rooms, gratings shall be used in the upper levels except in the way of switchboards.

5.5.21.12 Hinged sections of grating. Hinged sections of grating shall also be used over accesses to the lower level of machinery rooms where these accesses are located in passageways and are not provided with lifelines or life rails.

5.5.21.13 Guardrails. Guardrails shall be provided around all elevated platforms, gratings, and walkways or wherever there is danger of crew members becoming enmeshed with hazardous operating machinery. Where there is danger of personnel becoming enmeshed with hazardous operating machinery, guardrails shall be two courses high, evenly spaced between the top rail and the deck or toeplate. Near machinery that must be accessed for maintenance, guardrails may be removable. To do so, stanchion sockets may be welded to the outside of the frame bounding angle or coaming such that walkways are unimpeded but the stanchion firmly secured. Guardrail stanchions shall be perpendicular to the walking level. Guardrails shall be provided around all elevated platforms and gratings, walkways, passageways, switchboards, and moving parts of machinery.

5.5.22 Plumbing fixtures and fittings. Machinery spaces shall be provided with an eye/face bath which may be installed in connection with sinks or bubblers provided within the space. A drinking water cooler or bubbler shall also be provided in each main machinery space.

5.5.23 Garbage and trash disposal. Garbage and trash disposal spaces consist of incinerator spaces, pulping machine and plastic waste processing spaces, and other solid waste equipment spaces. Dedicated space allocations for incinerators, pulping machine and plastic waste processing machinery, and other solid waste equipment shall be provided. Garbage and trash disposal equipment installation shall be as specified in 593-7556875 and S9593-C6-IIN-010.

5.5.24 Incinerators. Incinerators are used to rid a ship of trash, garbage, or other waste products that result from normal operations. The greatest influence on the location of the incinerator is the routing of uptakes and intake air ducting. Duct routing considerations usually place the incinerator room at a location somewhere under a stack. In some cases, the incinerator has been placed far aft, with the smoke pipe exiting near the stern deck edge. Incinerator equipment installation shall be as specified in S9593-CZ-IIN-010.

5.5.25 Workshops, laboratories, test areas, and portable tools. If not adjacent to a suitable work shop, each main and auxiliary machinery room, air conditioning and refrigeration machinery room, motor room, and pump room shall contain at least one metal workbench, 762 millimeters (30 inches) wide and 1220 millimeters (48 inches) long, equipped with a 153 millimeters (6-inch) machinist's vise, and one metal tool locker.

5.5.26 Special stowage arrangement. Lockers and hooks shall be installed for stowage of portable telephone sets. Special rack stowage shall be provided for gas turbine lubricating oil. A lubricating-oil stowage tank for filling portable oiling cans shall be provided.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The information covered by this standard is intended for use on early stage machinery arrangements development. The information will be used to design and validate the sizes and locations of the following areas (including, but not limited to): machinery boxes, shafting, intakes and uptakes, and major machinery (such as engines, motors, reduction gears, propulsors, rudders, and their associated equipment).

Naval ship machinery arrangement design practices differ from commercial ship design practices in order to account for the potential hazards encountered in military service and in considerations for battle damage and mission essential system reliability.

The information provided in this standard is to be used by machinery arrangements engineers to design or validate on a ROM scale. Guidelines and information provided will generally be used to design and validate during early phases of design. The intent is to ensure that provisions are made to account for the space reservation and location of various elements and systems.

The standard is not intended to be a complete system design guide. It will not be used to size or locate every piece of a system, but rather the system as a whole.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this standard.

b. When machinery arrangement drawings are required to be prepared (see 6.3).

6.3 Machinery arrangement drawings. When specified (see 6.2), machinery arrangement drawings will be prepared in accordance with 803-6983515.

6.3.1 Scale of machinery arrangement drawings. Machinery and piping arrangements will be drawn to scales of not less than one quarter of an inch to the foot or 1:50 for metric drawings. Where practicable, all machinery arrangements for the same class will be drawn to the same scale.

6.3.2 Content of machinery arrangement drawings. Machinery arrangement drawings will show the following components to ensure against interference between mechanical and electrical components and to expose undesirable conditions:

a. Piping systems (as necessary).

b. Ventilation ducts.

c. Items of electrical equipment, including wireways.

d. Other pertinent features, such as:

   (1) Major machinery foundations.

   (2) Tube removal space outlines.

(3) Unshipping of shafting.

(4) Combustion air intake.

(5) Exhaust systems.

(6) Ladder landings and accesses.

(7) Stanchions.

(8) Overhead structure.

(9) Bulkhead stiffeners.

(10) Other hull structures necessary to indicate the following:

  (a) Machinery obstructions.

  (b) Large piping.

  (c) Locations of removal plates for shipping and unshipping machinery.

  (d) Permanent lifting gear and trolley arrangements.

  (e) Locations of firefighting equipment.

6.4 Subject term (key word) listing.

Machinery integration

GAS TURBINE ENGINE INTAKE AND UPTAKE SYSTEMS

A.1 SCOPE

A.1.1 Scope. This appendix details general design methodology for sizing of combustion air intakes and exhaust systems. This appendix is a mandatory part of this standard. The information contained herein is intended for compliance.

A.1.2 Gas turbine intake and uptake systems. The gas turbine intake and uptake system provides the ducting and components necessary to intake weather air for engine combustion and engine enclosure (module) cooling and to discharge the high temperature exhaust gas to the weather. The gas turbine characteristics require large duct areas, silencers, and intake air filtration; in addition surface combatants require infrared suppression of the exhaust gas and uptake.

A.1.3 Marine gas turbines. Use of Marine Gas Turbines (MGTs) is advantageous because of the engine's large power to weight ratio, the fact that they can be brought on-line quickly, and that they exhibit a lower vibration signature than comparable internal combustion engines (diesels).

A.1.4 Disadvantages of MGTs. The inherent disadvantages of using MGTs include the large volume combustion and exhaust ducting required, engine susceptibility to saltwater and particulate fouling, and high engine exhaust gas temperatures. Each of these disadvantages will influence the design of the engine intake and uptake system.

A.1.5 Airborne foreign object removal. Each MGT intake system shall have the ability to remove airborne water, salt, sand, and other foreign objects to prevent engine fouling and maintain engine life. High engine exhaust gas temperatures must be brought to reasonable levels before being emitted to the atmosphere to prevent heat damage to mast and deck mounted electrical equipment and to minimize the infrared signature on surface combatants.

A.2 APPLICABLE DOCUMENTS

A.2.1 General. The documents listed in this section are specified in sections A.3 through A.12 of this appendix. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they shall meet all specified requirements of documents cited in sections A.3 to A.12 of this appendix, whether or not they are listed.

A.2.2 Government documents.

A.2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this appendix to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-S-901 - Shock Tests. H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-769 - Thermal Insulation Requirements for Machinery and Piping

(Copies of these documents are available online at https://assist.dla.mil/quicksearch/.)

A.2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this appendix to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

NAVAL SEA SYSTEMS COMMAND (NAVSEA) DESIGN DATA SHEETS

DDS 221-1 - Data for Estimating Pressure Losses in Engine and Boiler Inlet and Exhaust Systems

(Copies of this document are available by email at CommandStandards@navy.mil with the subject line "DDS request".)

A.2.3 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this appendix and the references cited herein, the text of this appendix takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

A.3 DEFINITIONS

A.3.1 Elastic limit. The maximum stress without permanent deformation after complete load removal.

A.3.2 Elasticity. The tendency to return to original size or shape after being deformed.

A.3.3 Failure modes. Failure modes are defined as follows:

a. Corrosion: gradual chemical or electrochemical attack resulting in conversion into an oxide, salt, or other compound.

b. Creep: internal slip under reduced stress at elevated temperatures (in grain/grain boundary), failure starts as a slow spreading crack with loss of ductibility.

c. Deformation: when elastic limit is exceeded, plastic deformation occurs may result in failure (ductibility factor).

d. Fatigue: the tendency to break under conditions of repeated cyclic stressing, considerably below the ultimate tensile strength.

A.3.4 Recrystallization. The development of an entirely new grain structure by heating to a higher temperature than that required for recovery.

A.3.5 Stress. The internal resistance of a material to deformation of size or shape.

A.4 PHYSICAL CONFIGURATION

A.4.1 Intake/uptake duct configuration. The overall intake/uptake duct configuration will vary considerably dependent upon ship type, operating profile, engine power levels, etc.

