INCH-POUND
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SUPERSEDING
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(See 6.11)

MILITARY SPECIFICATION

COOLERS, FLUID, NAVAL SHIPBOARD: LUBRICATING OIL, HYDRAULIC OIL, AND FRESH WATER

This specification is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers lubricating oil, hydraulic oil, and fresh water coolers for Naval shipboard applications for which standards of resistance to shock and standards of construction are higher than for usual commercial marine use.

1.2 Classification. Coolers shall be of the following types (see 6.9) and classes as specified (see 6.2). (Type II has no class 1.)

Type I - Shell and tube design, with the coolant circulated through the tubes, and the fluid to be cooled passed through the shell.

Class 1 - Submarine, seawater cooled, seawater side subject to sea pressure for greater than 200-foot submergence, cyclic life stipulated.
Class 2 - Submarine, seawater cooled, seawater side secured for greater than 200-foot submergence.
Class 3 - Surface ship, seawater cooled.
Class 4 - Submarine, fresh water cooled.
Class 5 - Surface ship, fresh water cooled.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A FSC 4420
DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

Type II - Fabricated tube design with the coolant circulated through the casing, [illegible] cooled passed through the tubes.

Class 2 - Submarine, seawater cooled, seawater side secured for gre[illegible]nce
Class 3 - Surface ship, [illegible]
Class 4 - Submarine, fre[illegible] cooled.
Class 5 - Surface ship, fresh water cooled.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 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 listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL

FF-W-84	- Washers, Lock (Spring).
QQ-B-750	- Bronze, Phosphor; Bar, Plate, Rod, Sheet, Strip, Flat Wire, and Structural and Special Shaped Sections.
QQ-C-390	- Copper Alloy Castings (Including Cast Bar).
QQ-C-450	- Copper-Aluminum Alloy (Aluminum Bronze) Plate, Sheet, Strip, and Bar (Copper Alloy Numbers 606, 610, 613, 614, and 630).
QQ-C-591	- Copper-Silicon, Copper-Zinc-Silicon, and Copper-Nickel-Silicon Alloys: Rod, Wire, Shapes, Forgings, and Flat Products (Flat Wire, Strip, Sheet, Bar, and Plate).
QQ-N-281	- Nickel-Copper-Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections.
TT-P-645	- Primer, Paint, Zinc Chromate, Alkyd Type.

MILITARY

MIL-P-116	- Preservation, Methods of.
MIL-S-901	- Shock Tests, H.I. (High-Impact); Shipboard Machinery, Equipment and Systems, Requirements For.
MIL-A-907	- Antiseize Thread Compound, High Temperature.
MIL-G-1149	- Gasket Materials, Synthetic Rubber, 50 and 65 Durometer Hardness.
MIL-S-1222	- Studs, Bolts, Hex Cap Screws, Socket Head Cap Screws, and Nuts.
MIL-T-1368	- Tube and Pipe, Nickel-Copper Alloy, Seamless and Welded.

MILITARY (Continued)

MIL-R-6855 - Rubber, Synthetic, Sheets, Strips, Molded or Extruded Shapes, General Specification For.

MIL-T-15005 - Tubes, 70-30 and 90-10 Copper Nickel Alloy, Condenser and Heat Exchanger.

MIL-P-15024 - Plates, Tags and Bands for Identification of Equipment.

MIL-P-15024/5 - Plates, Identification.

MIL-S-15083 - Steel Castings.

MIL-C-15726 - Copper-Nickel Alloy, Rod, Flat Products (Flat Wire, Strip, Sheet, Bar, and Plate) and Forgings.

MIL-E-15809 - Expander, Tube, Condenser and Heat Exchangers.

MS16142 - Boss, Gasket Seal Straight Thread Tube Fitting, Standard Dimensions For.

MIL-T-16420 - Tube, Copper-Nickel Alloy, Seamless and Welded (Copper Alloy Numbers 715 and 706).

MIL-A-18001 - Anodes, Corrosion Preventive, Zinc; Slab Disc and Rod Shaped.

MIL-L-19140 - Lumber and Plywood, Fire-Retardant Treated.

MIL-A-19521 - Anodes, Corrosion Preventive, Zinc, and Plugs, Zinc Anode Retaining; Design of and Installation in Shipboard Condensers and Heat Exchangers.

MIL-F-20042 - Flanges, Pipe and Bulkhead, Bronze (Silver Brazing).

MIL-C-20159 - Copper-Nickel Alloy Castings (UNS No. C96200 and C96400).

MIL-T-20168 - Tubes, Brass, Seamless.

MIL-G-21610 - Gaskets, Heat Exchanger, Various Cross Section Rings, Synthetic Rubber.

MIL-T-22214 - Tube, Condenser and Heat Exchanger with Integral Fins (UNS Alloy Nos. C71500, C70600, C12200).

MIL-S-22473 - Sealing, Locking, and Retaining Compounds: (Single-Component).

MIL-S-22698 - Steel Plate, Shapes and Bars, Weldable Ordinary Strength and Higher Strength: Structural.

MIL-N-24106 - Nickel-Copper Alloy Bars, Rods, and Forgings.

MIL-T-24107 - Tube, Copper (Seamless) (Copper Alloy Numbers C10100, C10200, C10300, C10800, C12000, C12200 and C14200).

MIL-L-24478 - Lubricant, Molybdenum Disulfide in Isopropanol.

MIL-L-24479 - Lubricant, Red Lead and Graphite in Mineral Oil.

MIL-B-24480 - Bronze, Nickel-Aluminum (UNS No. C95800) Castings for Seawater Service.

MIL-P-24691 - Pipe and Tube, Carbon, Alloy and Stainless Steel, Seamless and Welded, General Specification for.

MIL-P-24691/1 - Pipe and Tube, Carbon Steel, Seamless.

MIL-G-24696 - Gaskets, Sheet, Non-Asbestos.

MIL-R-83248 - Rubber, Fluorocarbon Elastomer, High Temperature, Fluid, and Compression Set Resistant.

MIL-P-83461 - Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Improved Performance at 275°F (135°C).

STANDARDS

FEDERAL

FED-STD-H28	- Screw Thread Standards for Federal Services.

MILITARY

MIL-STD-22	- Welded Joint Design.
MIL-STD-278	- Welding and Casting Standard.
MIL-STD-438	- Schedule of Piping, Valves, Fittings, and Associated Piping Components for Submarine Service.
MIL-STD-777	- Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships.
MIL-STD-1186	- Cushioning, Anchoring, Bracing, Blocking and Waterproofing; with Appropriate Test Methods.
DOD-STD-1399, Section 301	- Interface Standard for Shipboard Systems, Ship Motion and Attitude. (Metric)
MIL-STD-2073-1	- DoD Materiel Procedures for Development and Application of Packaging Requirements.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.1.2 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 are those cited in the solicitation.

DRAWING

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

803-5959186 - Submarine Heat Exchanger Anode Plug.

(Application for copies should be addressed to the Commander, Portsmouth Naval Shipyard, Code 202.2, Portsmouth, NH 03801.)

PUBLICATION

NAVSEA

0900-LP-001-7000 - Fabrication and Inspection of Brazed Piping Systems.

(Application for copies should be addressed to the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN NATIONAL STANDARDS INSTITUTE, INC. (ANSI)
B1.12 - Class 5 Interference-Fit Thread.
B16.5 - Pipe Flanges and Flanged Fittings. (DoD adopted)

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

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)
Boiler and Pressure Vessel Code
Section III - Rules for Construction of Nuclear Power Plant Components.
Section VIII, Division I - Pressure Vessels.

(Application for copies should be addressed to the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
A 36 - Standard Specification for Structural Steel. (DoD adopted)
A 53 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless. (DoD adopted)
A 105 - Standard Specification for Forgings, Carbon Steel, for Piping Components.
A 106 - Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service. (DoD adopted)
A 179 - Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes.
A 181 - Standard Specification for Forgings, Carbon Steel, for General-Purpose Piping. (DoD adopted)
A 214 - Standard Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes.
A 285 - Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength. (DoD adopted)
A 515 - Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service. (DoD adopted)
A 516 - Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service. (DoD adopted)
A 569 - Standard Specification for Steel Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial Quality. (DoD adopted)
A 576 - Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality. (DoD adopted)
A 675 - Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties. (DoD adopted)
B 61 - Standard Specification for Steam or Valve Bronze Castings. (DoD adopted)

ASTM (Continued)

B 98 - Standard Specification for Copper-Silicon Alloy Rod, Bar, and Shapes. (DoD adopted)

B 111 - Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock. (DoD adopted)

B 122 - Standard Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel-Silver), and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar. (DoD adopted)

B 139 - Standard Specification for Phosphor Bronze Rod, Bar, and Shapes. (DoD adopted)

B 150 - Aluminum Bronze Rod, Bar, and Shapes. (Metric) (DoD adopted)

B 151 - Standard Specification for Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar. (DoD adopted)

B 152 - Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar. (DoD adopted)

B 169 - Aluminum Bronze Plate, Sheet, Strip and Rolled Bar. (DoD adopted)

B 171 - Standard Specification for Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers.

B 209 - Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate. (DoD adopted)

B 211 - Standard Specification for Aluminum-Alloy Bar, Rod, and Wire. (DoD adopted)

B 241 - Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube. (DoD adopted)

B 271 - Standard Specification for Copper-Base Alloy Centrifugal Castings.

B 359 - Standard Specification for Copper and Copper-Alloy Seamless Condenser and Heat Exchanger Tubes with Integral Fins, Metric.

B 369 - Standard Specification for Copper-Nickel Alloy Castings.

B 584 - Standard Specification for Copper Alloy Sand Castings for General Applications. (DoD adopted)

D 3951 - Standard Practice for Commercial Packaging. (DoD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION (TEMA)

Standards of Tubular Exchanger Manufacturers Association Class C - Tube Bundle Vibration.

(Application for copies should be addressed to the Tubular Exchanger Manufacturers Association, Inc., 707 Westchester Avenue, White Plains, NY 10604.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. 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. REQUIREMENTS

3.1 First article inspection. When specified (see 6.2), a sample shall be subjected to first article inspection (see 6.5) in accordance with 4.5.

3.2 Application of cooler types and classes.

(a) Coolers for submarine service with seawater as coolant that will be subject to sea pressure at submergence greater than 200 feet shall be type I, class 1. For these coolers, design and analysis as specified in 3.4.15 is required.
(b) Coolers for submarine service with seawater as coolant for applications in which the seawater side of the cooler will be secured for submergence greater than 200 feet (for example, engine jacket water cooler for a diesel) shall be type I, class 2.
(c) Coolers for surface ships and service craft with seawater as coolant shall be type I or II, class 3.
(d) Coolers for submarine service with fresh water as coolant shall be type I or II, class 4.
(e) Coolers for surface ship and service craft with fresh water as coolant shall be type I or II, class 5.
(f) Lubricating oil coolers for main propulsion turbines and gears or for main propulsion gears shall be type I.
(g) Lubricating oil coolers using scoop injection of circulating water shall be of single pass construction on the cooling water side and shall be straight tube, type I.
(h) Hydraulic oil coolers shall be type I.
(i) For small lubricating oil coolers, consideration may be given to designs that combine an oil cooler with a bypass valve, or an oil cooler with a bypass valve and oil strainer, in a single assembly.

3.3 General requirements.

3.3.1 Space and weight. The occupied space and weight of coolers shall be held to a minimum consistent with meeting the requirements of this specification and stipulated performance criteria (see 6.2).

3.3.2 Ship attitude and motion. Unless otherwise specified (see 6.2), coolers shall meet the requirements of DOD-STD-1399, section 301, for ship motion and attitude.

3.3.3 Ambient pressure. For submarine application, coolers shall operate at an ambient pressure of 30 inches of mercury absolute with a variation of plus or minus 6 inches of mercury, and shall not be damaged when subjected to an ambient pressure of 10 to 30 pounds per square inch (lb/in^2) absolute with the internal pressure held to the minimum that will prevail under any condition of operation.

3.3.4 Prohibited materials. The following materials shall not be used for service, manufacture, test or inspection of heat exchangers covered in this specification.

(a) Mercury (except for fluorescent or mercury vapor lighting).
(b) Carcinogenic materials.
(c) Cadmium, magnesium, or asbestos.

3.3.5 Welding and allied processes.

3.3.5.1 Fabrication, welding, and inspection. Fabrication, welding, and inspection shall be in accordance with MIL-STD-278, except as modified herein.

3.3.5.2 Type I, class 1, coolers. For type I, class 1, coolers, all welding on parts subjected to sea pressure, including the entire double tube sheet assembly, shall be in accordance with class A-F of MIL-STD-278, except as modified herein. Welded joints on the seawater side shall be radiographable except for vent and drain nipples. Waterbox vent and drain nipple welded connections shall meet the 100 percent weld efficiency requirement for pressure vessels. Welded joints used in shell construction shall be in accordance with class A-4 of MIL-STD-278.

3.3.5.3 Class A-4 pressure vessels. For coolers classified as class A-4 pressure vessels in accordance with MIL-STD-278, weld joints P-64 and P-66 of MIL-STD-22 will be allowed for waterbox (channel) nozzle and shell nozzle attachments.

3.3.6 Casting inspection and repair. Casting inspection and repair shall be in accordance with MIL-STD-278.

3.3.6.1 Class 1 cooler castings. If cast construction is used for waterboxes of coolers of class 1, they shall be in accordance with MIL-STD-278 for castings of category 2, subcategory G, except that no substitution of test shall be made. The extent of radiography shall be 100 percent to level 1 acceptance criteria, and the acceptance criteria for liquid penetrant inspection shall be class 1.

3.3.7 Brazing. Brazing shall be in accordance with NAVSEA 0900-LP-001-7000, except that requirements for use of preinserted brazing rings are applicable only to pipe fittings. Brazed joints shall permit ultrasonic inspection. Brazing shall not be used for the following applications:

(a) Joints for which a cyclic life requirement is stipulated (for example, the seawater side of a class 1 cooler).
(b) Shells of coolers for submarine service.
(c) Shell pipe to shell hub joints of nominal 10-inch diameter and larger.

3.3.8 Threaded fasteners. Threaded fasteners shall conform to MIL-S-1222, except that materials shall be as specified in 3.4.2 and 3.5.1. Configuration shall be such that standard wrenches can be used throughout. Tapered pipe threads shall not be used. The practice of "bottoming" or "shouldering" studs shall not be used. For the set end of studs, a class 3 fit used with locking compound in accordance with grade AV or AVV of MIL-S-22473, or a class 5 interference fit conforming to ANSI B1.12, shall be used.

3.3.8.1 Screw threads. Thread form, dimensions, and tolerances shall conform to FED-STD-H28.

3.3.8.2 Thread lubricants. Threaded fasteners that have torque requirements shall be lubricated before assembly. The lubricant used shall be identified on drawings (see 30.1.4, appendix A), and shall meet the following requirements as applicable:

(a) For class 1 coolers, the lubricant for bolting subject to submergence pressure shall conform to MIL-L-24479.
(b) For propulsion plant coolers on saturated steam plant ships, the lubricant shall conform to MIL-L-24478 or MIL-L-24479.
(c) For all other bolting, the lubricant shall conform to MIL-A-907.

3.3.8.3 Preferred fastener types. Preferred threaded fastener types are, in order of preference:

(a) Through bolt or through (two-nut) stud.
(b) Tap-end stud (one nut).
(c) Cap screw.

3.3.8.4 Cap screws. Cap screws shall not be used for waterbox-to-shell (or waterbox-to-tube sheet) bolting, for inspection cover bolting, or for corrosion preventive anode support cover bolting.

3.3.8.5 Waterbox and tube sheet bolting. For all waterbox and tube sheet bolting, the following requirements shall apply:

(a) Bolting shall be tightened to a stipulated torque value by torque wrench.
(b) For class 1 coolers, bolting design, including stipulated torque values and supporting calculations, shall be established.
(c) For class 1 coolers, bolting subject to submergence pressure shall meet the requirements specified in 3.4.15.3.

