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Managing Water in the West

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Long Term Durability of Plastic Pipe Joint Restraints

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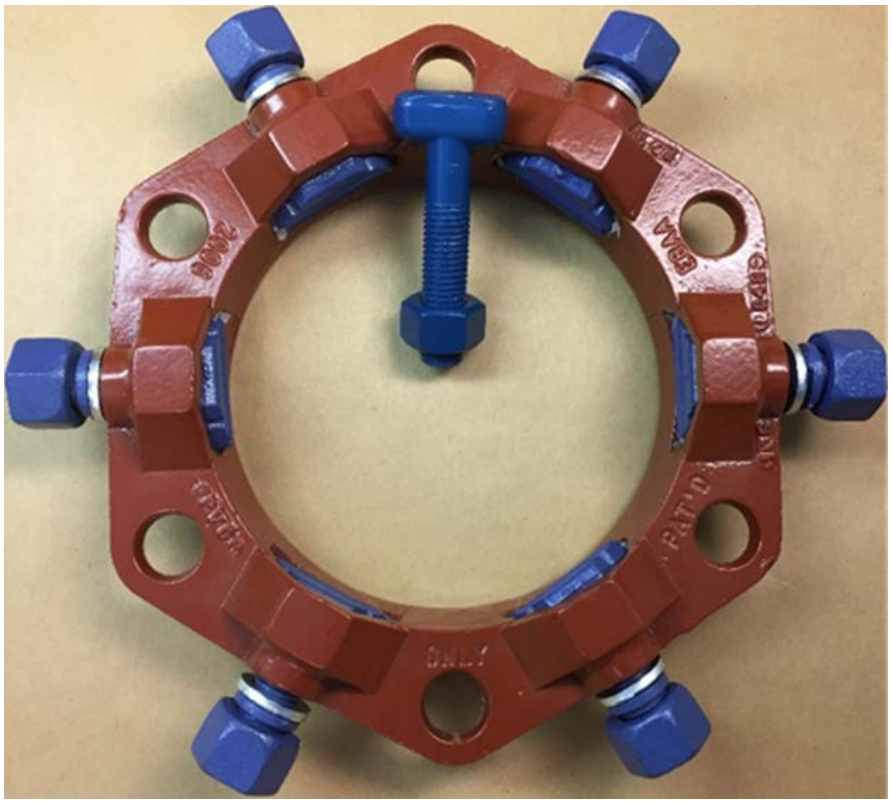
Final Report ST-2017-1793-01



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A comprehensive literature review was performed on pipe joint restraints and their resources. The purpose of this study was to collect information from manufacturers of joint restraints and investigate their long term durability. This study will help familiarize pipe designers and owners with pipe restraints and the requirements for their ability over long term exposure. It is recommended to test pipe restraints following ASTM F1674 and the requirements of AWWA for different types of plastic pipe to determine their performance over their lifetime.

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Long Term Durability of Plastic Pipe Joint Restraints

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Executive Summary

The purpose of this scoping study is to collect information from manufacturers of joint restraints and investigate their performance. This report contains:

- Information from several manufacturers of external mechanical joint restraints.
- Information from one manufacturer on long term burst strength of PVC pipe with mechanical joint restraint.
- Information from three manufacturers of internal joint restraints.
- Example of a failed mechanical joint restraint used for Pine Ridge Oglala Sioux Tribe Reservation Pipe, due to damaged coating and corrosion.
- Recommendation for future research.

The Bureau of Reclamation (Reclamation) is specifying more polyvinyl chloride (PVC) and high density polyethylene (HDPE) plastic pipe on many of its new pipe installations and planned installations. This is mainly due to the increased corrosion resistance and ease of installation. Technology has improved so that these non-metallic pipe options can handle much higher pressures at larger diameters. The higher pressure in the pipelines results in greater thrust at changes in direction, valves, and dead ends. This resulting thrust must be restrained by either thrust blocks or joint restraint. More and more methods of joint restraint, both external and internal, are currently available on the market. However, there has been little understanding on long term durability of joint restraints on plastic pipe.

While several products are available to restrain joints on molecularly oriented polyvinyl chloride (PVCO) pipe, PVCO joint restraint is outside the scope of this study.

This literature review found little test data that provides long-term performance of joint restraints on plastic pipe. Test data that was found was limited in scope.

Acronyms and Abbreviations

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BHN	Brinell hardness number
CIOD	cast iron outside diameter
HDPE	high-density polyethylene
IPS	iron pipe size
O.D.	outside diameter
psi	pounds per square inch
PVC	polyvinyl chloride
PVCO	molecularly oriented polyvinyl chloride
Reclamation	Bureau of Reclamation
SDR	standard dimension ratio
UV	ultra-violet

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Introduction

In all pipeline installations, the restraining of forces due to internal pressure at fittings, valves, changes in direction, and dead ends is an important consideration. Concrete thrust blocks have historically been used to prevent joint separation and pipe movement at these locations. Mechanical joint (a section of a machine that is used to connect one mechanical part to another) restraints can be a cost effective alternative to concrete thrust blocks. The mechanical joint restraints are manufactured from ductile iron in accordance with the American Society for Testing and Materials (ASTM) A536 [1] and are incorporated into the design of a follower gland. Dimensions of the gland allow it to be used with the standardized mechanical joint bell and tee-head bolts in accordance with American Water Works Association (AWWA) C111/A21.11 [2] and AWWA C153 [3]. The restraint mechanism consists of numerous individually activated gripping surfaces to maximize restraint capability. The gripping surfaces (wedges) are designed to spread the bearing surfaces on the pipe. Wedges are heat treated to a minimum of 370 Brinell hardness number (BHN). Twist-off nuts are used to ensure the proper actuating of restraining devices. When the nut is sheared off, a standard hex nut remains [4].

