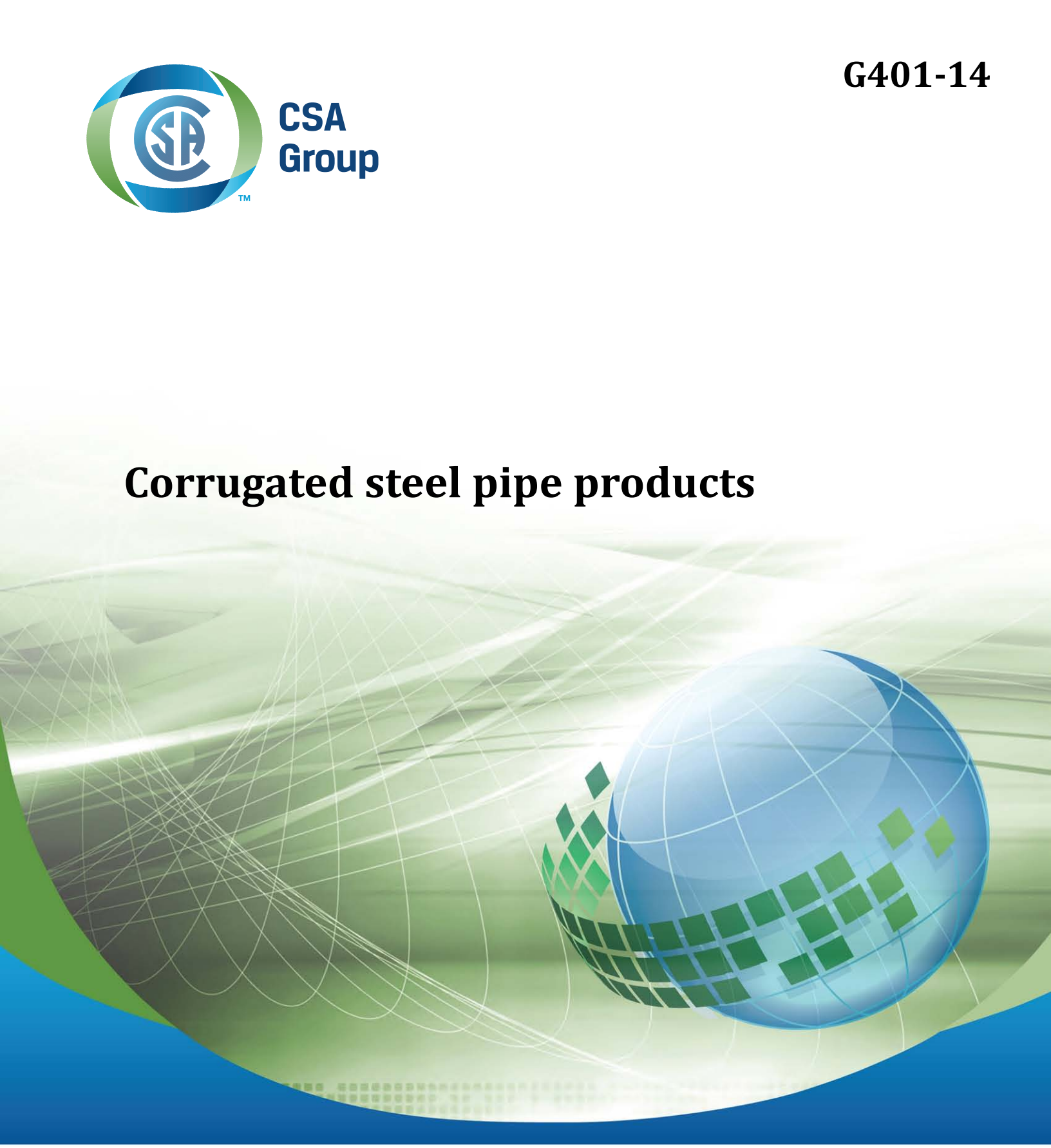
CSA Group

G401-14

Corrugated steel pipe products



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G401-14
March 2014

Title: *Corrugated steel pipe products*

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G401-14
Corrugated steel pipe products

Published in March 2014 by CSA Group
A not-for-profit private sector organization
5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada L4W 5N6

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ISBN 978-1-77139-395-9

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Preface

This is the fifth edition of CSA G401, *Corrugated steel pipe products*. It supersedes the previous editions, published in 2007, 2001, 1993, and 1981.

Changes have been made to this Standard to permit materials, manufacturing methods, and inspection procedures that meet appropriate current and projected industry practices. These changes include the following:

a) adding requirements for structural plate Type II, deep corrugated structural plate Type III, and tunnel liner plate corrugated steel pipe (CSP) products, including product specifications, sheet layout, and installation requirements;
b) adding requirements for polymer coating for structural plate products;
c) adding requirements for flange connections for structural plate and deep corrugated structural plate Types I and III;
d) changing requirements for chemical limits of structural plate;
e) adding requirements for alternative fasteners for applications in more aggressive environments;
f) removal of the requirements for asphalt and mastic coatings; and
g) updating the list of reference standards in Clause 2.

This Standard is considered suitable for use for conformity assessment within the stated scope of the Standard.

The development of this Standard was made possible thanks to the leadership and financial support of the Corrugated Steel Pipe Institute (CSPI). Such support does not indicate endorsement of the contents of this Standard.

This Standard was prepared by the Technical Committee on Corrugated Steel Pipe Products, under the jurisdiction of the Strategic Steering Committee on Construction and Civil Infrastructure, and has been formally approved by the Technical Committee.

Notes:

1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*

2) *Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*

3) *This Standard was developed by consensus, which is defined by* CSA Policy governing standardization — Code of good practice for standardization *as "substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity". It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this Standard.*

4) *To submit a request for interpretation of this Standard, please send the following information to* ***inquiries@csagroup.org*** *and include "Request for interpretation" in the subject line:*

a) *define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;*
b) *provide an explanation of circumstances surrounding the actual field condition; and*
c) *where possible, phrase the request in such a way that a specific "yes" or "no" answer will address the issue.*

Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization *and are available on the* Current Standards Activities *page at* ***standardsactivities.csa.ca****.*

5) *This Standard is subject to review five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to* ***inquiries@csagroup.org*** *and include "Proposal for change" in the subject line:*

a) *Standard designation (number);*
b) *relevant clause, table, and/or figure number;*

c) *wording of the proposed change; and*
d) *rationale for the change.*

G401-14
Corrugated steel pipe products

1 Scope

1.1
This Standard specifies material and fabrication requirements for corrugated steel pipe, spiral rib pipe, structural plate corrugated steel pipe products, and two-flange tunnel liner plate.

1.2
This Standard applies to the use of corrugated steel pipe, spiral rib pipe, and structural plate corrugated steel pipe for applications such as culverts, storm sewers, sanitary sewers, subdrains, ground recharge systems, well casings, underpasses, stream enclosures, shelters, and tunnels.

1.3
This Standard does not include requirements for hydraulic design, service life, structural design, construction, or installation.

1.4
In this Standard, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the standard.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material.

Notes to tables and figures are considered part of the table or figure and may be written as requirements.

Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

2 Reference publications
This Standard refers to the following publications, and where such reference is made, it shall be to the edition listed below, including all amendments published thereto.

CSA Group

G40.20-13/G40.21-13
General requirements for rolled or welded structural quality steel/Structural quality steel

CAN/CSA-G164-M92 (withdrawn)
Hot dip galvanizing of irregularly shaped articles

G189-1966 (withdrawn)
Sprayed metal coatings for atmospheric corrosion protection

W47.1-09
Certification of companies for fusion welding of steel

W59-13
Welded steel construction (metal arc welding)

ASTM International

A31-04 (2009)
Standard Specification for Steel Rivets and Bars for Rivets, Pressure Vessels

A90/A90M-13
Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

A153/A153M-09
Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A307-12
Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength

A370-12a
Standard Test Methods and Definitions for Mechanical Testing of Steel Products

A428/A428M-10
Standard Test Method for Weight [Mass] of Coating on Aluminum-Coated Iron or Steel Articles

A449-10
Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use

A563-07a
Standard Specification for Carbon and Alloy Steel Nuts

A563M-07
Standard Specification for Carbon and Alloy Steel Nuts [Metric]

A568/A568M-13
Standard Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

A635/A635M-09b
Standard Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for

A742/A742M-13
Standard Specification for Steel Sheet, Metallic Coated and Polymer Precoated for Corrugated Steel Pipe

A751-11
Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A754/A754M-11
Standard Test Method for Coating Weight (Mass) of Metallic Coatings on Steel by X-Ray Fluorescence

A792/A792M-10
Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process

A924/A924M-13
Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process

A929/A929M-01(2007)
Standard Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe

A1011/A1011M-12b
Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength

A1018/A1018M-10
Standard Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Carbon, Commercial, Drawing, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength

B6-13
Standard Specification for Zinc

B117-11
Standard Practice for Operating Salt Spray (Fog) Apparatus

B633-13
Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel

B695-04 (2009)
Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

C361M-12
Standard Specification for Reinforced Concrete Low-Head Pressure Pipe [Metric]

D522-93a (2008)
Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings

D543-06
Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents

D610-08 (2012)
Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces

D714-02 (2009)
Standard Test Method for Evaluating Degree of Blistering of Paints

D870-09
Standard Practice for Testing Water Resistance of Coatings Using Water Immersion

D1005-95 (2013)
Standard Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

D1056-07
Standard Specification for Flexible Cellular Materials — Sponge or Expanded Rubber

D1308-02 (2013)
Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes

D2247-11
Testing Water Resistance of Coatings in 100% Relative Humidity

D2794-93 (2010)
Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)

D3170-12
Standard Test Method for Chipping Resistance of Coatings

D3359-09e2
Standard Test Methods for Measuring Adhesion by Tape Test

D3363-05 (2011)e2
Standard Test Method for Film Hardness by Pencil Test

D4060-10
Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser

D4541-09e1
Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

E376-11
Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Testing Methods

F1554-07ae1
Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

F2329-13
Standard Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

G8-96 (2010)
Standard Test Methods for Cathodic Disbonding of Pipeline Coatings

G22-76 (1996) (withdrawn)
Standard Practice for Determining Resistance of Plastics to Bacteria

G23-96 (withdrawn)
Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials

G62-07 (2013)
Standard Test Methods for Holiday Detection in Pipeline Coatings

G154-12a
Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for UV Exposure of Nonmetallic Materials

CGSB (Canadian General Standards Board)

CAN/CGSB 1.181-99 (withdrawn)
Ready-Mixed Organic Zinc-Rich Coating

General Motors (GM)

GM9506P (1988)
Dime Scrape Test to Determine Paint Adhesion and Brittleness

GM9507P (2011)
Thumbnail Hardness Test for Painted Parts

ISO (International Organization for Standardization)

898-1:2013
Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs with specified property classes — Coarse thread and fine pitch thread

898-2:2012
Mechanical properties of fasteners made of carbon steel and alloy steel — Part 2: Nuts with specified property classes — Coarse thread and fine pitch thread

Québec Ministry of Transportation

LC 21-102 (2008)
Aggregate Polishing Resistance: Projection Method

SAE International

J429 (2013)
Mechanical and Material Requirements for Externally Threaded Fasteners

J995 (2012)
Mechanical and Material Requirements for Steel Nuts

J2334 (2003)
Laboratory Cyclic Corrosion Test

3 Definitions and abbreviations

3.1 Definitions

The following definitions shall apply in this Standard:

Aluminized coating — a coating of commercially pure aluminum applied to the surfaces of steel sheet using the hot-dip process.

Aluminum-zinc alloy coating — a coating that is 55% aluminum by weight and 1.6% silicon, with the remainder zinc, applied to the surface of a steel sheet using the hot-dip process.

Arch — corrugated steel sheets or plates formed to an arch shape and placed on footings. The invert can be the natural stream bed or any other suitable material but is not integral to the steel arch.

Base steel thickness — the steel thickness without a metallic or other protective coating.

Circumferential seam — a connection seam along the edge of the plate parallel to the corrugation.

Connections —

Note: *Structural plate is connected using a variety of methods to form pipes, arches, pipe-arches, and other shapes.*

> **Circumferential flange connection** — a circumferential seam that is connected through a flange along the edge of the plate.
> **Note:** *Circumferential flanges are cold-formed.*
>
> **Lap connection** — connection between structural plates that overlap.
>
> **Longitudinal flange connection** — a longitudinal seam that is connected through a flange along the edge of the plate.
> **Note:** *Longitudinal flanges are welded to structural plate.*

Corrugated steel pipe — metallic-coated sheet steel formed to finished sinusoidal corrugation and shape by the fabricator.

Note: *Unless otherwise noted, when corrugated steel pipe is specified in this Standard, the reference also applies to spiral rib steel pipe.*

> **Bolted corrugated steel pipe** — corrugated steel pipe that has annular corrugations, is fabricated from cut-to-length corrugated steel pipe sheet, and has longitudinal and circumferential seams fastened with bolts and nuts.
>
> **Helical corrugated steel pipe** — corrugated steel pipe that has helical corrugations, is fabricated from coiled corrugated steel pipe sheet, and has a continuous helical lockseam.
>
> **Riveted corrugated steel pipe** — corrugated steel pipe that has annular corrugations, is fabricated from cut-to-length corrugated steel pipe sheet, and has lapped longitudinal and circumferential seams fastened with rivets.

Corrugated steel pipe sheet — metallic-coated mill product in sheet or coil form for fabricating bolted, riveted, or helical corrugated steel pipe and spiral rib steel pipe products.

Coupler — a system for joining two sections of corrugated steel pipe. Couplers in standard use include corrugated band, flat band, semi-corrugated band, and universal dimple band types.

> **Corrugated band** — a fully corrugated band with annular corrugations.

Flat band — a one-piece or two-piece band that does not have corrugations or projections, has bolt or wedge fastening, and is normally used with small-diameter corrugated steel pipe.

Semi-corrugated band — an annular band coupler with both corrugations and flat portions.

Universal dimple band — a flat band with indentations designed to match the corrugation profile of helical and annular corrugated steel pipe.

Deep corrugated structural plate — corrugated hot-rolled sheets or plates that have pitches between 380 and 500 mm and depths between 140 and 237 mm and are curved to radius, custom hot-dip galvanized or polymer coated, assembled, and bolted together to form arches, box culverts, and other shapes.

Type I — a deep corrugated structural plate with a 381 × 140 mm corrugation.

Type II — a deep corrugated structural plate with a 400 × 150 mm corrugation.

Type III — a deep corrugated structural plate with a 500 × 237 mm corrugation.

Note: *Unless otherwise noted, when structural plate corrugated steel is specified in this Standard, the reference also applies to deep corrugated structural plate. When deep corrugated structural plate is specified in this Standard without specific reference to Type I, Type II, or Type III, all types are included.*

Diameter — the inside diameter, measured between the inside crests of corrugations or on the flats between ribs.

Ellipsed — structural plate corrugated steel pipe that is factory formed to an elliptical shape.

Equivalent diameter — the diameter of a round corrugated steel pipe from which a pipe-arch or other shape is formed.

Fabricator — the manufacturer of corrugated steel pipe or structural plate corrugated steel pipe products. The premises of a manufacturer are referred to as the fabricating plant.

Invert — the interior lower segment of a pipe.

Longitudinal seam — a connection seam along the edge of the plate perpendicular to the corrugation.

Mill — the base steel producer of sheet, structural plate, and protective-coated sheet and plate for the fabrication of pipe products.

Nominal thickness — the order thickness. For corrugated steel pipe sheet, nominal thickness includes the base steel and metallic coating. For structural plate corrugated steel pipe sheet and plate, the nominal thickness is the base steel thickness and excludes the metallic coating.

Perforated pipe — corrugated steel pipe product with perforations completely through the pipe wall.

Fully perforated pipe — pipe with perforations around the periphery, usually for recharge of storm water to ground.

Invert-perforated pipe — pipe with perforations in the lower segment, usually for subdrainage.

Pipe-arch — pipe shaped to a span greater than the rise, in a multi-radius shape with an arch-shaped top and a slightly convex (when viewed from inside the structure) integral bottom.

Polymer laminate coating — an organic barrier coating heat laminated to both sides of a metallic-coated flat sheet before fabrication.

Protective coating — an organic coating, e.g., mastic, applied to a pipe or plate post fabrication in addition to the standard metallic protection.

Purchaser — a specifier, agency, individual, or authorized representative purchasing or specifying pipe products.

Rise — the maximum inside vertical distance at the centreline of a pipe cross-section, measured between the inside crests of corrugations or on the flats between ribs.

Span — the maximum inside horizontal distance between the sidewalls of a pipe cross-section, measured between the inside crests of corrugations or on the flats between ribs.

Spiral rib steel pipe — metallic-coated sheet steel formed to finished shape by the fabricator. It has a full circular cross-section that is fabricated with helical ribs projecting outward and is reformable into a pipe-arch shape.

Type I — spiral steel rib pipe with 19 × 19 × 190 mm rectangular ribs.

Type II — spiral steel rib pipe with 19 × 19 × 190 mm quadrangular ribs and inserts.

Note: *Unless otherwise noted, when corrugated steel pipe is specified in this Standard, the reference also applies to spiral rib steel pipe.*

Structural plate corrugated steel — hot-rolled sheets or plates that are corrugated, curved to radius, custom hot-dip galvanized or polymer coated, assembled, and bolted together to form pipes, arches, pipe-arches, and other shapes.

Type I — a corrugated structural plate with a 152 × 51 mm corrugation.

Type II — a corrugated structural plate with a 230 × 64 mm corrugation.

Note: *Unless otherwise noted, when structural plate corrugated steel is specified in this Standard, the reference also applies to deep corrugated structural plate and two-flange steel tunnel liner plate. When structural plate is specified in this Standard without specific reference to Type I or Type II, all types are included.*

Subdrain — corrugated steel pipe conduit that is usually invert-perforated and is designed to collect and remove or control groundwater.

Swage — a manufacturing process in which one end of a tunnel liner plate is offset a distance equal to the thickness of the plate across its full width. Swaged ends are used to allow a continuous cross-section of adjoining plates through the bolted longitudinal plate seam overlap.

Thermoplastic copolymer coating (polymer coating) — an organic barrier coating that is formed, set, and bonded to the plate or pipe after fabrication in the presence of heat in a controlled environment.

Tunnel liner plate — a segmental plate product similar to structural plate corrugated steel and fabricated with plate connections and reduced plate sizes that permit complete assembly from the inside of the structure.

Zinc coating — a galvanic barrier coating applied to the surfaces of steel sheet, plate, or other components.

3.2 Abbreviations

The following abbreviations shall apply in this Standard:

CSP	—	corrugated steel pipe
DCSP	—	deep corrugated structural plate
EAA	—	ethylene acrylic acid
SPCSP	—	structural plate corrugated steel pipe
SRP	—	spiral rib pipe
SST	—	single spot test
TLP	—	tunnel liner plate
TST	—	triple spot test

4 Materials

4.1 Steel

4.1.1 General

4.1.1.1

Steel shall be produced by the electric or basic oxygen process.

4.1.1.2

Steel shall have the chemical composition specified in Table 1.

4.1.2 Heat analysis

4.1.2.1

An analysis of each heat or cast for corrugated steel pipe products shall be made by the mill to determine the percentages of elements specified in Table 1. The analysis shall be made from a test sample taken during the casting of the heat.

4.1.2.2

The mill shall keep a record of each analysis on file for at least seven years. For corrugated steel pipe, the record shall be traceable by heat or coil number. Copies of the record shall be made available to the fabricator on request.

4.1.3 Product analysis

Product analysis and product sampling of the steel shall not vary from the appropriate tolerance limits or analysis requirements specified in

a) ASTM A929/A929M for zinc, 55% aluminum-zinc, and aluminum;
b) ASTM A568/A568M or ASTM A635/A635M for structural plate corrugated steel pipe products;
c) ASTM A1011/A1011M or ASTM A1018/A1018M for deep corrugated structural plate products; and
d) CSA G40.20/G40.21 for longitudinal flange material.

Note: *For Items b) and c), the thickness of the plate dictates which Standard is used.*

4.1.4 Referee analysis

Where a referee analysis is required to resolve a dispute concerning the results of a chemical product analysis, the procedure for performing the referee analysis shall be in accordance with ASTM A751 unless otherwise agreed by the disputing parties.

4.1.5 Mechanical properties of structural plate

4.1.5.1

Steel used for manufacturing structural plate products shall have the mechanical properties specified in Table 2.

4.1.5.2

Mechanical tests shall be conducted in accordance with ASTM A370.

4.1.5.3

The mill shall keep a record of the mechanical properties by heat number on file for at least seven years. Copies of the record shall be made available to the fabricator on request.

4.2 Corrugated steel pipe and spiral rib steel pipe sheet

4.2.1 Material

4.2.1.1

Steel sheet in coils or cut lengths for corrugated steel pipe shall comply with Clauses 4.1.1 to 4.1.4.

4.2.1.2

Steel sheet in coils or cut lengths for corrugated steel pipe shall be zinc, aluminum, or 55% aluminum-zinc coated using a continuous hot-dip process. The metallic coating shall comply with Clause 4.5.1, 4.5.2, or 4.5.3, as applicable. If aluminum or 55% aluminum-zinc coating is not specified in the order, zinc-coated sheet shall be used.

4.2.1.3

Steel sheet in coils and cut lengths for corrugated steel pipe shall be ordered to the nominal thicknesses specified in Table 3.

Note: *See Annex A.*

4.2.1.4

Thickness shall be measured at a point on the sheet at least 10 mm from an edge and, for fabricated pipe, on a corrugation tangent or the flat between ribs.

4.2.2 Tolerances

4.2.2.1

The thickness tolerances shall be as specified in Table 3.

4.2.2.2
The permissible variations in width, length, and camber of coils and cut lengths shall be as specified in ASTM A929/A929M.

4.2.2.3
Flatness tolerances shall apply to cut lengths only. For a specified thickness of 1.6 mm or greater, the maximum deviation from a horizontal flat surface shall not exceed 13 mm for a specified width less than or equal to 1500 mm. For a specified thickness less than 1.6 mm, the maximum deviation shall not exceed 13 mm for a width less than or equal to 900 mm and 19 mm for a width greater than 900 mm and less than or equal to 1500 mm.

4.2.3 Mill marking
Each sheet and each 600 to 1500 mm length of coil or strip shall be mill-marked. The marking shall remain legible for at least 24 months after the manufacturing date and include the following:
a) the brand or company name of the sheet manufacturer;
b) the metallic coating designation;
c) the nominal thickness of the sheet;
d) “CSA G401” or the designation of the applicable ASTM Standard; and
e) the coil number.

4.3 Structural plate and deep corrugated structural plate

4.3.1 Material

4.3.1.1
The base steel shall comply with Clause 4.1. Structural plate corrugated steel shall be custom hot-dip galvanized and comply with Clause 4.5.1.3 or be polymer coated and comply with Clause 4.5.5.

4.3.1.2
Structural plate shall be ordered to the nominal thicknesses specified in Table 4.

Note: *See Annex A.*

4.3.1.3
Thickness shall be measured at a point at least 20 mm from a longitudinal edge. Field measurements shall be made on a corrugation tangent.

4.3.2 Tolerances

4.3.2.1
The thickness tolerances shall be as specified in Table 4.

4.3.2.2
The width, length, and camber tolerances for sheet products shall be as specified in
a) ASTM A568/A568M or ASTM A635/A635M for structural plate pipe; or
b) ASTM A1011/A1011M or ASTM A1018/A1018M for deep corrugated structural plate.

4.3.3 Mill marking

Structural plate in secured lifts shall be identified by the mill name or brand, heat number, nominal mass, mill order number, and dimensions stencilled or marked on the top plate of each lift or shown on a durable tag attached to each lift.

4.4 Fasteners

4.4.1 Rivets

Rivets shall be ASTM A31, Grade A, and shall be zinc plated to ASTM B633, Type RS. Their form shall be as shown in Figure 1.

4.4.2 Bolts and nuts for structural plate

4.4.2.1

Bolts shall be M20 in diameter with a thread pitch of 2.5 (M20 × 2.5) or M22 in diameter with a thread pitch of 2.5 (M22 × 2.5). M16 bolts with a thread pitch of 2.0 (M16 × 2.0) may be used in circumferential flange connections. Tunnel liner plate shall have bolts not less than M16 in diameter with a thread pitch of 3.6 (M16 × 3.6).

4.4.2.2

Bolts should be ISO 898-1, Class 8.8. Alternative bolts with at least equivalent strength may be used as required by design. Typical bolts are shown in Figures 2 and 3. Tunnel liner plate bolts shall conform to ASTM A449 for plate thicknesses equal to or greater than 5.0 mm and ASTM A307 for thicknesses less than 5.0 mm.

4.4.2.3

Nuts should be Class 12 ASTM A563M or ISO 898-2. Alternative nuts with at least equivalent strength may be used as required by design. Typical nuts are shown in Figures 2 and 3. Tunnel liner plate nuts shall conform to ASTM A563, Grade A.

4.4.2.4

Bolts and nuts should be

a) galvanized in accordance with ASTM A153/A153M and ASTM F2329 or CAN/CSA-G164, Class 5; or
b) mechanically galvanized in accordance with ASTM B695, Class 55.

Alternative coatings may be used in more aggressive environments as required by design.

4.4.2.5

Anchorage bolts should be Class 4.6 ASTM F568M or ISO 898-1. Anchorage nuts should be Class 5 ASTM A563M or ISO 898-2. Alternative bolts with at least equivalent strength may be used as required by design.

4.4.2.6

M20 bolt heads shall be identified in accordance with Figure 2. M22 bolt heads shall be identified in accordance with Figure 3.

Notes:

1) *Washers are not required and in some instances can have a negative impact on performance.*

2) *Imperial-sized bolts and nuts meeting the chemical and mechanical requirements of ASTM A449 (bolts), ASTM F1554, Grade 36 (anchor bolts) and ASTM A563 (carbon and alloy steel nuts, Grade C) may be used until metric fasteners are available.*

4.5 Coatings

Note: *Selection of coatings is at the purchaser's discretion. The coatings are not necessarily equivalent for all applications.*

4.5.1 Zinc

4.5.1.1 Material

4.5.1.1.1

Zinc shall be as specified in ASTM B6 and at least equal to the grade designated "Prime Western".

4.5.1.1.2

The zinc coating mass (total on both sides) shall be not less than

a) 610 g/m^2 (industry designation Z610) when tested using the triple spot test (TST) or 550 g/m^2 when tested using the single spot test (SST); or
b) 915 g/m^2 (industry designation Z915) when tested using the TST or 820 g/m^2 when tested using the SST.

Note: *The TST and SST are defined in ASTM A924/A924M.*

4.5.1.1.3

Coating mass acceptance shall be determined using the non-destructive magnetic test methods specified in ASTM E376. In cases of dispute, the basis for rejection shall be the chemical stripping test specified in ASTM A90/A90M for corrugated steel pipe products and in CAN/CSA-G164 for structural plate products.

Notes:

1) *The* 610 g/m^2 *(TST) zinc mass (total on both sides) is equivalent to a* 43 µm *zinc thickness measured on one side using the magnetic test method. For 550 g/m^2 (SST), the equivalent is* 39 µm*.*

2) *The* 915 g/m^2 *(TST) zinc mass (total on both sides) is equivalent to a* 64 µm *zinc thickness measured on one side using the magnetic test method. For 820 g/m^2 (SST), the equivalent is* 58 µm*.*

4.5.1.2 Zinc coating for corrugated steel pipe sheet

4.5.1.2.1

Zinc used for continuous hot-dip galvanizing shall comply with Clause 4.5.1.1.1.

4.5.1.2.2

The zinc coating mass shall be as specified in Clause 4.5.1.1.2a).

4.5.1.2.3

Coating mass testing shall be performed in the manner specified in Clause 4.5.1.1.3.

4.5.1.2.4

Mill sampling, test methods, markings, and record retention shall comply with ASTM A924/A924M.

4.5.1.2.5
The coating shall adhere in such a manner that no peeling occurs while the material is being fabricated into the finished product.

4.5.1.2.6
The finish shall be continuous, reasonably smooth, and free from such imperfections as pits, blisters, gritty or uncoated areas, storage stains, acid or black spots, or dross particles adhering to the coating.

