Seismic Pipe & Fittings
Is your infrastructure capable of delivering critical emergency services during seismic activity?
An earthquake is the vibration of Earth produced by the sudden and rapid release of energy caused by the abrupt displacement of adjacent rock masses (faults). This energy, known as seismic waves, sends out vibrations in all directions and is responsible for the resulting damage to the affected infrastructure and buildings. Water plays a critical role in the immediate and long-term efforts of post-earthquake recovery. Emergency services, health care, energy, transportation, and communications all rely on water to be operational and effective. Communities and municipalities have recognized the need for water resiliency and are incorporating resilient water systems into new projects and retrofit design efforts.

**HOW DO EARTHQUAKES DAMAGE PIPELINES?**

Earthquakes generate seismic waves that propagate through the soil and cause temporary and sometimes permanent ground deformations (PGD). Generally there are three different seismic hazards to pipelines.

**Seismic Hazards to Pipelines**

- **Temporary Ground Deformation**
  - General Shaking
  - Ground Amplification

- **Nearby Non-Resilient Infrastructure**
  - Reservoirs
  - Bridges
  - Structures

- **Permanent Ground Deformation**
  - Liquefaction
  - Landslide
  - Abrupt Offsets

### DESIGNING FOR SEISMIC RESILIENCY

Design for seismic events presents a challenging scenario, as it requires a multi-disciplinary approach to solve a multi-disciplinary problem. PGD’s are the most pervasive cause of damage to pipelines in a seismic event and materialize in the form of faulting, liquefaction, lateral spread, slope failure, and/or settlement. These PGD’s are often maximized at boundary conditions and careful consideration must be taken in these areas. Often times the criticality of the pipeline determines the amount of geotechnical investigation to locate and estimate PGD’s:

Based upon the seismic scenario the designer will need to specify a product that meets the anticipated needs. Not every design scenario requires an earthquake resistant product, however designers want to ensure that the correct product is chosen. This can be a challenging task based upon the breadth of available products and configurations.
Design for seismic loading needs to take into account additional external loading. Generally pipeline materials are separated into two types; continuous and segmented. A continuous pipeline is often welded or fused at the joints and seismic loads are accommodated by the pipe wall stretching and bending. Segmented pipelines accommodate seismic loads by deflecting and expansion/contraction of the pipe joint.

Ductile Iron Pipe is a segmented pipeline and has a long and proven history for survivability in seismic events. The inherent strength of ductile iron allows the pipe barrel to resist large amounts of strain while the gasketed joint allows deflection and provides pull apart resistance when restrained. Ductile Iron Pipe NEVER designs into yielding of the pipe wall and therefore a ductile iron pipeline can be expected to maintain a full service life even after a seismic event. This is a critical yet often overlooked component of seismic design and resiliency.

U.S. Pipe offers a broad range of products to accommodate seismic loading. The criticality of the pipeline and the anticipated external loads will determine how resilient of a product to select.

**INTERNATIONAL STANDARD ISO 16134**
Earthquake and subsidence-resistance design of ductile iron pipelines.

<table>
<thead>
<tr>
<th>CLASS</th>
<th>COMPONENT PERFORMANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>± 1% (L) or more</td>
</tr>
<tr>
<td>S2</td>
<td>± 0.5% (L) to ± 1% of (L)</td>
</tr>
<tr>
<td>S3</td>
<td>Less than ± 0.5% of (L)</td>
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**Pull Apart Resistance**

<table>
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<tr>
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<td>A</td>
<td>17,000 (d) lbs +</td>
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<tr>
<td>B</td>
<td>8,500 (d) lbs–17,000 (d) lbs</td>
</tr>
<tr>
<td>C</td>
<td>4,250 (d) lbs–8,500 (d) lbs</td>
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<td>D</td>
<td>Less than 4,250 (d) lbs</td>
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**Joint Deflection Angle**

<table>
<thead>
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<th>COMPONENT PERFORMANCE</th>
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<tbody>
<tr>
<td>M1</td>
<td>15° or more</td>
</tr>
<tr>
<td>M2</td>
<td>7.5° &lt; 15°</td>
</tr>
<tr>
<td>M3</td>
<td>Less than 7.5°</td>
</tr>
</tbody>
</table>

"\(L\)" is the component length in inches
"\(d\)" is the nominal pipe diameter in inches
In a class by itself, the SAM1 Seismic Fitting is the only fully cast ball joint with integral expansion sleeve allowing it to meet the most demanding criteria.

The SAM1 Seismic Fitting is another industry first developed by U.S. Pipe for the waterworks industry. It combines two existing proven products, the TELESCOPING SLEEVE and the USIFLEX Ball Joint, into a single as-cast fitting. This combination results in an unparalleled and economical combination of elongation, deflection, and pull apart resistance. The SAM1 Seismic Fitting connects seamlessly to U.S. Pipe’s existing pipe products which allows the entire piping system to maintain equal pull apart resistance and resiliency.