A.4.2 MGT duct configuration. Figure A-1 presents a typical MGT duct configuration. Components 1 to 13, 17, and 18 and 19 form the intake duct and components 6, 7, and 14 through 22 form the uptake duct.

1. WEATHER INLET LOUVERS
2. BLOW-IN DOOR
3. ANTI-ICING MANIFOLD
4. INTAKE FILTER / SEPERATOR
5. INTAKE SILENCERS
6. TRANSITION DUCT
7. EXPANSION JOINT
8. FOREIGN OBJECT DAMAGE SCREEN
9. INLET PLENUM
10. INLET BELLMOUTH
11. COOLING AIR FAN
12. COOLING DUCT SILENCER
13. GAS TURBINE COOLING DUCT
14. EXHAUST PLENUM
15. FOUNDATION
16. WATER TIGHT DECK RING
17. ACOUSTIC LINER
18. THERMAL/ACOUSTIC INSULATION
19. DUCT WALL
20. EXHAUST NOZZLE
21. MIXING TUBE
22. BLISS CAP

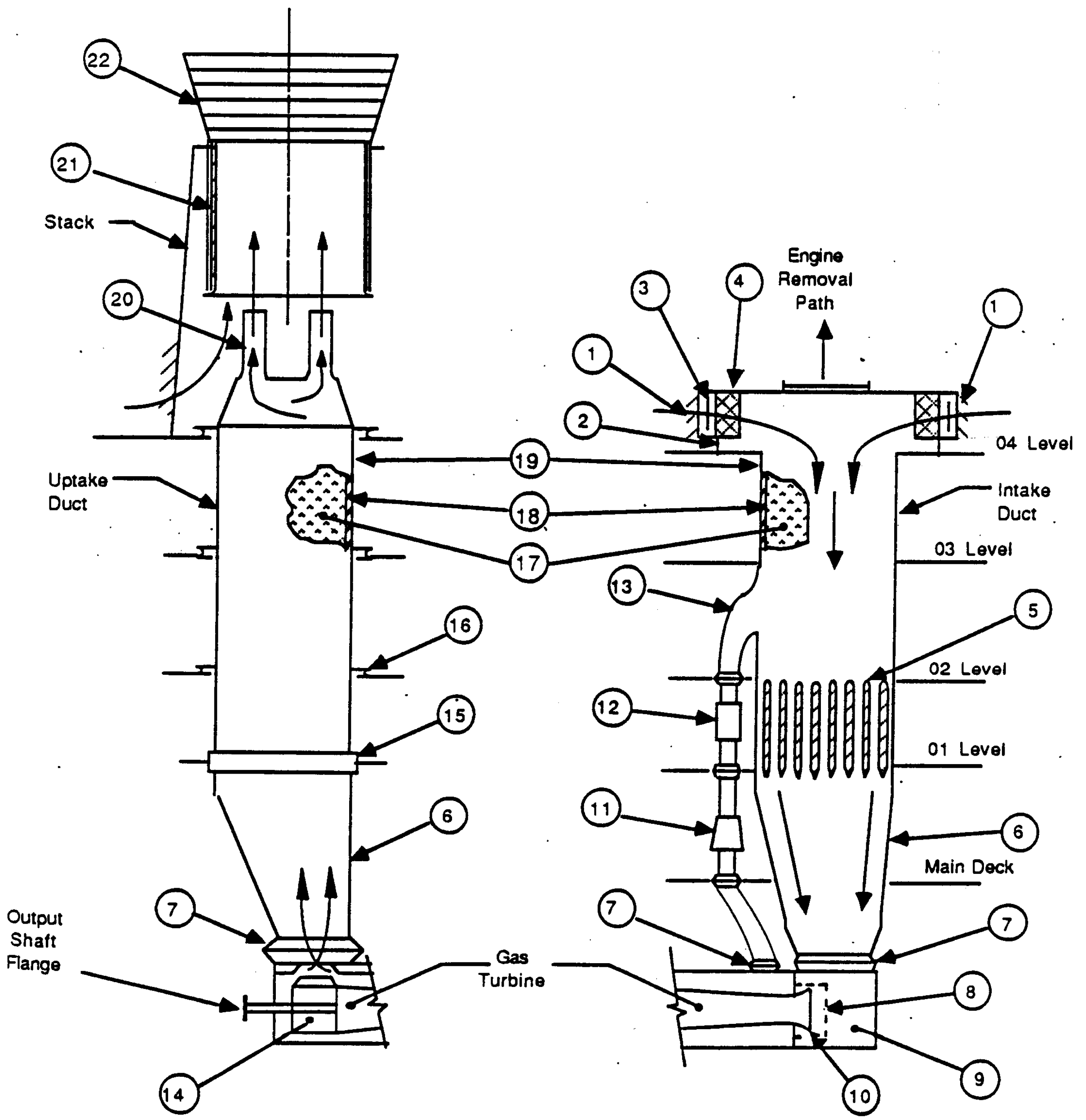


FIGURE A-1. Typical MGT duct configuration.

A.4.3 MGT removal. Most MGTs will be periodically removed from the ship for scheduled major overhauls and for unscheduled major repairs. The normal removal method is to mount the MGT on a dolly and then to move the dolly through the intake on rails (see figure A-2). Provisions shall therefore be made for removal of intake components such as the silencer, engine bellmouth, and foreign object damage (FOD) screen from the intake to allow a clear path for the engine. Provisions shall also be made in the intake ducting for the mounting of removal rails, mounting brackets, and lifting gear and their complete removal following engine replacement. Accessibility shall be provided to all fasteners involved in the removal process.

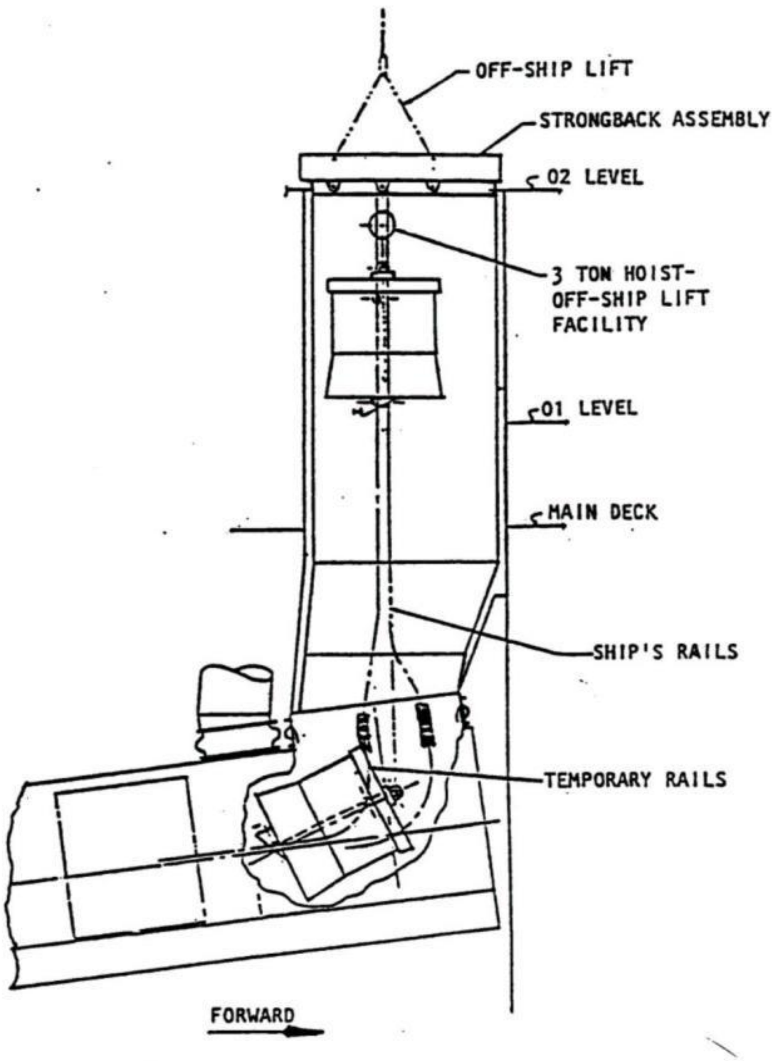


FIGURE A-2. Gas turbine removal technique.

A.4.4 Intake ducting. The intake ducting shall be self-draining.

