PIP VEEFG001
Fiberglass Tank and Vessel Design Guidelines
PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

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1. **Scope**

This Practice provides guidelines and describes the design criteria and fiberglass construction methods permitted in *ASME RTP-1* and *Code Section X* for fiberglass tanks and vessels. This Practice provides guidance regarding the applications of fiberglass resins and corrosion veil materials and the associated cure systems. This Practice provides guidance regarding site inspections and for the design provisions needed to properly install fiberglass equipment at the site.

2. **References**

Applicable parts of the following Practices and industry codes and standards shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 **Process Industry Practices (PIP)**

   PIP VESFG001 - Fiberglass Tank and Vessel Specification

2.2 **Industry Codes and Standards**

   - American Society of Mechanical Engineers (ASME)
     - *ASME Boiler and Pressure Vessel Code*
     - *Section X - Fiber-Reinforced Plastic Pressure Vessels*
     - *ASME RTP-1 - Reinforced Plastic Thermoset Plastic Corrosion Resistant Equipment*

3. **Standards Comparison**

3.1 **General**

   3.1.1 *ASME RTP-1* and *Code Section X* use different approaches to equipment design and cover different types of equipment.

   3.1.2 The choice between *ASME RTP-1* and *Code Section X* should be based primarily on the design pressure required for the vessel.

      3.1.2.1 For design pressures above 0.103 MPa (15 psi), *Code Section X* should be used.

      3.1.2.2 For design pressures below 0.103 MPa (15 psi) to full vacuum, *ASME RTP-1* should be used.

   3.1.3 The only exception to Section 3.1.2 is epoxy resin vessels, which should be built to *Code Section X* regardless of design pressure.

3.2 **ASME/ RTP-1 Philosophy and Coverage**

   3.2.1 The philosophy of *ASME RTP-1* is much like *Code Section VIII* in that many design rules are given and there is an opportunity to design using stress analysis.

   3.2.2 The design approach is like a “cookbook” with all phases of design, materials, fabrication, examination, and testing being covered.

   3.2.3 Very detailed procedures are given for laminating methods and quality assurance of the finished product.

   3.2.4 A hydrostatic test is required.
3.2.5 Design safety factors depend upon the method of design. Larger design factors are required for design by rules and for those in critical services as determined by the user.

3.2.6 All vessels are required to have a 2-ply minimum chopped strand mat and 1-ply veil corrosion liner and be constructed of corrosion-resistant resins such as polyester, vinyl ester, and epoxy novolac types which use contact molding or filament winding construction techniques.

3.2.7 ASME RTP-1 also covers thermoplastic-lined equipment and both shop- and field-fabricated vessels and tanks plus structural cored materials for flatheads and bottoms.

3.2.8 Furan, epoxy, or phenolic resins, and non-E glass structural reinforcement, are not within the scope of ASME RTP-1.

3.3 **Code Section X Philosophy and Coverage**

3.3.1 Code Section X is like a performance standard with few rules and fabrication procedures.

3.3.2 All designs are proven by either a destructive test (e.g., Class I vessels) or an acoustic emission test (e.g., Class II vessels).

3.3.3 Because of destructive proof test requirements and a 100,000-cycle pressure test requirement, Code Section X Class I vessels typically have been less than 1,000 gallons (3.785 m³) in size and of “standard” designs with very few nozzles. This significantly limits the applications of Class I vessels.

3.3.4 A destructive test is not required for Code Section X Class II vessels. Class II vessel designs are proven using an acoustic emission test at 1.1 times the Maximum Allowable Working Pressure at the design temperature. An acoustic emissions test is expensive and limits the use of Class II vessels because lined metallic vessels are generally less expensive.

3.3.5 Both contact-molded and filament-wound constructions are permitted for Class II equipment.

3.3.6 Bag molding and centrifugal casting techniques are permitted for Class I equipment.

3.3.7 Code Section X neither requires the use of nor defines the construction of a corrosion liner. Any liner is specified by the owner and is not included in the structural calculations. PIP VESFG001 requires an ASME RTP-1 liner as a minimum in any Code Section X vessel.

3.3.8 Code Section X permits metallic and thermoplastic liners, non-glass structural reinforcements, and all types of resins (including furan). However, PIP VESFG001 prohibits the use of metallic liners and furan or phenolic resins, and limits structural reinforcements to types E and S glass for Code Section X vessels.

