Be Flexible

Earthquake Resistant Ductile Iron Pipe Design

April 25, 2018 – Matthew Maring, P.E.

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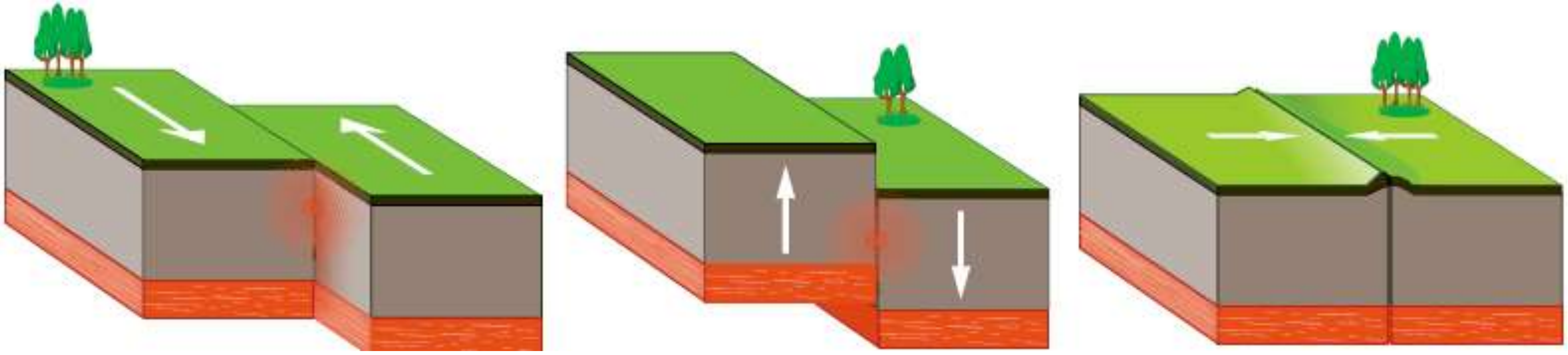
Presentation Overview

- ERDIP and Applicable Standards
- ERDIP Product Examples
- Joint Type Comparisons
- Seismic Risks and ERDIP Performance
- ERDIP Applications and Design Considerations

ERDIP and Applicable Standards

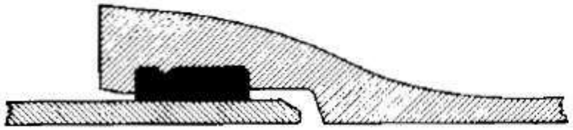
What is ERDIP?

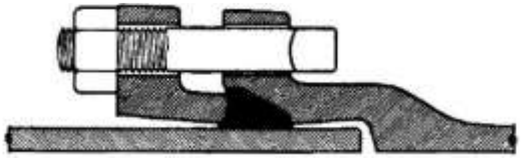
- Earthquake Resistant Ductile Iron Pipe uses specialized fittings and joints to:
  - Provide increased pipeline / joint flexibility and deflection ranges
  - Reduce risk of pipeline failures due to seismic and other differential displacement inducing events

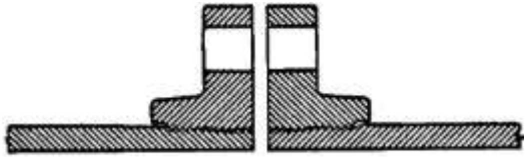


Ductile Iron Pipe Joint Options

- Unrestrained
  - Push-On Joint, AWWA C111
  - Mechanical Joint (MJ), AWWA C111
- Restrained
  - Flange (FL)*, AWWA C110, C111, C115
  - MJ with Wedge Restraint Gland (e.g. Megalug)
  - Shackle rod systems
  - Various proprietary joint systems
- ERDIP
  - Various proprietary joint systems







* Typically not recommended for buried use except under limited circumstances.