The Bureau of Reclamation's (Reclamation) main goal and responsibility is delivery of water and pipe failure can cause major issues including disruption of service, damage, and high costs for repair or replacement. The use of these mechanical pipe restraints can decrease costs and construction problems, but there is not enough knowledge about their longevity.

While joint restraints were originally used for ductile iron pipe, they have evolved for use on polyvinyl chloride (PVC), molecularly oriented polyvinyl chloride (PVCO), and high-density polyethylene (HDPE) plastic pipe types as well. There are many manufacturers fabricating these pipe restraints with various specifications and applications which are summarized in the next sections. PVCO joint restraint systems, while available, are outside the scope of this study. ASTM standard test methods are available to check the long term durability and strength of these restraints. These ASTM standards are also discussed in the next sections.

Manufacturers of Mechanical Joint Restraints

This section describes mechanical joint restraints available from several manufacturers shown below in table 1.

Table 1.—Manufacturers of External Mechanical Joint Restraints

Manufacturer	Product Name	Type of Pipe
EBAA Iron	MEGALUG®	PVC & HDPE
Ford Meter Box	Uni-Flange®	PVC
ROMAC	Roma Grip	PVC
SIP	EZ Grip	PVC
SIGMA	ONE-LOK™	PVC & HDPE
Smith-Blair	120 Cam-Lock™	PVC
STAR®	Stargrip®	PVC & HDPE
Tyler Union	TUF Grip™	PVC & HDPE

EBAA Iron

EBAA (founded in 1964) manufactures and sells a variety of pipe restraints and flexible expansion joints for the water and wastewater pipeline industry. EBAA mechanical joint restraints are sold under the tradename MEGALUG®. All of the EBAA joint restraint products including mechanical joint restraint, pipe bell restraint, and restrained flange adaptors, with restrained couplings cast, coated, machined assembled, and packaged in the United States. These products are [5]:

- MEGALUG® Series 2000PV: Mechanical joint restraint for PVC and HDPE pipe (including various products derived from the Series 2000PV, including Series 2200, 2500 and 2800).
- MEGAFLANGE® Series 2100 and EZ-FLANGE™ Series 1000: Restrained flange adaptors for PVC and HDPE pipe.
- MEGA-COUPLING® Series 3800: Restrained coupling for PVC and HDPE pipe.
- Tru-Dual® Series 1500TD, 1600TD, 15PF00TD, and 15MJ00TD: Bell restraint and ductile iron fitting restraints for PVC pipe.
- Bell restraints for PVC pipe including: Series 1500, 1600, 1900, 6500, and 7500.

The Mega-Bond coating system is used for EBAA restraint products for enhanced performance and longevity. This coating consists of the following [6]:

- All wedge assemblies and related parts are processed through a phosphate wash, rinse, and drying operation prior to coating application.
- The coating consists of a minimum of two coats of liquid thermoset epoxy coating with heat cure to follow each coat.
- All casting bodies are surface pretreated with a phosphate wash, rinse, and sealer before drying.
- The coating is electrostatically applied and heat cured.
- The coating is a polyester based powder to provide corrosion, impact, and ultra-violet (UV) resistance.

EBAA PVC Pipe Restraints

As discussed below, EBAA manufactures a variety of MEGALUG® pipe restraints for a wide variety of PVC pipe diameters, PVC pipe standards, and connection details.

2000PV MEGALUG®

The series 2000PV MEGALUG® mechanical joint restraint (figure 1) is used for restraining plain end PVC pipe at mechanical joint fittings. The pressure ratings are shown in table 2.

Features and applications:

- Used with AWWA C900 [7] or ASTM D2241 [8] IPS O.D. PVC pipe.
- Available in sizes **3 inch to 36 inch**.
- Constructed of ASTM A536 ductile iron.
- Coating : MEGA-BOND® Restraint Coating System.
- The mechanical joint follower gland is incorporated into the restraint.
- For use on water or wastewater pipelines subject to hydrostatic pressure and tested in accordance with ASTM D2774 [9].

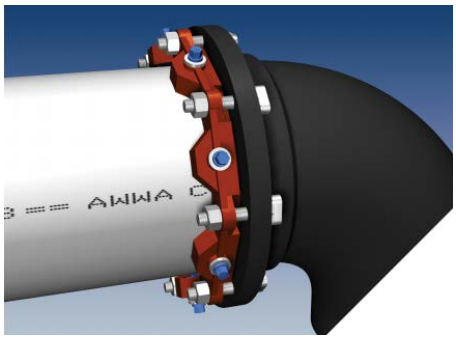


Figure 1.—Series 2012PV MEGALUG® joining 12 inch AWWA C900 [7] PVC pipe to a ductile iron fitting [10]

Table 2.—Pressure Ratings of Series 2000PV MEGALUG® for PVC Pipe [10]