3.3.9 Code Section X has Class III vessel for pressures from 20.68 MPa (3,000 psi) to 103.42 MPa (15,000 psi) with metallic and thermoplastic liners for the storage of hydrogen gas. Such vessels are beyond the scope of this Practice and PIP VESFG001.
4. Resins

4.1 Polyester Resins

4.1.1 Polyester resins were the first resins developed for fiberglass construction.

4.1.2 Polyester resin types include the following:

a. Orthophthalic and terephthalic resins are primarily used for marine applications (e.g., boat hulls).

b. Isophthalic, bisphenol-A fumerate, chlorendic anhydride, and brominated are primarily used for corrosion-resistant applications.

4.1.3 Isophthalic resins have limited corrosion resistance and should be used only for mild services.

4.1.4 Bisphenol-A fumerate polyester resins have excellent acid and good caustic resistances.

4.1.5 Chlorendic anhydride polyester resins are more resistant to oxidizing atmospheres but are not recommended for caustic environments.

4.1.6 All polyester resins are generally more brittle in nature than vinyl ester resins.

4.2 Vinyl Ester Resins

4.2.1 Vinyl ester resins are more recently developed and are widely used in all types of fiberglass construction.

4.2.2 Because of their flexibility, ease of application, and excellent corrosion resistance, vinyl ester resins are the preferred resins in most applications.

4.2.3 A variation of a vinyl ester resin called epoxy novalac is recommended for insoluble organic chemicals. Epoxy novalac resin has increased acid resistance and a higher temperature rating, but poor resistance to caustic solutions.

4.3 Epoxy Resins

4.3.1 Epoxy resins are primarily used for pipe manufacture, but are also permitted for Code Section X vessels.

4.3.2 Epoxy resins have better caustic resistance than vinyl esters, good acid resistance, and some resistance to organic chemicals.

4.3.3 Because they are difficult to cure, epoxy resins are not widely used for custom equipment.

5. Corrosion Veils

5.1 General

5.1.1 The corrosion veil is the inner most layer of the corrosion liner.

5.1.2 The corrosion liner should be 2.5 mm (100 mils) thick minimum, normally consisting of 1 ply of corrosion veil and 2 or more plies of chopped strand mat totaling 915 g/m² (3 oz/ft²). Severe corrosive applications may require 2 or more plies of veil and 3 or more plies of chopped strand mat. The resin manufacturer should be consulted for specific recommendations.
5.1.3 Three types of corrosion veils that are widely used for corrosion-resistant fiberglass equipment are as follows:
   a. C (chemical grade) glass veil
   b. Polyester veil
   c. Carbon veil

5.1.4 A corrosion liner is required by *PIP VESFG001* for all construction unless a thermoplastic liner is used.

5.1.5 Although corrosion veils are only covered in *ASME RTP-1*, all three are permitted in *ASME RTP-1* and *Code Section X* construction.

5.2 C Glass Veil

5.2.1 C glass veil is most commonly used.

5.2.2 C glass veil is a randomly deposited glass filament cloth approximately 0.25 mm (10 mils) thick.

5.2.3 C glass is a chemical-resistant glass which differs from the electrical grade or structural grade glass used in the structural portion of the laminate.

5.2.4 Because of the good saturation properties of C glass, the veil layer can have 90% resin (by weight) for maximum corrosion resistance.

5.2.5 For more severe applications, 2 or more plies of C glass veil are commonly used.

5.2.6 Because C glass can be damaged by hydrofluoric acid (HF), high concentrations of sodium hydroxide, and demineralized water, C glass veil should not be permitted in those applications. Even a small percentage of HF can damage C glass veil.

5.2.7 C glass veil has less resistance to abrasive services than other veils and should be avoided in that type of application.

5.3 Polyester Veil

5.3.1 Polyester veil is available in a variety of types including perforated, non-perforated, and conductive-treated.

5.3.2 Perforated (or aperatured) polyester veil is the most common type and can be used for most applications in lieu of C glass veil.

5.3.3 Polyester veil resists HF and demineralized water, and provides improved abrasion resistance over C glass veil.

5.3.4 Polyester veil is generally more expensive to use because it is stiff and removing entrapped air can be difficult.

5.3.5 Multiple plies of polyester veil are sometimes used; however, multiple plies can make it difficult to remove all of the entrapped air, and surface pits are common. Therefore, a ply of polyester veil is backed up with a ply of C glass veil in severe services.