Applicable ERDIP Standards

- Typical AWWA Standards
- JWWA Standards
- International Standard ISO 16134

  Earthquake- and subsidence-resistant design of ductile iron pipelines, First edition 2006-02-01


INTERNATIONAL STANDARD

ISO 16134

First edition
2006-02-01

Earthquake- and subsidence-resistant design of ductile iron pipelines

Conception de canalisations en fonte ductile résistant aux tremblements de terre et aux affaissements

Reference number
ISO 16134:2006(E)

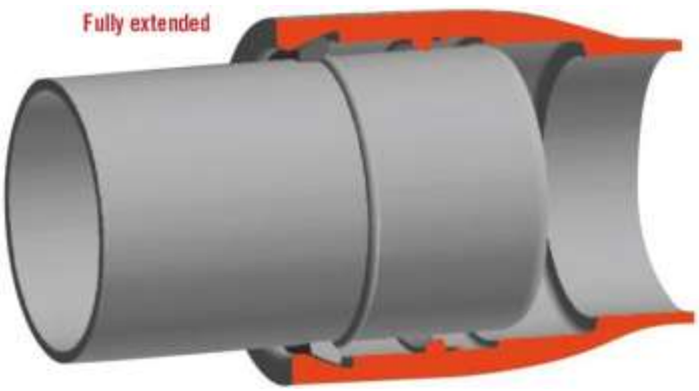
© ISO 2006

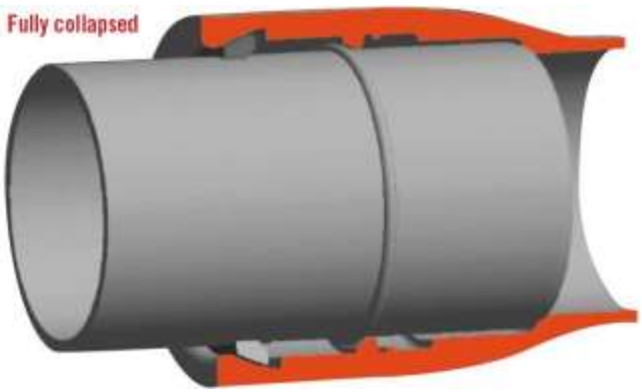
ISO 16134 Classification and Design Parameters

- Expansion and Contraction Range
- Joint Angle Deflection Range
- Joint Strength

ISO 16134 Expansion and Contraction Criteria

- S-1: ±1% of pipe length and above
- S-2: ±0.5% – ±1% of pipe length
- S-3: ±0.5% of pipe length and below





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ISO 16134 Joint Angle Deflection Criteria

- M-1: ±15° and above
- M-2: ±7.5° – ±15°
- M-3: ±7.5° and below

- Push-On Joint Comparison
  - ±5° for 6” – 12” pipe
  - ±3° for 16” pipe and above
- Mechanical Joint Comparison
  - ±7° for 6” pipe
  - ±5° for 8” – 12” pipe
  - ±3° for 16” – 18” pipe
  - ±2° for 24” pipe and above

ISO 16134 Joint Strength Criteria

- A: 8.6 tons per inch diameter and above
- B: 4.3 – 8.6 tons per inch diameter
- C: 2.1 – 4.3 tons per inch diameter
- D: 2.1 tons per inch diameter and below

- 250 psi Test Pressure Force Comparison
  - 0.8 tons per inch diameter for 8” pipe
  - 1.2 tons per inch diameter for 12” pipe
  - 1.6 tons per inch diameter for 16” pipe
  - 1.8 tons per inch diameter for 18” pipe
  - 2.4 tons per inch diameter for 24” pipe

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ERDIP Products

Disclaimers

- While this presentation references various product offerings, inclusion/exclusion should not be construed as an endorsement/criticism of any particular products or design approaches
- Product usage and design approaches should be determined on an application specific basis according to:
  - Sound professional and engineering judgement
  - Available standards
  - Identified best practices
  - Other cost, performance, and risk related factors as appropriate

ERDIP Product Examples

- American Pipe
  - Earthquake Joint System
  - Flex-Lok Ball Joint
- Clow
  - Ball and Socket
- EBAA Iron
  - Flex-Tend
  - Ex-Tend
  - Flex Joint
- Kubota
  - NS, S (metric)
  - Genex (metric)
- McWane
  - Seismic Flex Coupling
- U.S. Pipe
  - TR Xtreme
  - Xtra Flex
  - Tele Flex and Telescoping Sleeves

