MECHANICAL COUPLINGS FOR JOINING POLYETHYLENE PIPE

TN-45

2024

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105 Decker Court • Suite 825 • Irving, Texas 75062 • 469.499.1044 • www.plasticpipe.org

Foreword

This technical note was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute (PPI). These members have shown their commitment to developing and improving quality products by assisting standards development organizations in the development of standards, and also by developing design aids and reports to help engineers, code officials, specifying groups, contractors and users.

The purpose of this technical report is to provide a guide on mechanical fittings for use with HDPE pipe. It is intended for engineers, users, contractors, code officials, and other interested parties.

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PPI intends to revise this technical note within five years, or sooner if required, from the date of its publication, in response to comments and suggestions from users of the document. Please send suggestions for improvements to the address below. Information on other publications can be obtained by contacting PPI directly or visiting our website.

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1.0 INTRODUCTION & SCOPE

The purpose of this document is to illustrate the common designs of mechanical fittings used to join HDPE pipe. Although not exhaustive, included are fittings for gas distribution, oil & gas gathering, and municipal water applications.

This document does not address flanges, lateral or fused connections. This document also does not specifically address industrial, plumbing, heating, geothermal, or ice melt system applications; however, these fittings may be useful in some of these applications.

This document is intended to be informative and general in nature.

- **Always consult with the manufacturer when selecting a particular design and model of fitting to ensure it is appropriate for the application and operating conditions.**
- **Always follow the fitting manufacturer's instructions when installing fittings and follow recommendations for the use of stiffeners.**
- **Always be aware of any specific regulatory requirements that may apply.**

This document relates only to fittings designed for use with outside diameter controlled pipe.

The user should also be aware that some fittings may encroach on the pipe inside diameter (e.g., inserts, OD compression) so this should be kept in mind when selecting fittings for piping systems that may be pigged in the future.

2.0 DOCUMENT STRUCTURE

Section 3.0 provides information that is common to the mechanical fittings industry in general, such as terminology and generically the designs of mechanical fittings.

Sections 4.0 through 6.0 provide additional guidance by end-use application, including industry specific requirements, regulations, and terminology. Specifically, the following sections cover:

- **Section 4.0 – Gas Distribution**
- **Section 5.0 – Oil and Gas Gathering**
- **Section 6.0 – Municipal Water**

3.0 GENERAL

3.1. Definitions

Standard industry terms are as defined in ASTM F412.[1]

Nominal Pipe Size (NPS) referred to in this text may refer to Iron Pipe Size (IPS), Ductile Iron Pipe Size (DIPS), Copper Tube Size (CTS) or other commonly used standards that define pipe sizes for PE pipe.

3.1.1. Fitting Categories and Types

Fitting *Categories* and *Types*, as shown in Table 1 through Table 3, classify fitting designs on the degree of pipe restraint provided by the fitting design. *Categories* are taken from the gas industry (ASTM D2513[2]) or the water industry (ASTM F3536[3]), and may be used in other industries. *Types* are taken from ASTM F1476[4] *Standard Specification for Performance of Gasketed Mechanical Couplings for Use in Piping Applications*. Some industries also simply refer to restrained or unrestrained fittings.

Table 1: Fitting Category Definitions used in Gas

Categories	Definition (Source ASTM D2513 for Gas)
Category 1	A mechanical joint design that provides a seal plus a resistance to a force on the pipe end equal to or greater than that which will cause a permanent deformation of the pipe. **Note:** US Federal Code for gas requires Category 1 fittings and references the definitions as incorporated into the specific fitting standards and may vary slightly.

[1] ASTM F412 *Standard Terminology Relating to Plastic Piping Systems*, ASTM International, West Conshohocken, PA.
[2] ASTM D2513 *Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings*, ASTM International, West Conshohocken, PA.
[3] ASTM F3536 *Standard Specification for PE and PP Mechanical Fittings for use on NPS 3 or Smaller Cold-water Service Polyethylene (PE) or Crosslinked Polyethylene (PEX) Pipe or Tubing*, ASTM International, West Conshohocken, PA.
[4] ASTM F1476 *Standard Specification for Performance of Gasketed Mechanical Couplings for Use in Piping Applications*, ASTM International, West Conshohocken, PA.

Table 2: Fitting Category Definitions used in Water Industry for Small Diameter Fittings (NPS 3 and smaller)

Categories	Definition (Source ASTM F3536 for Water)
Category 1	A mechanical joint design that provides a seal plus a resistance to a force on the pipe end equal to or greater than that which will cause a permanent deformation of the pipe.
Category 2	A mechanical joint design that provides a seal only. A mechanical joint designed for this category excludes any provisions in the design or installation of the joint to resist any axial pullout forces; therefore, tensile tests are not required.
Category 3	A mechanical joint design that provides a seal plus a pipe restraint rating equivalent to the anticipated thermal stresses occurring in a pipeline. This category has a manufacturer's rated pipe end restraint less than the value required to yield the pipe as outlined in Category 1.