4.5.1.3 Zinc coating for structural plate and deep corrugated structural plate

4.5.1.3.1
Zinc used for coating of structural plate shall comply with Clause 4.5.1.1.1.

4.5.1.3.2
Molten zinc in the galvanizing bath shall contain not less than 98.5% zinc by mass. The aluminum content shall not exceed 0.01% by mass.

4.5.1.3.3
Structural plate shall be degreased, rinsed, pickled, and fluxed before zinc dipping, and quenched afterwards.

4.5.1.3.4
The zinc coating mass shall be as specified in Clause 4.5.1.1.2b). The zinc coating mass for steel tunnel liner plate shall be in accordance with CAN/CSA-G164.

4.5.1.3.5
Coating mass testing shall be performed in the manner specified in Clause 4.5.1.1.3.

4.5.1.3.6
The coating shall adhere as specified in CAN/CSA-G164.

4.5.1.3.7
The coating shall be free from injurious defects such as blisters, excessive flux, storage stains, foreign inclusions, and uncoated areas more than 3 mm wide. Uncoated areas that are more than 3 mm wide shall be repaired in accordance with Clause 6.2.

4.5.2 Aluminum

4.5.2.1 Material

4.5.2.1.1
Hot-dip aluminized coating shall be produced from a commercially pure aluminum bath, and the other elements in the bath shall conform to the limits specified in Table 5.

4.5.2.1.2
The aluminum coating mass (total on both sides) shall be not less than 305 g/m^2 (industry designation T2 305) when tested using the TST or 275 g/m^2 when tested using the SST.

Note: *The* 305 g/m² *(TST) aluminum mass (total both sides) is equivalent to a* 47 µm *aluminum plus alloy thickness measured on one side of* 1.6 mm *or thinner CSP using standard metallographic techniques. For* 275 g/m² *(SST), the equivalent thickness is* 43 µm *on one side of* 1.6 mm *or thinner CSP. For heavier thickness CSP, total coating thickness could be lower due to increased thickness of the dense alloy layer. Magnetic pull-off gauges can read 20% thinner than metallographic sections.*

4.5.2.1.3

Coating mass acceptance shall be determined using the non-destructive magnetic test methods specified in ASTM E376. In cases of dispute, the basis for rejection shall be the chemical stripping test specified in ASTM A428/A428M.

4.5.2.2 Aluminized coating for corrugated steel pipe sheet

4.5.2.2.1

Aluminum used for continuous hot-dip aluminizing shall comply with Clause 4.5.2.1.1.

4.5.2.2.2

The aluminum coating mass shall be as specified in Clause 4.5.2.1.2.

4.5.2.2.3

Coating mass testing shall be performed using the methods specified in Clause 4.5.2.1.3.

4.5.2.2.4

Mill sampling, test methods, markings, and record retention shall comply with ASTM A924/A924M.

4.5.2.2.5

The coating shall adhere in such a manner that no peeling occurs while the material is being fabricated into the finished product.

4.5.2.2.6

The finish shall be continuous, reasonably smooth, and free from such imperfections as pits, blisters, gritty or uncoated areas, storage stains, acid or black spots, or dross particles adhering to the coating.

4.5.3 55% aluminum-zinc alloy

4.5.3.1 Material

4.5.3.1.1

55% aluminum-zinc alloy shall comply with ASTM A792/A792M.

4.5.3.1.2

The 55% aluminum-zinc alloy coating mass (total on both sides) shall be not less than 210 g/m² (industry designation AZM210) when tested using the TST or 180 g/m² when tested using the SST.

4.5.3.1.3

Coating mass acceptance testing shall be performed using the X-ray fluorescence method specified in ASTM A754/A754M. In cases of dispute, the basis for rejection shall be the dilute hydrochloric acid method specified in ASTM A792/A792M.

Note: *The* 210 g/m² *(TST) 55% aluminum-zinc alloy mass (total on both sides) is equivalent to a* 28.5 µm *coating thickness measured on one side using the X-ray fluorescence test method. For* 180 g/m² *(SST), the equivalent is* 24.5 µm*.*

4.5.3.2 55% aluminum-zinc alloy coating for corrugated steel pipe sheet

4.5.3.2.1

55% aluminum-zinc alloy used for continuous hot-dip coating shall comply with Clause 4.5.3.1.1.

4.5.3.2.2

The 55% aluminum-zinc alloy coating mass shall be as specified in Clause 4.5.3.1.2.

4.5.3.2.3

Coating mass testing shall be performed as specified in Clause 4.5.3.1.3.

4.5.3.2.4

Mill sampling, test methods, markings, and record retention shall comply with ASTM A924/A924M.

4.5.3.2.5

The coating shall adhere in such a manner that no peeling occurs while the material is being fabricated into the finished product.

4.5.3.2.6

The finish shall be continuous, reasonably smooth, and free from such imperfections as pits, blisters, gritty or uncoated areas, storage stains, acid or black spots, or dross particles adhering to the coating.

4.5.4 Polymer laminate

4.5.4.1 Material

4.5.4.1.1

Polymer laminate, when specified, shall be applied to both sides of a corrugated steel pipe sheet.

4.5.4.1.2

Following galvanizing of flat steel sheet and before its conversion to corrugated steel pipe, polymer laminate shall be applied to the flat steel sheet using a continuous laminating process.

4.5.4.1.3

Polymer laminate shall comply with ASTM A742/A742M and be a film coating consisting of at least 85 wt% ethylene acrylic acid (EAA) copolymer.

4.5.4.1.4

When applied before forming, polymer laminate shall be capable of withstanding, without bruising or breaking, the forming involved in the corrugating, ribbing, riveting, lockseaming, or perforating of the sheet.

4.5.4.2 Classification and coating thickness

Polymer laminate shall be classified as Grade 250/250. The sheet shall be coated with polymer to a minimum thickness of 250 µm on each surface, unless otherwise agreed upon by the manufacturer and purchaser or fabricator.

4.5.4.3 Marking

Each sheet or 600 to 1500 mm length of polymer-laminated coil or strip shall be stencilled to include the following:

a) the brand or company name of the sheet manufacturer;
b) the metallic coating designation;
c) the thickness of the polymer laminate;
d) the nominal thickness of the metallic-coated sheet;
e) the coil number and date of coating; and
f) "CSA G401" or the designation of the applicable ASTM standard.

4.5.4.4 Repair

4.5.4.4.1

Damage to the zinc coating shall be repaired in accordance with Clause 6.2 before repair of the polymer coating.

4.5.4.4.2

Damage to the polymer coating shall be repaired in accordance with Clause 6.3 to match the properties and compatibility recommended by the manufacturer.

4.5.4.5 Inspection

4.5.4.5.1

Samples approximately 50 mm square, secured from fabricated pipe or coils of sheet used to fabricate pipe, shall be taken for a coating thickness check.

4.5.4.5.2

The thickness of the polymer coating on a flat sheet shall be determined in lots not greater than 15 t in accordance with ASTM D1005.

4.5.4.5.3

The thickness of the polymer coating on fabricated corrugated steel pipe shall be measured in lots not greater than 15 t using a micrometer, an eddy current thickness gauge, or any method with a minimum accuracy of ± 10 µm.

4.5.5 Thermoplastic copolymer coating

4.5.5.1 Material

4.5.5.1.1
The physical properties of the thermoplastic copolymer shall meet or exceed the results listed in Table 24.

4.5.5.1.2
Thermoplastic copolymer coating shall consist of at least 85 wt% EAA copolymer.

4.5.5.1.3
Thermoplastic copolymer coating, when specified, shall be applied to both sides of a corrugated steel plate.

4.5.5.1.4
Following fabrication of the corrugated steel plates, fittings, and components, the thermoplastic copolymer coating shall be applied in a controlled environment, using a continuous automated application process. The steel shall be free of rust, mill scale, and laser oxide prior to an eight-stage conversion coating pretreatment process to ensure proper adhesion of the coating system to the steel substrate. A zinc-rich primer with a minimum 60 wt% zinc content shall be applied before the EAA copolymer to promote adhesion and provide secondary corrosion resistance for the overall system.

4.5.5.1.5
Thermoplastic copolymer coated steel shall meet or exceed the performance requirements listed in Table 25.

4.5.5.2 Coating thickness
The material shall be coated to a minimum thickness of 250 µm on each surface, unless otherwise agreed upon by the manufacturer and the purchaser. The thickness of the polymer coating shall be determined at least once every 20 plates.

4.5.5.3 Marking
Plates shall be marked in accordance with Clause 5.2.7.1.

4.5.5.4 Repair
Damage to the thermoplastic copolymer coating shall be repaired in accordance with Clause 6.3.

4.5.5.5 Sampling and testing

4.5.5.5.1
All testing shall be conducted on verification panels supplied by the manufacturer that are consistent with the material listed Clause 4.1.

4.5.5.5.2
The exact coating process used for production material shall be followed for all verification panels, without any deviation from the process unless agreed upon by the purchaser and the manufacturer.

4.5.5.5.3
The manufacturer shall perform tests to verify that the coated material complies with the requirements listed in Table 25. For test requirements listed in Table 25, typical or documented external results may be used rather than results of tests on the specific lot of material.

5 Fabrication

5.1 Corrugated steel pipe and Types I and II spiral rib steel pipe

5.1.1 General

5.1.1.1 Forming
Corrugated steel pipe and spiral rib steel pipe shall be formed from sheet as specified in Clauses 4.1 and 4.2.

5.1.1.2 Corrugated steel pipe

5.1.1.2.1
Corrugated steel pipe shall have corrugations that form smooth continuous curves, as shown in Figure 4, in helical or annular rings about the pipe axis with the nominal inside diameters and profile dimensions specified in Table 6.

5.1.1.2.2
The profile radius of curvature, *R*, shall not be less than one-half the depth of the corrugation as shown in Figure 4.

5.1.1.2.3
The average pitch tolerance measurements taken at five adjacent corrugations shall be ± 3 mm, measured perpendicular to the corrugation as shown in Figure 4.

5.1.1.2.4
The average of the depth measurements taken at five adjacent corrugations shall be within ± 5% of the actual corrugation dimensions specified in Table 6. The corrugation depth shall be measured from outside crests to outside valleys, using a straightedge laid across two adjacent crests parallel to the pipe axis.

5.1.1.3 Types I and II spiral rib steel pipe

5.1.1.3.1
Type I spiral rib steel pipe shall have ribs in accordance with Figure 5, and Type II shall have ribs and coated steel inserts in accordance with Figure 6. The ribs and inserts shall be formed in helical rings about the pipe axis and have the nominal inside diameters and profile dimensions specified in Table 6.

For Type II spiral rib pipe, the corrugations shall be essentially rectangular ribs projecting outward from the pipe wall, but with the width of the rib opening on the inside surface of the pipe wall less than the width of the rib over the rest of the cross-section.

5.1.1.3.2
The average rib spacing shall be a maximum of 197 mm. The average rib spacing shall be calculated as an average of three adjacent rib spacings measured centre-to-centre of the ribs, at 90° to the direction of the ribs.

5.1.1.3.3
The average rib depth shall be at least 19 mm. The average rib depth shall be calculated as an average of three adjacent ribs measured from the inside of the pipe by placing a straightedge across the open rib and measuring to the bottom of the rib.

5.1.1.3.4
The rib width shall be at least 17 mm. The rib width shall be a dimension of the inside of the rib but measured on the outside of the pipe (outside of the rib). The measured rib width shall meet or exceed the minimum width plus twice the wall thickness.

5.1.1.3.5
The average of the two rib bottom radii (the radii at the flat-to-rib junction) measured outside the pipe shall be from 2.5 to 6.4 mm.

5.1.1.3.6
The average of the two rib top radii (the radii at the crest of the rib) measured outside the pipe shall be from 2.5 to 6.4 mm plus the wall thickness.

5.1.1.3.7
The Type II coated steel insert shall make continuous contact along the inside of the vertical legs on the rib (up to the radius of the insert), and the flat horizontal surface of the insert shall not extend into the inside surface of the interior pipe wall.

5.1.1.3.8
Coated steel inserts shall be of the same material specified for the pipe and shall have a coating of the same type and weight. An insert shall have a specified minimum thickness of 1.3 mm. Alternatively, when inserts fabricated from polymer laminate sheet are specified, the metallic-coated steel insert shall have a specified minimum thickness of 1.0 mm. When specified in the order, the coated steel insert shall be fabricated from polymer laminate sheet complying with Clause 4.5.4.

5.1.1.3.9
Coated steel inserts shall be formed before insertion into the open rib on the interior surface of the pipe wall and shall be crimped into place. The inserts shall be placed so that they do not become dislodged during normal handling, installation, and use of the finished pipe product.

5.1.1.3.10
After pipe fabrication but before annular rerolling of ends, the fabricator shall inspect the coated steel inserts at each end of the pipe and establish that they are secure and not easily dislodged. This inspection shall be conducted using a 13 × 13 × 200 mm steel bar and a 1.0 kg, 250 mm long ball-peen hammer. Systematically positioning each insert at the pipe invert, the fabricator shall place one end of the steel bar squarely against the underside of the insert at an angle of approximately 45° below the invert and then strike three medium blows against the opposite end of the steel bar in an attempt to dislodge the insert. Using the same steel bar and hammer, the fabricator shall then place the steel bar

vertically on top of the insert inside the pipe and strike three medium blows with the hammer in an effort to press in the insert. If no significant movement or damage is observed, the insert shall be considered secure. Such inspection shall be carried out each time the equipment is set up to manufacture a pipe of a different diameter, sheet, or insert thickness.

5.1.1.3.11

Coated steel inserts that are loose, protrude beyond the inside surface of the pipe, or have an exposed surface that is positioned in the rib more than 5.0 mm from the inside surface of the pipe shall be cause for rejection.

5.1.2 Riveted corrugated steel pipe

5.1.2.1 General

5.1.2.1.1

Riveted corrugated steel pipe shall have a longitudinal and circumferential lap seam construction.

5.1.2.1.2

Riveted corrugated steel pipe shall have annular corrugations complying with Clauses 5.1.1.1 and 5.1.1.2.

5.1.2.1.3

Diameters for normal fabrication purposes shall comply with Table 7.

5.1.2.1.4

Lengths of riveted corrugated steel pipe shall be in 610 mm (nominal) increments.

Note: *This length is measured from corrugation crest to corrugation crest. The actual theoretical increment is* 609.6 mm*. The overall length of the pipe is subject to manufacturing tolerances and includes lips at each end.*

5.1.2.2 Rivets

Rivet diameters and lengths shall be as specified in Table 8 and shown in Figure 1. The requirements of Clause 4.4.1 shall be met.

5.1.2.3 Fabrication

5.1.2.3.1

The minimum longitudinal seam lap shall be as specified in Table 9.

5.1.2.3.2

Longitudinal seams shall have at least one rivet in each corrugation. The rivet head shall be in the outside valley of the corrugation.

5.1.2.3.3

Longitudinal seams shall be riveted in accordance with Table 9.

5.1.2.3.4

The rivet centres in longitudinal seams shall not be closer than twice the rivet diameter from any sheet edge.

5.1.2.3.5

The distance between the centrelines of two rows of rivets shall nominally be three times the rivet diameter.

5.1.2.3.6

Rivets shall

a) be driven cold without bending;
b) have full heads;
c) be tight; and
d) completely fill the holes.

5.1.2.3.7

The sheet edges shall be drawn tightly together throughout the entire lap length.

5.1.2.3.8

The minimum circumferential seam lap shall be 30 mm.

5.1.2.3.9

Circumferential seams shall have a maximum rivet spacing of 150 mm measured on centres, except that six rivets shall be used on 300 mm diameter pipe.

5.1.2.3.10

Pipe may be rejected if more than 2% of rivets, or more than two adjacent rivets, do not meet the requirements of Clause 5.1.2.3. A defective rivet may be repaired by driving an additional rivet adjacent to the defective one or drilling out the defective rivet and replacing it with a nut and bolt of equivalent diameter that complies with ASTM A307. The finish for the nuts and bolts shall be zinc plated in accordance with ASTM B633.

5.1.2.4 Dimensions and tolerances

5.1.2.4.1

The average inside diameter tolerance shall be ± 13 mm or ± 1% of the diameter, whichever is greater, measured between inside crests of the corrugations perpendicular to the pipe axis.

Note: *The average inside diameter is the sum of the vertical and horizontal dimensions divided by two.*

5.1.2.4.2

The minimum outside circumferences shall be as specified in Table 7. The outside circumference shall be measured with a band that covers adjacent corrugation crests.

5.1.2.4.3

The specified pipe length shall be measured from the inside crest of the last corrugation at one end to the inside crest of the last corrugation at the other end.

Note: *The overall length is greater than the specified length by approximately 50% of the corrugation pitch.*

5.1.3 Helical lockseam corrugated steel pipe

5.1.3.1 General

5.1.3.1.1

The diameters of helical lockseam corrugated steel pipe and spiral rib steel pipe shall, for normal fabrication purposes, comply with Tables 10 and 11, respectively.

5.1.3.1.2

Helical corrugated steel pipe shall have helical corrugations that comply with Clause 5.1.1.2. Spiral rib steel pipe shall have ribs that comply with Clause 5.1.1.3.

5.1.3.1.3

The helix angle of pipe 600 mm or more in diameter shall not exceed 30° (see Figure 7).

5.1.3.2 Fabrication

5.1.3.2.1

The edges of the continuous sheet forming the pipe shall be continuously formed into a tight interlock by folding over the adjacent meeting edges into a lockseam configuration in accordance with the figure accompanying Table 12. The lockseam shall be located within the corrugation tangent or spiral rib flat.

5.1.3.2.2

The minimum seam lap dimensions shall be as specified in Table 12.

5.1.3.2.3

The maximum gap dimension shall be 1.5 times the sheet thickness.

5.1.3.3 Inspection

5.1.3.3.1 Inspection frequency

5.1.3.3.1.1 General

Helically corrugated steel pipe shall be inspected in accordance with Clauses 5.1.3.3.1.2 to 5.1.3.3.1.5.

5.1.3.3.1.2 New set-up

At the start of each new set-up, including diameter changes, the following shall be carried out:

a) checking the corrugation depth in accordance with Clause 5.1.1.2.4 or the rib dimensions in accordance with Clauses 5.1.1.3.2 to 5.1.1.3.6;
b) visually inspecting the lockseam in accordance with Clause 5.1.3.3.2;
c) checking the pipe diameter in accordance with Clauses 5.1.3.7.1 and 5.1.3.7.2; and
d) checking the coated steel inserts in accordance with Clauses 5.1.1.3.10 and 5.1.1.3.11.

5.1.3.3.1.3 New coil

At the start of each new coil, the coil thickness and coil width shall be checked in accordance with Clauses 4.2.2.1 and 4.2.2.2.

5.1.3.3.1.4 Length change

At the start of each length change, the following shall be carried out:

a) a visual check that the pipe end is cut square in accordance with Clause 5.1.3.5; and
b) a check that the pipe length is in accordance with Clauses 5.1.3.7.3 and 5.1.3.7.4.

5.1.3.3.1.5 Daily lockseam inspection

One sample of the lockseam shall be taken each day in accordance with Clause 5.1.3.3.2. The inspection shall be recorded in a lockseam quality report.

5.1.3.3.2 Visual inspection

5.1.3.3.2.1

The quality of the lockseam shall be visually inspected in accordance with Clauses 5.1.3.3.2.2 to 5.1.3.3.2.7 and the figure that accompanies Table 12. Lockseams at pipe ends shall be saw-cut normal to the helix angle (see Figure 7). The cut shall be of sufficient length to show the complete lockseam profile, including offset.

5.1.3.3.2.2

The lapped surfaces of the lockseam shall be in tight contact.

5.1.3.3.2.3

There shall be no excessive angularity or deformation at the 180° fold.

5.1.3.3.2.4

The total sum of the retaining offsets on both sides shall be a minimum of one sheet thickness.

Note: *The retaining offset, as shown in the figure that accompanies Table 12, is that portion of the sheet profile adjacent to the lockseam and in tight contact with the* 180° *fold.*

5.1.3.3.2.5

Lockseam forming shall not cause cracking of the base steel.

5.1.3.3.2.6

There shall be no significant roller indentations that injure or disfigure the lockseam on the 180° fold or beyond the lapped area.

5.1.3.3.2.7

For pipe with recorrugated ends, visual inspection of the lockseam shall be made on a non-recorrugated portion of the lockseam.

Note: *See the figure that accompanies Table 12 for an illustration of a proper lockseam.*

5.1.3.4 Seam strength

5.1.3.4.1

At the option of the purchaser, the referee tests specified in Clauses 5.1.3.4.2 and 5.1.3.4.3 shall be performed. Lateral seam strength shall meet the minimum values specified in Table 13.

5.1.3.4.2

The lateral seam test sample preparation (see Figure 7) shall be as follows:

a) torch or saw-cut a piece measuring approximately 100 × 200 mm from the pipe;
b) saw-cut a 25 × 150 mm coupon perpendicular to the lockseam, with edges parallel; and
c) flatten the ends of the coupon, one end at a time, for gripping in the test machine. To flatten the ends of the coupon, insert the coupon in a vise 10 mm from the lockseam. As the vise flattens the corrugation or pipe wall, the coupon will rotate. Realign the lockseam with the flattened ends using a crescent wrench or vise grips tightened over the lockseam. (This prevents distortion of the seam itself while the coupon is being bent back into line.)

5.1.3.4.3

The test procedure shall be as follows:

a) measure the actual length of the lockseam;
b) tension test the specimen;
c) determine the maximum tensile load per unit length of seam; and
d) compare the test result to the specified minimum lateral seam strength specified in Table 13.

If the test result does not meet the specified strength requirement, an additional test shall be performed on a second test sample immediately adjacent to the first sample as specified in Items a) and b) of Clause 5.1.3.4.2. Failure of the second test shall be cause for rejection.

5.1.3.5 Cut lengths

The ends of helical pipe shall be finished with a straight cut perpendicular to the longitudinal centreline. Any saw-cut mismatch shall not exceed 10 mm. The ends shall be finished without significant burrs and sharp edges.

5.1.3.6 Recorrugated ends

5.1.3.6.1

Some helical pipe is recorrugated to provide annular corrugations on each pipe end in order to accommodate coupling systems with annular corrugations. Where recorrugated, pipe shall have at least two annular corrugations at each end unless the specified coupling system dictates that a larger number of corrugations be used.

5.1.3.6.2

The lockseam in the recorrugated end shall not contain any visible cracks in the base steel. The minimum lateral seam strength of the recorrugated lockseam shall be not less than 60% of the values specified in Table 13. In the recorrugated ends of aluminum- and 55%-aluminum-zinc-coated helical corrugated steel pipe and spiral rib steel pipe, the inside and outside of the lockseams shall be coated with zinc-rich paint as specified in Clause 6.2.1. This paint requirement shall not apply to aluminum-coated helical corrugated steel pipe with a 68 × 13 mm corrugation and nominal thickness up to and including 2 mm. This paint requirement may also be waived by the specifier.

5.1.3.6.3

All inspection saw-cuts shall be tack-welded before recorrugation.

5.1.3.6.4

After recorrugation, the pipe shall be inspected and shall meet the following requirements:

a) the lips at the ends of the pipe shall project between 15 and 30 mm past the outside crest of the last corrugation;
b) the pipe length shall be within the tolerance of +50 mm, –25 mm;
c) the lockseam in the recorrugated end shall not contain any visible cracks in the base steel;
d) damage to recorrugated ends of polymer laminated pipe shall be repaired in accordance with Clause 6.3.1;
e) the cut ends shall be finished without significant burrs or sharp edges; and
f) the recorrugations shall be perpendicular to the longitudinal axis of the pipe and shall not contain any significant waves or misalignment that would interfere with the assembly of the coupler band.

5.1.3.7 Dimensions and tolerances

5.1.3.7.1

The average inside diameter tolerance shall be ± 6 mm or ± 0.5% of the diameter, whichever is greater, measured between inside crests of the corrugations or inside flats between ribs perpendicular to the pipe axis. A pipe shall be round to the extent that the major axis diameter shall not exceed the minor axis diameter by more than 2%.

Note: *The average inside diameter is the sum of the vertical and horizontal dimensions, divided by two.*

5.1.3.7.2

The minimum helical corrugated steel pipe outside circumferences for inspection purposes shall be as specified in Table 10. The minimum spiral rib steel pipe outside circumferences for inspection purposes shall be as specified in Table 11. Measurements of the outside circumference shall be made with a band that covers adjacent corrugation crests or rib tops.

5.1.3.7.3

Standard fabricated lengths shall be in 1000 mm increments.

5.1.3.7.4

The length tolerance for individual pipes shall be ± 25 mm of the specified length and for pipe with recorrugated ends shall be +50 mm, –25 mm.

5.1.3.8 Welding of coil ends

5.1.3.8.1

Successive coil ends shall be joined using a square groove or vee-groove weld with an effective throat of 100% across the sheet width. A suitable welding procedure shall be developed and proved by the manufacturer to ensure that the 100% effective throat can be obtained during production. Protective coatings shall be removed from the localized area of welding to prevent contamination unless suitable welding procedures that incorporate the coating have been established by the manufacturer.

5.1.3.8.2

Non-metallic deposits shall be removed after welding.

5.1.3.8.3
Both sides of the welded area shall be repaired in accordance with Clauses 6.2 and 6.3.

5.1.3.8.4
Welding consumables used in the fabrication of corrugated steel pipe shall have minimum strength levels meeting that of the base steel welded.

5.1.3.8.5
Welding consumables shall be stored in accordance with the manufacturer's recommended practices. Wet SMAW electrodes or SAW fluxes shall be discarded. Shielding gas (when used) shall be of welding grade with a dew point of 40 °C or lower.

5.1.4 Pipe-arch

5.1.4.1 General
Non-circular corrugated steel pipe shall be made by reshaping standard round corrugated steel pipe or by curving individual sheets to form arc dimensions.

5.1.4.2 Pipe-arch shape

5.1.4.2.1 Standard dimensions
Corrugated steel pipe-arches shall have the dimensions specified in Table 14 for the 68 × 13 mm corrugation profile and in Table 15 for the 76 × 25 mm and 125 × 26 mm corrugation profiles. Spiral rib steel pipe-arches shall have the dimensions specified in Table 16. In addition, the requirements of Clause 5.1.2.4.1 or 5.1.3.7.1 for pipe of equivalent diameter shall be met.

5.1.4.2.2 Inspection
Corrugated steel pipe-arches shall be inspected and meet the following requirements:

a) visual inspection shall show that there is
   i) reasonably continuous symmetry about the vertical centreline;
   ii) no undue variation of the corner radius from a straight horizontal line;
   iii) no creasing or significant buckling in the corner radius;
   iv) no excessive camber through the longitudinal axis of the arch; and
   v) no significant humping in the invert at the transition between successive passes;
b) the minimum corner radius shall be as specified in Tables 14 to 16; and
c) the span and rise dimensions measured from the inside crests of corrugations or the inside flats of spiral rib steel pipe, for the equivalent pipe diameters specified in Tables 14 to 16, shall be within the tolerances specified in Tables 14 to 16.

5.1.4.2.3 Fabrication
For riveted corrugated steel pipe, the longitudinal seam or seams shall be placed in the top arch section and not in an area of change of radius or minimum radius.

5.1.5 Perforated corrugated steel pipe

5.1.5.1 General
Perforated corrugated steel pipe shall be specified as Type 1 invert perforated or Type 2 fully perforated.

5.1.5.2 Fabrication

5.1.5.2.1
Perforated riveted corrugated steel pipe shall meet the fabrication and dimensional requirements of Clause 5.1.2.

5.1.5.2.2
Perforated helical corrugated steel pipe shall meet the fabrication and dimensional requirements of Clause 5.1.3.

5.1.5.3 Perforation dimensions

5.1.5.3.1
Circular perforations shall have a diameter of 8 or 10 ± 0.5 mm.

5.1.5.3.2
Slotted perforations shall be chisel punched from the inside of the pipe. The slot shall be 25 ± 7 mm long by 2.5 ± 1 mm wide.

5.1.5.4 Invert perforation

5.1.5.4.1
Circular perforations shall be as specified in Clause 5.1.5.3.1 and shall be located in all outside valleys or along tangents of corrugations.

5.1.5.4.2
Perforations shall not be required within 150 mm of the ends of each pipe or where seams are located.

5.1.5.4.3
Perforations shall be spaced in a minimum of two equal groups of longitudinal rows placed symmetrically, with one group on each side of an unperforated bottom segment as shown in Figure 8.