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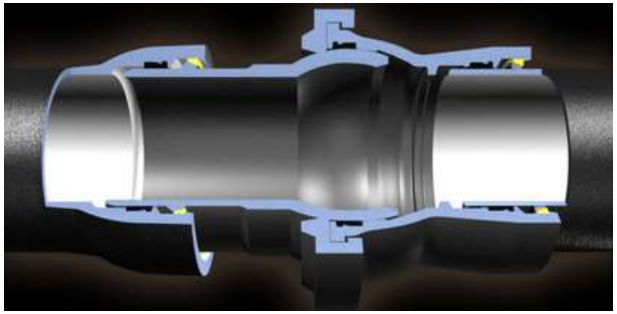
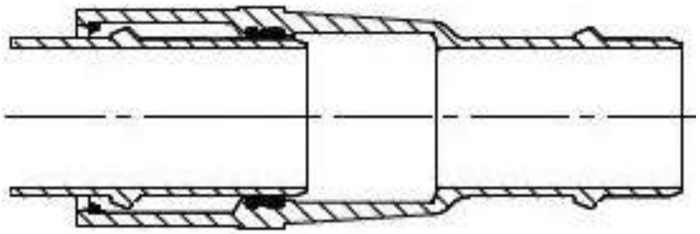
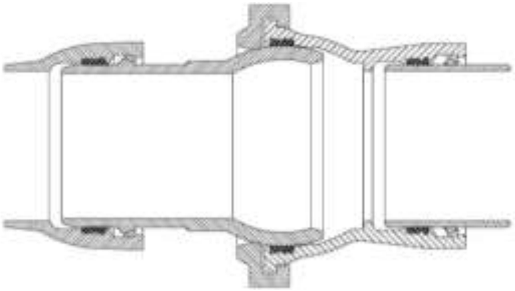
American Pipe

