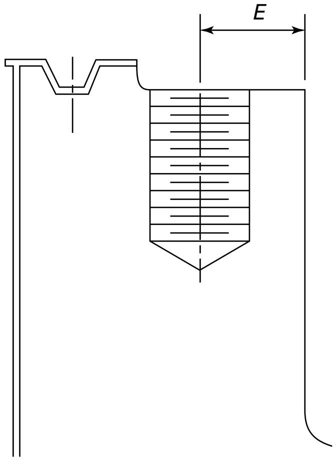
$$L_c = \frac{2 \times 8.0898}{3.1416 \times 3.1297\left[\frac{1}{2} + 0.57735 \times 8(3.1623 - 3.1297)\right]}$$
$$= 2.529 \text{ in.}$$

Since actual thread depth ($4\frac{1}{2}$ in.) exceeds calculated L_c, length of engagement is adequate for either a Class 2 or 3 fit.



Check distance required from the edge of the nozzle forging to the centerline of the stud bolt

$$\text{force generated by stud bolt} = S_B A_s$$

$$\text{maximum allowed force on forging} = \frac{\pi}{4}\left[(2E)^2 - d_s{}^2\right]S_F$$

Assuming the new stud diameter of $3\frac{1}{4}$ in., set the force the maximum allowed force on the forging and solve for the minimum edge distance, E

$$S_B A_s = \frac{\pi}{4}\left[(2E)^2 - d_s{}^2\right]S_F$$
$$21{,}200 \times 8.0898 = \frac{\pi}{4}\left[(2E)^2 - 3.25^2\right]14{,}520$$
$$E = 2.523 \text{ in.}$$

The actual edge distance of 3 in. exceeds the required minimum edge distance, E.

NOTE: Enlargement of the existing 3 in. 8 UN Stud Bolt to a $3\frac{1}{4}$ in. 8 UN Stud Bolt appears to be okay; however, nozzle opening reinforcement should be verified.

303-II-1.3 Nozzle Reinforcement Calculation

Minimum thickness of hemispherical head, t_r:

$$t_r = \frac{PL}{2S_sE_s - 0.2P} = \frac{2160 \times 61.1875}{(2 \times 14{,}520 \times 1.0) - (0.2 \times 2160)}$$
$$= 4.62 \text{ in.}$$

Minimum thickness of nozzle neck, t_{rn}

$$t_{rn} = \frac{PR_n}{S_FE_n - 0.6P} = \frac{2160 \times 12.1875}{(14{,}520 \times 1.0) - (0.6 \times 2160)}$$
$$= 1.99 \text{ in.}$$

Required reinforcement area, A

$$A = 0.5dt_rF = 0.5 \times 24.375 \times 4.62 \times 1.0 = 56.305 \text{ in.}^2$$

Available reinforcement

$$A_1 = 0.5d\,(t - t_{rn}) = 0.5 \times 24.375\left(4.625 - 4.62\right)$$
$$= 0.061 \text{ in.}^2$$

$$A_2 = \frac{1}{2}(h_o + h_i)(t_n - t_{rn})$$
$$= \frac{1}{2} \times (10.75 + 8.8577) \times (8.3125 - 1.99)$$
$$= 61.985 \text{ in.}^2$$

$$A_3 = \frac{1}{2}b_3h_3 = \frac{1}{2} \times 2.2114 \times 8.9375 = 9.8822 \text{ in.}^2$$

$$\sum A_n = A_1 + A_2 + A_3 = 0.061 + 61.985 + 9.8822$$
$$= 71.928 \text{ in.}^2$$

Subtract stud hole area from EA_n:

(a) For a 3 in. stud bolt:

$$A_4 = (d_s \times \text{stud depth}) + \left[\frac{1}{2} \times d_s \times (d_s/2 \div \tan 59)\right]$$
$$= (3 \times 4.5) + \left(\frac{1}{2} \times 3 \times 0.901\right) = 14.852 \text{ in.}^2$$

Therefore, available reinforcement

$$\sum A_n - A_4 = 71.928 - 14.852 = 57.076 \text{ in.}^2 > A$$

(b) For a $3\frac{1}{4}$ in. stud bolt:

$$A_4 = (d_s \times \text{stud depth}) + \left[\frac{1}{2} \times d_s \times (d_s/2 \div \tan 59)\right]$$
$$= (3.25 \times 4.5) + \left(\frac{1}{2} \times 3.25 \times 0.976\right) = 16.211 \text{ in.}^2$$