Benefits

- Available in 6, 12, 24, 30, 36, 42, 48 inch Diameters
- 15 degrees of deflection with 12” total elongation
- Integral connections to TR FLEX® / TR-XTREME® / HDSS® / HP LOK®
- Manufactured to ANSI/AWWA C110/A21.10
- Pressure rating from 250–350 psi

Performance Specifications

<table>
<thead>
<tr>
<th>SIZE</th>
<th>MINIMUM PULL APART RESISTANCE</th>
<th>ELONGATION AT MIDPOINT</th>
<th>COMBINED DEFLECTION</th>
<th>ISO 16134 DESIGNATION</th>
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</thead>
<tbody>
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<tr>
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<tr>
<td>24</td>
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<td>±6</td>
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<td>S1, A, M1</td>
</tr>
<tr>
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<td>S1, A, M1</td>
</tr>
<tr>
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<td>S1, A, M1</td>
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<tr>
<td>48</td>
<td>816,000</td>
<td>±6</td>
<td>16.0</td>
<td>S1, A, M1</td>
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</table>
A large diameter solution to provide resiliency to the most critical pipelines in any water system.

The SAM1 Seismic Assembly was developed to provide a resilient solution for larger diameter trunk and transmission pipe systems. It utilizes our existing time-proven products in combination to accommodate anticipated seismic ground strains. The SAM1 Seismic Assembly consists of (2) HP LOK or HDSS Pipe Segments and (1) SAM1 Seismic Fitting and has the capability to meet the most stringent performance criteria.

It utilizes the TYTON® Gasket which is familiar to both the contractor and municipal industry. All pipe and fitting joints utilize HP LOK or HDSS joint connections that allow flexible boltless joint restraint to be accomplished at the crown of the pipe. Pipe segments to be inserted into the SAM1 Seismic Fitting have an assembly stripe to allow visual verification of midpoint installation within the expansion sleeve.

Benefits
- Available in 24, 30, 36, 42, 48 inch Diameters
- Utilizes (2) HP LOK / HDSS Pipe Segments & (1) SAM1 Seismic Fitting
- Joint connection uses proven TYTON Gasket
- Simple integral restraint with easy disassembly
- Assembly pressure rating from 250–350 psi

Performance Specifications

<table>
<thead>
<tr>
<th>SIZE</th>
<th>ASSEMBLY LENGTH AT MIDPOINT</th>
<th>MINIMUM PULL APART RESISTANCE</th>
<th>ELONGATION AT MIDPOINT ASSEMBLY</th>
<th>ASSEMBLY DEFORMATION</th>
<th>RADIUS OF CURVATURE</th>
<th>ISO 16134 DESIGNATION</th>
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</thead>
<tbody>
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<tr>
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<td>141</td>
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</tr>
<tr>
<td>48</td>
<td>532 (44ft 4in)</td>
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<td>± 1.13%</td>
<td>16.5</td>
<td>153</td>
<td>S1, A, M3</td>
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</table>
The first and only domestic earthquake resistant ductile iron pipe that provides expansion/contraction deflection within a single bell joint connection.

TR-XTREME is manufactured out of ductile iron, a material that has a long and successful history to withstand seismic activity. Joint integrity is accomplished by a robust and unique extended bell that provides 2.9” of expansion and contraction capability with up to 5° of deflection per joint. TR-XTREME incorporates technology we’ve learned from over 40 years of designing restrained joints for the water works industry. The TR-XTREME joint is one of the strongest and most robustly designed restrained joints for water works as proven by Cornell University during full-scale 3rd party testing. The TR-XTREME restrained joint utilizes the time proven and droptight TYTON Gasket for a reliable seal. It is manufactured in Northern California, meets AIS requirements, and is available in 18’ lengths up to 24” diameter. Additionally, U.S. Pipe offers a complete line of standard and custom fittings to complement TR-XTREME pipe. The features incorporated into TR-XTREME help ensure that when disaster strikes, water will be available.

Benefits

- Available in 6, 8, 12, 16, 20, and 24 inch Diameters
- ONLY domestic seismic pipe with expansion/contraction & deflection in single joint
- Increased quantity of locking segments for increased pull apart resistance
- Easy boltless assembly and disassembly
- Full line of fittings and adapters for complete resiliency
- 350 psi pressure rating