- Earthquake Joint System
- Flex-Lok Ball Joint

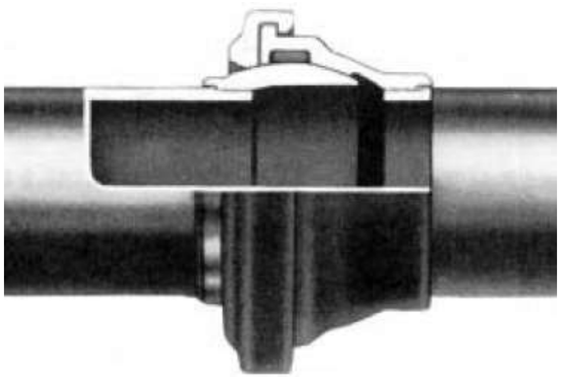




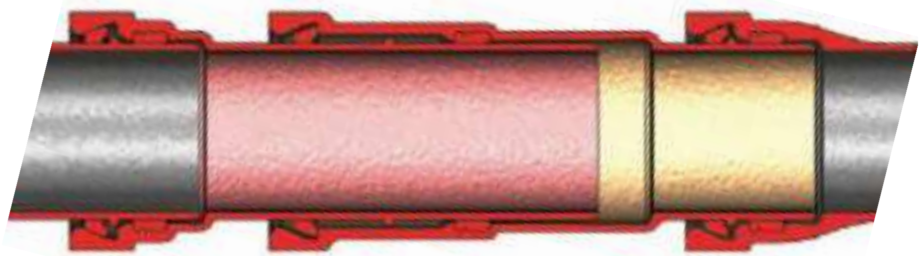


Clow and McWane

- Clow Ball and Socket



- McWane Seismic Flex Coupling



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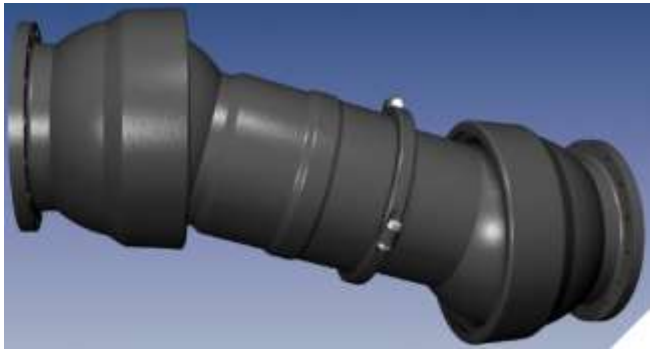
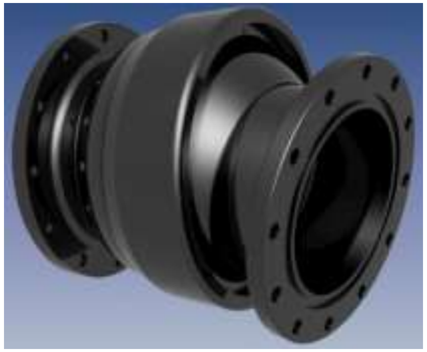
EBAA Iron

- Flex-Tend, Ex-Tend, and Flex Joint Series





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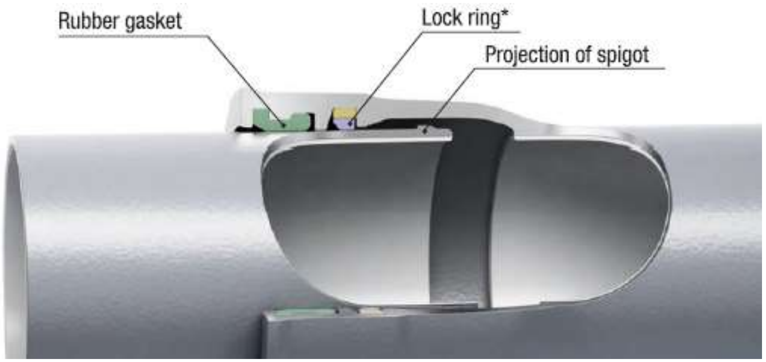
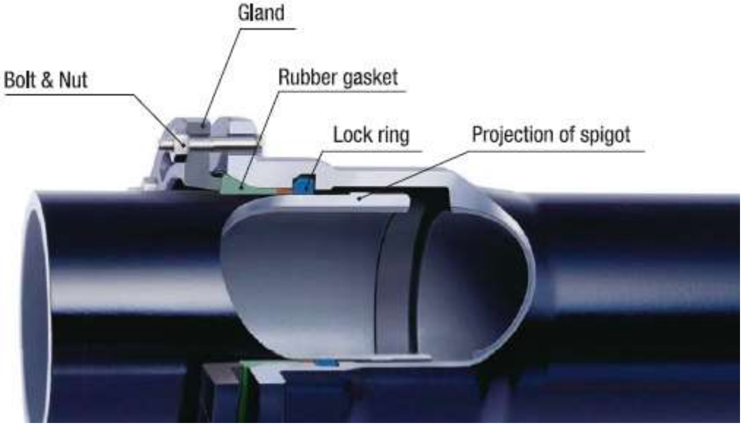
Kubota

- Genex (metric)

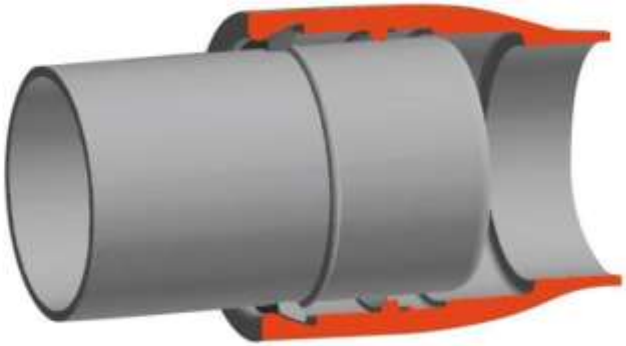


- NS and S (metric)