Table 3: Fitting & Connection Types Used in the Water Industry

Types/Classes	Description (Source ASTM F1476)
Type 1 Grooved Mechanical Couplings	A device which consists of two or more housings, closure members such as sets of bolts and nuts or pins, and a pressure-responsive gasket. It is used to mechanically join and seal grooved pipe or fitting, forming a joint.
Type 2 Plain End mechanical Couplings	Device consisting of gasket(s), housing(s), sleeve(s), end rings, threaded fasteners, pipe or fitting anchoring (gripping) features and seal retainers, as applicable.
Type 2 Class 1 – Rigid & Restrained	A connection where there is essentially no angular or axial pipe movement. Also the connection wherein thrust loads generated by internal pressure or external means are absorbed within the joint connection.
Type 2 Class 2 – Flexible & Restrained	A connection where there is available limited angular and axial pipe movement. Also the connection wherein thrust loads generated by internal pressure or external means are absorbed within the joint connection.
Type 2 Class 3 – Flexible and Unrestrained	A connection where tightening of the fasteners compresses the gasket(s), creating a seal on the outside of the plain end pipe.

3.2. Designs of Mechanical Couplings and Connections

The following subsections outline several of the common designs of mechanical couplers for HDPE pipe. The list is not exhaustive and specific designs, features and capabilities will vary by manufacturer. Different applications will have varied requirements and all designs of a type of fitting may not be intended for all applications. Always consult with the fitting manufacturer when selecting a particular design and model of fitting to ensure it is appropriate for the application and operating conditions.

3.2.1. Bolt Tightening Designs

In this fitting design, the pipe is inserted into the fitting body that includes an external seal and grip ring, as illustrated in Figure 1.

Bolt and compression segment orientations can vary. Figure 2 illustrates a product wherein the bolts are oriented parallel to the axis of inserted pipe. Figure 3 and Figure 4 illustrate product wherein the bolts are oriented perpendicular to the axis of inserted pipe. In both cases, gripping rings, if present, and sealing elements are radially compressed as the bolts are tightened. The tightening of nuts and bolts may be required to a specified torque, refer to manufacturer's installation instructions.

These fittings may be made of steel, ductile iron, or brass. Sizes for water & wastewater range typically from NPS 2 and larger. Sizes for gas applications range from NPS ¼ and larger.

Fittings of this design may be of any Category or Type and may require insert stiffeners.

Figure 1 - Example of a bolt tightening design of fitting installed on PE pipe (Image courtesy of Georg Fischer Piping Systems)

Figure 2 - A bolt tightening design of fitting with axial bolts (Image courtesy of Georg Fischer Piping Systems)

Figure 3 - A bolt tightening design of fitting with perpendicular bolts (Courtesy of Victaulic)

Figure 4 - Bolt tightening designs of fitting with perpendicular bolts. Unrestrained: Left & Center; Restrained: Right. (Courtesy of Hamilton Kent)

3.2.2. Compression Nut Designs (aka. Nut Follower)

In these types of fitting, the pipe is inserted into a socket fitting that includes an external seal, grip ring and a nut, as illustrated in Figure 5. Then the nut is tightened to compress the grip ring over the pipe and provide proper grip as shown in Figure 6. Sometimes the nut also compresses the seal over the pipe. In some types, the tightening of the nut provides only part of the required compression, and additional compression of the seal and/ the grip ring is provided by the hydrostatic axial force that pushes the grip ring or the seal into a tapered section.

These fittings may be made of plastic or brass and are typically available in sizes NPS ½ to 4. Typical designs are shown in Figure 7 and Figure 8.

Fittings of this design may be of any Category or Type, and may require insert stiffeners.

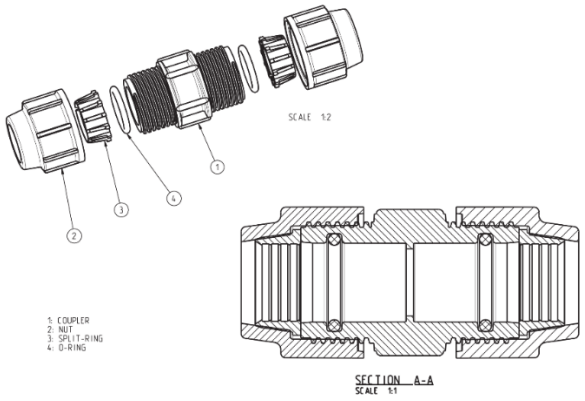

Figure 5 - Schematic of a compression nut fitting design (Courtesy of Plasson)

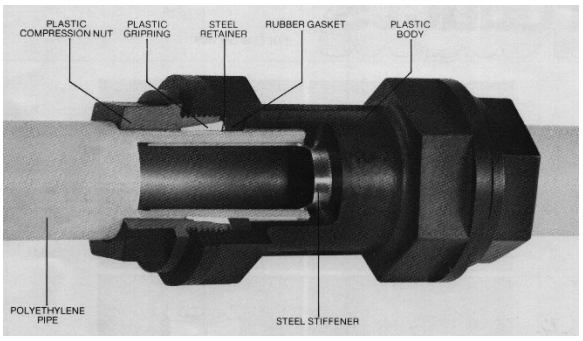

Figure 6 - Cut away illustration of a compression nut fitting design.

