PART 1
SCOPE, ORGANIZATION, AND INTENT

Article 101
Introduction

101-1 SCOPE

This Standard provides methods for repair of equipment, piping, pipelines, and associated ancillary equipment within the scope of ASME Pressure Technology Codes and Standards[1] after they have been placed in service. These repair methods include relevant design, fabrication, examination, and testing practices and may be temporary or permanent, depending on the circumstances.

The methods provided in this Standard address the repair of components when repair is deemed necessary based on appropriate inspection and flaw assessment. These inspection and flaw evaluation methods are not covered in this Standard, but are covered in other post-construction codes and standards.

This Standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this Standard to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.

Only technical procedures and information are provided; administrative or policy requirements are outside of the scope of this Standard.

101-2 ORGANIZATION

This Standard is divided into five Parts.

(a) Part 1 covers the scope, organization, and intent and is applicable to all articles in this Standard.

(b) Part 2 covers repair methods and techniques that include the use of welding, brazing, soldering, or other methods involving metal deposit.

(c) Part 3 covers mechanical repairs, with or without sealant, such as bolted clamps or fixtures and includes all repair methods not covered in Part 2 or Part 4.

(d) Part 4 covers repairs using nonmetallic means, such as nonmetallic liners and wraps, and bonding (e.g., joining by epoxy), including bonding of metallic components.

(e) Part 5 covers examination and testing methods and techniques.

101-3 INTENT

101-3.1 General

This Standard provides technical information, procedures, and recommendations for repair methods that were determined by consensus to be recognized and generally accepted good engineering practice. Where equipment repair is subject to jurisdictional regulation, jurisdictional approvals may be required.

101-3.2 Acronyms and Definitions (22)

The words *shall*, *should*, and *may* are defined in the Foreword of this Standard. When used in the repair articles of this Standard, they have the following intent:

shall: indicates an action that is an essential element of the repair method that cannot be eliminated.

should: indicates an action that when performed, is generally considered to be good practice; however, there are some circumstances when the action is not appropriate or required, so the word *should* is used to provide flexibility for the article to cover a broad range of circumstances. It is not mandatory unless so specified by others in the application of these articles.

may: indicates an action that is permitted, but not required.

101-3.2.1 Acronyms

API	American Petroleum Institute
ASM (ASM International)	American Society of Metals
ASME	The American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
AWS	American Welding Society
AWWA	American Water Works Association
BPVC	Boiler and Pressure Vessel Code

[1] Equipment and piping within the scope of ASME Pressure Technology Codes and Standards includes piping (including pipelines) and piping components (such as valves), boilers, pressure vessels (including heat exchangers), and storage tanks.

Table continued

BS (BSI)	British Standards Institute
EPRI	Electric Power Research Institute
ID	Inside diameter
IDLH	Immediately dangerous to life or health
ISO	International Standards Organization
MAOP	Maximum allowable operating pressure
MAWP	Maximum allowable working pressure
NDE	Nondestructive examination
NDT	Nondestructive testing
NPS	Nominal pipe size
OD	Outside diameter
OSHA	Occupational Safety and Health Administration
QA/QC	Quality assurance/quality control
SMYS	Specified minimum yield strength
SSPC-SP	Steel Structures Painting Council Standards
UV	Ultraviolet (radiation)
WRC	Welding Research Council

101-3.2.2 Definitions

clad restoration: the application of corrosion-resistant weld metal on carbon steel or low alloy base metal, for the purpose of restoring the original corrosion-resistant weld overlay or cladding. The original cladding could have been applied by methods such as roll bonding or explosion bonding.

closure weld: the final weld connecting pressurized systems (e.g., piping or vessel) or components usually performed in the field.

effective depth: the depth below the finished weld surface at which weld metal chemical analysis is performed. The effective depth is as defined in ASME BPVC, Section IX, QW-462.5(a).

examination: the process of determining the condition of an area of interest by nondestructive means against established acceptance or rejection criteria.

fitness-for-service (FFS) assessment: methodology outlined in ASME/API FFS-1/API 579-1, whereby flaws or a damage state in a component is evaluated to determine the adequacy of the component for continued operation.