Therefore, available reinforcement

$$\sum A_n - A_4 = 71.928 - 16.211 = 55.72 \text{ in.}^2 < A$$

NOTE: If we consider on a given plane through the nozzle centerline that only one stud hole is enlarged to $3\frac{1}{4}$ in. while maintaining the opposite hole diameter at 3 in. we may be able to calculate the required reinforcement, A, as follows:

$$A = 2 \times 56.305 = 112.61 \text{ in.}^2$$

$$\sum A = 2 \times 71.928 - A_{4\,(3\frac{1}{4}\text{ in.})} = A_{4(3\text{ in.})}$$
$$= 2 \times 71.928 - 14.8 - 16.03 = 113.03 > 112.61$$

303-II-2 EXAMPLE 2

Example 1 in section 303-II-1 is for a centrally located opening in a spherical shell. Example 2 has been modified for an opening in a cylindrical shell, to illustrate the difference associated with studs that straddle the natural centerlines such that the required area for the nearest pair of tapped holes would be in a plane of reduced required reinforcement area. Only the reinforcement calculation is repeated here, the preceding calculations involving length of engagement and edge distance remain valid.

NOTE: Enlargement of the existing 3 in. 8 UN stud bolt to a $3^1/_4$ in. 8 UN Stud Bolt appears to be okay; however, nozzle opening reinforcement should be verified.

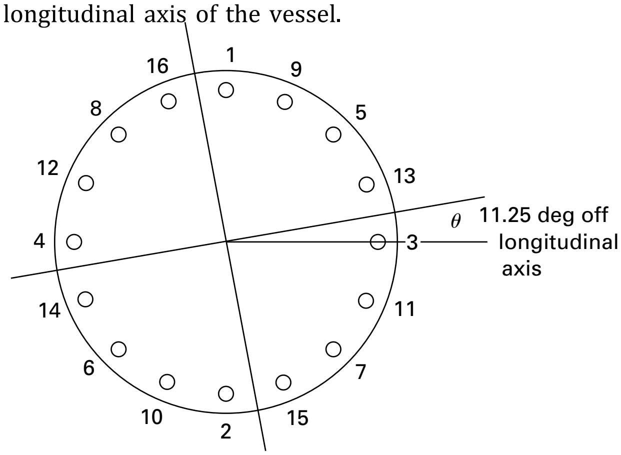
303-II-2.1 Nozzle Reinforcement Calculation

303-II-2.1.1 Minimum Thickness of Cylindrical Shell, t_r. For the purposes of this illustrative example, the minimum thickness of the cylindrical shell, t_r, will be assumed to be the same as that for the spherical shell (4.62 in.).

303-II-2.1.2 Minimum Thickness of Nozzle Neck, t_{rn}

$$t_{rn} = \frac{PR_n}{S_F E_n - 0.6P} = \frac{2160 \times 12.1875}{(14{,}520 \times 1.0) - (0.6 \times 2160)}$$
$$= 1.99 \text{ in.}$$

The nozzle in this example will be installed in the cylindrical shell such that the studs will straddle the natural centerlines of the vessel. The reinforcement area will be checked in the plane containing the hole closest to the longitudinal axis of the vessel.



The forging contains 16 studs, thus the angle defined by adjacent studs is: 360 ÷ 16 = 22.5 deg.

Since the stud holes straddle the natural centerlines of the vessel, the angle θ from the longitudinal centerline to the adjacent stud hole is: 22.5 ÷ 2 = 11.25 deg.

From ASME BPVC, Section VIII, Division 1, Figure UG-37, for angle θ of 11.25 deg, F = 0.98.

Required reinforcement area, A

$$A = 0.5dt_rF = 0.5 \times 24.375 \times 4.62 \times 0.98 = 55.181 \text{ in.}^2$$

Available reinforcement

$$A_1 = 0.5d\,(t - t_{rn}) = 0.5 \times 24.375\left(4.625 - 4.62\right)$$
$$= 0.061 \text{ in.}^2$$

$$A_2 = {}^1/_2(h_o + h_i)(t_n - t_{rn})$$
$$= {}^1/_2 \times (10.75 + 8.8577) \times (8.3125 - 1.99)$$
$$= 61.985 \text{ in.}^2$$

$$A_3 = {}^1/_2 b_3 h_3 = {}^1/_2 \times 2.2114 \times 8.9375 = 9.8822 \text{ in.}^2$$

$$\sum A_n = A_1 + A_2 + A_3 = 0.061 + 61.985 + 9.8822$$
$$= 71.928 \text{ in.}^2$$

Subtract stud hole area from ΣA_n:

(a) For a 3-in. stud bolt

$$A_4 = \left(d_s \times \text{ stud depth}\right) + \left[{}^1/_2 \times d_s \times (d_s/2 \div \tan 59)\right]$$
$$= (3 \times 4.5) + \left({}^1/_2 \times 3 \times 0.901\right) = 14.852 \text{ in.}^2$$