Performance Specifications

<table>
<thead>
<tr>
<th>SIZE</th>
<th>ASSEMBLY LENGTH AT MIDPOINT</th>
<th>MINIMUM PULL APART RESISTANCE</th>
<th>PERCENT ELONGATION AT MIDPOINT ASSEMBLY</th>
<th>DEGREES JOINT DEFLECTION</th>
<th>LINEAR FEET RADIUS OF CURVATURE</th>
<th>ISO 16134 DESIGNATION</th>
<th>AVAILABLE CLASSES</th>
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<tbody>
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<td>± 0.68%</td>
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<td>204</td>
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<td>Class 51, 52, 53, 56</td>
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<tr>
<td>8</td>
<td>214 (17ft 10in)</td>
<td>136,000</td>
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<td>5.0</td>
<td>204</td>
<td>S2, A, M3</td>
<td>Class 51, 52, 53, 56</td>
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<tr>
<td>12</td>
<td>214 (17ft 10in)</td>
<td>204,000</td>
<td>± 0.68%</td>
<td>5.0</td>
<td>203</td>
<td>S2, A, M3</td>
<td>Class 50, 52, 53, 56</td>
</tr>
<tr>
<td>16</td>
<td>213 (17ft 9in)</td>
<td>272,000</td>
<td>± 0.68%</td>
<td>5.0</td>
<td>203</td>
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<td>PC350, Class 52, 53, 56</td>
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<tr>
<td>20</td>
<td>207 (17ft 8 in)</td>
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<tr>
<td>24</td>
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<td>337</td>
<td>S2, A, M3</td>
<td>PC350, Class 52, 53, 56</td>
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</table>
When the highest level of resiliency is needed, TR-XTREME S1 will rise to the occasion while maintaining repeatable simplicity.

TR-XTREME S1 incorporates all the same benefits of TR-XTREME, however it is supplied in shorter pipe segments to meet the most stringent performance requirements. Shorter pipe segments allow the pipeline assembly to provide large amounts of expansion/contraction and deflection that can accommodate large temporary and permanent ground deformations resulting from seismic activity or unstable soils.

Benefits
- Available in 6, 8, 12, 16, 20, and 24 inch Diameters
- Integral deflection and expansion/contraction provided in each joint
- Shorter segments of TR-XTREME to meet the highest performance criteria
- No special assembly procedures or tools required

Performance Specifications

<table>
<thead>
<tr>
<th>SIZE</th>
<th>ASSEMBLY LENGTH AT MIDPOINT</th>
<th>MINIMUM PULL APART RESISTANCE</th>
<th>ELONGATION AT MIDPOINT ASSEMBLY</th>
<th>JOINT DEFLECTION</th>
<th>RADIUS OF CURVATURE</th>
<th>ISO 16134 DESIGNATION</th>
<th>AVAILABLE CLASSES</th>
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<tbody>
<tr>
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<td>± 1.15%</td>
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<td>136,000</td>
<td>± 1.15%</td>
<td>5.0</td>
<td>137</td>
<td>S1, A, M2</td>
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<td>12</td>
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<td>± 1.15%</td>
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<td>Class 53, 56</td>
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<td>3.0</td>
<td>229</td>
<td>S1, A, M3</td>
<td>Class 53, 56</td>
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</table>
Robust. Simple. Practical. Effective. HDSS has the strength to resist seismic forces when expansion and contraction are not required.

Not all seismic applications require a pipe that can integrally expand and contract. HDSS incorporates a full circumference of locking segments which results in large amounts of pull apart resistance while increasing allowable deflection. A single slot in the bell cavity allows installers to insert the locking segments from the crown of the pipe which facilitates a simple installation and inspection. The simple robust design and added deflection make this the strongest joint in the market and ideal for seismic applications. Each pipe joint has approximately 0.5” to 0.6” of pullout which is intended to facilitate the assembly of the locking segments. For seismic applications designers and owners can opt to leave the joint fully inserted which allows for some expansion to accommodate ground deformations.

Benefits

- Available in 12, 16, 20, 24, 30, 36, 42, and 48* inch Diameters
- Full circumference of locking segments for increased pull apart resistance & deflection
- Easy boltless assembly and disassembly
- Single bell cavity for easy installation and inspection
- Seamless transition to TR FLEX and HP LOK
- Full line of fittings and adapters for complete resiliency

Performance Specifications

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<th>SIZE</th>
<th>INCHES</th>
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<th>MINIMUM PULL APART RESISTANCE</th>
<th>ELONGATION AT FULL INSERTION ASSEMBLY</th>
<th>DEGREES</th>
<th>JOINT DEFLECTION</th>
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<th>LINEAR FEET</th>
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<td>12</td>
<td>216 (18ft)</td>
<td>204,000</td>
<td>+ 0.28%</td>
<td>5.00</td>
<td>206</td>
<td>S3, A, M3</td>
<td></td>
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<td>16</td>
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<td>272,000</td>
<td>+ 0.28%</td>
<td>-</td>
<td>203</td>
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<tr>
<td>42</td>
<td>42</td>
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<td>+ 0.67%</td>
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<tr>
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<td>48</td>
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<td>556</td>
<td>S3, A, M3</td>
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* - 48 inch HDSS to begin production in 2021
Since 1978 TR FLEX has become the industry standard for boltless integrally restrained push-on ductile iron pipe and has a proven track record in seismic events.

TR FLEX is U.S. Pipe’s original boltless integrally restrained pipe joint and it has a long and successful history of survivability in seismic events and other high profile applications. It is an excellent choice for applications that do not require expansion and contraction to accommodate permanent ground deformations. Ductile Iron locking segments, inserted through a slot (or slots) in the bell face, provide a positive axial lock between the bell interior surface and a retainer weldment on the spigot end of the pipe. Each pipe joint has approximately 0.4” to 0.6” of pullout which is intended to facilitate the assembly of the locking segments. For seismic applications designers and owners can opt to leave the joint fully inserted which allows for some expansion to accommodate ground deformations.