5.1.5.4.4
The minimum number of longitudinal rows of perforations and the minimum arc length, *L*, shall be as specified in Table 17. The distance between the centrelines of rows shall be not less than 25 mm.

5.1.5.5 Fully perforated

5.1.5.5.1
Circular perforations shall be as specified in Clause 5.1.5.3.1 and shall be equally spaced around the periphery of the pipe. Perforations shall provide an opening area of not less than 2.3% of the pipe surface.

5.1.5.5.2
Slotted perforations shall be as specified in Clause 5.1.5.3.2 and shall be located in a staggered pattern on outside crests of each corrugation. Perforations shall be spaced 45 to 65 mm on centres around the pipe circumference.

5.1.6 Bolted corrugated steel pipe

Note: *Shapes include arch, round, ellipse, and pipe-arch.*

5.1.6.1 General

5.1.6.1.1

Bolted corrugated steel pipe shall have a circumferential and (when required) longitudinal lap seam construction.

5.1.6.1.2

Bolted corrugated steel pipe shall have annular corrugations complying with Clauses 5.1.1.1 and 5.1.1.2.1.

Note: *Corrugations available for this product include* 68 × 13 mm*,* 125 × 26 mm*, and* 230 × 64 mm*.*

5.1.6.1.3

Bolted corrugated steel pipe sheet shall comply with Table 3.

5.1.6.1.4

Lengths of bolted corrugated steel pipe shall be in 610, 625, and 1143 mm (nominal) increments.

Note: *This length is measured from corrugation crest to corrugation crest. The overall length of the pipe is subject to manufacturing tolerances and includes lips at each end.*

5.1.6.2 Fabrication

5.1.6.2.1

The longitudinal seams on the 125 × 26 mm and 230 × 64 mm corrugation profiles shall have at least one bolt per valley or crest (two bolts per corrugation).

5.1.6.2.2

Sheets shall be punched along the edges with holes to form longitudinal and circumferential lap seams when assembled by bolting. The centreline of the bolt hole shall not be more than 6 mm from the corrugation crest or valley.

For the 68 × 13 mm corrugation profile, 11 × 19 mm slotted holes shall be provided on the circumferential and longitudinal seams as shown in Figure 9.

For the 125 × 26 mm corrugation profile, a combination of 14 mm diameter holes and 14 × 22 mm slots shall be provided as shown in Figure 10.

For the 230 × 64 mm corrugation profile, the hole diameter shall not exceed the bolt diameter by more than 6.3 mm. The minor axis of a winked hole shall be at least 1 mm greater than the nominal bolt diameter. The sheet configuration shall be as shown in Figure 11.

5.1.6.2.3

Sheet arrangements should be designed with seams staggered so that not more than three sheets come together at any one bolt hole.

5.1.6.2.4
Circumferential hole spacing shall not exceed 488 mm along the sheet width.

5.1.6.2.5
Sheets shall be curved to a radius along the inner crest dimension (plate net arc width) to form radial arcs. Each lift of curved sheets shall be inspected and meet the following requirements:

a) all holes shall be punched and free of burrs;
b) the lip length shall be not greater than 64 mm;
c) the rise of the second corrugation in from both ends on the top curved sheet shall meet the requirement of the specified shape; and
d) the tolerance of each sheet shall meet the requirements of Clause 5.1.6.3.1.

5.1.6.2.6
For the 68 × 13 mm corrugation profile, bolts shall be SAE J429 Grade 2-3/8” × 1” and nuts shall be 3/8” diameter SAE J995 Grade 2.

For the 125 × 26 mm corrugation profile, bolts shall be SAE J429 Grade 2-1/2” × 1-1/4” and nuts shall be 1/2” diameter SAE J995 Grade 2.

For the 230 × 64 mm corrugation profile, bolts and nuts shall meet the requirements of Clause 4.4.2.

5.1.6.2.7
Bolt lengths shall be sufficient to provide full thread engagement in the nut when assembled sheets are tightened in place.

5.1.6.2.8
The number of bolts of each length furnished shall exceed by at least 2% the theoretical number required.

5.1.6.2.9
Erection drawings showing sheet arrangements, together with assembly instructions, shall be provided for field erection. Manufacturers shall provide assembly drawings or other means of showing their required plate lap.

5.1.6.3 Dimensions and tolerances

5.1.6.3.1
The average inside diameter tolerance shall be ± 13 mm or ± 1% of the diameter, whichever is greater, measured between inside crests of the corrugations perpendicular to the pipe axis.

Note: *The average inside diameter is the sum of the vertical and horizontal dimensions divided by two.*

5.1.6.3.2
The specified pipe length shall be measured from the inside crest of the last corrugation at one end to the inside crest of the last corrugation at the other end.

Note: *The overall length is greater than the specified length by approximately* 38 mm *for both the* 68 × 13 mm *and* 125 × 26 mm *corrugation profiles and 50% of the corrugation pitch for the* 230 × 64 mm *corrugation profile.*

5.1.7 Couplers

5.1.7.1 General

5.1.7.1.1
Couplers shall be used to join pipe sections, preserve pipe alignment, resist separation, and deter root penetration or infiltration of normal backfill materials.

5.1.7.1.2
Coupler sheet and wedge material shall comply with Clauses 4.1 and 4.2.

5.1.7.1.3
Standard coupler systems shall have the minimum dimensions specified in Table 18.

Note: *See Figures B.1 to B.4.*

5.1.7.1.4
Rod and lug, flange, bar and strap, helically corrugated, internal expanding, and other coupler systems may be used with the approval of the purchaser.

5.1.7.2 Coupler fastening

5.1.7.2.1 General
The ends of coupler bands shall be connected by bolts or wedges through flanges or steel brackets on the coupler band.

5.1.7.2.2 Bolt fastening

5.1.7.2.2.1
Coupler flanges may be integrally formed with the coupler sheet or be angle riveted or welded to the coupler sheet. Individual steel brackets may be used in lieu of angles. Bracket or angle flanges shall be zinc coated in accordance with Clause 4.5.1.2 of this Standard or CAN/CSA-G164.

5.1.7.2.2.2
Where flanges are riveted to couplers, the rivets shall meet the requirements of Clause 4.4.1 and have a minimum nominal diameter of 10 mm. The minimum number of rivets per angle shall be two for the 180 mm width coupler, three for the 300 mm coupler, and five for the 600 mm coupler. The minimum number of rivets per bracket shall be two.

Note: *The actual rivet diameter is* 9.5 mm.

5.1.7.2.2.3
Where flanges are welded to the couplers, welds shall be of a strength equivalent to riveted connections. The weld area shall be thoroughly cleaned and treated with zinc-rich coating in accordance with Clause 6.2.1.

5.1.7.2.2.4
The minimum number of standard coupler connecting bolts shall be as specified in Table 18. Bolts shall be ASTM F568M, Property Class 4.6, M12 × 1.75, hexagonal head, and 150 mm in nominal length. Bolts

shall be complete, with hexagonal free-running nuts in accordance with ASTM A563M, Property Class 5. Washers shall not be required. Bolts and nuts shall be zinc plated in accordance with ASTM B633, Type RS, or zinc coated in accordance with CAN/CSA-G164, Class 4, or ASTM B695, Class 50.

5.1.7.2.2.5

Connecting bolts for flat band couplers shall be standard carriage bolts at least 9 mm in diameter or shall otherwise be in accordance with ASTM F568M, Class 4.6. The finish for the connecting bolts and nuts shall be zinc plated in accordance with ASTM B633, Type RS, or zinc coated in accordance with CAN/CSA-G164, Class 4, or ASTM B695, Class 50.

5.1.7.2.3 Wedge fastening

5.1.7.2.3.1

The coupler band flange lips shall be integrally formed at the band ends to form a contained angle of approximately 45° and shall be at least 10 mm wide.

5.1.7.2.3.2

The wedge shall have an overall minimum height of 16 mm at the narrow end, be at least 75 mm longer than the width of the coupler, and at least 2 mm in nominal thickness.

5.1.7.2.3.3

Wedge flange lips shall be formed to provide approximate contact at the root of the band lip and shall be at least 13 mm wide.

5.1.7.2.3.4

Both band and wedge flange lips shall be tapered approximately 5°.

5.1.7.3 Couplers for polymer-coated pipe

Unless otherwise specified by the purchaser, coupler bands for corrugated steel pipe with protective coating shall all have the same protection. Coupler components, e.g., angles, bolts, nuts, and wedges, need not be protected other than by galvanizing.

5.1.7.4 Gasketed joints

Gaskets can be used to improve the watertightness of coupler joints (see Figures B.5 and B.6). Flat or O-ring gasket material shall be in accordance with ASTM D1056, for RE closed-cell grades, or with ASTM C361M.

Note: *Other gasket or sealant materials are available and may be used at the purchaser's discretion.*

5.1.8 Fittings and appurtenances

Fittings and appurtenances, e.g., elbows, tees, wyes, access openings, and catch basins, shall comply with Clauses 4.1 to 4.3, as applicable.

5.2 Structural plate and deep corrugated structural plate steel pipe

5.2.1 General

Structural plate pipe shall be formed from sheet or plate as specified in Clauses 4.1 and 4.3.

Note: *Shapes include round, vertical and horizontal ellipse, pipe-arch, arch, box culvert, and vehicular, pedestrian, or animal underpass.*

5.2.2 Corrugation profile

5.2.2.1 General

Structural plate pipe shall have annular corrugations, with crests and valleys forming circumferential rings about the pipe axis.

5.2.2.2 Pitch, depth, and tolerances

Profile pitch, depth, and tolerances shall be as shown in Figure 12.

5.2.2.3 Inspection

At the start of each new set-up for thickness, width, and length, and on the second plate of every bundle, corrugated plates shall be inspected and meet the following requirements after corrugation and punching:

a) visual inspection shall show that
   i) the corrugation profile for depth, pitch, and symmetry corresponds to the profile template;
   ii) the identification stamp is correct and clear; and
   iii) all holes are punched and free of burrs;
b) the net length shall be within the tolerance of ± 6 mm for structural plate, ± 13 mm for deep corrugated structural plate Type I, ± 20 mm for deep corrugated structural plate Type II, and ± 13 mm for deep corrugated structural plate Type III; and
c) the lip shall project at least 1.75 x the bolt diameter and not more than 64 mm for structural plate and at least 38 mm for deep corrugated structural plate Types I, II, and III. When circumferential flanges are used, tolerances illustrated in Figure 13a) shall be used in lieu of these lip tolerances.

5.2.3 Pipe and plate dimensions

5.2.3.1 Standard round

Round structural plate corrugated steel pipe shall have one of the nominal inside diameters specified in Table 19.

5.2.3.2 Plate dimensions

Plates shall be fabricated to the following dimensions:

a) For structural plate Type I, the standard dimensions shall be as specified in Table 20 and shown in Figure 14. Nominal corrugated plate lengths shall be 1220, 3050, and 3660 mm. Actual corrugated plate lengths, subject to manufacturing tolerances, shall be 1219, 3048, and 3658 mm. Overall actual structure lengths shall be a multiple of the 1219 mm length, or any combination of the 3048 and 3658 mm lengths, plus a nominal allowance of 100 mm for the end lips.
b) For structural plate Type II, the standard dimensions shall be as specified in Table 20 and shown in Figure 15. Nominal corrugated plate lengths shall be 1150 mm. Actual corrugated plate lengths, subject to manufacturing tolerances, shall be 1143 mm. Overall actual structure lengths shall be a multiple of the 1143 mm length plus a nominal allowance of 76 mm for the end lips.
c) For Type I deep corrugated structural plate, the standard dimensions shall be as specified in Table 22 and shown in Figure 16. The nominal corrugated plate length shall be 760 mm. Overall structure lengths shall be any multiple of the actual length of 762 mm, plus a nominal allowance of 75 mm for the end lips.

d) For Type II deep corrugated structural plate, the standard dimensions shall be as specified in Table 22 and shown in Figures 17 and 18. The nominal corrugated plate length shall be 1200 mm. Overall structure lengths shall be any multiple of 1200 mm, plus a nominal allowance of 80 mm for the end lips.
e) For Type III deep corrugated structural plate, the standard dimensions shall be as specified in Table 22 and shown in Figure 19. The nominal corrugated plate length shall be 1000 mm. Overall structure lengths shall be any multiple of 1000 mm, plus a nominal allowance of 75 mm for the end lips.
f) For tunnel liner plate, the standard dimensions shall be as specified in Table 21 and shown in Figure 20. The nominal, gross, and net plate width in the longitudinal direction of the structure shall be 500 mm. Overall structure lengths shall be any multiple of 500 mm. The net circumferential plate length shall be in multiples of 50 × π mm (157.07 mm).

5.2.3.3 Bolt holes

5.2.3.3.1

Plates shall be punched along the edges with holes to form longitudinal and circumferential lap seams when assembled by bolting. The centreline of the bolt hole shall not be more than 6.4 mm from the corrugation crest or valley, or specified tangent location.

5.2.3.3.2

For structural plate
a) the hole diameter shall not exceed the bolt diameter by more than 6.4 mm;
b) holes in circumferential seams of structural plate Type II shall be slotted with a width not exceeding the bolt diameter by more than 6.4 mm and length (parallel to corrugation) not exceeding the bolt diameter plus 10 mm; and
c) the minor axis of a slotted hole shall be at least 1 mm greater than the nominal bolt diameter.

5.2.3.3.3

For deep corrugated structural plate Types I and III
a) the diameter of bolt holes in the circumferential and longitudinal seams of barrel and base plates shall not exceed the bolt diameter by more than 6.4 mm; and
b) the diameter of bolt holes in the circumferential and longitudinal seams of rib plates shall be slotted holes with a width not greater than the bolt diameter plus 6.4 mm and a length not greater than the bolt diameter plus 12.7 mm.

For deep corrugated structural plate Type III, bolt holes in tangents of longitudinal seams shall be slotted with a width not greater than the bolt diameter plus 6.4 mm and a length not greater than 45 mm for plates with a nominal thickness not greater than 10.3 mm and 50 mm for plates with a nominal thickness greater than 10.3 mm.

5.2.3.3.4

For deep corrugated structural plate Type II
a) the diameter of bolt holes in the longitudinal seams shall not exceed the bolt diameter by more than 6 mm, except for those in the plate corners, which shall be the same as the circumferential holes described in Item b); and
b) bolt holes in the circumferential seams shall be slotted holes with a width not greater than the bolt diameter plus 5 mm and a length not greater than the bolt diameter plus 10 mm.

5.2.3.3.5

For tunnel liner plate

a) bolt holes in the offset plate ends of longitudinal seams shall be slotted holes with a width not greater than the bolt diameter plus 3.2 mm and a length not greater than the bolt diameter plus 10 mm. Bolt holes in non-offset plate ends of longitudinal seams shall be square holes no larger than the square bolt shoulder dimension plus 1.75 mm; and
b) Bolt holes in the circumferential flange shall be slotted holes with a width not greater than the bolt diameter plus 1.6 mm and length not greater than the bolt diameter plus 6.4 mm.

5.2.3.4 Plate connections

5.2.3.4.1 Longitudinal lap plate connections bolt hole pattern

The longitudinal hole pattern shall be a minimum of two holes per corrugation for structural plate, six holes per corrugation for deep corrugated structural barrel plate Types I and II, and twelve holes per corrugation for deep corrugated structural barrel plate Type III. Depending on seam strength requirements, additional holes per corrugation may be specified for structural plate corrugated steel pipe (see Figures 14 to 19).

5.2.3.4.2 Longitudinal flange connections bolt hole pattern

The longitudinal hole pattern shall be a minimum of two holes per corrugation for structural plate, four holes per corrugation for deep corrugated structural plate Type I, and four holes per corrugation for deep corrugated structural plate Type III. Depending on seam strength requirements, additional holes per corrugation may be specified. Other dimensional requirements shall be as shown in Figure 13a). Longitudinal flanges shall be welded to the plates, in accordance with the manufacturing drawings, by welders certified in accordance with CSA W47.1. Welding shall conform to CSA W59.

5.2.3.4.3 Circumferential flange connections bolt hole spacing

The circumferential flange bolt spacing shall be a maximum of 152 mm for structural plate, 406 mm for deep corrugated structural plate Type I, and 500 mm for deep corrugated structural plate Type III. Other dimensional requirements shall be as shown in Figure 13a).

5.2.3.4.4 Longitudinal plate seams

Longitudinal plate seams for tunnel liner plate shall be through an overlapping plate connection. One end of the adjoining plates shall be swaged (offset) by two times the thickness of the plate across its full width. The plate cross-section shall be continuous through the overlapping plates. The longitudinal hole pattern and plate types for tunnel liner plate shall be as shown in Figure 20.

5.2.3.4.5 Circumferential plate connections

Circumferential plate connections for tunnel liner plate shall be through flanges. Circumferential flanges shall be cold formed 90° to the shell and oriented inward. Slotted holes in the flange shall be spaced at 157 mm (50π) on centres. The circumferential hole pattern for tunnel liner plate shall be as shown in Figure 13b).

5.2.3.5 Plate arrangements

Except where reinforcing ribs are used, plate arrangements in structures should be designed with seams staggered so that not more than three plates come together at any one bolt hole.

5.2.3.6 Plate arc width

Plate arc width shall be in accordance with Tables 20 to 22 and Figures 14 to 20 and shall equal

a) the number of circumferential bolt hole spaces times (*N*) at 244 mm nominal centres along the plate for structural plate;
b) the number of circumferential bolt hole spaces times (*S*) at 406 mm nominal centres along the plate for deep corrugated structural plate Type I;
c) the number of circumferential bolt hole spaces times (*H*) at 425 mm nominal centres along the plate for deep corrugated structural plate Type II;
d) the number of circumferential bolt hole spaces times (*U*) at 500 mm nominal centres along the plate for deep corrugated structural plate Type III; and
e) for two-flange tunnel liner plate, the net plate arc width shall equal the plate size designation (300, 350, or 400) times π (3.1416) mm. Circumferential holes are spaced at 50π mm nominal centres (157 mm) along the flange.

Note: *The actual dimensions, subject to manufacturing tolerances, are (N) =* 243.84 mm*, (S) =* 406.4 mm*, (H) =* 425 mm*, and (U) =* 500 mm*.*

5.2.4 Plate curvature

5.2.4.1

Plates shall be curved to a radius along the inner crest dimension (plate net arc width) to form radial arcs.

5.2.4.2

The maximum flat length on the lap of longitudinal seams shall be 120 mm for structural plate, 203 mm for deep corrugated structural plate Type I, 225 mm for deep corrugated structural plate Type II, and 255 mm for deep corrugated structural plate Type III (see Figure 21).

5.2.4.3

The tolerance on the measured rise, when compared to the calculated shop curvature, shall be ± 6 mm (see Figure 21). The length of straightedge used shall be not less than 75% of the chord length.

Note: *Structural plate fabricators will make available on request the standard rise dimensions for plates of varying curvature, using varying straightedge inspection lengths.*

5.2.5 Unbalanced channel and receiving angle

The unbalanced channel and receiving angle shall be as specified in Table 23 and formed as shown in Figure 22 and shall comply with the minimum material requirements of Clause 4. The coating type shall match the structure wall where it connects to the unbalanced channel or receiving angle. Galvanized or polymer coatings may be used with structures having aluminum coatings.

5.2.6 Bolts and nuts

5.2.6.1

Bolts and nuts shall meet the requirements of Clause 4.4.2.

5.2.6.2

Bolt lengths shall be sufficient to provide full thread engagement in the nut when assembled plates are tightened in place.

5.2.6.3
The number of bolts for each length furnished shall be at least 2% more than the theoretical number required to erect the structure.

5.2.6.4
Fasteners shall be supplied in size-specific containers.

5.2.6.5 Shear studs

5.2.6.5.1 General
Interconnection between steel sections and concrete shall be by use of welded or bolted shear connectors meeting the requirements of Clause 5.2.6.5.2 or 5.2.6.5.3.

5.2.6.5.2 Welded shear studs
Welded studs shall meet the requirements of CSA W59. The diameter of a welded stud shall not exceed 2.5 times the thickness of the part to which it is welded unless test data satisfactory to the purchaser or specifier are provided to establish the capacity of the stud as a shear connector. Shear connectors shall be welded to the base steel before galvanizing.

5.2.6.5.3 Bolted shear studs
Bolted shear studs shall meet the requirements of Clause 4.4.2.

5.2.7 Drawings and plate identification

5.2.7.1
Structural plates shall be clearly identified by the fabricator for field erection.

Note: *Identification may include thickness, radius, drawing or code numbering, and job or order number.*

5.2.7.2
The fabricator shall provide a bill of material for each structure order.

5.2.7.3
Erection drawings showing plate arrangements, together with assembly instructions, shall be provided for field erection. Manufacturers shall provide assembly drawings or other means of showing the required plate lap.

Note: *Figure 23 provides an example of a drawing in which plates are lapped so that the line of valley bolts is always closest to the visible edge when viewed from the inside or outside of the structure. Figure 24 shows examples of lapping for deep corrugated structural plate products.*

5.2.7.4
For field erection, cut plates for bevelled or skewed ends shall be legibly identified to designate positions in the finished structure and shall be referenced on erection drawings.

6 Quality of work and repair

6.1 Quality of work

Completed pipe shall demonstrate a high quality of work in all particulars. The following defects shall be considered poor quality of work and may be cause for rejection:

a) uneven laps in riveted pipe;
b) distortion from intended cross-sectional shape;
c) variation from a straight centreline;
d) ragged or diagonal sheared edges;
e) loose, unevenly lined, or spaced rivets;
f) defective welds (as defined in CSA W59);
g) illegible marking;
h) dents or bends in the steel;
i) bruised, scaled, or damaged coating;
j) holes not punched and free of burrs;
k) identification not clear; and
l) tolerances not met.

6.2 Repair of damaged metallic coating

6.2.1

Small, localized areas of damage or storage stain, scratches, or burns where metallic coating has been damaged by welding or other procedures shall be repaired by thorough cleaning, followed by the application, to a dry thickness of 50 µm, of a zinc-rich coating complying with CAN/CGSB-1.181.

6.2.2

Uncoated surfaces of width greater than 3 mm and up to 50 mm shall be repaired in accordance with Clause 6.2.1. Saw-cut ends shall be excluded from this requirement.

Uncoated areas wider than 50 mm shall be redipped in accordance with this Standard or zinc-metallized in accordance with CSA G189.

6.3 Repair of damaged polymer and thermoplastic copolymer coatings

6.3.1

Damaged polymer laminate coatings shall be repaired using suitable materials to match the properties of the original coating, as recommended by the manufacturer. Factory saw-cut ends shall be excluded from this requirement. Small, localized areas of damage where metal has been exposed shall be repaired.

6.3.2

Damaged thermoplastic copolymer coatings shall be repaired using suitable materials to match the properties of the original coating, as recommended by the manufacturer. Small, localized areas of damage where metal has been exposed shall be repaired.

7 Manufacturer's quality control

7.1 Materials control

The manufacturer shall, when requested, demonstrate to the satisfaction of the purchaser that

a) material specifications for the ordering of all material for corrugated steel pipe products and other appurtenances are at hand and up-to-date;
b) the supplied mechanical fasteners are of a type and size suitable for the intended application and comply with the appropriate Standard;
c) the purchasing practices of the manufacturer ensure that the materials specified are those actually ordered; and
d) the method of inventory and of stocking material for subsequent fabrication ensures that the appropriate material is used.

7.2 Fabrication

The manufacturer shall, when requested, demonstrate to the satisfaction of the purchaser that

a) the tolerances on manufactured components can be maintained within the limits specified in this Standard; and
b) all components and parts are suitably marked or otherwise positively identified as required by this Standard before shipment.

7.3 Plant quality program

7.3.1 Objectives and methods

The manufacturer shall, when requested, demonstrate to the satisfaction of the purchaser that

a) a policy on quality control has been established and documented by the manufacturer's management and that all personnel are familiar with the policy;
b) a quality control program has been established by the manufacturer;
c) the manufacturer has prepared appropriate standards and procedures for quality control, and the standards and procedures are in use; and
d) the authority and responsibility for the management of the quality control program at the plant remain with a qualified individual who reports directly to the senior management of the manufacturer.

7.3.2 Inspection, testing, and record-keeping

The manufacturer shall, when requested, demonstrate to the satisfaction of the purchaser that

a) inspection procedures are sufficient to maintain the quality of the products in accordance with the requirements specified in Clause 7.3.1;
b) testing is conducted in accordance with the procedures established in the quality program;
c) sufficient records are maintained by the plant to establish evidence of proper manufacturing and the quality control of the elements; and
d) the plant has an internal procedure to ensure that the requirements of the quality program are being observed by the staff.

7.3.3 Assessment of plant standards

The manufacturer shall, when requested, demonstrate to the satisfaction of the purchaser that plant standards are compatible with the manufacturing process, the manufactured product, and industrial safety in general.

8 Handling, transport, storage, and repair

8.1 General

8.1.1

Corrugated steel pipe materials and products shall be handled in a manner that retards the formation of wet storage stain during shipment and storage.

Note: *Steps to prevent the formation of wet storage stain include, but are not limited to, the following:*

a) *treating materials with a surface passivation;*
b) *storing materials under cover in dry, well-ventilated conditions in heated facilities;*
c) *stacking materials in a manner that provides complete drainage during storage or shipping; or*
d) *using strip spacers for materials that will be in long-term storage.*

Note: *Alternative steps may be taken, in which case a fabricator should be consulted.*

8.1.2

Zinc-, aluminum-, and 55%-aluminum-zinc-coated material shall be protected from moisture during storage, preferably indoors. Sheets or finished parts stacked for storage shall be adequately supported to prevent sagging and be separated with spacers to provide air circulation and eliminate capillary moisture penetration.

8.1.3

Corrugated steel pipe and plate shall be carefully handled to prevent denting and damage to the coating. The fabricator shall be responsible for repairing pipe, plate, or coating damage before shipment.

8.1.4

Coating damage shall be repaired in accordance with Clauses 6.2 and 6.3.

8.1.5

The manufacturer should, when requested, demonstrate to the satisfaction of the purchaser that finished components and parts are being handled, stored, and transported in accordance with good practice, taking into consideration the nature of the product, its susceptibility to damage, the intended mode of transportation, and the intended destination.

8.2 Storage stains

8.2.1

White storage stain on the metallic coating shall not exceed 3% in any square metre of each side of the component. Storage stain shall be assessed and repaired in accordance with Clauses 8.2.2 and 8.2.3.

Note: *For galvanized components, a light white smooth surface condition is normal. A powdered surface is an indication of wet storage stain. Wet storage stain colour is an indication of staining severity. The colour can vary from white to black or red, indicating increasing severity of damage.*

8.2.2

White storage stain can be removed by wire brushing. The remaining coating mass shall meet the requirements of Clauses 4.5.1.1.2 and 4.5.1.1.3. When the requirements of Clauses 4.5.1.1.2 and 4.5.1.1.3 are not met, the coating shall be repaired in accordance with Clause 6.2.1.

8.2.3

Metallic coating that has sustained storage damage that appears as red or black stains shall be

a) assessed and repaired in accordance with Clauses 6.2.1 and 6.2.2; or
b) rejected.

9 Inspection

9.1

The manufacturer should provide the purchaser's inspector with all reasonable facilities for ensuring that the products are manufactured as specified in this Standard. Unless otherwise specified by the customer, all inspection and testing shall be made at the manufacturer's plant before shipment. Such inspection or sampling shall be made concurrently with the manufacturer's regular inspection and test operations unless it causes interference with normal operations or is otherwise specified by the customer.

9.2

Unless otherwise specified by the purchaser in the purchase order, the manufacturer shall be responsible for the performance of all inspection requirements specified in this Standard. The purchaser, or the purchaser's authorized representative, shall have the right to perform any of the inspections in this Standard, where such inspections are deemed necessary to ensure that the products comply with this Standard.

9.3

On request, the manufacturer shall give the purchaser the mill test certificates required by this Standard.

10 Rejection

Material, product, or work quality not meeting the requirements of this Standard shall be rejected when non-compliance with such requirements is established.

Table 1
Chemical composition of steel
(See Clauses 4.1.1.2 and 4.1.2.1.)