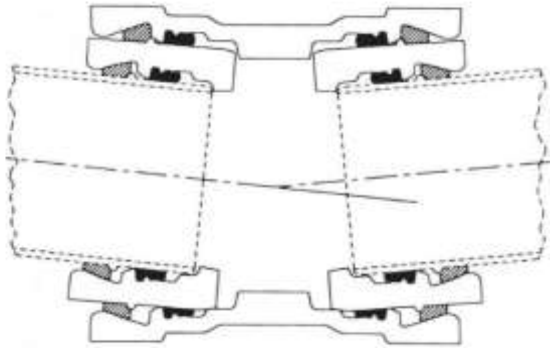


U.S. Pipe

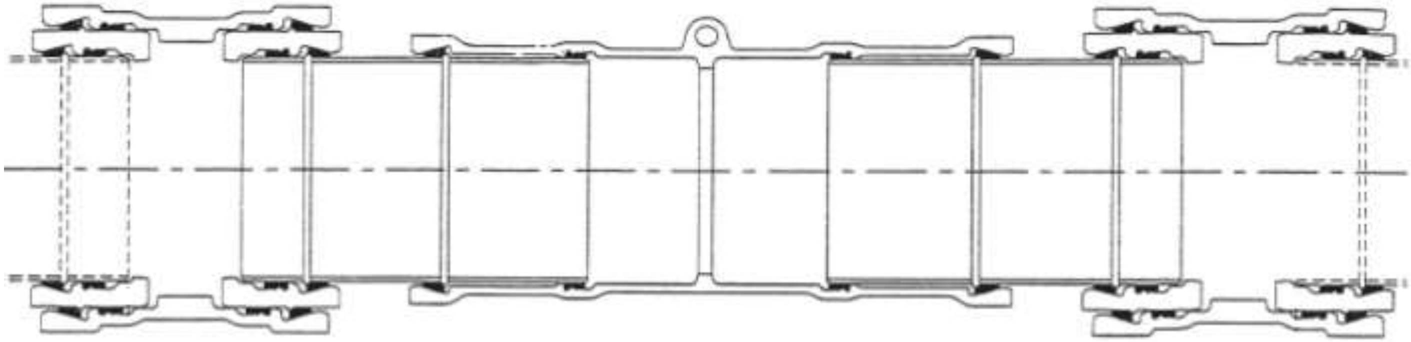
- TR Xtreme



- Xtra Flex



- Tele Flex and Telescoping Sleeves



Joint Type Comparisons

Joint Type Characteristics

Joint Type	Ease of Assembly	Deflection Flexibility	Expansion and Contraction Flexibility	Restraint
Push-On Joint	High	Moderate	Limited	None
Mechanical Joint (MJ)	Moderate	Moderate	Limited	None
Flange (FL)*	Moderate	None	None	Yes
MJ with Wedge Restraint Gland (WRG)	Moderate	None	None	Yes
Shackle Rod Systems	Low	Moderate	Limited	Yes
Restrained Joint (RJ, proprietary)	High	Moderate	Limited	Yes
ERDIP (proprietary)	Moderate	High	High	Yes