5.4 Carbon Veil

5.4.1 Carbon veil is used if surface conductivity is desired (e.g., for dissipation of static charges in some flammable gas applications such as stacks or scrubbers).
5.4.2 Carbon veil is relatively expensive and very difficult to apply.
5.4.3 Carbon veil has the least abrasion resistance of any type of veil.
5.4.4 A conductive-treated polyester veil is preferred over carbon veil.

6. **Fiberglass Construction Methods**

6.1 **Contact Molding**

6.1.1 Contact molding was the initial method used for fiberglass vessel construction. In this method, resin-saturated glass fabric is applied over a male mold or cylindrical mandrel.

6.1.2 The fabric layers are of one of the following configurations:
   a. Chopped strand mat
   b. Woven roving
   c. Uni-directional fabric layers
   d. Bi-directional fabric layers

6.1.3 The resin is typically applied using brushes, but may also be sprayed on. The contact molding method is also referred to as hand lay-up, but this term does not capture all methods included in the contact molding category such as spray-up and machine-applied.

6.1.4 The contact molding method is well suited for complex and non-circular shapes. This method is normally used for small diameter shells, dished heads and flat bottoms on vessels and tanks.

6.1.5 Because of the higher void area associated with the types of glass fabric used, contact molding provides for greater resin content (typically above 70%). Therefore, contact molding is the most corrosion-resistant type of construction.

6.1.6 Because glass reinforcement is not continuous, this type of construction typically has less tensile strength and modulus of elasticity than filament-wound construction. Therefore, a vessel wall is typically thicker using contact-molded construction.

6.1.7 *Code Section X* limits the maximum pressure for Class I contact-molded vessels to 1.03 MPa (150 psi). For Class II vessels, the product of the pressure (in psi) and the diameter (in inches) is limited to 255 kg/mm (14,400 lb/in).

6.2 **Filament Winding**

6.2.1 In the filament-wound method, multiple glass filaments are applied to a rotating mandrel in a band. The band is typically dipped in a resin bath during this application.

6.2.2 Because the glass fibers are continuous, the resulting laminate has the greatest tensile strength and modulus of elasticity of any type of laminate construction.

6.2.3 Filament winding is a faster construction process than contact molding.

6.2.4 Filament winding is normally less expensive than the other methods for applications on large vessel shells.
6.2.5 The resin content is lower in percent by weight and therefore the corrosion resistance is lower than for contact-molded construction.

6.2.6 The vessel wall can be difficult to repair because of the following:
   a. Any repair overlay will necessarily be of contact-molded construction and typically be twice as thick as the original wall.
   b. Because liquids can weep along the fibers, the external location of a leak does not represent the internal location of a liner failure.

6.2.7 Because of the greater strength of continuous filaments, Code Section X limits the maximum pressure of Class I vessels with uncut filaments to 20.68 MPa (3,000 psi) and with cut filaments to 10.34 MPa (1,500 psi). For Class II vessels, the product of the pressure and the diameter cannot exceed 127.5 lb/mm (7,200 lb/in).

6.3 Centrifugal Casting and Bag Molding

6.3.1 Centrifugal casting and bag molding methods are used primarily for small diameter (i.e., less than 300 mm (12 in) in diameter) Code Section X Class I vessels because the tooling is not suitable for large fabrications.

6.3.2 In the centrifugal casting method, a female mold is loaded with the appropriate fiberglass reinforcement mats and cloth. Resin is injected into the center of the spinning mold, and thrown to the outside of the mold. An important advantage of the centrifugal casting method is that the fabrication is quick and provides a well-saturated resin laminate with no joints. An important disadvantage is that applications are limited because of the difficulty with handling side-mounted nozzles.

6.3.3 In the bag molding method, fiberglass cloth is inserted into a female mold. Resin is added and a central inflatable bag squeezes the resin into the cloth. Complex shapes are very difficult to manufacture using the bag molding method. Because the reinforcement fibers are not continuous, the maximum pressure permitted in Code Section X is 1.03 MPa (150 psi).