3.3.8.6 Wrench flats. Where collar bolts or stud bolts are used to make up a multiple flange joint so that it can be selectively disassembled, the bolts shall have a square extension (or pair of opposed flats) beyond the threads on one end, for use of a wrench to prevent turning when the nuts are tightened or removed.

3.3.9 Shock resistance. Coolers shall pass the high-impact shock tests specified in MIL-S-901, grade A, with the shipboard mounting fixtures being used. (For barge tested units, barge foundations will be shipbuilder furnished.)

Shock test extension criteria given in MIL-S-901 shall be adhered to with the following exception - shock test extension request will not be granted if the request is for a cooler that is longer or larger in diameter than the previously approved cooler.

3.3.10 Allowable pressure drop. Unless otherwise specified (see 6.2), the fluid side pressure drops (in lb/in^2), under design conditions, shall not exceed the following tabulated values:

(a) For main propulsion turbine lubricating oil coolers that use scoop injection of circulating water:

Tube (seawater) side ---------------- 4 lb/in^2
Shell (oil) side --------------------15 lb/in^2

(b) For other lubricating oil coolers and fresh water coolers:

Coolant side ------------------------ 6 lb/in^2
Cooled fluid side (oil) -------------12 lb/in^2
Cooled fluid side (fresh water) ----- 6 lb/in^2

(c) For hydraulic oil coolers:

Tube (coolant side) ----------------- 6 lb/in^2
Shell (oil) side --------------------25 lb/in^2

3.3.11 Cooling water velocity limits. Cooling water velocities shall not exceed those shown in table I. For coolers using seawater as coolant, velocity through tubes shall be a minimum of 4.5 feet per second. (In determining shell side velocities, class C in accordance with TEMA should be taken into consideration, but the shell side velocities shall not exceed those shown in table I for velocity through tubes.)

TABLE I. Maximum cooling water velocities.

Coolant and method of supply	Velocity through inlet flange, feet per second	Velocity through tubes, feet per second
Seawater, supplied by scoop injection	11.0	9.0
Seawater, otherwise supplied	9.0	7.5
Fresh water, however supplied	11.0	9.0

3.3.12 Cooling water inlet temperature. Unless otherwise specified (see 6.2), for design purposes, temperatures of coolant supply shall be taken as follows:

Ship or craft	Coolant	Temperature, °F
Submarines	Seawater	85
	Fresh water	95
Large surface ships	Seawater (electronic system)	95
	Seawater (other systems)	90
	Fresh water	95
Patrol boats and small craft	Seawater	95
	Fresh water	100

3.3.13 Heat transfer surface. The amount of heat transfer surface installed in coolers shall be based on the following:

(a) For submarine coolers, a 10 percent fouling factor shall be applied to the heat coefficient for clean tubes.

(b) For surface ship coolers, the service heat transfer coefficient shall be calculated in accordance with the fouling resistances given in table II. For fluid not listed in table II, use the resistance specified in TEMA.

TABLE II. Fouling resistances (for calculating service heat transfer coefficients for surface ship coolers).

Fluid	Resistance (R), (hr ft^2 °F)/Btu
Seawater	0.0005
Fresh water	.0005
Lubricating oil	.001
Hydraulic oil	.001
Fuel oil (R to vary with viscosity)	
100 SSU (at 100°F) or less	.002
100 to 500 SSU (at 100°F)	.003
500 to 2000 SSU (at 100°F)	.004
2000 SSU (at 100°F) or greater	.005

3.3.14 Inlet and outlet connections. Inlet and outlet connections for coolant and for cooled fluid shall be flanged, unless hose connections are specified (see 6.2). Connection flanges shall be of the cast-integral or the welding type, and are further described in 3.3.15.

3.3.15 Connection flanges. Unless otherwise specified (see 6.2), requirements for flanged connections on waterboxes shall be as follows:

(a) Flanges shall be in accordance with MIL-STD-777 for surface ships, and MIL-STD-438 for submarines, in regard to diameter, minimum thickness, drilling, and flange finish, except as specified herein.
(b) For flanges using O-ring gaskets, the groove for the O-ring shall be in the companion flange on the shipbuilder's piping.
(c) For nonferrous applications, the requirements for flanges specified in MIL-F-20042 shall constitute minimum standards.
(d) For ferrous applications, the 150-pound primary service pressure rating requirements for flanges specified in ANSI B16.5 shall constitute minimum standards.
(e) For cast waterboxes, shells, shell hubs, and the equivalent, cast-integral nozzle flanges may be used in cases where connections are expressed in terms of pipe flange standards; for these cases, requirements for flange identification markings are waived.

3.3.16 Vents and drains. Provisions shall be made to permit complete venting and draining of the coolant and cooled fluid circuits. If double tube sheet construction is specified, the inter-tube sheet spaces shall have flanged vent and drain connections. The smallest acceptable size for vent and drain connections shall be 1/8-inch nominal pipe size (nps). Unless otherwise specified (see 6.2), the connections shall have wall thickness in accordance with MIL-T-16420; 70-30 copper-nickel tube (class 6000 for 1-inch nps and smaller; class 3300 for 1.050-inch nps and larger) and shall be as follows:

(a) For coolant side and inter-tube sheet spaces of submarine cooler applications designed for seawater cooling.

(1) Full penetration weld with joint design in accordance with P-70, P-71, or P-72 of MIL-STD-22. Nipples shall be composition 70-30 copper-nickel in accordance with MIL-C-15726.

(b) For other applications, in addition to the method specified in (a), the following are acceptable:

(1) Single-J, fillet-reinforced weld V-27 in accordance with MIL-STD-22. Nipples shall be copper-nickel conforming to MIL-T-16420.
(2) Tapped hole in accordance with MS16142 fitted with an adapter, except fitting shall be composition 90-10, copper-nickel alloy, in accordance with MIL-C-15726.

(c) In addition to methods specified in (b), for applications where the connection will not normally be in contact with seawater, a socket weld using a T by 2T minimum fillet in accordance with P-14 of MIL-STD-22 will be acceptable.

3.3.16.1 High pressure cooler vent and drain egress. For high pressure applications, waterbox vents and drain connections shall be led out by means of the waterbox flange or tube sheet.

3.3.17 Pressure gauge connections. Connections for pressure gauges shall be provided at inlets and outlets of coolant and cooled fluid sides when specified (see 6.2). Gauge connections shall conform to 3.3.16.

3.3.18 Supports. Coolers shall be provided with supports for securing to a foundation or parent machine. The means of support shall be independent of connecting piping. For coolers designed to be supported from a vertical structure such as a bulkhead, the supports shall be such that bolts in shear will not constitute the primary means of support. Coolers shall not be supported by plates or brackets in such manner that the primary means of support is obtained from the bolts that secure the joint between shell-end flange, tube sheet, and waterbox flange.

3.3.19 Foundation bolt hole allowances. The drilling of foundation bolt holes in cooler feet, other than for close-allowance bushing application (see 3.3.20), shall meet the following criteria:

(a) For bolt sizes of 3/4-inch diameter and smaller, the bolt hole shall be not larger than bolt diameter plus 1/32 inch.
(b) For bolt sizes larger than 3/4-inch diameter, the bolt hole shall be not larger than bolt diameter plus 1/16 inch.

3.3.20 Provision for shell expansion relative to supports. If the distance between cooler supports exceeds 24 inches, provision shall be made for expansion and contraction of the shell with respect to its supports. The use of elongated or oversized bolt holes in support feet is not, by itself, an acceptable method. The following are acceptable methods:

(a) Providing freedom for one end of the shell to move in the axial direction by means of elongated holes in the foot of that shell support, with shell end motion in the other two planes being restricted by use of close allowance collared bushing (collar may be integral or separate from the bushing) assemble over and rigidly bolted down by the foundation bolts at that end. When this method of support is used, the other (fixed) support and its foundation bolts shall carry the entire load due to high-impact shock in the direction longitudinal of the shell.
(b) Providing freedom for one end of the shell to move in the axial direction by use at that end of the cooler of a support designed to flex as the shell expands or contracts. When this method of support is used, the other (fixed) support and its foundation bolts shall carry the entire load due to high-impact shock in the

direction of longitudinal of the shell. Where coolers have cast shells or shell hubs, the flexible support may be a separate piece bolted to the cast shell end.

3.3.21 Provision for shell expansion relative to tubes. For fixed bundle coolers (stationary tube sheets at both ends), a shell expansion joint shall be provided to compensate for differential expansion between shell and tubes when the tube bundle length (back-to-back of tube sheets) is greater than 18 inches. The expansion joint shall be located between one support and the shell end flange.

3.3.22 Gasket application. For liquid side applications of 200 lb/in^2 design pressure and less, flat gaskets may be used. O-ring gaskets shall be used for design pressures greater than 200 lb/in^2 gauge. Use of blind gaskets or packings (those not replaceable without destructive disassembly) is prohibited.

3.3.23 Flat gaskets. Flat gaskets shall be 1/16 inch thick. Coolers shall have adequate gasket width provided under waterbox partitions, and this gasket width shall be not less than 5/16 inch, unless otherwise specified (see 6.2). Flat gaskets shall conform to the material tables, with the following exceptions:

(a) For type I cooler applications where design pressure does not exceed 100 lb/in^2, synthetic rubber in accordance with MIL-G-1149, type II, class 5, may be used.
(b) For type I cooler applications where temperature of metal in contact with the gasket will exceed 250 degrees Fahrenheit (°F), gasket material shall be in accordance with MIL-G-24696 unless otherwise specified (see 6.2).

3.3.24 O-ring gaskets. O-ring gaskets for application in fresh water, seawater or standard lubricating and petroleum hydraulic oil shall be in accordance with one of the following specifications; MIL-G-21610, type I; MIL-R-83248 or MIL-P-83461. O-rings for special applications of adapters and plugs shall be in accordance with MIL-R-83248, class 2. When the application is for an oil that is not compatible with the rubber in accordance with specifications then the desired rubber shall be as specified (see 6.2). O-ring segments for sealing under waterbox partitions shall be integral with the peripheral O-ring.

3.3.25 Selection of rubber packing materials. Rubber packing materials shall be selected to meet the temperature demands of the application, and be compatible with the working fluids. Packing rings conforming to class 5 of MIL-G-1149 have good compatibility with petroleum base lubricating oils.

3.3.26 Drawings. (See 6.3 and appendix A.)

3.3.27 Identification plates. Each cooler shall bear an identification plate conforming to class A, B, C, or D of MIL-P-15024 and MIL-P-15024/5, with material choice being limited to the wrought brass, cast brass, cast bronze, or corrosion-resisting steel. (Plates shall be normal service plates.) Design pressure entries shall not appear on identification plates. Provision shall be made for the following information:

(a) Name of unit (examples: lubricating oil cooler, fresh water cooler, battery cooler, hydraulic oil cooler).
(b) Type of unit (see 1.2).
(c) Class of unit (see 1.2).
(d) Manufacturer's service part number.
(e) National stock number. (Allow 20 spaces.)
(f) Name of manufacturer.
(g) Contract or purchase order number. The contract or purchase order number shall be entered in this space. (Utilize width of plate to allow maximum number of spaces.)
(h) Blank space for Defense Contract Administration Services Management Area (DCASMA) stamp.
(i) Date of manufacture.
(j) Serial number.
(k) Maximum factory test pressure, shell side.
(l) Maximum factory test pressure, tube side. For coolers for seawater service on submarines, no entry shall be made in this space.
(m) Blank space for unit number. This space will be used for numbering for shipboard reference purposes when required, the stamping to be done by shipyard. (Allow four spaces.)
(n) Designation "U.S." (without quotation marks).

3.3.28 Interchangeability. In no case shall parts be physically interchangeable or reversible unless such parts are also interchangeable or reversible with regard to function, performance and strength.

3.4 Type I (shell and tube design) requirements.

3.4.1 Code requirements for type I coolers. Type I coolers shall be constructed in accordance with TEMA, class C, except as otherwise specified herein. The structural design calculations for the class 1 coolers shall be in accordance with Section III (class 1 vessel) of ASME Boiler and Pressure Vessel Code. Structural design calculations for coolers other than class 1 shall be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division I.

3.4.2 Materials. For type I coolers, materials as specified hereinafter by table shall be used as the basis for design. These shall be used in the construction of the coolers, except that the contractor shall have the option of substituting commercial material having equal or better physical and chemical properties than the materials specified under Federal or Military specifications, subject to approval by the drawing review agency.

3.4.2.1 Type I, class 1. Type I, class 1 coolers shall be constructed of materials specified in table III.

3.4.2.2 Type I, class 2. Type I, class 2 coolers shall be constructed of materials specified in table IV.

3.4.2.3 Type I, class 3. Type I, class 3 coolers shall be constructed of materials specified in table V.

3.4.2.4 Type I, class 4. Type I, class 4 coolers shall be constructed of materials specified in table VI.

3.4.2.5 Type I, class 5. Type I, class 5 coolers shall be constructed of materials specified in table VI or table VII.

TABLE III. Type I, class 1 cooler materials.

Part	Material	Applicable document
Shells 1/	Copper-nickel alloy or tubing, Copper-nickel alloy	MIL-C-15726 MIL-T-16420
Waterboxes 2/	Copper-nickel alloy, composition 70-30; Tubing, copper-nickel alloy, composition 70-30; Copper-nickel alloy, cast composition 70-30; or cast bronze, nickel-aluminum	MIL-C-15726 MIL-T-16420 MIL-C-20159 MIL-B-24480
Tube sheets	Copper-nickel alloy, composition 70-30	MIL-C-15726
Tubes	Copper-nickel alloy, composition 70-30	MIL-T-15005
Gland rings and lantern rings	Bronze, tin, centrifugal castings, alloy C90300 or C92200; Bronze, tin, sand castings, alloy C90300 or C92200; or Copper-nickel alloy	QQ-C-390, type II QQ-C-390, type I MIL-C-15726
Baffles	Copper-nickel alloy	MIL-C-15726
Spacers	Copper-nickel alloy	MIL-T-15005 or MIL-T-16420
Spacer rods and nuts	Copper-nickel alloy	MIL-C-15726
Bolts or studs in joints involving seawater tightness or subject to submergence pressure	Nickel-copper-aluminum alloy, grade A, hot finished, annealed, and age hardened; or cold drawn, annealed, and age hardened.	MIL-S-1222
Nuts for bolts and studs in joints involving seawater tightness or subject to submergence pressure	Nickel-copper-aluminum alloy, Nickel-copper alloy, or Nickel-copper alloy, cold drawn and stress relieved, or hot finished	MIL-S-1222, grade 500 MIL-S-1222, grade 400 MIL-N-24106

See footnotes at end of table.

TABLE III. Type I, class 1 cooler materials - Continued.

Part	Material	Applicable document
Bolts, studs, and nuts for service other than specified above	Nickel alloys, grade 400 or 405	MIL-S-1222
Jackscrews	Copper-aluminum alloy, copper alloy C61400; Phosphor bronze; or Copper-silicon alloy	ASTM B 150 ASTM B 139 ASTM B 98
Corrosion preventive anodes	Zinc	MIL-A-18001
Gaskets 3/	Rubber, synthetic, class 1, grade 80	MIL-R-6855
Washers	Copper-aluminum alloy, copper alloy C61400	ASTM B 150, ASTM B 169 or QQ-C-450
Plugs and adapters	Copper-nickel alloy, composition 70-30	MIL-C-15726
Packing rings	Rubber, synthetic, type II, class 5	MIL-G-1149
O-ring gaskets 3/	Rubber, synthetic, type I; Rubber, synthetic, or Rubber, synthetic	MIL-G-21610 MIL-R-83248 MIL-P-83461

1/ Use of steel for shell support members is acceptable.
2/ Inspection covers shall be of the same copper alloy as the waterboxes to which fitted.
3/ See 3.3.22, 3.3.23, and 3.3.24.

TABLE IV. Type I, class 2, cooler materials.