Benefits

- Flexible restraint with ample pull apart resistance
- 350 psi rating: 4”–24”, 250 psi rating: 30”–36”
- Seamless transition to HDSS and HP LOK
- Full line of fittings and adapters for complete resiliency
- No special assembly procedures or tools required

Performance Specifications

<table>
<thead>
<tr>
<th>SIZE</th>
<th>NOMINAL LAY LENGTH</th>
<th>MINIMUM PULL APART RESISTANCE</th>
<th>PERCENT ELONGATION AT FULL INSERTION ASSEMBLY¹</th>
<th>DEGREES JOINT DEFLECTION</th>
<th>RADIUS OF CURVATURE</th>
<th>ISO 16134 DESIGNATION</th>
</tr>
</thead>
<tbody>
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<td>3.25</td>
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<td>337</td>
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<td>+ 0.28%</td>
<td>1.50</td>
<td>684</td>
<td>S3, A, M3</td>
</tr>
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</table>

¹ The pipe joint can be installed in a fully inserted position to allow for expansion to accommodate anticipated seismic strains. See page 13 for thrust restraint considerations.
The only ductile iron pipe joint with a pressure rating of 350 psi in sizes 30" and larger. Higher pressure ratings correlate to larger pull apart resistance. HP LOK is the large diameter restrained joint offering of U.S. Pipe and it is the only ductile iron pipe joint 30" and greater to have a pressure rating of 350 psi. This equates to large pull apart resistance in a seismic application. It is an excellent choice for alignments that do not anticipate medium to large ground deformations. An HP LOK Ring that is factory installed in the bell provides a full circumference of positive axial lock between the bell interior surface and a weldment on the spigot end of the pipe. Each pipe joint has approximately 0.5" to 0.6" of pullout which is intended to facilitate joint assembly. For seismic applications designers and owners can opt to leave the joint fully inserted which allows for some expansion to accommodate ground deformations.

Benefits

- Available in 30”–64” Diameters
- Full circumference locking ring for large pull apart resistance
- Pre-installed locking ring with single bolt assembly
- Full line of HP LOK fittings and adapters for complete resiliency
- Highest pressure rating of any 30”–64” ductile iron pipe
- Seamless transition to TR FLEX and HDSS

Performance Specifications

<table>
<thead>
<tr>
<th>SIZE</th>
<th>NOMINAL LAY LENGTH</th>
<th>MINIMUM PULL APART RESISTANCE</th>
<th>ELONGATION AT FULL INSERTION ASSEMBLY</th>
<th>JOINT DEFLECTION</th>
<th>RADIUS OF CURVATURE</th>
<th>ISO 16134 DESIGNATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>213 (17ft 9in)</td>
<td>510,000</td>
<td>+0.28%</td>
<td>0.5</td>
<td>2063</td>
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<tr>
<td>36</td>
<td>215 (17ft 11in)</td>
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<tr>
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<td>48</td>
<td>234 (19ft 6in)</td>
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<td>2063</td>
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<td>234 (19ft 6in)</td>
<td>918,000</td>
<td>+0.26%</td>
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<td>60</td>
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<td>+0.26%</td>
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<tr>
<td>64</td>
<td>234 (19ft 6in)</td>
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<td>+0.26%</td>
<td>0.5</td>
<td>2034</td>
<td>S3, A, M3</td>
</tr>
</tbody>
</table>

1 The pipe joint can be installed in a fully inserted position to allow for expansion to accommodate anticipated seismic strains. See page 13 for thrust restraint considerations.
M-FLEX™ restrained joint fitting is a ball joint fitting that provides up to 15° of deflection that is ideally suited for underwater installations where the high cost of equipment and manpower emphasizes the importance of ease and speed of assembly.

The assembly of M-FLEX ball and socket is the same as our USIFLEX® joint, however, the short lay length of the M-FLEX with bell and spigot ends can be connected between standard TR FLEX®, HP-LOK® or HDSS® pipe. This arrangement allows the designer or installer to quickly and easily make field additions without long lead times and downtime. M-FLEX can also be supplied with plain end x plain end TR FLEX, HP-LOK or HDSS restrained spigots or mechanical joint plain end x mechanical joint bell to make tie-ins, connections or the transition to over land piping.

M-FLEX is not only for river crossings or underwater applications but can be utilized on any projects requiring large amounts of deflection. Another benefit of M-FLEX, used in conjunction with our restrained joints, is that the deflection of the restrained joint is also available. This provides an additional 1 to 8° of deflection depending upon the type of restrained joint pipe used. M-FLEX can also be used with TR EXTREME® seismic piping.