Nominal Pipe Size (in)	Series Number	Pressure Ratings (psi)								
		DR14	DR18	DR21	DR25	DR32.5	DR41	SDR17	SDR21	SDR26
3	2003PV	305	235	-	165	-	-	250	200	160
4	2004PV	305	235	-	165	-	-	250	200	160
6	2006PV	305	235	-	165	-	-	250	200	160
8	2008PV	305	235	-	165	-	-	250	200	160
10	2010PV	305	235	-	165	-	-	250	200	160
12	2012PV	305	235	-	165	-	-	250	200	160
14	2014PV	305	235	-	165	125	100	-	-	-
16	2016PV	235	235	-	165	125	100	-	-	-
18	2018PV	-	200	165	165	125	100	-	-	-
20	2020PV	-	200	-	165	125	100	-	-	-
24	2024PV	-	235	-	165	125	100	-	-	-
30	2030PV	-	-	165	165	125	-	-	-	-
36	2036PV	-	-	125	125	125	-	-	-	-

2200PV MEGALUG®

The Series 2200 MEGALUG® mechanical joint restraint (figure 2) for use on large diameter PVC pipe is a solid ring restraint for restraining PVC pipe to mechanical joint fittings. The pressure ratings are shown in table 3.

Features and applications:

- Series 2500 restraint used for PVC pipe at PVC fittings and Series 2800 bell restraint harness used for PVC pipe.
- Available in sizes **30 inch to 48 inch**.

- Constructed of ASTM A536 ductile iron.
- Coating: MEGA-BOND® Restraint Coating System.
- The restraint gland is separate from the mechanical joint follower gland.
- For use on water or wastewater pipelines subject to hydrostatic pressure and tested in accordance with either AWWA C605 [11] or ASTM D2774 [9].

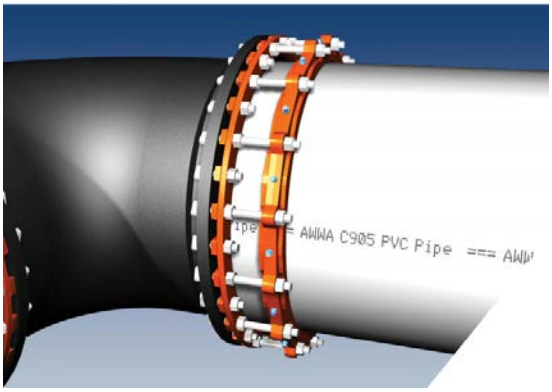


Figure 2.—Series 2248 MEGALUG® joining a 48 inch plain end PVC pipe to a ductile iron mechanical joint fitting [12]

Table 3.—Pressure Ratings of Series 2200PV, 2500PV, and 2800PV MEGALUG® for PVC Pipe [12]

Nominal Pipe Size (in)	Series Number	Pressure Ratings (psi)					
		DR14	DR21	DR25	DR32.5	DR41	DR51
30	2230	150*	165	165	125	100	80
30	2530	-	-	-	-	-	-
30	2830	150*	-	165	125	100	80
36	2236	-	-	165	125	100	80
36	2536	-	-	-	-	-	-
36	2836	-	-	125	125	100	80
42	2242	-	-	-	125	100	80
42	2542	-	-	-	125	100	80
42	2842	-	-	-	125	100	80
48	2248	-	-	-	125	100	80
48	2548	-	-	-	125	100	80
48	2848	-	-	-	125	100	80

* For higher pressures a tandem restraint is available.

15MJ00TD Tru-Dual®

The Series 15MJ00TD Tru-Dual® (figure 3) is composed of a split serrated restraint ring with heat treated Tru-Dual® inserts. The restraint is installed on the spigot end of the pipe and connects to the fitting with an array of thrust bolts. The pressure ratings are shown in table 4.

Features and applications:

- Used for AWWA C900 [7] PVC pipe at ductile iron mechanical joint fittings.
- Available in sizes **4 inch to 12 inch**.
- Constructed of ASTM A536 ductile iron.
- Coating: MEGA-BOND® Restraint Coating System.
- Minimum 2 to 1 safety factor.
- For use on water or wastewater pipelines subject to hydrostatic pressure and tested in accordance with either C605 [11]or ASTM D2774 [9].

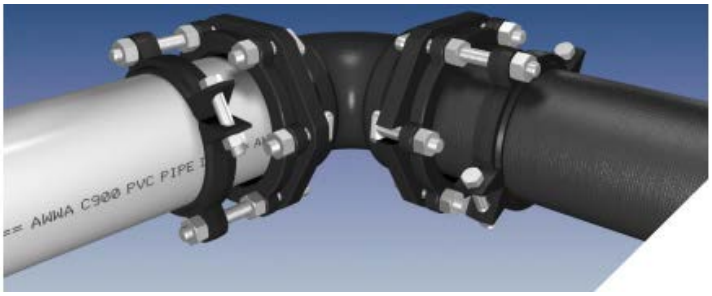


Figure 3.—Series 15MJ06TD restraining AWWA C900 PVC pipe at a MJ fitting with a MJ gland [13]

Table 4.—Pressure Ratings of Series 15MJ00TD for PVC Pipe [13]

Nominal Pipe Size (in)	Series Number	Pressure Ratings (psi)		
		AWWA C900		
		DR14	DR18	DR25
4	15MJ04TD	200	150	100
6	15MJ06TD	200	150	100
8	15MJ08TD	200	150	100
10	15MJ10TD	200	150	100
12	15MJ12TD	200	150	100

2000SV MEGALUG® Split Restraint

The Series 2000SV MEGALUG® split restraint (figure 4) is comprised of a split series 2000PV and clamping hardware. The pressure ratings are shown in table 5.