Part	Material	Applicable document
Shells 1/	Copper-nickel alloy or Tubing, copper-nickel alloy	MIL-C-15726 MIL-T-16420
Waterboxes 2/	Copper-nickel-alloy, composition 70-30; Tubing, copper-nickel alloy, composition 70-30; Copper-nickel alloy, cast composition 70-30; or Bronze, nickel-aluminum castings	MIL-C-15726 MIL-T-16420 MIL-C-20159 MIL-B-24480
Tube sheets 3/	Copper-nickel alloy, composition 70-30	MIL-C-15726
Tubes	Copper-nickel alloy, composition 70-30	MIL-T-15005
Gland rings and lantern rings	Bronze, tin, centrifugal castings, alloy C90300 or C92200; Bronze, tin, sand castings, alloy C90300 or C92200; or Copper-nickel alloy	QQ-C-390, type II QQ-C-390, type I MIL-C-15726
Baffles	Copper-nickel alloy	MIL-C-15726
Spacers	Copper-nickel alloy	MIL-T-15005 or MIL-T-16420
Spacer rods and spacer nuts	Copper-nickel alloy	MIL-C-15726
Bolts or studs in joints involving seawater tightness	Nickel alloy, grade 400, 405, or 500	MIL-S-1222
Nuts for bolts and studs in joints involving seawater tightness	Nickel alloy, grade 400, 405, or 500	MIL-S-1222
Bolts, studs, and nuts for service other than specified above	Nickel alloys	MIL-S-1222

See footnotes at end of table.

TABLE IV. Type I, class 2 cooler materials - Continued.

Part	Material	Applicable document
Jackscrews	Copper-aluminum alloy, copper alloy C61400; Phosphor bronze; or Copper-silicon alloy	ASTM B 150 QQ-B-750 QQ-C-591
Corrosion preventive anodes	Zinc	MIL-A-18001
Gaskets 4/	Rubber, synthetic, class 1, grade 80	MIL-R-6855
Washers	Copper-aluminum alloy, copper alloy C61400	ASTM B 150 or ASTM B 169
Plugs and adapters	Copper-nickel alloy, composition 70-30	MIL-C-15726
Packing rings	Rubber, synthetic, type II, class 5	MIL-G-1149
O-ring gaskets 4/	Rubber, synthetic, type I, Rubber, synthetic, or Rubber, synthetic	MIL-G-21610 MIL-R-83248 MIL-P-83461

1/ Use of steel for shell support members is acceptable.
2/ Inspection covers shall be of the same copper alloy as the waterboxes to which fitted.
3/ For double tube sheet construction, an additional material for inner tube sheets is copper-nickel alloy, composition 90-10, in accordance with MIL-C-15726.
4/ See 3.3.22, 3.3.23, and 3.3.24.

TABLE V. Type I, class 3 cooler materials.

Part	Material	Applicable document
Shells 1/	Copper-nickel alloy, composition 90-10; Tubing, copper-nickel alloy, composition 90-10; Copper-nickel alloy; Copper-nickel alloy, C70600 or C71500 temper OS035, Copper-aluminum alloy, copper alloy C61400;	MIL-C-15726 MIL-T-16420 ASTM B 171 ASTM B 151 QQ-C-450

See footnotes at end of table.

TABLE V. Type I, class 3 cooler materials - Continued.

Part	Material	Applicable document
	Bronze, tin, sand castings, alloy C90500 or C92200; or Bronze, nickel-aluminum	ASTM B 584 MIL-B-24480
Waterboxes 2/	Copper-nickel alloy; Tubing, copper-nickel alloy; Copper-nickel alloy; Bronze, nickel-aluminum; or Bronze, sand castings, alloy C90500 or C92200	MIL-C-15726 MIL-T-16420 MIL-C-20159 MIL-B-24480 ASTM B 584
Tube sheets 3/	Copper-nickel alloy, composition 90-10; or Bronze, nickel-aluminum, alloy C63000	MIL-C-15726 ASTM B 171
Tubes	Copper-nickel alloy, composition 90-10	MIL-T-15005 or MIL-T-22214 (class A)
Outer tubes, for double tube construction	Copper	MIL-T-24107
Fins	Nonferrous	----
Gland rings and lantern rings	Bronze, tin, centrifugal casting alloy C90300 or C92200; Bronze, tin, sand castings, alloy C90300 or C92200; or Copper-nickel alloy	ASTM B 271 ASTM B 584 MIL-C-15726
Baffles	Copper-nickel alloy	MIL-C-15726
Spacers	Copper-nickel alloy	MIL-C-15005 MIL-C-16420
Spacer rods and spacer rod nuts	Copper-nickel alloy	MIL-C-15726
Bolts, studs, and nuts	Nickel alloys	MIL-S-1222

See footnotes at end of table.

TABLE V. Type I, class 3 cooler materials - Continued.

Part	Material	Applicable document
Jackscrews	Copper alloys	MIL-S-1222
Corrosion preventive anodes	Zinc	MIL-A-18001
Plugs, zinc support	Copper-nickel alloy, composition 70-30	MIL-C-15726
Gaskets 4/	Rubber, synthetic, class 1, grade 80	MIL-R-6855
Washers	Copper-aluminum alloy, copper alloy C61400	ASTM B 150 or ASTM B 169
Plugs and adapters:		
For all services	Nickel-copper alloy; Copper-nickel alloys; Bronze, tin, sand castings, alloy C90300 or C92200; or Copper-nickel alloy, alloy C71500, temper OS035	QQ-N-281 MIL-C-15726 ASTM B 584 ASTM B 122
For other than seawater service	Copper-aluminum alloy, copper alloy alloy C61400; or Nickel-aluminum bronze, alloy C63200	ASTM B 150 or QQ-C-450 ASTM B 150
Packing rings	Rubber, synthetic, type II, class 5	MIL-G-1149
O-ring gaskets 4/	Rubber, synthetic, type I; Rubber, synthetic, or Rubber, synthetic	MIL-G-21610 MIL-R-83248 MIL-P-83461

1/ Use of steel for shell support members is acceptable.
2/ Inspection covers shall be of the same copper alloy as the waterboxes to which fitted.
3/ For double tube sheet construction, additional materials for inner tube sheets are copper-aluminum alloys, copper alloys C61300 and C61400 conforming to QQ-C-450, and copper-nickel alloy, composition 90-10, in accordance with MIL-C-15726.
4/ See 3.3.22, 3.3.23, and 3.3.24.

TABLE VI. Type I, class 4 and 5 cooler materials.

Part	Material	Applicable document
Shells 1/	Copper-nickel alloy; Tubing, copper-nickel-alloy; Copper-nickel alloy, C70600 or C71500 Copper-nickel alloy, C70600 or C71500, temper 0S035 Copper-aluminum alloy, copper alloy C61400; Bronze, tin, sand castings, alloy C90500 or C92200; or Bronze, nickel-aluminum, casting	MIL-C-15726 MIL-T-16420 ASTM B 171 ASTM B 151 QQ-C-450 ASTM B 584 MIL-B-24480
Waterboxes	Copper-nickel alloy; Tubing, copper-nickel alloy; Copper-nickel alloy; Bronze-nickel-aluminum castings; Aluminum bronze, alloy C95400 as cast, or alloy C95200; or Bronze, tin, sand castings, alloy C90500 or C92200	MIL-T-15726 MIL-T-16420 MIL-C-20159 MIL-B-24480 QQ-C-390 ASTM B 584
Tube sheets	Copper-nickel alloy; Nickel-aluminum bronze, alloy C63000; or Aluminum bronze, nickel-aluminum, alloy C61400	MIL-C-15726 ASTM B 171 ASTM B 171
Tubes	Copper-nickel alloy, composition 90-10	MIL-T-15005 or MIL-T-22214 (class A)
Gland rings and lantern rings	Bronze, tin, centrifugal castings, alloy C90300 or C92200; Bronze, tin sand castings, alloy C90300 or C92200; or Copper-nickel alloy	ASTM B 271 ASTM B 584 MIL-C-15726
Baffles	Copper-nickel alloy	MIL-C-15726
Spacers	Copper-nickel alloy	MIL-T-15005 or MIL-T-16420
Spacer rods and spacer rod nuts	Copper-nickel alloy	MIL-C-15726

See footnotes at end of table.

TABLE VI. Type I, class 4 and 5 cooler materials - Continued.

Part	Material	Applicable document
Bolts, studs, and nuts	Nickel-copper, grade 400 or 405; or Nickel-copper-aluminum, grade 500	MIL-S-1222
Jackscrews	Copper-aluminum alloy, copper alloy C61400; Phosphor bronze; or Copper-silicon alloy	ASTM B 150 QQ-B-750 QQ-C-591
Gaskets 2/	Rubber, synthetic, class 1, grade 80	MIL-R-6855
Washer	Copper-aluminum alloy, copper alloy C61400	ASTM B 150, ASTM B 169 or QQ-C-450
Plugs and adapters	Copper-nickel alloy; or Copper-nickel alloy, alloy C71500, temper OS035	MIL-C-15726 ASTM B 122
Packing rings	Rubber, synthetic, type II, class 5	MIL-G-1149
O-ring gaskets 2/	Rubber, synthetic, type I; Rubber, synthetic, or Rubber, synthetic	MIL-G-21610 MIL-R-83248 MIL-R-83461

1/ Use of steel for shell support members is acceptable.
2/ See 3.3.22, 3.3.23, and 3.3.24.

TABLE VII. Alternative type I, class 5, cooler materials.

Part	Material	Applicable document
Waterboxes	Aluminum-bronze, alloy C95400 as cast, or alloy C95200	QQ-C-390
Tube sheets	Copper-aluminum alloy, copper alloy C61300; Aluminum bronze D, copper alloy C61400	QQ-C-450 ASTM B 171
Tubes	Copper-nickel alloy, composition 90-10	MIL-T-15005 or MIL-T-22214 (class A)

3.4.2.6 Use of steel material for the shell side of lubricating oil and hydraulic oil coolers. For lubricating oil and hydraulic oil cooling applications, the shell side of coolers may be constructed of the materials specified in table VIII (see 6.2).

3.4.2.7 Use of aluminum shell side internals for lubricating oil and hydraulic oil coolers. For lubricating oil and hydraulic oil cooling applications, the shell side internal part of type I coolers may be constructed of the materials specified elsewhere herein or those specified in table IX (see 6.2).

3.4.2.8 Materials for heat exchangers cooling synthetic lubricating oil. For certain applications, the synthetic lubricating oil side of a synthetic lubricating oil cooler shall contain no material that has more than 5 percent copper, except nickel-copper material. When specified (see 6.2), the cooler shall be made of materials listed in table X. Materials in table X shall be limited in application to coolers of type I, class 3, 4, or 5.

3.4.3 Tube features. Cooler tubes shall be seamless. Coolers shall have either straight tubes or U-bend tubes.

3.4.3.1 U-bend tubes. Bending radii for U-bend tubes shall be not less than the dimensions specified in table XI. After bending, tubes shall retain round cross-section. The bending procedure shall be qualified to the satisfaction of the cognizant inspector by production of sample tube bends.

TABLE VIII. Optional shell side materials for oil cooling applications.

Part	Material	Applicable document
Shell	Steel pipe, type S; Seamless carbon steel pipe, grade B; Steel plate, grade C; Seamless drawn steel tubing; Steel plate; Cast steel; or Carbon steel plate	ASTM A 53 ASTM A 106 ASTM A 285 MIL-P-24691/1 MIL-S-22698 MIL-S-15083 ASTM A 515 or ASTM A 516
Flanges	Carbon steel plate; Steel plate, grade C; Cast steel; Steel pipe flange; or Carbon steel forgings	ASTM A 515 or ASTM A 516 ASTM A 285 MIL-S-15083 ASTM A 181 ASTM A 105

TABLE VIII. Optional shell side materials for oil cooling applications - Continued.

Part	Material	Applicable document
Shell supports	Carbon steel; Carbon steel plate; Cast steel, grade B; Steel plate, grade C; or Steel plate, class C	ASTM A 105 ASTM A 36, ASTM A 515, or ASTM A 516 MIL-S-15083 ASTM A 285 ASTM A 515, or ASTM A 516
Tube, outer	Brass, class A; or Steel	MIL-T-20168 MIL-P-24691/1
Tube sheet, inner	Steel plate, grade C; or Carbon steel plate	ASTM A 285 ASTM A 515 or ASTM A 516
Baffles	Steel plate; Steel plate, grade C; Steel plate; Steel; Steel plate, class 1018 or 1020; Steel plate, class C; or Carbon steel plate	MIL-S-22698 ASTM A 285 ASTM A 515 or ASTM A 516 ASTM A 569 ASTM A 576 or ASTM A 675 ASTM A 36
Stay rods	Carbon steel, bolt material, grade 2 or 5	MIL-S-1222
Nuts	Steel	MIL-S-1222
Spacers	Steel or Steel pipe	MIL-P-24691/1 ASTM A 179, or ASTM A 214 ASTM A 53 or ASTM A 106

TABLE IX. Optional materials for shell side internal parts for oil cooling applications, type I coolers.

Part	Material	Applicable document
Baffles	Aluminum, alloy 2024-T3	ASTM B 209
Spacers	Aluminum, alloy 6061-T6	ASTM B 241
Tie rods	Aluminum, alloy 6061-T6	ASTM B 211
Tie rod nuts	Aluminum, alloy 6062-T9	ASTM B 211

TABLE X. Materials for synthetic lubricating oil coolers, type I, class 3, 4, or 5.

Part	Material	Applicable document
Shells	Steel pipe; Seamless carbon steel pipe, grade B; Steel plate, grade C; Cast steel; or Carbon steel plate	ASTM A 53 ASTM A 106 ASTM A 285 MIL-S-15083 ASTM A 515 or ASTM A 516
Waterboxes	Copper-nickel alloy, composition 90-10; Copper-nickel alloy, composition 90-10; Bronze, nickel-aluminum; or Bronze, tin, sand castings, alloy C90500 or C92200	MIL-C-15726 MIL-C-20159 MIL-B-24480 ASTM B 584
Tube sheets 1/	Nickel-copper alloy, class A	QQ-N-281
Tubes 2/	Nickel-copper alloy, type I, condition 1	MIL-T-1368
Gland rings and lantern rings	Steel plate, grade C; or Steel plate	ASTM A 285 MIL-S-22698
Baffles	Steel plate, grade C; Steel plate;	ASTM A 285 MIL-S-22698, ASTM A 515, or ASTM A 516

See footnotes at end of table.

TABLE X. Materials for synthetic lubricating oil coolers, type I, class 3, 4, or 5 - Continued.

Part	Material	Applicable document
	Steel; Steel plate, class 1018 or 1020; or Carbon steel plate	ASTM A 569 ASTM A 576 or ASTM A 675 ASTM A 36
Spacers	Steel pipe or Steel tubing	ASTM A 106 or ASTM A 179 ASTM A 214
Spacer rods	Carbon steel bolt material, grade 2; or Steel rod, class 1018 or 1020	MIL-S-1222 ASTM A 576 or ASTM A 675
Spacer rod nuts	Carbon steel bolt material, grade 2 or 5; or Steel	MIL-S-1222 Commercial
Bolts, studs, and nuts 3/	Nickel-copper alloy	MIL-S-1222
Jackscrews	Copper-aluminum alloy, copper alloy C61400; or Phosphor bronze	ASTM B 150 QQ-B-750
Corrosion preventive anodes	Zinc	MIL-A-18001
Plugs, zinc support	Copper-nickel alloy, composition 70-30	MIL-C-15726
Gaskets 4/	Rubber, synthetic, class 1, grade 80	MIL-R-6855
Plugs and adapters:		
For seawater service	Copper-nickel alloy, composition 70-30; or Copper-nickel alloy, alloy C71500 or temper OS035	MIL-C-15726 ASTM B 122
For lube oil service	Steel plate, grade C	ASTM A 285

See footnotes at end of table.

TABLE X. Materials for synthetic lubricating oil coolers, type I, class 3, 4, or 5 - Continued.

Part	Material	Applicable document
Packing rings	Rubber, synthetic, type II, class 5	MIL-G-1149
O-ring gaskets 4/	Rubber, synthetic, type I; Rubber, synthetic, or Rubber, synthetic	MIL-G-21610 MIL-R-83248 MIL-P-83461

1/ For double tube sheet construction, additional materials for inner tube sheets are steel plate, class C, conforming to ASTM A 285; steel plate conforming to MIL-S-22698; or carbon steel plate in accordance with ASTM A 515 or ASTM A 516.