	Heat analysis, %, maximum			
Element	**Corrugated steel pipe and spiral rib pipe**	**Structural plate corrugated steel pipe**	**Deep corrugated structural plate**	**Chemical limits for longitudinal flange connections**
Carbon*	0.15	0.10	0.25	0.22
Manganese	0.60	0.50	1.50	1.5
Phosphorus	0.08	0.08	0.08	0.04
Sulphur	0.05	0.05	0.04	0.05

* *To avoid brittle steel behaviour, a minimum of 0.02% carbon content shall be used.*

Table 2
Mechanical properties of structural plate
(See Clause 4.1.5.1.)

Product	Minimum yield strength, MPa	Minimum tensile strength, MPa	Minimum elongation in 50 mm, %
Structural plate	195	290	30
Deep corrugated structural plate	275	380	25
Longitudinal flange connections	300	450	23

Notes:

1) *These mechanical properties are for the virgin material before corrugating and galvanizing. See Annex A for design base steel properties.*

2) *The designer should consult the fabricator for finished product properties.*

Table 3
Corrugated steel pipe sheet — Tolerances
(See Clauses 4.2.1.3, 4.2.2.1, 5.1.6.1.3, A.1.2, and A.2.1.)

Nominal thickness, mm*	Tolerance, mm
1.00†	± 0.13
1.30†	± 0.15
1.60	± 0.18
2.00	± 0.18
2.80	± 0.20
3.50†	± 0.23
4.20†	± 0.23

* *Nominal thickness includes the base steel and metallic coating.*

† *Spiral rib steel pipe is not available in these thicknesses.*

Table 4
Structural plate and deep corrugated structural plate sheet and plate — Thicknesses and tolerances

(See Clauses 4.3.1.2, 4.3.2.1, A.1.3, and A.2.2 and Figures 14 to 20.)

Product	Blank width, mm†	Nominal thickness, mm*												
		2.69	3	3.43	4	4.19	4.3	5	5.41	6	6.19	7	7.94	9.52	12.7
		Tolerance, mm													
Structural plate (see Figures 14 and 15)	1340	—	± 0.28	—	± 0.28	—	—	+0.40 –0.30	—	+0.40 –0.30	—	+0.50 –0.30	—	+0.60 –0.56	—
	1422	—	± 0.28	—	± 0.28	—	—	+0.40 –0.30	—	+0.40 –0.30	—	+0.50 –0.30	—	+0.60 –0.56	—
	1585	—	± 0.28	—	± 0.28	—	—	+0.40 –0.30	—	+0.50 –0.30	—	+0.60 –0.30	—	+0.60 –0.56	—
	1631	—	± 0.28	—	± 0.28	—	—	+0.40 –0.30	—	+0.50 –0.30	—	+0.50 –0.30	—	+0.60 –0.56	—
	2315	—	± 0.30	—	± 0.30	—	—	+0.60 –0.30	—	+0.60 –0.30	—	+0.70 –0.30	—	+0.60 –0.56	—
Deep corrugated structural plate, Type I (see Figure 16)	1070	—	—	± 0.28	± 0.28	± 0.28	—	+0.40 –0.30	+0.40 –0.30	+0.40 –0.30	+0.40 –0.30	+0.40 –0.30	+0.40 –0.30	+0.60 –0.56	— —
Deep corrugated structural plate, Type II (see Figures 17 and 18)	1660	—	—	—	—	—	+0.40 –0.30	+0.40 –0.30	—	+0.40 –0.30	—	+0.40 –0.30	+0.40 –0.30	—	—

(Continued)

Table 4 (Concluded)

Product	Blank width, mm†	Nominal thickness, mm*													
		2.69	3	3.43	4	4.19	4.3	5	5.41	6	6.19	7	7.94	9.52	12.7
		Tolerance, mm													
Deep corrugated structural plate, Type III (see Figure 19)	1540	—	—	—	—	—	+0.40 –0.30	+0.40 –0.30	—	+0.40 –0.30	—	+0.40 –0.30	+0.40 –0.30	+0.60 –0.56	+0.60 –0.56
Two-flange tunnel liner plate (see Figure 20)	638	—	+0.05 −0.15	—	+0 −0.2	—	—	+0 −0.25	—	+0 −0.2	—	—	—	—	—

* *Nominal thickness is the base steel thickness excluding zinc coating.*
† *Wider blank widths may be required in accordance with design when plates have circumferential flanges.*

Notes:

1) *For the plate field thickness check, the coating thickness should be added to the base steel thickness as specified in the notes to Clause 4.5.1.1.3.*

2) *This Table covers only standard thicknesses. For thicknesses not covered in the Table, tolerances shall be determined by interpolation between the values given.*

Table 5
Aluminum bath analysis
(See Clause 4.5.2.1.1.)

Element	Maximum, %
Iron	3.0
Silicon	0.35
Magnesium	0.50
Other trace — each	0.05
Other trace — total	0.20
Aluminum	To 100

Table 6
Standard corrugation and rib profiles, mm
(See Clauses 5.1.1.2.1, 5.1.1.2.4, and 5.1.1.3.1.)

Corrugation profile				
Nominal		**Actual**		
Pitch	**Depth**	**Pitch**	**Depth**	**Inside diameter**
38	6.5	38.1	6.35	100, 150, 200, or 250
68	13	67.7	12.7	300–2400
76	25	76.2	25.4	1200–3600
125	26	125	26.0	1200–3600
230	64	228.6	63.5	1200–3600
Rib profiles Types I and II				
Nominal		**Actual**		
Pitch	**Depth and width**	**Pitch**	**Depth and width**	**Inside diameter**
191	19	190.5	19.05	450–2600

Table 7
Riveted corrugated steel pipe — Minimum outside circumference on crest of corrugation
(See Clauses 5.1.2.1.3 and 5.1.2.4.2.)

Inside diameter, mm	Minimum outside circumference, mm	
	Corrugation depth, mm	
	13	25 or 26
300	1 000	—
400	1 310	—
500	1 630	—
600	1 940	—
700	2 260	—
800	2 570	—
900	2 880	—
1 000	3 200	—
1 200	3 830	3 900
1 400	4 460	4 520
1 600	5 080	5 150
1 800	5 700	5 770
2 000	6 330	6 390
2 200	6 950	7 020
2 400	7 570	7 640
2 700	—	8 580
3 000	—	9 510
3 300	—	10 450
3 600	—	11 380

Notes:

1) *Extension pipes and couplers for existing imperial-sized corrugated steel pipe are available through special orders.*

2) *For Manitoba Transportation and Government Services, pipe diameters of* 450, 750, 1050*, and* 1500 mm *are standard sizes in addition to the sizes specified in this Table.*

Table 8
Rivet diameters and lengths
(See Clause 5.1.2.2.)

Nominal sheet thickness, mm	Nominal rivet diameter, mm		Minimum rivet length, mm
	Corrugation depth, mm		
	13	25 or 26	
1.00	8	—	16
1.30	8	—	16
1.60	8	10	16
2.00	8	10	16
2.80	10	12	20
3.50	10	12	20*
4.20	10	12	25

* *The minimum rivet length where three steel sheets are joined shall be* 25 mm.

Table 9
Riveted corrugated steel pipe — Longitudinal seam lap and rows of rivets
(See Clauses 5.1.2.3.1 and 5.1.2.3.3.)

Diameter, mm	Corrugation depth, mm	Rows of rivets	Minimum longitudinal seam lap, mm
300–500	13	Single	40
600–1000	13	Single	50
1200 and larger	13, 25, or 26	Double	75

Table 10
Helical corrugated steel pipe — Minimum outside circumferences
(See Clauses 5.1.3.1.1 and 5.1.3.7.2.)

Inside diameter, mm	Minimum outside circumference, mm		
	Corrugation depth, mm		
	6.5	13	25 or 26
100	350	—	—
150	500	—	—
200	660	—	—
250	820	—	—
300	—	1 010	—
400	—	1 330	—
500	—	1 650	—
600	—	1 950	—
700	—	2 280	—
800	—	2 590	—
900	—	2 910	—
1 000	—	3 220	—
1 200	—	3 850	3 920
1 400	—	4 480	4 550
1 600	—	5 110	5 170
1 800	—	5 730	5 800
2 000	—	6 360	6 450
2 200	—	6 980	7 050
2 400	—	7 610	7 680
2 700	—	—	8 620
3 000	—	—	9 560
3 300	—	—	10 500
3 600	—	—	11 400

Notes:

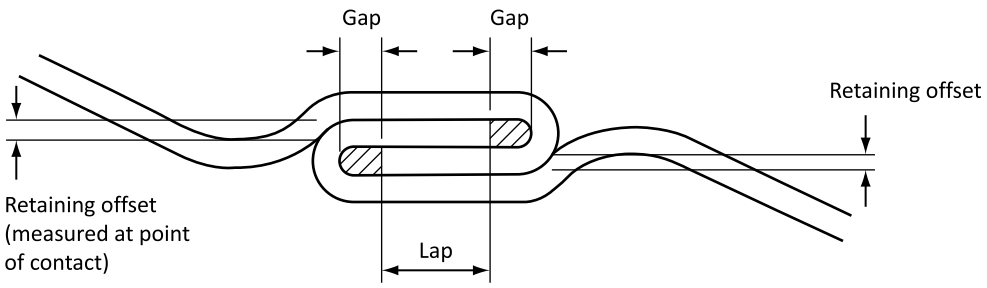
1) *Extension pipes and couplers for existing imperial-sized corrugated steel pipe are available through special orders.*

2) *For Manitoba Transportation and Government Services, pipe diameters of* 450, 750, 1050*, and* 1500 mm *are standard sizes in addition to the sizes specified in this Table.*

Table 11
Types I and II spiral rib steel pipe — Minimum outside circumferences
(See Clauses 5.1.3.1.1 and 5.1.3.7.2.)

Inside diameter, mm	Minimum outside circumference, mm
450	1523
525	1759
600	1994
750	2566
900	2937
1050	3408
1200	3879
1350	4351
1500	4820
1650	5289
1800	5757
2000	6383
2200	7013
2400	7638
2600	8263

Table 12
Helical lockseam pipe — Minimum seam lap dimensions
(See Clauses 5.1.3.2.1, 5.1.3.2.2, 5.1.3.3.2.1, 5.1.3.3.2.4, and 5.1.3.3.2.7.)



Ideal cross-section of lockseam

Corrugation profile			
Pitch, mm	**Depth, mm**		**Lap, mm**
38	6.5		4.0
68	13		6.5
76	25		8.0
125	26		8.0
Rib profile			
Pitch, mm	**Depth, mm**	**Width, mm**	**Lap, mm**
191	19	19	6.5

Table 13
Helical lockseam pipe — Minimum lateral seam strength
(See Clauses 5.1.3.4.1, 5.1.3.4.3, and 5.1.3.6.2.)

Nominal sheet thickness, mm	Minimum lateral seam strength, N/mm
1.00	36
1.30	51
1.60	65
2.00	88
2.80	136
3.50	182
4.20	234

Table 14
Corrugated steel pipe — Standard pipe-arch dimensions — Corrugation profile, 68 × 13 mm
(See Clauses 5.1.4.2.1 and 5.1.4.2.2.)

Span, mm*	Rise, mm*	Equivalent diameter, mm	Minimum corner radius, mm
450	340	400	75
560	420	500	100
680	500	600	125
800	580	700	150
910	660	800	150
1030	740	900	150
1150	820	1000	150
1390	970	1200	175
1630	1120	1400	175
1880	1260	1600	250
2130	1400	1800	300

* *A tolerance of* 25 mm *or 2% of equivalent diameter, whichever is greater, shall be permitted in the span or rise.*

Table 15
Corrugated steel pipe — Standard pipe-arch dimensions — Corrugation profiles, 76 × 25 mm and 125 × 26 mm

(See Clauses 5.1.4.2.1 and 5.1.4.2.2.)

Span, mm	Rise, mm	Equivalent diameter, mm	Minimum corner radius, mm	Maximum *B*, mm*
1330^{+0}_{-65}	1030^{+65}_{-0}	1200	175	400
1550^{+0}_{-75}	1200^{+75}_{-0}	1400	175	550
1780^{+0}_{-90}	1360^{+90}_{-0}	1600	250	635
2010^{+0}_{-100}	1530^{+100}_{-0}	1800	300	650
2230^{+0}_{-110}	1700^{+110}_{-0}	2000	355	660
2500^{+0}_{-125}	1830^{+125}_{-0}	2200	400	750
2800^{+0}_{-140}	1950^{+140}_{-0}	2400	400	805
3300^{+0}_{-165}	2080^{+165}_{-0}	2700	400	905
3650^{+0}_{-180}	2280^{+180}_{-0}	3000	400	1005
3890^{+0}_{-195}	2690^{+195}_{-0}	3300	400	1090
4370^{+0}_{-220}	2890^{+220}_{-0}	3600	400	1195

** B is defined as the vertical dimension from the horizontal line across the widest portion of the arch to the lowest portion of the base.*

Table 16
Types I and II spiral rib steel pipe — Standard pipe-arch dimensions
(See Clauses 5.1.4.2.1 and 5.1.4.2.2.)

Span, mm*	Rise, mm*	Equivalent diameter, mm	Minimum corner radius, mm
500	410	450	125
580	490	525	125
680	540	600	125
830	660	750	125
1010	790	900	125
1160	920	1050	150
1340	1050	1200	175
1520	1200	1350	200
1670	1300	1500	225
1850	1400	1650	250

* *A tolerance of* 25 mm *or 2% of equivalent diameter, whichever is greater, shall be permitted in the span or rise.*

Table 17
Corrugated steel pipe invert perforations
(See Clause 5.1.5.4.4 and Figure 8.)

Inside diameter, mm	Minimum number of rows of perforations	Minimum outside arc, *L*, mm*
100	2	85
150	4	120
200	4	160
250	4	195
300	6	240
400	6	315
500	6	390
600	8	465

* *See Figure 8.*

Table 18
Minimum coupler dimensions
(See Clauses 5.1.7.1.3 and 5.1.7.2.2.4.)

Coupler type	Pipe diameter, mm	Nominal thickness, mm	Minimum width, mm	Number of bolts per coupler segment	Dimples	
					Minimum number of circumferential rows	Minimum number per row*
Flat	100–600	1.30	140	2	—	—
Corrugated and semi-corrugated	300–600	1.30	180	2	—	—
	700–1600	1.60	300	2	—	—
	Over 1600	1.60	300 or 600*	3	—	—
				5	—	—
Universal dimple	300–600	1.30	300	2	4	6
	700–1200	1.60	300	2	4	7
	Over 1200	1.60	600	3	4	8
Internal flat and semi-corrugated	900 and greater	1.60	290	—	—	—
Internal coupler	900 and greater	1.60	610	3	—	—

* *The width depends on the application.*

Table 19
Permitted nominal inside diameters for round structural plate corrugated steel pipe, mm
(See Clause 5.2.3.1.)

1500	2590	4610	6780
1660	2740	4920	7090
1810	3050	5230	7400
1970	3360	5540	7710
2120	3670	5850	8020
2280	3990	6160	
2430	4300	6470	

Table 20
Structural plate corrugated steel pipe — Flat plate width dimensions
(See Clauses 5.2.3.2 and 5.2.3.6.)

Width designation, number of hole spaces*	Net arc width, mm	Overall width, mm		Number of circumferential bolt holes
		Type I†	Type II‡	
3*N*	732	859	852	4
4*N*	975	1102	1095	5
5*N*	1219	1346	1339	6
6*N*	1463	1590	1583	7
7*N*	1707	1834	1827	8
8*N*	1951	2078	2071	9
9*N*	2195	2322	2315	10
10*N*	2438	2565	2588	11
11*N*	2682	2809	2802	12
12*N*	2926	3053	3046	13
13*N*	3170	3297	3290	14
14*N*	3414	3541	3534	15
15*N*	3658	3785	3778	16
16*N*	3901	4028	4021	17

* *N* = 244 mm *nominal.*
† *For Type I, larger overall arc widths may be used and shall be* 127 mm *plus a multiple of N.*
‡ *For Type II, larger overall arc widths may be used and shall be* 120 mm *plus a multiple of N.*

Table 21
Steel two-flange tunnel liner plate — Flat plate width dimensions
(See Clauses 5.2.3.2 and 5.2.3.6.)

Width designation*	Net arc width, mm	Overall width, mm	Number of circumferential bolt holes
300π	942	1037	6
350π	1100	1195	7
400π	1257	1352	8

* *π = 3.1416.*

Table 22
Deep corrugated structural plate — Flat plate width dimensions
(See Clauses 5.2.3.2 and 5.2.3.6.)

Type I*				
Width designation, number of hole spaces†	**Net arc width, mm**	**Overall width of barrel plates, mm**	**Minimum overall width of rib plates, mm**	**Number of circumferential bolt holes**
1*S*	406	635	482	2
2*S*	813	1042	889	3
3*S*	1219	1448	1295	4
4*S*	1626	1855	1702	5
5*S*	2032	2261	2108	6
6*S*	2438	2667	2514	7
7*S*	2845	3074	2921	8
8*S*	3251	3480	3327	9
9*S*	3658	3887	3734	10
10*S*	4064	4293	4140	11
11*S*	4470	4699	4546	12
12*S*	4876	5105	4952	13

Type II			
Width designation, number of hole spaces‡	**Net arc width, mm**	**Overall width, mm**	**Number of circumferential bolt holes**
4*H*	1700	1980	5
5*H*	2125	2405	6
6*H*	2550	2830	7
7*H*	2975	3255	8
8*H*	3400	3680	9
9*H*	3825	4105	10

Type III§			
Width designation, number of hole spaces**	**Net arc width, mm**	**Overall width, mm**	**Number of circumferential bolt holes**
1*U*	500	729	2
2*U*	1000	1229	3
3*U*	1500	1729	4
4*U*	2000	2229	5
5*U*	2500	2729	6
6*U*	3000	3229	7
7*U*	3500	3729	8
8*U*	4000	4229	9

(Continued)

Table 22 (Concluded)

Type III§			
Width designation, number of hole spaces**	**Net arc width, mm**	**Overall width, mm**	**Number of circumferential bolt holes**
9*U*	4500	4729	10
10*U*	5000	5229	11
11*U*	5500	5729	12
12*U*	6000	6229	13
13*U*	6500	6729	14
14*U*	7000	7229	15

* *For Type I, larger overall arc widths may be used and shall be* 229 mm *plus a multiple of S.*
† *S =* 406 mm *nominal.*
‡ *H =* 425 mm *nominal.*
§ *For Type III, larger overall arc widths may be used and shall be* 229 mm *plus a multiple of U.*
** *U =* 500 mm *nominal.*

Table 23
Unbalanced channel and receiving angle dimensions
(See Clause 5.2.5 and Figure 22.)

									Hole h1		Hole h2		Hole h3	
Product	**A, min**	**B, min**	**C, min**	**D, min**	**E**	**F**	**G**	**α**	**Dimensions***	**Spacing, max**	**Dimensions***	**Spacing, max**	**Dia ***	**Typical spacing‡**
Bolted CSP 125 x 25	76	76	0	4.0	35	n/a	41	90°	14 × 32	250	n/a	n/a	14 x 22	500
Bolted CSP 230 x 64	133	76	0	4.0	35	79	44	80° or 90°	25 × 32	457.2	25 x 32	457.2	25 x 32	457
Two-flange TLP	108	108	0	6.4	31	n/a	72	Varies	17.5†	215	n/a	n/a	Ø22	500
SPCSP Type I	120	83.0	35	4.0	30	n/a	42	90°	25 × 45	305	n/a	n/a	Varies	381
SPCSP Type II	133	76	0	4.0	35	79	44	80° or 90°	25 × 32	457.2	25 x 32	457.2	25 x 32	457
DCSP Type I	157	175	33	5	33	109	88	90°	25 × 32	381	25 x 32	381	25 x 32	381
DCSP Type II	185	185	35	5	30	n/a	93	90°	22 × 44	400	n/a	n/a	Ø 22	400
DCSP Type III	157	282	33	5	33	109	131	90°	29 × 44	500	29 x 44	500	Ø 29	500

* *The long dimension (major axis) of slotted holes shall run longitudinally to the base channel.*
† *Square hole.*
‡ *The bolt holes for anchoring the base channel to the foundation shall be punched as shown on the plans, with a maximum spacing of* 610 mm *on centres.*

Table 24
Physical properties of thermoplastic copolymer coating
(See Clause 4.5.5.1.1.)

Property	Result
Chemistry	Thermal plastic EAA copolymer
Colour	Black
60° gloss	50+
Peak melting point, °C (°F)	92.8 (199)
Vicat softening point, °C (°F)	82.2 (165)
Relative differential scanning calorimetry (DSC) crystallinity, %	25.2
Maximum service temperature, °C (°F)	93.9 (160)
Thermal conductivity, W/(m•K) (Btu•ft/h/ft^2/°F)	0.215 (0.214)
Thermal expansion, 10^{-6} mm/mm/°C (10^{-6} in/in/°C)	160 (160)
Tensile yield, MPa (psi)	8 (1160)
Tensile strength, MPa (psi)	20 (2900)
Elongation, %	610
Shore D hardness	54
Tensile impact, kJ/m^2 (ft-lb/in^2)	550 (234)

Table 25
Performance requirements for thermoplastic EAA copolymer coatings
(See Clause 4.5.5.1.5 and 4.5.5.5.3.)

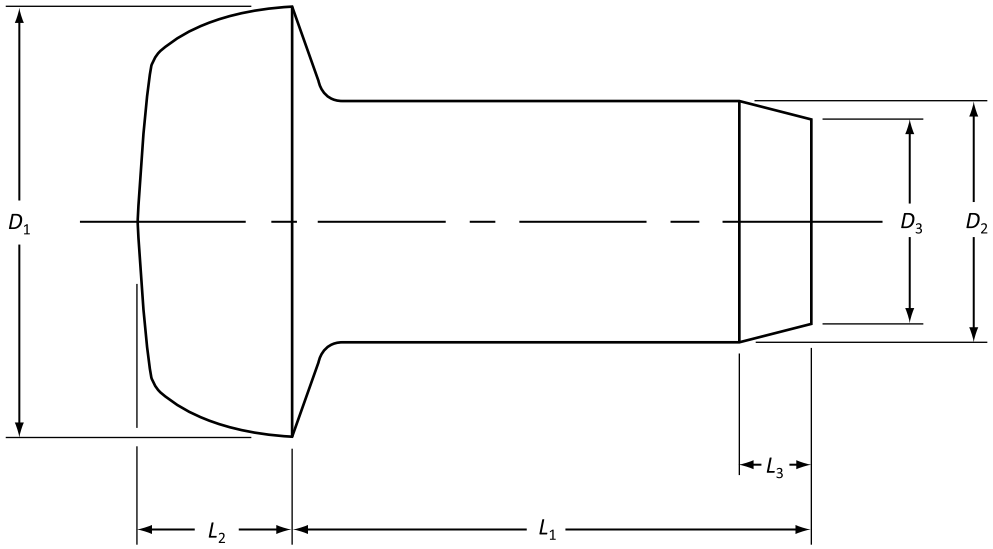
Property	Test method	Requirement
Humidity	ASTM D2247, X scribe, air blow off, 4500 h	Blister rating 10 Undercut rating 10
	ASTM D2247, unscribed, 5000 h	Blister rating 10
Chip resistance	ASTM D3170, 483 ± 21 kPa (70 ± 3 psi), feed rate 7 to 10 s	Minimum 6A to 8A rating
Salt spray	ASTM B117, X scribe, air blow off, 4000 h	Blister rating 10 Undercut rating 10
	ASTM B117, X routered, brush off, 4000 h	Corrosion only in routered X with no peel back at X
	ASTM B117, X scribe, air blow off, 7700 h	Max 2.0 mm creepage
Cyclic corrosion	SAE J2334, vertical scribe, scrape, 60 cycles	Max. 6.3 mm, average 3.6 mm undercut
Pencil hardness	ASTM D3363, Staedtler Mars Lumograph	Pass 5H gouge
Impact	ASTM D2794, Gardner impact, 4 lb (1.81437 kg), 5/8 in (15.9 mm) indenter	Ambient temperature: Pass 1.8434 kg•m (160 in-lb) direct
	ASTM D2794, Gardner impact, 4 lb (1.81437 kg), 5/8 in (15.9 mm) indenter	−40 °C: Pass 1.61297 kg•m (140 in-lb) direct
Adhesion	ASTM D3359, X cut, Method A, Elcometer 99 Tape	Pass 5A rating
	ASTM D4541, Pull adhesion — Glue failure	At 9 MPa (1400 lb/in)
Water immersion	ASTM D870, deionized water, 38 ± 2 °C, 240 h	No blistering or other changes in appearance
QUV accelerated weathering testing	ASTM G154, condensation 4 h, 50 °C; UV 8 h, 60 °C — Cycles	Delta E rating 0.68 to 0.84 at 3000 h
Chemical resistance	ASTM D1308, 24 h, chloroform, methylene, tetrahydrofuran (THF)	No change
Dime scrape	GM 9506P	Good adhesion
Thumbnail hardness	GM 9507P	Marred
Mandrel bend	ASTM D522, Gardner rod mandrels	Passed 1/4 in mandrel
Taber abrasion	ASTM D4060, CS-10, 1000 cycles, 1000 g load	10.6 mg to 11.1 mg
	ASTM D4060, CS-17, 1000 cycles, 1000 g load	8.8 to 13 mg loss
Abrasion — humid blast	LC 21-102, sand blast, 570 g/min, four 43.3 min cycles	Maximum 0.43 g or 2 µm loss
Cathodic disbondment	ASTM G8	Maximum disbondment 4.74 cm² and 2.47 cm²
Holidays test	ASTM A742/A742M; ASTM G62, Method A	No holidays present
Freeze thaw resistance	ASTM A742/A742M, 24 h cycles, 100 cycles	No spalling, disbonding, or detrimental effects

(Continued)

Table 25 (Concluded)

Property	Test method	Requirement
Microbial attack	ASTM A742/A742M; ASTM G22, Procedure B	No visible effect of bacterial attack
Impact	ASTM A742/A742M, 4.0 J impact on a 15.88 mm punch	Ambient: No evidence of cracking
	ASTM A742/A742M, 4.0 J impact on a 15.88 mm punch	−40 °C: No evidence of cracking
Weatherability	ASTM A742/A742M; ASTM G23	No cracking, delamination, dulling, or blistering
Thickness of coating	ASTM A742/A742M; ASTM D1005	Minimum 10 mils or 250 μm per side
Imperviousness	ASTM D543 60T, 2160 h, sulphuric acid 50%	No change
	ASTM D543 60T, 2160 h, sodium hydroxide 50%	No change
	ASTM D543 60T, 2160 h, sodium chloride saturated	No change
Resistance — acids and bases	ASTM D543 60T, 2160 h, hydrochloric acid 35%	No change
	ASTM D543 60T, 2160 h, nitric acid 5%	No change
	ASTM D543 60T, 2160 h, aluminum hydroxide	No change
	ASTM D543 60T, 2160 h, sodium hydroxide, 50%	No change

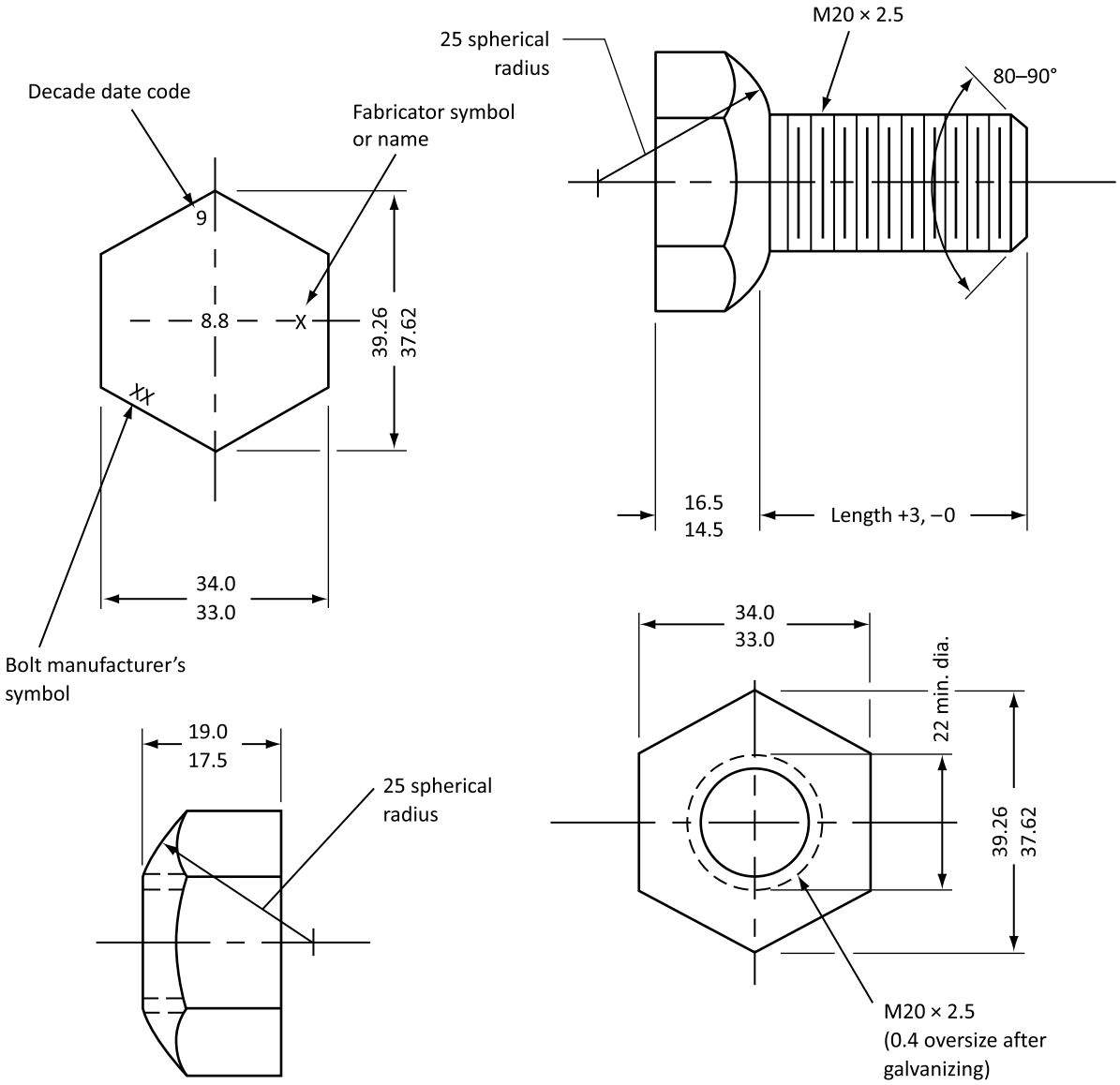
Figure 1
Standard rivets for riveted corrugated steel pipe
(See Clauses 4.4.1 and 5.1.2.2.)