**Benefits**

- Full circumference locking ring for large pull apart resistance
- 15° of Deflection
- Compatible with HDSS, TR FLEX, and HP LOK fittings and adapters for complete resiliency

**Performance Specifications**

<table>
<thead>
<tr>
<th>SIZE</th>
<th>WORKING PRESSURE</th>
<th>DEFLECTION</th>
<th>PERCENT</th>
<th>DEGREES</th>
<th>LINEAR FEET</th>
<th>ISO 16134 DESIGNATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>350</td>
<td>15°</td>
<td>23</td>
<td>39.95</td>
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<tr>
<td>20</td>
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<td>15°</td>
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<tr>
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<td>3672</td>
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</tr>
<tr>
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<td>250</td>
<td>15°</td>
<td>46</td>
<td>56.86</td>
<td>5141</td>
<td>S1, A, M1</td>
</tr>
</tbody>
</table>
Depending on the criticality of the pipeline, designers will need to determine the level of resiliency required for the system. Fittings play a key component to any resilient piping system as they can often act as “anchors” and can be failure points.

**RESTRAINED JOINT FITTINGS**

High criticality pipeline systems should incorporate integrally restrained joint fittings which allow active deflections and uniform pull apart resistance. U.S. Pipe manufactures a full line of TR FLEX and HP LOK integrally restrained joint fittings that will create uniform system resiliency. A complete list of fittings can be found in the TR FLEX and HP LOK Submittal documents as found on www.uspipe.com.

**MECHANICAL JOINT FITTINGS**

Common industry practice for fittings involves field cutting and installing Mechanical Joint fittings with Wedge Action Restraining Glands. **Wedge Action Restraining Glands are not designed for deflection after installation and therefore designers and owner must understand this limitation when determining the level of system resiliency.** If Wedge Action Restraining Glands are desired, U.S. Pipe recommends the use of Tandem Wedge Action Restraining Glands to provide additional pull apart resistance.

**SPECIALTY FITTINGS & RETROFIT**

In addition to standard restrained joint fittings, U.S. Pipe manufactures a suite of specialty fittings that can provide extended amounts of deflection and expansion/contraction. These can be utilized in new construction but are ideal for retrofit applications where large amounts of deflection or expansion/contraction is desired. More information can be found in the XTRA FLEX® FITTINGS and TELESCOPING SLEEVE brochures as found on www.uspipe.com.
Closures
A fully integrally restrained system requires a slightly different approach than most standard installation practices. It requires that the installer utilize closure pieces which are exact length spools of pipe that have spigot weld beads for axial restraint, instead of common friction based connections.

Installers and designers have three options when installing closures:

1. **Factory Made Closures**
   For jobs that require engineered line drawings, closure pieces may be fabricated at the factory. U.S. Pipe can assist you with customized pipeline layout drawings for your project.

2. **Field Cutting and Welding**
   Closure pieces may be fabricated on site using the TR-XTREME and TR FLEX FIELD WELD KITS in accordance with the U.S. Pipe Field Cutting and Welding Procedure. By using U.S. Pipe field cutting and welding procedures, closure pieces can be fabricated on-site. U.S. Pipe offers field weld kits and templates to ensure proper weld bead placement.

3. **Multi-Bead**
   For ease of field installation, TR-XTREME pipe can be ordered with multiple beads along a single pipe length. Multi-bead pipe makes it easy to field-cut plain end transitions between TR-XTREME and TR FLEX fitting bells. The bead locations are set for the minimum lay length between two TR-XTREME bells. A supplied bead gauge is used to mark the pipe for cutting. The bead gauge can be used to quickly mark and trim the TR-XTREME plain end for fitment to TR FLEX fitting bells. The distance between weld beads is designed so that two TR-XTREME x TR-XTREME plain ends can be cut.

---

### Specifications

<table>
<thead>
<tr>
<th>Size</th>
<th>TR-XTREME</th>
<th>TR FLEX</th>
<th>Min. Lay Length</th>
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<tbody>
<tr>
<td></td>
<td>&quot;A&quot;</td>
<td>&quot;B&quot;</td>
<td>&quot;C&quot;</td>
</tr>
<tr>
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<td>3.53</td>
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<tr>
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</tr>
<tr>
<td>16</td>
<td>7.08</td>
<td>5.15</td>
<td>26&quot;</td>
</tr>
</tbody>
</table>
CONNECTIONS TO EXISTING PIPELINES

■ **BOLT-LOK™**
Bolt-Lok is a flexible restraint that is an axial mechanical joint connection. Bolt-Lok can be used to connect to any Mechanical joint valve or fitting, but still maintain an axial restraint that can actively deflect, opposed to wedge action restraints that bite into the exterior pipe wall. Bolt-Lok is available in 4”–48” diameters.

■ **FLANGE ADAPTER**
Cast or fabricated flange adapters are available for 4”–64” diameter pipe for connections to valves, fittings, hydrants, and structures. This allows seamless transitions to flanges while allowing joint deflection to a rigid connection. Connections are available in TR FLEX, HDSS, and HP LOK.