A.5 MATERIALS

A.5.1 Corrosion. The intake duct and intake system components therein are subject to corrosion. Not only is this corrosion detrimental to the strength of the ducting itself, but corrosion byproducts can be entrained in the engine combustion air stream thus presenting a FOD threat to the engine. The intake system components shall be structurally sound and able to withstand shock, blast, and engine surge overpressure loads. CRES 316L has proven to be a reliable material for applications where the intake duct is not part of the ship's superstructure. The superstructure material is used otherwise; and is usually either steel or aluminum.

A.5.2 Avoiding corrosion. The exhaust duct is subjected to both corrosion and high temperature from the gas turbine exhaust. The steps taken to avoid corrosion in the intake duct also apply to the exhaust duct. The materials of the exhaust duct shall also be:

a. Structurally sound and able to withstand shock and blast at elevated temperature (1100 °F).

b. Able to withstand thermal cycling for the life of the ship.

A.6 STRUCTURAL

A.6.1 Structural considerations. The duct system is to have an expected life equal to that of the ship. The following are structural considerations in the design of the ducting:

a. Thermal expansion of the ducts and duct movement due to shock and seaway movements are to be accommodated without imposing unacceptable loads on the duct structures.

b. Duct support is to be arranged so that the loading imposed by the ducting on the MGT enclosure is within the limits set by the MGT manufacturer. Supports are to be provided to maintain the integrity of the ducting and positioned to provide the required degree of system flexibility. The complete system of ducting and joints are to meet the air tightness standards required by the applicable ship specifications.

A.6.2 Cladding, noise insulation, and fastening. All cladding, noise insulation, and fastening are to be positively secured.

A.7 THERMAL

A.7.1 Temperature. Exhaust gas temperature poses considerable problems for the MGT uptake designer. Engine exhaust gas temperature may reach 1100 °F at the turbine exit. A temperature differential of approximately 1100 °F can be expected between cold iron and full power operating conditions. The designer may expect to encounter problems in thermal growth, thermally induced stresses, and fatigue due to thermal cycling.

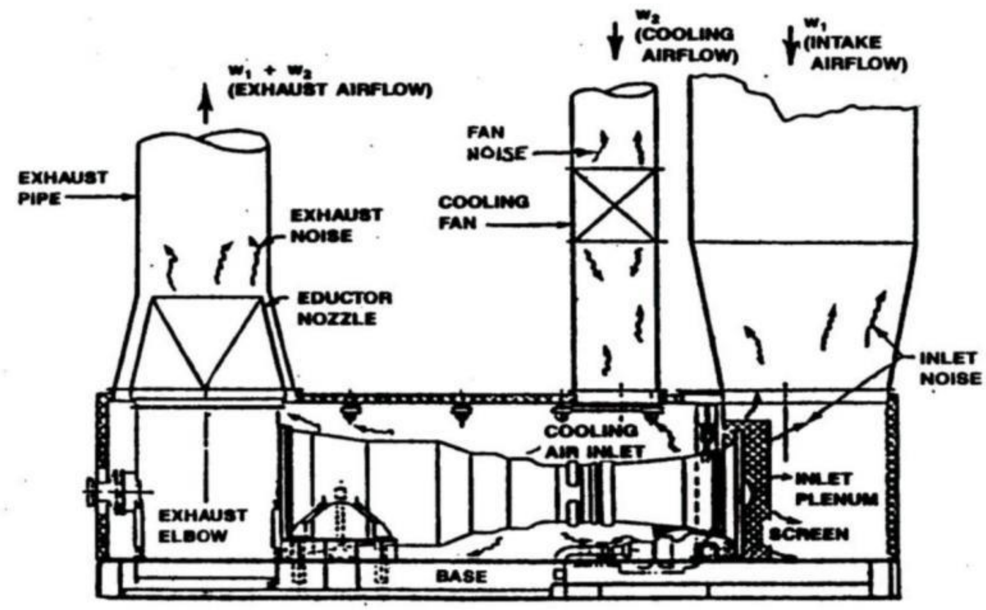
A.7.2 Insulating materials. Insulating materials are required on MGT uptake duct and other engine hot parts to reduce heating of the compartment and hazards to personnel. Insulating materials shall be applied in accordance with MIL-STD-769.

A.8 NOISE ATTENUATION

A.8.1 Duct noise reduction. Noise shall be considered from the standpoint of the relative locations of the MGT and its intake and uptake ducting (see figure A-3) to other spaces in the ship. The ducting system is to provide the required degree of noise attenuation of the machinery spaces, adjacent ship compartments, and to outside deck areas as required by the ship specification. Reduction of duct noise and vibration can take two forms.

A.8.1.1 Airborne noise reduction. Reduction of airborne noise from the MGT by use of a silencer or liner in the system.

A.8.1.2 Vibration level reduction. Reduction of vibration levels transmitted through the ducting and to the weather duct by suitable treatment of the duct and of the casing, design of mounting arrangements, and by the selection of duct materials.



NOTES:

1. NOISE RADIATES IN ALL DIRECTIONS
2. SMALL ARROWS INDICATE ASSUMED AIRBORNE NOISE PATH DIRECTION
3. IF DUCTING OR NOISE PATHS ARE CONNECTED, NOISE LEVELS ARE COMBINED

FIGURE A-3. Gas turbine airborne noise sources.

A.9 PRESSURE LOSSES AND BACK PRESSURE

A.9.1 Intake and uptake duct pressure losses and back pressure. Intake and uptake duct pressure losses and back pressure affect the performance of a MGT engine in compressor stall, power output, and fuel consumption. A MGT engine is most efficient when there is little restriction to airflow as is accomplished with a wing mounted aircraft engine. A negative or total pressure loss will occur in the intake duct and a positive or static back pressure will occur in the uptake duct. Every effort should be made to minimize ducting losses consistent with arrangement and other total ship design driving considerations in the design of any intake or uptake system.

A.10 SHOCK

A.10.1 Shock requirements. The gas turbine intake and uptake ducting systems for surface combatants and other ships, as specified, shall meet Grade A shock requirements in accordance with MIL-S-901.

A.11 GENERAL DESIGN CONSIDERATIONS

A.11.1 Interdependence of design and arrangement. The interdependence of the design and arrangement of the combustion air intake ducting, combustion uptakes, and the stack is a major factor in the intake/uptake system design and machinery arrangement.

A.11.2 Routing path. Because the dedicated ducting, both intake and uptake, shall provide a continuous air path between the atmosphere and the engine served, it is imperative that the routing path be considered and established as early in the design process as possible.

A.11.3 Intake and uptake design and arrangement criteria. The intake and uptake design and arrangement criteria consist of information in three categories which are:

a. Requirements.

b. Mandatory design practices.

c. Normal design practices.

A.12 DETAILED CONSIDERATIONS

A.12.1 Intake duct system considerations. Intake duct system considerations are as follows:

a. The intake ducting shall be designed to provide combustion air to the gas turbine engine within specified salt and sand ingestion limits, and without exceeding engine inlet pressure loss and air flow distortion limits. At the same time, the ducting design shall be compatible with shipboard physical weight and space constraints.

b. The overall intake duct configuration and its routing path from the engine inlet plenum interface to the atmosphere is usually dictated by ship structure, allowable deck cut openings, engine removal considerations, and the location of nearby ship or mission critical hardware. The ducting should be a straight, vertical run from the engine inlet plenum to the atmosphere to facilitate engine removal. If such a straight vertical run cannot be provided, special provisions for engine removal shall be provided.

c. This straight run of duct is essentially required to facilitate engine removal by a dockside lifting crane and elbows or bends will complicate the proven engine removal method. Additionally, the LM2500 gas generator dolly characteristics limit the port/starboard inclination of the dolly wheels to 4 degrees off the vertical axis. Intake duct athwartship angle is therefore limited to less than 4 degrees off the vertical axis.

A.12.2 Intake duct design considerations. For preliminary design, the intake duct envelope should be as large as practical without unduly impacting the ship design. Even if subsequent analyses reveal that the intake duct cross-section dimensions can and should be reduced, the suggested approach is to maintain the original intake duct envelope throughout the design process. This point cannot be overemphasized. The designer will come to realize that getting additional space reservations at later design stages will be extremely difficult. Conversely, any excess allocation may be returned to the ship arrangement group anytime during the design process.