Therefore, available reinforcement

$$\sum A_n - A_4 = 71.928 - 14.852 = 57.076 \text{ in.}^2 > A$$

(b) For a $3^1/_4$-in. stud bolt

$$A_4 = (d_s \times \text{ stud depth}) + \left[{}^1/_2 \times d_s \times (d_s/2 \div \tan 59)\right]$$
$$= (3.25 \times 4.5) + \left({}^1/_2 \times 3.25 \times 0.976\right) = 16.211 \text{ in.}^2$$

Therefore, available reinforcement

$$\sum A_n - A = 71.928 - 16.211 = 55.72 \text{ in.}^2 > A$$

Article 304
Flaw Excavation and Weld Repair

304-1 DESCRIPTION

Surface flaws see Figure 304-3.1-1, or embedded flaws see [Figure 304-3.1-2, illustration (a)] in base material or welds that exceed the allowances of the applicable construction code or post-construction code can be removed by excavation [see Figure 304-3.1-1, illustration (b); and Figure 304-3.1-2, illustration (b)]. The remaining cavity can be filled with weld filler metal [see Figure 304-3.1-1, illustration (c); and Figure 304-3.1-2, illustration (c)], or left as-is, under conditions described in this Article. Depending on the type and location of the flaw, and the type of base metal or weld material, excavation can be accomplished by mechanical removal methods (grinding, machining, lapping, honing, or flapping), or by thermal removal methods (thermal gouging). Descriptions of these excavation techniques are provided in Mandatory Appendix 304-I.

304-2 LIMITATIONS

304-2.1 Additional Requirements

Part 1 of this Standard contains additional requirements and limitations. This Article shall be used in conjunction with Part 1.

304-2.2 Grinding

304-2.2.1 Grinding wheels shall not be forced or overloaded, in order to avoid the safety hazards from wheel failure. Furthermore, overloading the grinding wheel can cause areas of localized high temperature in the substrate being ground, leading in some cases to the formation of brittle untempered martensite, or tight, shallow surface cracks. Abusive grinding and uneven and rough finish can result in reduced fatigue strength or premature failure due to the introduction of large surface residual tensile stresses and stress risers. These problems normally can be avoided by using lighter grinding practices that avoid surface oxidation, evident through discoloration. It may be necessary to preheat some high strength alloy steels prior to grinding. Grinding wheels are manufactured to be used on specific materials (ferritic or austenitic steels, masonry, etc.). Therefore, only grinding wheels specifically designed to work on the material being ground shall be used. Rotary files should be considered for nickel alloys.

304-2.2.2 Grinding or cutting consumables used on carbon or low alloy steel materials will become impregnated with residues of those materials and become unsuitable for use with austenitic stainless steels. Abrasive cutting or grinding consumables should be segregated for use on carbon and low alloy steels from those used for austenitic stainless steel substrates. Surface contamination of austenitic stainless steel with carbon or low alloy steel residues can result in surface corrosion or pitting of the austenitic stainless steel. To avoid such problems, only grinding wheels designated as austenitic stainless steel grinding wheels shall be used on these materials.

304-2.2.3 When grinding out stress corrosion cracks in stainless steel, or in the case of steels that have suffered from anodic stress corrosion cracking (such as amine or caustic stress corrosion cracking), it is necessary to qualify and control the amount of heat generated to avoid making the cracks deeper and longer as a result of excessive heat. Steel contaminated with caustic or amines can also recrack during welding repairs or thermal cutting. Appropriate cleaning procedures shall be used prior to excavation or repair.

304-2.2.4 In tight spaces, burring tools may be used in place of grinding wheels.

304-2.3 Machining

When cutting fluids are used, care shall be taken to prevent their contact on surfaces where they may be detrimental. Furthermore, chips of the machined metal shall be controlled and kept from entering components where their presence can be detrimental.

304-2.4 Honing

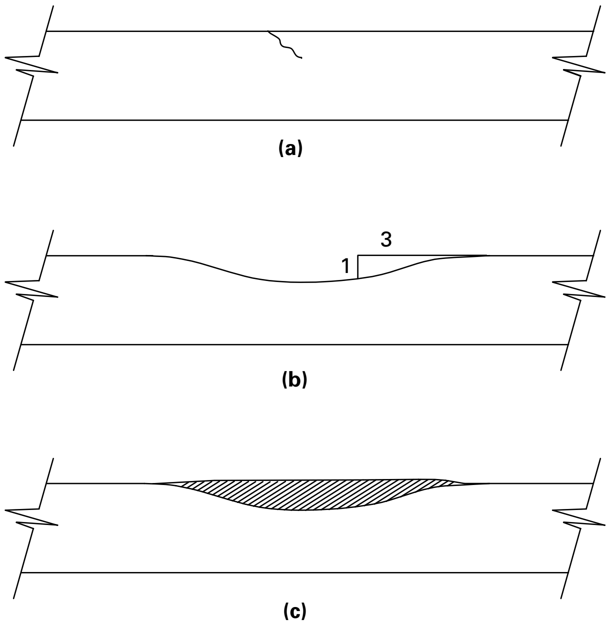
The honing speeds shall be adjusted as a function of length-to-bore ratio of the component and its material hardness.