6.4 Dual Laminates

6.4.1 Dual laminates are thermoplastic-lined fiberglass vessels with materials and thickness as permitted in Code Section X and ASME RTP-1. TFE, FEP, PFA, MFA, PVDF, ECTFE, ETFE, PP, HDPE, PVC, or CPVC from 1 to 6 mm (40 to 250 mils) thick can be used for thermoplastic linings.

6.4.2 Linings are formed into the required vessel shape, and glued, welded, or molded into one piece. Fiberglass laminate is laid on top of the thermoplastic liner.

6.4.3 Normally, the thermoplastic liner is backed by imbedded glass or polyester cloth which helps anchor it to the outside fiberglass laminate.

6.4.4 In some cases like PVC or CPVC, a solvent primer is used to bond the liner to the fiberglass over-wrap.

6.4.5 Normally, a conductive cloth is placed directly behind the plastic liner so that the entire surface can be spark tested to find voids or defects.

6.4.6 Only a few fabricators maintain the tooling and special skills required for this type of construction.
6.4.7 Advantages of dual laminate construction are as follows:
   a. Greatly improved corrosion resistance over straight fiberglass
   b. Although typically much more expensive than the straight fiberglass constructions, dual laminate construction may be advantageous if compared to high-alloy or shorter life solid fiberglass tanks and vessels.

7. Cure Systems

7.1 Polyester and Vinyl Ester Resins

7.1.1 Cure systems used for polyester and vinyl ester resins are as follows:
   a. Methyl ethyl ketone peroxide/cobalt naphthenate (MEKP/CoN)
   b. Benzoyl peroxide/dimethylanaline (BPO/DMA)
   c. Cumene hydroperoxide/cobalt naphthenate (CHP/CoN)

7.1.2 In each of the cure systems, the peroxide acts as a catalyst and the other part acts as a promoter.

7.1.3 The MEKP/CoN system is most commonly used. Both parts of the system can be mixed together in a single resin pot. An elevated temperature post cure can be used with this system to ensure maximum resin cure, but is normally not needed.

7.1.4 A BPO/DMA cure is normally used for the highest degree of resin curing which provides greater corrosion resistance for tougher applications. A BPO/DMA cure is more difficult to use because it requires a two-part pot system and normally an elevated temperature post cure for maximum effectiveness. Therefore, a BPO/DMA cure is generally more expensive than the MEKP/CoN cure. BPO/DMA cures are primarily used in hypochlorite or chlorine services because these services attack the cobalt in the CHP/CoN and MEKP/CoN cure systems.

7.1.5 A CHP/CoN cure is used in certain applications involving thicker laminates requiring longer gel times so that the exotherm temperature during the cure does not cause damage to the laminate because of excessive heat. CHP/CoN cures can be used in the same services as MEKP/CoN cures.

7.2 Epoxy Resins

7.2.1 Epoxy resins are typically mixed together with a curing agent such as an organic acid hardener.

7.2.2 Because of the difficulty in achieving a cure in a reasonable period, elevated temperature post cures are normally required for epoxy resins in order to achieve a reasonable curing time.

8. Design Methods

8.1 General

8.1.1 Both \textit{ASME RTP-1} and \textit{Code Section X} provide for two design methods:
   a. Method A - Design by Rules
   b. Method B - Design by Stress Analysis
8.1.2 The design rules of Method A are limited to specific configurations in both ASME RTP-1 and Code Section X. For most other configurations, Method B is used.

8.1.3 ASME RTP-1 includes fabrication details and additional rules and guidance for supports that are not included in Code Section X.

8.1.4 In Code Section X, Method A and Method B are used for Class II vessels only. For Class I vessels, the design is verified by cyclic testing and a burst test. For Class II vessels, the design is verified by performing an acoustic emission test.

8.1.5 All design calculations required by ASME RTP-1 or Code Section X should be performed and certified by an engineer experienced in fiberglass design with pressures, temperatures, material properties and process conditions similar to that required for the subject equipment.

8.2 Method A - Design by Rules

8.2.1 ASME/ RTP-1 Part 3A and Code Section X Paragraph RD-1170 include basic design rules for the fabrication of fiberglass vessels including the following elements:

a. Cylindrical shells and torispherical, elliptical, and conical heads under internal and external pressures

b. Nozzle reinforcements, stiffening rings, and flange designs

c. ASME RTP-1 contains design rules for lug and double ring supports and hold-down lugs

8.2.2 Generally, the design rules are similar in ASME RTP-1 and Code Section X, but each has different design factors that are applied. The design rules in ASME RTP-1 use a higher design factor than in Code Section X.