2/ For double tube construction, additional material for outer tube is steel tube in accordance with MIL-P-24691/1 or carbon steel tube in accordance with ASTM A 179.

3/ Form shall be in accordance with MIL-S-1222.

4/ See 3.3.22, 3.3.23, and 3.3.24.

TABLE XI. Minimum radii for U-bend tubes, type I coolers.

Outside tube diameter (inch)	Minimum radius of bend at tube centerline (inch)
5/8	15/16
1/2	13/16
3/8	5/8

3.4.4 Shell end construction. The following kinds of shell end construction will be acceptable (see 3.4.5):

(a) Ring flange, drilled for bolting of tube sheets and bonnet (as applicable) thereto, with shell welded to the flange or cast integral with it.

(b) Additionally, for hydraulic oil cooling and other applications where double tube construction is specified (see 3.4.8), shell flange omitted, shell welded to tube sheet.

3.4.5 Cooler end construction.

3.4.5.1 Submarine cooler applications (except type I, class 4, applications not exceeding 150 lb/in^2 gauge). Except for hydraulic oil cooling applications and other applications where double tube construction is specified (see 3.4.8), the cooler shall have a removable tube bundle with stationary tube sheet at the front end of the cooler. (For a type I cooler, the front end is the end at which the coolant first arrives, in normal operation. The opposite end is the rear end. The terms "front" and "rear" relate to the cooler, while "forward," "aft," and "after" relate to the ship in which the cooler is installed.) The removable feature may be achieved by use of U-bend tube construction or by use of straight tube construction in conjunction with a floating tube sheet at the rear end of the cooler. Standard construction for these coolers shall conform to the following:

(a) Front end construction shall be either of the following:

(1) Gasket or O-ring joint for tube sheet-to-shell flange; gasket or O-ring joint for waterbox-to-tube sheet; tube sheet secured to shell flange by use of collar studs, or studs threaded into the tube sheet, so that the tube sheet-to-shell flange joint can withstand shell side hydrostatic test with the waterbox disassembled.

(2) Full face gasket or O-ring joint for tube sheet-to-shell flange with independent bolting ring; reduced diameter stationary tube sheet-to-waterbox flange gasket or O-ring joint secured by independent bolting ring.

(b) Rear end construction, where use of a floating tube sheet is elected, shall be as follows (see figure 1): The waterbox shall be attached to the floating tube sheet by means of a ring of studs, set in the face of the tube sheet, and used to form a gasketed joint between waterbox and tube sheet. The seal between shell and floating tube sheet shall be effected by rubber or rubberlike packing rings. The packing rings shall fit in a counterbore in the shell end and be compressible by a gland ring held in place by nuts on studs set in the shell end. The perimeter of the floating tube sheet (or an extension of it) shall bear against the concave side of the packing rings in the manner of a piston in a cylinder.

3.4.5.2 <u>Submarine cooler (type I, class 4, not exceeding 150 lb/in^2 gauge) and surface ship cooler applications</u>. Except for hydraulic oil cooling and other applications where double tube construction is specified (see 3.4.5.3), the cooler shall incorporate a removable tube bundle with a stationary tube sheet at the front end of the cooler. The removable feature may be achieved by use of U-bend tube construction or by use of straight tube construction in conjunction with a floating tube sheet at the rear end of the cooler. Standard construction for these coolers shall conform to the following:

(a) Front end construction.

(1) Gasket joint for the tube sheet-to-shell flange; gasket joint for the waterbox-to-tube sheet joint; tube sheet secured to shell flange by use of collar studs, or studs threaded into the tube sheet, so that the tube sheet-to-shell flange joint can withstand shell side hydrostatic test with the waterbox

disassembled. For U-bend tube construction, all the fasteners of the bolting ring shall be of one of the types described above; for floating tube sheet construction, not less than 50 percent of them shall be of such construction.

(b) Rear end construction where a floating tube sheet is used.

(1) The shell and waterbox flanges shall each be counterbored to retain one or more integral packing rings. A lantern ring shall be located between the respective packing rings or sets of packing rings. This lantern ring shall have a groove around the inside, and leakoff holes shall be arranged so that leakage past the packing ring (whether from shell or waterbox) will be relieved to the outside. The waterbox-to-shell bolting shall compress this double packed joint. Where this packed lantern ring construction is used, a test ring shall be provided so that hydrostatic testing of the shell side may be accomplished with the rear waterbox removed. Rear end construction of this kind is shown on figure 2.

(2) The shell and waterbox flanges shall have a packing gland retaining ring to hold one or more integral packing rings in place. A lantern ring shall be located between the respective packing rings or sets of packing rings. This lantern ring shall have a groove around the inside and leakoff holes arranged so that leakage past the packing ring (whether from shell or waterbox) will be relieved to the outside. The waterbox-to-shell bolting shall compress this double packing joint. Where this construction is used, no test ring will be required, since the waterbox stud bolts will be threaded into the lantern ring and the lantern ring will therefore remain in place after the waterbox is removed. This rear end construction is shown on figure 3.

(c) As special construction for these coolers, units may feature coolant flow paths led through the shell, with coolant piping connections integral with the shell. The stationary tube sheet shall be of reduced diameter relative to shell and waterbox flanges, but with joint configuration such that both waterbox and shell shall limit lateral motion of the stationary tube sheet. A test ring shall be provided to allow testing of the shell side with the stationary waterbox removed.

(d) As other special construction for these coolers, any of the constructions permitted for submarine coolers may be used. For hydraulic oil cooling and other applications for which double tube construction is specified (see 3.4.5.3).

3.4.5.3 Hydraulic oil cooling applications and other applications for which double tube construction is specified. For these coolers, the method specified in 3.4.4(b) shall be used to attach the shell to the tube sheets. These coolers shall be of the following construction:

(a) Shells shall be of fabricated construction. Straight tubes shall be used.

(b) If the tube bundle effective length (back to back of tube sheets) exceeds 18 inches, a shell expansion joint shall be provided to compensate for differential expansion between shell and tubes. This joint shall be located outboard of the shell supports and shall withstand lateral high impact shock. Stuffing box type joints will not be acceptable.

3.4.6 Hydraulic oil coolers. For application as hydraulic oil coolers, coolers shall be of the fixed bundle straight tube type specified in 3.4.5.3, and shall incorporate the double tube sheet feature of 3.4.7 and the double tube feature of 3.4.8.

3.4.7 Double tube sheet construction (cyclic loading not specified). For hydraulic oil coolers, and as specified (see 6.2) for other coolers, two tube sheets shall be provided at each end of the cooler. A space between the two sheets of a pair shall be provided by use of a spacing ring or by machining one or both sheets. The joint between the sheets or the joints between sheets and ring shall be welded (see figures 4 and 5). The space between tube sheets shall be vented and drained to atmosphere. The tubes shall be expanded into each tube sheet as specified in 3.4.10.3, and the discontinuity in tube surface caused by the expansion shall be kept to a minimum. After expansion of the tubes, the specified tube side hydrostatic test pressure shall be applied to the spaces between the two tube sheets at each end, and there shall be no leakage under this pressure. Double tube sheet construction subject to cyclic loading shall be as specified in 3.4.15.

3.4.8 Double tube construction. For hydraulic oil coolers and as specified for other coolers (see 6.2), double tube construction shall be combined with fixed bundle construction and double tube sheet construction. If this combination is used, provision shall be made for a telltale system for detecting leaks. Outer tubes shall be jointed to the inner tube sheets by expanding, welding, or silver brazing. The outer tubes shall have their internal surfaces longitudinally grooved so that, after the inner tubes are expanded tightly into the outer tubes, there will be adequate contact between the two tubes to conduct heat, and the multiple grooves will readily lead off leakage from any perforation of an inner tube to the end of the compartments formed between outer and inner tube sheets. Each of the end compartments shall be provided with vent and leakoff connections. Visual means shall be provided for readily detecting leakage through the use of a telltale system leading from the leakoff connections of each end compartment. An instruction plate conforming to MIL-P-15024 and MIL-P-15024/5 shall be provided to indicate the function of these connections and to warn against improper plugging of them. This plate shall be located close to one of the leakoff connections. Inner tubes shall have one of the nominal outside diameters specified below, with corresponding wall thickness, and shall be sized for rolling into the outer tube sheets with a standard expander. After assembly, the specified tube side hydrostatic test pressure shall be applied to the end compartments and leakage warning passages, and there shall be no leakage under this pressure.

3.4.9 Shell side tinning. For submarine battery cooling, and for other applications as specified (see 6.2), the shell side shall be completely tinned by electroplating or dipping. The tinning shall include the following surfaces:

(a) Inside surface of shell subassembly.
(b) Outside surface of tubes.
(c) Support plates, baffles, spacers, tie rods, nuts, and locking devices.
(d) Areas of tube sheets exposed to shell side fluid.

3.4.9.1 Electroplating. In the electroplating method, the parts shall be tinned to a thickness of 0.001 to 0.0015 inch. The plating shall have a smooth, fine grain appearance, and shall be free from burnt deposits such as may result from high-current-density in spots.

3.4.9.2 Dipping. In plating by dipping, a lead-tin solution with lead content of not more than 25 percent may be used.

3.4.10 Tubes. Tubes shall be of the following sizes and configurations.

3.4.10.1 Tube sizes. Tube sizes shall be in accordance with 3.4.10.1.1 through 3.4.10.1.4.

3.4.10.1.1 Submarine coolers, seawater coolant. Submarine coolers designed for use with seawater as coolant shall be provided with tubes of 5/8-inch outside diameter, 0.065-inch (number 16 Birmingham wire gauge (BWG)) wall thickness.

3.4.10.1.2 Surface ship coolers, seawater coolant. Surface ship coolers designed for use with seawater as coolant shall be provided with tubes of 5/8-inch outside diameter, 0.049-inch (number 18 BWG) wall thickness, or 1/2-inch outside diameter, 0.049-inch (number 18 BWG) wall thickness; but the 5/8-inch outside diameter size shall be used for lubricating oil coolers for main propulsion turbine units that use scoop injection of circulating water.

3.4.10.1.3 Coolers with freshwater coolant. Coolers designed for use with fresh water as coolant shall be provided with tubes of 5/8-inch outside diameter, 0.049-inch (number 18 BWG) wall thickness, 1/2-inch outside diameter, 0.049-inch (number 18 BWG) wall thickness, or 3/8-inch outside diameter, 0.035-inch (number 20 BWG) wall thickness.

3.4.10.1.4 Specifying tube size. Unless otherwise specified (see 6.2), the tube size shall be in accordance with 3.4.10. For applications in which a tube wall thickness greater than those specified in 3.4.10.1.1 through 3.4.10.1.3 is required, the tube wall thickness shall be as specified in the contract or order (see 6.2).

3.4.10.1.5 Special tolerances. For tubes furnished to requirements of ASTM B 111 or B 359, tolerances on the outside diameter of plain tubes and the outside diameter of unfinned sections of finned tubes shall be plus 0.000 inch and minus 0.005 inch.

3.4.10.2 Fins. The use of fins is permissible on the outer tube of double tube coolers. The use of fins on single tube coolers shall be as specified in 3.4.10.2.1 or 3.4.10.2.2.

3.4.10.2.1 Integral fins. Tubes shall be of the low fin type with fins worked out of the tube wall in such a way that the outside diameter of the fins shall not exceed the outside diameter of the plain ends of the tubes. The tube wall at the plain end shall be two BWG sizes heavier than the wall thickness specified in 3.4.10.1, to permit use of a standard tube expander.

3.4.10.2.2 Applied fins. Tubes shall be of the low fin type. One end of the finned tube shall be gradually enlarged (flared) to diameter slightly greater than the outside diameter of the fins. This practice will permit removal and replacement of individual tubes. The enlarged end shall be the discharge end of the tube. The holes in the tube sheets for these enlarged tube ends shall be reamed 0.001 inch larger than the outside diameter of the tube end, with a plus 0.005 inch tolerance, and the nominal ligament between tube holes shall be not less than 3/16 inch.

3.4.10.3 Tube expansion. Tubes of coolers shall be expanded into the tube sheets at both ends, except as specified in 3.4.8. The expansion shall be by means of a tube expander in accordance with MIL-E-15809 and shall be governed by an automatic tube expander control. The expanded portion of the tube-to-tube sheet joint shall not approach closer than 1/8 inch to the back face of single or outer tube sheets, nor closer than 1/8 inch to either face of inner tube sheets (double tube sheet construction). Depths of expansion of tubes shall be not less than those specified in table XII.

TABLE XII. Minimum depth of tube expansion.

Tube outside diameter (inch)	Minimum depth of expansion (inch)
5/8	5/8
1/2	5/8
3/8	1/2

3.4.11 Tube sheets.

3.4.11.1 Minimum thickness. Tube sheet thickness shall be not less than the following:

(a) For joints with inlet end flare (see 3.4.11.3) -- depth of expansion plus depth of flare plus 1/8 inch.
(b) For nonflared joints -- depth of expansion plus 1/8 inch.
(c) For inner tube sheets -- depth of expansion plus 1/4 inch.

3.4.11.2 Spacing and size of holes. Holes for tubes in tube sheets shall be spaced center to center and reamed to diameters shown in table XIII.

TABLE XIII. Spacing and diameter of tube holes.

Tube outside diameter (inch)	Tube spacing center to center, to be not less than 1/ (inch)	Diameter of holes for tubes 2/ (other than where tinning of shell side is specified) (inch)	Diameter of holes for tubes 2/ (where tinning of shell side is specified) (inch)
5/8	13/16	0.626	0.631
1/2	21/32	.503	.508
3/8	1/2	.376	.381

1/ A tolerance of plus 0.015 or minus 0.017 inch on the nominal ligament thickness will be permitted.

2/ A tolerance of minus 0.000, or plus 0.005 inch will be permitted. A maximum of 1 percent (to the nearest hole) of the tube holes in each tube sheet may range to plus 0.010 inch, provided that two oversized holes are not adjacent and that the ligament thickness requirements are met.

3.4.11.3 Inlet end hole flaring. The holes for the inlet ends of the tubes shall be flared as specified in table XIV to allow for belling the ends of the tubes.

TABLE XIV. Flaring of tube holes for inlet ends.

Tube outside diameter (inch)	Radius of flare (inch)	Diameter of flared hole at outside face of tube sheet (inch)
5/8	1/2	3/4
1/2	3/8	5/8
3/8	5/16	1/2

3.4.11.4 Grooving of holes in tube sheets. The holes for tubes in the tube sheets shall be grooved with annular grooves as specified in table XV.

TABLE XV. Annular grooving of holes in tube sheets.

Tube size (outside diameter)	Cooler application	Number of grooves in outer tube sheet	Number of grooves in inner tube sheet (inch)	Width of groove (minimum) (inch)	Depth of groove (±0.005 inch)	Space between grooves (inch)
5/8 inch and 1/2 inch	Submarine cooler with single tube sheets and designed for submergence pressure	3	----	1/16	0.012	1/8
	Submarine cooler with double tube sheets and designed for seawater cooling	3	1	1/16	.012	1/8
	Other coolers with single tube sheets	1	----	1/16	.012	---
	Other coolers with double tube sheets	2	1	1/16	.012	1/8
3/8 inch	Double tube sheet cooler	2	1	1/16	.012	1/8
	Single tube sheet cooler	1	----	----	-----	---

NOTES:

1. With the double tube construction specified in 3.4.8, no grooving of the inner sheet is required where a welded or brazed joint is used for the outer-tube to inner-tube sheet attachment.
2. The first groove of grooved outer tube sheets shall be 3/8 inch from the sheet face nearest the tube end.
3. The groove of grooved inner tube sheets shall be at the expanded portion of the joint.

3.4.11.5 Hole edge rounding. The edges of holes for tubes shall be rounded as specified in table XVI, except where a flared contour is required for the tube inlet end.

TABLE XVI. Rounding of tube hole edges.