304-2.5 Flapping

304-2.5.1 Flapping should only be used to smooth or polish a surface. Flapping is unsuitable for removing defects other than superficial surface blemishes.

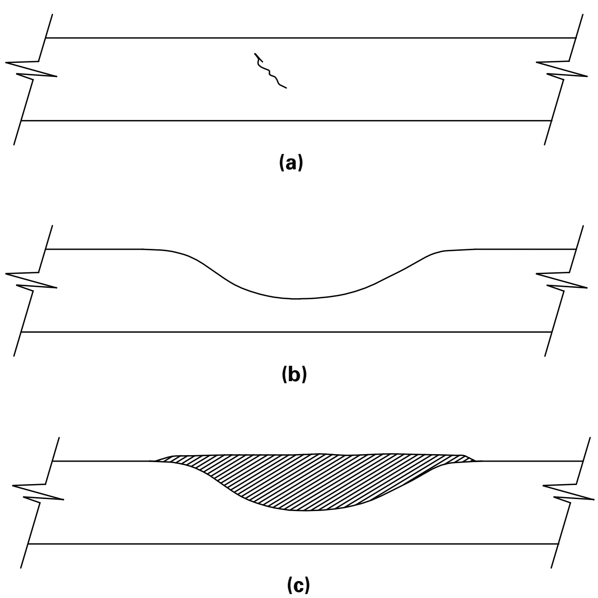
304-2.5.2 The abrasive marks of the flapper should be directed perpendicular to the direction of the preceding pass. Marks of the preceding pass should be removed prior

Figure 304-3.1-1 Excavation and Weld Repair of Surface Flaw



GENERAL NOTE:
A 3-to-1 taper is not required when the cavity will be filled with weld metal.

Figure 304-3.1-2 Excavation and Weld Repair of Embedded Flaw



GENERAL NOTE:
A 3-to-1 taper is not required when the cavity will be filled with weld metal.

to proceeding to the next finer grit. In this way, distortion of the surface will be minimized and smooth surfaces can be obtained.

304-2.6 Thermal Gouging

304-2.6.1 When thermal gouging by carbon arc or plasma arc, the very rapid heating to molten temperatures and subsequent quenching to ambient temperature can result in hardened or brittle heat-affected zones. This thermally affected material should be subsequently removed by a mechanical process, such as grinding.

304-2.6.2 For some materials it may be necessary to preheat the metal prior to arc gouging in order to prevent cracking, in particular materials that are required to be postweld heat treated by the construction code or post-construction code.

304-2.7 Generalized Damage

This repair technique applies well to local defects. Where damage is extensive, such as general stress corrosion cracking of stainless steel, replacement should be considered.

304-3 DESIGN

304-3.1 Excavation Without Weld Deposit

Material or weld flaws open to the surface [Figure 304-3.1-1, illustration (a)] or embedded flaws [Figure 304-3.1-2, illustration (a)] are typically removed by a mechanical (abrasive) method (Figure 304-3.1-3). If the remaining wall thickness of the excavation, with allowance for future corrosion, is greater than the minimum required wall thickness required by the applicable construction code or post-construction code, such as the local thin area rules of API 579-1/ASME FFS-1, then the excavated area may be blended to a 3:1 or smoother profile slope, and left as-is for return to service.

304-3.2 Weld Deposition

When the removal of a flaw produces a remaining wall thickness below the limit permitted by the applicable construction code or post-construction code, including allowance for future corrosion, then the cavity shall be repaired by deposition of weld metal [Figure 304-3.1-1, illustration (c) and Figure 304-3.1-2, illustration (c)] or analyzed for fitness-for-service. When the depth of material excavated necessitates a weld repair, the cavity shall be prepared for welding. Either during or following defect removal, the excavation shall be shaped to provide adequate access for the welding operation in order to facilitate proper fusion, and avoid slag entrapment, or lack of penetration. To minimize weld shrinkage stresses, the width of the cavity should only

Figure 304-3.1-3 Grinding of Weld Flaw

be as wide as needed to ensure defect removal and to facilitate welding as previously described.