A.12.3 Transition duct design considerations and requirements. Transition duct design considerations and requirements are as follows:

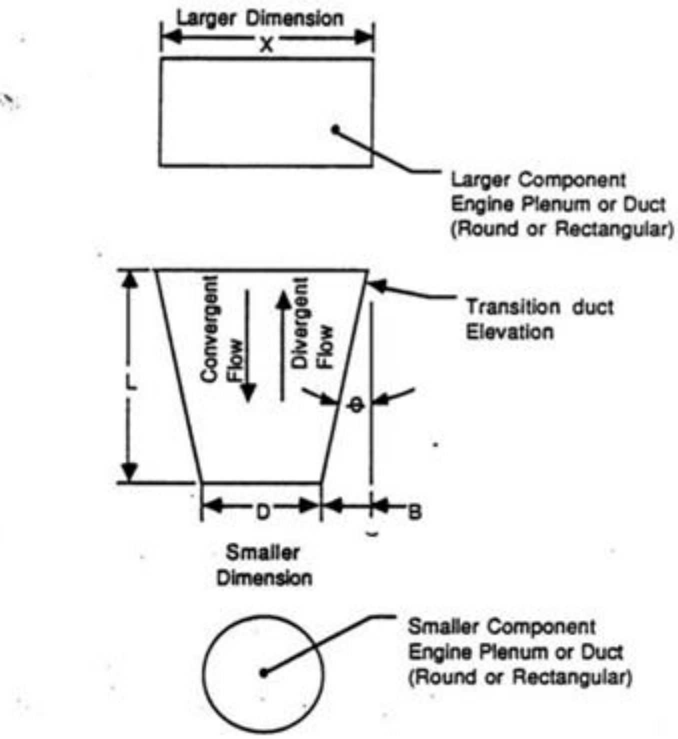
a. Proper design of the transition duct is important to obtain minimum flow disturbance through it. The section can also be a powerful tool in reducing flow disturbance if designed properly. Proper design includes incorporation of the following requirements.

b. The transition duct centerline shall not vary by more than 10 degrees with respect to the centerlines of adjacent components. Maximum inclination of the transition duct wall with respect to its centerline or with respect to the wall of adjacent components shall not be more than 10 degrees.

c. Most transition ducts start off as a rectangular section at the intake duct and converge to either a smaller rectangular section or a round form at the entrance to the engine inlet plenum. The length of the transition duct is dependent on the largest dimension of the intake duct and on the smallest dimension at the engine inlet plenum. The length may be calculated using figure A-4.

A.12.4 Uptakes duct system considerations. Uptakes duct system considerations are as follows:

a. The uptake ducting is designed to conduct exhaust and cooling air from the MGT exhaust terminal to the atmosphere without exceeding back pressure and velocity limitations. The ducting design shall be compatible with shipboard weight and space constraints and able to withstand thermal cycling and stresses.



$\tan\theta = \frac{B}{L}$ $\quad X - D = 2B \quad$ $L = \frac{X-D}{2\tan\theta}$

$L = \frac{B}{\tan\theta}$ $\quad B = \frac{X-D}{2}$

1. Centerline not to vary by more than 10° with respect to centerline of adjacent components.
2. Maximum inclination of a wall with respect to the centerline of the transition or with respect to the wall of adjacent component to be no more than:

For uptakes:	θ = 15°	when wall converges the flow
	= 10°	when wall diverges the flow
For intakes:	= 15°	when wall converges the flow
	= 8°	when wall diverges the flow

FIGURE A-4. Transition duct dimensions.

b. The uptake duct configuration and its routing path from the engine exhaust plenum to the atmosphere is usually dictated by the exhaust stack location, allowable deck cut openings and clearances, and the location of nearby ship or mission critical hardware. The ducting is circular shaped to prevent thermal stress concentration and should be kept as straight as possible to minimize back pressure on the engine. The duct wall is constructed from two concentric sheets of metal and in between is placed 51 to 102 millimeters (2 to 4 inches) of thermal/acoustic insulation. The inner sheet is perforated and with the insulation acts to attenuate engine exhaust noise.

c. Ring stiffeners placed strategically along the duct length provide structural strength to the uptake. The foundation secures the uptake to the ship structure and carries the uptake weight. Sway braces keep the uptake in position above the foundation while allowing it to grow thermally.

d. High exhaust gas temperature presents a threat to mast borne equipment and acts as a target for heat seeking missiles. An infrared suppression system (IRSS) installed on top of the uptake duct cools the exhaust gas and reduces the IR risks.

e. Define the overall uptake duct envelope dimensions. Define the minimum uptake duct based on a maximum exhaust gas velocity of 150 fps through the uptake duct.

A.12.5 Wall construction. Wall construction is as follows:

a. The exhaust duct is constructed to provide room for thermal expansion, negate the effects of thermal stress and cycling, and to inhibit the conduction of heat to the ship interior. The current construction method is shown on figure A-5. The insulation supports are offset 15 degrees and relief cut at a maximum of every 153 millimeters (6 inches) to reduce thermal stresses. Thermal insulators are placed between the duct casing and insulation supports to reduce heat transfer. Currently, the duct wall is constructed from CRES 316L plate and the acoustic liner is constructed from a 1.524-millimeter (0.060-inch) sheet of Inconel perforated with 4.77-millimeter (0.1875-inch) holes on 9.53-millimeter (0.375-inch) staggered centers. The insulation supports are also currently Inconel.

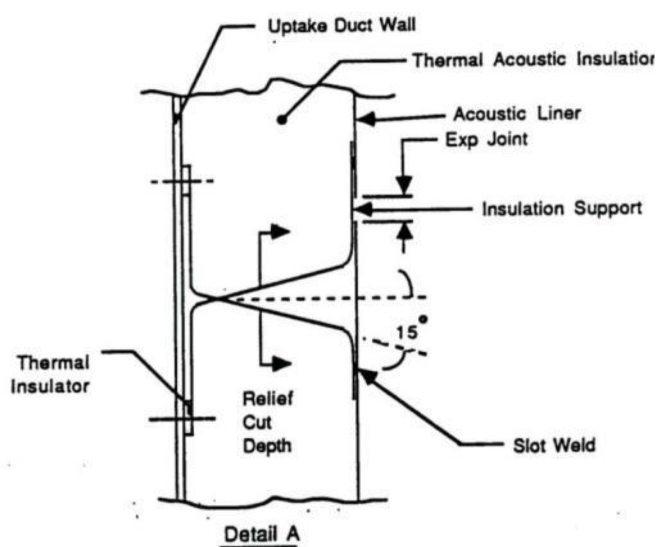


FIGURE A-5. Uptake duct construction.

b. The entire internal surface of the uptake, from the lower flange of the exhaust plenum expansion joint to the top of the uptake duct, shall be treated with a combined thermal/acoustic liner as shown on figure A-6. Fifty-one (51) millimeters (2 inches) of external insulation is usually applied of the uptake exterior.

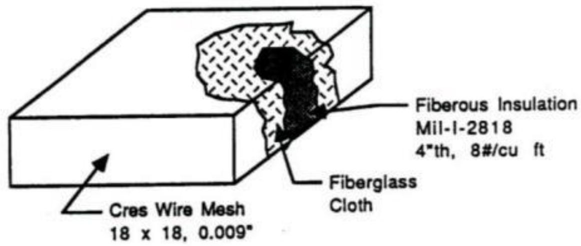


FIGURE A-6. Insulation construction.

A.12.6 Structural considerations. The uptake duct structural wall is constructed from metal plate approximately 0.375inch thick. Consideration shall be given to the duct wall thickness when designing the uptake duct. The duct shall be constructed to support the weight, absorb thermal growth, and shock excursion motion.

A.12.6.1 Sway braces. The uptake and IRS system is required to meet ship motion and shock requirements set forth by the ship specifications, usually Grade A shock. Sway braces are constructed as shown on figure A-7 and placed as necessary to meet the specifications. The most convenient placement location is below each deck level where an anchor point for the braces is provided.