hydrostatic test: a pressure or tightness test where liquid, typically water, is the test medium (not to be confused with *in-service leak test*).

in-service leak test: a test using the process medium of the pressure equipment performed at start-up of the equipment.

inspection: the observation of any operation performed on materials and/or components to determine its acceptability in accordance with given criteria.

lamination: internal separation or weakness generally aligned parallel to the worked surface of the metal. May be the result of blisters, seams, inclusions, or segregation elongated and made directional by working.

owner: the company or entity that owns or is responsible for the equipment.

piping: assemblies of piping components (e.g., pipe, fittings, flanges, gaskets, bolting, valves) used to convey fluids.

pneumatic test: a pressure or tightness test where a gas, generally nitrogen or air, is the test medium.

pressure test: a test performed to ensure the gross integrity of the pressure component on new pressure equipment or on previously manufactured pressure and piping equipment that has been or is in service and that has undergone an alteration or repair to a pressure boundary(s) to determine the gross integrity of the pressure component. A pressure test may be performed with liquid (hydrostatic test), with gas (pneumatic test), or with a combination of both (hydro-pneumatic test).

ring-type joints (RTJ): flanges that have been hexagonally grooved to concentrate the bolt load over a small area producing high sealing stresses when fitted with a metal ring-type joint gasket (as detailed in ASME B16.20).

risk: the product of the probability of an event (likelihood) and its consequence (outcome). In some situations, risk is a deviation from the expected. When probability and consequence are expressed numerically, risk is the product.

risk analysis: the systematic use of information to identify sources and to estimate the risk. Risk analysis provides a basis for risk evaluation, mitigation, and acceptance. Information can include historical data, theoretical analysis, informed opinions, and concerns of stakeholders.

risk-based inspection (RBI): a risk assessment and management process outlined in ASME PCC-3 that is focused on loss of containment of pressurized equipment in processing facilities, due to material deterioration. These risks are managed primarily through equipment inspection.

safety data sheet (SDS): a data sheet for chemicals that defines important information such as the levels of toxicity, flammability, and first-aid actions required.

tightness test: a test that is performed to ensure overall leak tightness of the system or its connections before the process medium is introduced.

weld buildup: the application of weld metal that is the same chemistry as the base metal for the purpose of restoring metal thickness.

weld overlay: the application of weld metal that is different from the base metal for the purpose of a desired property (e.g., corrosion resistance, chloride resistance, etc.).

101-3.3 Administrative Requirements

For administrative requirements such as inspection, documentation, and quality control, the user is referred to an applicable post-construction code and to the jurisdictional requirements. In the absence of an applicable post-construction code or jurisdictional requirements, the owner of the pressure equipment or piping should establish the administrative requirements. A post-construction code is one that provides requirements and guidance for inspection and/or repair of equipment after it has been placed in service, and may include the references to the original construction code. Examples of post-construction codes include NB-23, API 510, API 570, and API 653.

101-3.4 Application

(a) Users of the articles contained in this Standard are cautioned that these articles have been developed generically and are recommended for general applications. They may not necessarily be suitable for all applications. Precautionary considerations are provided, but should not be considered all inclusive. Sound *engineering practices and judgment* should be used to determine the applicability of a specific method or part of a method to a specific application. The phrase *engineering practices and judgment* refers to technical judgments made by knowledgeable engineers or subject-matter experts experienced in the application of repair practices. *Engineering judgments* shall be consistent with good engineering practices, and such judgments shall never be used to overrule mandatory requirements or specific prohibitions of this Standard. Each repair should be subject to an appropriate review by qualified personnel, and this review should consider subsequent deterioration of the repaired component.

(b) Additional limitations and considerations are contained in section 2 of the individual articles.

(c) The repair methods provided in the articles in this Standard are applicable to a variety of damage mechanisms. Examples of damage mechanisms may be found in API Recommended Practice 571. Other applications of repair for damage mechanisms are provided for in individual articles.

101-3.5 Alternative Use

While this Standard covers repair of equipment within the scope of ASME Pressure Technology Codes and Standards, it may be used on equipment constructed in accordance with other Codes and Standards.

101-3.6 Articles' Independence

Individual articles in this Standard may be used independently of other articles, except when otherwise noted. However, Part 1 applies to all articles in this Standard.

