Essentials for the Design & Specifications of Earthquake Resistant DIP

May 2, 2024

John Kitchen
Business Development
Territory Manager – OR, WA, ID & AK

AMERICAN
THE RIGHT WAY

American Water Works Association
Pacific Northwest Section

AGENDA

- Introduction
- ERDIP Standards
- Pipe Joint Performance
- Designing ERDIP Systems
- Specifications
- Summary

INTRODUCTION

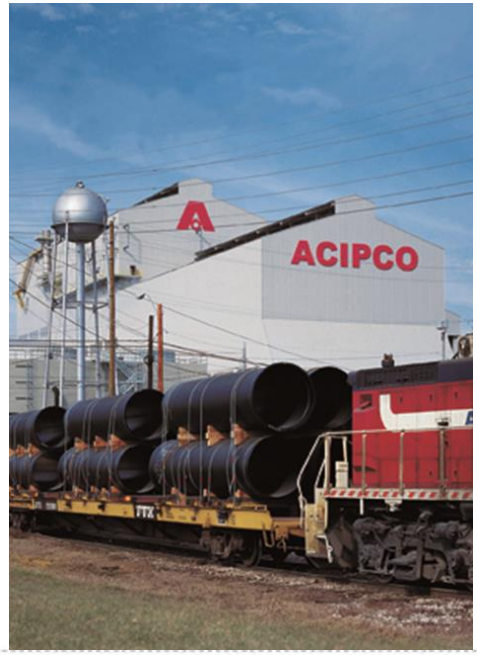
AMERICAN Cast Iron Pipe Company

Founded in 1905, by Mr. John J. Eagan

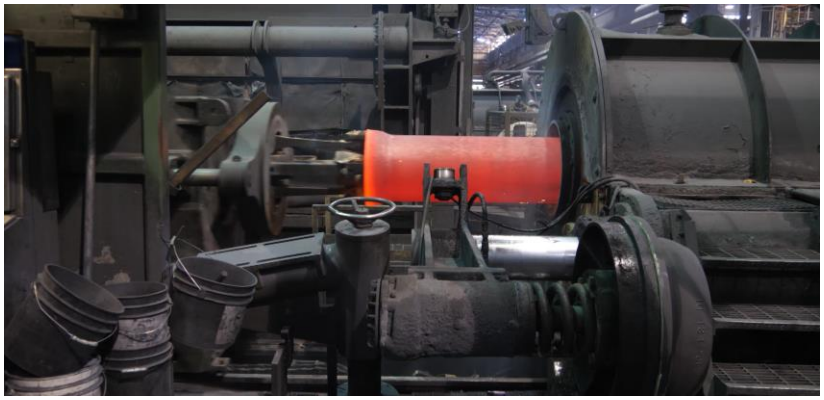
- The Golden Rule

Largest Ductile Iron Pipe Foundry in America!

- Headquarters: Birmingham, AL
- 2000+ Acres, 75 acres under roof



How DIP is Made



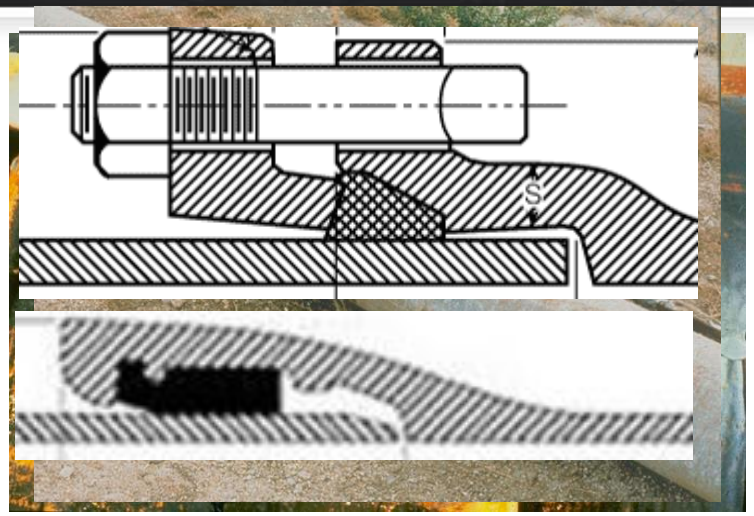
ERDIP Standards

ISO 16134

History

- Japanese Earthquake Forensics 1995
  - Cast Iron / AC = Brittle
  - PVC / Steel = Barrel & Joint
  - DIP – Failure @ Joints

- Improve DIP Joint
  - Strain Relief
  - Slip-Out Strength
  - Deflection



PERFORMANCE SPECS

EXPANSION/CONTRACTION	CLASS	COMPONENT PERFORMANCE
Performance (Elongation)	S1	± 1% L or more
	S2	± 0.5% L to ± 1% of L
	S3	Less than ± 0.5% of L
Slip-Out	A	17,000 d lbs. +
	B	8,500 d lbs-17,000 d lbs.
	C	4,250 d lbs-8,500 d lbs.
	D	Less than 4,250 d lbs.
Joint Deflection Angle	M1	15-degrees or more
	M2	7.5-degrees < 15-degrees
	M3	Less than 7.5-degrees

"L" is the component length in inches. "d" is the nominal pipe diameter in inches.
See component performance results by diameter on Page 6.