Rivet diameter	Length	L_1	L_2	L_3	D_1	D_2	D_3
8	16	15.7–16.3	4.6–5.0	1.7–2.3	13.4–14.2	7.8–8.1	6.3–6.5
10	16	15.6–16.4	5.7–6.2	2.0–2.9	16.7–17.7	9.7–10.1	8.1–8.4
10	20	19.6–20.4	5.7–6.2	2.0–2.9	16.7–17.7	9.7–10.1	8.1–8.4
10	25	24.6–25.4	5.7–6.2	2.0–2.9	16.7–17.7	9.7–10.1	8.1–8.4
12	20	19.5–20.5	6.9–7.4	2.5–3.5	20.0–21.2	11.7–12.1	9.7–10.1
12	25	24.5–25.5	6.9–7.4	2.5–3.5	20.0–21.2	11.7–12.1	9.7–10.1

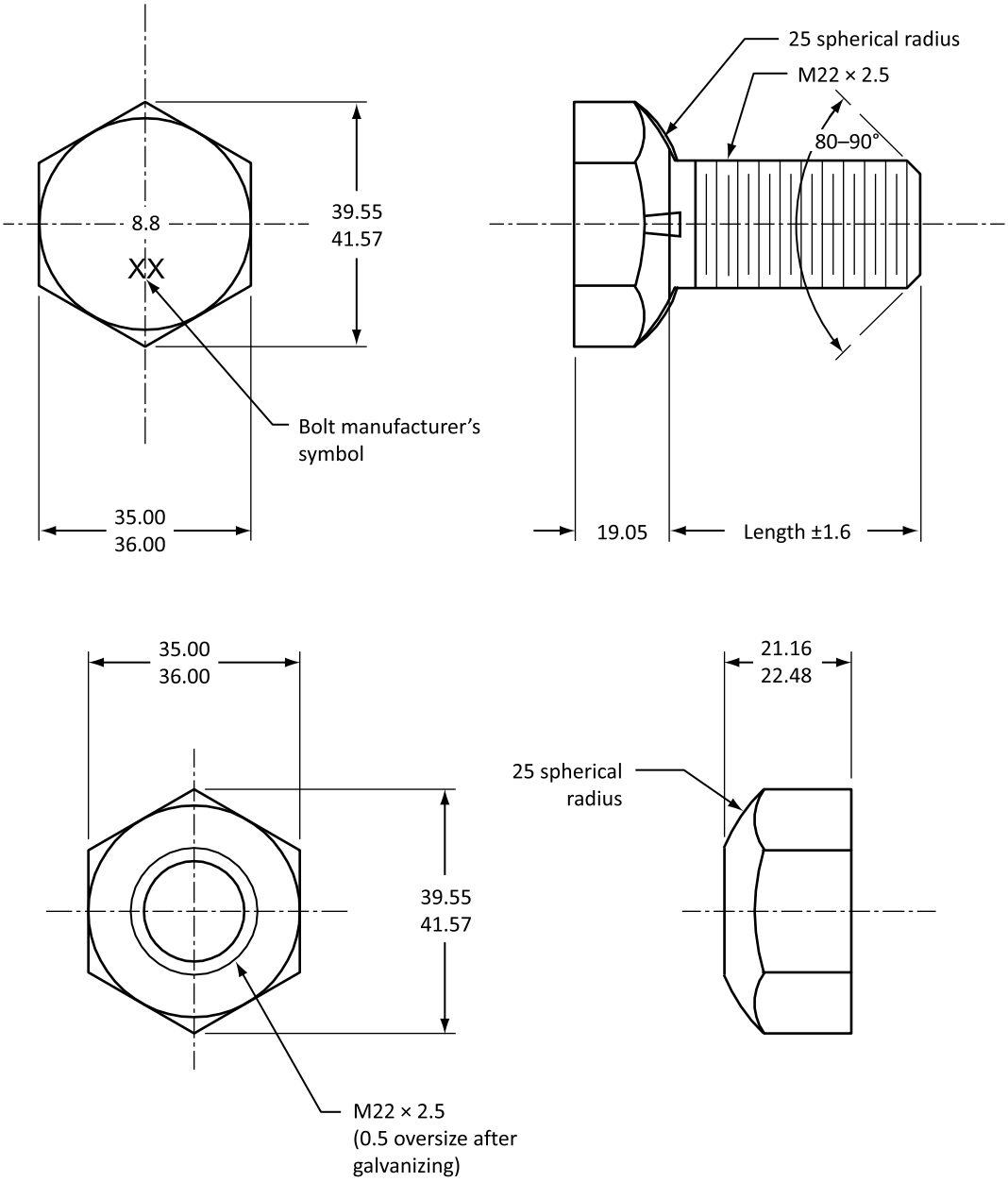
Note: *All dimensions are in millimetres.*

Figure 2
M20 structural plate nuts and bolts
(See Clauses 4.4.2.2, 4.4.2.3, and 4.4.2.6.)



Note: *All dimensions are in millimetres.*

Figure 3
M22 structural plate nuts and bolts
(See Clauses 4.4.2.2, 4.4.2.3, and 4.4.2.6.)



Note: *All dimensions are in millimetres.*

Figure 4
Corrugated steel pipe corrugated profile
(See Clauses 5.1.1.2.1 to 5.1.1.2.3.)

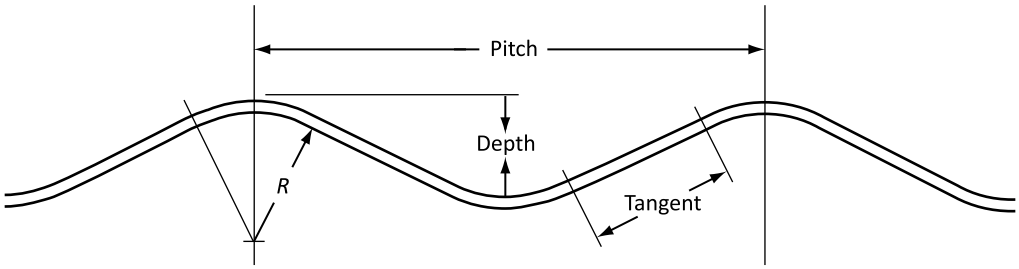


Figure 5
Type I spiral rib steel pipe profile
(See Clause 5.1.1.3.1.)

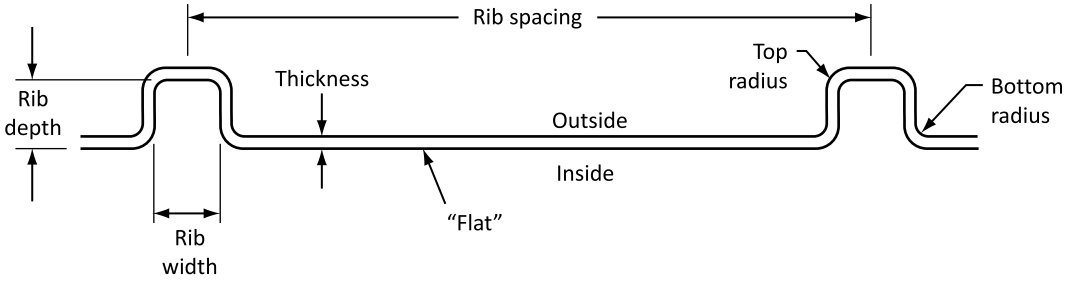
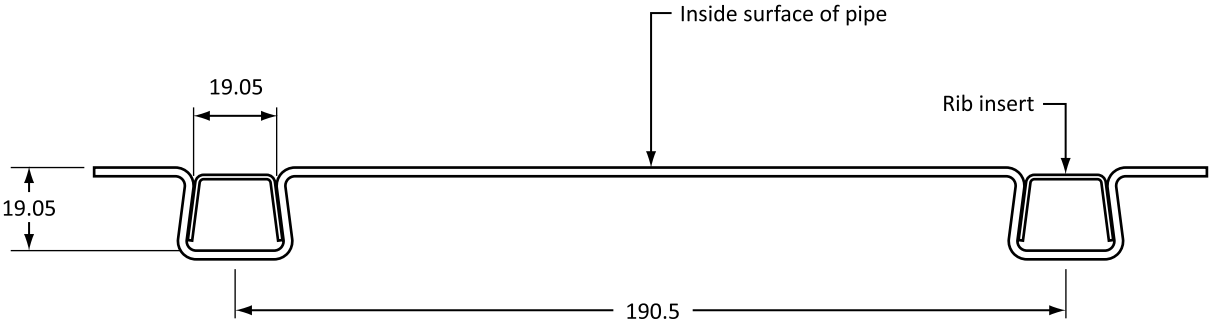


Figure 6
Type II spiral rib steel pipe profile
(See Clause 5.1.1.3.1.)



Note: *All dimensions are in millimetres.*

Figure 7
Location of lockseam sample
(See Clauses 5.1.3.1.3, 5.1.3.3.2.1, and 5.1.3.4.2.)

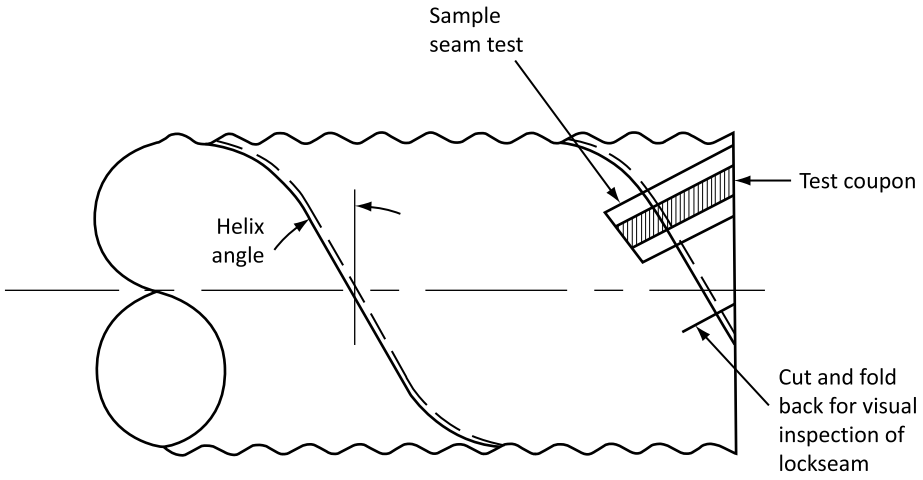


Figure 8
Invert perforated corrugated steel pipe
(See Clause 5.1.5.4.3 and Table 17.)

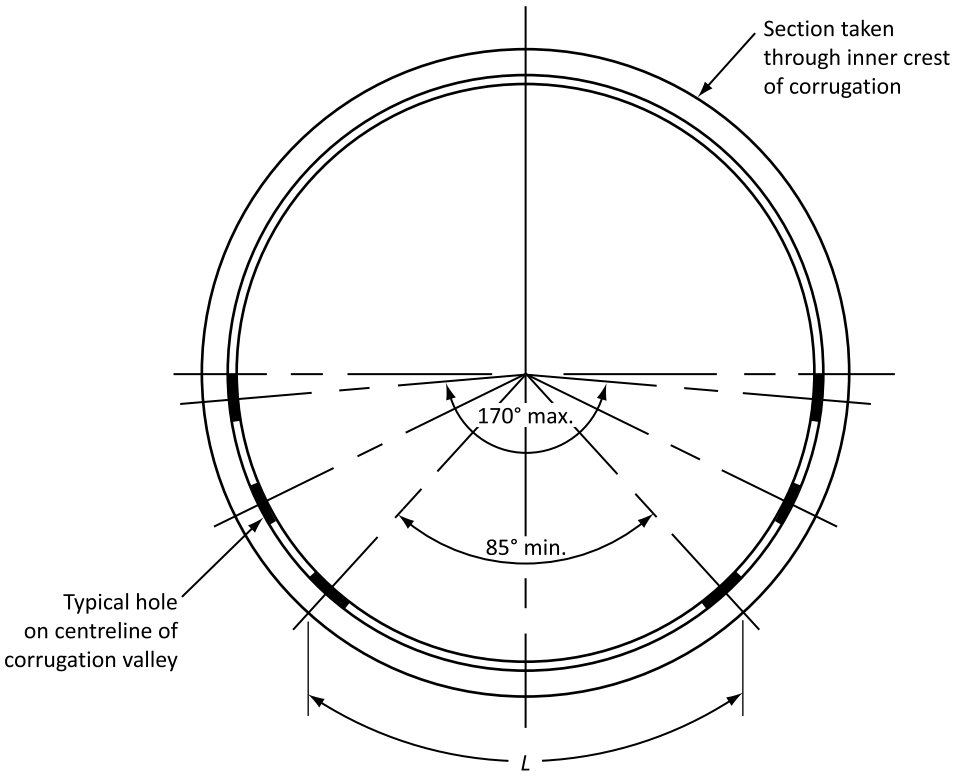
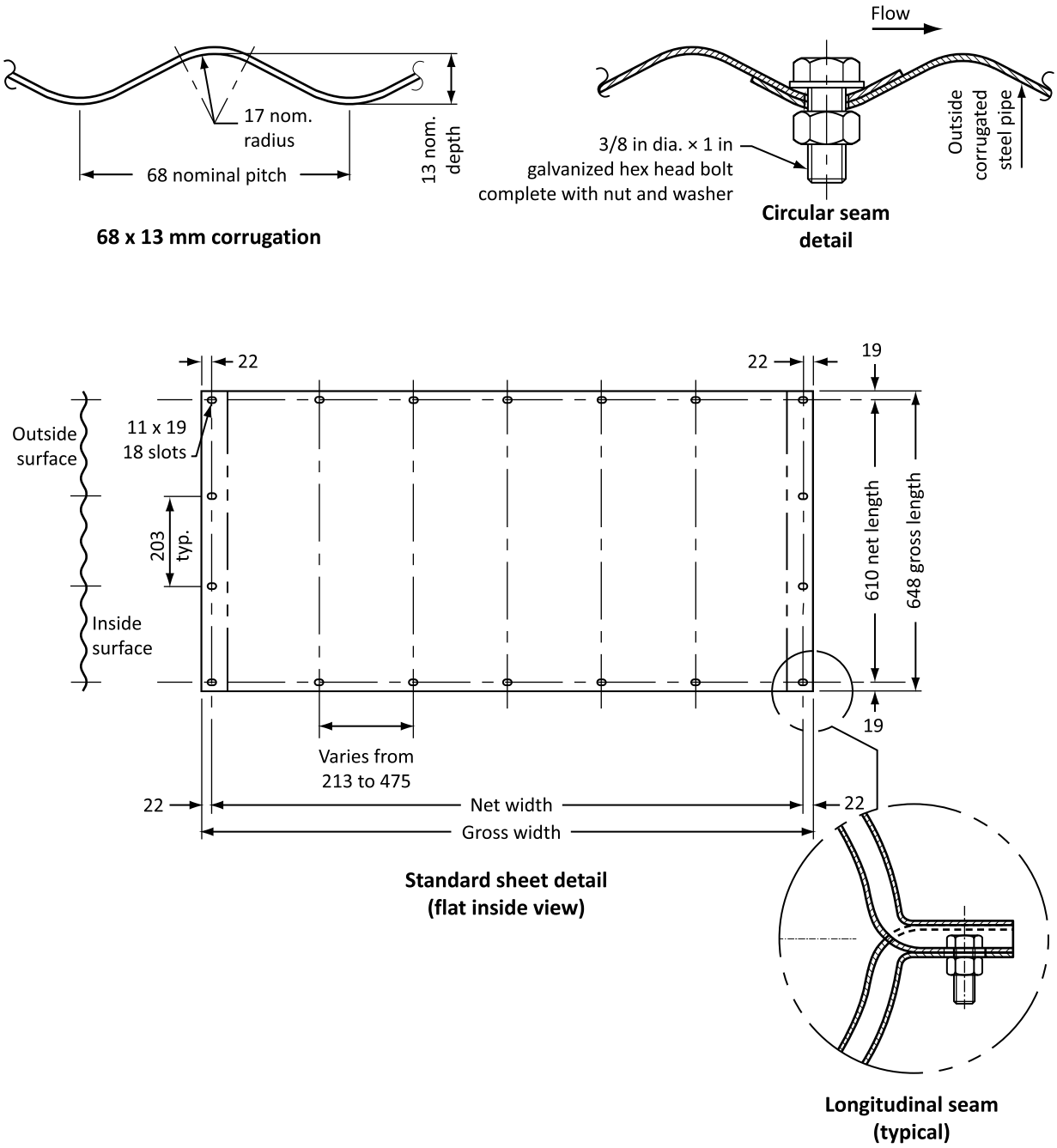
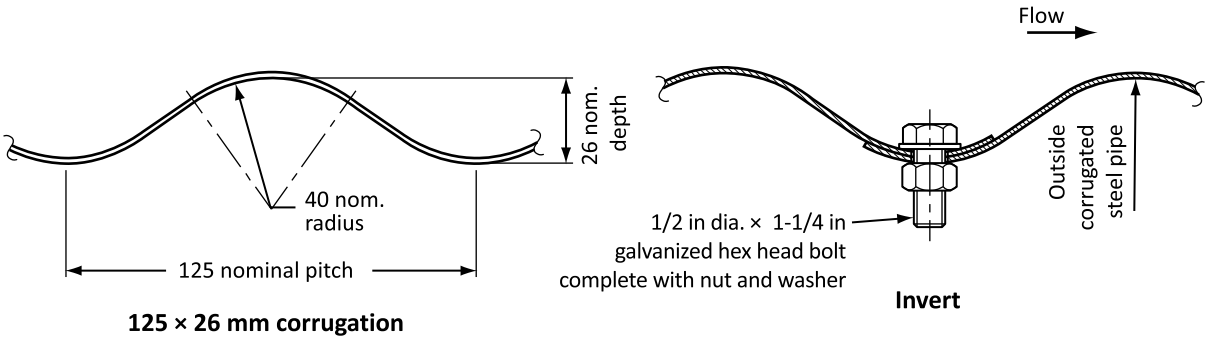


Figure 9
Standard sheet detail for 68 × 13 mm bolted corrugated steel pipe
(See Clause 5.1.6.2.2.)

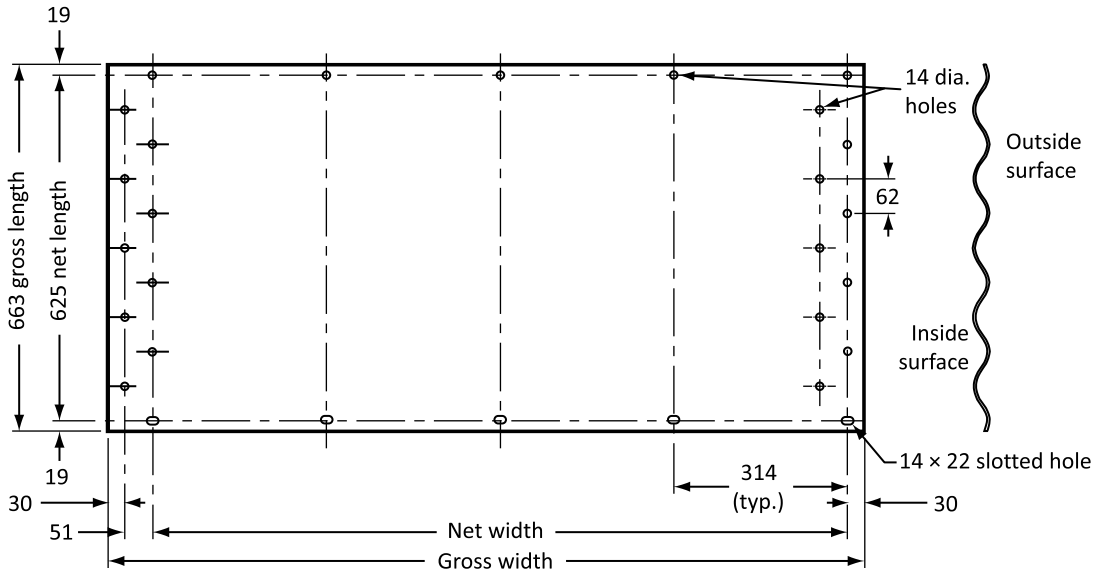


Note: *Unless otherwise stated, all dimensions are in millimetres.*

Figure 10
Standard sheet detail for 125 × 26 mm bolted corrugated steel pipe
(See Clause 5.1.6.2.2.)



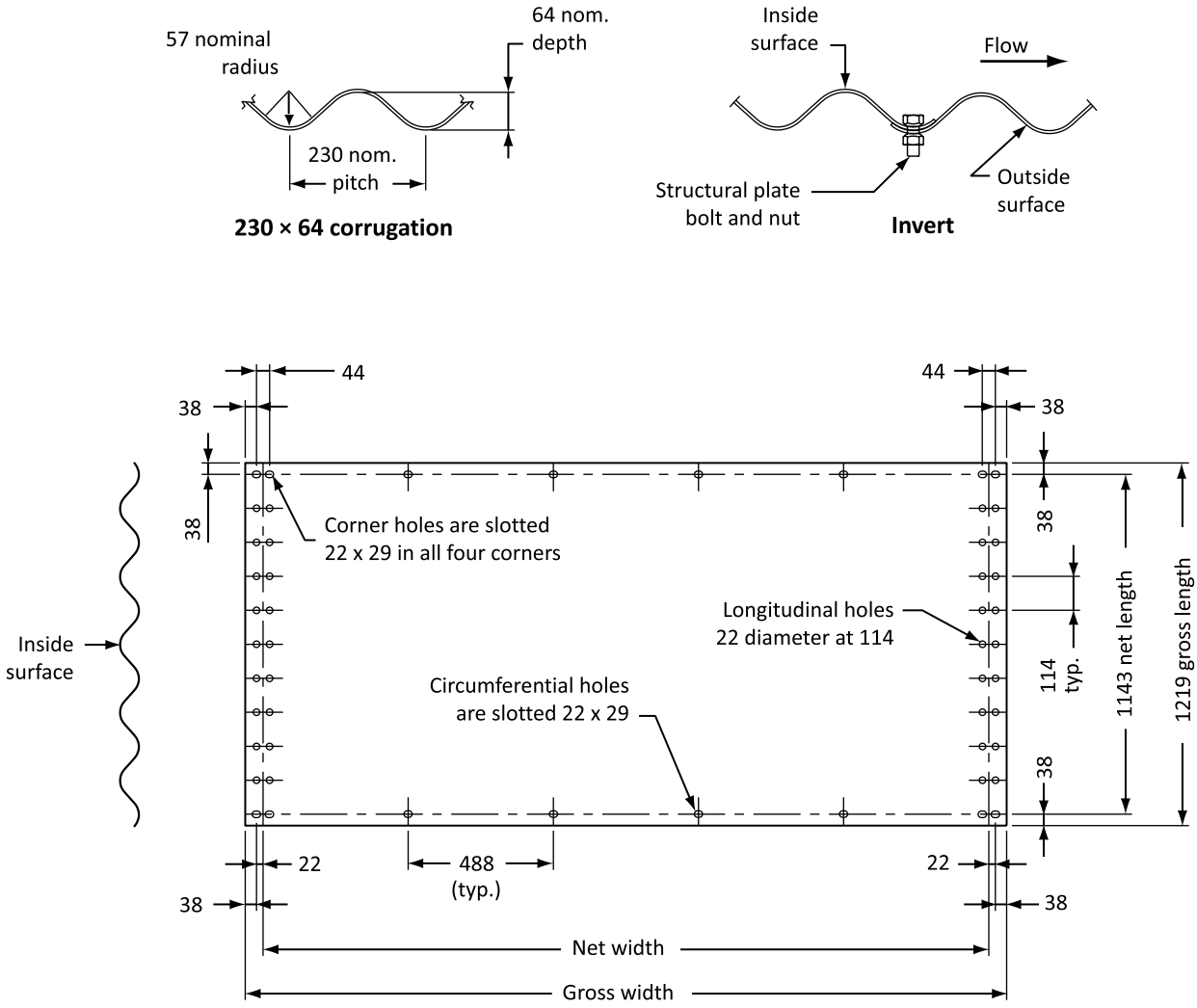
125 × 26 mm corrugation



Standard sheet detail
(Flat inside view)

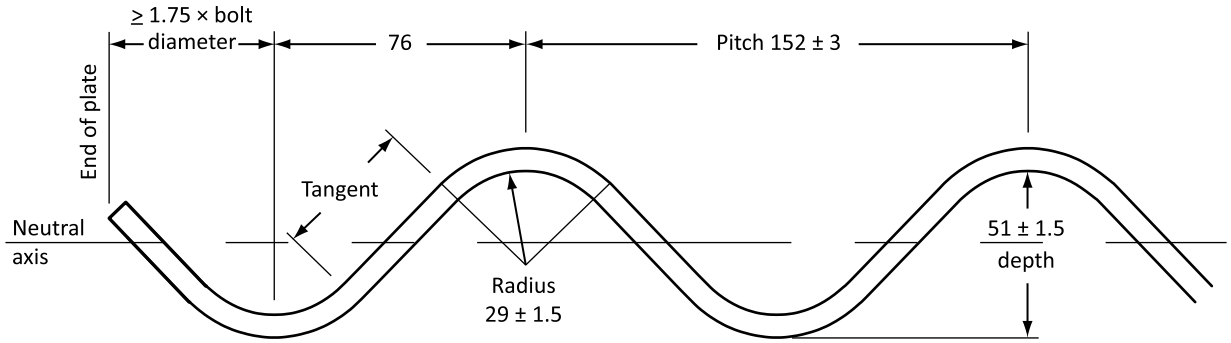
Note: *Unless otherwise stated, all dimensions are in millimetres.*

Figure 11
Standard sheet detail for 230 × 64 mm bolted corrugated steel pipe
(See Clause 5.1.6.2.2.)