304-3.3 Mechanical Excavation

If the excavation is performed using a thermal removal process (carbon arc or plasma arc gouging), an additional 1.5 mm ($^1/_{16}$ in.) of material shall be removed by a mechanical removal process such as grinding, prior to the final inspection and before welding begins. This is necessary to remove any surface cracks, hardened material, scale, or carbon deposit.

304-4 FABRICATION

304-4.1 Repair Steps

The requirements specified in paras. 304-4.1.1 through 304-4.1.5 are generally followed to excavate a flaw.

304-4.1.1 Locate and expose the flaw. Characterize the flaw (size, depth, orientation) to the extent possible. If the flaw is a crack, the crack tips may be rounded by drilling to preclude crack from propagating during its excavation.

304-4.1.2 Remove the flaw by grinding, machining, honing, or thermal gouging. In selecting and applying a removal process, refer to the guidance in sections 304-2 and 304-3.

304-4.1.3 Verify defect removal by inspecting the cavity using visual examination (VT) and liquid penetrant testing (PT), magnetic particle testing (MT), or eddy current testing (ET) as appropriate. Measure the remaining wall thickness of the excavated cavity using an approved thickness measurement technique. If remaining is greater than the minimum required thickness as determined by a fitness-for-service evaluation, the excavation cavity need not be filled with weld deposit, as provided in para. 304-3.1.

304-4.1.4 When required by design (section 304-3), repair the cavity by welding according to a qualified welding procedure specification (WPS), using a qualified welder, as required by the applicable construction code or post-construction code.

304-4.1.5 Perform preheat or postweld heat treatment, when required by the applicable construction code or post-construction code, as indicated by owner–user specification, or as dictated by service conditions.

304-4.2 Special Fixtures

In some cases, special fixtures may be required to accomplish precision work. In addition, it is often beneficial to develop special gages to monitor the depth of metal removal and to prevent excessive material from being removed. Special contour templates or common carpenter gages may be used and may be integrated into special fixtures.

304-5 EXAMINATION

304-5.1 Critical Service

In critical service applications, following a local repair, the final surface and adjacent area shall be examined using VT and PT, MT, or ET, in accordance with the defect acceptance criteria of the applicable construction code or post-construction code.

304-5.2 Volumetric Examination

Volumetric examination (RT or UT) shall be considered where there is a possibility of flaws introduced during repair welding, such as shrinkage cracks from deep weld repairs in thick sections.

304-5.3 Additional Examinations

Additional examinations shall be performed if required for similar welds by the applicable construction code or post-construction code.

304-6 TESTING

304-6.1 Applicability

Generally, and unless specified otherwise in the applicable construction code or post-construction code, weld repairs that have fully penetrated the component wall should be subjected to either leak testing or volumetric examination, or both, following the repair and any postweld heat treatment to verify the integrity of the repair.

304-6.2 Test Method

If a leak test is performed, it may be hydrostatic, pneumatic, sensitive leak, or in-service as required by the applicable construction code or post-construction code.

304-6.3 Exemption

When the excavation does not fully penetrate the component pressure boundary, leak testing may be waived.

304-7 REFERENCES (18)

The following is a list of publications referenced in this Article. Unless otherwise specified, the latest edition shall apply.

ANSI B7.1, Safety Requirements for the Use, Care and Protection of Abrasive Wheels

ANSI B74.2, Specifications for Shapes and Sizes of Grinding Wheels, and for Shapes, Sizes and Identification of Mounted Wheels

ANSI B74.13, Markings for Identifying Grinding Wheels and Other Bonded Abrasives

Publisher: American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036 (www.ansi.org)

API 579-1/ASME FFS-1, Fitness-for-Service

Publisher: American Petroleum Institute (API), 1220 L Street, NW, Washington, DC 20005 (www.api.org)

Mandatory Appendix 304-I
Metal Removal Process

304-I-1 FLAPPING

Flapping is a metal removal process involving a rotating tool fabricated of abrasive papers. Flapper wheels come in a variety of grit sizes and should be worked from the more coarse grit to the finer grit.

304-I-2 GRINDING

(a) Grinding is the process of abrading the surface of a material for the purpose of removing portions of the material. The process is used to remove localized cracks, pits, deposits, hardened surfaces, etc. Equipment used for grinding includes pencil or small disc grinders to remove local defects, and large disc or wheel grinders to remove larger defects. The grinding equipment can be electric or air-driven; with wheels of various shapes, sizes, and abrasive characteristics.