8.2.3 The design rules in Code Section X for Class II vessels limit the design pressure and vessel inside diameter to maximums of 0.52 MPa (75 psi) and 2438 mm (96 inches), respectively.

8.2.4 The design rules of ASME RTP-1 Part 3A or Code Section X Paragraph RD-1170 should be used whenever possible for vessels composed of standard elements.

8.3 Method B - Design by Stress Analysis

8.3.1 ASME RTP-1 Part 3B and Code Section X Paragraph RD-1180 cover design of fiberglass vessels using stress analysis. Design by stress analysis can be any of several methods, but the most common method is finite element analysis using the laminate properties determined by lamination analysis.

8.3.2 ASME RTP-1 permits a lower design factor if Part 3B is used. Code Section X uses the same design factors as in design by rules (Method A).

8.3.3 ASME RTP-1 requires design by stress analysis for some parts of tanks greater than 16 feet (4.87 m) diameter.

8.3.4 For design by stress analysis, Code Section X allows a 1.38 MPa (200 psi) maximum design pressure for Class II vessels.

8.3.5 Because design by stress analysis can be applied to many vessel configurations, it should be used for all types of complex vessels and for designs that include transient loading (e.g., thermal and cyclic).
8.4 Design Factors

8.4.1 For *ASME RTP-1* Part 3A analysis using design by rules (Method A), the design factor is 10 for continuous loads and 5 for intermittent loads (e.g., wind and seismic) and for external pressure. The maximum ultimate tensile stress established by laminate testing is divided by the design factor to give the allowable design stress. *ASME RTP-1* also requires that for vessels in critical corrosion service, the design factor should be multiplied by 1.25.

8.4.2 For *ASME RTP-1* Part 3B analysis using design by stress analysis (Method B), the design factor can be reduced to 9 without acoustic emission examination and 8 if an acoustic emission examination is performed on the completed vessel. A design Factor of 10 shall be used for internal attachments to corrosion liner. The corrosion liner does not contribute to the strength of the vessel. *ASME RTP-1* also requires that for vessels in critical corrosion service, the design factor should be multiplied by 1.25.

8.4.3 For *Code Section X* analysis using design by rules (Method A), the design factor is related to a strain limit of 0.001 for both internal and external pressure.

8.4.4 For *Code Section X* analysis using design by stress analysis (Method B), the design factor is related to a maximum stress ratio of 6.

8.5 Maximum Allowable Design Stress

8.5.1 For both *ASME RTP-1* and *Code Section X*, the maximum allowable design stress is established by testing.

8.5.2 For *ASME RTP-1*, the test data should be provided for all qualified laminates. In general, the minimum allowable design stress for continuous loads should not be below 6.2 MPa (900 psi) for an all-mat construction and can be over 13.8 MPa (2,000 psi) for a well-constructed laminate of mat and woven roving. Testing is not required for filament-wound laminates, but the laminate properties are determined by lamination analysis. Filament-wound laminates can have design stresses that exceed 20.7 MPa (3000 psi).

8.5.3 *Code Section X* Class I vessels are destructively tested to verify the design.

8.5.4 For *Code Section X* Class II vessels, a basic laminate unit is qualified and the maximum allowable design stress is determined from that test data.

8.5.5 *ASME RTP-1* and *Code Section X* permit a maximum shear design stress of 1.38 MPa (200 psi).

8.5.6 *ASME RTP-1* permits a maximum allowable stress of 0.35 MPa (50 psi) in peel.

8.5.7 For all field-fabricated tanks and vessels designed for 0.0138 MPa (2 psi) and greater, *ASME RTP-1* requires a proof test of the as-constructed laminates to verify the design stress values in both the axial and hoop directions.

8.6 Maximum Allowable Design Strain

8.6.1 For filament-wound laminates, the maximum allowable design strain for *ASME RTP-1* vessels is 0.001 for continuous loading and 0.002 for intermittent loading and for external pressure.
8.6.2 *Code Section X* permits the allowable strain is to be approximately 0.001 for all types of loading and using Method A analysis.