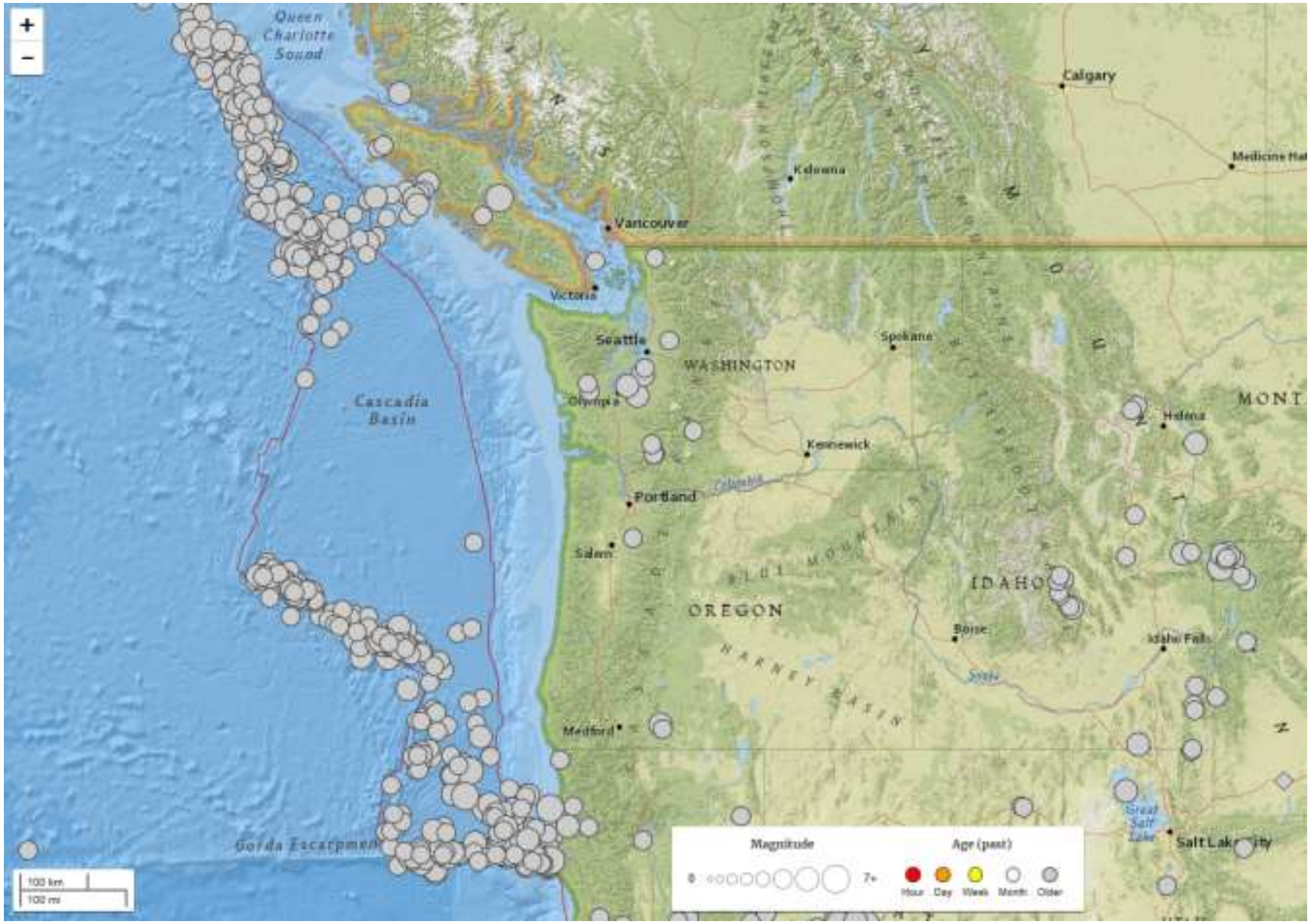
* Typically not recommended for buried use except under limited circumstances.