Features and applications:

- Used for restraining AWWA C900 [7] PVC pipe.
- Available in sizes **3 inch to 12 inch**.
- Constructed of ASTM A536 ductile iron.
- Coating: MEGA-BOND® Restraint Coating System.
- The mechanical joint follower gland is incorporated into the restraint.
- Split design used for ease of installation at existing mechanical joints.
- For use on water or wastewater pipelines subject to hydrostatic pressure and tested in accordance with either C605 [11] or ASTM D2774 [9].

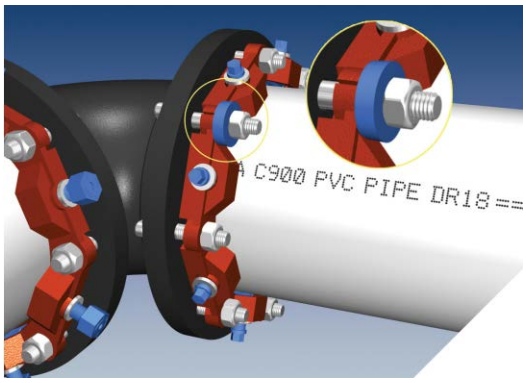


Figure 4.—Series 2010SV MEGALUG® on 10 inch AWWA C900 PVC pipe [14]

Table 5.—Pressure Ratings of Series 2010SV MEGALUG® for PVC Pipe [14]

Nominal Pipe Size (in)	Series Number	Pressure Ratings (psi)	
		DR18	DR25
4	2003SV	150	100
6	2004SV	150	100
8	2008SV	150	100
10	2010SV	150	100
12	2012SV	150	100

15MJ00 Split Serrated Restraint

The Series 15MJ00 (figure 5) is a split serrated ring with thrust rods that rod back to the fitting. The pressure ratings are shown in table 6.

Features and applications:

- Used for restraining AWWA C900 [7] PVC pipe systems using mechanical joint fittings and mechanical joint gland.
- Available in sizes **4 inch to 12 inch**.
- Constructed of ASTM A536 ductile iron.
- Coating: MEGA-BOND® Restraint Coating System.
- Minimum 2 to 1 safety factor.
- Split design used for ease of installation.
- For use on water or wastewater pipelines subject to hydrostatic pressure and tested in accordance with either C605 [11] or ASTM D2774 [9].

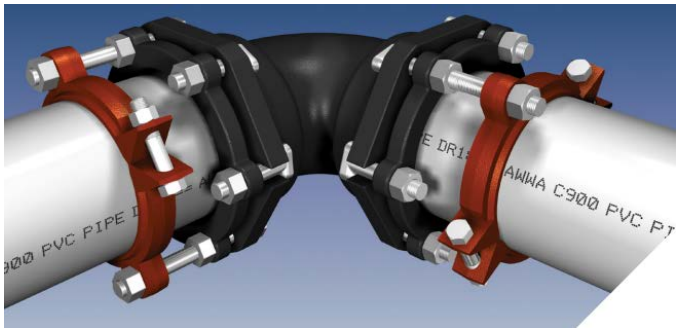


Figure 5.—Series 15MJ00 restraining a mechanical joint fitting with a mechanical joint gland [15]

Table 6.—Pressure Ratings of Series 15MJ00 for PVC Pipe [15]

Nominal Pipe Size (in)	Series Number	Pressure Ratings (psi)		
		DR14	DR18	DR25
4	15MJ04	200	150	100
6	15MJ06	200	150	100
8	15MJ08	200	150	100
10	15MJ10	200	150	100
12	15MJ12	200	150	100

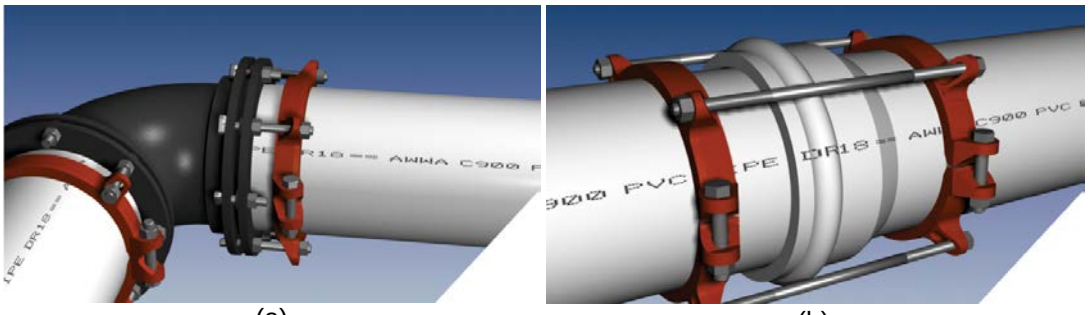
19MJ00 and 1900 Split Serrated Restraint

The Series 19MJ00 (figure 6a) is a split serrated ring with thrust rods that rod back to the fitting. The restraint is rated for the full pressure of AWWA C900 [7] PVC pipe.

The Series 1900 (figure 6b) is a split serrated restraint harness for restraining AWWA C900 PVC pipe joints. It's comprised of two split serrated restraint rings; one on the plain end or spigot of pipe and the other behind the bell. They are fastened into a harness by an array of thrust rods. The 1900 is rated to the full pressure of AWWA C900 PVC Pipe. The pressure ratings are shown in table 7.

Features and applications:

- Used for restraining mechanical joint follower glands on AWWA C900 PVC pipe.
- Available in sizes **4 inch to 12 inch**.
- Constructed of ASTM A536 ductile iron.
- Coating: MEGA-BOND® Restraint Coating System.
- Rated to the full pressure of the pipe.
- Minimum 2 to 1 safety factor.
- Split serrated restraint rings used for ease of installation.
- For use on water or wastewater pipelines subject to hydrostatic pressure and tested in accordance with ASTM D2774 [9].



