$F_f =$ fillet weld strength, but not greater than $F_t$

$S = \text{allowable stress value as given in the applicable part of Section II, Part D}$

$S_a =$ allowable stress in tube (see $S$, above)

$S_t =$ allowable stress of the material to which the tube is welded (see $S$, above)

$S_w =$ allowable stress in weld (lesser of $S_a$ or $S_t$, above)

$t =$ nominal tube thickness

$F_f = 0.55a_r(d_a + 0.67a_g)S_w$

$f_f =$ ratio of the fillet weld strength to the design strength

$F_g =$ groove weld strength, but not greater than $F_t$

$F_t =$ axial tube strength

$F_f =$ groove weld strength, but not greater than $F_t$

$F_t =$ axial tube strength

$f_w =$ weld strength factor

$= \pi (d_a - t) S_a$

$F_{fabeled} =$ weld strength factor

$= \pi (d_a - t) S_a$

$F_f =$ groove weld strength, but not greater than $F_t$

$F_f =$ groove weld strength, but not greater than $F_t$

$F_t =$ axial tube strength

$F_f =$ groove weld strength, but not greater than $F_t$

$F_f =$ groove weld strength, but not greater than $F_t$

$F_t =$ axial tube strength

$F_f =$ groove weld strength, but not greater than $F_t$

$F_t =$ axial tube strength

$F_f =$ groove weld strength, but not greater than $F_t$

$F_f =$ groove weld strength, but not greater than $F_t$

$F_t =$ axial tube strength

$F_f =$ groove weld strength, but not greater than $F_t$

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$F_f =$ groove weld strength, but not greater than $F_t$

$F_t =$ axial tube strength

$F_f =$ groove weld strength, but not greater than $F_t$

$F_t =$ axial tube strength

$F_f =$ groove weld strength, but not greater than $F_t$
material of integral clad tubesheets, the integral clad material to be used for tubesheets shall meet the requirements in (a)(1) and (a)(2) for any combination of clad and base materials. The shear strength test and ultrasonic examination specified in (a)(1) and (a)(2) are not required for weld metal overlay clad tubesheets.

(1) Integral clad material shall be shear strength tested in accordance with SA-263. One shear test shall be made on each integral clad plate or forging and the results shall be reported on the material test report.

(2) Integral clad material shall be ultrasonically examined for bond integrity in accordance with SA-578, including Supplementary Requirement S1, and shall meet the acceptance criteria given in SA-263 for Quality Level Class 1.

(b) When the design calculations for clad tubesheets are based on the total thickness including the cladding, the clad material shall meet any additional requirements specified in Part UCL.

(c) When tubesheets are constructed using linings, or integral cladding that does not meet the requirements of (a)(1) and (a)(2), the strength of the tube-to-tubesheet joint shall not be dependent upon the connection between the tubes and the lining.

(d) When ASME B16.5 slip-on flanges are shown to comply with all the requirements provided in Mandatory Appendix 2 of this Division, the weld sizes in Mandatory Appendix 2 may be used as an alternative to the requirements in (b).

**FABRICATION**

**UW-26  GENERAL**

(a) The rules in the following paragraphs apply specifically to the fabrication of pressure vessels and vessel parts that are fabricated by welding and shall be used in conjunction with the general requirements for Fabrication in Subsection A, and with the specific requirements for Fabrication in Subsection C that pertain to the class of material used.

(b) Each Manufacturer or parts Manufacturer shall be responsible for the quality of the welding done by his organization and shall conduct tests not only of the welding procedure to determine its suitability to ensure welds that will meet the required tests, but also of the welders and welding operators to determine their ability to apply the procedure properly.

(c) No production welding shall be undertaken until after the welding procedures which are to be used have been qualified. Only welders and welding operators who are qualified in accordance with Section IX shall be used in production.

