

Technical Note 813-TN

PE Pressure Water Piping Systems

Mechanical Restraint and Poisson Effects

Introduction

When non-PE pipe and components are installed in the same pressure pipeline with PE pipe, or when PE pipe is connected to unrestrained joint piping such as bell and spigot joint PVC or ductile iron, unrestrained joints in the transition area should be protected against pullout disjoining.

When pipes made from ductile materials are pressurized, the diameter expands slightly and the length decreases in accordance with the Poisson ratio of the material. With unrestrained bell and spigot joined lengths, the effect is limited to the individual pipe lengths, but with fully restrained pipes such as fusion-joined PE pipe, the effect is cumulative over the entire restrained length of pipe. When fusion-joined PE pipe is connected to unrestrained mechanical couplings or bell and spigot joint PVC or ductile iron piping, Poisson effect pipe shortening can cause pullout disjoining of unrestrained joints where the PE pipe transitions to the unrestrained non-PE pipe. To prevent Poisson effect pullout disjoining in the transition area, provide protection by installing external joint restraints at unrestrained bell and spigot joints, or by installing an in-line anchor in the HDPE pipeline, or by a combination of both techniques.

Conventional thrust blocks at directional fittings are not effective against Poisson effect pullout because conventional thrust blocks are intended to resist pressure and fluid flow thrust forces that would push the fitting off the end of the pipe. Thrust blocks cannot counteract forces that would pull the pipe end out of the joint. Snaking pipe in the trench is generally not effective and is not recommended.

The Poisson Effect

When a tensile stress is applied to a material, the material elongates in the direction of the applied stress, and contracts perpendicular to the direction of the applied stress. This relationship, called the Poisson effect, is a natural response to applied stress that occurs with all materials, but is particularly apparent with ductile materials. For example, when a metal bar is pulled in a tensile test, it stretches out and necks down on the sides. The Poisson effect occurs naturally in all materials including iron, steel, copper, concrete, glass and plastics. When pipes such as polyethylene, PVC and metal pipes are pressurized, the diameter will expand slightly, and due to the Poisson effect, the pipe will shorten in length.

A pipe section with fully restrained joints such as a long string of butt-fused HDPE pipe will transmit Poisson forces from length to length through the restrained joints along the pipe string. Restrained joints include fusions, bolted flange connections, MJ adapter connections or other restrained mechanical connections. If an unrestrained bell and spigot or mechanical joint is in-line with the restrained section, the cumulative Poisson effect shortening may cause in-line unrestrained joints or connections to be pulled apart. Therefore, unrestrained joints or mechanical connections that are in-line with fully restrained HDPE pipe must be either restrained or otherwise protected against pullout disjoining.

Connection Restraint Techniques for Pressure Water Systems

In pressure water systems where DriscoPlex™ HDPE pipe is connected to non-HDPE components such as belled PVC or ductile iron pipe, belled fittings and components, and mechanical joint bell pipe, fittings and components, the connection must be restrained to prevent Poisson force joint pullout.

Adapters for Flanges and Mechanical Joints

Adapters are available for connecting DriscoPlex™ HDPE pipe to flanged pipe and components and to pipe and components with mechanical joints bells. DriscoPlex™ Flange Adapters and MJ Adapters are fully pressure rated and fully restrained. DriscoPlex™ Flange Adapters and MJ Adapters are butt fused to DriscoPlex™ HDPE pipe, then connected to the mating flange or mechanical joint bell. See Performance Pipe fittings literature and technical notes for adapter information and installation instructions.

NOTICE. This publication is intended for use as a guide to support the designer of piping systems, but it should not be used in place of the advice of a professional engineer. Performance Pipe has made every reasonable effort to ensure the accuracy of this publication, but it may not provide all necessary information, particularly with respect to special or unusual applications. This publication may be changed from time to time without notice. Contact Performance Pipe to determine if you have the most current edition.