(a) (b)

Figure 6.—(a) Series 19MJ00 mechanical joint restraint for 4-12 inch AWWA C900 PVC and (b) Series 1900 restraint harness for 4-12 inch AWWA C900 PVC [16]

Table 7.—Pressure Ratings of Series 19MJ00 and 1900 for PVC Pipe [16]

Nominal Pipe Size (in)	Series Number	Pressure Ratings (psi)		
		DR14	DR18	DR25
4	19MJ04 / 1904	305	235	165
6	19MJ06 / 1906	305	235	165
8	19MJ08 / 1908	305	235	165
10	19MJ10 / 1910	305	235	165
12	19MJ12 / 1912	305	235	165

65MJ00 Split Serrated Restraint

The Series 65MJ00 (figure 7) is a split serrated ring with thrust rods that rod back to the fitting. The pressure ratings are shown in table 8.

Features and applications:

- Used on ASTM D2241 IPS O.D. PVC pipe systems to restrain mechanical joints.
- Available in sizes **4 inch to 12 inch**.
- Constructed of ASTM A536 ductile iron.
- Coating: MEGA-BOND® Restraint Coating System.
- Minimum 2 to 1 safety factor.
- Split design used for ease of installation.
- For use on water or wastewater pipelines subject to hydrostatic pressure and tested in accordance with either C605 or ASTM D2774 [9].

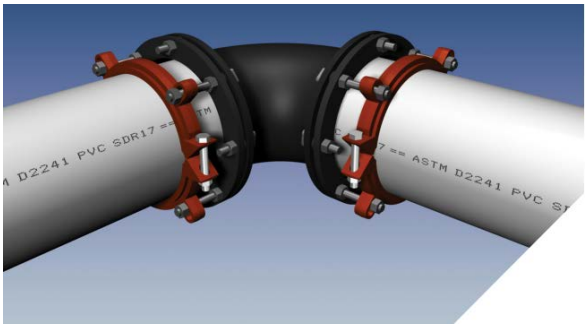


Figure 7.—Series 65MJ12 restraining a mechanical joint fitting with a mechanical joint gland [17]

Table 8.—Pressure Ratings of Series 65MJ00 for PVC Pipe [17]

Nominal Pipe Size (in)	Series Number	Pressure Ratings (psi)		
		DR14	DR18	DR25
4	65MJ04	250	200	160
6	65MJ06	250	200	160
8	65MJ08	250	200	160
10	65MJ10	250	200	160
12	65MJ12	250	200	160

The other products for push-on AWWA C900 [7] PVC pipe joints are: 1500 and 1600 split serrated restraint harness, 2800 MEGALUG® restraint harness, 1100HV split restraint harness, 2500 and 2600 restraint harness for AWWA C900 PVC fittings, 1500TD and 1600TD Tru-Dual®, 5000 MEGA-STOP, 6500 bell restraint harness, and 7500 ASTM D2241 IPS fitting restraint [5].

EBAA HDPE Pipe Restraint

EBAA Iron offers several restraint solutions for HDPE ductile iron outside diameter (O.D.) pipe:

- Mechanical joint restraint:
  - MEGALUG® Series 2000PV (figure 8): **3-12 inch**
  - MEGALUG® Series 15PF00: **4-12 inch**

- Push-on fitting restraint:
  - MEGALUG® Series 15PF00: **4-12 inch**

- Flange adapter and restraint:
  - MEGAFLANGE® Series 2100: **3-12 inch**

The pressure ratings are shown in table 9.

Features and applications:

- Pipe must be manufactured in accordance with AWWA C906 [18] with respect to size.

- For use on water or wastewater pipelines subject to hydrostatic pressure and tested in accordance with ASTM D2774 [9].

- Products are intended for use in underground service only.

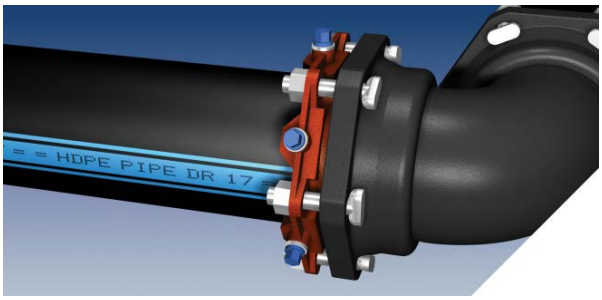


Figure 8.—Series 2006PV MEGALUG® on HDPE pipe at a MJ fitting [19]

Table 9.—Pressure Ratings of Series 2000PV MEGALUG®, 15PF00 MEGALUG®, and 2100 MEGAFLANGE® for HDPE Pipe [19]

Nominal Pipe Size (in)	Series 2000PV	Series 15PF00	Series 2100	Pressure Ratings (psi)		
				DR11	DR13.5	DR17
3	2003PV	15PF03	2103	160	130	100
4	2004PV	15PF04	2104	160	130	100
6	2006PV	15PF06	2106	160	130	100
8	2008PV	15PF08	2108	160	130	100
10	2010PV	15PF10	2110	160	130	100
12	2012PV	15PF12	2112	160	130	100

The Ford Meter Box Company, Inc.