Figure 7 - Example of a plastic body compression nut fitting design (Courtesy of Plasson)

Figure 8 - Example of a metal body compression nut fitting design

3.2.3. Stab Fittings Designs

In these fitting designs, the pipe is inserted into a socket shaped fitting that includes an external seal and an external grip ring, as illustrated in Figure 9. The seal is compressed by

pushing the pipe into the socket. The grip ring is designed in a way that enables insertion in one direction, but "grabs" the pipe in the opposite direction. Compression of the grip ring is achieved by the hydrostatic pressure that pushes the pipe with the tapered grip ring into a conical shaped section.

These fittings may be made of plastic or brass, usually available for small pipe sizes, NPS 1/2 up to 2, as shown in Figure 10.

Fittings of this design may be of any Category or Type, and may require insert stiffeners as shown in Figure 11.

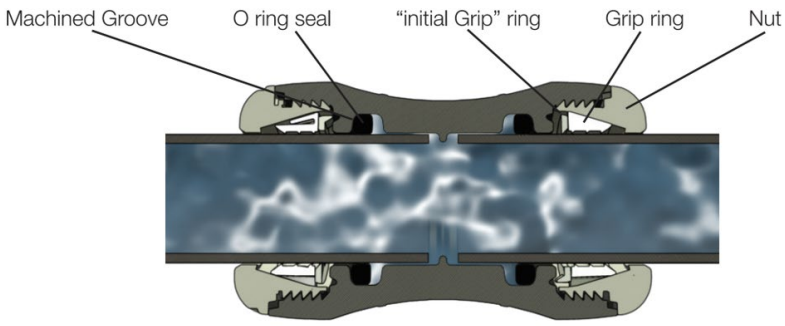

Figure 9 - Schematic of a stab fitting design showing inserted pipe (Courtesy of Plasson)

Figure 10 - Example of a plastic body stab fitting design (Courtesy of Plasson)

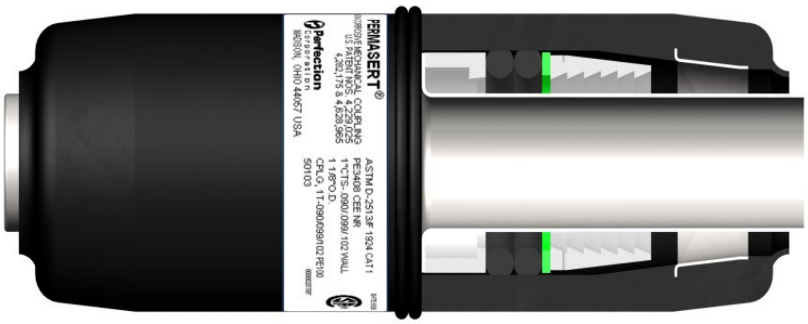

Figure 11 - Example of a stab fitting design showing stiffener, without pipe inserted (Courtesy of Perfection)

3.2.4. Axial Compression Ring Designs

In these fitting designs, the barbed end of the fitting is inserted inside the end of the pipe or tubing. An integral ring is pulled axially over the pipe/tube creating an interference fit. A specialty tool is required to complete this operation as shown in Figure 12. This interference fit creates a compressive force between the pipe/tube and the retaining barb. The compression is designed to provide restraint of axial movement and sealing of internal fluids to the atmosphere. These designs may or may not contain a secondary elastomeric sealing element.

These fittings may be made of metal or plastic and of any Category or Type. Usually applicable for small size tubing, NPS 1/2 - 2. Figure 13 and Figure 14 illustrates various designs of axial compression ring fittings.

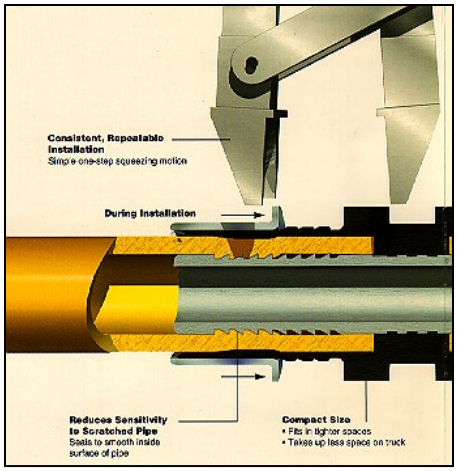

Figure 12 – Left: Cut away of an axial compression fitting design, showing application of tool to pull the compression ring over the barb thus compressing the pipe into the barbs. Right: Example of sleeve being installed with power tool (Courtesy of Viega)