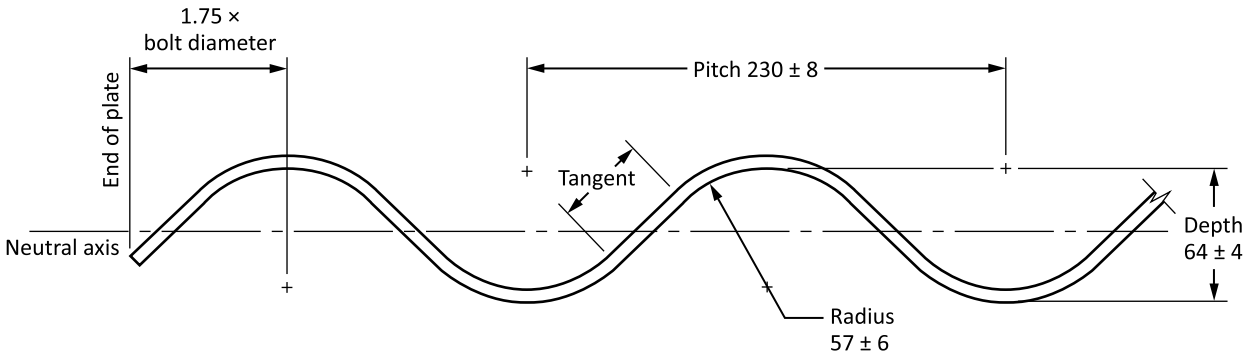


Note: *All dimensions are in millimetres.*

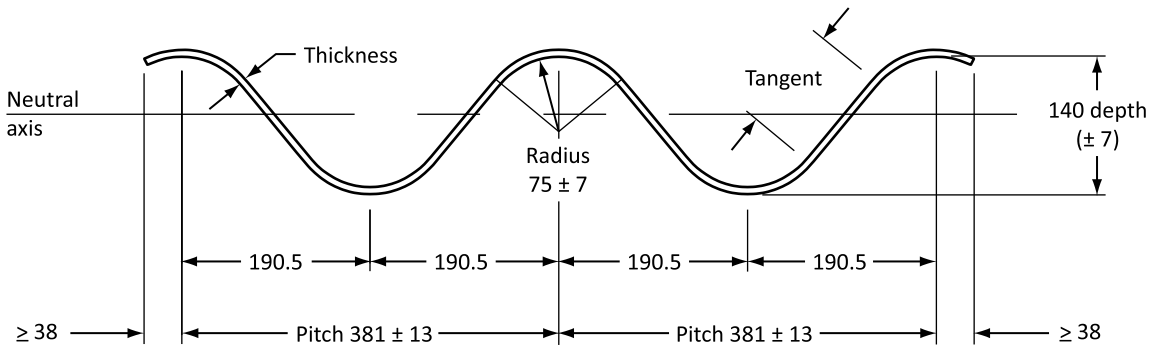
Figure 12
Corrugation profiles for structural plate corrugated, deep corrugated structural plate, and two-flange tunnel liner plate pipe
(See Clause 5.2.2.2.)



a) Structural plate Type I



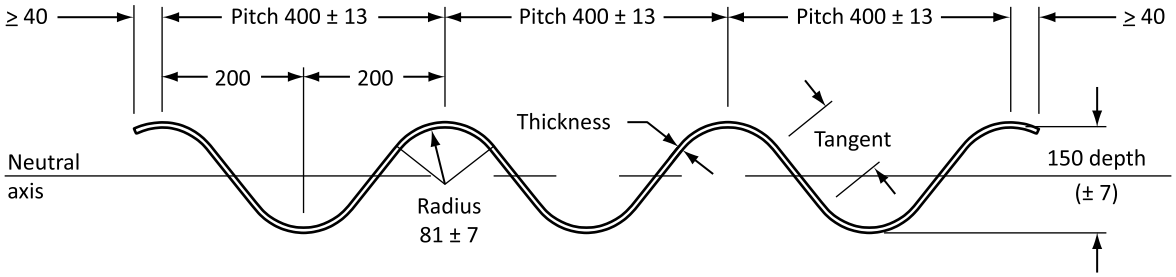
b) Structural plate Type II



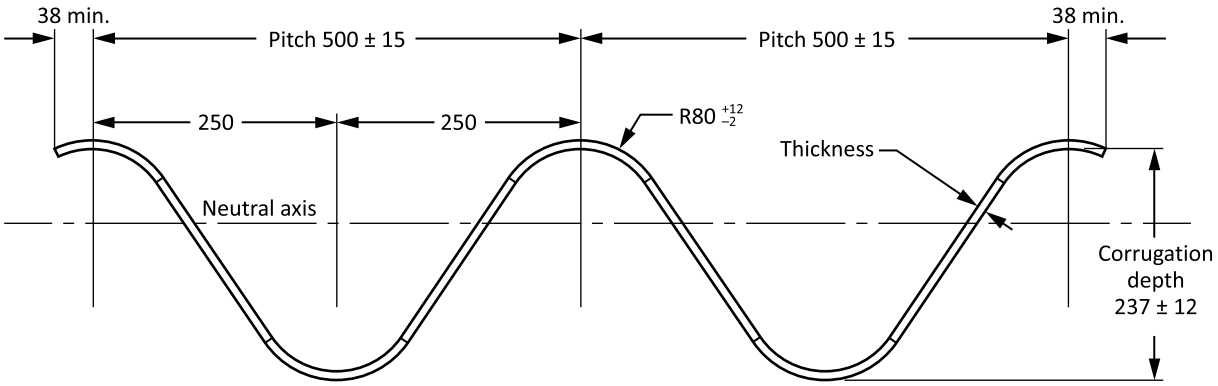
c) Deep corrugated structural plate Type I

(Continued)

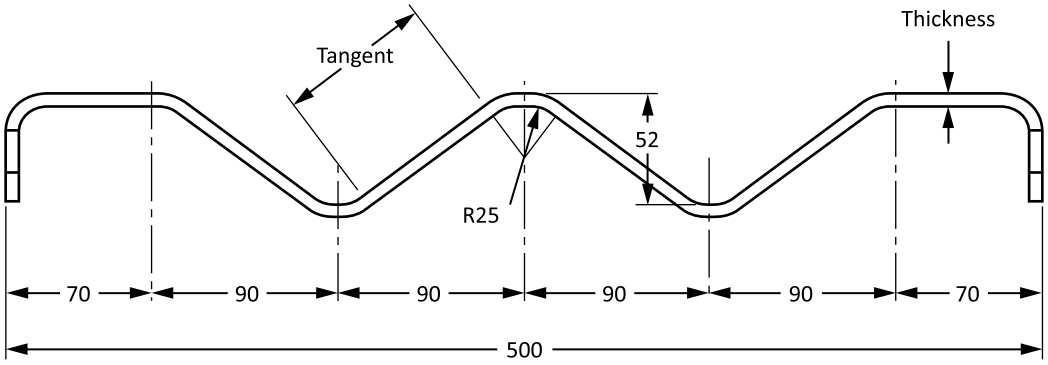
Figure 12 (Concluded)



d) Deep corrugated structural plate Type II



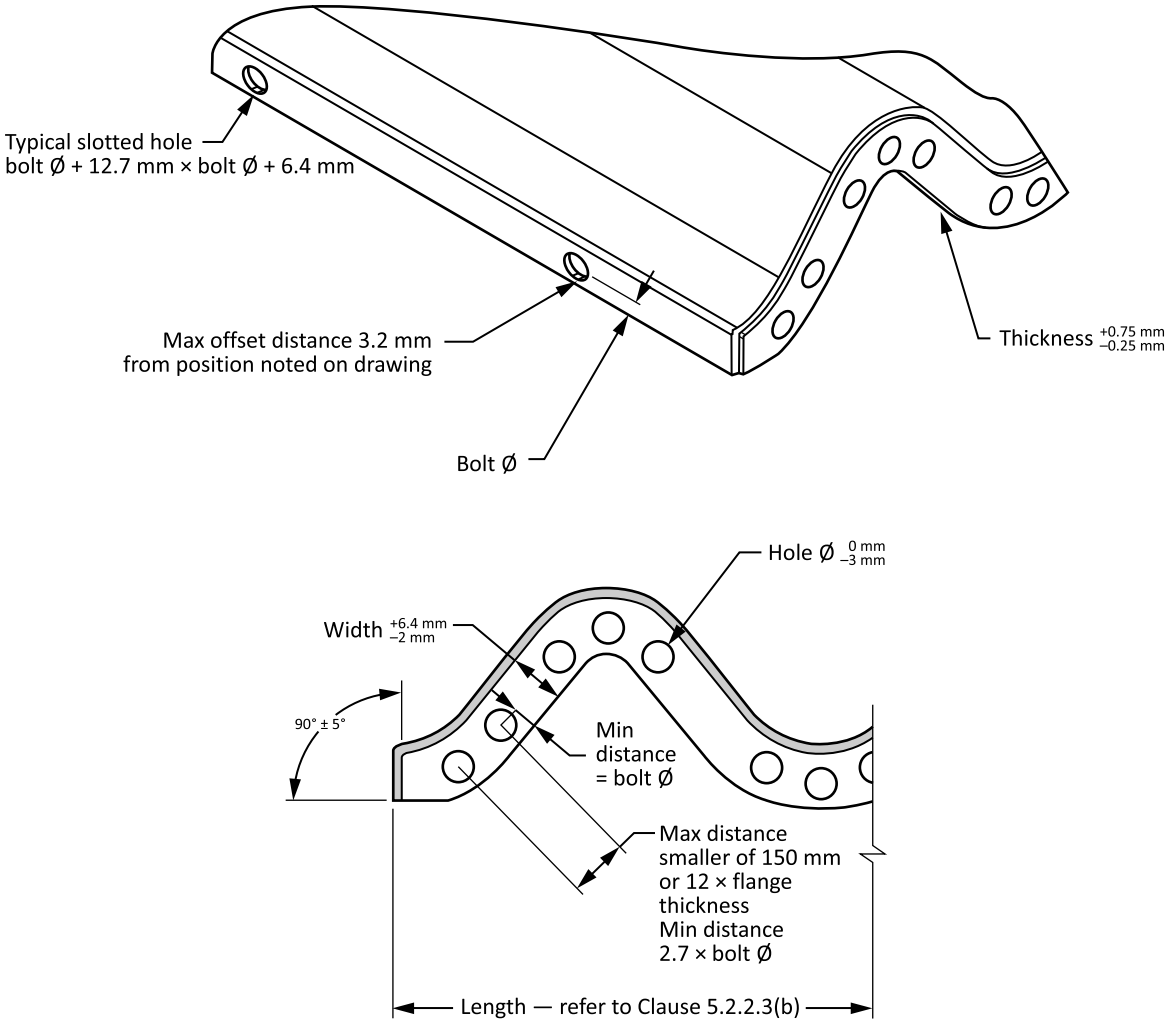
e) Deep corrugated structural plate Type III



f) Two-flange tunnel liner plate

Note: *All dimensions are in millimetres.*

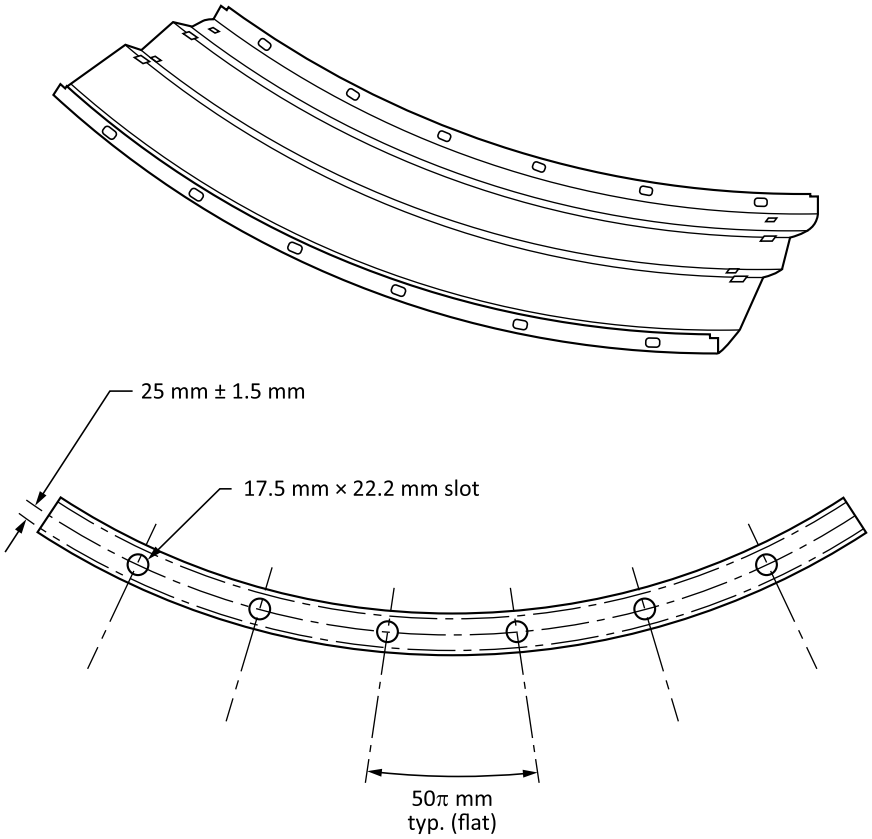
Figure 13
Flange profiles for structural plate Type II, deep corrugated structural plate Types I and III, and tunnel liner plate
(See Clauses 5.2.2.3, 5.2.3.4.2, 5.2.3.4.3, and 5.2.3.4.5.)



a) Longitudinal and circumferential flange profile for structural plate Type II and deep corrugated structural plate Types I and III

(Continued)

Figure 13 (Concluded)



b) Circumferential flange profile for tunnel liner plate

Figure 14
Structural plate Type I configuration and dimensions
(See Clauses 5.2.3.2, 5.2.3.4.1, and 5.2.3.6 and Table 4.)

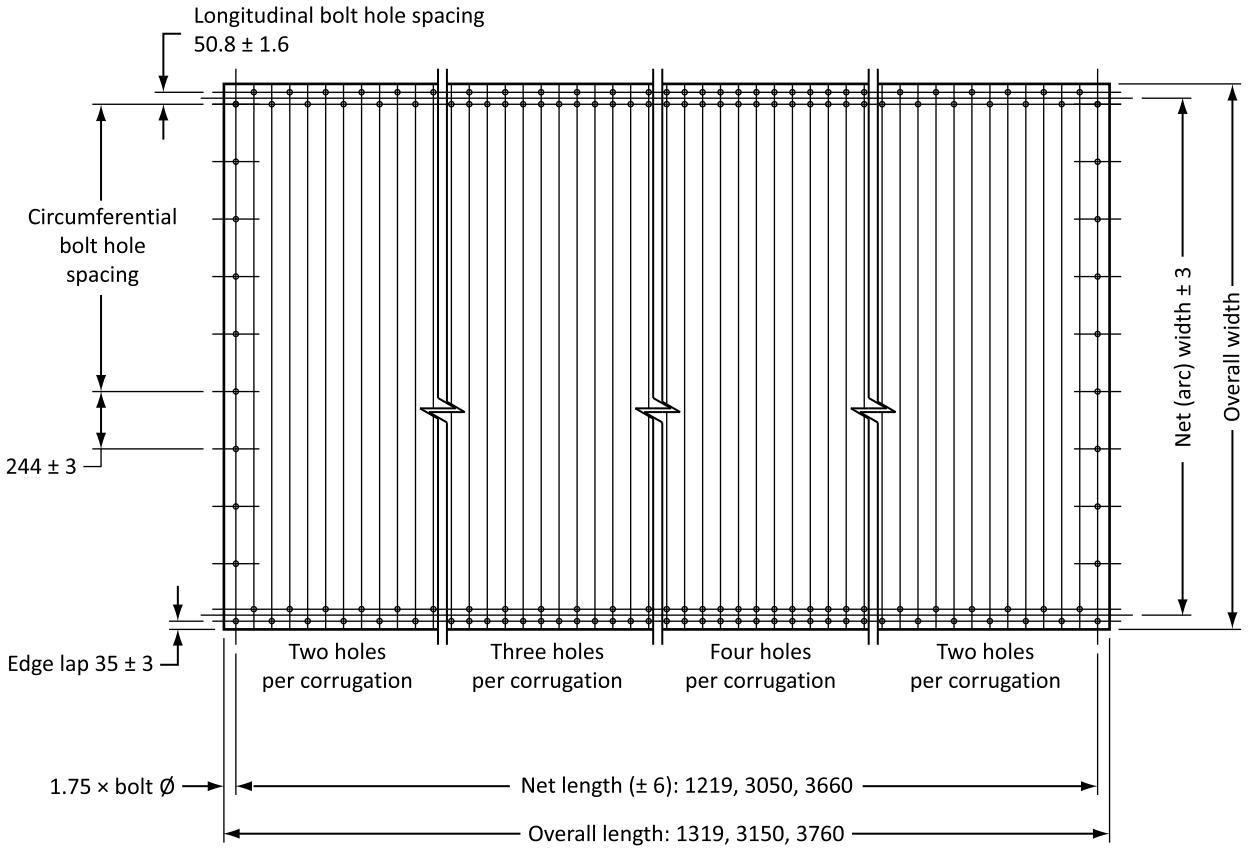
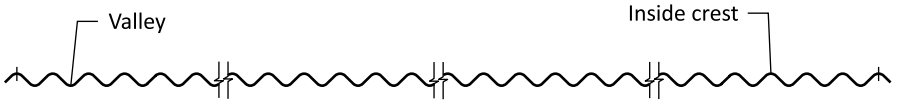


Plate plan view



Longitudinal side view
(showing corrugation profile)

Note: *All dimensions are in millimetres.*

Figure 15
Structural plate Type II configuration and dimensions
(See Clauses 5.2.3.2, 5.2.3.4.1, and 5.2.3.6 and Table 4.)

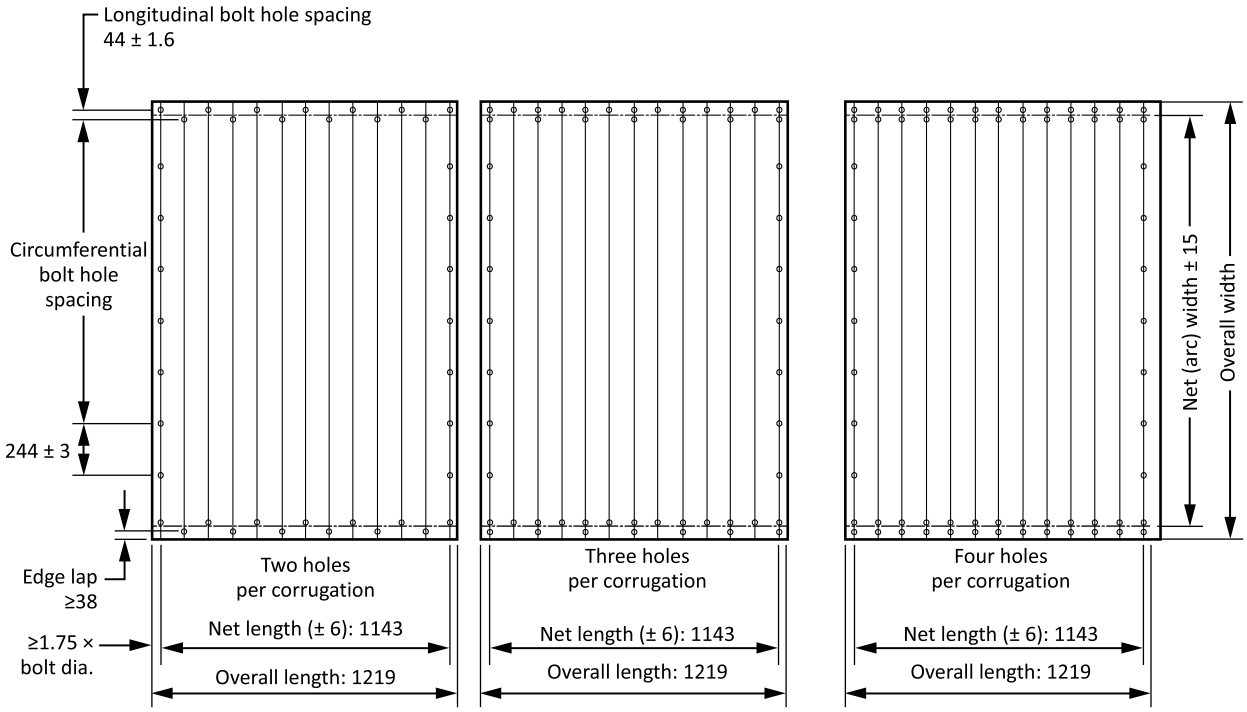
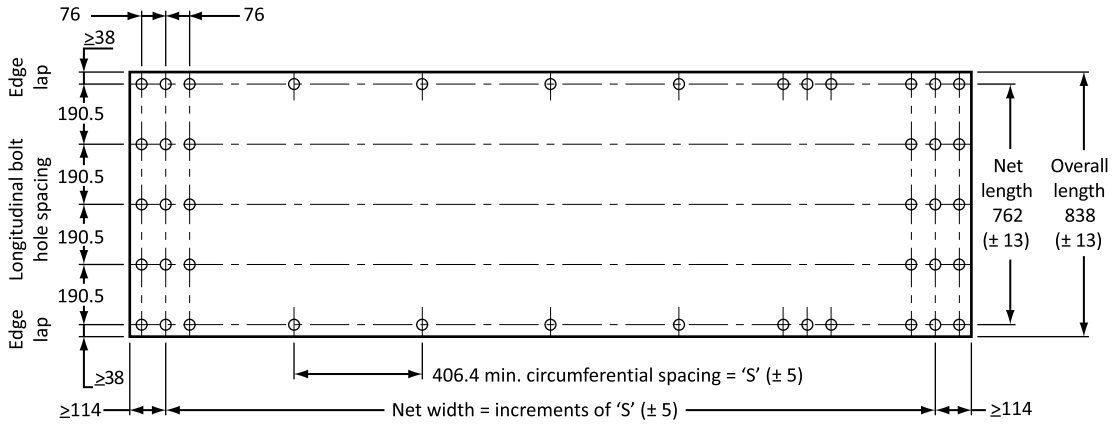


Plate plan view

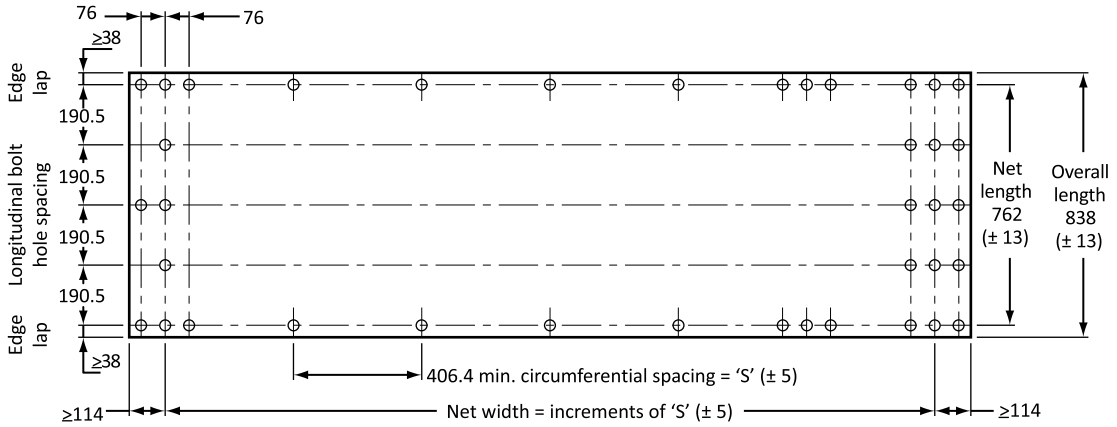
Longitudinal side view
(showing corrugation profile)

Note: *All dimensions are in millimetres.*

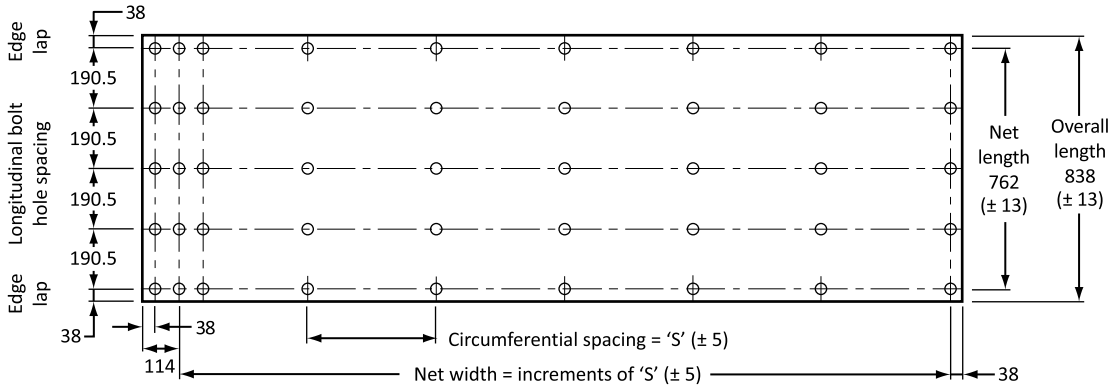
Figure 16
Type I deep corrugated structural plate configuration and dimensions
(See Clauses 5.2.3.2, 5.2.3.4.1, and 5.2.3.6 and Table 4.)



a) Main barrel plate



b) Base plate



c) Reinforcing rib plate*

** The end plate bolt hole configuration for the reinforcing rib plate shall be in accordance with the design.*

(Continued)

Figure 16 (Concluded)

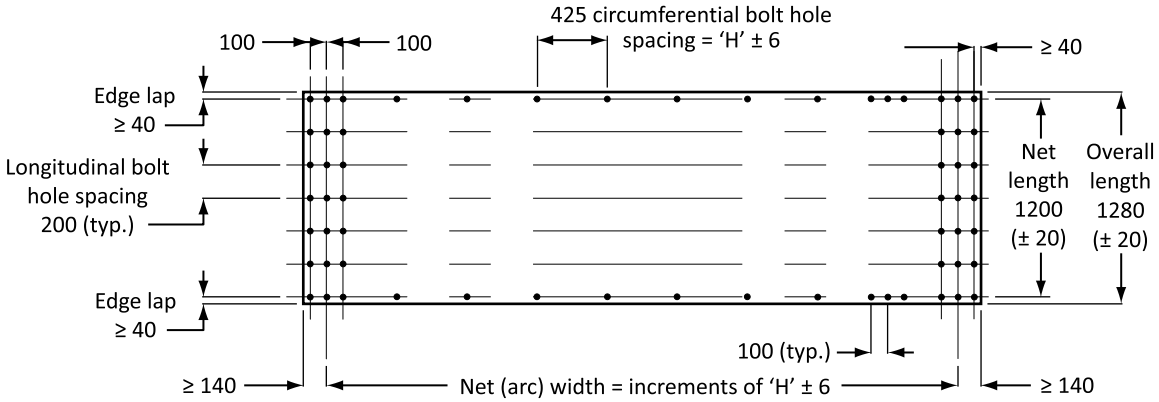
Notes:

1) *All dimensions are in millimetres.*

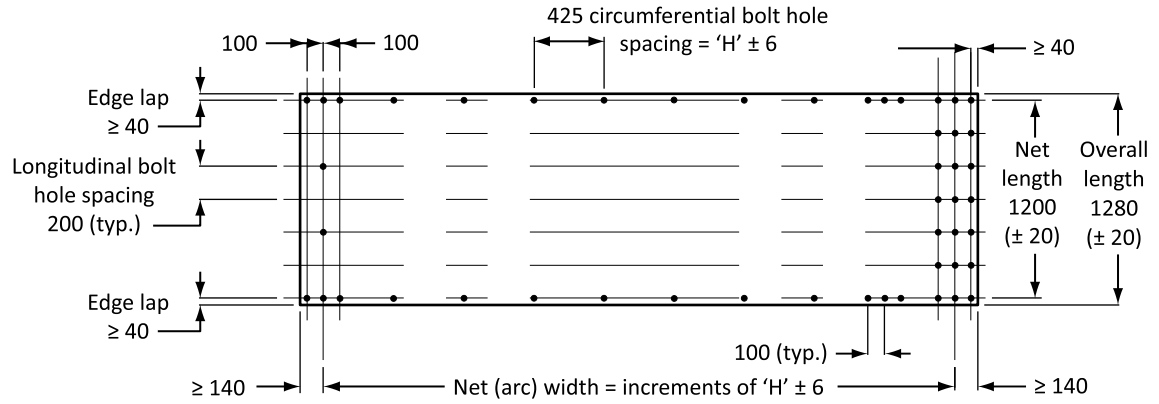
2) *The distance, S, on the rib plate is dependent upon the plate curvature and shall be a minimum of* 406.4 mm.