Uni-Flange® Series 1500 "Circle Lock"

Uni-Flange® Series 1500 mechanical joint restraint (figure 9) for PVC pipe joined with standardized mechanical joint fittings is incorporated in the design of the follower gland and provides full circle contact and support of the pipe wall. Restraint is accomplished by a series of ring segments mechanically retained inside the gland housing and designed to grip the pipe wall in an even and uniform manner. Restraining ring segments are actuated by bolts featuring "Auto-Tork" twist-off heads to ensure proper installation torque is applied. A safety stop on the Auto-Tork bolt limits the force applied to the ring segment against the pipe. All components of the restrainer, including the gland, bolts, and restraint segments are of high strength ductile iron, ASTM A536.

Features and applications:

- Used on AWWA C900 [7] PVC and ASTM D2241 IPS PVC, and can also be used on DR35 as long as a SO-EZ gasket is used (SO-EZ gasket snaps to MJ Gland or Restraint Gland for a stab-fit pipe insertion). The pressure ratings are shown in table 10.

- Available in sizes **3 inch to 12 inch**.
- Constructed of ASTM A536 ductile iron.
- Coating: E-coat epoxy coating.
- Passed the rigorous quality assurance and pressure tests required by Factory Mutual Research Corporation and ASTM F1674 [20]. These include the following tests conducted on AWWA C900 PVC pipe, DR18:
- Tested to a minimum of 755 psi.
- 1,000 hours at 500 psi.
- Over 1,000,000 cycles oscillating between 94 psi to 188 psi.

Figure 9.—Uni-Flange® Series 1500 mechanical joint restraint [21]

Table 10.—Pressure Ratings of Uni-Flange® Series 1500 PVC Pipe Sizes 3-12 Inch [21]

Pressure Ratings (psi)					
AWWA C900			ASTM D2241 IPS		SDR35
DR25	DR18	DR14	SDR26	SDR21	
165	235	305	160	200	≥ 46

ROMAC Industries, Inc.

RomaGrip

The Romac RomaGrip restraining gland (figure 10) is used for the restraint of valves, fittings, and fire hydrants with mechanical joints in PVC water transmission lines.

Features and applications:

- Provides restraint of mechanical joints; lug style PVC pipe restraint.
- Available in sizes **3 inch to 24 inch**.
- Constructed of ASTM A536 ductile iron.
- Coating: Shop coat applied to cast parts for corrosion protection. Romabond polyester available.
- Working pressure: Up to pressure rating of the pipe with a 2 to 1 safety factor.

Figure 10.—PVC ROMAGRIP™ mechanical joint restraint [22]

SIP Industries

EZ Grip®

EZ Grip® Joint Restraint (figure 11) is a method of restraining PVC pipe with mechanical joint pipe, by integrating a series of gripping wedges into a mechanical joint follower gland. The pressure ratings are shown in table 11.

Features and applications:

- Performs with all mechanical joint sockets and is used with **4 inch to 12 inch** AWWA C900 [7] PVC or **3 inch to 12 inch** ASTM D2241 iron pipe size (IPS) PVC pipe.
- Constructed of ASTM A536 ductile iron.
- Coating: Provided with a coating that is compatible with most field applied coatings.
- Has a minimum safety factor of at least 2 to 1.

- Designed for potable and recycled water, and for wastewater applications.

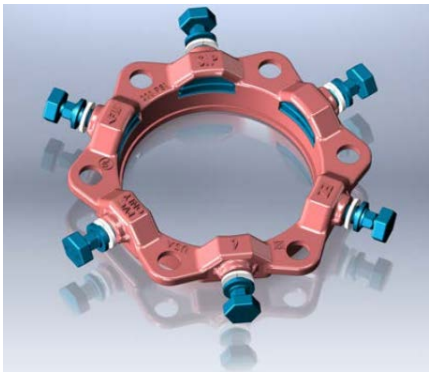


Figure 11.—EZ Grip® mechanical joint restraint for PVC pipe [23]

Table 11.—Pressure Ratings of EZ Grip® Mechanical Joint Restraint for PVC Pipe [23]

Nominal Pipe Size (in)	Pressure Ratings (psi)					
	AWWA C900			ASTM D2241 IPS		
	DR14	SDR18	SDR25	SDR17	SDR21	SDR26
3	-	-	-	250	200	160
4	305	235	165	250	200	160
6	305	235	165	250	200	160
8	305	235	165	250	200	160
10	305	235	165	250	200	160
12	305	235	165	250	200	160

SIGMA Corporation

ONE-LOK™ SLCE for PVC Pipe

The SIGMA ONE-LOK Series SLCE (figure 12) is a mechanical joint restraining gland that implements a series of individually activated wedges into the mechanical joint follower gland. When the wedge segment is engaged by the actuating bolt, the primary contact edges of each wedge segment lock onto the pipe wall. The pressure ratings are shown in table 12.

Features and applications:

- Used to effectively restrain all classifications of both AWWA C900 [7] and ASTM D2241 IPS size PVC pipe.

- Available in sizes **3 inch to 36 inch**.

- Constructed of ASTM A536 ductile iron.
- Coating: CORRSAFE™ which is a cationic epoxy base coating applied using a time tested electrodeposition process.
- The mechanical joint restraining devices provide no less than a safety factor of 2 to 1.
- Tested in accordance with ASTM F1674 [20].