ISO 16134-2020

PERFORMANCE SPECS

PARAMETER	CLASS	COMPONENT PERFORMANCE
Expansion/Contraction Performance	S1	±1% of L or more
	S2	± 0.5% to less than ±1% of L
	S3	Less than ±0.5% of L
Slip-Out Resistance	A	3 d kN or more (17,000 d lbs or more)
	B	1.5 d kN to less than 3 d kN (8,500 d lbs - 16,999 d lbs)
	C	0.75 d kN to less than 1.5 d kN (4,250 d lbs - 8,499 d lbs)
	D	Less than 0.75 d kN (Less than 4,250 d lbs)
Joint Deflection Angle	M1	θ_a or more
	M2	$\theta_a/2$ to less than θ_a
	M3	Less than $\theta_a/2$

JOINT DEFLECTION ANGLE TABLE

Nominal Diameter *d*	80 to 400	450 to 1000	1100 to 1500	1600 to 2200	2400 to 2600
	3 in. - 16 in.	18 in. - 36 in.	42 in. - 54 in.	60 in. - 86 in.	94 in. - 102 in.
Joint deflection angle θ_a	8°	7°	5°30'	4°	3°30'
(Ref) Pipe Length[a]	6 m (19.69 ft)	6 m (19.69 ft)	6 m (19.69 ft)	5 m (16.40 ft)	4 m (13.12 ft)

SIZE (IN.)	MINIMUM PULL APART RESISTANCE (LBS.)
4	68,000
6	102,000
8	136,000
10	170,000
12	204,000
14	238,000
16	272,000
18	306,000
20	340,000
24	408,000
30	510,000
36	612,000
42	714,000
48	816,000
54	918,000

ISO 16134

2006

PERFORMANCE SPECS

EXPANSION/CONTRACTION	CLASS	COMPONENT PERFORMANCE
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	S2	± 0.5% L to ± 1% of L
	S3	Less than ± 0.5% of L
Slip-Out Resistance	A	17,000 d lbs. +
	B	8,500 d lbs-17,000 d lbs.
	C	4,250 d lbs-8,500 d lbs.
	D	Less than 4,250 d lbs.
Joint Deflection Angle	M1	15-degrees or more
	M2	7.5-degrees < 15-degrees
	M3	Less than 7.5-degrees

"L" is the component length in inches. "d" is the nominal pipe diameter in inches.
See component performance results by diameter on Page 6.

2020

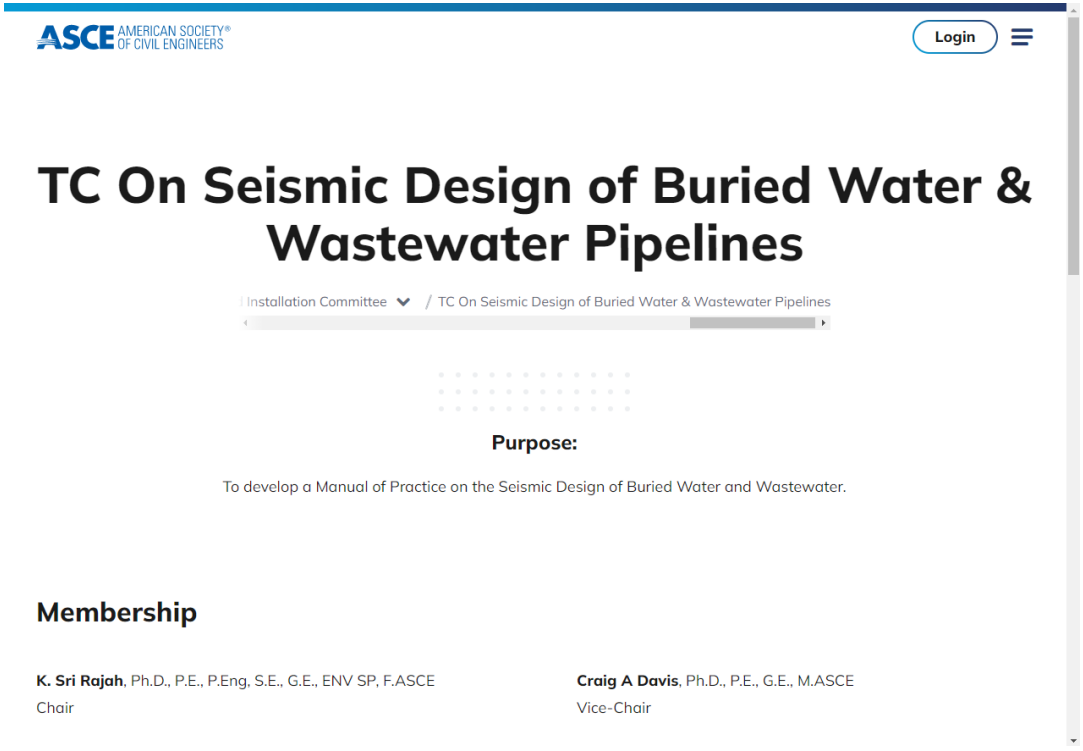
PERFORMANCE SPECS

PARAMETER	CLASS	COMPONENT PERFORMANCE
Expansion/Contraction Performance	S1	±1% of L or more
	S2	± 0.5% to less than ±1% of L
	S3	Less than ±0.5% of L
Slip-Out Resistance	A	3 d kN or more (17,000 d lbs or more)
	B	1.5 d kN to less than 3 d kN (8,500 d lbs - 16,999 d lbs)
	C	0.75 d kN to less than 1.5 d kN (4,250 d lbs - 8,499 d lbs)
	D	Less than 0.75 d kN (Less than 4,250 d lbs)
Joint Deflection Angle	M1	θ_a or more
	M2	$\theta_a/2$ to less than θ_a
	M3	Less than $\theta_a/2$

