



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

STANDARD SPECIFICATION**4-11-4** Page 1 of 10**TUBULAR EXCHANGERS
SHELL AND TUBE TYPE**

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

1. GENERAL**1.1 Scope**

- a. This Standard Specification covers general requirements for the design of shell and tube heat exchangers.
- b. Exceptions or variations shown in the UOP Project Specifications take precedence over requirements shown herein.

1.2 References

Unless noted below, use the edition and addenda of each referenced document current on the date of this UOP Standard Specification. When a referenced document incorporates another document, use the edition of that document required by the referenced document.

- a. Standards of the Tubular Exchanger Manufacturers Association (TEMA)
- b. American Petroleum Institute (API) Standard 660, Shell and Tube Heat Exchangers for General Refinery Services / ISO 16812 Petroleum and natural gas industries – Shell-and-tube heat exchangers
- c. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels
- d. ASME B16.5, "Pipe Flanges and Flanged Fittings NPS ½ Through NPS 24"
- e. ASME B16.47, "Large Diameter Steel Flanges, NPS 26 Through NPS 60"
- f. ASME B46.1, "Surface Texture (Surface Roughness, Waviness, and Lay)"
- g. ASME Specifications SA-193, SA-194, SA-263, SA-264, SA-265, SA-450, SA-498, SA-516, SB-127, and SB-359
- h. ASME B16.20, "Metallic Gaskets for Pipe Flanges, Ring Joint, Spiral Wound and Jacketed"
- i. National, state, and local governmental regulations and laws

2. DESIGN**2.1 General Requirements**

- a. Exchangers shall comply with TEMA Class R, API 660/ISO 16812, and the ASME Boiler and Pressure Vessel Code, Section VIII Division 1, and shall be suitable for ASME Code stamping when required.

Note: The information in this document is confidential and the property of UOP LLC and must not be disclosed to others or reproduced in any manner or used for any purpose whatsoever without its written permission.



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

STANDARD SPECIFICATION

4-11-4 Page 2 of 10

TUBULAR EXCHANGERS SHELL AND TUBE TYPE

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

- b. Flange classes are specified in accordance with ASME B16.5 or ASME B16.47 Series B (Series A is required if connecting directly to an item furnished with Series A flanges.). Flange classes listed in the UOP Project Specifications are based upon design pressure and temperature conditions only and do not account for other loads. The final design of all flanges shall account for gasket seating and external loads. Differential thermal expansion, including joints between dissimilar materials, and transient thermal conditions such as start-up/shutdown and operational upset shall be accommodated.
- c. Flanges intended for use with spiral wound gaskets shall have a flange surface finish of 125 microinch Ra minimum to 250 microinch Ra maximum. Flanges intended for use with other gaskets shall have a flange finish within the optimal range for the specified gasket. Finishes shall be judged by visual comparison with surface finish roughness standards conforming to ASME B46.1. Flange finishes shall be protected from damage during fabrication, heat treatment, shipping, storage, and installation.
- d. Spiral wound gaskets are not required for cooling water, plant air, or instrument air lines.
- e. Pressure drops shall include entrance and exit losses.
- f. Exchangers shall be designed for maximum interchangeability of parts.
- g. Exchanger connections shall be flanged except for vent and/or drain connections in cooling water or low pressure steam service which may be threaded.
- h. Gaskets for use with raised face flanges shall be spiral wound per ASME B16.20, with a non-asbestos filler material. In lined portions of the equipment, the winding material shall be the same as the equipment lining. In unlined portions of the equipment the winding material shall be a minimum of ASTM A 240 Type 304. Gaskets shall include an outer retaining ring. The outer retainer ring may be carbon steel, protected against corrosion. Gaskets for Class 900 and greater flanges, flanges over 24 inch NPS, and gaskets in vacuum service shall have an inner retainer ring of the same material as the windings. Gaskets with an inner retainer ring shall also be used between flanges of different metallurgies with different coefficients of thermal expansion when they operate at an elevated temperature. The contractor shall verify the adequacy of all gaskets considering potential buckling of the outer or inner retaining ring(s) and the windings.
- i. Ring joint flanges shall have a flat bottom groove with the intersection between the bottom and sides of the groove machined to a smooth 1/8 inch (3 mm) minimum radius.
- j. Flanges and bolts shall be analyzed to ensure that they are not overstressed during gasket seating. Overstressing is more likely to occur when Class 300 and lower flanges are used with spiral wound metal gaskets.