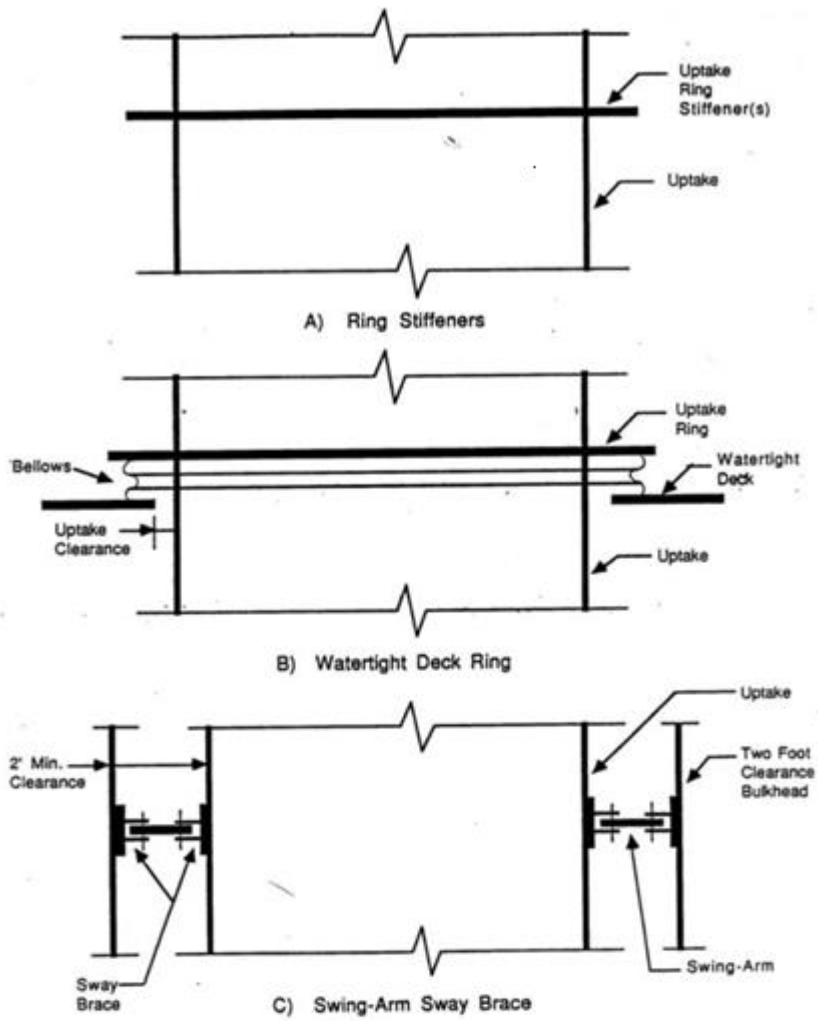


FIGURE A-7. Typical uptake structural components.

A.12.6.2 Ring stiffeners. The uptake shall be stiff enough to resist compressor surge and ship movement and to support the uptake weight. Ring stiffeners give backbone to the uptake and are placed as required. They are constructed as shown on figure A-7.

A.12.6.3 Watertight decks. Watertight decks are maintained as per the ship specifications, usually below the weather deck. Penetration of watertight decks should be accomplished as shown on figure A-7.

A.12.7 Pressure loss/backpressure calculations. Gas flow turbulence and duct wall frictional resistance causes pressure loss in the direction of gas flow. Turbulence is a function of turning the gas flow and changes in the duct shape or area. Frictional resistance is a function of flow velocity and duct wall material. The total gas pressure of the flow through a duct consists of the sum of the static and dynamic pressure components, as follows:

$$Pt = Ps + Pd \qquad Pd = Dg \times V2 / 2g$$

Where:

Pt = Free Stream Total Pressure (lb/ft^2)

Ps = Static Pressure (lb/ft^2)

Pd = Dynamic Pressure (lb/ft^2)

Pa = Ambient Pressure (lb/in^2 or psi) = 14.7 psi

V = Free Stream Air Velocity (fps)

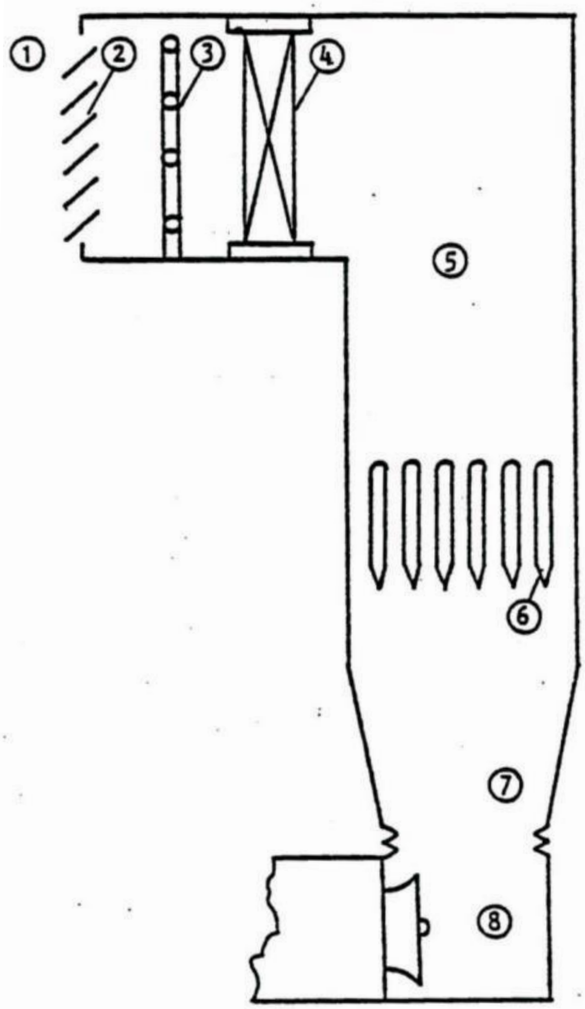
Dg = Gas Density (lb/ft^3)

Air = 0.071 lb/ft^2 @ 1000 °F

In still air the Ambient Pressure (Pa), Static Pressure (Ps), and Total Pressure (Pt) are equal, and the Dynamic Pressure (Pd) is zero. As air is induced into a duct the Dynamic Pressure (Pd) increases with a corresponding decrease in Static Pressure (Ps), and Total Pressure (Pt). A typical intake duct configuration, along with expected pressure losses, is shown on figure A-8.

Pressure losses decrease the intake duct from ambient pressure (Pa), at the duct inlet to a negative total pressure (-Pt) at the gas turbine bellmouth and also creates a positive static pressure (+Ps) at the gas turbine exhaust plenum, which is reduced to ambient pressure (Pa), at the exhaust gas uptake nozzles exit.

Intake and uptake ducting shall be designed to meet the engine specifications to keep the effects of pressure loss or backpressure to an acceptable level.



ITEM	LOSS	
	kPa	in H_2O
① ENTRANCE LOSS	0.125	0.5
② INLET LOUVERS	0.075	0.3
③ ANTI-ICING MANIFOLD	0.125	0.5
④ INLET FILTERS	0.75	3.0
⑤ INLET ELBOW	0.25	1.0
⑥ INLET SILENCER	0.25	1.0
⑦ TRANSITION DUCT	0.125	0.5
⑧ INLET PLENUM*	0.374	1.5

*Inlet plenum loss includes FOD screen pressure loss.

FIGURE A-8. Typical inlet duct losses.