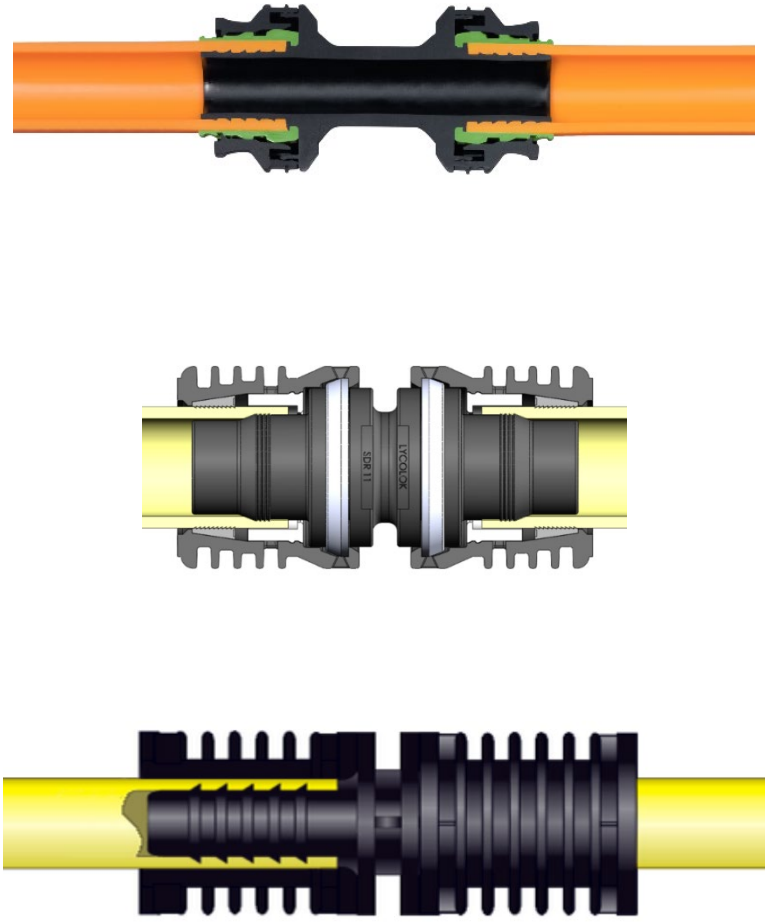

Figure 13 - Cut aways of axial compression ring fitting designs, with pipe installed (Courtesy of Viega (top), Lyall (center, bottom)).

Figure 14 - Example of a plastic body axial compression ring fitting designs (Courtesy of Viega (left), Lyall (right)).

3.2.5. Fittings for Grooved Pipe

This fitting design features a restraint mechanism that engages with circumferential grooves machined into the outside diameter of pipe ends to be joined.

The joint, as shown in Figure 15, has four elements: the grooved pipe, the gasket, the coupling housings, and the fasteners. The pipe ends have a groove that provides an engagement point for the coupling and locates the sealing surface for the gasket. The gasket seals the pipe ends, trapping fluid within as it is enclosed by the coupling housings. The housings are held together by bolts and nuts. The coupling housing encases the gasket and engages the circumferential pipe groove to produce a leak-tight seal in a self-restrained pipe joint.

Inserts may be used with these fittings depending on the required end-restraint loads.

These fittings are for larger pipes, typically NPS 16-36, and used on pipe of wall thickness SDR 21 or thicker.

Grooving of the pipe may be done by the manufacturer or in the field. The groove must conform with the manufacturer's specifications.

Figure 15 - Examples of a grooved pipe fitting design (Courtesy of Victaulic).

4.0 GAS DISTRIBUTION

This section addresses the requirements for mechanical fittings for Gas Distribution, including codes, standards, certifications, joint categories, and special considerations.

4.1. Current Codes

4.1.1. US DOT Code

DOT CFR Title 49 Part 192[5] mandates that all mechanical couplings be rated as Category 1 as per the fitting specification incorporated by reference in Part 192.7 and an internal stiffener must be used. The code reads:

§ 192.281 PLASTIC PIPE
MECHANICAL JOINTS. EACH COMPRESSION TYPE MECHANICAL JOINT ON PLASTIC PIPE MUST COMPLY WITH THE FOLLOWING:
(1) THE GASKET MATERIAL IN THE COUPLING MUST BE COMPATIBLE WITH THE PLASTIC.
(2) A RIGID INTERNAL TUBULAR STIFFENER, OTHER THAN A SPLIT TUBULAR STIFFENER, MUST BE USED IN CONJUNCTION WITH THE COUPLING.
(3) ALL MECHANICAL FITTINGS MUST MEET A LISTED SPECIFICATION BASED UPON THE APPLICABLE MATERIAL.
(4) ALL MECHANICAL JOINTS OR FITTINGS INSTALLED AFTER JANUARY 22, 2019, MUST BE CATEGORY 1 AS DEFINED BY A LISTED SPECIFICATION FOR THE APPLICABLE MATERIAL, PROVIDING A SEAL PLUS RESISTANCE TO A FORCE ON THE PIPE JOINT EQUAL TO OR GREATER THAN THAT WHICH WILL CAUSE NO LESS THAN 25% ELONGATION OF PIPE, OR THE PIPE FAILS OUTSIDE THE JOINT AREA IF TESTED IN ACCORDANCE WITH THE APPLICABLE STANDARD.

[5] As of January 22, 2019. Always verify current code requirements.

4.1.2. Canadian CSA Z662 Code

The Canadian Code for Oil and Gas CSA Z662[6] specifies in Clause 12 Gas Distribution:

> CLAUSE 12.7.10.3
> MECHANICAL FITTINGS, INCLUDING COMPRESSION COUPLINGS, SHALL PROVIDE BOTH LEAK RESISTANCE AND PULLOUT RESISTANCE AS SPECIFIED FOR CATEGORY 1 FITTINGS IN CSA B137.4 "POLYETHYLENE (PE) PIPING SYSTEMS FOR GAS SERVICES".
>
> CLAUSE 12.7.10.2
> INTERNAL TUBULAR STIFFENERS SHALL BE USED IN CONJUNCTION WITH ANY COMPRESSION-TYPE COUPLINGS. TUBULAR STIFFENERS SHALL REINFORCE THE ENDS OF THE PIPE OR TUBING AND SHALL EXTEND AT LEAST TO THE OUTSIDE ENDS OF THE COMPRESSION FITTINGS AS INSTALLED. STIFFENERS SHALL BE FREE OF ROUGH OR SHARP EDGES AND SHALL NOT BE FORCE-FITTED INTO THE PIPE. SPLIT TUBULAR STIFFENERS SHALL NOT BE USED.