Connecting Plain-End HDPE Pipe to Belled Connections

When plain-end HDPE pipe is connected to belled pipe, fittings or components in a pressure water system, the connection must be mechanically restrained against Poisson force joint pullout. Mechanical restraint can be provided with clamp and tie-rod devices that clamp behind the bell and on the pipe end, and connect the clamps with tie rods. For connections to mechanical joint bell pipe, fittings and components, a clamp on the HDPE pipe end, and extended length gland bolts or all-thread extended through the MJ flange, gland and through the clamp on the HDPE pipe end can provide mechanical restraint. Additional nuts between the HDPE pipe clamp and the gland secure the gland, and to ensure the long-term security of the clamp on the HDPE pipe end; a stiffener should be installed in the HDPE pipe end. The internal stiffener extends into the HDPE pipe end so that the stiffener supports the HDPE pipe under the seal and under the clamp.

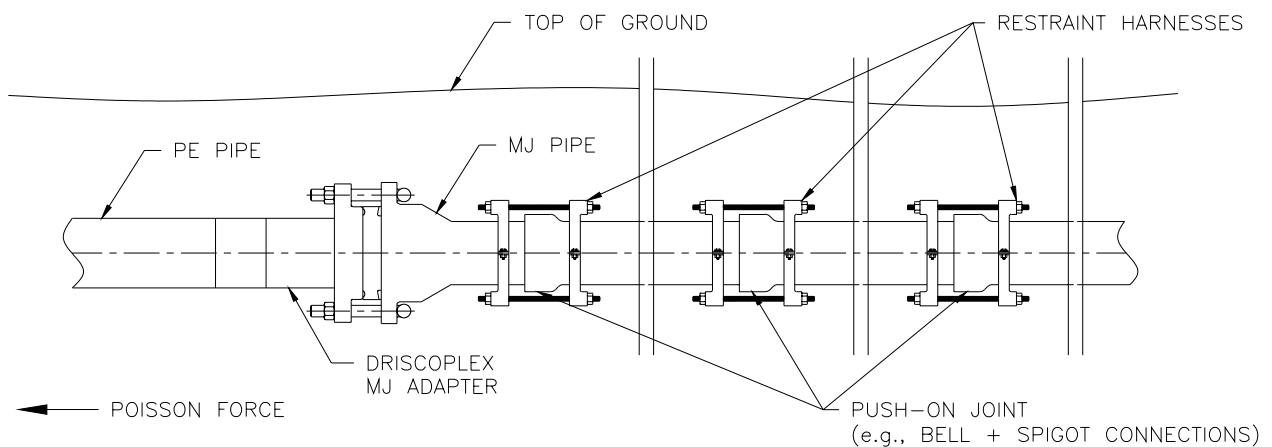
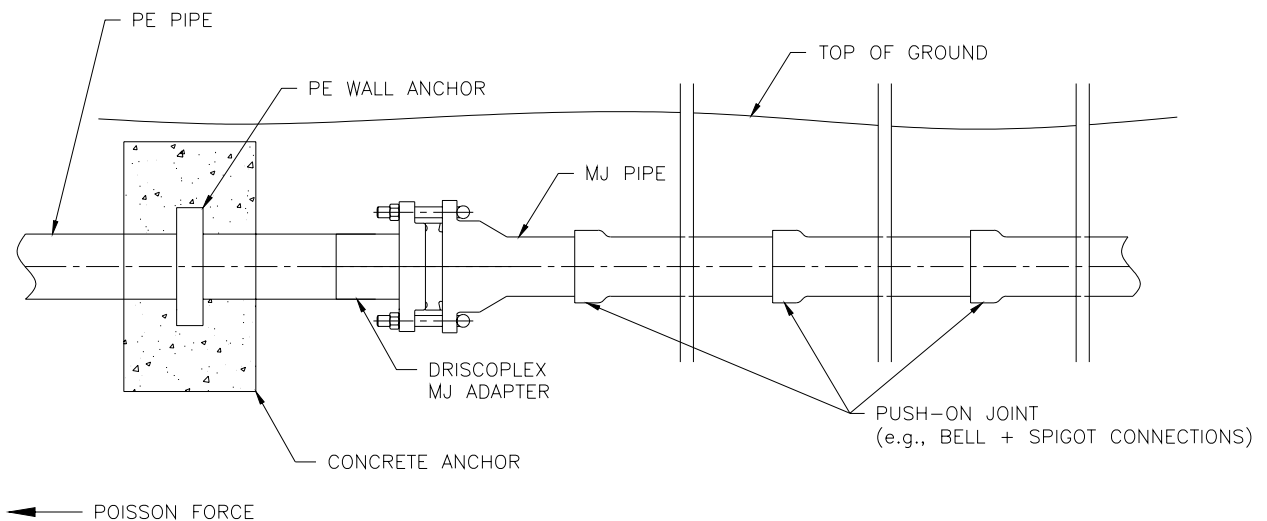
Other mechanical restraint and coupling devices that provide restraint may also be available. Contact restraint or coupling manufacturers for recommendations for use with HDPE pipe, and always install mechanical restraint and couplings in accordance with the device manufacturer's recommendations and instructions.