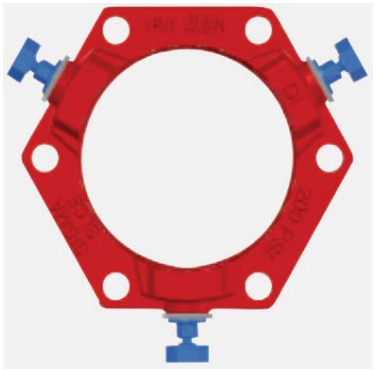


Figure 12.—ONE-LOK™ Series SLCE for PVC pipe [24]

Table 12.—Pressure Ratings of SIGMA ONE-LOK Series SLCE for PVC Pipe [24]

Nominal Pipe Size (in)	Series Number	Pressure Ratings (psi)									
		AWWA C900							ASTM D2241 IPS		
		DR14	DR18	DR21	DR25	DR32.5	DR41	DR51	SDR17	SDR21	SDR26
3	SLCE3	-	-	-	-	-	-	-	250	200	160
4	SLCE4	305	235	-	165	-	-	-	250	200	160
6	SLCE6	305	235	-	165	-	-	-	250	200	160
8	SLCE8	305	235	-	165	-	-	-	250	200	160
10	SLCE10	305	235	-	165	-	-	-	250	200	160
12	SLCE12	305	235	-	165	-	-	-	250	200	160
14	SLCE14	-	235	200	165	125	100	-	-	-	-
16	SLCE16	-	235	200	165	125	100	-	-	-	-
18	SLCE18	-	235	200	165	125	100	80	-	-	-
20	SLCE20	-	235	200	165	125	100	80	-	-	-
24	SLCE24	-	235	200	165	125	100	80	-	-	-
30	SLCE30	-	-	-	165	125	100	80	-	-	-
36	SLCE36	-	-	-	165	125	100	80	-	-	-

ONE-LOK™ and PV-LOK™ for HDPE Pipe

The ONE-LOK™ and PV-LOK™ pipe restraint systems (figure 13) can be used for restraining of HDPE pipe with ductile iron mechanical joint and push-on fittings. Rated pressure of the restraint is limited to the rated pressure of the HDPE pipe. The pressure ratings are shown in table 13.

Features and applications:

- Restraint devices are SIGMA ONE-LOK SLCE, SIGMA PV-LOK PVM/PWM, or approved equal.
- Available in sizes **3 inch to 12 inch**.
- All HDPE pipe meets the requirements of AWWA C906.
- Constructed of ASTM A536 ductile iron.
- Coating: Red Alkyd paint for CIOD pipe and green Alkyd paint for IPS pipe. CORRSAFE™ is also available.
- Restraint devices for HDPE are not recommended for use in above ground applications.

- HDPE pipe restrained with these devices are reinforced with an internal pipe wall stiffening device.

Figure 13.—ONE-LOK™ and PV-LOK™ pipe restraint systems for HDPE pipe [25]

Table 13.—Pressure Ratings of ONE-LOK™ and PV-LOK™ Pipe Restraint Systems for HDPE Pipe [25]

Nominal Pipe Size (in)	ONE-LOK	PV-LOK		Pressure Ratings (psi)		
	SLCE	PVM (CIOD)	PVM (IPS)	DR11	DR13.5	DR17
3	SLCE3	-	PVM-S3	160	130	100
4	SLCE4	PVM-C4	PVM-S4	160	130	100
6	SLCE6	PVM-C6	PVM-S6	160	130	100
8	SLCE8	PVM-C8	PVM-S8	160	130	100
10	SLCE10	PVM-C10	PVM-S10	160	130	100
12	SLCE12	PVM-C12	PVM-S12	160	130	100

Smith-Blair

120 Cam-Lock™

Smith-Blair joint restraints are used for restraining hydrants, values, PVC pipe, bells, and fittings used in water and wastewater systems. 120 Cam-Locks (figure 14) are mechanical joint restraint glands with multiple independent single-tooth, cam-action wedges designed to restrain a fitting on a piece of pipe. The Cam-Lock's lower bolt torque and wider wedges reduce pipe stress.

Features and applications:

- Available in sizes **3 inch to 36 inch**.

- Restraining pipe ends on mechanical joint fittings and there are fewer wedges for time saving installations.
- Lower torque required to fully actuate bolts.
- Constructed of ASTM A536 ductile iron.
- Coating: Gland is Flexi-Coat® Epoxy per AWWA C213 [26]. Wedges and Actuating Bolts are E-coated Epoxy.
- Pressure Ratings: Rated at the pressure rating of PVC pipe it is used on.
- The 120 Cam-Locks have been tested without failure according to ASTM F1674 [20] on sizes 4 to 12 inch DR18 PC 150 pipe, conforming to the requirements of AWWA C900.

Figure 14.—120 Cam-Lock™ joint restraints for PVC pipe [27]

STAR® Pipe Products

Stargrip® Series 4000

The PVC Stargrip® mechanical joint restraint system (figure 15) is a restraining system for mechanical joint fittings, valves, and hydrants on a variety of plastic pressure pipe. The pressure ratings for PVC and HDPE pipe are shown in table 14.

Features and applications:

- Can be used on AWWA C900 PVC pipe, ASTM D2241 IPS PVC pipe, and HDPE pipe.
- Available in sizes **4 inch to 36 inch**.

- Gland is made from high strength ductile iron per ASTM A536 and is compatible with all mechanical joints conforming to American National Standards Institute (ANSI)/AWWA C111/A21.11.
- Coating: Alkyd enamel.
- All sizes have curved wedges that do not flatten pipe.
- The safety factor is twice (2 to 1) the standardized pressure rating.
- Tested to and meets the requirements of ASTM F1674 [20] through 14 inch.