101-3.7 Repair Life

Many of the repair techniques included in this Standard are considered to be permanent, intended to remain in place for the life of the repaired component. Others may only be suitable for short-term service, and should be replaced with a more permanent repair at an appropriate opportunity. The anticipated life of a repair depends on many circumstances, and could include consideration of risk. As such, this Standard does not classify repair methods as permanent or temporary. Rather, technical considerations that affect the expected life of the repair are stated in the individual articles.

101-3.8 Code References

Reference to specific codes is generally avoided in this Standard because the equipment or piping could have been constructed in accordance with a number of different codes. Where such a reference is provided, it is generally the intent to include, by reference, a specific technical provision.

101-3.9 Welding

Requirements for welding, including qualification of welding procedures, welders, and welding operators should generally follow an applicable construction code or post-construction code, except when otherwise specified herein.

101-3.10 Allowable Stress

Calculations involving the allowable stress use the allowable stress from the original construction code or post-construction code, unless otherwise specified in specific articles.

101-3.11 Examination

When qualifications of examiners, methods of examination, extent of examination, and acceptance criteria are not specified, they should follow the requirements of an applicable construction code or post-construction code.

101-3.12 Records

The owner should keep records that document the repair. Specific requirements for documentation are not provided in this Standard. The owner should retain records that comply with applicable jurisdictional and post-construction code requirements. Documentation may include such items as a description of the condition that required attention and its cause, repair procedures that were used, photos prior to and after the repair, examination procedures and records, heat treatment records, test records, and the names of the persons/firms performing the repair and examination and their certification. The documentation forms part of the history of the pressure component and should be retained as long as it is relevant.

PART 2
WELDED REPAIRS

Article 201
Butt-Welded Insert Plates in Pressure Components

201-1 DESCRIPTION

201-1.1 General Considerations

The repair of pressure components by butt-welded insert plates involves the replacement of pressure boundary material in a pressure component with an insert plate attached by full penetration butt welds. This repair method is applicable to cylindrical, spherical, and conical shells and to flat pressure components. It may be used for single and double curvature shells. It may also be used on other pressure components (such as formed heads) if the curvature of the replaced section matches the curvature of the original pressure part. It is not limited by the size of the pressure component, except where practical considerations preclude the use of an insert, such as on small diameter pipe or tube. It may be used on small diameter pressure components if special care is taken to ensure a close fit of the insert plate and the existing pressure component and that the repaired pressure component meets the tolerance requirements of the applicable construction code.

201-1.2 Replacement of Local Areas in Pressure Vessel Shells or Pipe Walls

This repair method is intended to be used to replace portions of pressure-retaining vessel shells or pipe walls that have been damaged by cracks, local wall thinning from erosion, corrosion, and other damage mechanisms. The insert plate may contain one or more nozzles/manways.

201-1.3 Replacement of Entire Component

Replacement of an entire component, shell plate, or a complete shell course of a cylindrical shell, or a complete circular segment of a sphere, or a complete head, or a section of a pipe is not considered in this repair method.

201-2 LIMITATIONS

201-2.1 Part 1 of This Standard

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

201-2.2 Additional Considerations and Limitations

When applying this repair method, consideration shall be given to compatibility of materials, operating conditions for the intended life of the component, fitting and welding to minimize the residual stresses and distortions, and any limitations on nondestructive examination and pressure testing.

201-2.3 Loadings

This method may be used for equipment subject to either internal or external pressure. If the pressure component is subject to external pressure, additional consideration shall also be given to any loss of buckling strength as a result of permanent distortions or misalignment in the repaired component. If the pressure component is subject to cyclic loading, additional consideration shall be given to the effect of permanent distortions on the fatigue life of the repaired component.

201-2.4 Corrosion-Resistant Weld Overlay or Cladding

This repair method may also be used in vessels that are either clad with corrosion-resistant lining or weld overlay. The insert plate cladding or weld overlay shall be compatible with the existing materials and suitable for the intended service. Consideration shall also be given to the use of weld details and welding procedures suitable for the intended service.