(b) Every grinding wheel has two constituents: the abrasive that does the cutting and the bond that holds the abrasive component. Variations of these components can be selected to give a wide range of grinding characteristics. The three American National Standards Institute (ANSI) standards that provide specifications for grinding wheels are as follows:

(1) ANSI B74.13, Markings for Identifying Grinding Wheels and Other Bonded Abrasives

(2) ANSI B74.2, Specifications for Shapes and Sizes of Grinding Wheels, and for Shapes, Sizes and Identification of Mounted Wheels

(3) ANSI B7.1, Safety Requirements for the Use, Care and Protection of Abrasive Wheels

(c) Manual grinding is generally divided into one of three categories:

(1) rough grinding — relatively rapid removal of excess weld metal or base material using coarse abrasives

(2) polishing and blending — achieving a semi-smooth finish, using medium abrasives

(3) buffing — achieving a lustrous and reflective finish, using fine abrasives usually in a paste or liquid vehicle

304-I-3 HONING

(a) Honing is an abrasive process that is used to obtain a fine finish on the inside surface of a cylindrical component.

(b) Honing tools are placed in the bore of the component and a radial load is applied such that the honing stones are in contact with the bore surface. The hone is then rotated in the bore, generating a high-quality surface.

(c) Honing stones generally are manufactured of aluminum oxide, silicon carbide, or diamond abrasive grits, held together by vitrified clay, resin, or a metal bond. The grain and grade of abrasive to be used is based on the amount of stock to be removed and the surface finish desired. Silicon carbide is generally used for cast iron, while aluminum oxide is generally used on steel. As with grinding discs and lapping compound, the finer the grit, the finer the surface finish.

304-I-4 LAPPING

(a) Lapping is a polishing technique that can be used to prepare surfaces requiring a very smooth finish. Lapping is not economical for removing deep defects. A general rule of thumb is that lapping methods are suitable for shallow defects less than 0.05 mm (0.002 in.). Defects located greater than this depth should be removed by other methods.

(b) Lapping machines are available as portable or bench-type systems. In many cases, lapping is performed with special discs or plates made specifically for a given type of application. These plates are normally very thick to maintain dimensional stability. After defect removal, the surface should be lapped to the finish and dimensions specified by the design.

304-I-5 MACHINING

(a) Machining using portable equipment can provide for defect removal and weld preparation in a single step. Machining with mechanized cutting equipment is used to remove defects with precision. Machining equipment used to remove defects or prepare a surface for repair include boring bars, milling machines, magnetic drills, flange facers (portable lathes), and pipe cutting and beveling machines. Machining has the advantage of cutting and forming the weld preparation with a single piece of equipment while closely controlling dimensional tolerances.

(b) Portable boring bars have been used where circumferential machining of a bore is required, such as in valve maintenance. Other bars are available with accessories to grind or mill unique geometries, and to drill and tap stud holes.

(c) Portable milling machines can be used to remove localized materials at a faster rate than machines mounted on the component outer or inner diameters. Small milling machines have been developed to operate in relatively restricted locations.

(d) Machining generally involves the use of cutting fluids that perform several functions including lubrication, cooling, and chip removal.

304-I-6 THERMAL GOUGING

(a) In situations where defects are found to be extensive and where accuracy is not critical, thermal gouging (carbon arc gouging or plasma arc gouging) can be used effectively.

(b) Thermal gouging techniques are thermal removal processes that involve localized melting of the metal, which is quickly swept away by the force of high velocity air or gas jets.

304-I-7 BOAT SAMPLE CUTTING

(a) Boat samples are metal samples in the shape of a boat hull that are cut out from base metal, weldments, or weld heat-affected zones (Figure 304-I-7-1). The process can be used for removal of weld defects, but is more commonly used for obtaining samples of base materials or welds for metallurgical or mechanical testing.

(b) *Boat sample cutters*, sometimes referred to as *weld probers* or *trepanning machines*, are mechanical devices designed to remove a portion of a weld or metal plate by saw cutting from the plate surface. The machine is a saw with a dished shape blade, capable of excavating and removing a boat-shaped specimen from a flat surface in any position.

(c) Boat sample cutters can be air powered or electric motor driven. They are portable devices that are easily mounted on the surface of the material to be excavated by means of four anchoring bolts welded to the surface. Shim spacers are used to adjust the width and depth of cut by controlling the space between the saw mounting frame and the surface of the plate.