Tube outside diameter (inch)	Edge of hole rounded to a radius of (inch)
5/8	1/16
1/2	1/16
3/8	1/16

3.4.12 Tube ends. The inlet ends of tubes shall be expanded and belled, and the ends finished flush with the face of the tube sheet. Discharge ends of tubes shall protrude not more than 1/16 inch beyond the face of the tube sheet, but shall not terminate within a tube sheet.

3.4.13 Baffles. Within the shell space, close fitting transverse baffles shall be installed to provide for multiple passes of the shell side fluid across the tubes and to provide support for the tubes. The segmental type of baffle shall be used. Baffles shall have a finish of 250 micro-inches root mean square or smoother on the periphery, including the cut edge. The baffles shall be held in position by tie rods and spacer sleeves. The tie rods shall be threaded into but not through one of the tube sheets. Where one sheet is of the floating type, the tie rod shall be assembled to the stationary sheet. Nominal diameters of holes for tubes in baffles shall be not more than 1/64 inch greater than the outside diameter of the tube. Edges of holes shall have roughness removed.

3.4.13.1 Baffle thickness. Minimum baffle thickness shall be in accordance with TEMA, class C, except that where low finned tubes are used, the baffle thickness shall be not less than 1/8 inch.

3.4.13.2 Baffle spacing. Baffles shall be so spaced that the unsupported tube spans shall not exceed the values required in accordance with TEMA, class C requirements. (For baffles adjacent to the bends of U-bend tube exchangers, the unsupported tube length is defined as the distance measured along the outer edge of the tube from one support to the next support, by means of the U-bend.)

3.4.13.3 Sealing strips. To improve cooler performance, installation of sealing strips between tube bundle and shell will be permitted. These strips shall be installed in slots in the baffles and tack welded.

3.4.14 Waterboxes. To allow distribution of coolant to the tubes, the waterbox depth measured normal to the tube sheet shall be not less than one-half the mean diameter of the tube sheet area exposed to the flow of the cooling water to the tubes. For coolers of equivalent inside shell diameter D, the waterbox head depth shall be not less than 0.50D for single-pass coolers, 0.345D for two-pass coolers, or 0.25D for four-pass coolers. For multipass coolers, preferred construction shall let coolant between passes flow either vertically upward or horizontally from pass to pass, with vent holes provided in the waterbox partitions.

3.4.14.1 Partition plate width. Waterbox pass partition plate width shall be not less than 1/4 inch at the gasket contact surface.

3.4.14.2 Jackscrews. Jackscrews shall be fitted on waterboxes of coolers of 12-inch and larger nominal shell diameter.

3.4.14.3 Cathodic protection. Readily replaceable zinc anodes in accordance with MIL-A-19521 shall be installed in the salt water circuits of all heat exchangers in accordance with the following:

(a) For submarine submergence pressure applications, threaded support plugs shall not be used. Cover plates secured by four or more threaded fasteners shall be used for support of anodes.
(b) For submarine non-submergence pressure applications, bolted cover plates or threaded plugs shall be used for support of anodes. If used, threaded plugs shall conform to Drawing 803-5959186.
(c) For surface ship applications, support plugs shall be of the straight thread O-ring seal type in accordance with MIL-A-19521. In exception to the material requirements of MIL-A-19521, plug materials shall conform to the following:

Composition 70-30 Copper-nickel alloy of MIL-C-15726

3.4.15 Cyclic life requirements for type I, class 1 coolers. Unless otherwise specified (see 6.2), cyclic life requirements for type I, class 1 coolers shall be as specified in 3.4.15.1 through 3.4.15.6.

3.4.15.1 Parts subject to submergence pressure. Parts, including structure composed of outer and inner tube sheets (together with short sections of tubes between paired inner and outer tube sheets), are subject to submergence pressure, and they shall be constructed in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Component, class 1 components, as a minimum requirement, except that welding shall be in accordance with MIL-STD-278. Reinforcement of openings shall be integral with the waterbox shell or nozzle, or both; separate pads or saddle type reinforcements shall not be used. Welds shall be ground smooth and the corners and fillets shall be rounded as necessary to minimize notch effect. In designing heat exchangers, the forces exerted by the circulating water inlet and discharge piping on their respective waterbox nozzles shall be calculated as follows (see 6.2):

Piping axial load $= \pi\ r_m\ t\ (s_y - Pr_i/2t)$ pounds

Piping bending moment $= 1.3\ \pi\ r_m^2 t\ (s_y - Pr_i/2t)$ pound-inches

Piping torsional moment $= \pi\ r_m^2\ t \sqrt{s_y^2 - (Pr_i/2t)^2}$ pound-inches

Where:

P = design pressure for the component, lb/in^2

r_i = pipe inside radius, inches

r_m = pipe mean radius, inches, $= (r_i + r_o)/2$

r_o = pipe outside radius, inches

s_y = tabulated value of yield strength of the piping material at the component's design temperature, lb/in^2

t = pipe thickness, inches

π = ratio of circumference to diameter, circa 3.14159; and numerical coefficients and exponents are dimensionless

3.4.15.2 Cyclic pressure and external force loading. In the design of heat exchanger seawater sides, full consideration shall be given to the cyclic nature of the pressure loading and external force loading. Unless otherwise specified (see 6.2), the design shall be based on (1) the number of total depth changing cycles, with associated temperature variation, in conjunction with that piping reaction load (see 3.4.15.1) that produces the highest stress, and (2) 150 cycles each of the specified hydrostatic test pressure applied in the waterbox, or between the double tube sheets. The analysis shall be in accordance with the methods and criteria of the latest edition (including revisions, addenda, and applicable code cases) of ASME Boiler and Pressure Vessel Code, Section III, Division 1, class 1 components. Design fatigue curves for materials commonly used in coolers, and design stress intensity values for materials not covered in ASME Boiler and Pressure Vessel Code, Section III, Division 1, class 1 components shall be obtained from NAVSEA. Method of analysis of flat perforated plates shall be in accordance with article A-8000 of ASME Boiler and Pressure Vessel Code, Section III, Division 1, appendices. Cumulative usage factor for all cyclic transients shall not exceed 0.8.

3.4.15.3 Bolting subject to submergence pressure. For class 1 coolers, bolting subject to submergence pressure shall meet the following requirements:

(a) Calculated bolt stress due to design pressure shall be limited to one-third of the yield strength of the material at the design temperature.

(b) Maximum value of service stress averaged across bolt cross-section and neglecting stress concentration factor shall be limited to two-thirds of the yield strength of the material at the design temperature.

(c) Maximum value of service stress at periphery of the bolt cross-section resulting from tension plus bending, but neglecting stress concentration factor, shall be limited to the yield strength of the material at the design temperature.

(d) The range of coefficient of friction for the lubricant shall be accounted for in determination of torque value as follows:

(1) Using the hydrostatic test load, or the load based on design pressure plus maximum piping load on nozzles, whichever is greater, and high coefficient of friction ($\mu = 0.13$), determine installation torque using the following equation:

$$T = \frac{Pr_t}{12}\left(\frac{\cos\theta\ \tan\alpha + \mu}{\cos\theta - \mu\tan\alpha} + \frac{r_c}{r_t}\mu\right)$$

Where:

r_t = minimum pitch radius of external threads, inches

θ = 1/2 of thread angle, degrees

α = helix angle, degrees, = Arc tan $1/(2\pi r_t N)$

r_c = collar radius, average of $D_h/2$ and bolt major radius, inches

D_h = diameter across flats of nuts (average of maximum and minimum), inches

D = average of mean pitch and minor diameters of external thread, inches, = $2r_t - 0.32476/N$

μ = 0.13, coefficient of friction (high value), dimensionless

T = torque, foot-pounds

N = number of threads per inch

P = hydrostatic test load or load based on design pressure plus maximum piping load on nozzles, whichever is greater, pounds

(2) Using the installation torque above and the low coefficient of friction ($\mu = 0.065$) determine S_{av}, the average stress on the bolt cross-section, from the following equation.

$$S_{av} = \frac{P}{6\pi\mu^2 D_h^2 D^3}\left[(D^2+16\mu^2 D_h^2)^{3/2} - D^3\right],\ \text{lb/in}^2$$

P in this equation is the preload force, in pounds, found from the equation in (1) by substituting the low coefficient of friction (0.065) and using the installation torque, T, calculated above. This calculated stress, when combined with other stresses specified in the ASME Nuclear Code, shall not exceed the limits of the ASME Nuclear Code.

(e) Fatigue analysis of bolts shall be in accordance with ASME Boiler and Pressure Vessel Code, Section III, Division 1, subsection NB, class 1 components, except that cumulative usage factor shall not exceed 0.8.

(f) Submergence pressure boundary studs and bolts shall be of a reduced shank construction to reduce bending stresses.

3.4.15.3.1 Bolted waterbox inspection openings. Unless otherwise specified (see 6.2), threaded fasteners securing waterbox inspection openings subject to submergence pressure shall be constructed so that 200 inspection cover removal and reinstallation cycles, 150 hydrostatic test pressure cycles, and the number of total depth changing cycles will not cause the maximum cumulative usage factor to exceed 0.8. The effect on threaded fastener stress levels caused by movement between the inspection cover and inspection cover flange when the seawater side of the waterbox is pressurized shall be specifically analyzed. The amount of movement or relative slip used in the foregoing analysis shall be confirmed during factory hydrostatic testing (see 4.6.2). The contractor shall ensure that the fastener design meets the requirements of ASME Boiler and Pressure Vessel Code, Section III, Division 1, subsection NB, class 1 components, when the measured slip (rather than the assumed slip) is factored into the analysis.

3.4.15.4 Number of seawater passes. Heat exchangers subject to submergence pressure shall have an even number of seawater passes, so that the inlet and outlet seawater nozzles will be on the same waterbox. Thus the stiffness of the piping will not affect expansion or contraction of the heat exchanger tubes.

3.4.15.5 Double tube sheet design. For class 1 coolers, the double tube sheet design shall be in accordance with one of the following:

(a) Bolted and gasketed, with O-ring. The outer tube sheet shall be secured to the inner tube sheet or spacer piece (if provided) by means of threaded fasteners. These fasteners shall be of sufficient size and number to maintain tightness of the O-ring gasketed joint whenever specified design pressure is applied to the space between double tube sheets, without dependence on the waterbox flange bolting. The O-ring gasket shall be replaceable without the necessity of retubing the cooler. The spacer piece, if provided, shall be welded (full penetration weld) to the inner tube sheet. This weld may be magnetic particle inspected on the root passes, on the back chipped side of the initial root weld, and on the surface passes, as specified in MIL-STD-278 in lieu of radiographic inspection, if so elected. If materials involved are not magnetic, then liquid penetrant inspection of the root passes, the back chipped side of the initial root weld, and the surface passes, as specified in MIL-STD-278, may be substituted for radiographic inspection. The structural adequacy of this welded joint shall be demonstrated by analysis.

(b) Completely welded. The outer tube sheet shall be secured to the inner tube sheet by a full penetration butt welded joint. This joint shall maintain the tightness of the assembly when the specified design pressure is applied to the space between the sheets, without dependence on the waterbox flange bolting. This weld shall be in accordance with class A-F of MIL-STD-278, except that, for magnetic material, the weld may be magnetic particle inspected on each weld pass as specified in MIL-STD-278 in lieu of being radiographed. If materials involved are not magnetic, liquid penetrant inspection of each weld pass in accordance with MIL-STD-278 shall be substituted for magnetic particle inspection.

3.4.15.6 Waterbox. Waterboxes for cyclic loading shall be hemispherically shaped with nozzles aligned radially. Waterboxes not constructed to permit analysis for fatigue life adequacy shall operate as specified when tested in accordance with 4.5.

3.4.15.7 Design reports. (See 6.3 and appendix B.)

3.5 Type II (fabricated tube design) requirements.

3.5.1 Materials.

3.5.1.1 Type II, class 2. Coolers of type II, class 2 (submarine, seawater cooled, seawater side secured at depths greater than 200-foot submergence) shall be constructed of the materials specified in table XVII.

3.5.1.2 Type II, class 3. Coolers of type II, class 3 (surface ship, seawater cooled) shall be constructed of the materials specified in table XVIII.

3.5.1.3 Type II, class 4. Coolers of type II, class 4 (submarine, fresh-water cooled) shall be constructed of the materials specified in table XIX.

3.5.1.4 Type II, class 5. Coolers of type II, class 5 (surface ship, fresh-water cooled) shall be constructed of the materials specified in table XX.

TABLE XVII. Type II, class 2 cooler materials.

Part	Material	Applicable document
Casings, fabricated	Copper-nickel alloy, composition 90-10; or Tubing, copper-nickel alloy, composition 90-10	MIL-C-15726 MIL-T-16420
Casings, cast, and core frames	Copper-nickel alloy, composition C96200; or Tin bronze, alloy C90300	ASTM B 369 QQ-C-390
Header plates, baffles, and reinforcement plates	Copper-nickel alloy, composition 90-10	MIL-C-15726
Tube halves	Copper-nickel alloy 1/	MIL-C-15726
Oil tube centers	Steel, cold rolled	Commercial
Brazing sheets	Electrolytic copper	Commercial
Covers, tube side	Copper-nickel alloy, composition 90-10; or Bronze, tin, sand casting, alloy C92200 or C90300	MIL-C-15726 ASTM B 584
Pipe plugs and adapters	Copper-nickel alloy, composition 70-30; or Nickel-copper alloy	MIL-C-15726 QQ-N-281
Packing rings 2/	Rubber, synthetic, class 2 or 5	MIL-G-1149
Gaskets, flat	Nonasbestos-containing material	MIL-G-24696
Bolts or studs for seawater side	Nickel alloy, grade 400 or 500	MIL-S-1222
Nuts for bolts and studs, seawater side	Nickel alloy, grade 400 or 500	MIL-S-1222
Bolts, studs, and nuts for service other than as specified above	Copper alloy, grade 651, 632 or Nickel alloy, grade 400 or 405 or Copper-aluminum alloy, copper alloy C61400	MIL-S-1222 QQ-C-465
Lockwashers	Phosphor bronze or silicon bronze	FF-W-84
Jackscrews	Copper-aluminum alloy, copper alloy C61400; Phosphor bronze; or Copper-silicon alloy	ASTM B 150 ASTM B 139 ASTM B 98

See footnotes at top of next page.

1/ Tube halves shall be formed from a bimetal strip made of an outer layer of composition 90-10, 0.006 to 0.009 inch thick, clad on a basic layer of composition 70-30. Thickness of the strip shall be not less than 0.020 inch.

2/ See 3.3.25.

TABLE XVIII. Type II, class 3 cooler materials.

Part	Material	Applicable document
Casings, fabricated	Copper-nickel alloy, composition 90-10; or Tubing, copper-nickel alloy, composition 90-10	MIL-C-15726 MIL-T-16420
Casings, cast, and core frames	Copper-nickel-alloy, composition C96200; or Bronze, tin, sand castings, alloy C90300 or C92200	ASTM B 369 ASTM B 584
Header plates, baffles, and reinforcement plates	Copper-nickel alloy, composition 90-10	MIL-C-15726
Tube halves	Copper-nickel alloy 1/	MIL-C-15726
Oil tube centers 2/	Steel, cold rolled	Commercial
Brazing sheets	Electrolytic copper	Commercial
Covers, tube side	Copper-nickel alloy, composition 90-10; or Bronze tin, sand castings alloy C90300 or C92200; Valve bronze; or Copper-aluminum alloy, copper alloy C61400	MIL-C-15726 ASTM B 584 ASTM B 61 ASTM B 150, ASTM B 169
Packing rings 3/	Rubber, synthetic, class 2 or 5	MIL-G-1149
Gaskets, flat	Nonasbestos-containing material	MIL-G-24696
Bolts, studs, nuts, and jackscrews	Copper alloys	MIL-S-1222
Lockwashers	Phosphor bronze or silicon bronze	FF-W-84

1/ Tube halves shall be formed from a bimetal strip made of an outer layer of composition 90-10, 0.006 to 0.009 inch thick, clad on a basic layer of composition 70-30. Thickness of the strip shall be not less than 0.020 inch.