**HYDRANTS**
Often times hydrants are one of the most critical appurtenances to a seismically resilient pipeline as they provide water for fire suppression and act as a regional water depot for post-earthquake recovery. Each municipality has a preferred connection method and U.S. Pipe offers a variety of products to maintain resiliency. Bolt Lok provides active deflection and restraint to mechanical joint connections. TR FLEX, HDSS, and HP LOK flange adapters allow active deflection at a rigid flanged connection. A SAM1 Seismic Fitting or M Flex ball joint can be utilized to provide large amounts of deflection and/or expansion and contraction.
DESIGN CONSIDERATIONS

THRUST RESTRAINT
When utilizing connections that allow expansion and contraction, it is imperative that designers provide proper thrust restraint to ensure safe and reliable system operation. There are two general approaches to providing thrust restraint for seismically resilient piping systems.

- **JOINT EXTENSION**
  Restraint can be accomplished by installing the pipe joints in a fully expanded position which axially transfers the thrust forces. This method of thrust restraint is ideal for installations in liquefaction zones or with soft organic soils.

- **THRUST BLOCKS**
  Restraint can be accomplished by installing thrust blocks at fittings which allows complete expansion and contraction of the piping system. For suggested design procedures design engineers should refer to the current DIPRA publication “Thrust Restraint Design for Ductile Iron Pipe”.

POLYWRAP
Polywrap should be used to encase joints with expansion and contraction to ensure movement is not hampered by backfill in the joints. Additionally, polywrap installation has been shown to reduce the axial friction force between the pipe and soil during a seismic event which reduces axial pullout force. Polywrap will also articulate with the pipe and continue to provide corrosion protection post event. Installation should be in accordance with AWWA C105 and should be installed with sufficient slack to allow joint expansion.

JOINT LUBRICATION
Joints that provide expansion and contraction should be installed subaqueous lubricant. This lubricant is NSF approved and does not dry over time thus allowing mobility for the life cycle of the pipeline. Subaqueous lubricant is supplied with all U.S. Pipe products that provide expansion, contraction, or utilize a ball joint for deflection.
Seismically resilient piping systems are often the most critical pipelines in a municipal system. When supplying products for these systems it is imperative to understanding the performance and limitations of these systems. U.S. Pipe has performed the most 3rd party testing of any domestic ductile iron pipe manufacturer for seismic applications.

**THIRD PARTY TESTING**
U.S. Pipe was the first ductile iron pipe manufacturer to test seismically resilient pipe at the Cornell University Large-Scale Lifelines Testing Facility and has subsequently conducted the most third party testing with Cornell of any pipe manufacturer.

Test findings state:

“The test results and FE simulations presented in this report confirm that the TR-XTREME™ joints are able to sustain without leakage large levels of ground deformation through axial displacement and rotation.”

Complete reports can be viewed online at: [www.lifelines.cee.cornell.edu/projects/](http://www.lifelines.cee.cornell.edu/projects/)

**3D FINITE ELEMENT ANALYSIS**
U.S. Pipe contracted with VIAS to conduct 3D Finite Element Analysis on both the SAM1 Seismic Fitting and SAM1 Seismic Assembly. The analysis used lab test data from Cornell University to calibrate input variables and the associated response spectra. Test results demonstrated that a 48” SAM1 Seismic Assembly had the capacity to accommodate a 4.9ft offset from a 66 degree strike-slip fault.
SPECIFICATIONS

SAM1 SEISMIC ASSEMBLY

As shown or required by the plans, a Ductile Iron Seismic Assembly shall be furnished and installed such that it has the capacity to both deflect, expand, or contract to accommodate anticipated seismic ground strains. The Seismic Assembly shall consist of (2) Restrained Joint Pipe Lengths and (1) SAM1 Seismic Fitting. This Assembly shall be known as the SAM1 Seismic Assembly and be capable of achieving the following performance criteria:

Per ISO 16134:2006 Earthquake & Subsidence Resistance Design of Ductile Iron the SAM1 Seismic Assembly shall meet or exceed the following classifications:

1. Expansion/Contraction Performance – Classification S1. Minimum expansion/contraction performance of ±1% of assembly length.

2. Pull apart resistance – Classification A. The pipe and fitting joint shall be rated to have a minimum 17,000 lbs per inch/diameter (3 d kN) of axial pull apart resistance.

3. Deflection/Radius of Curvature – Classification M2/M3. The assembly shall have a minimum radius of curvature corresponding to Classification M2/M3.

The components of the SAM1 Seismic Assembly shall be manufactured and supplied as follows:

PIPE & FITTINGS:

1. Restrained joint pipe shall be Ductile Iron manufactured in accordance with the requirements of ANSI/AWWA C151/A21.51. Push-on joints for such pipe shall be rated to 350 psi in accordance with ANSI/AWWA C111/A21.11 “Rubber-Gasket Joints for Ductile-Iron Pipe and Fittings.” Sealing gaskets shall be constructed of Styrene Butadiene Rubber (SBR).
   a. Restrained joint Pipe shall be HP LOK Pipe or HDSS (High Deflection Single Slot) or pre-approved equal.
   b. Restrained Joint Fittings shall be HP LOK or HDSS (High Deflection Single Slot) or pre-approved equal. Mechanical friction wedge restraints shall not be allowed.