4.2. Certifications for Gas Distribution

Within the United States, products used in gas distribution must be marked with listed specification; however, 3rd party certification is typically not required. Users should verify with the gas company for specific requirements and approvals.

Within Canada, fittings shall be marked with CSA B137.4 and certified by a 3rd party certification agency.

4.3. Specifications

For the US, DOT listed specifications can be found in Part 192.7 of the code.
For Canada, fittings must comply with CSA B137.4

4.4. Hydrocarbon Contamination

When liquid hydrocarbons penetrate into the PE pipe wall, heat fusion should not be attempted and pipe suspected of hydrocarbon permeation should only be joined with mechanical fittings. The US Code does not address this situation, but guidance for the operator is

[6] As of 2023.

provided in ANSI/GPTC Z380.1 – 2022, Guide for Gas Transmission, Distribution, and Gathering Piping.[7]

The Canadian Code for Oil and Gas CSA Z662 was recently revised to mandate that when bubbles during heat fusion are observed, the operator shall de-rate their pipe and shall only use mechanical fittings.

5.0 OIL AND GAS GATHERING (REGULATED & UNREGULATED)

This section covers piping used in oil and gas gathering applications, which can include produced water, liquid, and gaseous hydrocarbon transport, both regulated and unregulated pipelines.

5.1. Current Codes and Standards

5.1.1. United States

In the US, approximately 10% of the oil and gas pipelines are regulated by the Code of Federal Regulations (CFR) in Title 49 Part 192. With the new Gas Transmission Rule that number will increase. For regulated pipelines, the gas operator shall only use Category 1 mechanical fittings, as specified in the CFR and discussed in Section 4.0. This is the same requirement as for gas distribution pipelines. For non-regulated pipelines, the gas operator can select the joining method of their choice.

5.1.2. Canada

In Canada, all oil and gas pipelines are regulated by the Canadian Code CSA Z662 “Oil and Gas Pipeline Systems”. Clause 13.3 specifies the requirements for polyethylene (PE) oil and gas pipelines. Joining of these pipelines is covered in Clause 13.3.5:

13.3.5.1
HDPE PIPE AND FITTINGS SHALL BE JOINED BY HEAT FUSION, ELECTROFUSION, MECHANICAL FITTINGS, FLANGES, OR A COMBINATION OF THESE METHODS.

Thus, for PE pipelines mechanical fittings are allowed by code.

[7] Available from the American Gas Association, 400 North Capitol Street, NW, Suite 450 Washington, DC 20001, USA.

5.2. Examples of each Category of Mechanical joint used in Oil & Gas Gathering

In the US in regulated pipelines, all mechanical fittings must be Category 1 type fittings. For non-regulated pipelines, any category/class of mechanical fitting type can be used. See Section 2.0 for examples meeting these requirements.

6.0 MUNICIPAL WATER

This section addresses the requirements for mechanical fittings for municipal water applications, including codes, standards, certifications, joint categories, and special considerations.

AWWA M55[8], 2nd Edition, *PE Pipe – Design and Installation*, requires HDPE municipal water piping systems to be joined using methods that provide restraint such as heat fusion, electrofusion, and restrained mechanical connections. Joining methods that do not provide restraint against pullout are not acceptable for use in HDPE pressure piping systems.

6.1. Considerations for Fitting Selection

6.1.1. Buried vs Above Ground

Soil conditions should be taken into account due to corrosion and communicated to the fitting suppliers for buried applications. With above ground applications the temperature of the environment needs to be considered. For fittings used above ground, the user must consider the forces resulting from thermal contraction and expansion.

Coatings for corrosion resistance may be available from the manufacturer. Also, municipalities may have their coating requirements, along with other corrosion inhibitor methods (e.g., anodes, chemical wrap.)

Coatings used for potable water must be listed to NSF/ANSI/CAN-61[9].

6.1.2. Use of fitting Classes in Municipal Applications

AWWA M55*, 2nd Edition PE Pipe– Design and Installation* specifies restrained mechanical fittings for HDPE in municipal water systems.

[8] AWWA M55 *PE Pipe - Design and Installation*, Second Edition, American Water Works Association, Denver, CO, 2020.
[9] NSF/ANSI/CAN-61-2023 *Drinking Water System Components – Health Effects*, NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140, 2023 http://www.nsf.org.

While AWWA does not list classes, the following mechanical fitting types per ASTM F1476 (see Table 2) are permitted:

- Class 1 – Rigid and restrained
- Class 2 – Flexible and restrained

6.1.3. Sizes and Pressure Capacity

The user must ensure that the fitting is selected to match the specific pipe size, operating temperature, operating pressure, and surge pressure requirements of the system design.