JOINT DEFLECTION ANGLE TABLE

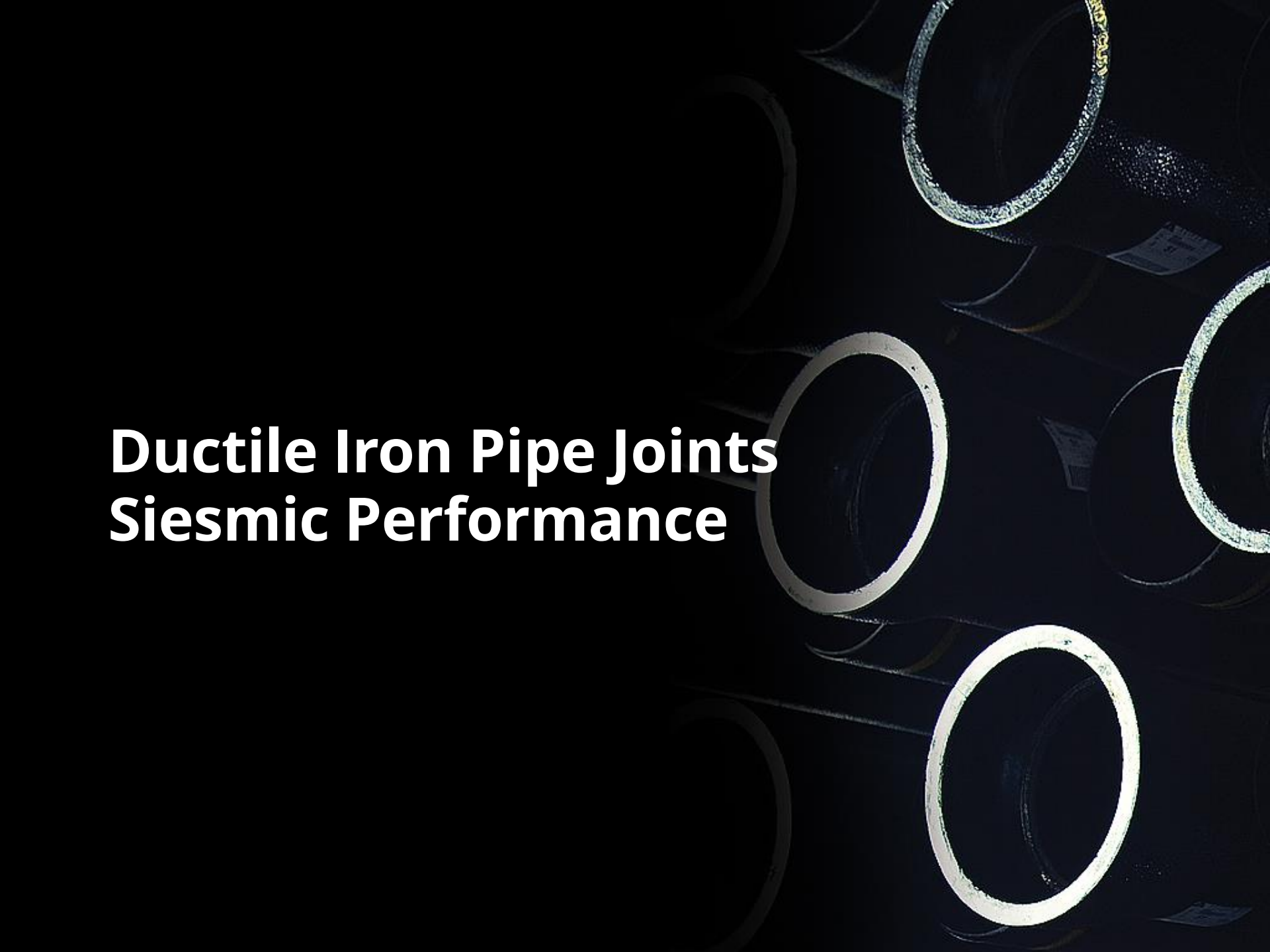
Nominal Diameter *d*	80 to 400	450 to 1000	1100 to 1500	1600 to 2200	2400 to 2600
	3 in. - 16 in.	18 in. - 36 in.	42 in. - 54 in.	60 in. - 86 in.	94 in. - 102 in.
Joint deflection angle θ_a	8°	7°	5°30'	4°	3°30'
(Ref) Pipe Length[a]	6 m (19.69 ft)	6 m (19.69 ft)	6 m (19.69 ft)	5 m (16.40 ft)	4 m (13.12 ft)

ASCE MOP



- https://earthquake.usgs.gov/hazards/interactive/
- https://earthquake.usgs.gov/nshmp/
- https://asce7hazardtool.online/

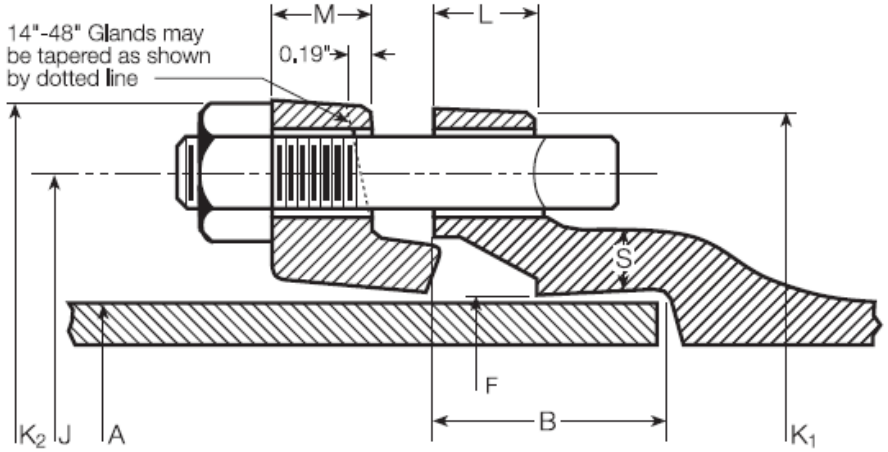
Ductile Iron Pipe Joints Siesmic Performance