201-2.5 Dissimilar Metals

Use of dissimilar materials (base metal and welds) is not prohibited, but the materials shall meet the required minimum mechanical properties for the pressure component and shall be carefully evaluated for compatibility between the dissimilar materials and the service environment, both internal and external. If thermal fatigue is a possibility, consideration shall be given to the potential for accelerated fatigue cracking in the dissimilar metals combination.

201-3 DESIGN

201-3.1 Construction Code

The insert plate thickness, material, and welds shall meet the design requirements in the applicable construction code for the existing pressure component into which it is being installed and shall be consistent with the joint efficiency or joint quality factors used in the original design, except as permitted in para. 201-3.3. The allowable stresses shall be the same as in the applicable construction code for the existing component.

201-3.2 Materials

Insert plates and welds should be of the same material as the existing pressure component, or of another material that has at least equal notch toughness and allowable stress, conforms to the requirements of the applicable construction code, and is suitable for the intended service. Where ASME materials are used, the replacement material should have the same ASME P-Number designation as the pressure component material into which the insert is being installed.

201-3.3 Insert Plate Thickness

The insert plate thickness should be not less than the nominal thickness of the material it welds into. If a thinner insert plate than the nominal thickness of the material it welds into must be used, it shall be evaluated for the intended service (such as fatigue due to cyclic loading) using the rules in the applicable construction code for the pressure component, or the applicable post-construction code. See para. 201-4.1.5.

201-3.4 Rectangular and Square Insert Plates

Rectangular and square insert plates shall have corners rounded to a radius, except when the entire shell plate is replaced. Rectangular and square insert plates 13 mm (½ in.) thick and up to and including 25 mm (1 in.) thick should have a 75 mm (3 in.) or a larger corner radius. Insert plates less than 13 mm (½ in.) thick may have smaller corner radii. Insert plates over 25 mm (1 in.) thick should have a 150 mm (6 in.) or a larger corner radius.

201-3.5 Flush Inserts

Flush inserts in pipe or tube may be round or oblong cutouts, as shown in Figure 201-3.5-1, or rectangular cutouts with rounded corners.

201-3.6 Insert Plate Size

The insert plate shall be of sufficient size to replace the entire area of the existing pressure component that has been assessed as not being fit for continued operation and to ensure that all welds are in sound material.

201-3.6.1 Minimum Size of Insert Plates. The minimum diameter, or length and width dimensions of nonpostweld heat-treated, butt-welded carbon and low alloy steel insert plates shall be the lesser of $12t$ or 380 mm (15 in.) (where t is the thickness of the parent material). See para. 201-3.8.

201-3.7 Structural Stability at Cutouts

Consideration should be given to structural stability and possible distortion of the unsupported plate edges of large openings (cutouts) in the vessel shell. An assessment should be made for the need of temporary supports around the unsupported edges of such openings during removal of the shell section to be replaced with an insert plate. The assessment shall consider all loading conditions that may occur on the vessel and the component during the repair, including structural stability of vessels during postweld heat treatment (PWHT).

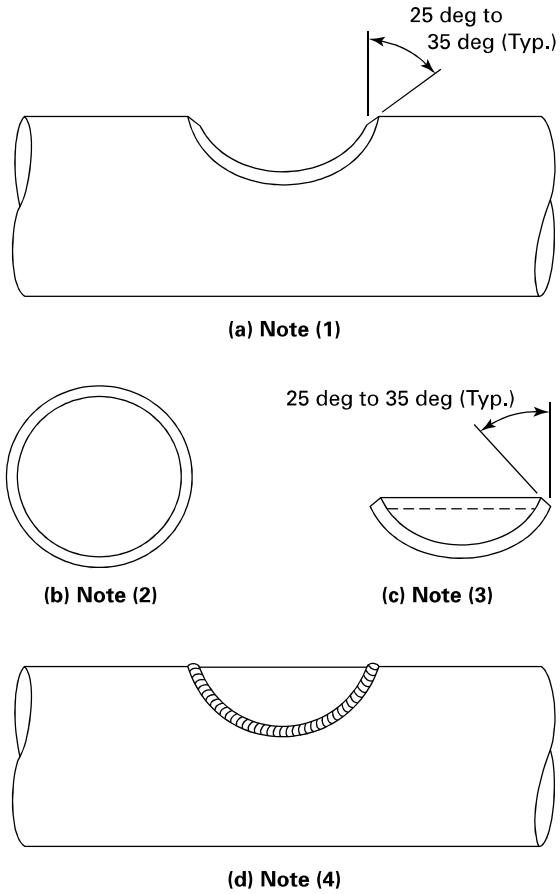
201-3.8 Insert Plates With Nozzles

The nozzle/manway reinforcement in insert plates with nozzles shall meet the design requirements and weld details of the applicable construction code for the pressure component. The minimum diameter of insert plate with a nozzle shall be the larger of the following:

(a) for all nozzle/manway assemblies, the diameter of the nozzle/manway penetration plus the width needed for nozzle reinforcement and any edge bevels.

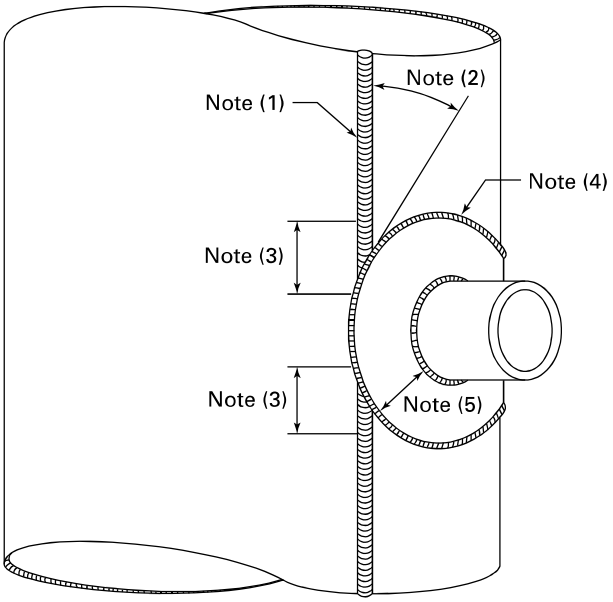
(b) for carbon and low alloy steel nozzle/manway assemblies for which the nozzle-to-butt patch (shell) weld is not postweld heat treated before or after the assembly is welded into the shell, the diameter of the insert plate needed to maintain a minimum distance of 150 mm (6 in.) between the nozzle attachment weld and the nearest edge of the insert plate butt weld. However, the diameter of the insert plate for nozzles having an outside diameter 300 mm (12 in.) or smaller need not be larger than 2 times the outside diameter of the nozzle. (See also Figures 201-3.8-1 and 201-3.8-2.)

Figure 201-3.5-1
Flush Insert in Pipe or Tube



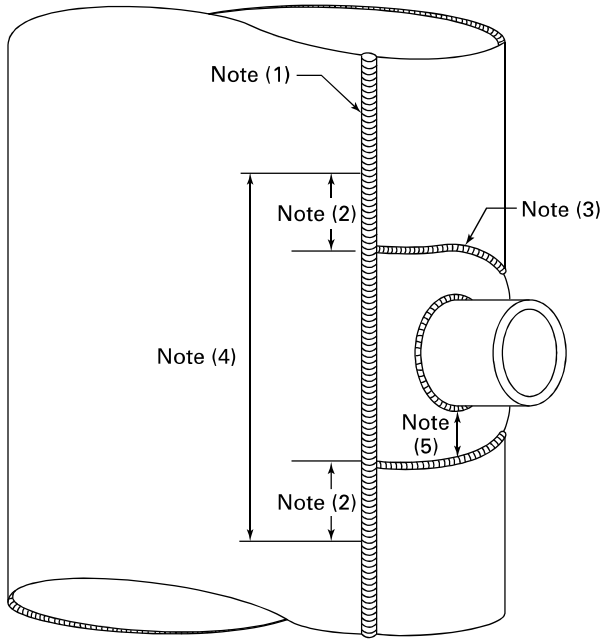
NOTES:
(1) Side view of cutout in pipe or tube with edge bevels. [Illustration (a) shows single-grooved joint detail with 25 deg to 35 deg edge bevel in pipe or tube. Other joint details and edge bevels may be used, as appropriate for a particular weld joint.]
(2) Plan view of insert with edge bevels. [Illustration (b) shows an insert with one-sided joint detail.]
(3) Side view of the insert with edge bevels. (Other joint details and edge bevels may be used, as appropriate for a particular weld joint.)
(4) Side view of welded insert in pipe or tube.