2/ Where nonmagnetic construction is specified, oil tube centers shall be 70-30 copper-nickel alloy conforming to MIL-C-15726.
3/ See 3.3.25.

TABLE XIX. Type II, class 4, cooler materials.

Part	Material	Applicable document
Tube halves	Copper-nickel alloy no. 710	ASTM B 122
All parts not otherwise specified 1/	Copper-nickel alloy; Copper-silicon alloy, wrought: Bars, forgings, plates, rods, shapes, sheets and strips; Copper-aluminum alloy, copper alloy C61400; Copper; Bronze, tin, sand castings, alloy C90300 or C92200; Valve bronze; Copper-nickel alloy, cast, composition C96200	MIL-C-15726 QQ-C-591 ASTM B 150 ASTM B 152 ASTM B 584 ASTM B 61 ASTM B 369
Oil tube centers	Steel, cold rolled	Commercial
Brazing sheets	Electrolytic copper	Commercial
Packing rings 2/	Rubber, synthetic, class 2 or 5	MIL-G-1149
Gaskets, flat	Nonasbestos-containing material	MIL-G-24696
Bolts, studs, nuts, and jack screws	Nickel alloys or Copper alloys	MIL-S-1222
Lockwashers	Phosphor bronze or Silicon bronze	FF-W-84

1/ Cast casings may be tinned with a 15 percent tin, 85 percent lead solder.
2/ See 3.3.25.

TABLE XX. Type II, class 5, cooler materials.

Part	Material	Applicable document
All parts not otherwise specified 1/	Copper-nickel alloy; copper-silicon alloy, wrought:	MIL-C-15726
	Bars, forgings, plates, rods, shapes, sheets and strips;	QQ-C-591
	Copper-aluminum alloy, copper alloy C61400;	ASTM B 150
	Copper;	ASTM B 152
	Bronze, tin, sand castings, alloy C90300 or C92200;	ASTM B 584
	Valve bronze;	ASTM B 61
	Copper-nickel alloy, cast, composition C96200	ASTM B 369
Oil tube centers 2/	Steel, cold rolled	Commercial
Brazing sheets	Electrolytic copper	Commercial
Packing rings 3/	Rubber, synthetic, class 2 or 5	MIL-G-1149
Gaskets, flat	Nonasbestos-containing material	MIL-G-24696
Bolts, studs, nuts, and jack screws	Nickel alloys or Copper alloys	MIL-S-1222
Lockwashers	Phosphor bronze or Silicon bronze	FF-W-84

1/ Cast casings may be tinned with a 15 percent tin, 85 percent lead solder.
2/ Where nonmagnetic construction is specified, oil tube centers shall be copper-nickel alloy conforming to MIL-C-15726.
3/ See 3.3.25.

3.5.1.5 Use of aluminum alloys. When specified (see 6.2), type II coolers may be constructed entirely of aluminum alloys approved by the contracting activity.

3.5.1.6 Nonmagnetic material. Where nonmagnetic construction is specified (see 6.2), all material, except the special tube halves, shall be 70-30 copper-nickel.

3.5.2 Minimum thickness. Thickness of header plates shall be not less than 0.090 inch; of tube halves, not less than 0.020 inch.

3.5.3 Assembling of strut and plate type tubes. Strut and plate type tubes shall be assembled by furnace brazing of formed tube halves that have been mechanically assembled with brazing sheets. Grid type centers shall be provided for oil tubes to improve flow characteristics.

3.5.4 Forming larger assemblies.

3.5.4.1 Larger assemblies from strut type tubes. The assembling of strut type tubes into cores, case and core subassemblies, or coolers shall be accomplished by either of the following two methods:

(a) The first method shall consist of furnace brazing the tube to header joint, after which the joints thus formed shall be given a sealing coat of lead-tin solder.
(b) The second method shall consist of lead-silver soldering of the tube-to-header joint, after which a coating of lead-tin solder shall be applied.

3.5.4.2 Larger assemblies from plate type tubes. The assembling of plate type tubes into cores shall be accomplished by furnace brazing.

3.5.5 Casings and covers. Casings and covers shall be of brazed, welded, or cast construction, except that brazed construction shall not be used for the casings of class 2 coolers.

3.6 Workmanship. Nonconformance to requirements of drawings shall be cause for rejection on grounds of poor workmanship.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.2 Critical dimensions. A critical dimension is defined as a dimension based on fatigue analysis or directly related to another dimension so based (for example, the size of a tube hole). For class 1 coolers, critical dimensions such as waterbox thicknesses, tube sheet thicknesses, tube hole sizes, and tube sheet ligaments shall be measured. Departures from limits established by accepted drawings shall be classed as major variations. For class 1 coolers, a 100 percent examination of the tube sheet holes and ligament widths shall be made.

4.3 Critical material items. For class 1 coolers, the following items are designated as critical material. Each of these items shall have material traceability, including heat lots and chemical and physical test reports. Critical materials shall consist of the following:

(a) Tube sheets (both inner and outer).
(b) Seawater vent and drain connections, including double tube sheet void space vents and drains.
(c) Heat transfer tubing (this tubing need not be marked for traceability identification, but shall be stored in secured, identified containers).
(d) Waterboxes, including all parts, subparts, and access covers.
(e) Nuts, studs, and bolts used in joining seawater containing parts.

Traceability records shall be retained by the contractor for 7 years. At expiration of the retention period, the records shall be made available to NAVSEA or its authorized representative by written notification. If no disposition is authorized within 6 months, the records may be destroyed.

4.4 Classification of inspections. The inspection requirements specified herein are classified as follows:

(a) First article inspection (see 4.5).
(b) Quality conformance inspection (see 4.6).

4.5 First article inspection. First article inspection shall consist of the performance test, pressure drop test, and high impact shock test as specified in 4.5.1 through 4.5.3 (see 6.3).

4.5.1 Performance test. The cooler shall be subjected to a factory or laboratory test to demonstrate the ability of the cooler to remove the required heat load (British thermal units (Btu)) under design conditions of flow and inlet, outlet temperatures of the cooled and cooling mediums (see 6.3).

4.5.2 Pressure drop test. The cooler shall be tested to determine pressure drops under various flow conditions in both cooled and cooling mediums (see 6.3).

4.5.3 High impact shock test. The test shall be as specified for grade A, class I in MIL-S-901 and as follows:

(a) The cooler shall be shock tested in its installed position.

(b) The shell and tube sides of the cooler shall be pressurized to design operating pressures during the test. Equipment or parts shall be mounted on the shock machine in a manner simulating the installation on board ship. The weight designation of the shock test shall be as required by the combined weight of the equipment being tested. When the cooler is being tested, grade 2 bolts in accordance with MIL-S-1222 shall be used to hold down the cooler during the shock test.

(c) Failure to perform principal function - Any of the following failures will be considered cause for rejection of the equipment:

(1) Breaking of any part.
(2) Appreciable distortion or dislocation of any parts such as mounting feet, tubes, baffles, or attached piping.
(3) Leakage of water from the cooling water side of the cooler. Following the shock test, the cooler shall be hydrostatically tested in accordance with 4.6.2, with no evidence of leakage acceptable.

(d) Disposal of shock-tested equipment:

(1) Equipment that has been subjected to the high impact shock test, but has failed to perform any of the principal functions specified herein, will not be acceptable, either in whole or in any of its parts.
(2) Equipment that has been subjected to the high impact shock test and has successfully performed all the principal functions specified herein, will not be considered for acceptance until it is first disassembled, inspected, and refurbished.

(e) Place at which shock tests shall be conducted - Shock tests may be performed at the contractor's plant or at any commercial laboratory or Government laboratory suitably equipped to perform the tests. For shock tests conducted at a Government laboratory, copies of master drawings shall accompany the equipment.

(f) Number of coolers to be tested - Unless otherwise specified in the contract or purchase order (see 6.2), a cooler of each size and similar construction shall be shock tested.

4.6 <u>Quality conformance inspection</u>.

4.6.1 <u>Examination</u>. Each cooler offered for delivery shall be examined for adjustment, fit, material, finish, and any other requirements specified herein, not involving tests. Both the assembled tube bundle (including tube internals) and the shell shall be visually inspected for cleanliness in accordance with MIL-P-116 before the bundle is installed in the shell. The shell and internals of coolers incorporating fixed tube bundles shall also be inspected for cleanliness as specified herein, as the cooler is assembled. Inspection records shall indicate that inspections were performed, and shall indicate the results of the inspections.

4.6.2 Hydrostatic tests. Each cooler offered for delivery shall be given a separate hydrostatic test of the shell side, tube side, and void spaces (between double tube sheets), as applicable. Unless otherwise specified (see 6.2), test pressures shall be held for not less than 30 minutes, and no leakage will be allowed. Additional requirements shall be as specified in 4.6.2.1 and 4.6.2.2.

4.6.2.1 Cooler test pressure. Coolers shall be tested at 1-1/2 times design pressure. Double tube sheet void spaces and leakage warning passages shall be tested to the same pressure as the coolant side.

4.6.2.2 Additional requirements for class 1 coolers. For class 1 coolers, the contractor shall use a NAVSEA approved test procedure for hydrostatic test of the assembled cooler. The test procedure shall include, as a minimum, the following:

(a) A sketch of the complete system, including provision to prevent overpressurization of the cooler and test components.
(b) Types of gasket material, if used.
(c) Calibration of instruments and relief valve settings.
(d) Instructions to operators.
(e) Acceptance criteria.

When the specified hydrostatic test pressure is reached, the pump and any other pressurizing devices shall be isolated from the cooler under test. The test pressure shall be applied for not less than 2 hours, and for time to permit inspection of all joints and connections. No leakage is permitted. The tube sheets shall be inspected during the hydrostatic test of the shell side to ensure that no leakage or weepage from the tube or tube joint occurs. During hydrostatic test of the double tube sheet void space, any drop in pressure greater than that expected as a result of temperature changes shall be cause for rejection of the cooler.

4.6.3 Eddy current test. When tubes in accordance with ASTM B 111 or ASTM B 359 are provided, each tube shall be subjected to the eddy current test, in addition to the hydrostatic test or pneumatic test, as specified in the applicable specification.

4.7 Proof test - special case (cyclic loading stipulated). When specified (see 6.2), for the special case of an inlet-outlet waterbox not amenable to analysis for determination of its adequacy for meeting cyclic life requirements, the adequacy of the waterbox or a scale model thereof shall be verified by a proof test. This proof test shall consist of a qualitative survey of the waterbox utilizing brittle coating (stress coat or its equivalent), or photostress (molded birefringent coatings) techniques, as deemed suitable, in order to determine the location of maximum strain. Quantitative measurement of the magnitude of maximum principal strain in the waterbox shall be obtained from strain gauges of 1/8-inch gauge length or shorter. Each waterbox loading shall comprise a combination of the design submergence pressure with a piping reaction load (that load which will produce highest stress) applied to the nozzles. The nozzle loads shall be calculated as specified in 3.4.15.1. A suitable loading jig utilizing mechanical or hydraulic jacks shall be provided to apply external loads to the nozzle flanges. The following two combinations of loads shall be applied:

(a) Internal pressure and external piping load (that piping reaction load which produces the highest stress) applied to one flange.
(b) Internal pressure and mutually equal external loads (that piping reaction load which provides the highest stress) applied to both flanges.

4.7.1 Evaluation. When the maximum value of principal strain (stress) in the waterbox have been determined for load combinations specified in (a) or (b) of 4.7, the following steps shall be taken in evaluating results:

(a) Determine the number of allowable cycles (corresponding to the maximum applied stress) from the design fatigue curve for the particular material involved. Call this number of cycles N_1.
(b) Unless otherwise specified (see 6.2), determine (1) the number of design cycles, n_1, corresponding to 100 percent test depth changes, (2) the number of design cycles, n_2, corresponding to 50 percent test depth changes, and (3) the number of design cycles, n_3, corresponding to 150 hydrostatic test pressure cycles.
(c) Determine the number of allowable cycles (corresponding to half the maximum applied stress) from the design fatigue curve for the particular material involved. Call this number of cycles N_2.
(d) Determine the number of allowable cycles (corresponding to 1.5 times the maximum applied stress) from the design fatigue curve for the particular material involved. Call this number of cycles N_3.
(e) Form the sum of ratios, $n_1/N_1 + n_2/N_2 + n_3/N_3$. If this sum does not exceed 0.8, the waterbox design meets the criterion for resistance to fatigue.

4.8 Inspection of packaging. Sample packages and packs, and the inspection of the preservation, packing and marking for shipment and storage shall be in accordance with the requirements of section 5 and the documents specified therein.

5. PACKAGING

(The packaging requirements specified herein apply only for direct Government acquisition. For the extent of applicability of the packaging requirements of referenced documents listed in section 2, see 6.6.)

5.1 Preservation. Preservation shall be level A or commercial, as specified (see 6.2).

5.1.1 Level A.

5.1.1.1 Cleaning and drying. Prior to preservation (unit protection), each cooler shall be cleaned and dried by a process and procedure, respectively, in accordance with MIL-P-116 which will ensure removal, without damage to the cooler, of all corrosion, dirt, grease, rust, scale, and other foreign material.

5.1.1.2 Unit protection. Unit protection and methods of preservation of coolers shall be in accordance with MIL-P-116 and the following:

(a) Method III - Method III shall apply to coolers constructed of corrosion-resistant materials. Closure of openings shall be as specified in 5.1.1.2.1.

(b) Method I - Method I shall apply to coolers constructed of ferrous or dissimilar materials wherein corrosion or deterioration will occur. Unpainted exterior surfaces shall be protected either by painting with a primer conforming to TT-P-645, or coated with a non-tacky, hard-drying preservative meeting the requirement of MIL-P-116, type P-19. The oil (lubricating or hydraulic) sides shall be protected with the normal operating oil. Unless otherwise specified (see 6.2), the seawater and freshwater sides of the coolers shall be protected with a preservative meeting the requirement of MIL-P-116, type P-21. Closure of openings shall be as specified in 5.1.1.2.1.

5.1.1.2.1 Closure of openings. Openings such as inlets, outlets, and vents shall be covered with a flexible, greaseproof, waterproof barrier material and a blank flange of mild steel, tempered hardboard, or fully waterproofed plywood. Mild steel flanges should be of not less than 1/16-inch thickness; tempered hardboard of 1/8-inch thickness for openings having a diameter up to and including 9 inches, and 1/4-inch thickness for openings having a diameter over 9 inches; or fully waterproofed plywood of 1/4-inch thickness for openings having a diameter over 9 inches. Flanges shall be secured with not less than four bolts, with nuts and lockwashers. On openings up to and including 2-1/2 inches in diameter, plastic plugs or caps may be used in lieu of the barrier material and blank flanges.

5.1.2 Commercial. Commercial packaging (cleaning, preservation, cushioning, and unit pack) requirements shall be in accordance with ASTM D 3951. Closure of openings shall be as specified in 5.1.1.2.1.

5.2 Packing. Packing shall be level A, B, C, or commercial as specified (see 6.2).

5.2.1 General.

5.2.1.1 Navy fire retardant treated lumber and plywood. When specified (see 6.2), all lumber and plywood (including laminated veneer material used in shipping containers and pallet construction) shall be fire-retardant treated material conforming to MIL-L-19140 as follows:

Levels A and B	- Type II - weather resistant. Category 1 - general use.
Level C	- Type I - non-weather resistant. Category 1 - general use.

5.2.2 Levels A, B, and C. Each cooler shall be anchored, blocked, braced, and cushioned within its shipping container in accordance with MIL-STD-1186 and the applicable container specification or appendix thereto. Shipping containers shall be of the wood cleated box construction, or wood or plywood, open or closed type crate construction as specified in table VII, exterior shipping container, of MIL-STD-2073-1, appendix C therein. Boxes exceeding a gross weight of 200 pounds shall be modified with skids in accordance with the applicable box specification. Crates shall be used for coolers exceeding the weight limitation of the box specification. Coolers, when shipped in open type crates, shall be provided with flexible, reinforced, waterproof barrier material shrouds. Plastic shrouds shall be of minimum 0.006-inch thickness. Shrouds shall be secured to prevent their loss or damage during handling, shipment, and storage. Shipping container closure and reinforcing shall be in accordance with the applicable container specification or appendix thereto.