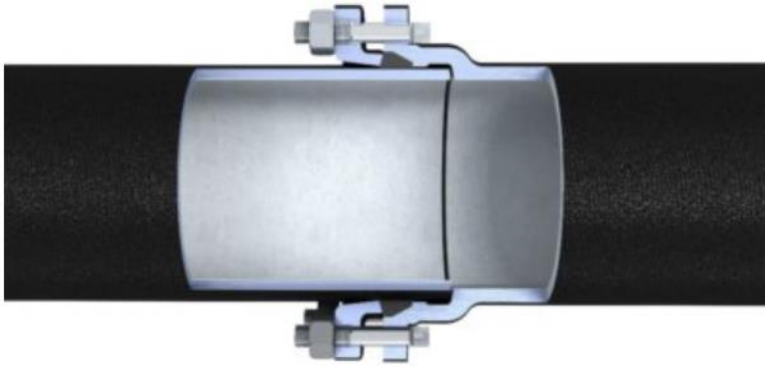


Mechanical Joints

ISO 16134 Rating

- 4” D, M1, S3
- 6”-16” D, M2, S3
- 18” – 48” D, M3, S3





Mechanical Joints w/RJ Gland

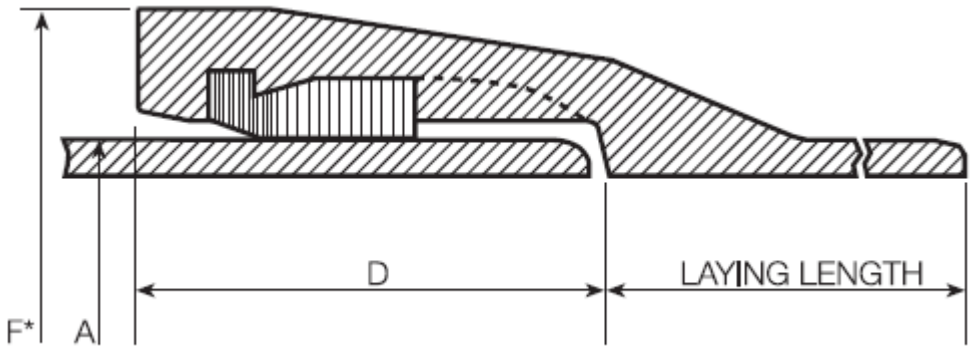
ISO 16134 Rating

- 4” ?, M3, S3
- 6”-16” ?, M3, S3
- 18” – 48” ?, M3, S3

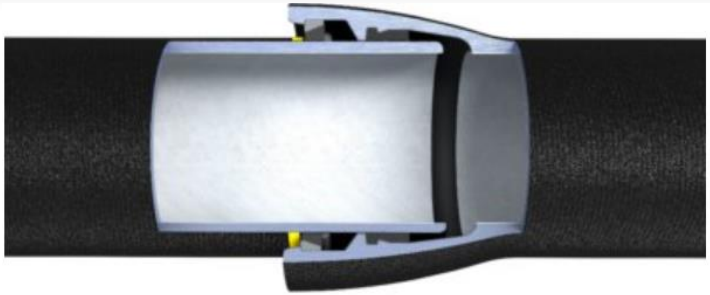
Unrestrained Push on Joints

ISO 16134 Rating

- 4” – 64” D, M2, S3



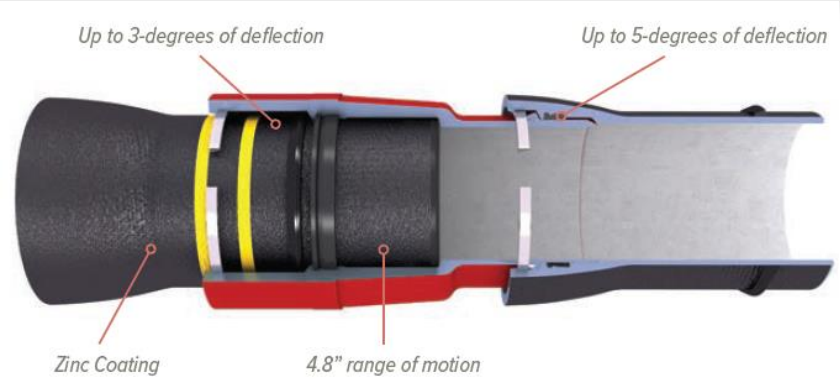
Integral Locking Restrained Joints

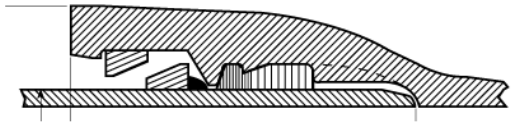


PERFORMANCE SPECS - AMERICAN FLEX-RING® JOINT EARTHQUAKE CAPACITY

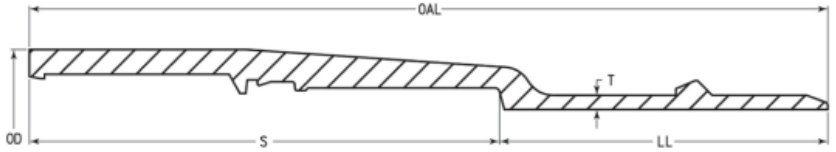
SIZE (IN.)	NOMINAL LAY LENGTH (IN.)	RADIUS OF CURVATURE (LINEAR FT.)	MINIMUM PULL APART RESISTANCE (LBS.)	JOINT DEFLECTION (DEGREES)	ELONGATION AT FULL INSERTION ASSEMBLY	ISO 16134 DESIGNATION
4	239 (19'-11")	230	68,000	5.00	+0.31% (0.75")	A, M2, S3
6	239 (19'-11")	230	102,000	5.00	+0.31% (0.75")	A, M2, S3
8	239 (19'-11")	230	136,000	5.00	+0.31% (0.75")	A, M2, S3
10	238 (19'-10")	230	170,000	5.00	+0.32% (0.75")	A, M2, S3
12	238 (19'-10")	230	204,000	5.00	+0.32% (0.75")	A, M2, S3
14	238 (19'-10")	285	238,000	4.00	+0.53% (1.25")	A, M2, S3
16	237.5 (19'-9.5")	305	272,000	3.75	+0.53% (1.25")	A, M2, S3
18	237 (19'-9")	305	306,000	3.75	+0.53% (1.25")	A, M2, S3
20	237 (19'-9")	327	340,000	3.50	+0.53% (1.25")	A, M2, S3
24	237 (19'-9")	380	408,000	3.00	+0.53% (1.25")	A, M3, S3
30	236.75 (19'-8.75")	458	510,000	2.50	+0.53% (1.25")	A, M3, S3
36	236.75 (19'-8.75")	570	612,000	2.00	+0.53% (1.25")	A, M3, S3
42	236.75 (19'-8.75")	570	714,000	2.00	+0.53% (1.25")	A, M3, S3
48	235.75 (19'-7.75")	570	816,000	2.00	+0.53% (1.25")	A, M3, S3
54	235.75 (19'-7.75")	570	918,000	1.50	+0.53% (1.25")	A, M3, S3