Figure 201-3.8-1
Flush Insert Plate (With or Without Nozzle/Manway) With Its Butt Weld Intersecting Existing Butt Weld in Shells or Heads



NOTES:
(1) Existing butt weld in vessel shell or head. (This figure shows butt weld in a cylindrical shell.)
(2) Thirty deg minimum angle.
(3) Full RT or UT, or MT or PT both sides of existing butt weld, 100 mm (4 in.) min. each side of intersection with insert plate.
(4) Insert plate butt weld. Full RT or UT, or MT or PT both sides of weld.
(5) See para. 201-3.8.

Figure 201-3.8-2
Intersecting "Doghouse" Type Insert Plate Butt Weld (With or Without Nozzle/Manway) With Shell Butt Weld in Vessel Shells and Heads



NOTES:
(1) Existing butt weld in vessel shell or head. (This figure shows butt weld in a cylindrical shell.)
(2) Length of cut in shell butt weld, 150 mm (6 in.) minimum on each side of intersecting insert plate butt weld.
(3) Insert plate butt weld.
(4) Cut existing shell butt weld to 150 mm (6 in.) minimum on each side of intersecting insert plate butt weld and bevel edges (or arc gouge edges) to the desired edge bevels. Reweld after completion of insert plate butt weld. Full RT or UT, or MT or PT both sides of new weld.
(5) See para. 201-3.8.

201-4 FABRICATION

201-4.1 Cutting and Forming

201-4.1.1 Edge Bevels. Edge bevels in the insert plate and in the pressure component may be prepared by thermal cutting, arc gouging, machining, or grinding. The method should be appropriate for the material and welding process(es) used.

All edges prepared for welding shall be examined to the requirements of the applicable construction code or post-construction code for the pressure component being repaired. All unacceptable indications shall be repaired to the requirements of the applicable construction code or post-construction code.

201-4.1.2 Forming. Forming the insert plate to the desired shape may be accomplished by any process that does not impair the properties of the plate material. It may be rolled or pressed to the proper curvature such that it conforms to the curvature of the vessel shell after it has been installed and welded into the vessel shell, pipe, or tube. For pipe or tube inserts, the insert may also be cut from another piece of pipe or tube of the same diameter and thickness as the pipe or tube to be repaired. Thicker pipe or tube inserts may be used, provided they meet the requirements of para. 201-4.1.5.

201-4.1.3 Forming Strains in Carbon and Low Alloy Steels. Carbon steel and low alloy steel insert plates should be heat treated (stress relieved, normalized, or quenched and tempered, if appropriate) subsequently when the resulting extreme fiber elongation during cold forming is more than 5%, as determined by the following formulas:

(a) For single curvature shells (cylinders)

$$\text{percent extreme fiber elongation} = \frac{50t}{R_f}\left(1 - \frac{R_f}{R_o}\right), \%$$

(b) For double curvature (heads and spherical shells),

$$\text{percent extreme fiber elongation} = \frac{75t}{R_f}\left(1 - \frac{R_f}{R_o}\right), \%$$

where
R_f = final centerline radius, mm (in.)
R_o = original centerline radius, mm (in.). (Radius equals infinity for flat plate.)
t = plate thickness, mm (in.)

As an alternative, the rules of the original construction code may be used.

201-4.1.4 Forming Strains in Other Materials. Cold-forming strains (e.g., from bending) in materials other than carbon and low alloy steel shall not exceed the limitations in the applicable construction code without a subsequent heat treatment.

201-4.1.5 Alignment at Edges of Insert Plate. The alignment at edges of the insert plate butt weld shall be such that the maximum offset is within the limitations of the applicable construction code for the pressure component. If the insert plate thickness exceeds these limitations, the edge(s) of the insert plate shall have a tapered transition having a length not less than 3 times the offset between the adjacent surfaces of abutting sections.

201-4.2 Welding

201-4.2.1 Welded Joints. The weld between the insert plate and the existing pressure component shall be a full penetration butt weld. Where possible, double-welded butt joints should be used.