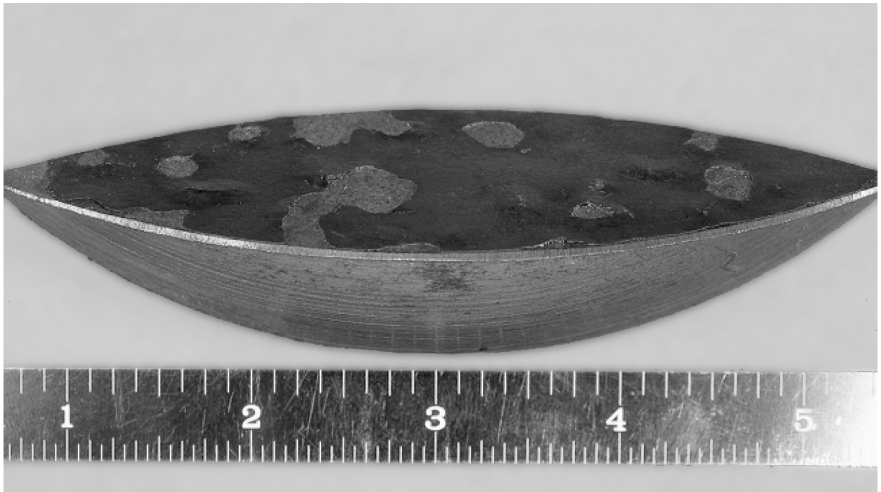
(d) Once securely mounted on the anchor bolts, the cutting process begins by making a single cut at the edge of the material to be excavated. The curved blade is fed into the material until the desired depth is achieved and the saw circumference is at right angles to the joint. The blade is then retracted, the saw rotated 180 deg and a second cut is made. The two cuts meet automatically in the same plane and the excavation is complete.

(e) Boat samples can be cut either longitudinal or transverse with respect to the weld joint. They are boat shaped and the cut sides have a spherical curvature. The size varies in proportion to the thickness of the plate being cut; however, specimens can range from a small size of $\frac{1}{8}$ in. depth × $2\frac{3}{8}$ in. length × $\frac{3}{8}$ in. width to a large size of 1 in. depth × $4\frac{3}{4}$ in. length × $1\frac{1}{2}$ in. width. Larger specimens can be excavated with specially designed equipment.

(f) The excavated boat samples are large enough to allow for various mechanical testing processes. Cross sections of the "boats" can be used for hardness testing or metallographic inspection. Full-length specimens can be machined for tensile testing, bend testing, or Charpy V-notch impact testing.

(g) Once the boat sample has been removed, the cutter can be detached from its mounted position and the anchor bolts can be removed from the plate surface. The cavity left by the removal of the excavated boat sample is very conducive to repair welding. The tapered nature of the cavity ends and the sloping curvature of the cavity walls allow complete and easy access for most welding processes.

Figure 304-I-7-1 Boat Sample



Article 305
Flange Repair and Conversion

305-1 DESCRIPTION

305-1.1 Introduction

This Article applies to the refinishing of flange faces to repair mechanical imperfections or damage from corrosion or other damage in service, or to changing the flange face finish to enable the use of a different gasket. The surface finish of a flange contact surface is essential to the leak tightness of the gasketed joint. When surface finish deteriorates in service, it can become necessary to either replace the flange or refinish the flange face.

305-1.2 Work Location

The repair can be performed in situ using a portable machine tool, or the pipe section or equipment containing the damaged flange can be removed and repaired in the shop.

305-2 LIMITATIONS

305-2.1 Additional Requirements

Part 1 of this Standard contains additional requirements and limitations. This Article shall be used in conjunction with Part 1.

305-2.2 Recurrence of Damage

Flange refinishing will restore the flange facing but may not eliminate the cause of the initial imperfection or damage. Therefore, the imperfection or damage may recur. Consideration shall be given to the possible recurrence of the original imperfection/damage mechanism.

305-2.3 Remaining Thickness

The flange may not be sufficiently thick to permit metal removal by machining and still meet the minimum thickness required for the design pressure rating. In such a case, it will be necessary to increase the flange ring thickness by weld metal buildup before remachining the surface. As an alternative solution, a split ring flange may be added to the back of the existing flange to compensate for reduced flange ring thickness, where geometry and spacing permits, and as qualified by the appropriate design calculations.

305-2.4 Residual Stress

The machining of weld overlayed or weld built-up surfaces that have not been stress-relieved may cause the redistribution of residual stresses and subsequent dimensional distortion over time. In such instances, precautions such as performing a stress-relieving heat treatment prior to finish machining shall be considered to ensure final dimensional stability.

305-3 DESIGN

305-3.1 Raised Face

Under-thickness of a raised face due to refinishing shall be acceptable, provided the minimum finished height of the raised face is 0.8 mm (0.031 in.).

305-3.2 Thickness Evaluation

If flange refinishing necessitates removal of material from other than the raised face such that the flange dimensions no longer comply with the original design dimensions minus the original corrosion allowance or the requirements of an applicable specification or standard, the flange shall be evaluated to ensure that the removal of material does not compromise design integrity. Design evaluation methods of an applicable new construction code (such as ASME BPVC, Section VIII, Division 1, Mandatory Appendix 2), or an applicable post-construction code or standard shall be used.

305-3.3 Finish and Flatness

The gasket seating requirements in terms of flange surface finish and flatness shall be considered.