Adding Strain Relief





Standard Dimensions

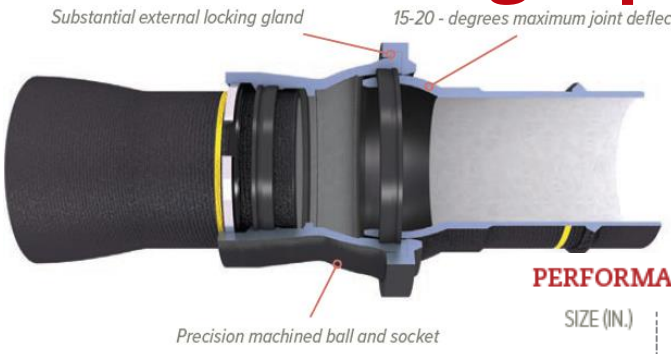


PERFORMANCE SPECS

SIZE (IN.)	PIPE JOINT DEFLECTION (DEGREES)	CASTING JOINT DEFLECTION (DEGREES)	COMBINED ASSEMBLY DEFLECTION (DEGREES)	EXPANSION OR CONTRACTION FROM MID-POINT	DEAD-END THRUST RESISTANCE (LBS.)	ISO 16134 RATING
6	5	3	8	± 1.00% (2.40")	102,900	A, M1, S1
8	5	3	8	± 1.00% (2.40")	137,200	A, M1, S1
12	5	3	8	± 1.00% (2.40")	205,800	A, M1, S1
16	3.75	3.25	7	± 1.00% (2.40")	274,400	A, M2, S1
20	3.5	2.5	6	± 1.00% (2.40")	343,000	A, M2, S1
24	3	3	6	± 1.00% (2.40")	411,600	A, M2, S1
30	2.5	2.5	5	± 1.00% (2.40")	514,500	A, M2, S1

Ball and Socket

River Crossing Pipe



PERFORMANCE SPECS - AMERICAN FLEX-LOK® JOINT EARTHQUAKE CAPACITY

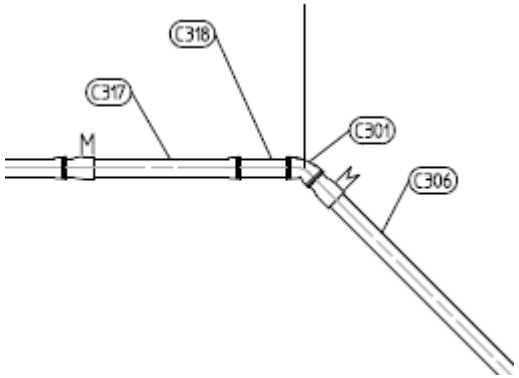
SIZE (IN.)	NOMINAL LAY LENGTH (IN.)	RADIUS OF CURVATURE (LINEAR FT.)	MINIMUM PULL APART RESISTANCE (LBS.)	JOINT DEFLECTION (DEGREES)	ELONGATION AT FULL INSERTION ASSEMBLY	ISO 16134 DESIGNATION
4	258 (21'-6")	48	68,600	25.00	+0.68% (1.75")	A, M1, S3
6	259 (21'-7")	49	102,900	25.00	+0.68% (1.75")	A, M1, S3
8	260 (21'-8")	49	137,200	25.00	+0.67% (1.75")	A, M1, S3
10	259.63 (21'-7.63")	49	171,500	25.00	+0.67% (1.75")	A, M1, S3
12	260.63 (21'-8.63")	49	205,800	25.00	+0.67% (1.75")	A, M1, S3
14	246 (20'-6")	78	240,100	15.00	+0.10% (0.25")	A, M1, S3
16	265.56 (22'-1.56")	56	274,400	22.50°	+0.85% (2.25")	A, M1, S3
18	246 (20'-6")	78	308,700	15.00	+0.10% (0.25")	A, M1, S3
20	267.31 (22'-3.31")	57	343,000	22.00	+0.84% (2.25")	A, M1, S3
24	271.13 (22'-7.13")	61	411,600	21.00	+1.66% (4.50")	A, M1, S2
30	268.63 (22'-4.63")	63	514,500	20.00	+1.68% (4.50")	A, M1, S2
36	275.94 (22'-11.94")	69	617,400	19.00	+1.63% (4.50")	A, M1, S2