(d) The Manufacturer (Certificate Holder) may engage individuals by contract or agreement for their services as welders at the shop location shown on the Certificate of Authorization and at field sites (if allowed by the Certificate of Authorization) for the construction of pressure vessels or vessel parts, provided all of the following conditions are met:

1. All Code construction shall be the responsibility of the Manufacturer.

\[ t_n = \text{nominal thickness of the shell or nozzle} \]

\[ X_{\text{min}} = \text{the lesser of } 1.4t_n \text{ or the thickness of the hub} \]

\[ 1.5 \text{ mm (1/16 in.) approximate gap before welding} \]
$T_{t,mx}$ = tube axial mean metal temperature for operating condition $x$, as applicable
$T_{s,mx}$ = shell axial mean metal temperature for operating condition $x$, as applicable
$T_{s,m}$ = mean shell metal temperature along shell length
$T_{t,m}$ = mean tube metal temperature along tube length
$T'_{t}$ = tubesheet metal temperature at the rim for operating condition $x$
$T'_{cx}$ = channel metal temperature at the tubesheet for operating condition $x$
$T'_{sx}$ = shell metal temperature at the tubesheet for operating condition $x$
$t_{c}$ = channel thickness
$t_{s}$ = shell thickness
$t_{s,1}$ = shell thickness adjacent to the tubesheets
$t_{t}$ = nominal tube wall thickness
$W_{c}$ = channel flange design bolt load for the gasket seating condition (see 4.16)
$W_{s}$ = shell flange design bolt load for the gasket seating condition (see 4.16)

$W_{max} = \text{MAX}[(W_{c}), (W_{s})]$
$W_{dc}$ = channel flange design bolt load (see $W_{o}$, 4.16)
$W_{ds}$ = shell flange design bolt load (see $W_{o}$, 4.16)

$W_{dmax} = \text{MAX}[(W_{dc}), (W_{ds})]$

$W^{*}$ = tubesheet design bolt load determined in accordance with Table 4.18.6
$W_{t}$ = tube-to-tubesheet joint load
$x$ = 1,2,3,...,n, integer denoting applicable operating condition under consideration, (e.g., normal operating, start-up, shutdown, cleaning, upset)

$\alpha_{s,m}$ = mean coefficient of thermal expansion of shell material at $T_{s,m}$
$\alpha_{s,m,1}$ = mean coefficient of thermal expansion of shell material adjacent to the tubesheets at $T_{s,m}$
$\alpha_{t,m}$ = mean coefficient of thermal expansion of tube material at $T_{t,m}$
$\alpha$ = mean coefficient of thermal expansion of tubessheet material at $T'$
$\alpha_{c}$ = mean coefficient of thermal expansion of channel material at $T'_{c}$
$\alpha_{s}$ = mean coefficient of thermal expansion of shell material at $T'_{s}$
$\gamma$ = axial differential thermal expansion between tubes and shell
$\nu$ = Poisson’s ratio of tubesheet material
$\nu_{c}$ = Poisson’s ratio of channel material
$\nu_{s}$ = Poisson’s ratio of shell material
$\nu_{t}$ = Poisson’s ratio of tube material

(e) Nomenclature for tube-to-tubesheet welds (see 4.18.10)

$\alpha_{c}$ = length of the combined weld legs measured parallel to the longitudinal axis of the tube at its outside diameter
$\alpha_{f}$ = fillet weld leg
$\alpha_{g}$ = groove weld leg
$\alpha_{r}$ = minimum required length of the weld leg(s) under consideration
$d_{o}$ = nominal tube outside diameter
$f_{d}$ = ratio of the design strength to the tube strength
$f_{f}$ = ratio of the fillet weld strength to the design strength
$f_{w}$ = weld strength factor
$F_{d}$ = design strength, but not greater than $F_{t}$
$F_{f}$ = fillet weld strength, but not greater than $F_{t}$
$F_{g}$ = groove weld strength, but not greater than $F_{t}$
$F_{t}$ = axial tube strength
$L_{max}$ = maximum allowable axial load in either direction on the tube-to-tubesheet joint
$t$ = nominal tube wall thickness
$S_{o}$ = allowable stress from Annex 3-A of the tube
$S_{t}$ = allowable stress from Annex 3-A of the material to which the tube is welded
$S_{w}$ = allowable stress in weld, $S_{w} = \min[S_{o}, S_{t}]$

See 3.3.7.4
3.3.6.2 Design Calculations Based on Total Thickness.