2.2 Shell Side

- a. The shell side shall be horizontal, single pass with a conventional floating head tube bundle having rolled in tubes and arranged with two or more tube passes per shell.
- b. When a U-tube bundle is used, the shell cover shall be integral with the shell.

Note: The information in this document is confidential and the property of UOP LLC and must not be disclosed to others or reproduced in any manner or used for any purpose whatsoever without its written permission.



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

STANDARD SPECIFICATION

4-11-4 Page 3 of 10

TUBULAR EXCHANGERS
SHELL AND TUBE TYPE

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

- c. A removable tube bundle with a longitudinal shell baffle may be used with the following limitations:

- (1) TEMA shells, Type "G" or "H" when applied to low pressure drop reboilers or condensing operations with a pressure drop not exceeding 2.0 psi (0.14 kg/cm²).
- (2) TEMA shell, Type "F", when applied to condensing and liquid service with a pressure drop not exceeding 5.0 psi (0.35 kg/cm²) and a 350°F (195°C) maximum temperature differential.

Seal strips shall be replaceable and shall be securely attached to the longitudinal sides of the baffle plate adjacent to the shell wall.

- d. Impingement baffles shall be no closer to the inlet nozzle than is required for escape height and flow area.

- (1) Impingement plates shall be a solid plate that extends at least 1 inch (25 mm) beyond the projection of the nozzle bore.
- (2) Rod impingement devices shall include a minimum of 2 rows of rods on a triangular pitch. When impingement protection is required, rods shall be used on all No Tube in Window (NTIW) exchangers.
- (3) Perforated baffles are not permitted.

2.3 Tube Side

- a. Single pass tube bundle exchangers, with a bellows type expansion joint between the floating head and shell cover, are permitted when required. The design shall include provisions (guide device) that allow quick and easy mating of the expansion joint end flange to its companion flange on the inside face of the shell cover. Expansion bellows shall be hydraulically or mandrel formed and shall permit replacement in the field. Bellows shall be constructed of Inconel 600, Inconel 625, Incoloy 800, or Incoloy 825.
- b. For TEMA type "B" stationary heads, the tubesheet shall be a full diameter type with threaded holes that permit pressure testing of the shell side with the head removed. A confined tubesheet with a test ring for pressure testing is an acceptable alternative.
- c. Tube sheet holes and the grooving in them shall conform to TEMA "R". Grooves shall be square edged and concentric. When heat treatment of the tube sheet is required, final tube hole sizing shall be attained by reaming after heat treatment.
- d. Tubes shall be expanded within the tube sheet per TEMA "R" requirements. In addition, for tube sheets with thickness in excess of 2 inches (50 mm), tube expansion shall begin 1/8 inch (3 mm) from the shell side face. The expanding procedure shall provide substantially uniform expansion throughout the expanded portion of the tube without a sharp transition to the unexpanded portion.



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

STANDARD SPECIFICATION**4-11-4** Page 4 of 10**TUBULAR EXCHANGERS
SHELL AND TUBE TYPE**

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

- e. The following table lists the minimum and maximum velocity limits in water service for different tube materials:

Tube Material	Velocity Limit, ft/s (m/s)	
	Minimum	Maximum
Admiralty Brass	3.0 (0.9)	8.0 (2.4)
Carbon Steel	3.0 (0.9)	10.0 (3.0)
Cupro-Nickel 70/30	3.0 (0.9)	10.0 (3.0)
Cupro-Nickel 90-10	3.0 (0.9)	8.0 (2.4)
Titanium	3.0 (0.9)	10.0 (3.0)
Austenitic Stainless Steel	3.0 (0.9)	10.0 (3.0)

- f. When the water carries solids, the maximum velocity shall be reduced by 20%.
- g. When permitted by the UOP Project Specification, tube bundles may be designed for the specified differential pressure between the tube and shell sides. The vendor shall provide a visible warning plate adjacent to, or part of, the nameplate outlining test pressure regulations, when differential design is used.
- h. The use of integral low fin tubing is permitted provided the fluid film coefficients, when corrected for fouling, show the shell side controlling by a ratio of at least 2:1.