Seismic Risks and ERDIP Performance

Pacific Northwest Faults

Pacific Northwest Seismic History

- Magnitude 5+ Earthquakes, USGS Records 1900 – present



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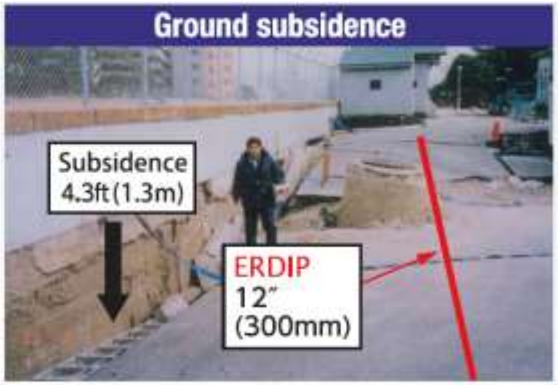
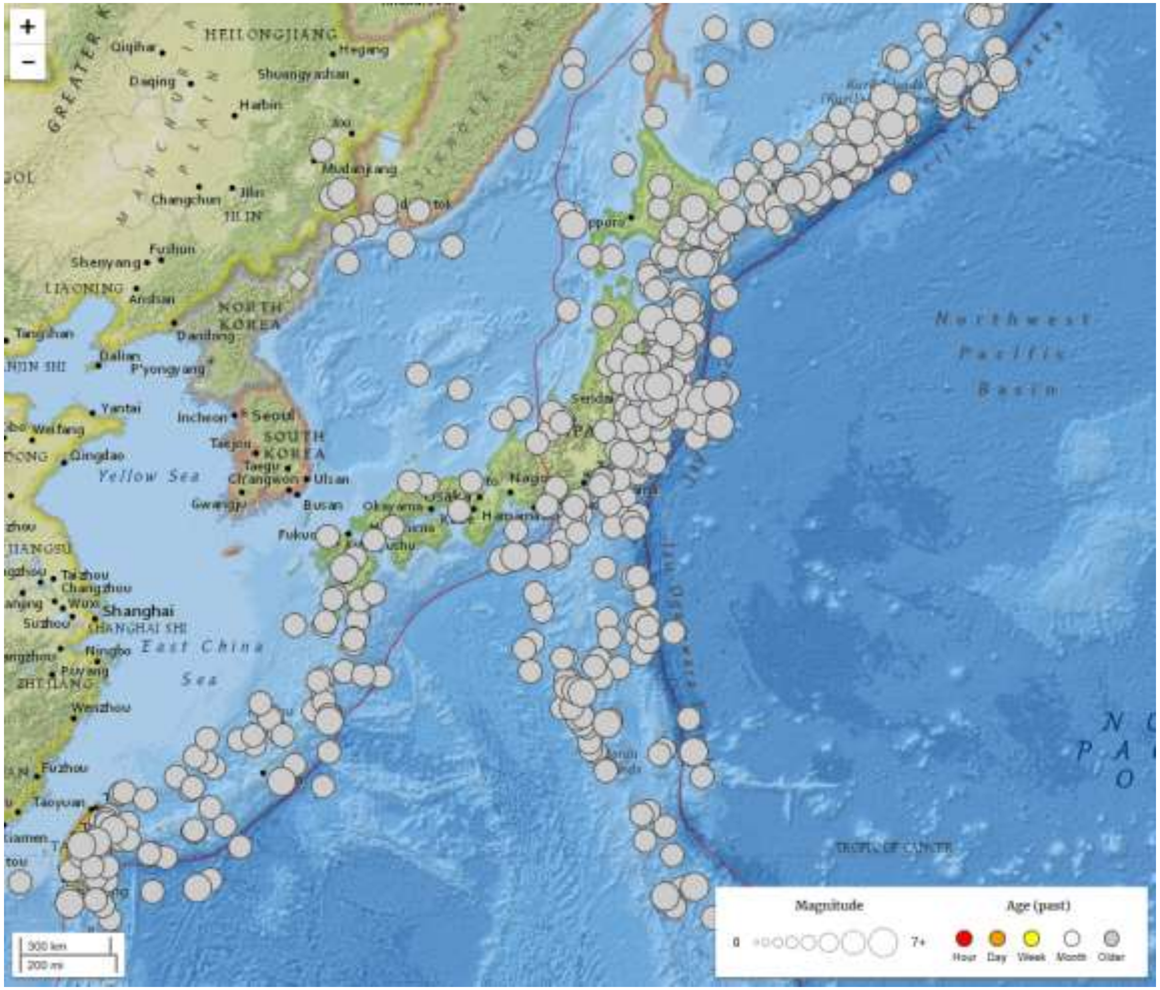
ERDIP in Japan

- Usage steadily increasing in Japan since initial development of ERDIP products by Kubota in mid 1970s
- Kubota has documented no failures of ERDIP due to seismic events in Japan, including the:
  - 1995 Kobe / Great Hanshin 6.9 earthquake
  - 2011 Pacific Coast / Tōhoku 9.1 earthquake / tsunami



ERDIP Era Japanese Seismic History

- Magnitude 6+ Earthquakes, USGS Records 1985 – present



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ERDIP Applications and Design Considerations

Applications

- Seismically Active Areas
- Fault Crossings
- Unstable Slopes and Landslide Areas
- Liquefaction Zones
- Subsidence Zones
- Differential Settlement Areas and Connections to Structures
- Erosion and Undercutting Prone Areas

Design Considerations

- Seismic and Geotechnical Analysis
  - Peak Ground Displacement (PGD)
  - Peak Ground Velocity (PGV)
  - Peak Ground Acceleration (PGA)
  - Seismic wavelengths
  - Fault proximity and rupture risks
  - Subsurface layer characteristics and natural frequency/period
  - Saturation and liquefaction risk
  - Strain and subsidence rates
  - Slide movement and creep rates
  - Differential settlement
  - Erosion rates and risk
- Pipe Design and Installation
  - ISO design and pipe parameters
  - Joint types and locations
  - Expansion / contraction presets
  - Deflection presets
  - Isolation valve locations and looping
  - Thrust / pressure restraint, connection to unrestrained piping
  - System weight and buoyancy
  - Polyethylene encasement
  - Field cuts and closures
  - Installation procedures and pressure testing requirements