2. Pipe thickness shall be designed in accordance with ANSI/AWWA C150/A21.50 “Thickness Design of Ductile-Iron Pressure Pipe,” and shall be based on laying conditions and internal pressures as stated in the project plans and specifications.

4. Fittings shall be manufactured of Ductile Iron per grade 70-50-05 as specified in AWWA C153 and C110.

3. All flanged ductile iron fittings shall be fabricated in accordance with ANSI/AWWA C110/A21.10, unless otherwise specified herein or shown on the drawings.

6. Cement mortar lining and seal coating for pipe and fittings, where applicable, shall be in accordance with ANSI/AWWA C151/A21.51 for pipe and ANSI/AWWA C110/A21.10 or ANSA/AWWA C153/A21.53 for fittings.

SAM1 SEISMIC FITTING:

Flexible expansion joints shall be installed every 2nd joint and shall be manufactured of Ductile Iron conforming to the material requirements of ASTM A536 and ANSI/AWWA C110/A21.10.

1. Each flexible expansion joint shall be pressure tested prior to shipment against its own restraint to a minimum of 250 PSI. A minimum 2:1 safety factor, determined from the published pressure rating, shall apply.

2. Each flexible expansion joint shall consist of an expansion joint designed and cast as an integral part of a ball and socket type flexible joint, having a minimum per ball deflection of: 15º and a minimum of 12 inches stroke.

3. Sealing gaskets shall be constructed of Styrene Butadiene Rubber (SBR).

4. Polyethylene sleeves, meeting ANSI/AWWA C105/A21.5, shall be installed for direct buried applications.

5. Manufacturer’s certification of compliance to the above standards and requirements shall be readily available upon request.
SPECIFICATIONS

TR-XTREME-S1

As shown or required by the plans, a Ductile Iron Seismic Piping System shall be furnished and installed such that it has the capacity to both deflect, expand, or contract to accommodate anticipated seismic ground strains. The piping system shall be capable of achieving the following performance criteria:

Per ISO 16134:2006 Earthquake & Subsidence Resistance Design of Ductile Iron the TR-XTREME S1 shall meet or exceed the following classifications:

1. Expansion/Contraction Performance–Classification S1. Minimum expansion/contraction performance of ±1% of assembly length.
2. Pull apart resistance – Classification A. The pipe and fitting joint shall be rated to have a minimum 17,000 lbs per inch/diameter (3 d kN) of axial pull apart resistance.
3. Deflection/Radius of Curvature – Classification M2 and M3. The assembly shall have a minimum radius of curvature corresponding to Classification M2 for 6” – 12” and M3 for 16”–24” diameters.

Pipe and fittings shall be manufactured and supplied as follows:

PIPE & FITTINGS

1. Restrained joint pipe shall be designed in accordance with ANSI/AWWA C150/A21.50 and manufactured in accordance with the requirements of ANSI/AWWA C151/A21.51. Push-on joints for such pipe shall be rated to 350 psi in accordance with ANSI/AWWA C111/A21.11 "Rubber-Gasket Joints for Ductile-Iron Pipe and Fittings." Sealing gaskets shall NSF/ANSI 61 approved and be constructed of Styrene Butadiene Rubber (SBR) or as noted on project plans.

a. Restrained Joint Pipe shall be gasketed push-on joint with integral boltless restraint and shall be U.S. Pipe TR-XTREME S1 or pre-approved equal.

b. Restrained Joint Fittings shall be push-on with integral boltless restraint and shall be U.S. Pipe TR FLEX or pre-approved equal. Friction restraint devices shall not be allowed unless as directed by the engineer.

c. Restrains field cut pipe shall be accomplished with factory weld bead closure spools.

2. Fittings shall be manufactured of Ductile Iron per grade 70-50-05 as specified in AWWA C153 and C110.

3. Cement mortar lining and seal coating for pipe and fittings, where applicable, shall be in accordance with ANSI/AWWA C104/A21.4. Asphaltic outside coating shall be in accordance with ANSI/AWWA C151/A21.51 for pipe and ANSI/AWWA C110/A21.10 or ANSA/AWWA C153/A21.53 for fittings.

4. Joint connections that allow expansion and contraction shall be installed with polyethylene encasements, meeting ANSI/AWWA C105/A21.5

5. Manufacturer’s certification of compliance to the above standards and requirements shall be readily available upon request.
As shown or required by the plans, a Ductile Iron Seismic Piping System shall be furnished and installed such that it has the capacity to both deflect, expand, or contract to accommodate anticipated seismic ground strains. The piping system shall be capable of achieving the following performance criteria:

Per ISO 16134:2006 Earthquake & Subsidence Resistance Design of Ductile Iron the TR-XTREME shall meet or exceed the following classifications:

1. Expansion/Contraction Performance – Classification S2. Minimum expansion/contraction performance of ±0.68% of assembly length.
2. Pull apart resistance – Classification A. The pipe and fitting joint shall be rated to have a minimum 17,000 lbs per inch/diameter (3 d kN) of axial pull apart resistance.
3. Deflection/Radius of Curvature – Classification M3. The assembly shall have a minimum radius of curvature corresponding to Classification M3 for 6”–24” diameters.