(a) Base material with corrosion resistant integral or weld metal overlay cladding used in construction in which the design calculations are based on total thickness including cladding (4.1.9) shall consist of base plate listed in one of the material tables in Part 3 and shall conform to one of the following specifications or utilize weld metal overlay cladding meeting the requirements of this Division.

(1) SA-263 Specification for Corrosion-Resisting Chromium-Steel Clad Plate, Sheet and Strip;
(2) SA-264 Specification for Corrosion-Resisting Chromium-Nickel Steel Clad Plate, Sheet and Strip; or
(3) SA-265 Specification for Nickel and Nickel-Base Alloy Clad Steel Plate.

(b) Base material with corrosion resistant integral cladding in which any part of the cladding is included in the design calculations, as permitted in (a), that is constructed of multiple cladding plates welded together prior being bonded to the base material shall have the cladding-alloy-to-cladding-alloy welding that is performed prior to bonding to the base material:

(1) performed by a Manufacturer holding a Certificate of Authorization.
(2) radiographically examined for their full length in the manner prescribed in 7.5.3. In place of radiographic examination, welds may be ultrasonically examined for their full length (see 7.5.5).
(3) be supplied with a Partial Data Report if that welding is not performed by the vessel Manufacturer.

3.3.6.3 Design Calculations Based on Base-PlateThickness. Clad plate used in constructions in which the design calculations are based on the base-plate thickness, exclusive of the thickness of the cladding material, may consist of any base-plate material satisfying the requirements of Part 3 and any metallic integral or weld metal overlay clad material of weldable quality that meets the requirements of 6.5 of this Division.

3.3.6.4 Shear Strength of Bond of Integrally Clad Plates. Integrally clad plates in which any part of the cladding is included in the design calculations, as permitted in 4.1.9, shall show a minimum shear strength of 140 MPa (20 ksi) when tested in the manner described in the plate specification. One shear test shall be made on each such clad plate and the results shall be reported on the certified test report. A shear or bond strength test is not required for weld metal overlay cladding.

3.3.6.5 Removal of Cladding for Mill Tension Tests. When any part of the cladding thickness is specified an allowance for corrosion, such added thickness shall be removed before mill tension tests.

3.3.7 CLAD TUBESHEETS

3.3.7.1 Tube-to-tubesheet welds in the cladding of either integral or weld metal overlay clad tubesheets may be considered strength welds (full or partial), provided the welds meet the design requirements of 4.18.10. In addition, when the strength welds are to be made in the clad material of integral clad tubesheets, the integral clad material to be used for tubesheets shall meet test and ultrasonic:

(a) Integral clad material of each integral clad plate;
(b) Integral clad material shall be shear strength tested in accordance with SA-263. One shear test shall be made on each integral clad plate or forging, and the results shall be reported on the material test report.

3.3.7.2 When the clad material shall meet:

(a) Integral clad material shall be ultrasonically examined for bond integrity in accordance with SA-578, including Supplementary Requirement S1, and shall meet the acceptance criteria given in SA-263 for Quality Level Class 1.

3.3.7.3 When tubesheets are constructed using linings or integral cladding that does not meet the requirements of 3.3.7.1(a) and 3.3.7.1(b), the strength of the tube-to-tubesheet joint shall not be dependent upon the connection between the tubes and the lining or integral cladding, as applicable.

3.3.7.4 When the tubes are strength welded (full or partial) to integral or weld metal overlay clad tubesheets, \( S_b \) shall be the allowable stress value of the integral clad or the wrought material whose chemistry most closely approximates that of the weld metal overlay cladding. The thickness of the integral or weld metal clad overlay material shall be sufficient to prevent any of the strength weld from extending into the base material.

3.4 SUPPLEMENTAL REQUIREMENTS FOR Cr–Mo STEELS

3.4.1 GENERAL

3.4.1.1 The rules in 3.4 include supplemental requirements for fabrication and testing for Cr-Mo steels. The materials and appropriate specifications covered by this paragraph are listed in Table 3.1.

3.4.1.2 Certification that the requirements of 3.4 have been satisfied shall be shown on the Manufacturer's Data Report Form.

3.4.2 POSTWELD HEAT TREATMENT

The final postweld heat treatment shall be in accordance with the requirements of 6.4.2 of this Division.