8.6.3 For *ASME RTP-1*, actual strain as a function of the elastic modulus is determined using lamination analysis.

8.6.4 For *Code Section X*, the actual strain as a function of the elastic modulus is determined by test method. However, because the test method is difficult to apply because it involves winding a flat laminate, only contact-molded laminates are used for Class II equipment.

9. **Receiving Inspection**

9.1 Plans should be made to inspect a fiberglass vessel before removing it from the truck, trailer, railcar, or shipping container at the site to determine if damage was incurred during transit.

9.2 The receiving inspection should include a complete check for the following:
   a. External surface damage such as cuts, penetrations, de-laminations, or fractured areas
   b. Nozzle damage such as broken nozzles, broken flanges, or gouged flange faces
   c. Internal surface damage such as crazing-white areas with star-shaped surface cracks
   d. Vessel damage at contact points of dunnage, cradles, chocks, or hold-down strap bands

9.3 The procedure for immediately notifying the carrier representative if damage to the vessel is found should be developed with provisions to delay the unloading operation until the carrier representative’s inspection has been completed.

10. **Storage**

To avoid localized damage during storage or repositioning, provisions should be made at the site for placing fiberglass vessels on firm level surfaces that are free of stones, tools, or other small hard objects.

11. **Support Bases of Flat-Bottom Tanks**

11.1 The support base surface for flat-bottom tanks should be nonporous and free of cracks, depressions, and vertical projections. Reinforced concrete with a trowel finish is often used as a support base.

11.2 The support base should be flat within 6 mm (1/4 inch) of a horizontal plane. If sloped, the support base should not have projections greater than 6 mm (1/4 inch) above the surface plane.

11.3 Flat-bottom tanks should be set on a cushioning pad to minimize stresses caused by seams, shrinkage distortions, and/or support base or vessel bottom irregularities. The pad should be 12 mm (1/2 inch) thick, closed cell elastomeric sponge material of suitable composition with a compression deflection range per ASTM D-1056 of 34.5 to 62.1 kPa (5 to 9 psi) or 12 mm (1/2 inch) asphalt-impregnated felt.

11.4 Resin or cement grout, petroleum base mastic/sand mortar, or other suitable, conforming material that can cushion the vessel bottom over surface irregularities of the support base or tank bottom may also be used.
11.5 If the support base requires a trench to accommodate bottom discharge piping, a structural grating trench cover should be provided flush with the top of the support base to minimize any unsupported area of the tank bottom.

12. Provisions for Vessel Connections

12.1 Vents, Drains and Overflows

12.1.1 A positive venting arrangement should be provided (e.g., conservation vent, relief valve, open vent) and sized to prevent the maximum allowable working internal and external pressure from being exceeded.

12.1.2 If the vessel has a bottom drain, the support base should be notched to provide clearance for the nozzle flange or reinforcement.

12.1.3 Storage tanks should have overflows that are the same size or greater than any inlet nozzle. In accordance with ASME RTP-1, Paragraphs 5-400(b) and 5-400(c), roof nozzles should not be used as overflows for flat-bottom storage tanks.

12.1.4 Provision should be made to prevent the vessel contents from freezing.

12.2 Independent Support Systems

12.2.1 To prevent nozzle or vessel wall damage caused by excessive vibration, vertical or side-entering agitation equipment should be supported independently from the vessel.

12.2.2 To prevent nozzle damage due to piping strains, flexible connectors should be used to connect metallic piping that is 50 mm (2 inch) and greater to vessel nozzles.

12.2.3 To prevent weight and torque forces from being transmitted into the nozzle, valves attached directly to vessel nozzles shall be independently supported.

12.3 Flanged Connections

12.3.1 Flanged piping connections should use flat face flanges with full face gaskets.

12.3.2 If a raised face piping flange needs to be connected to a flat face fiberglass flange, a blocking ring spacer should be provided in accordance with ASME RTP-1, Figure NM9-2.

12.3.3 Metal washers should be provided under all bolt heads and nuts.

12.3.4 Provisions should be made to lubricate all bolts or studs before tightening.

12.3.5 The vessel fabricator’s recommended torque should not be exceeded when tightening the bolting.

12.3.6 Provisions should be made to tighten the bolting in a sequence in accordance with ASME RTP-1, Figure NM9-3.