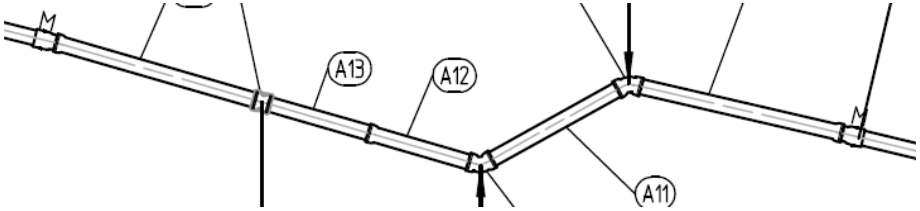
Larger diameters are available. Please consult your AMERICAN representative for more details.

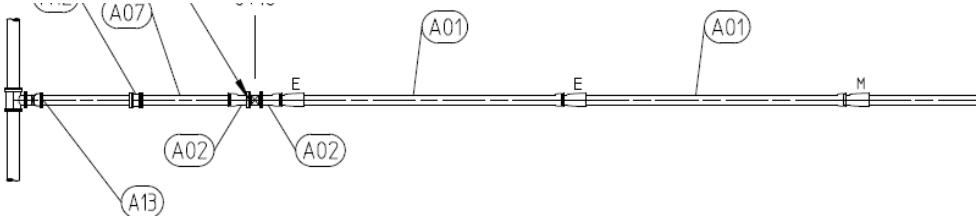
DESIGNING ERDIP SYSTEM

Thrust

- **System is Fully Restrained However Design as if Unrestrained**
- **Thrust Block May Act as an Anchor**





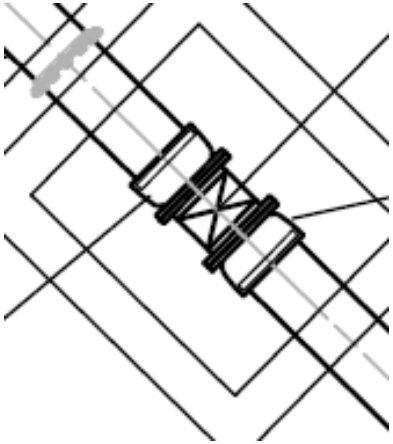


Valves

- Maintain “A” Pull Apart Resistance
- Maintain Flexibility
- Strain Relief ??

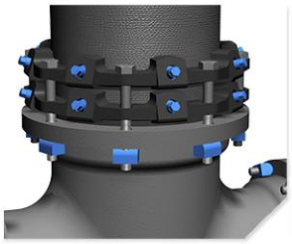
RJ Gate Valve

Flange w/RJ Adapters



Fittings

- Maintain “A” Pull Apart Resistance
- Maintain Flexibility
- Strain Relief ??

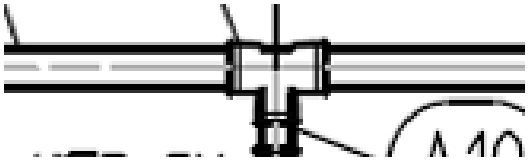


1100TDM **MEGALUG®**

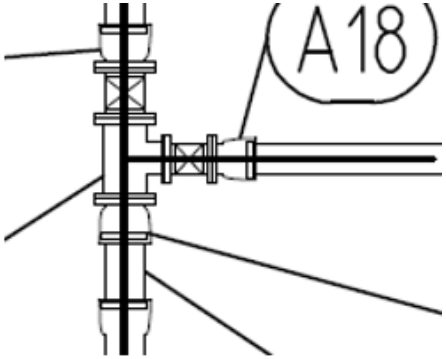
Tandem MEGALUG® Mechanical Joint Restraint

The Series 1100TDM Tandem MEGALUG restrain ductile iron pipe to mechanical joint fittings, pipe and appurtenances that require high PSI ratings. It consists of one Series 1100 MEGALUG and one Series 1100 MEGALUG with the MJ lip removed as to sit properly behind the first.

RJ Fittings, Best



Flange w/RJ Adapters



Avoid MJ w/ Megalug

Structures

ERDIP = Custom Design

- **Every project is unique!**

Mark #	Description	Length (LL)	Deflection (D)	Settlement (S)	Required Elongation	Allowed Elongation
Y106	36" FLXSKT FLXBAL PIPE	7' 0"	15°	22.5"	3"	4"
Y113	48" FLXSKT FLXBAL PIPE	7' 0"	15°	22.5"	3"	4"