Common pipe sizes for which mechanical fittings are available include:

- AWWA C906[10] for potable water
  - DIPS, IPS, 4” thru 65”
  - SDR 7 thru 21 (100–335 psi) (80 °F, 27 °C)
  - Surge pressure capacity (200-670 psi) (80 °F, 27 °C)
- AWWA C901[11] for potable water
  - CTS 3/4” thru 2”, IPS 3/4” thru 3”
  - SDR 9 (250 psi) (80 °F, 27 °C)
  - Surge pressure capacity (500 psi) (80 °F, 27 °C)
- For other applications reference ASTM F71412, D303513.

6.1.4. Inserts

Consult the fitting manufacturer on the need for inserts (stiffeners) and whether plastic or metal is recommended.

6.1.5. Other Fitting Configurations

Configurations other than straight couplings exist, such as fittings that provide:

- Transition Fittings -Transition from one pipe material to another pipe material or from one wall thickness to another
- Reducing Fittings - Reducing from one pipe diameter to another pipe diameter
- Other configurations: Tees, wyes, crosses, elbows, saddles, etc.

6.1.6. Elastomeric seals

Seals of the following materials are typically used:

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[10] AWWA C906-2021 *Polyethylene (PE), Pressure Pipe and Fittings, 4in. Through 65 in. (100mm through 1,650 mm), for Waterworks*, American Water Works Association, Denver, CO, 2021.
[11] AWWA C901-2020 *Polyethylene (PE) Pressure Pipe and Tubing, 3/4 In. (19 mm) Through 3 In. (76 mm), for Water Service*, American Water Works Association, Denver, CO, 2020.
[12] ASTM F714-24 *Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter*, ASTM International, West Conshohocken, PA, USA, 2024.
[13] D3035-22 Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter, ASTM International, West Conshohocken, PA, USA, 2022.

- EPDM
- SBR
- NBR

Seals used for potable water must be listed to NSF/ANSI/CAN-61.

Note: AWWA C901 Section II-B warns that elastomers may be degraded when exposed to chlorine and chloramine used as a disinfectant in water. Consult with the fitting or gasket manufacturer for the selection of the appropriate seal material.

6.2. Codes & Regulations

Canadian and US regulatory bodies require that all piping components used for potable water be listed to NSF/ANSI/CAN-61 by a 3rd party certifier.

6.3. Product Standards

The following provides a list of product standards (not exhaustive) for mechanical fittings:

- ASTM F1476 - Standard Specification for Performance of Gasketed Mechanical Couplings for Use in Piping Applications
- ASTM F3536 - Standard Specification for PE and PP Mechanical Fittings for use on NPS 3 or Smaller Cold-water Service Polyethylene (PE) or Crosslinked Polyethylene (PEX) Pipe or Tubing
- AWWA C60614 - Grooved and Shouldered Joints
- AWWA C21915 - Bolted, Split-Sleeve Couplings
- AWWA C111/A21.1116 – Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
- AWWA C15317 – Ductile-Iron Compact Fittings

6.4. Certification of Couplings

For North American municipal drinking water applications, certification by a 3rd party independent certification of products must be made to and marked with NSF/ANSI/CSA Standard 61 *Drinking Water System Components – Health Effects*. There are various accredited agencies that provide this 3rd party certification to products standard.

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[14] AWWA C606-22 *Grooved and Shouldered Joints*, American Water Works Association, Denver, CO, USA, 2022.
[15] AWWA C219-23 Bolted, Split-Sleeve Couplings, American Water Works Association, Denver, CO, USA, 2023.
[16] AWWA C111/A21.11-23 Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fitting, American Water Works Association, Denver, CO, USA, 2023.
[17] AWWA C153-19 *Ductile-Iron Compact Fittings*, American Water Works Association, Denver, CO, USA, 2019.

For non-drinking water applications, NSF/ANSI/CSA Standard 61 certification is not required but may be used.

For fire protections systems, certification by Factory Mutual is required.

Manufacturers indicate within their literature to which product standards their products conform, e.g., ASTM, AWWA.

Municipalities may have specific requirements or approved products. Users should check with the municipality for specific requirements or necessary approvals.

7.0 CONCLUSION

Mechanical fittings have been successfully used for decades as a joining method for PE pipe in gas distribution, gas gathering and municipal water applications. Mechanical fittings also offer a joining method where the installation environments or conditions can make the fusion process difficult or challenging.

There exists many types and designs of mechanical fittings on the market. Consideration of the application is necessary in the selection of the fitting type. The fitting manufacturer can support with the appropriate selection.

APPENDIX A
MECHANICAL COUPLINGS IN GAS DISTRIBUTION: A HISTORICAL PERSPECTIVE

A.1 INTRODUCTION

This appendix provides a historical timeline to assist material engineers, when assessing older PE systems, and to determine what the governing requirements were for mechanical fittings at the time of their installation.

The use of polyethylene piping material has steadily increased over the past half century and today it's the material of choice for natural gas piping systems up to 12" size. Mechanical couplings and fittings played a vital part in this evolution, especially in the earlier years, when distribution service line installations were the most common application. Many of these mechanical fittings were metallic and connected to steel or cast-iron main piping with a PE outlet connection for the service line. Both plastic and metallic mechanical fittings have provided the industry with fast and easy pipe joining, and repair and transition techniques. Their nearly 50 years of performance history is testimonial to the safe and reliable service these fittings provide.