Figure 17
Type II deep corrugated structural plate configuration and dimensions

(See Clauses 5.2.3.2, 5.2.3.4.1, and 5.2.3.6, and Table 4.)



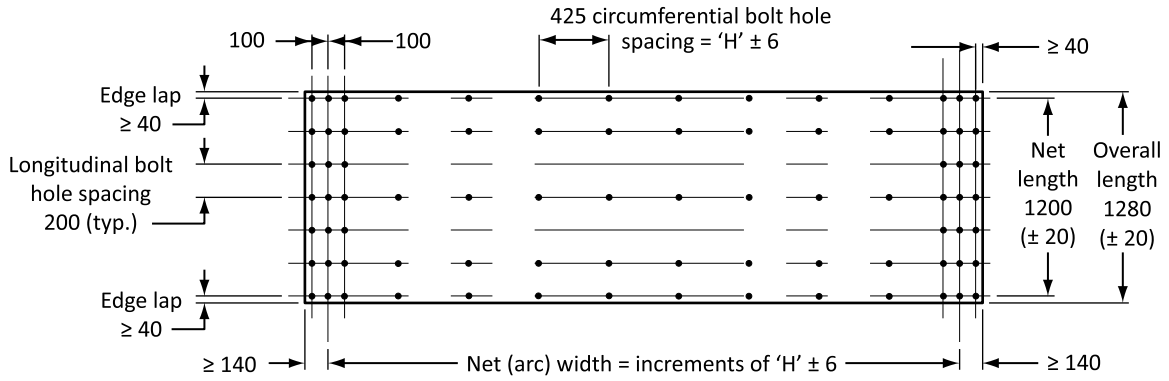
a) Main barrel plate



b) Footing plate

(Continued)

Figure 17 (Concluded)

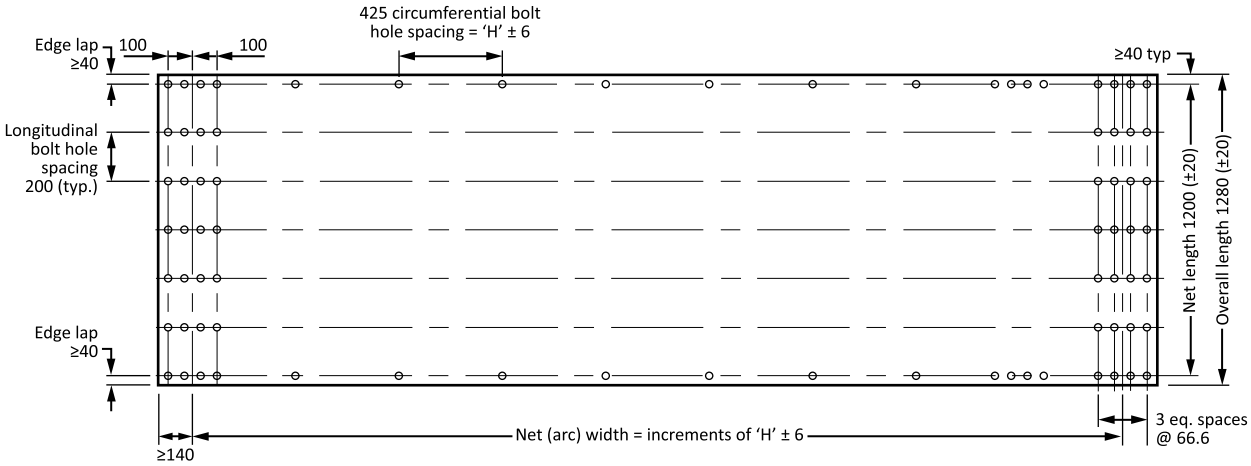


c) Reinforcing rib plate

Note: *All dimensions are in millimetres.*

Figure 18
Type II deep corrugated structural plate (alternative 4 row bolt pattern) configuration and dimensions

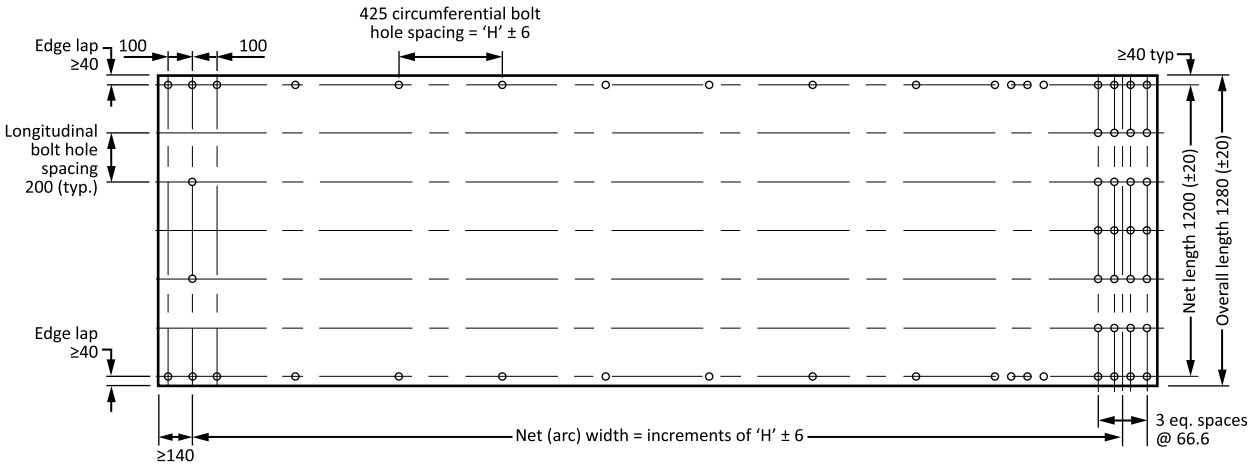
(See Clauses 5.2.3.2, 5.2.3.4.1, and 5.2.3.6, and Table 4.)



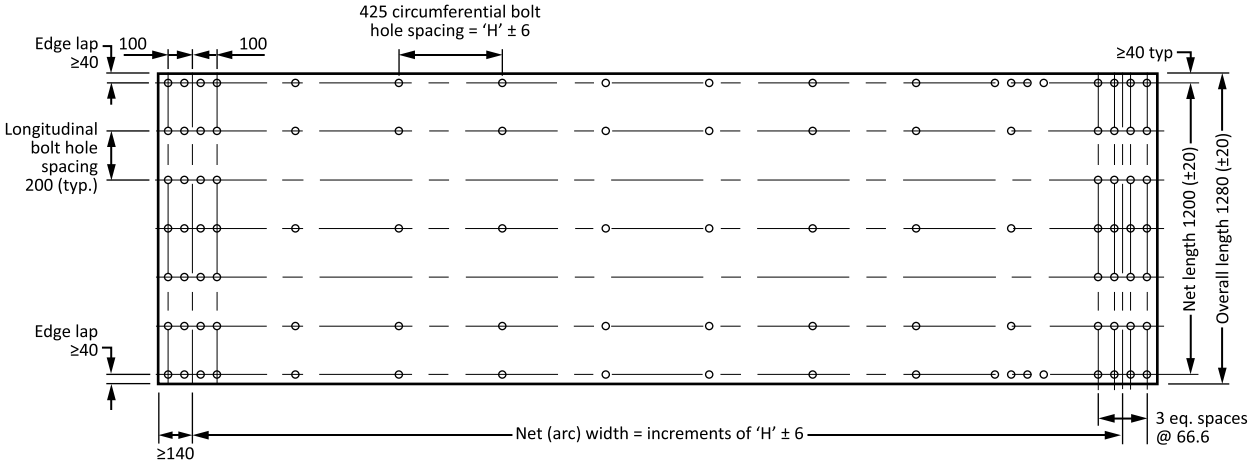
a) Main barrel plate

(Continued)

Figure 18 (Concluded)



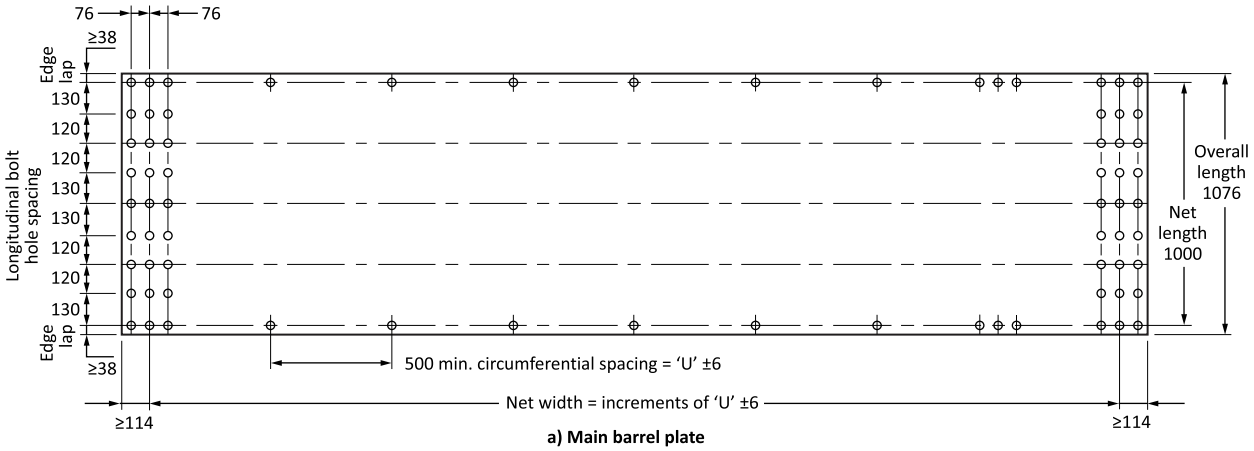
b) Footing plate



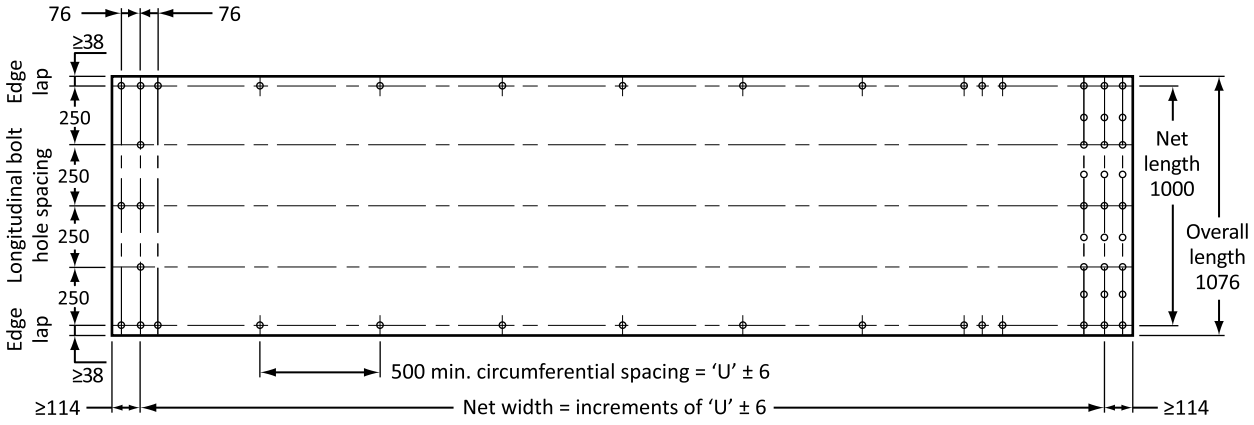
c) Reinforcing rib plate

Note: *All dimensions are in millimetres.*

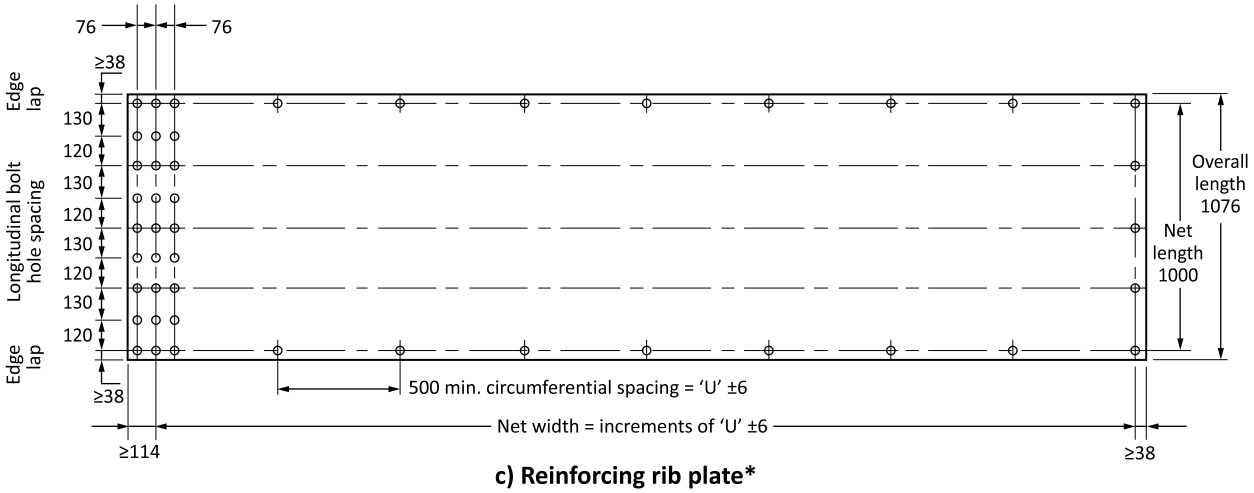
Figure 19
Type III deep corrugated structural plate configuration and dimensions
(See Clauses 5.2.3.2, 5.2.3.4.1, and 5.2.3.6, and Table 4.)



a) Main barrel plate



b) Base plate



c) Reinforcing rib plate*

** The end plate bolt hole configuration for the reinforcing rib plate shall be in accordance with the design.*

(Continued)

Figure 19 (Concluded)

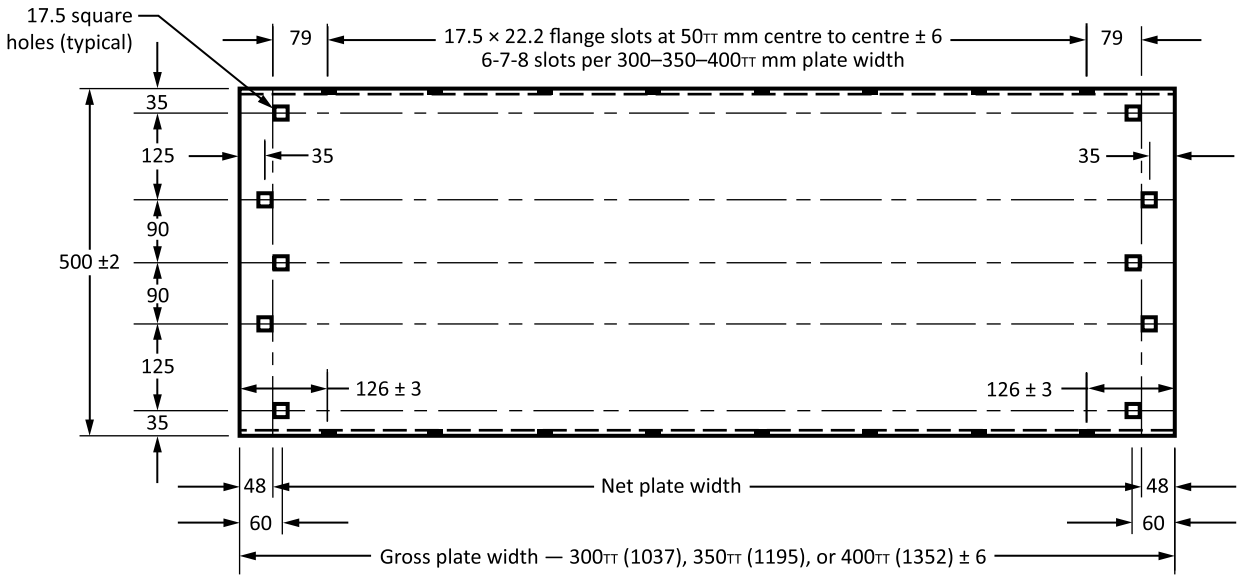
Notes:

1) *All dimensions are in millimetres.*

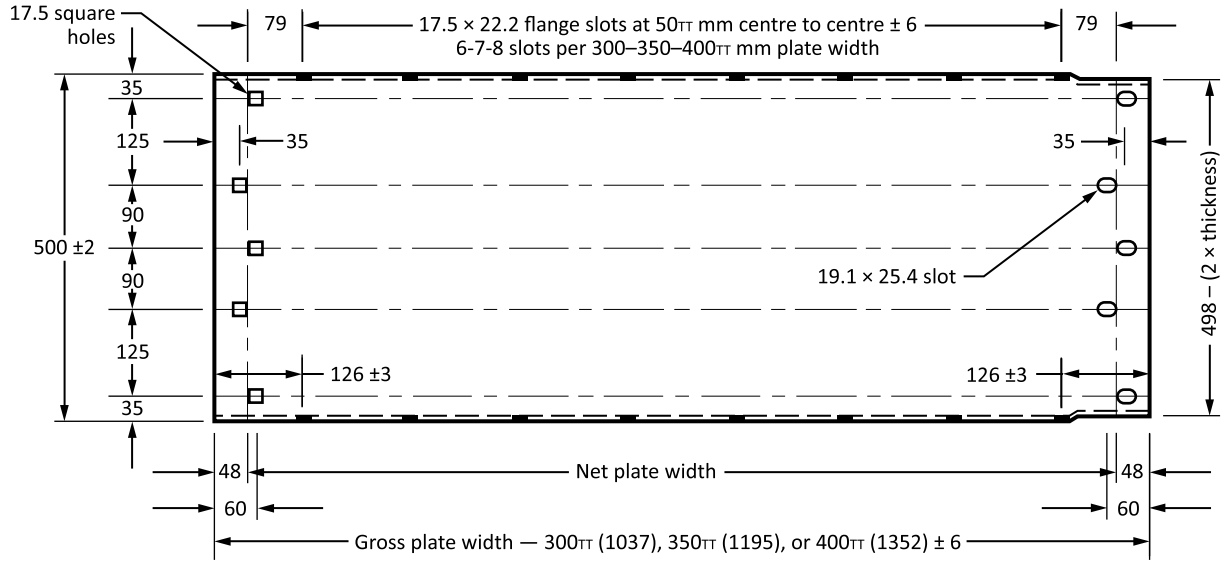
2) *The distance, U, on the rib plate is dependent upon the plate curvature and shall be a minimum of* 500 mm.

Figure 20
Two-flange tunnel liner plate configuration and dimensions

(See Clauses 5.2.3.2, 5.2.3.4.4, 5.2.3.6, and Table 4.)



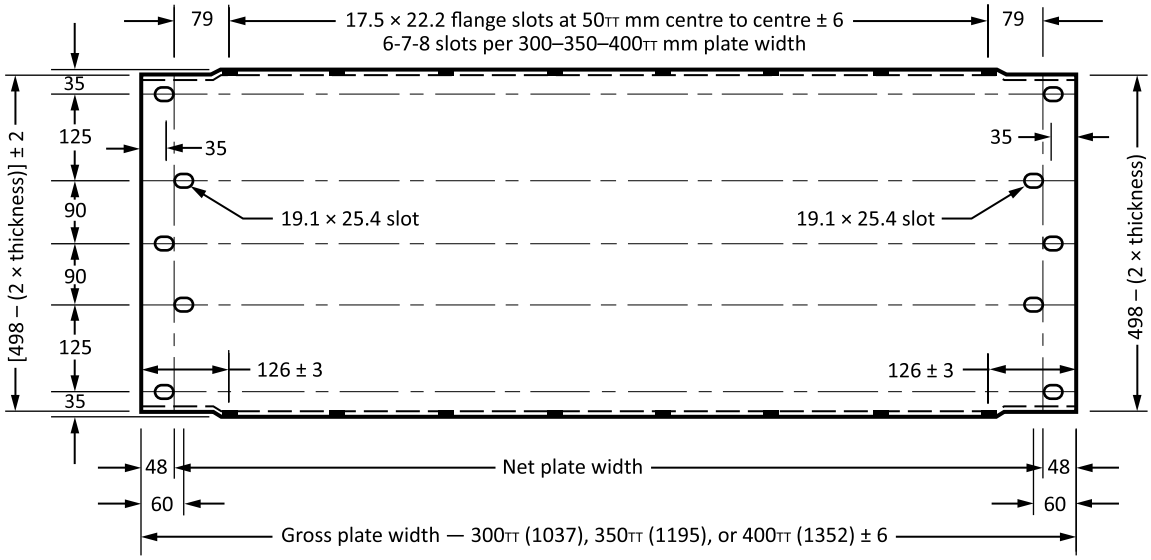
a) Plan view — No swage plate (NS)



b) Plan view — Single swage plate (SS)

(Continued)

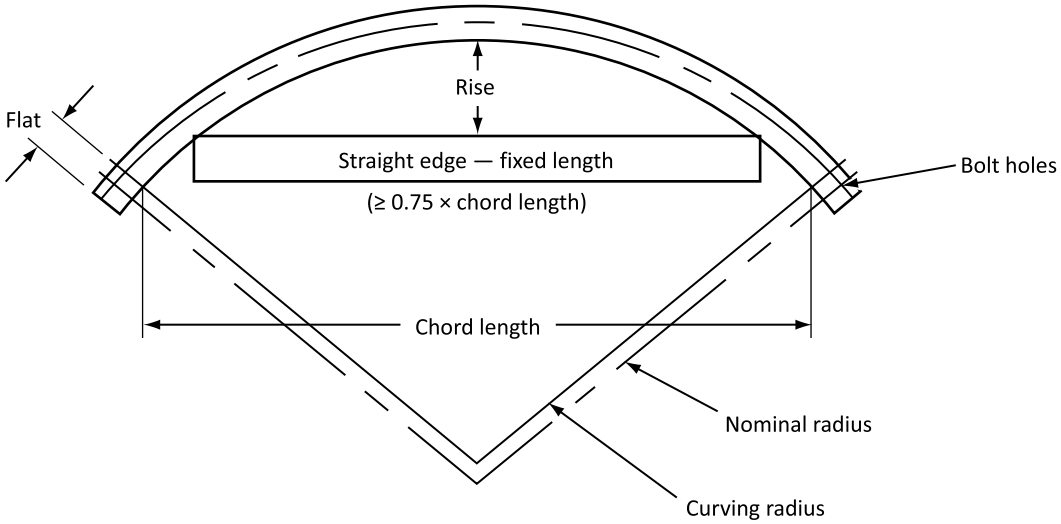
Figure 20 (Concluded)



c) Plan view — Double swage plate (DS)

Figure 21
Structural plate curvature

(See Clauses 5.2.4.2 and 5.2.4.3.)



Note: *The flat section changes depending on the plate type.*

Figure 22
Unbalanced channel and receiving angle
(See Clause 5.2.5 and Table 23.)

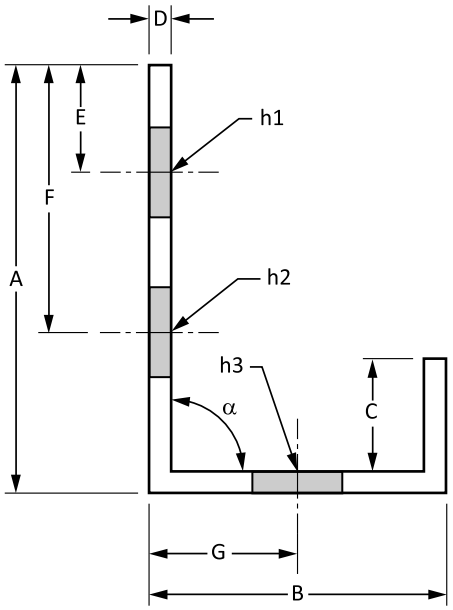


Figure 23
Recommended lapping of structural plates
(See Clause 5.2.7.3.)

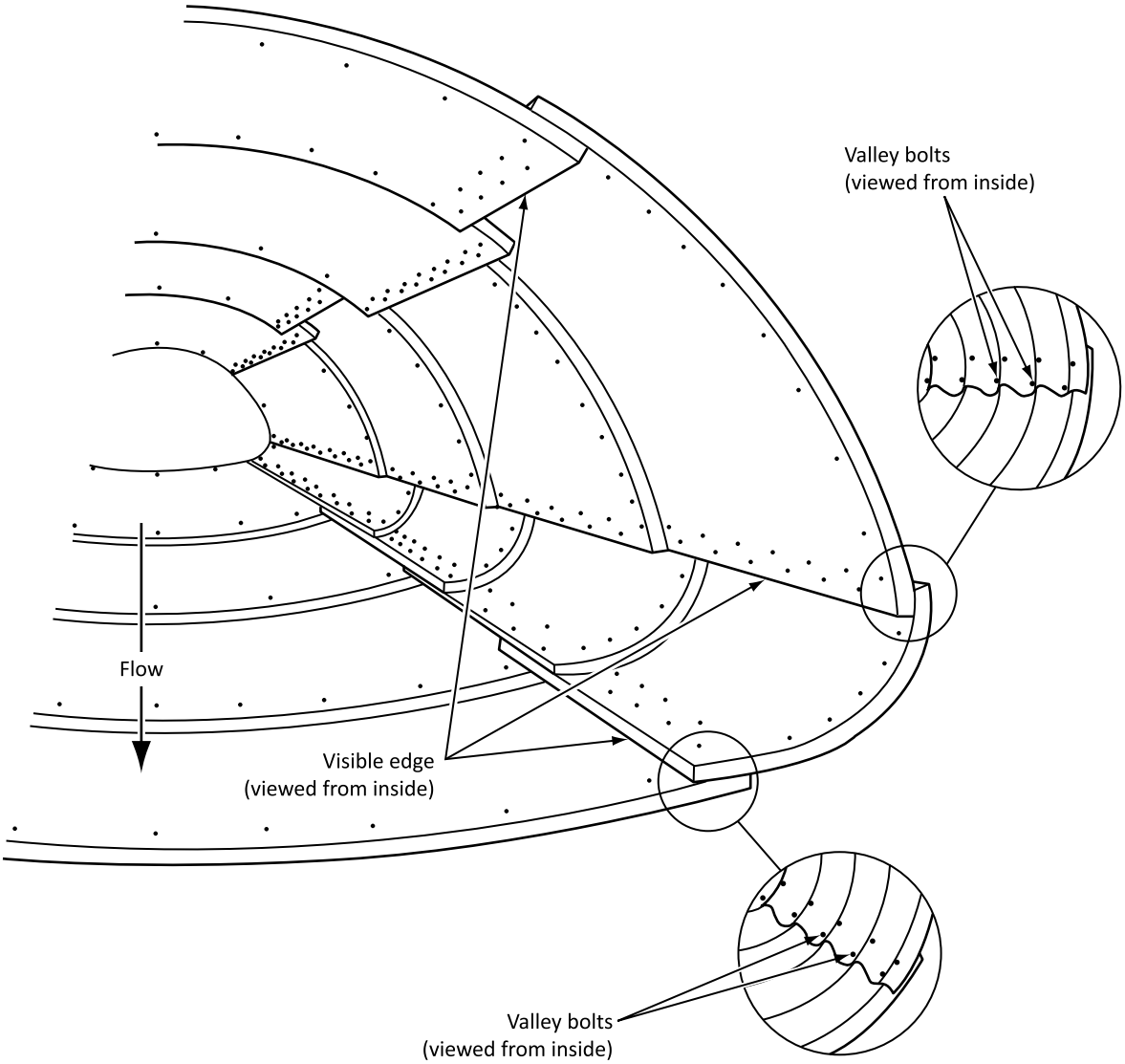


Figure 24
Recommended lapping of deep corrugated structural plates
(See Clause 5.2.7.3.)