For PE butt fusion and where DriscoPlex™ Flange Adapter and DriscoPlex™ MJ Adapter fittings are used, ID stiffeners and external joint restraints are *NOT* required.

Conventional thrust block restraint is not effective in preventing Poisson force joint pullout.

Pullout Prevention Techniques

Pullout can occur at joints in the non-PE pipe system downline from any transition area where a long HDPE pipe string is connected in-line to unrestrained piping because a restrained connection at the transition joint can transmit Poisson force to the next in-line unrestrained joint in the non-PE pipe. Typical pullout prevention techniques include restraining several non-PE pipe joints that are in-line with the transition connection, or restraining the transition connection and installing an in-line anchor in the HDPE pipe close to the transition connection. The figures below illustrate typical pullout prevention techniques.



Pullout Force

Poisson forces will occur whenever the pipe is pressurized. Because internal pipe pressures are higher during pressure testing and surge events, Poisson effect pipe shortening can be greater at these times compared to normal steady pressure operation.

Caution – Before pressure testing, all mechanical joint restraints must be completely installed and secured per manufacturer’s instructions, and concrete at in-line anchors and thrust blocking (if used) must be sufficiently cured and properly backfilled. See Performance Pipe Technical Note PP-802-TN Leak Testing.

The Project Design Engineer should determine the Poisson Effect pullout force conditions that are appropriate for the application; then determine the appropriate techniques to protect unrestrained in-line mechanical connections against disjoining from Poisson effect pullout forces.

For a given PE pipe diameter and DR, approximate Poisson effect pullout force may be determined by multiplying the end area of the PE pipe by the product of the internal pressure hoop stress and the appropriate Poisson ratio.

$$F = S \mu \pi D_M^2 \left[\frac{1}{DR} - \frac{1}{DR^2} \right]$$

Where F = pullout force, lbs
S = internal pressure hoop stress, lb/in²

$$S = \frac{P(DR-1)}{2}$$

P = internal pressure, lb/in²
DR = dimension ratio
 μ = Poisson ratio (for PE, 0.45 for long-term stress; 0.35 for short-term stress)
 π = Pi (approximately 3.142)
D_M = pipe mean diameter, in

The following table presents approximate Poisson effect pullout forces for selected sizes of PE pipe while operating at rated system internal pressure, during leak testing at 150% of rated system pressure and during a severe water hammer event while operating at steady pressure that causes a pressure surge to 200% of rated system pressure.

Approximate Poisson Effect Pullout Force for DIPS DR 11 PE 3408

Pipe Size	Approximate Pullout Force, lbs (a)		
	Operating at Full Rated Pressure (b)	During Pressure Tests at 150% of Rated Pressure (c)	Operating at Full Rated Pressure Plus Maximum Allowable Occasional Surge Pressure (d)
4"	1,892	2,208	3,364
6"	4,102	4,786	7,293
8"	6,953	8,112	12,361
10"	10,801	12,602	19,202
12"	15,195	17,727	27,013
16"	23,928	27,916	42,539

(a) Values for water at 73°F.

(b) Rated pressure for DR 11, Class 160 = 160 psi. Pullout force determined using long-term Poisson ratio of 0.45.

(c) Pullout force determined using short-term Poisson ratio of 0.35.

(d) Total pressure in pipe during surge event = 160 psi steady pressure + 160 psi surge pressure = 320 psi. Values determined by combining pullout force for steady pressure (long-term Poisson ratio of 0.45) plus pullout force for surge event (short-term Poisson ratio of 0.35).

Other longitudinal forces from thermal expansion and contraction, or fluid thrust, or installation are not incorporated into table values. See the *Performance Pipe Engineering Manual* for information on additional loads.

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