Although there have been some incidents of joint failures in the long history of the use of mechanical compression fittings installed on PE pipe, the overall performance record of these mechanical joints has been excellent. Most incidents can be attributed to misuse or misunderstanding of the fitting capabilities at the time of installation. Resulting design and performance requirement improvements, along with an increase in the understanding of the application and limitations of different types of compression fittings, has served to ensure that modern compression jointing technologies are safe and reliable.

A.2 HISTORICAL BACKGROUND

When plastic pipe was first designed and developed for the natural gas distribution industry in the 1960's, the dimensions were called IPS and CTS or Iron Pipe Size and Copper Tubing Size. The outside diameter (OD) of IPS pipe was based on the corresponding iron pipe outside diameter so that the same fittings that were used for metal pipe could also be used for plastic pipe. For example, nominal 2" IPS PE pipe has an outside diameter of 2.375", which is the OD of metal pipe.

When mechanical compression couplings were first used for plastic gas pipe in the early 1960's they provided a leak-tight seal only, and this seal was based on the OD dimensions. These first compression couplings, which were originally designed for metal pipe, provided the necessary gas-tight seal, but did not provide resistance (restraint) to pull out. As the use of plastic pipe, and particularly PE pipe, increased, the compression coupling manufacturers began to design their couplings specifically for plastic pipe. In the case of PE pipe, this included an insert stiffener to provide the needed rigidity to the PE pipe to improve the required seal. By the late 1960's, some compression coupling manufacturers also

began to design their fittings with pullout resistance in addition to leak-tight seals. By 1980, there were several manufacturers that sold compression couplings that provided both a leak-tight seal and gripping mechanisms that provided pullout restraint.

In their 1972 report, "*Comparison of Long-Term Sealing Characteristics of Compression Type Couplings on Steel & Polyethylene Pipe*" Dresser Manufacturing stated:

"A new mechanical design was initiated to develop a mechanical joint for PE. Requirements were obviously long-term reliable sealing ability and a joint locking strength equal to the longitudinal strength of the plastic pipe being joined, as required by (our interpretation) the DOT regulations Volume 35, number 61, paragraph 192.273 (a)".

This statement indicates that Dresser Manufacturing interpreted the code as meaning that a compression coupling needed to have restraint to pullout, and they were manufacturing couplings to meet that requirement. The mechanical couplings manufactured by Dresser in sizes 2" IPS and below had a locking feature to prevent pullout. This had been the industry standard since the late 1960's.

In the late 1970's as a result of two compression fitting pullout failures in Fremont, Nebraska and Lawrence, Kansas, the DuPont Company published an article, "*Pull Out Forces on Joints in PE (Polyethylene) Pipe Systems*", in which the joint strength for compression fittings ½" to 1" was deemed "equal or greater" than pipe strength. DuPont deemed compression fittings larger than 1" to have joint strength "less" than pipe strength.

As a result of several more industry gas pipeline failures due to PE pipe pulling out of a non-restraint compression coupling, some manufacturers included caution statements in their literature, such as:

"When pipe pullout could occur as a result of forces other than that caused by internal line pressure of 150 psig maximum, pipe joint MUST be anchored. Failure to anchor pipe joint could result in escaping line content and cause property damage, serious injury or death."

Also, as a result of these incidents, the US DOT (Department of Transportation) Part 192.273 required that "*the pipeline must be designed and installed so that each joint will sustain the longitudinal pullout or thrust forces caused by contraction or expansion of the piping or by anticipated external or internal loading*." Also, DOT Part 192.703 required that each segment of pipeline that becomes unsafe must be replaced.

In 1980, Part 192 was revised to incorporate additional mechanical joint requirements in Part 192.283. These new requirements included qualifying joining procedures for mechanical joints and qualifying the person to make such joints, including a pullout test that requires the pipe to neck down with at least 25% elongation to qualify the joining procedure.

On March 4, 2008, as a result of more compression coupling pullout failures, DOT issued Advisory Bulletin ADB-08-02 on mechanical couplings. This ADB states:

"PHMSA ADVISES OPERATORS OF GAS DISTRIBUTION PIPELINES USING MECHANICAL COUPLINGS TO DO THE FOLLOWING TO ENSURE COMPLIANCE WITH 49 CFR PART 192:

(1) REVIEW PROCEDURES FOR USING MECHANICAL COUPLINGS, INCLUDING THE COUPLING DESIGN AND INSTALLATION AND ENSURE THAT THEY MEET MANUFACTURER'S RECOMMENDATIONS. DOT ALSO ADVISES OPERATORS OF GAS DISTRIBUTION PIPELINES USING MECHANICAL COUPLINGS TO CONSIDER TAKING THE FOLLOWING MEASURES TO REDUCE THE RISK OF FAILURES OF MECHANICAL COUPLINGS:

(4) USE CATEGORY 1 FITTINGS ONLY IF MECHANICAL COUPLINGS ARE USED ON PIPE SIZES ½" CTS TO 2" IPS.