2.4 Vibration

For exchangers subject to vibration, the tube bundle design shall include the following:

- a. For baffles spaced less than 12 inches (300 mm) apart, the tube hole diameter shall not exceed the OD of the tube plus 0.021 inches (0.53 mm). For baffles spaced 12 inches (300 mm) or more apart or for the tube support plates the tube hole diameter shall not exceed the OD of the tube plus 0.015 inches (0.38 mm).
- b. Tube holes in tube sheets shall be finished to the diameters and tolerances specified by TEMA for special close fit.
- c. Use a full periphery distribution belt at the shell inlet, or provide internal distribution space and impingement protection.

2.5 Vents, Drains, and Other Connections

- a. When the tube side fluid is steam or condensing hydrocarbon, a 3/4 inch (minimum) vent connection shall be provided in the channel cover or bonnet head at the high point of the pass where condensing is complete.

Note: The information in this document is confidential and the property of UOP LLC and must not be disclosed to others or reproduced in any manner or used for any purpose whatsoever without its written permission.



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

**TUBULAR EXCHANGERS
SHELL AND TUBE TYPE****STANDARD SPECIFICATION****4-11-4** Page 5 of 10

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

- b. When the shell side fluid is steam or condensing hydrocarbon, provide a flanged 1 inch (minimum) vent nozzle on the top of the shell at the end opposite the shell inlet. For stacked units, provide a vent nozzle in each shell.
- c. Provide 2 inch (minimum) flanged neutralizing connections in all main shell and tube side nozzles of exchangers constructed of, or lined with, austenitic stainless steel.

3. MATERIALS**3.1 Tubes**

- a. The tube gauge specified in the UOP Project Specifications is the minimum tube wall thickness.
- b. For U-tubes the wall thickness specified applies to the outside of the bend. U-tubes shall be formed from continuous lengths of tubing, free of girth welds.
- c. The minimum mean radius of U-bends shall be 1.5 times the OD of the tube.
- d. Nonferrous U-bends shall be stress relieved after bending.
- e. Tubes shall be in the fully heat treated condition as received from the mill. Heat treatment may be annealed, normalized, or normalized and tempered, per the ASME specification used.
- f. Welded austenitic stainless steel tubes shall be cold drawn to a minimum reduction of 15% in wall thickness prior to a final solution anneal. Selective cold reduction of the weld bead is an acceptable alternative.
- g. Welded tubing shall pass the nondestructive eddy current test set forth in ASME SA-450.
- h. Integral low fin tubes shall conform to ASME SA-498 (ferrous) or SB-359 (nonferrous).

3.2 Alloy Linings

- a. Lining shall be either integrally bonded cladding conforming to ASME SA-263, SA-264, or SA-265, as applicable, or machined weld overlay.
- b. Tube sheets may be alloy lined by cladding or weld deposit overlay with the following restrictions:
 - (1) Cladding shall be integrally and continuously bonded to the base metal.



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

STANDARD SPECIFICATION**4-11-4** Page 6 of 10**TUBULAR EXCHANGERS
SHELL AND TUBE TYPE**

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

(2) When other parts in contact with the same fluid are specified as killed carbon steel, the base metal of the clad or faced tube sheet shall also be killed carbon steel.

(3) Silver soldered or brazed bonded liners shall not be used.

3.3 Bolting and Flange Closures

- a. Bolts for channels, floating heads, and girth flanges shall be continuously threaded. Use ASME SA-193 grade B7 bolts and ASME SA-194 grade 2H nuts.
- b. When bolt diameter exceeds 1-1/2 inches, the bolting design shall provide clearance dimensions that permit use of a stud and bolt tensioner device of the hydraulic type, the spring tension-resilient washer type, or the electric stud heater type.
- c. Floating heads shall be through-bolted.

4. SPECIAL APPLICATIONS**4.1 Kettle Reboilers**

- a. Shells shall be TEMA Type "K" with the weir plate directly behind the tube bundle. The weir shall be welded to the shell, contain no drain holes, and shall have sufficient height to flood the top tubes with a minimum of 2 inches (50 mm) of process fluid during normal operation.
- b. Provide riding rails, or tracks, that are fully seal welded to the shell sides to support and guide the tube bundle.