Pipe and fittings shall be manufactured and supplied as follows:

PIPE & FITTINGS

1. Restrained joint pipe shall be designed in accordance with ANSI/AWWA C150/A21.50 and manufactured in accordance with the requirements of ANSI/AWWA C151/A21.51. Push-on joints for such pipe shall be rated to 350 psi in accordance with ANSI/AWWA C111/A21.11 "Rubber-Gasket Joints for Ductile-Iron Pipe and Fittings." Sealing gaskets shall be NSF/ANSI 61 approved and be constructed of Styrene Butadiene Rubber (SBR) or as noted on project plans.
   a. Restrained Joint Pipe shall be gasketed push-on joint with integral boltless restraint and shall be U.S. Pipe TR-XTREME or pre-approved equal.
   b. Restrained Joint Fittings shall be push-on with integral boltless restraint and shall be U.S. Pipe TR FLEX or pre-approved equal. Friction restraint devices shall not be allowed unless as directed by the engineer.
   c. Restraint of field cut pipe shall be accomplished with factory weld bead closure spools.
2. Fittings shall be manufactured of Ductile Iron per grade 70-50-05 as specified in AWWA C153 and C110.
3. Cement mortar lining and seal coating for pipe and fittings, where applicable, shall be in accordance with ANSI/AWWA C104/A21.4. Asphalitic outside coating shall be in accordance with ANSI/AWWA C151/A21.51 for pipe and ANSI/AWWA C110/A21.10 or ANSA/AWWA C153/A21.53 for fittings.
4. Joint connections that allow expansion and contraction shall be installed with polyethylene encasements, meeting ANSI/AWWA C105/A21.5
5. Manufacturer’s certification of compliance to the above standards and requirements shall be readily available upon request.
HDSS

When joint restraint for 20” through 36” push-on joint pipe installation is required and indicated in the project plans and specifications, restrained push-on joint pipe and fittings utilizing ductile iron components shall be provided.

Restrained joint pipe shall be ductile iron manufactured in accordance with the requirements of ANSI/AWWA C151/A21.51. Push-on joints for such pipe shall be in accordance with ANSI/AWWA C111/A21.11.

Pipe thickness shall be designed in accordance with ANSI/AWWA C150/A21.50 “Thickness Design of Ductile Iron Pressure Pipe,” and shall be based on laying conditions and internal pressures as stated in the project plans and specifications.

Restrained joint fittings and the restraining components shall be manufactured of ductile iron per grade 70-50-05 in accordance with applicable requirements of ANSI/AWWA C110/A21.10 and/or C153/A21.53 with the exception of the manufacturer’s proprietary design dimensions. Push-on joints for such fittings shall be in accordance with ANSI/AWWA C111/A21.11.

Restrained push-on joints for pipe and fittings shall utilize individual ductile iron locking segments that are inserted through a single slot in the bell face and be easily removed. The pressure rating of the joint shall equal the pressure rating of the pipe when deflected to its maximum joint deflection. Restrained joint pipe and fittings shall be U.S. Pipe’s HDSS Pipe and Fittings or approved equal. Restraint of field cut pipe shall be provided with U.S. Pipe’s HDSS Pipe field weldments or approved equal.

Cement mortar lining and seal coating for pipe and fittings, where applicable, shall be in accordance with ANSI/AWWA C104/A21.4. Asphalitic outside coating shall be in accordance with ANSI/AWWA C151/A21.51 for pipe and ANSI/AWWA C110/A21.10 or ANSI/AWWA C153/A21.53 for fittings.

TR FLEX & HP LOK

For specifications please see product brochures located at www.uspipe.com or contact your local sales manager.
U.S. Pipe, a Forterra Company, is the leading manufacturer and a principal supplier of highly engineered ductile iron pipe and fabrication in the United States and Canada. Providing custom solutions to owners, engineers and contractors for even the most demanding applications, including water transmission and distribution lines, plant piping, intake and outfall lines, and other diverse applications.
**SAM1**
Seismic Assembly

ISO 16134 Classification S1, A, M1
SIZE (inches) 24, 30, 36, 42, 48

**TR-XTREME S1**

ISO 16134 Classification S1, A, M2/M3
SIZE (inches) 6, 8, 12, 16, 24

**TR-XTREME**

ISO 16134 Classification S2, A, M3
SIZE (inches) 6, 8, 12, 16, 20, 24

**HDSS**

ISO 16134 Classification S2, A, M3
SIZE (inches) 12, 16, 20, 24, 30, 36, 42, 48

**TR FLEX**

ISO 16134 Classification S3, B/A, M3
SIZE (inches) 4–36

**HP LOK**

ISO 16134 Classification S3, A, M3
SIZE (inches) 30–64