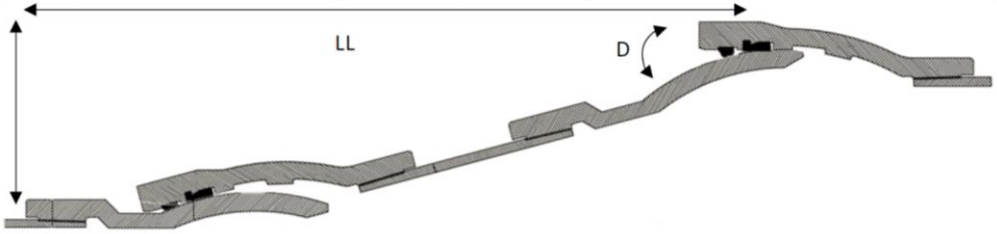
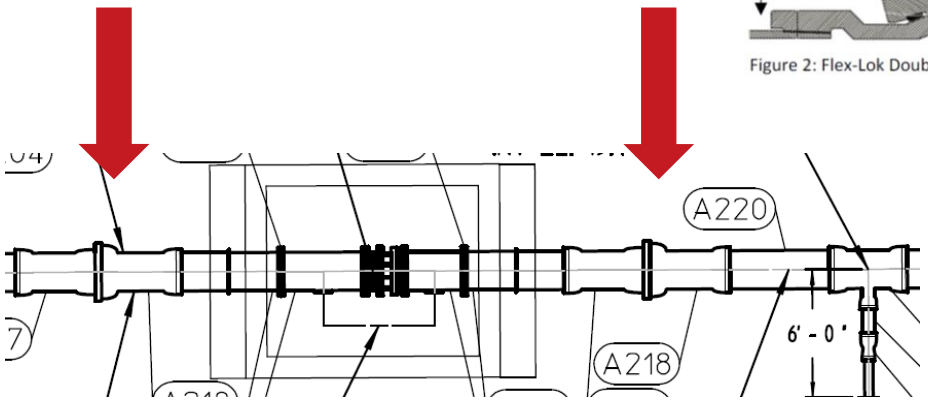
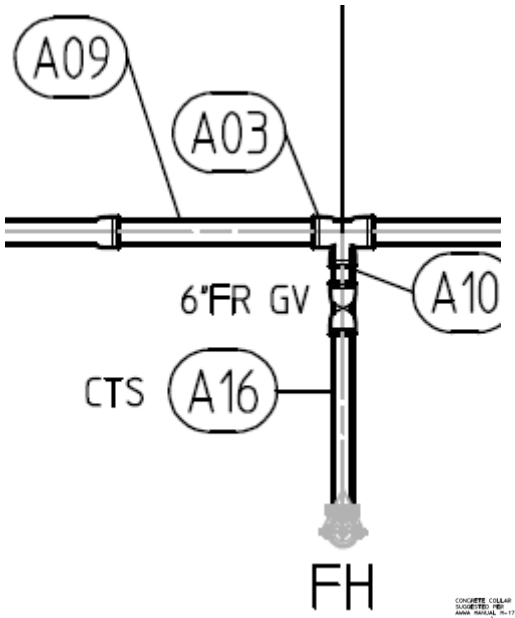


Figure 2: Flex-Lok Double Ball Pipe Settlement Table and Detail

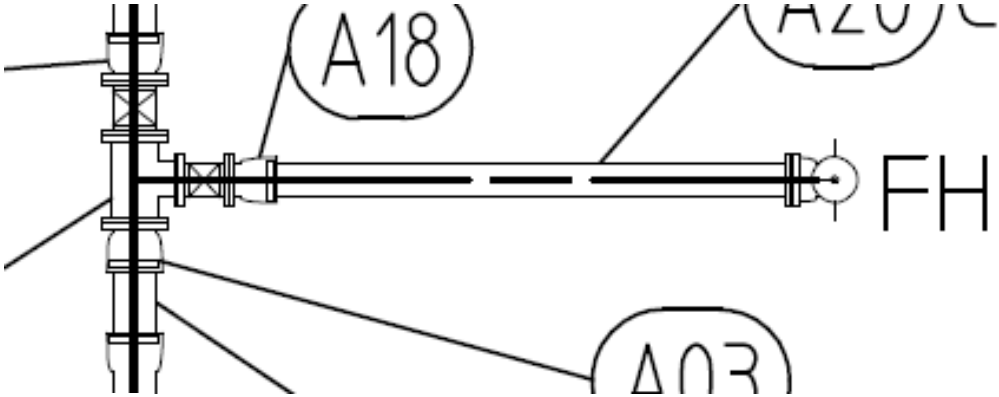


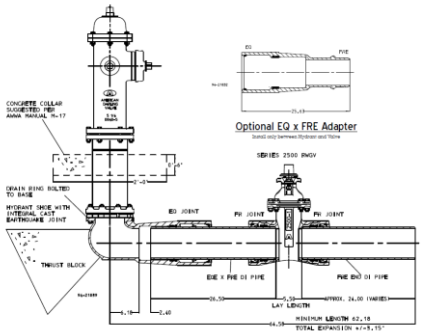
Fire Hydrants Tee

RJ Tee



Flange Tee





Specifications

Performance Based

Example Specification

Ductile iron earthquake and hazard resistant pipe shall meet all applicable requirements of **AWWA C150** (design), **AWWA C151** (manufacture), **AWWA C104** (lining), **C111** (joints), **AWWA C153** (fittings), **AWWA C105** (polyethylene encasement), and **AWWA C600** (installation). The ductile iron pipe shall be sized in inches, and be special thickness class 53.

The piping shall meet defined classifications detailed below as shown in **ISO 16134 Earthquake Resistant Ductile Iron Pipe and Subsidence-Resistant Design**. The seismic design shall be verified by an independent seismic lab such as Cornell University or an owner-approved institution.

1. All ductile iron pipe and fitting joints shall meet or exceed **3dKN pull-out strength or category A**.

2. Designated Earthquake System piping shall meet or exceed a minimum deflection of **8 degrees for category M1** for sizes 6" - 12", between **4 degrees to 8 degrees for category M2** for 16", and between **3.5 degrees to 7 degrees for category M2** for 20" and above, whether in the mid-point, fully inserted, or fully extended positions.

3. Designated ductile iron Earthquake System piping will have a minimum **expansion/contraction of plus or minus 1% or category S1**.

As a designation, the minimum requirements would be A-M1-S1 per ISO 16134 for sizes 6" - 12" and A-M2-S1 for sizes 16" and above, unless otherwise shown on plans and specifications.