305-3.3.1 Flatness. For example, API 660 and TEMA permit deviations from flatness that exceed those that are recommended for certain gasket types of materials (e.g., flat metal). For guidance on flange face flatness tolerance, refer to ASME PCC-1, Nonmandatory Appendix D.

305-3.3.2 Finish. See TEMA Fig. F-4 for permissible imperfections in flange-facing finish. The choice of flange-facing finish shall be in accordance with the applicable standard and compatible with the requirements specified by the user or recommended by the gasket manufacturer. For example, unless otherwise agreed to by the purchaser or manufacturer, ASME B16.5 specifies the following flange-facing finishes (as judged by visual comparison with *Ra* standards per ASME B46.1):

(a) Tongue and groove and small male and female flanges: not to exceed 3.2 μm (125 μin.) roughness.

(b) Ring joint: not to exceed 1.6 μm (63 μin.) roughness.

(c) Other: Either a serrated concentric or serrated spiral finish having a resulting surface finish from 3.2 μm to 6.4 μm (125 μin. to 250 μin.) average roughness shall be furnished. The cutting tool employed should have an approximate 1.5 mm (0.06 in.) or larger radius and there should be from 1.8 grooves/mm to 2.2 grooves/mm (45 grooves/in. to 55 grooves/in.).

305-4 FABRICATION

305-4.1 Repair Without Welding

If either the flange ring thickness or hub dimensions, or both, are sufficient, then the entire gasket surface may be machined to remove the area of degradation or imperfection and thus achieving the desired finish without weld metal buildup.

305-4.2 Repair by Welding

In repairing a flange face, it may be necessary to use weld metal to either fill a local area (e.g., a gouge or a scratch) or to restore thickness by a weld buildup of the base metal or existing weld overlay face. Where the flange is to be repaired by welding, the area where the buildup is to be applied shall be free of any residue, gasket material, corrosion deposits, etc., that would unduly affect the weld. Cleaning may be by mechanical or chemical procedures. Welding procedures and personnel shall be qualified per the requirements of an applicable new construction code (such as ASME BPVC, Section IX), or an applicable post-construction code or standard. Where weld metal buildup is necessary, the filler metal, welding technique, welder qualifications, and heat treatment (if any) shall be selected to meet service and metallurgical requirements.

305-4.3 Postweld Heat Treatment

When weld metal buildup is required, postweld heat treatment shall be performed prior to flange face machining if required by an applicable new construction or post-construction code. Postweld heat treatment is not required if the thickness of the weld metal buildup is less than the limits prescribed in the applicable new or post-construction code or standard unless dimensional stability is an issue, or postweld heat treatment is required for process reasons.

305-4.4 Machining

The cutting tool radius and feed rate should be set to prequalified values in order to consistently achieve the desired surface finish. For minor imperfections, careful filing may be adequate for the removal and dressing of the flange faces.

305-4.5 Conversion of Flange Facing From Ring-Type Joint to Raised Face

Ring-type joint flanges may be converted to raised face type flanges with the following considerations along with relevant sections of this Article. The decision to convert to raised face flanges can result from observed or potential ring groove cracking or other reasons. One method of conversion is performed by welding new material into the ring groove and machining to meet the raised face dimensions as called out in the applicable standard. Special conversion gaskets that can be used with an unmodified ring joint flange may also be used but consideration needs to be given to the width of the gasket, location of the gasket reaction load, the effect of flange rotation, and surface finish on the ability of the gasket to seal.

305-4.5.1 Considerations. Prior to converting flange types, consideration shall be given to the impact of such a change on the system design bases and specifications, including such negative potential consequences as sealing difficulties and gasket blowout. The impact of the change with respect to system design bases and specifications should be considered. Gasket materials for the new gasket type should be selected with due consideration for the service environment.

305-4.5.2 Materials. The material used for filling in the groove may match the base metal of the flange or may be a different material suitable for the process conditions. For example, in some instances it may be desirable to fill in a groove in a Cr–Mo flange using an austenitic stainless steel filler. If the groove is filled with a material that has a different coefficient of thermal expansion than the base metal of the flange, consideration should be given to the effects of differential thermal expansion. It is recognized that some material may be removed from the bottom of the groove in order to prepare the surface for welding or to remove cracks or other flaws. If material other than the base material is used to fill in the groove, this material removal can result in the flange thickness (see Figure 305-4.5.2-1) composed of base metal being less than that specified by the applicable standard. This is acceptable if the depth of the weld does not exceed 10% of the flange thickness. This 10% criterion may be increased if justified by an engineering analysis. This analysis should be similar to a Level 3 assessment in accordance with API 579-1/ASME FFS-1.