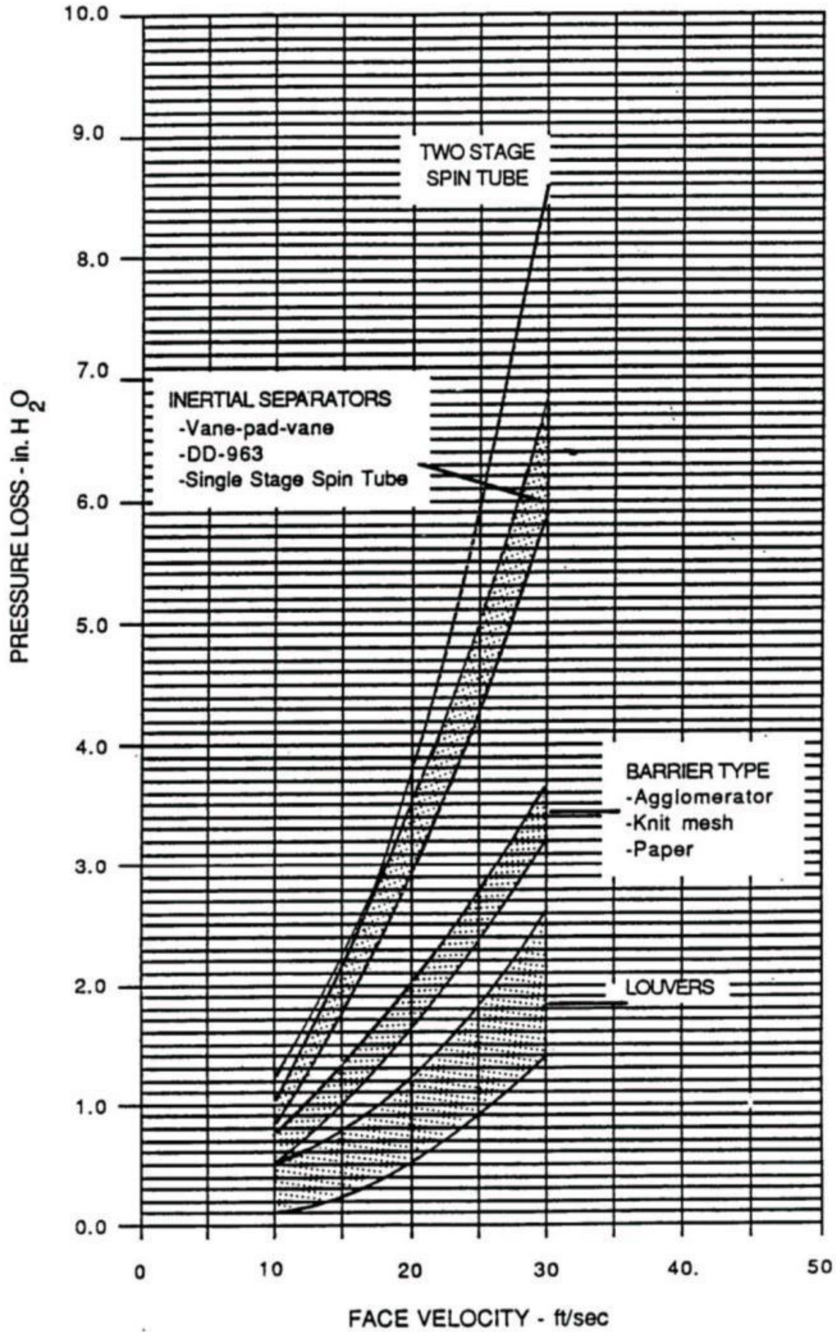


FIGURE A-9. Generalized intake filter pressure loss.

A.12.8 Pressure loss design considerations. Pressure loss design considerations are as follows:

a Moisture separators (filters):

(1) If specific moisture separator manufacturer's performance data is not available, use figure A-9 to determine the initial pressure drop estimate.

b. Generalized intake filter pressure loss:

(1) Typically, rectangular ducts are used for intakes, particular care should be taken to maintain a low aspect ratio, and round ducts are used for uptakes.

(2) Frictional losses increase with increasing aspect ratios, and hence the aspect ratio should be kept below 6 to 1.

c. Elbows:

(1) Elbows, bends, and miters are used to change the direction of the gas flow, with resultant turbulence, and all treated as elbows for pressure loss calculations.

(2) In elbows, the outer gas flow is deflected around the turn and the inner flow tends to continue in a straight line until it impinges against the outer flow, the resulting turbulence and pressure loss can be high. Hence, elbows are a primary source of pressure loss and their use should be minimized.

(3) The following two parameters are important when designing an elbow:

(a) Aspect ratio (Ar) = height/width.

(b) Radius ratio (Rr) = mean radius/diameter of the elbow.

(4) Figure A-10 provides a physical definition of the Ar and the Rr. Note: W is always in the radius plane and H is perpendicular to W.

(5) When computing pressure losses, a rectangular duct or elbow shall be converted to its Hydraulic Diameter (Dh) (i.e., equivalent circular duct) as follows:

$$\text{Dh} = \frac{4 \times \text{area of cross section}}{\text{Wetted perimeter of cross section}}$$

(6) Minimize pressure losses by:

(a) Allowing 4 Dh upstream and downstream of an elbow.

(b) Using a Rr of $1.5 < \text{Rr} < 5$.

(7) Using splitters, in round cornered ducts, and turning vanes, in sharp cornered ducts, to reduce turbulence and pressure losses.

(8) Note: vanes or splitters in intake ducts may complicate gas turbine removal.

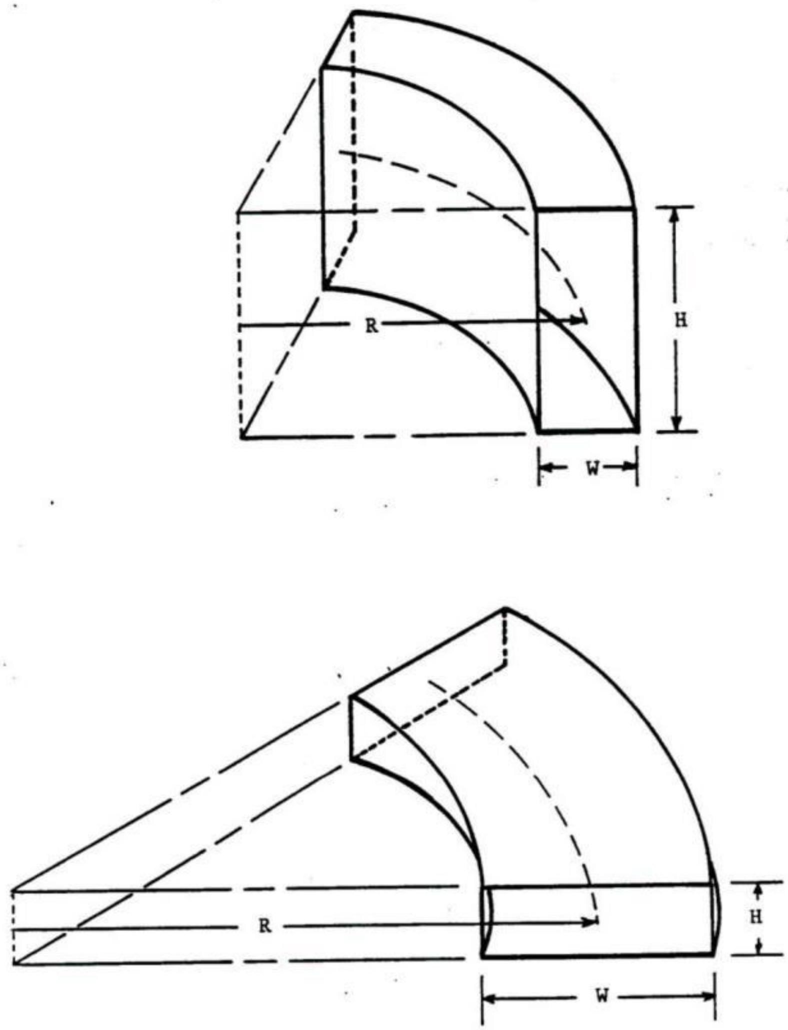
(9) To determine the pressure loss through an elbow, a "K" factor for the elbow is selected from figure A-11 and multiplied by the elbow Pd to determine the pressure drop.

d. Splitters:

(1) Splitters are more effective in reducing pressure loss than turning vanes. The number and placement of splitters is dependent on the ratio of the inside radius to the outside radius, use figure A-12 to determine the number and placement of splitters.

e. Turning vanes:

(1) Turning vanes may be of two types: single thickness, rounded sheet, (minimal reduction in pressure loss) and double thickness, airfoil shape, (significant reduction in pressure loss). See figure A-13 for illustrations and placements of turning vanes.



AR = Aspect Ratio
$= \frac{H}{W}$

RR = Radius Ratio
$= \frac{R}{W}$

Note: W is always in same plane as R.

FIGURE A-10. Elbow characteristics.