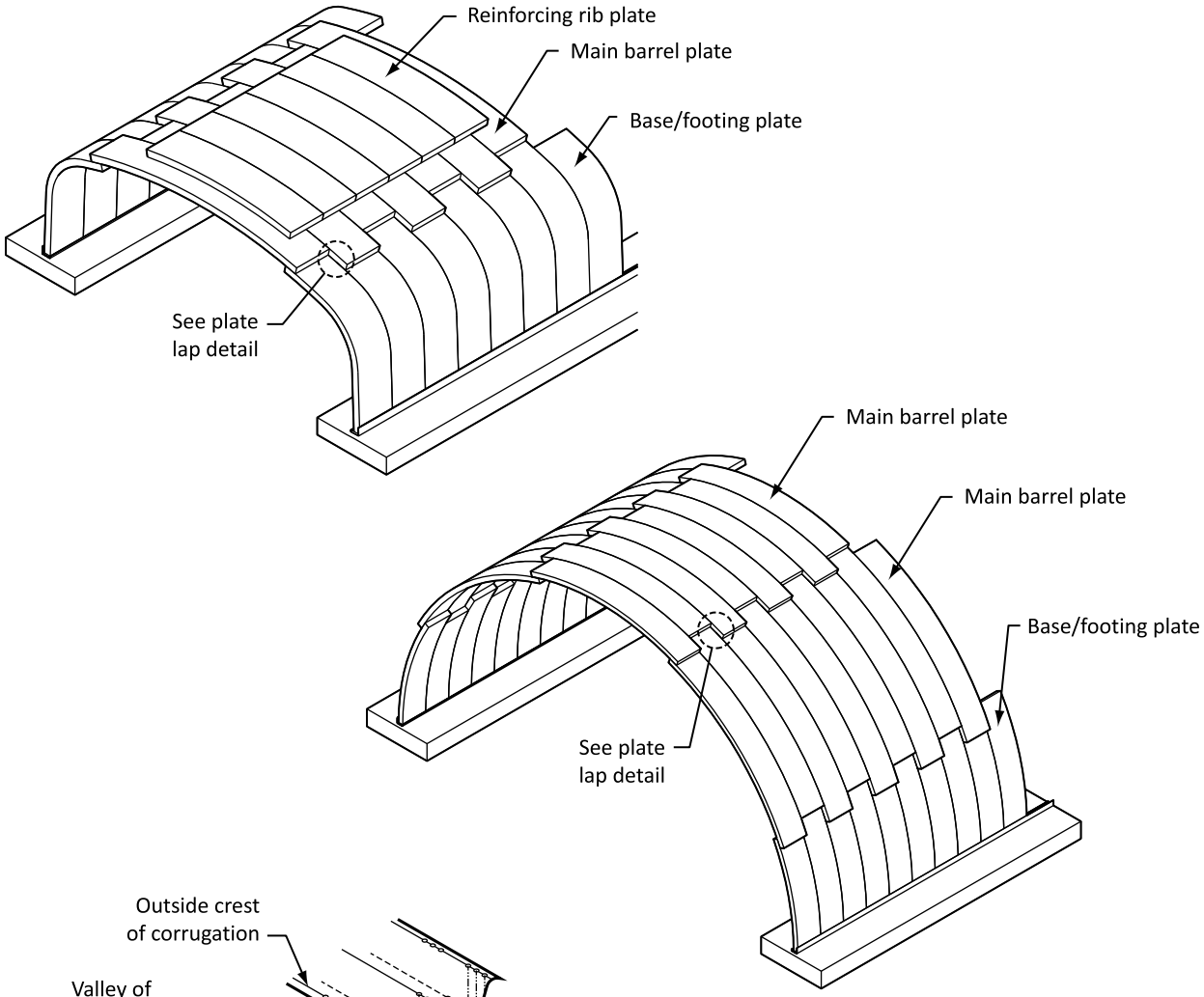


Plate lap detail

Annex A (informative)
Design base steel properties

Note: *This informative Annex has been written in mandatory language to facilitate adoption by anyone wishing to do so.*

A.1 General

A.1.1
The minimum base steel thickness shall be not less than 95% of the thickness used for design. Conversely, design base steel thickness shall be equal to or greater than the minimum base steel thickness times 1.053 but shall not exceed the nominal base steel thickness.

A.1.2
For corrugated steel pipe, the minimum base steel thickness shall be equal to the nominal thickness minus the tolerance and minus an allowance for metallic coating (see Table 3). The design base steel thickness shall be as specified in Table A.1.

A.1.3
For structural plate and deep corrugated steel pipe, the minimum base steel thickness shall be equal to the nominal thickness minus the tolerance (see Table 4). The design base steel thickness shall be as specified in Table A.2.

A.1.4
The minimum yield strength used for design (which shall be achieved through cold working) shall be 230 MPa for structural plate and 300 MPa for deep corrugated steel plate. The designer should consult with the fabricator to determine product properties.

A.2 Steel thickness examples

A.2.1 Corrugated steel pipe
For this corrugated steel pipe example, the nominal thickness equals 1.60 mm. From Table 3, the tolerance on the nominal thickness equals ± 0.18 mm. The nominal thickness includes the base steel and metallic coating.

The minimum steel thickness is the nominal thickness minus the tolerance and an allowance for the thickness of zinc of 0.09 mm. The minimum steel thickness is therefore 1.60 – 0.18 – 0.09 = 1.33 mm.

From Table A.1, the design base steel thickness equals 1.40 mm. As specified in Clause A.1.1, the design base steel thickness is 1.053 (i.e., 1/0.95) times the minimum thickness, but it cannot be greater than the nominal thickness. Applying the 1.053 factor to the minimum thickness of 1.33 mm results in a design base steel thickness of 1.40 mm, which conforms to the value specified in Table A.1.

A.2.2 Structural plate and deep corrugated steel pipe
For this structural plate and deep corrugated steel pipe example, the nominal thickness equals 5.00 mm. From Table 4, the minus tolerance on the nominal thickness equals – 0.30 mm. The nominal thickness excludes the zinc coating.

The minimum steel thickness is the nominal thickness minus the tolerance. The minimum steel thickness is therefore 5.00 – 0.30 = 4.70 mm.

From Table A.2, the design base steel thickness equals 4.95 mm. As specified in Clause A.1.1, the design base steel thickness is 1.053 (i.e., 1/0.95) times the minimum thickness, but it cannot be greater than the nominal thickness. Applying the 1.053 factor to the minimum thickness of 4.70 mm results in a design base steel thickness of 4.95 mm, which conforms to the value specified in Table A.2.

Table A.1
Corrugated steel pipe design base steel thickness
(See Clauses A.1.2 and A.2.1.)

Nominal thickness, mm	Design base steel thickness, mm
1.00*	0.82
1.30*	1.12
1.60	1.40
2.00	1.82
2.80	2.64
3.50*	3.35
4.20*	4.08

* *Spiral rib pipe is not available in these thicknesses.*

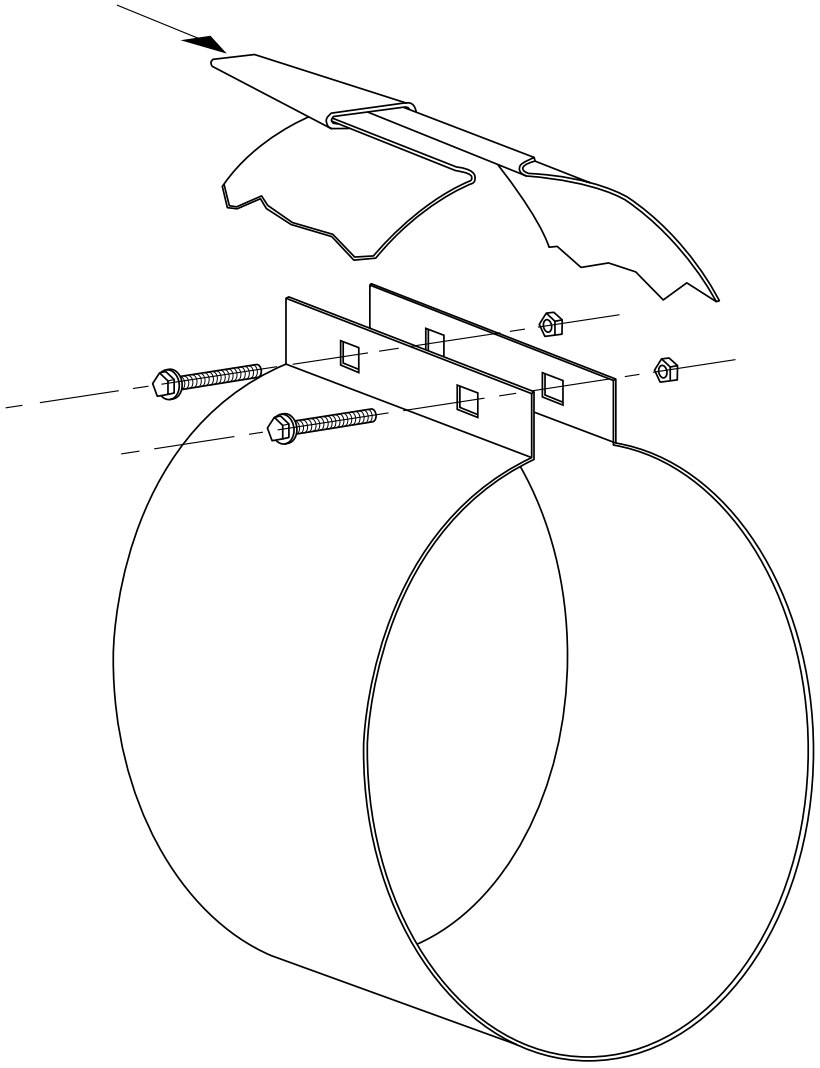
Table A.2
Structural plate and deep corrugated steel pipe design base steel thickness
(See Clauses A.1.3 and A.2.2.)

Nominal thickness, mm	Design base steel thickness, mm
2.69	2.54
3.00	2.84
3.43	3.32
4.00	3.89
4.19	4.12
4.30	4.21
5.00	4.95
5.41	5.38
6.00	6.00
6.19	6.19
7.00	7.00
7.94	7.94
9.52	9.52
12.7	12.7

Annex B (informative)
Typical coupler systems for corrugated steel pipe

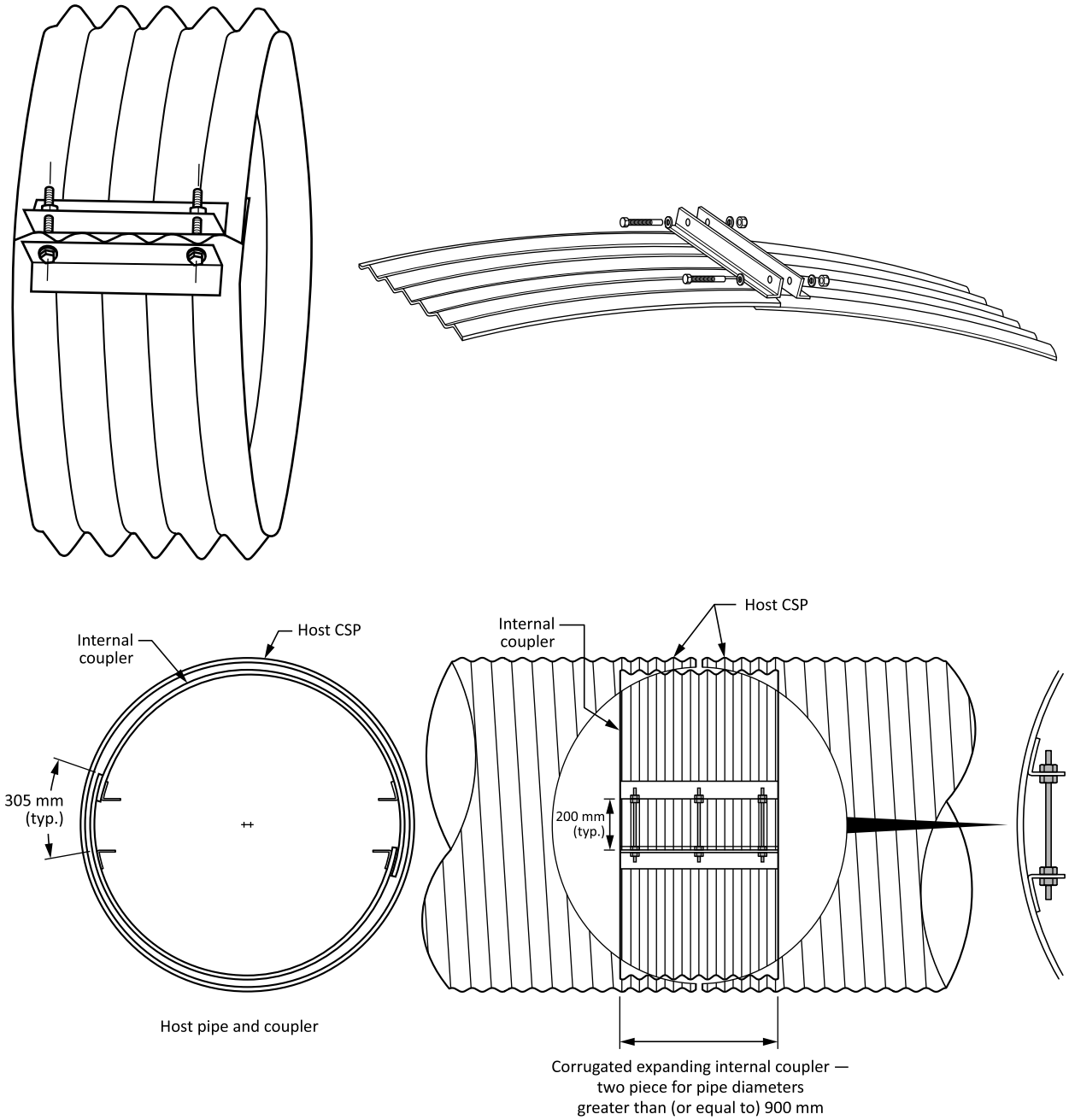
Note: *This Annex is not a mandatory part of this Standard.*

Figure B.1
Flat band
(See Clause 5.1.7.1.3.)



Notes:
1) *This is usually a one-piece coupler.*
2) *Flat bands may be used on annular or helical corrugations. Normal use is for small-diameter applications such as subdrainage.*

Figure B.2
Corrugated band
(See Clause 5.1.7.1.3.)



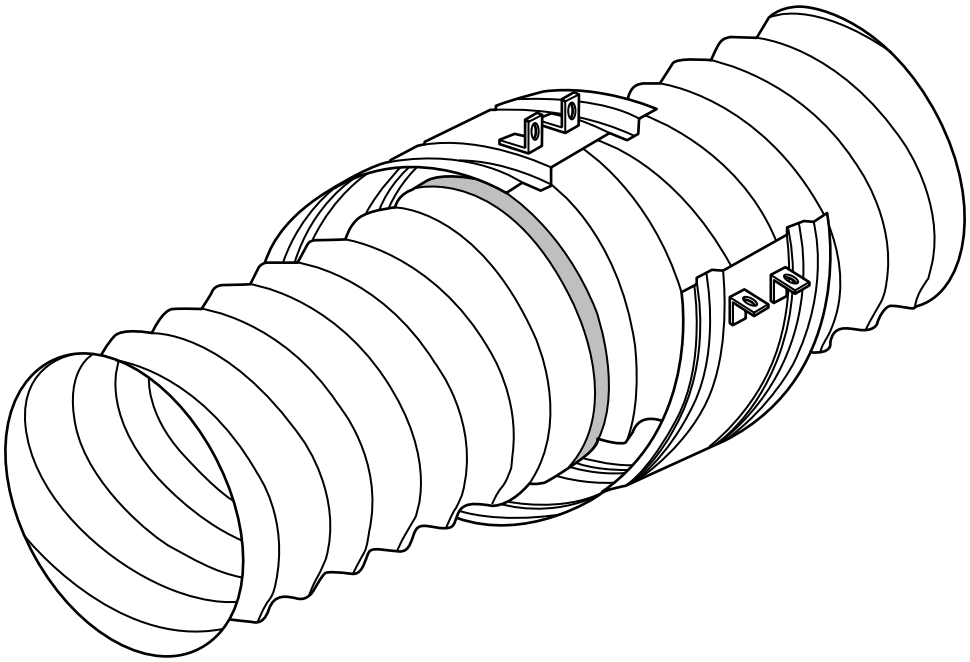
Notes:

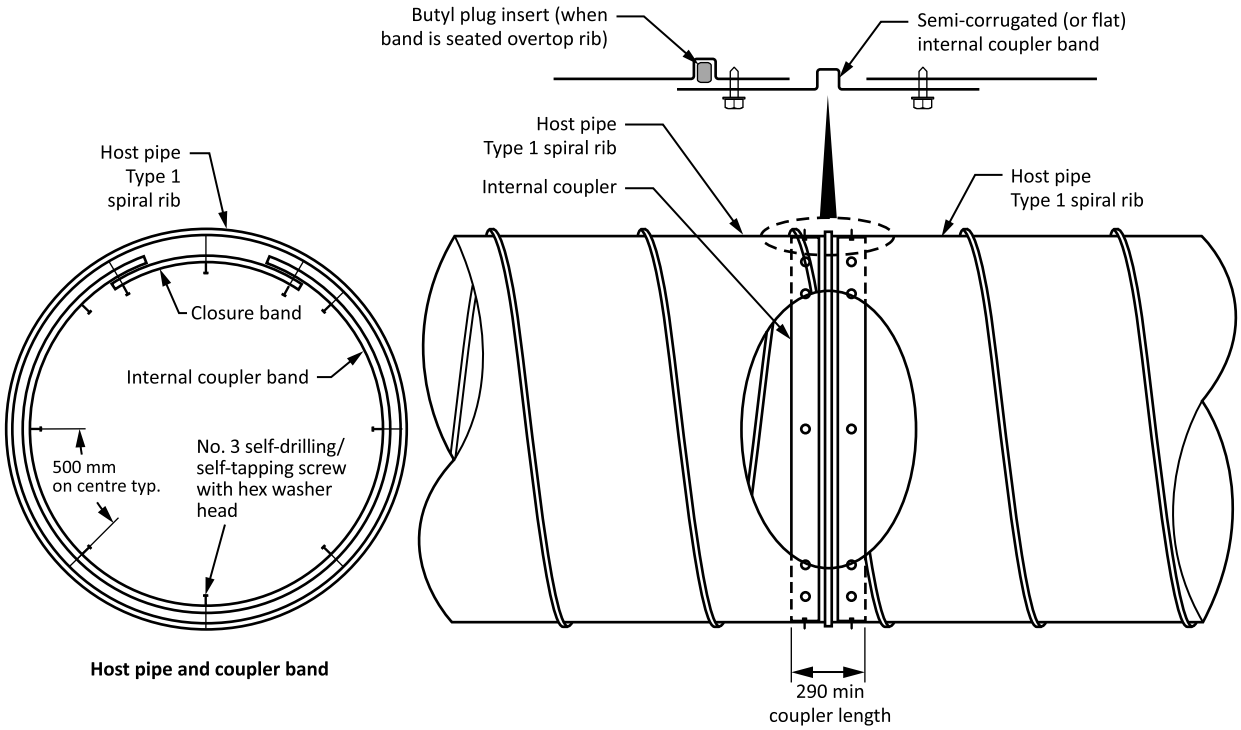
1) *Shown with angle flange and bolt connectors. Formed angles, lug brackets, or wedge-fastening systems are equally applicable.*

2) *Usually one piece; may be two or three piece for large diameters or other shapes.*

3) *For use with riveted corrugated steel pipe or helical corrugated steel pipe with recorrugated ends.*

Figure B.3
Semi-corrugated band
(See Clause 5.1.7.1.3.)





Host pipe and coupler band

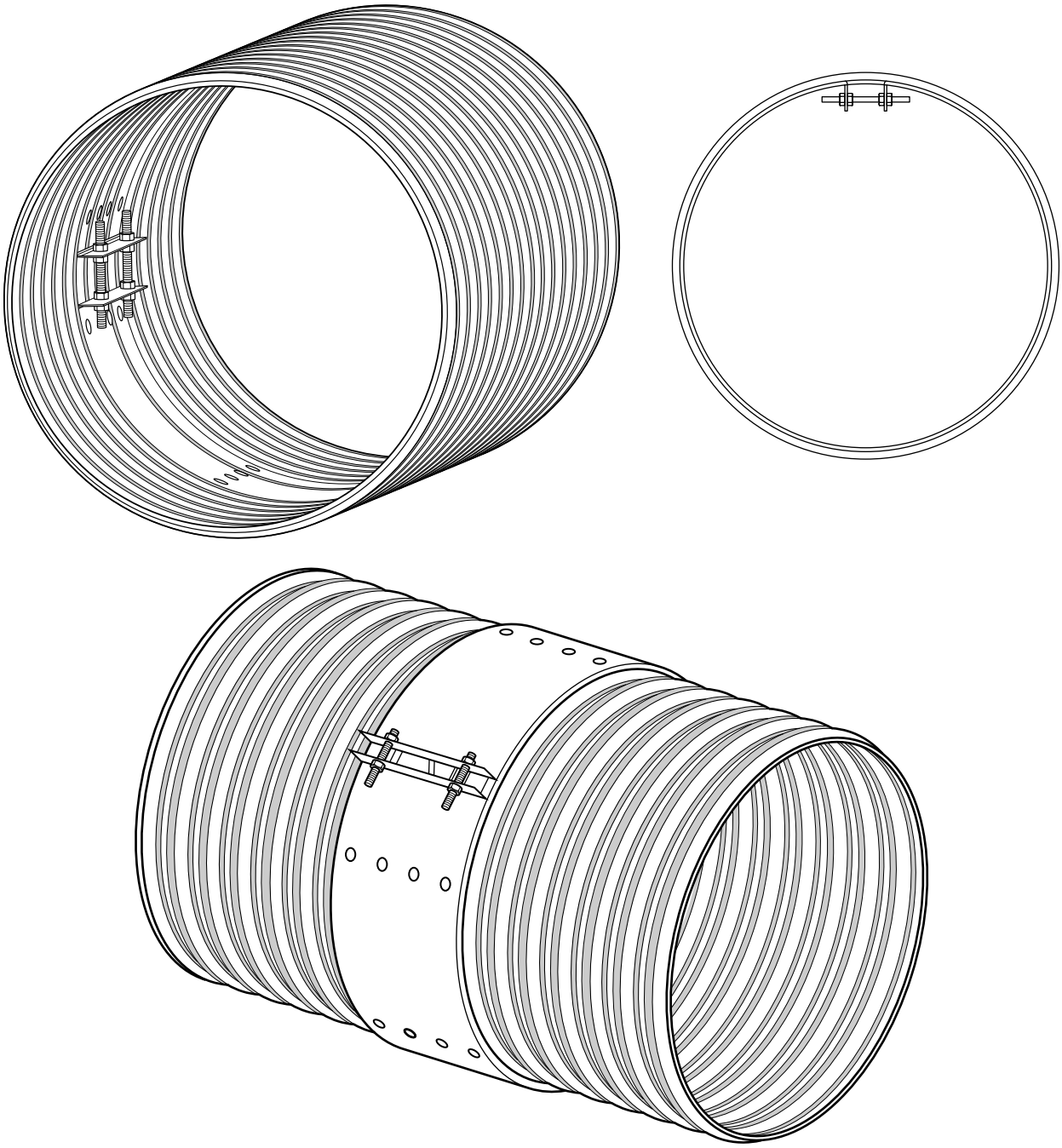
Semi-corrugated (or flat) expanding internal coupler for pipe diameters greater than (or equal to) 900 mm

Notes:

1) *Shown with bracket or lug connectors. Other fastening systems are equally applicable.*

2) *For use with riveted corrugated steel pipe or helical corrugated steel pipe with recorrugated ends.*

Figure B.4
Universal dimple band
(See Clause 5.1.7.1.3.)

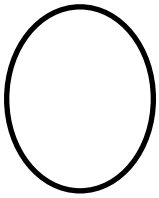


Notes:

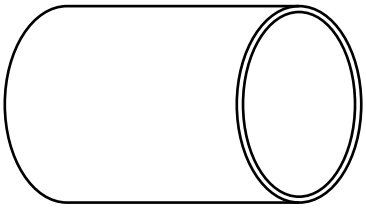
1) *Shown with bracket connectors. Other fastening systems are equally applicable.*

2) *Standard band for helical corrugated steel pipe coupling. Universal in that it can also be used for coupling of helical to annular corrugation profile (e.g., a new helical extension to in-place riveted corrugated steel pipe).*

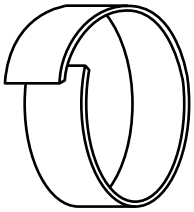
Figure B.5
Typical corrugated steel pipe gaskets
(See Clause 5.1.7.4.)



O-ring gasket

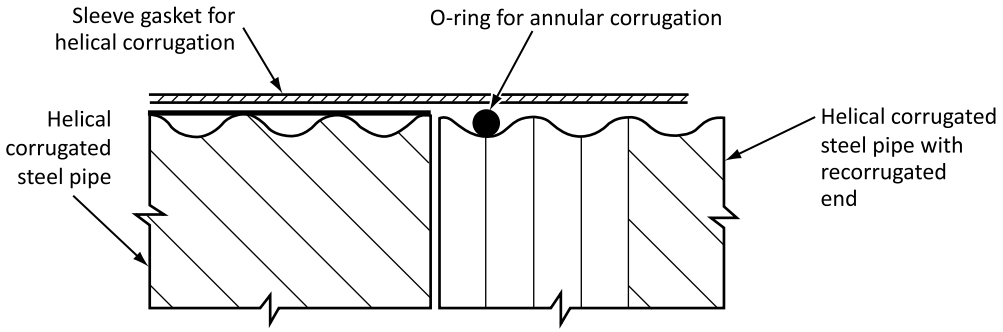


Sleeve gasket

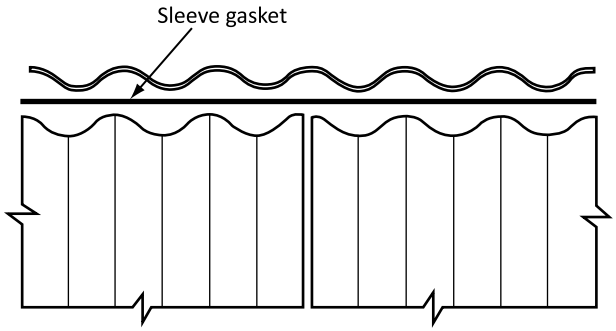


Strip gasket

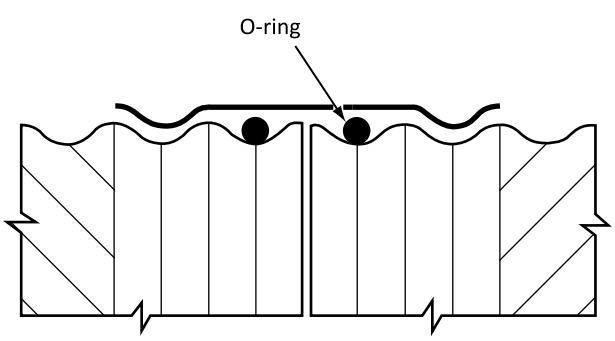
Figure B.6
Applications of typical corrugated steel pipe gaskets
(See Clause 5.1.7.4.)



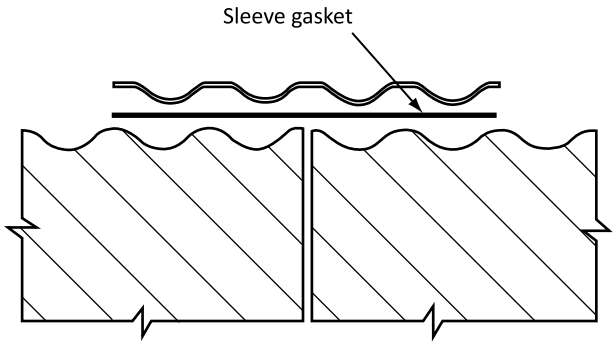
With flat band couplers



With corrugated band couplers



With semi-corrugated bands



With universal dimple bands