(6) CONSIDER WHETHER TO ADOPT A FULL REPLACEMENT PROGRAM IF THERE ARE TOO MANY UNKNOWNS RELATED TO COUPLINGS IN SERVICE."

A.3 INDUSTRY CODES/STANDARDS FOR MECHANICAL COUPLINGS

A.3.1 AGA Plastic Pipe Manual

The industry document that gas companies rely on the most for general guidelines on installing plastic pipe is the AGA Plastic Pipe Manual. This manual is prepared by plastics piping experts in the AGA Plastic Materials Committee, both gas companies and manufacturers, to assist the users with proper installation and maintenance of plastic pipe. The original 1977 AGA Manual references DOT Part 192.273 and states:

"The installed joint must effectively 'sustain longitudinal pullout or thrust forces caused by contraction or expansion of the piping or by anticipated external or internal loading.' Such provision may be made in the design of the joint or in the installation or a combination of both."

The 1977 AGA Manual also states:

"Earth movement, ground movement and third party construction activity can impose stresses on the pipe which can be transmitted to joints. In most situations it is desirable to have pipe joints which are as strong as the pipe itself in the axial (longitudinal) direction. Mechanical joints not specifically designed for use with plastic pipe may not provide complete resistance to pullout."

Later versions of the AGA Plastic Pipe Manual were updated to reflect the new mechanical joint requirements in DOT Part 192.283.

A.3.2 ASTM F17

The industry standard that the gas companies rely on the most for product requirements when installing plastic pipe is ASTM D2513. This is a consensus standard prepared by plastics piping experts in ASTM

F17, that is referenced by DOT in Part 192. Early versions of ASTM D2513 stated:

"Mechanical joints categorized by 8.14 should be engineered to provide adequate resistance to pullout caused by thermal contraction and earth movement, or both, anticipated during its service life."

D2513 also stated:

"Earth settlement, internal pressure and ground movement can impose stresses on the pipe which when in the vicinity of joints can be transmitted to the joints themselves. It is desirable to have pipe joints that are as strong as the pipe itself in the longitudinal (axial) direction. For those mechanical joints made with fittings which are not designed to restrain the pipe against pullout forces which could be experienced, provisions must be made in the field to prevent pullout. Another somewhat limited alternative is to use long sleeve-type fittings which permit limited movement without loss of the pressure seal. Otherwise, provisions must be made in the field to prevent pullout through suitable anchoring at the joint."

In 1980, while DOT Part 192 was being revised to incorporate additional mechanical coupling requirements in Part 192.283, ASTM D2513 was also revised. Mechanical fitting categories were established based on the fitting leak-tightness and the fitting pullout resistance as follows:

- A category 1 fitting provides both a seal and full pullout restraint.
- A category 2 fitting provides a seal only.
- A category 3 fitting provides seal and limited restraint, equivalent to the anticipated thermal stresses occurring in a pipeline.

ASTM D2513 Note 9 was also revised to state:

"The ability to restrain pipe or tubing to its yield as specified above does not guarantee that a properly installed joint will prevent pullout under actual long-term field conditions. Joints that cannot pass this test would be expected to pullout under actual long-term field conditions. To date, this test is the best available for disqualifying unsound joints."

In more recent years, standards for mechanical fitting design and performance have been written specifically for natural gas distribution systems that contain performance requirements intended to establish minimum requirements for longitudinal force capability and to verify pullout resistance. Separate standards now exist for both plastic and metal bodied compression fittings that impose the same level of pullout resistance regardless of the compression design type. These standards require full resistance to pullout forces equal to that which would cause permanent deformation of the PE pipe:

- ASTM F1948 – "Standard Specification for Metallic Mechanical Fittings for Use on Outside Diameter Controlled Thermoplastic Gas Distribution Pipe and Tubing"
- ASTM F1924 – "Standard Specification for Plastic Mechanical Fittings for Use on Outside Diameter Controlled Polyethylene Gas Distribution Pipe and Tubing"

Additional requirements for long-term pullout resistance include a “dead weight” or constant tensile load joint test that subjects the joint to an internal pressure and longitudinal force to achieve a defined stress in the PE pipe.

A.3.3 National Transportation Safety Board (NTSB) Recommendations

In 1985, NTSB reported that it had determined that the probable cause of a mechanical joint failure was the gas company’s failure to understand the limitations of the coupling, which led to the pullout of the PE pipe from the coupling. This NTSB Report prompted AGA to issue a memo to all its member companies regarding NTSB Recommendation P-85-30. In this memo, AGA stated:

“When using couplings to join plastic pipe, we urge you to consider the forces anticipated to act on the coupling and assure that these forces will not exceed the capabilities of the coupling.”

This NTSB Report also led to DOT Advisory Bulletin in 1986 (ADB-86-02) on mechanical couplings. This advisory bulletin was intended to inform natural gas pipeline operators to review procedures for using mechanical couplings, and to ensure that coupling design, procedures, and personnel qualifications meet Part 192.

A.3.4 Department of Transportation (DOT)

As discussed in Section 4.0, DOT CFR Title 49 Part 192 now mandates that all mechanical couplings be rated as Category 1 as per the fitting specification incorporated by reference in Part 192.7 and an internal stiffener must be used.