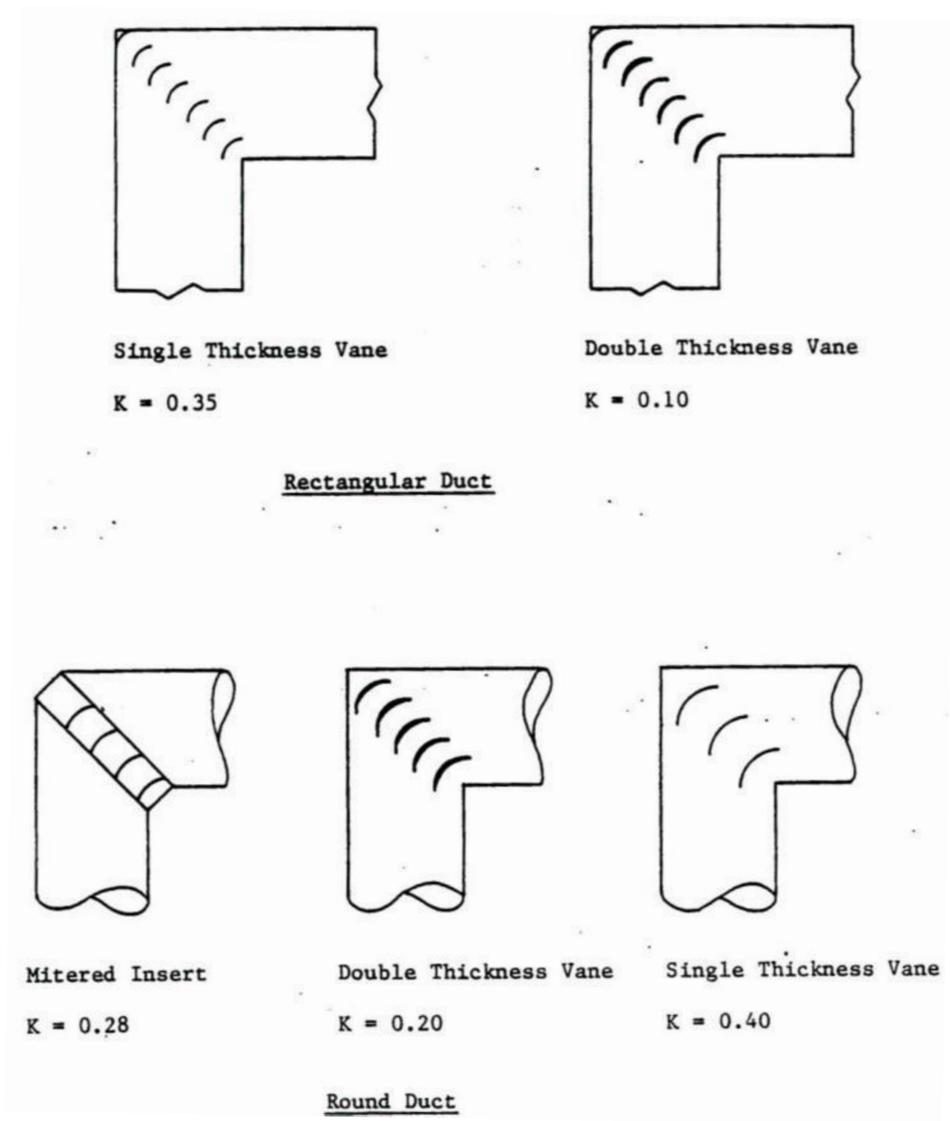


FIGURE A-11. Loss coefficients for rectangular and round elbows with turning vanes.

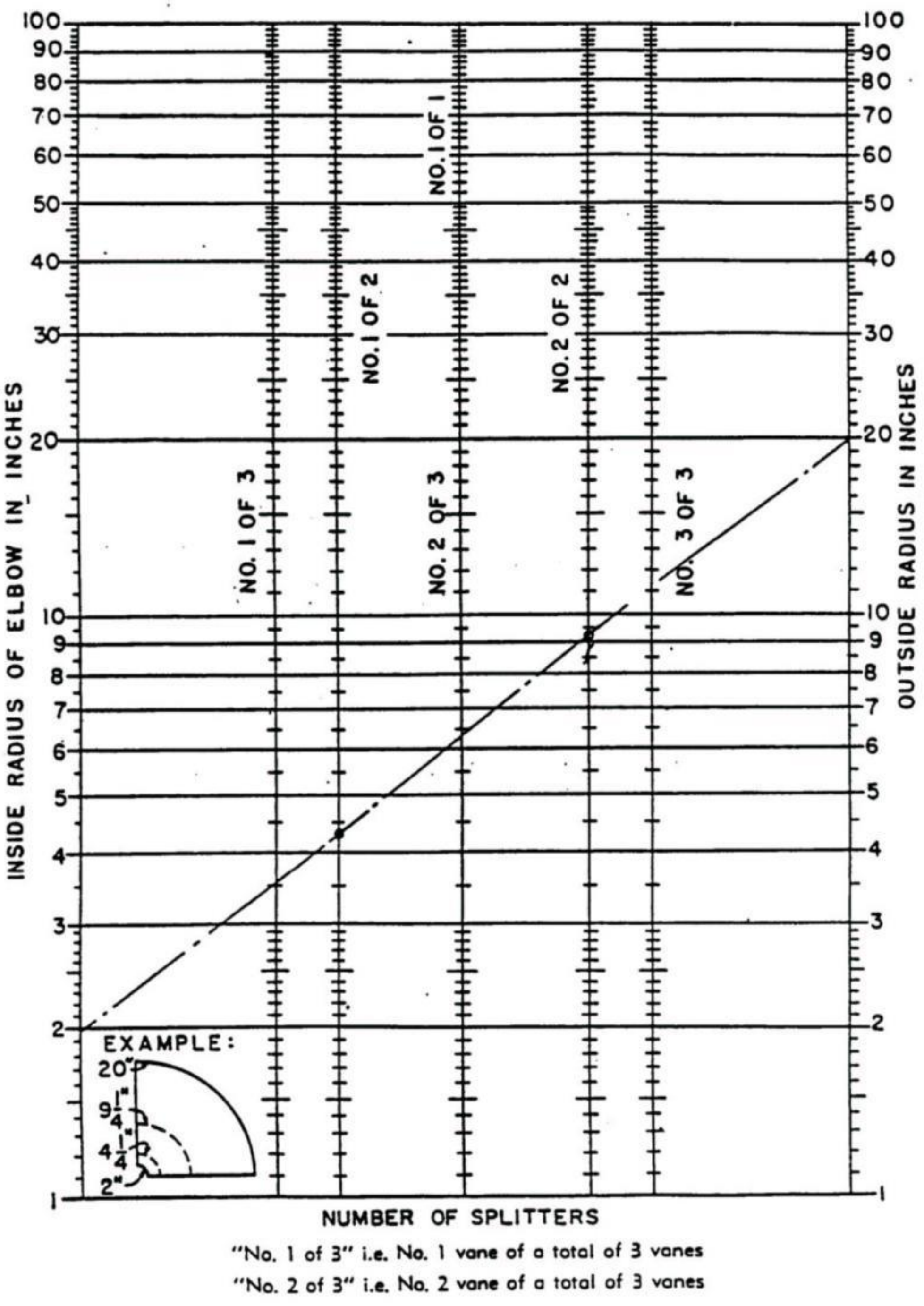


FIGURE A-12. Splitter placement.