5.2.3 Commercial. Commercial packing shall be in accordance with ASTM D 3951 and herein.

5.2.3.1 Container modification. Shipping containers exceeding 200 pounds gross weight shall be provided with a minimum of two, 3- by 4-inch nominal wood skids laid flat, or a skid- or sill-type base which will support the material and facilitate handling by mechanical handling equipment during shipment, storage, and stowage.

5.3 Marking.

5.3.1 Levels A, B, C, and commercial. In addition to any special marking required (see 6.2) and herein, shipping containers shall be marked in accordance with MIL-STD-2073-1, appendix F.

5.3.1.1 Special marking.

(a) Equipment serial number - The equipment serial number shall be included with the exterior identification markings.
(b) Open crates - Coolers packed in open crates exceeding 1000 pound gross weight shall be marked on one side and one end with the following:

"DO NOT STACK MORE THAN THREE HIGH"

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 coolers described in this specification are intended for use on board Navy surface ships and submarines for cooling lubricating oil, hydraulic oil, and fresh water. No one cooler is intended to cool more than one of these three categories of fluid in any one application. The coolers are divided into two types according to their design and to whether the fluid to be cooled is the inner fluid or outer (see 1.2). The coolers are also divided into five classes, according to whether they are for use on submarines or surface ships, whether they use seawater or fresh water as cooling medium, and whether they are to be subjected to seawater pressure at depths greater than 200 feet (see 1.2). Coolers of type I may be of any class; coolers of type II may be of any class except class 1.

6.2 Acquisition requirements. Acquisition documents must specify the following:

(a) Title, number, and date of this specification.
(b) Type, class, and service of cooler (see 1.2).
(c) Issue of DoDISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1 and 2.2).
(d) Identification of fluid to be cooled. Lubrication oil should be designated by specification or Military symbol.
(e) Rate of flow of fluid to be cooled, gal/min.
(f) Inlet temperature of fluid to be cooled, °F.
(g) Outlet temperature of fluid to be cooled, °F or rate of heat exchange, Btu per hour.
(h) Identification of coolant.
(i) Rate of flow of coolant, if established, gal/min.
(j) Design pressure of fluid to be cooled, lb/in^2.
(k) Design pressure of coolant, lb/in^2.
(l) Whether coolers are for submarine, surface ship, landing craft, or small boat application.
(m) When first article inspection is required (see 3.1).
(n) Space limitations governing the cooler size, if established (see 3.3.1).
(o) Ship motion and attitude requirements if other than specified (see 3.3.2).
(p) Allowable design point pressure drops for respective cooler sides, lb/in^2, if other than as specified (see 3.3.10).
(q) Inlet temperature of coolant, if other than specified (see 3.3.12).
(r) When hose connections are required (see 3.3.14).
(s) Description of inlet and outlet flanges, if other than specified (see 3.3.15).
(t) Wall thickness of vent and drain root connections, if other than specified (see 3.3.16).
(u) Whether pressure gauge connections are required at inlet and outlet of coolant and cooled fluid sides (see 3.3.17).
(v) Gasket width, if other than specified (see 3.3.23).
(w) Gasket material for type I coolers, when metal-to-gasket temperature is greater than 250°F (see 3.3.23(b)).
(x) Rubber for O-rings if application is for an oil with which MIL-G-21610, type I, rubber is not compatible (see 3.3.24).
(y) Whether steel shell side materials are required or may be used (see 3.4.2.6).
(z) Whether aluminum shell side internals are required or may be used (see 3.4.2.7).
(aa) When materials in accordance with table X are required for synthetic lubricating oil cooler (see 3.4.2.8).
(bb) When double tube sheets are required at each end of the cooler (see 3.4.7).
(cc) When double tube construction is required (see 3.4.8).
(dd) Whether shell side tinning is required (see 3.4.9).
(ee) Outside diameter of tubes if other than as specified (see 3.4.10.1.4).

(ff) Wall thickness of tubes, if greater than optional standard (see 3.4.10.1.4).
(gg) For type I, class 1, coolers, cyclic life requirements, if other than specified (see 3.4.15).
(hh) Diameter (that is, doubled radius) and thickness of attached circulating water piping (see 3.4.15.1).
(ii) For type I, class 1 coolers, the number of design cycles corresponding to 100 percent test depth changes, and the number of design cycles corresponding to 50 percent test depth changes (see 3.4.15.2, 3.4.15.3.1 and 4.7.1).
(jj) When aluminum alloys are specified for type II coolers (see 3.5.1.5).
(kk) Whether nonmagnetic construction is specified for type II coolers (see 3.5.1.6).
(ll) Number of coolers to be shock tested, if other than specified (see 4.5(f)).
(mm) Hydrostatic test pressures for cooler shell sides, tube sides, and void spaces as applicable, if other than specified (see 4.6.2).
(nn) When proof test cyclic loading is required (see 4.7).
(oo) Level of preservation and packing required (see 5.1 and 5.2).
(pp) Water side preservative if other than specified (see 5.1.1.2(b)).
(qq) Fire-retardant requirement when required (see 5.2.1.1).
(rr) Special marking required (see 5.3.1).

6.3 Consideration of data requirements. The following data requirements should be considered when this specification is applied on a contract. The applicable Date Item Descriptions (DID's) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the DID's are tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where DoD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
3.3.26 and appendix A	DI-DRPR-80651	Engineering drawings	Level 3
3.4.15.7 and appendix B	DI-MISC-80653	Test reports	----
4.5	DI-T-4902	First article inspection report	----
4.5	DI-T-5329	Inspection and test reports	----
4.5	UDI-T-23753	Report, equipment shock test	----

The above DID's were those cleared as of the date of this specification. The current issue of DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

6.4 Technical manuals. The requirement for technical manuals should be considered when this specification is applied on a contract. If technical manuals are required, military specifications and standards that have been cleared and listed in DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL) must be listed on a separate Contract Data Requirements List (DD Form 1423), which is included as an exhibit to the contract. The technical manuals must be acquired under separate contract line item in the contract (see appendix C).

6.4.1 Coolers with double tube sheets. Technical manuals should be furnished for coolers that have double tube sheets.

6.4.2 Other coolers. For other coolers, technical manuals should be furnished only when specified.

6.5 First article. When first article inspection is required, the item should be a first article sample (see 3.1). The contracting officer should also include specific instructions in acquisition documents regarding arrangements for examinations, approval of first article test results, and disposition of first articles. Invitations for bids should provide that the Government reserves the right to waive the requirement for samples for first article inspection to those bidders offering a product which has been previously acquired or tested by the Government, and that bidders offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior Government approval is presently appropriate for the pending contract. Bidders should not submit alternate bids unless specifically requested to do so in the solicitation.

6.6 Provisioning. Provisioning Technical Documentation (PTD), spare parts, and repair parts should be furnished as specified in the contract.

6.6.1 When ordering spare parts or repair parts for the equipment covered by this specification, the contract should state that such spare parts and repair parts should meet the same requirements and quality assurance provisions as the parts used in the manufacture of the equipment. Packaging for such parts should also be specified.

6.7 Sub-contracted material and parts. The packaging requirements of referenced documents listed in section 2 do not apply when material and parts are acquired by the contractor for incorporation into the equipment and lose their separate identity when the equipment is shipped.

6.8 Drawing review agency. As used herein, "drawing review agency" is generally a Government command or agency such as Naval Sea Systems Command, a Supervisor of Shipbuilding, or an authorized representative. Communication with the drawing review agency should be handled through the contracting activity.

6.9 Cross-reference. Cooler types I and II were formerly known as types A and B, respectively. This change in designation does not affect storability or usability. Old stocks need not be altered merely to change type designation.

6.10 Subject term (key word) listing.

Drums
Fins
Flanges
Fouling resistance
Gaskets
Heat exchanger
Shells
Tubes
Tube sheets
Vents

6.11 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Preparing activity:
Navy - SH
(Project 4420-N058)

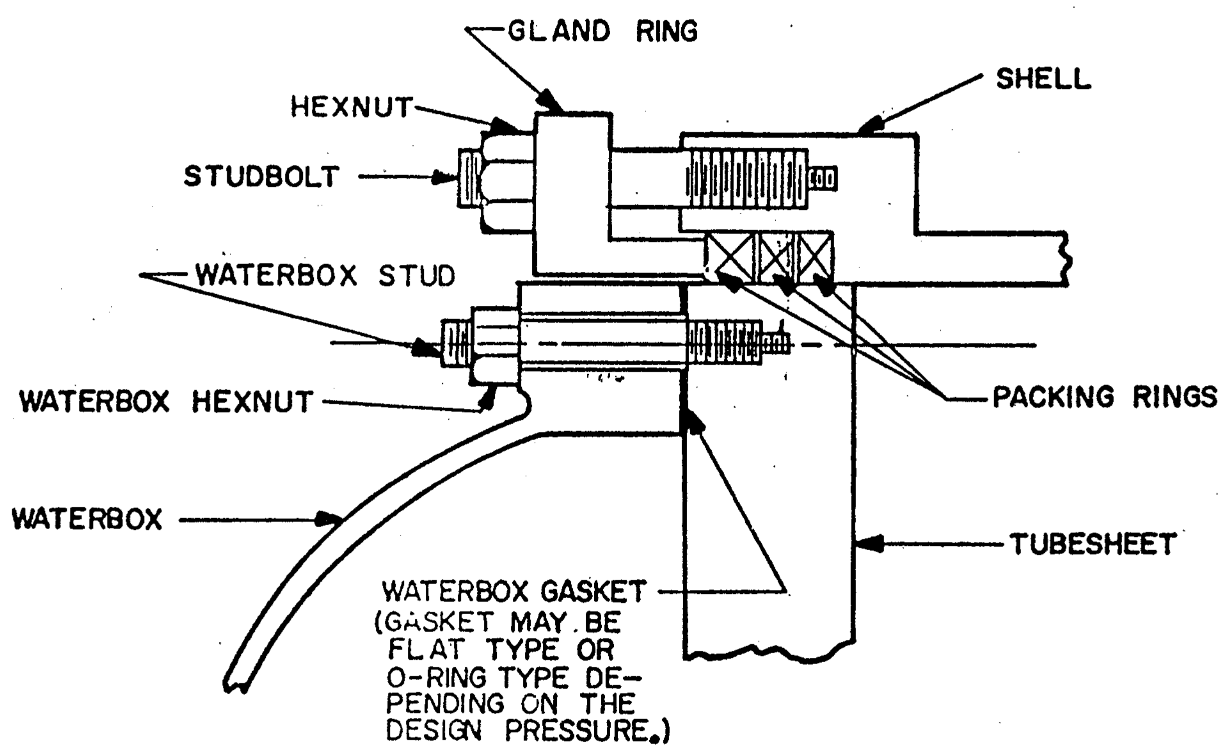

FIGURE 1. Straight tube, floating head, removable bundle, outside packed stuffing box.

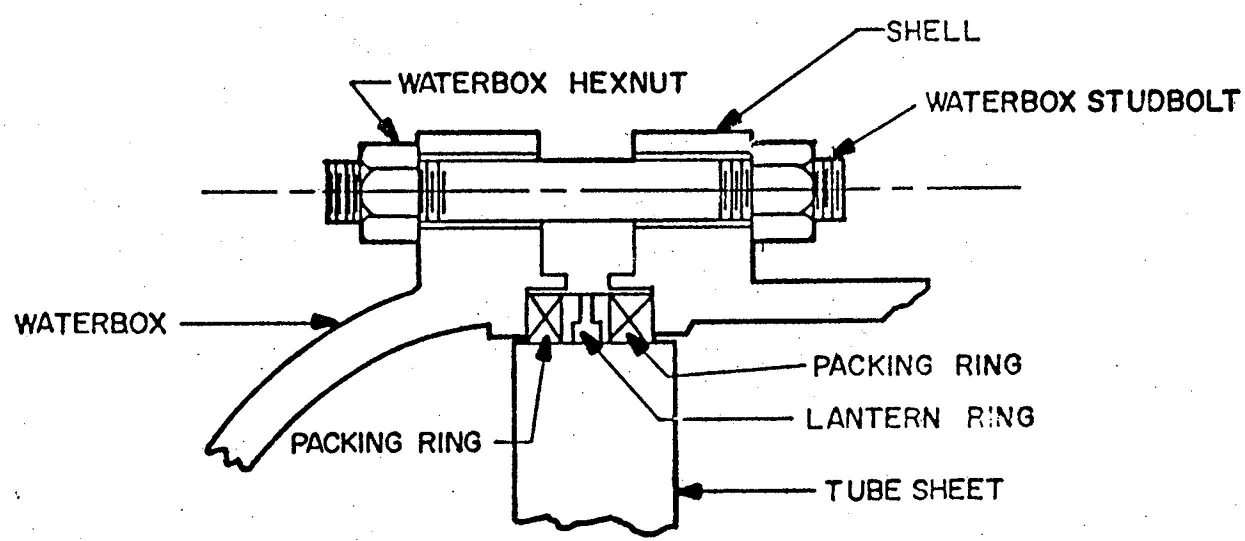

FIGURE 2. Straight tube, floating head, removable bundle, outside packed lantern ring construction.

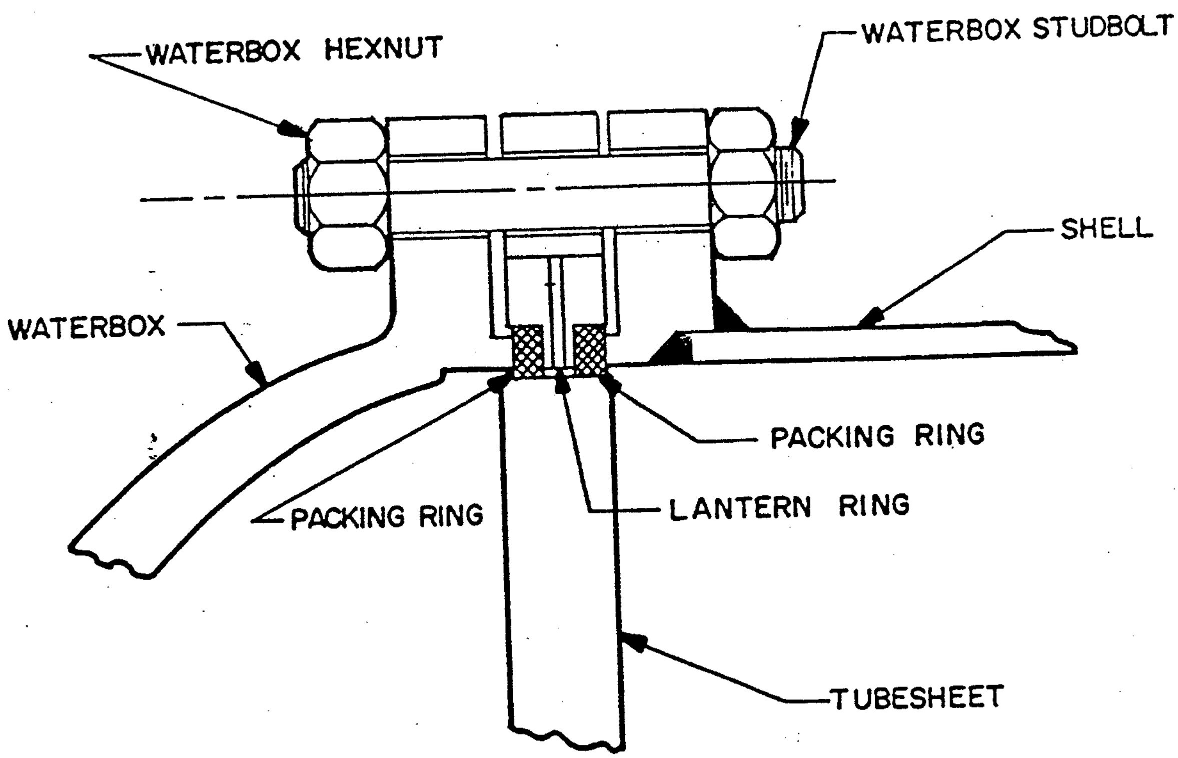

FIGURE 3. Straight tube, floating head, removable bundle, outside packed lantern ring construction; waterbox studbolt threaded into lantern ring.