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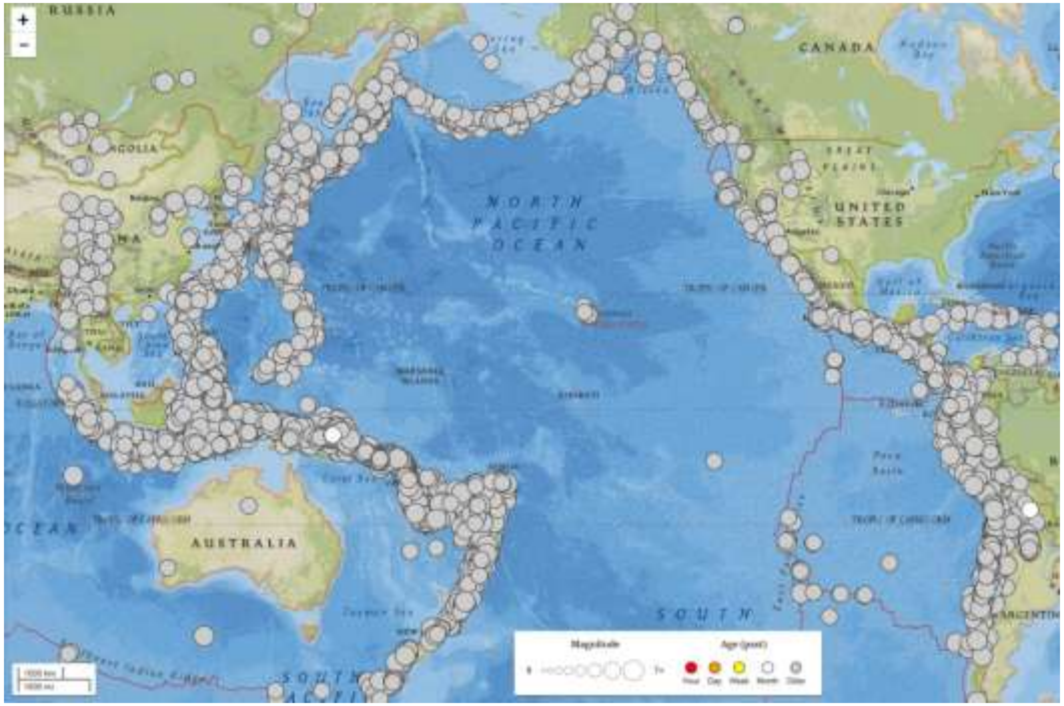
ISO 16134 Design Process and Calculations

- Evaluate seismic motion potential
- Characterize subsurface and soil parameters
- Estimate displacement and liquefaction potential
- Develop ERDIP conceptual design parameters and evaluate relative to:
  - Pipe body and joint stress
  - Joint expansion / contraction
  - Joint deflection
- ISO 16134 standard content:
  - Pipeline seismic hazard descriptions
  - Qualitative design considerations
  - Design procedure
  - Design parameters and equations (metric)
  - Reference tables and values (metric)
  - Detailed calculation examples (metric)

North American ERDIP Pilots, Projects, and Context

- Los Angeles
- San Francisco
- East Bay Municipal Utility District
- Menlo Park
- Palo Alto
- San Jose
- Eugene
- Portland
- Joint Water Commission
- Seattle
- Kent
- Vancouver BC

- Pacific Magnitude 6.5+ Earthquakes USGS Records 1900 – present



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References and Acknowledgements

- Information for this presentation is sourced from the following manufacturers and organizations:
  - American Water Works Association
  - American Pipe
  - Clow and McWane
  - Ductile Iron Pipe Research Association
  - EBAA Iron
  - International Standards Organization
  - Kubota
  - Pacific Northwest Seismic Network
  - USGS
  - U.S. Pipe

Questions and Discussion

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Earthquake Resistant Ductile Iron Pipe Design

April 26, 2018