4.2 Kettle Steam Generators

The general arrangement is in accordance to Section 4.1 except:

- a. A weir is not required.
- b. A steam separating device shall be provided, if necessary, to meet a 99.95% steam purity when operated at 125% of design capacity.

4.3 Slurry Service

When UOP Project Specifications indicate slurry service, the following additional requirements apply:

- a. Process streams containing fines (slurry) shall be routed downflow through the tube side of the exchanger.
- b. Slurry velocities at specified process flowing conditions shall be between 4.5 feet per second (1.37 m/s) and 8.0 feet per second (2.44 m/s).



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

STANDARD SPECIFICATION**4-11-4** Page 7 of 10**TUBULAR EXCHANGERS
SHELL AND TUBE TYPE**

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

- c. Tubes shall not be less than 1 inch (25 mm) OD, 0.109 inch (2.77 mm) tube wall thickness to minimize plugging of the tubes and to protect against erosion.
- d. Provide a replaceable deflector or impact plate at the channel inlet to divert flow from the pass partition plate.

4.4 Hydrofluoric (HF) Acid Service

When UOP Project Specifications indicate a process stream contains free HF, dissolved HF, or trace HF, the following additional requirements apply:

a. General

- (1) To minimize chances of acid leakage into the process area, the exchanger design shall include as few joint closures as is practical, (e.g. U-tubes, removable TEMA "C" stationary head, etc.).
- (2) When the steam pressure is higher than the process side pressure, tube to tube sheet joints shall be strength welded and fully rolled.
- (3) Process fluids shall flow downward to assure good drainage. When the process fluid is on the shell side, the baffles shall contain a "V" notch at the low point of the bottom edge. Also, the sleeve spacers on the tie rods between baffles shall contain 3/8 inch (10 mm) diameter (minimum) holes or slots to permit entry of neutralizing solutions prior to pulling tube bundles.
- (4) Threaded surfaces are not permitted in contact with process fluids. Attachments provided for disassembly (eyebolts, lugs) shall be attached via welding.
- (5) When acid is present in a condenser shell, provide only one auxiliary connection, a 2 inch flanged vent located at the high point of the shell at the end opposite from the vapor inlet. In all other channels or shells where acid is present, do not provide connections for vents, drains, pressure gauge, etc.
- (6) Nozzles and their reinforcements shall be attached to the exchanger with full penetration welds. When back-up strips are used they shall be removed after welding and the weld ground smooth.
- (7) Longitudinal and circumferential welded joints shall be full penetration double-welded butt type or equivalent.
- (8) Flange closure shall use ASME SA-193 grade B7M bolts and ASME SA-194 grade 2HM nuts.
- (9) Ring type joint flanges are acceptable in HF acid services.
- (10) After fabrication full radiography is required for all welded joints in contact with free HF or dissolved HF service. Spot radiography, as a minimum, is required in



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

STANDARD SPECIFICATION**4-11-4** Page 8 of 10**TUBULAR EXCHANGERS
SHELL AND TUBE TYPE**

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

trace HF service.

- (11) Weld repairs on pressure parts shall be completed before heat treatment. If repairs are found to be necessary after heat treatment, pressure parts affected shall be heat treated again.
- (12) Ferrous and nonferrous tubing shall be annealed after finning as defined in the appropriate ASME Specification.
- (13) Flame cutting is not permitted unless the cut surface is ground back to sound metal.

b. Carbon Steel

- (1) Plate steel shall be fully killed in accordance with ASME SA-516.
- (2) After fabrication, stress relieve at 1150°F (620°C) ± 25°F (14°C) for one hour per inch (25 mm) of thickness with a minimum hold of one hour followed by cooling in still air. U-bends shall be stress relieved at 1150°F (620°C) ± 25°F (14°C) after bending.