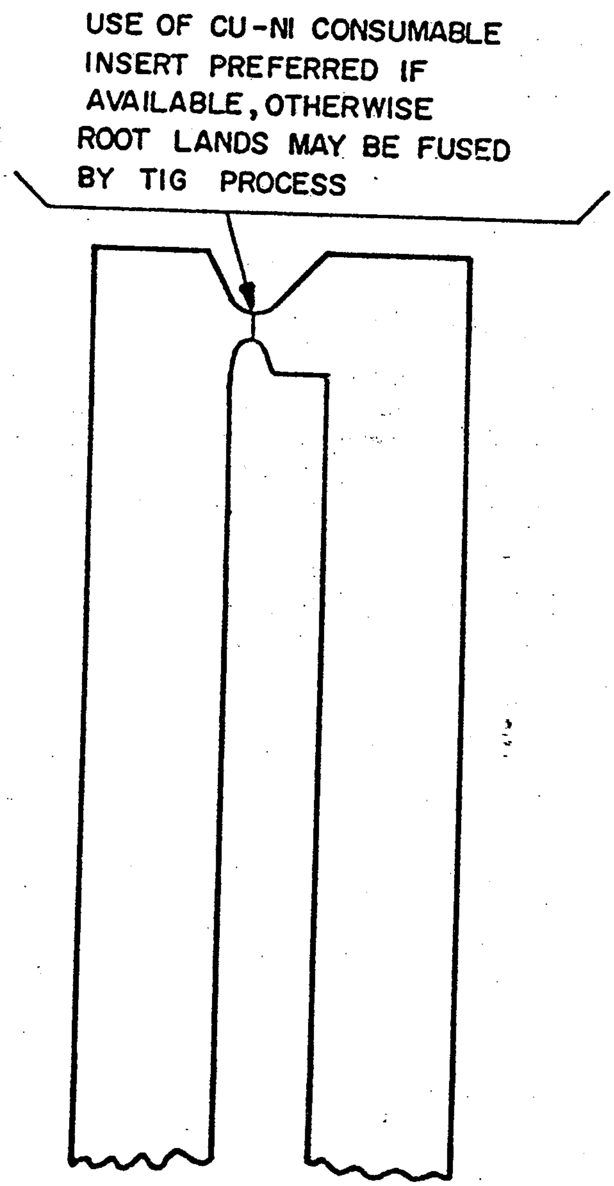

FIGURE 4. Acceptable method of welding inner and outer tube sheets - all double tube sheet cooler applications.

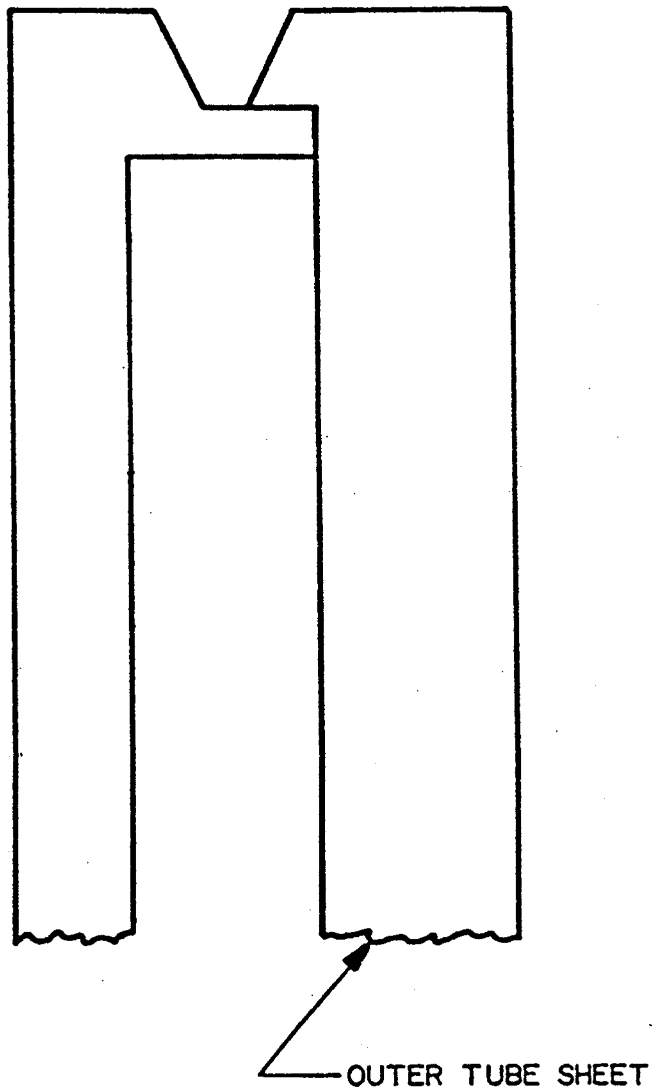

FIGURE 5. Acceptable method of welding inner and outer tube sheets - cooler applications for which cyclic life requirements are not specified.

APPENDIX A

ENGINEERING DRAWINGS TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers information that should be included in the drawings when specified in the contract or order. This appendix is applicable only when DI-DRPR-80651 is cited on the DD Form 1423.

20. APPLICABLE DOCUMENTS

20.1 Government document.

20.1.1 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 the documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATION

MILITARY

DOD-D-1000 - Drawings, Engineering and Associated Lists.

30. SUGGESTED DRAWING CONTENTS

30.1 Drawing content. Drawings shall be in accordance with DOD-D-1000. The cooler drawings shall be those of the cooler contractor. Cooler drawings prepared by other than the cooler contractor will be considered for preliminary review only. Assembly and detail drawings of the cooler, subassemblies, and parts shall be level III drawings. Any proposed areas of departure from the specifications must be explicitly requested, with supporting basis, by the initial letter of submittal, and shall be called out as exceptions in the certification data (cd) sheet "Statement of Conformance".

30.1.1 Waterbox and tube sheet bolting. Drawings shall contain instructions covering the torquing of bolts.

30.1.2 Assembly drawings. Assembly drawings shall show details of equipment furnished. Information usually furnished on outline or installation drawings may be shown on the assembly drawing. Sectional views and enlarged views shall be adequate in number and quality employed to indicate details of parts, subassemblies, and assemblies. Where multiple detail views are shown on more than one sheet, the drawing titles shall be distinctive. The title "Details" shall not be sufficient.

30.1.3 Certification data drawing. A certification data drawing shall be furnished. It shall be titled "Certification Data for ..." (kind of cooler, such as lubricating oil cooler, jacket water cooler, or battery cooler, and its designation by model number or by size and type, or the equivalent, shall be entered to complete the title). The certification data drawing shall be included in the first submission of ship equipment drawings.

30.1.3.1 Content of certification data drawing. The certification data drawing shall include the following information:

(a) Identification by hull (side) number of the applicable ships, the hull numbers to be located above the title block.

(b) Notes attesting to conformance to the specification, indicating the contract or order, the application (service) of the unit, and the number of coolers per ship and per unit of parent equipment (such as engine). The following examples illustrate requirements for notes:

(1) NAVSHIPS contract N00024-7X-C1234 (this number is for example only) with ABC Engine Company; ABC Engine Company purchase order 5678 on EFG Cooler Manufacturing Company.

(2) Service: Lubricating oil cooling for main propulsion turbines and gears; or jacket water cooling for emergency diesel generator set; or submarine main storage battery cooling.

(3) Eight coolers per ship, one cooler per blower; or four coolers per ship, one cooler per engine; or 12 coolers furnished as stock material (use only when ship application is not known).

(c) A drawing list tabulation. This list shall include all equipment drawings that make up the given design. The revision symbols shall be kept up to date to the time of manufacture so that it will finally indicate the latest revision of each drawing applicable to the equipment as built. The list shall include the following three columns:

(1) Drawing title.
(2) Manufacturer's drawing number.
(3) Revision symbol.

(d) A performance data tabulation to include the following:

(1) Identification of cooled and cooling mediums.
(2) Flow rate of cooled and cooling mediums in gallons per minute.
(3) Inlet temperature of cooled and cooling mediums, °F.
(4) Outlet temperature of cooled and cooling mediums, °F.
(5) Pressure drops of cooled and cooling mediums through cooler, lb/in^2.
(6) Velocities of cooled and cooling mediums at inlet connection, feet per second.
(7) Velocities of cooled and cooling mediums through tubes and shell, feet per second.
(8) Number of passes of cooled and cooling mediums through cooler.

(9) Design pressures of cooled and cooling mediums, lb/in^2, gauge. (For coolers for seawater service on submarines, no design pressure entry shall be made for the seawater side.)

(10) Factory test pressure, shell side, lb/in^2, gauge.

(11) Factory test pressure, tube side, lb/in^2, gauge. (For coolers for seawater service on submarines, in lieu of an entry in the tabulation opposite this heading, the space should be left blank, and the following procedure used instead. Beside the tabulation, use an arrow leading in to indicate this blank space, and at the tail of the arrow add as noce "For tube side test pressure see note ... on ... dwg ... NAVSEA Nr ... Test Data ...". This note is to be completed when the information becomes available from the building yard.)

(12) Factory test pressure, space between double tube sheets, lb/in^2, where applicable. (For coolers for seawater service on submarines, in lieu of an entry in the tabulation opposite this heading, the space should be left blank, and the following procedure used instead. Beside the tabulation use an arrow leading in to indicate this blank space, and at the tail of the arrow add a note "For test pressure for space between double tube sheets, see note ... on ... dwg ... NAVSEA Nr ... Test data ...". This note is to be completed when the information becomes available from the building yard.)

(13) Logarithmic mean temperature difference, °F.

(14) Heat transfer rates for both service and clean tube conditions, Btu per hour per square foot per °F logarithmic mean temperature difference.

(15) Cooling surface, square feet. (For coolers using extended surface tubes, both the plain tube surface and the total surface (including fins) shall be shown.)

(16) Heat transfer capacity at design point, Btu per hour.

(17) Dry weight and operating weight of cooler, pounds.

(e) A view of the identification plate with all data entered, except date of manufacture, serial number, and tube side maximum test pressure for submarine seawater applications. For these applications, use an arrow leading in, to indicate the blank spaces where tube side maximum test pressure would have been entered, with notation "Tube side maximum test pressure not to be stamped on identification plate" placed at the tail of the arrow. This view shall be enlarged as necessary to ensure that data entries shall meet lettering height requirements (1/8 inch).

(f) The technical equipment manual number, provided that such manuals are required by the contract or purchase order and that the manufacturer has been apprised of the assigned number.

(g) The component identification number allowance parts list (APL) number, if available.

(h) Certifying signature of manufacturer's responsible engineering representative, whose professional qualification should be not less than that of a professional engineer.

(i) An approval notation of the type required for type II drawings in accordance with DOD-D-1000.

(j) Compliance with MIL-A-19521 (see 3.4.14.3).

30.1.4 Thread lubricant. The type of thread lubricant to be used shall be specified on drawings (see 3.3.8.2).

30.1.5 Commercial material. If commercial material is used (see 3.4.2), the drawings shall include the following. Two columns shall be included in the list of materials; one column shall show the specified Federal or Military specifications, and the other shall show the commercial specification number for the substituted material. Notes shall then be added to the drawings stating that:

(a) The design is based on the Federal or Military specification materials.
(b) The materials listed in the commercial specification column have physical and chemical properties equal to or better than those of the specified Federal or Military specification and may be substituted by the manufacturer.

APPENDIX B

TEST REPORT TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers information that should be included in the reports when specified in the contract or order. This appendix is applicable only when DI-MISC-80653 is cited on the DD Form 1423.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. SUGGESTED REPORT CONTENTS

30.1 Report contents. The reports shall contain, but are not limited to, the following information.

30.1.1 Tube rolling procedure. For class 1 coolers, a tube rolling procedure shall be developed and submitted to the Command or agency concerned for approval. This procedure shall be supported by data derived from mockup test work to demonstrate the adequacy of the tube rolling procedure. The procedure shall include a sketch of the tube joint. The minimum acceptable increase in diameter as a percentage of initial tube wall thickness or interference fit for production shall be determined and prescribed. The contractor shall recommend whether a limit shall be established and inserted in the technical report for a maximum tube inside diameter after maintenance rerolling. The maximum acceptable shop increase in diameter as a percentage of the initial tube wall thickness or interference fit shall be established as a production control, this value being set to ensure feasibility of rerolling the tubes several times (in the shop and in service for corrective maintenance). The recommended increment of tube inside diameter change for maintenance rerolling shall be included. The expander control settings for the production rolls shall be specified in the procedure, along with the necessary instructions for accomplishing correct expansion. Tensile test for rolled joints in class 1 heat exchangers shall be as follows:

(a) A seven-tube mockup shall be prepared to test the tensile strength of the thinner tube sheet tube joint on double tube sheet units. The mockup shall consist of two tube sheet sections identical in fabrication and thickness to the thinner of the tube sheets and separated by a distance equal to the tube sheet separation on the production units. The pattern of the seven tube holes shall be centered on the mockup tube sheets and shall be otherwise identical to the production pattern. The total area of the tube sheet shall be that which will produce the tensile load specified below on the tubes when the hydrostatic pressure in the void space is at the pressure specified in 4.6.2. At least one of the tube sheets shall be unrestrained, except for the tubes, so that load imposed by hydrostatic test will be borne by the tubes. The mockup shall be prepared by using the exact production tube rolling procedure, and shall be pressurized to the specified hydrostatic test pressure (see 4.6.2).

(b) Failure in the tube shall occur before failure in the tube-to-tube sheet joint. Tube failure is considered to have occurred when the tube between the tube sheets either breaks or undergoes a tensile stress (due to pressure alone) equal to the minimum yield strength of the tube. Failure of the tube-to-tube sheet joint is considered to have occurred when the tube slips in the tube sheet or when the joint leaks.

30.1.2 Design report. For applications for which cyclic life requirements are established, an analysis demonstrating the adequacy of the design shall be prepared. The contractor shall prepare a design report for class 1 coolers. The report shall be self-contained and in a format to facilitate independent review of its content; it is imperative, therefore, that it be simple to follow and free from ambiguity. The report should contain the following as a minimum:

(a) Description of design requirements such as steady state and transient pressure, temperature, and external loading.
(b) The regions of the components which were analyzed.
(c) The materials that were used and their mechanical properties.
(d) A general description of the methods of analysis and assumptions.
(e) List of reference sources.
(f) Computer programs properly identified and described.
(g) Copies of computer printouts (input and output).
(h) Stresses tabulated for each area of investigation and compared to allowable stresses for all stress categories.
(i) Satisfaction of cyclic requirements, including stress concentration factors used in the cyclic analysis.

Additional requirements for demonstrating the adequacy of design in the form of an engineering design report will apply when and as stipulated in the contract.

APPENDIX C

MANUAL TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers information that should be included in the technical manuals when specified in the contract or order.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. SUGGESTED MANUAL CONTENTS

30.1 Technical manuals. Technical manuals shall be as specified in 30.1.1 and 30.1.2.

30.1.1 Submarine coolers subject to submergence pressure. Technical manuals shall be furnished for submarine coolers subject to seawater submergence pressure. These manuals shall include instructions as to the prestress values and corresponding torques to be applied to bolts in making up joints subject to submergence pressure, and shall also include the pattern of tightening the bolting. Technical manuals shall give special attention to tube expanding procedures where single tube - double tube sheet construction is involved.

30.1.2 Waterbox and tube sheet bolting. Manuals shall contain a full description of the procedures for torquing of bolts.

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3a. NAME OF SUBMITTING ORGANIZATION

b. ADDRESS *(Street, City, State, ZIP Code)*

4. TYPE OF ORGANIZATION *(Mark one)*

☐ VENDOR

☐ USER

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