Corrosion Prevention

Example Specification

The network of ductile iron pipe connected to the Earthquake Joint System shall have the exterior of the pipe coated with a layer of arc-sprayed zinc. The mass of the zinc applied shall be a minimum of 200 g/m² of pipe surface area, and the coating system shall conform in every respect to **ISO 8179-1, "Ductile Iron Pipes - External Zinc-Based Coating - Part 1: Metallic Zinc with Finishing Layer,"** second edition 2004-06-01. The zinc shall have a top coat of approved materials. (Component pieces and field touch up may require the use of a zinc-rich coating 85% zinc per **ISO-8179-part 2**).

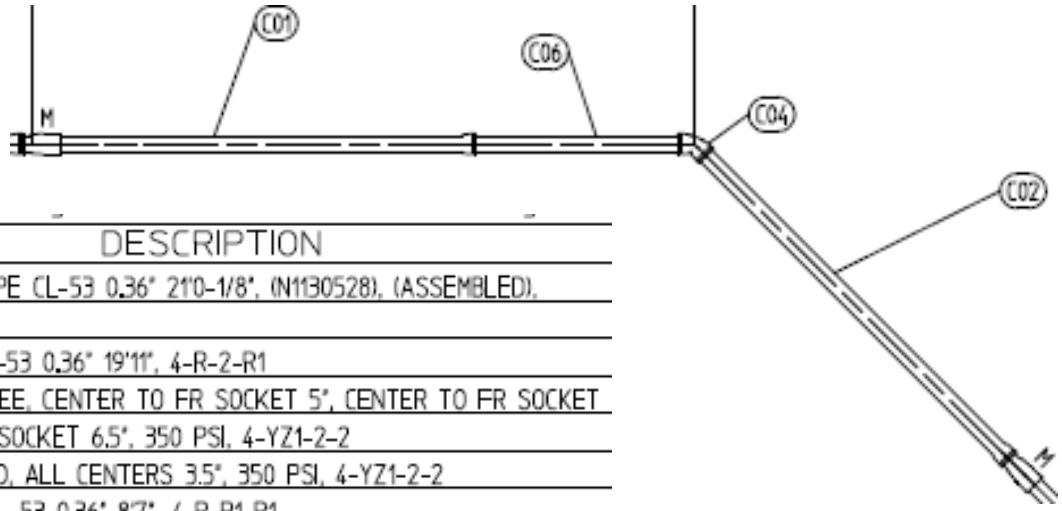
The Earthquake System piping will be installed in the fully extended, fully contracted, or mid-point position per project criteria. To facilitate determining field joint alignment, the expansion spigot in the assembly shall have a minimum of two assembly stripes–one indicating fully contracted and one indicating the mid-point of assembly. Full extension can be achieved by pulling out the completed joint until the joint stops movement.

In addition, the connected network of ductile iron pipe shall be encased in 8-mil **V-Bio polyethylene encasement** meeting the requirements of **AWWA C105** concerning both materials and installation.

The pipeline will be installed with a **locator tape** that identifies the buried line as an earthquake resistant pipeline. The tape will be a minimum 2 inches in width and red in color labeled, "Earthquake Resistant Ductile Iron Pipeline Below."

Lay Drawing

01145.05 Manufacturer Produced Shop Drawings – Submit a complete ERDIP layout plan developed by the ERDIP manufacturer showing the length and location of each pipe, valve, and fitting from the beginning to the ending of the alignment shown on the Contract Drawings. The ERDIP layout plan shall be created using CAD software. The pipe layout shall show the plan view. Provide details including pipe length, fitting and joint type for each planned vertical offset in the layout plan. The ERDIP layout plans shall include a list of all required ERDIP system materials including type, size, length, and description. Pipe installation is prohibited without an Owner approved ERDIP layout plan.



QTY	SPBID	MARK	DESCRIPTION
21	DCL-ZINC CN	C01	8" EQJT FR FRE PIPE CL-53 0.36" 21'0-1/8", (N1130528), (ASSEMBLED),
			4-R/C
3	DCL-ZINC	C02	8" FR FRE PIPE CL-53 0.36" 19'11", 4-R-2-R1
1	DCL-ZINC	C03	8"X8"X6" FR C153 TEE, CENTER TO FR SOCKET 5", CENTER TO FR SOCKET
			5", CENTER TO FR SOCKET 6.5", 350 PSI, 4-YZ1-2-2
2	DCL-ZINC	C04	8" FR C153 45 BEND, ALL CENTERS 3.5", 350 PSI, 4-YZ1-2-2
1	DCL-ZINC	C05	8" FRE FRE PIPE CL-53 0.36" 8'7", 4-R-R1-R1
1	DCL-ZINC	C06	8" FRE FRE PIPE CL-53 0.36" 10'4", 4-R-R1-R1

Installation Methods

(c) Joints shall be installed in the condition shown in the Contract Documents. (i.e. Homed, Mid-point, Expanded, Restrained)

(d) Ensure all previously assembled joints are not moved from their original installation position.

Installation Training

Manufacture Training

- Assembly
- Disassembly
- Special Tools
- Joint Position
  - Mid-point
  - Homed
  - Fully Extended

02477.13 Manufactures Training - Manufacture's suppling ERDIP shall perform project specific training for all Contractor personnel that will be installing ERDIP. Training shall provide instruction in proper joint assembly, joint disassembly, pipe cutting, field installation of pipe for restrained and unrestrained joints, and positioning of joints at the homed, midpoint and fully extended position.

SUMMARY

SUMMARY

- **Every ERDIP Project is Unique**
- **Performance Based Spec with Localized Special Requirements**
- **ERDIP - Only as Strong as it's Weakest Link**

Essentials For the Design & Specs of Earthquake Resistant Ductile Iron Pipe

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Pacific Northwest Section

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