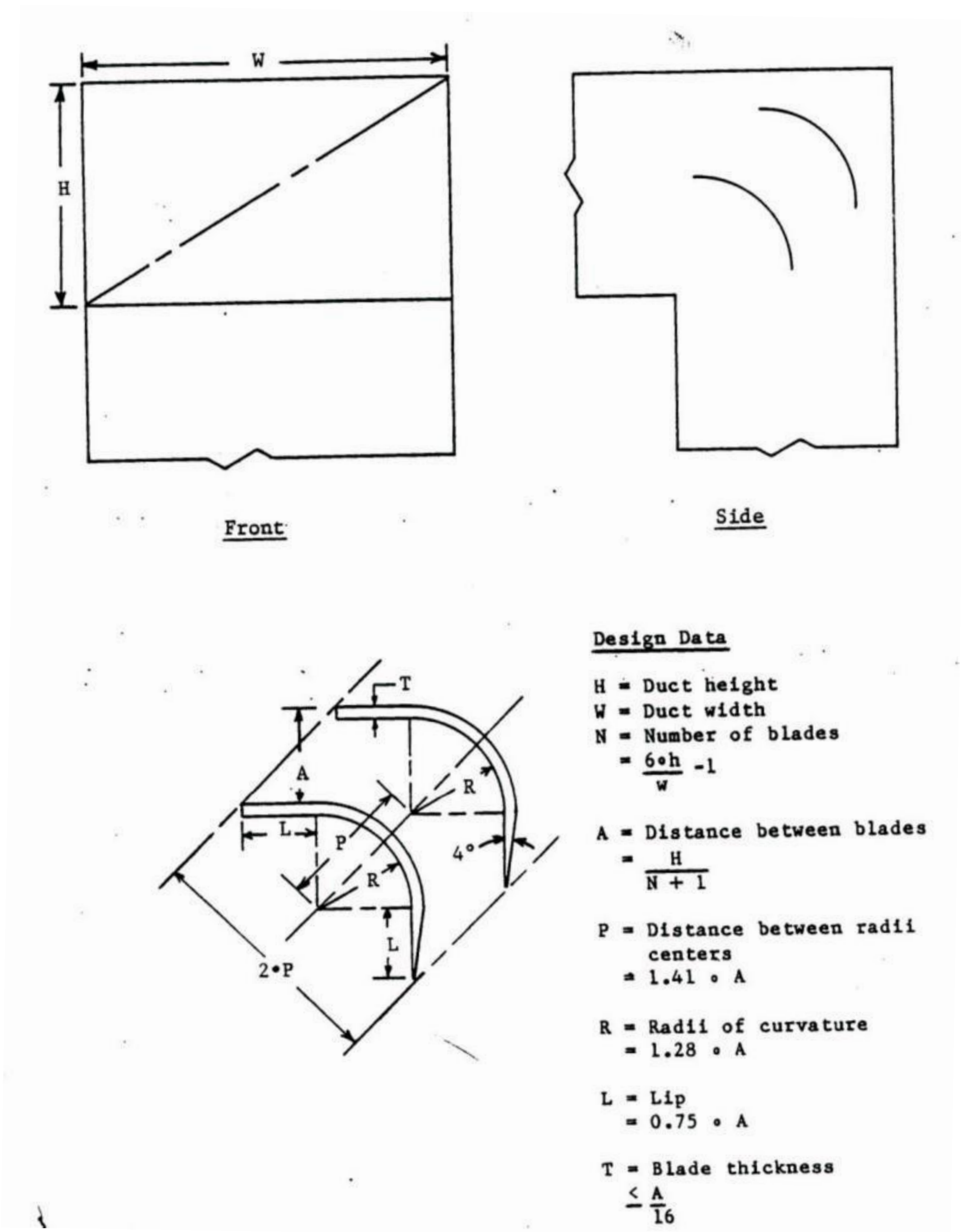


FIGURE A-13. Turning vane design characteristics.

A.12.9 Pressure loss calculation procedure.

a. Use DDS 221-1 to determine the following at each calculation station:
   (1) Cross-sectional area.
   (2) Hydraulic diameter.
   (3) Velocity.
   (4) Dynamic pressure.
   (5) Reynolds number.
   (6) Mach number.

b. Use the pressure loss worksheets in DDS 221-1 to determine the pressure loss at each station.

c. Sum the station pressure losses to determine the system pressure loss.

d. Determine the static pressure losses.

e. Compare the total and static pressure losses to the specified limits for the losses.

Note for uptakes: For calculation purposes, the uptake system is considered to end at the uptake nozzle outlet with the expelled gasses dumping to atmosphere.

A.12.10 Structural analysis. The designer should perform a structural analysis on the proposed uptake system before the design is finalized. The analysis should take into consideration weight, thermal growth, shock and blast, and exhaust gas induced vibrations. The preferred method of analyses is finite element, thermal stress analysis, and Dynamic Design Analysis Method (DDAM) Shock Analysis.

A.12.11 Stress calculation. Stress calculation is defined as follows:

a. The expansion or contraction of materials due to temperature change may induce stresses in the material under consideration (strength decreases at elevated temperatures).

b. The coefficient of linear expansion (or contraction) is the linear deformation per inch of length per degree change in temperature (med. steel: 0.00000067 in/in/°F)

c. For restrained material:
   (1) S = ENT where:
      (a) S = stress.
      (b) E = modulus of elasticity.
      (c) N = coefficient linear expansion.
      (d) T = temperature change (°F).

A.12.12 Material selection. Many systems failures can be traced back to a material failure of a component. Typically the component will have failed because of strength, fatigue, or environment, or a combination of all three. All components shall be designed for a specific application in a specific environment.

A.12.13 Austenitic stainless steel. The principal alloy ingredients are as follows:

a. Chromium (a ferrite stabilizer).

b. Nickel (an austenite stabilizer).

c. CRES 316L 16/18 – 10/14 and 0.03 carbon
   316 16/18 – 10/14 and 0.08 carbon
   (18-8 heated to 1800 °F becomes austenitic).

Beyond 0.12 percent carbon, the potential quantity of carbide which may precipitate is large enough to produce a serious tendency toward intergranular corrosion.

A.12.14 Material design considerations. Three considerations dominate material design for an intake/uptake system: strength, corrosion, and fatigue. Table A-1 shows which considerations are likely to drive each intake/uptake component. The materials used for the intake/uptake shall be able to handle the physical loadings imposed on them. These loads will include both static and transient loadings.

TABLE A-I. Material design considerations.

		Intake	**Uptake**	**Cooling Duct**
Strength	Steady state	X	X	X
	Transient	X	X	X
	Steady state and transient	X	X	X
Corrosion	Direct chemical attack	-	X	-
	Electrochemical attack	X	-	X
Fatigue	-	-	X	-

A.12.15 Steady state. The weight of the system itself imposes the greatest pure steady state load on the cooling duct and the uptake. The intake is usually formed from the ship's bulkheads and therefore is not affected by its own weight.

A.12.16 Transient. The entire intake/uptake system is to be designed to meet Grade A shock requirements in accordance with MIL-S-901. The materials used shall reflect this requirement. The materials used for the intake/uptake system shall be able to withstand the roll, pitch, and heave encountered with operation on high seas. Ship specifications will detail the loadings. The materials used shall be able to handle vibratory loads. Typically, vibrations are generated by ship equipment and by duct airflow turbulence.

A.12.17 Combined steady state and transient. Gas pressure within the duct will impart a steady state load on the system. This load is precipitated by a negative gauge gas pressure within the intake and the cooling air duct and by a positive gauge pressure within the uptake. Transient gas pressure loads are imparted on the system by changes in engine power and compressor surge.

The duct materials are subjected to steady state thermal stresses at the operating temperature because of the difference between cold iron and operating temperature. The ducting will be subjected to transient thermal stresses during warm up and cool down. The uptake is most affected by thermal stresses because of the 1000 °F temperature change.

A.12.18 Corrosion. Corrosion is the wasting of material and is generally a result of direct chemical attack or electrochemical attack. Corrosion is to be prevented if at all possible, but because the work is being performed in a marine environment, corrosion will occur. Wasting usually occurs either as general plating off of material or as pitting, depending on the corrosion mechanism and material. In some situations it is better to corrode by plating off such as in water or airtight boundaries where pitting would violate the integrity of the boundary. In other cases, pitting is the preferred mechanism (such as cases where there cannot be a loss of strength due to reduction in thickness of the material).

A.12.19 Direct chemical attack. As the title implies, corrosion of this kind occurs from direct chemical attack. Chemicals react with the metal and corrode it. The uptake is affected by this form of corrosion.

A.12.20 Electrochemical attack. Electrochemical attack is corrosion which occurs in the presence of an electrolyte. Seawater acts as an electrolyte within the intake/uptake system. The filters remove most of the seawater from the combustion air; however, a small percentage still invades the ductwork. Even small quantities of an electrolyte are sufficient to cause corrosion. Various forms of electrochemical corrosion which affect the intake/uptake system are as follows:

a. Galvanic corrosion:

(1) All metals have electric potential and the potential varies from one metal type to another. When an electrolyte is present, current will flow from the metal with a high potential to a lower potential metal with which it is in contact. As current flows, galvanic corrosion occurs to the metal with the high electrical potential. Galvanic corrosion can be avoided by using metals with similar electric potential or by electrically insulating dissimilar metals from one another.

b. Pitting corrosion:

(1) Pitting occurs when there is a localized difference in electric potential between two points on the surface of a single material. Pitting occurs most often within stagnant flows and predominantly among noble metals such as stainless steel.

c. Crevice corrosion:

(1) Crevice corrosion is a severe form of pitting which occurs when the corroding liquid is trapped between two surfaces such as under rivets or bolt heads. Corrosion will occur either between the two surfaces or immediately outside their junction. The exact corrosion area is dependent on material type and electrolyte.

d. Stress corrosion:

(1) Stress corrosion occurs as a local deterioration brought about by combining static stress with corrosion. It eventually leads to cracking of the material. Stress corrosion will only occur during tensile stress and may either be an applied stress, a residual stress, or both. Metals with high yield strength are more susceptible to stress corrosion then those with lower yield strengths.

A.12.21 Fatigue failure. Fatigue failure occurs when a material is subjected to repeated loading and unloading. The relationship between failure, the stress loading, and number of cycles to failure is simple. The higher the stress, the lower the cycles to failure. Most materials exhibit a threshold stress below which they may be repeatedly loaded and unloaded without failure. For intake/uptake design, the thermal loading and unloading of the uptake is the primary concern. The large difference between cold iron and operating temperatures produce large thermal stresses which in turn result in a relatively short number of cycles to failure if not designed properly.

Custodians:
Army – AV
Navy – SH
Air Force – 99

Preparing activity:
Navy – SH
(Project 20GP-2010-001)

Review activity:
Army – MI

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