c. Monel

- (1) Plate shall in accordance with ASME Specification SB-127. All plate shall be supplied in an annealed condition.
- (2) The fabrication and thermal treatment of Monel shall comply with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Part UNF, Appendix NF, Paragraphs NF-7 and NF-14.
- (3) After fabrication, stress relieve at 1150°F (620°C) ± 25°F (14°C) for one hour per inch (25 mm) of thickness with a minimum hold of one hour, followed by cooling in still air. U-bends shall be stress relieved at 1150°F (620°C) ± 25°F (14°C) after bending.
- (4) Provide 1/16 inch (1.5 mm) corrosion allowance except on tubing.

d. Gaskets

- (1) Raised face flange gaskets in contact with HF acid shall be spiral wound Monel with flexible graphite filler, or double jacketed Monel with flexible graphite filler in accordance with ASME B16.20, or solid monel.
- (2) Ring joint gaskets in contact with HF acid shall be solid Monel. Ring joint gaskets shall be oval cross section. Gaskets shall be in accordance with ASME B16.20.

4.5 Seawater or Brackish Water Service (Tubeside)

- a. Tubes shall be aluminum brass, 90-10 Cu-Ni, 70-30 Cu-Ni or titanium. When ammonia,

Note: The information in this document is confidential and the property of UOP LLC and must not be disclosed to others or reproduced in any manner or used for any purpose whatsoever without its written permission.



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

**TUBULAR EXCHANGERS
SHELL AND TUBE TYPE****STANDARD SPECIFICATION****4-11-4** Page 9 of 10

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

amines, or hot sulfides are present on the shell side, use 70-30 Cu-Ni or titanium tubes only.

- b. Tube sheets and floating heads shall be clad steel or solid naval brass, aluminum bronze, 90-10 Cu-Ni, 70-30 Cu-Ni, titanium, or Monel.
- c. Channels shall be solid naval brass, aluminum bronze, 90-10 Cu-Ni, 70-30 Cu-Ni, titanium, Monel, or steel clad with the same materials. Alternately they may be solid steel that is faced and coated as follows:
 - (1) A weld deposited machined facing of aluminum bronze, Monel, 90-10 Cu-Ni, or 70-30 Cu-Ni, shall be applied to the contact edges of the partition plates at the tube sheet sides, and the face of the channel flange which is adjacent to the tube sheet. These weld deposits shall extend a minimum of 1 inch (25 mm) from the tube sheet contact surface.
 - (2) Install sacrificial zinc anodes in the channel and the floating head. Anodes shall be of sufficient size for four years of continuous operation.
 - (3) Steel surfaces including nozzles and supports, excluding the zinc anodes, shall be painted with a primer coating.

4.6 Hydrogen Service

When the UOP Project Specification indicates hydrogen service, the following additional requirements shall apply:

- a. Parts in contact with hydrogen shall be killed carbon steel.
- b. Vent and drain connections shall be provided with a blind flange of the same class and facing as the main inlet nozzles.
- c. Girth joint gaskets shall be solid metal type, spiral wound in accordance with ASME B16.20, or double jacketed graphite filled in accordance with ASME B16.20. Spiral wound gaskets shall have stainless steel windings and flexible graphite filler. For design pressures over 500 psig (35 kg/cm²(g)), use a stainless steel inner ring. For design temperatures above 800°F (430°C), stainless steel materials shall be Type 321 or 347.
- d. Welds in contact with hydrogen shall be full penetration.
- e. Weld neck flanges shall be used for terminal connections.

4.7 Wet Hydrogen Sulfide Service

When the UOP Project Specification indicates wet hydrogen sulfide service, the following additional requirements shall apply:

- a. Parts in contact with wet hydrogen sulfide shall be killed carbon steel.



Note: The information in this document is confidential and the property of UOP LLC and must not be disclosed to others or reproduced in any manner or used for any purpose whatsoever without its written permission.



UOP LLC • 25 East Algonquin Road • Des Plaines, Illinois 60017-5017 • USA

TUBULAR EXCHANGERS SHELL AND TUBE TYPE

STANDARD SPECIFICATION

4-11-4 Page 10 of 10

DATE	STATUS	APVD	AUTHD
02MAY05	Revised	SAV	RGP

- b. Provide 3/16 inch (5 mm) corrosion allowance except for tubing. Postweld heat treat the shell and the floating head cover.
- c. Bolts for floating heads and girth flanges shall be continuously threaded. Use ASME SA-193 grade B7M bolts and ASME SA-194 grade 2M nuts.