Figure 15.—6 inch PVC Stargrip® Series 4000 for PVC pipe [28]

Table 14.—Pressure Ratings of Stargrip® Series 4000 for PVC and HDPE Pipe [28]

Nominal Pipe Size (in)	Pressure Ratings (psi)													
	AWWA C900 PVC					ASTM D2241 IPS PVC			AWWA C906 HDPE					
	DR14	SDR18	SDR21	SDR25	DR32.5	SDR17	SDR21	SDR26	DR7.3	DR9	DR9.3	DR11	DR13.5	DR17
3	305	235	-	165	-	250	200	160	254	200	193	160	130	100
4	305	235	-	165	-	250	200	160	254	200	193	160	130	100
6	305	235	-	165	-	250	200	160	254	200	193	160	130	100
8	305	235	-	165	-	250	200	160	254	200	193	160	130	100
10	305	235	-	165	-	250	200	160	254	200	193	160	130	100
12	305	235	-	165	-	250	200	160	254	200	193	160	130	100
14	-	235	200	165	125	-	-	-	-	200	193	160	-	-
16	-	235	200	165	125	-	-	-	-	-	-	160	-	-
18	-	235	200	165	125	-	-	-	-	-	-	160	-	-
20	-	235	200	165	125	-	-	-	-	-	-	-	-	-
24	-	235	200	165	125	-	-	-	-	-	-	-	-	-
30	-	-	-	165	125	-	-	-	-	-	-	-	-	-
36	-	-	-	165	125	-	-	-	-	-	-	-	-	-

Tyler Union

TUF Grip™ Series 2000

TUF Grip™ Series 2000 (figure 16) is used for restraining PVC and HDPE pipe in the waterworks market. The pressure ratings for PVC and HDPE pipe are shown in table 15.

Features and applications:

- Restrain plain end AWWA C900 PVC pipe in diameters **3 inch to 36 inch**, ASTM D2241 IPS PVC pipe in diameters **3 inch to 12 inch**, and AWWA C906 HDPE Pipe **3 inch to 16 inch**.
- Constructed of ASTM A536 ductile iron.
- Coating: Standard coating for Domestic restraint is 4-6 mil of TUF-Bond™ (thermoset polyester for impact, corrosion, and UV protection).
- Restraint and all components are designed and proven for a 2 to 1 safety factor.
- Gripping wedge assembly pivots providing stronger engagement of pipe wall at lower torque requirement.
- Testing based on ASTM F1674 [20]: 3-12 inch tested to 755 psi, 14-16 inch tested to 755 psi, and 18- 24 inch tested to 535 psi.

Figure 16.—TUF Grip™ Series 2000 mechanical joint restraint for PVC pipe [29]

Table 15.—Pressure Ratings of TUF Grip™ Series 2000 for PVC Pipe [29]

Nominal Pipe Size (in)	Pressure Ratings (psi)											
	AWWA C900 PVC				ASTM D2241 IPS PVC			AWWA C906 HDPE				
	DR14	SDR18	SDR25	DR32.5	SDR17	SDR21	SDR26	DR7.3	DR9	DR11	DR13.5	DR17
3	-	-	-	-	250	200	160	254	200	160	128	100
4	305	235	165	-	250	200	160	254	200	160	128	100
6	305	235	165	-	250	200	160	254	200	160	128	100
8	305	235	165	-	250	200	160	254	200	160	128	100
10	305	235	165	-	250	200	160	254	200	160	128	100
12	305	235	165	-	250	200	-	254	200	160	128	100
14	-	235	165	125	-	-	-	254	200	160	128	100
16	-	235	165	125	-	-	-	254	200	160	128	100
18	-	200	165	-	-	-	-	-	-	-	-	-
20	-	200	165	-	-	-	-	-	-	-	-	-
24	-	165	165	125	-	-	-	-	-	-	-	-
30	-	-	165	125	-	-	-	-	-	-	-	-
36	-	-	125	125	-	-	-	-	-	-	-	-

Pipe Internal Joint Restraints

Bell-and-spigot gasket-joint PVC pipe is widely used in pressure applications for potable water distribution and transmission, and sewer force mains. The use of external joint restraints in PVC pipe has increased significantly. However, the external mechanical joint restraints are fitted on the outside of the joint, which can be exposed to soils; making them susceptible to corrosion. While the typical joint restraint system is external, the next generation of joint restraints for PVC pipe-to-pipe and ductile iron fitting-to-PVC pipe connections are internal to the system. Internal joint restraints types include the BullDog™ joint, MJ Field LOK-PV® joint, and Diamond LOK-21®.

BullDog™ Integral Joint Restraint System

The BullDog™ joint is integral to a PVC pipe bell. This joint is designed for pipe-to-pipe connections and meets all the requirements of ASTM F1674 [20]. The available sizes for pipe manufactured to AWWA C900 [7] are 4 inch to 12 inch. Figure 17 shows a cross-sectional drawing of the components of the joint. In the field, the joint is assembled like a regular push-on joint and the spigot is pushed into the bell up to the insertion mark. Once the pipe is put into service, expansion of the spigot and its backward movement as a result of hydrostatic pressure application within the pipeline causes the grip ring serrations to become evenly wedged into the wall of the spigot, thus engaging the restraint mechanism fully. At higher pressure, there is also some expansion of the bell. The depths to which the serrations penetrate the spigot wall do not exceed 10 percent of the wall thickness. Sealing of the joint is carried out by the Rieber gasket. This gasket prevents the pipeline fluid to become in contact with the restraint mechanism (grip ring and casing).

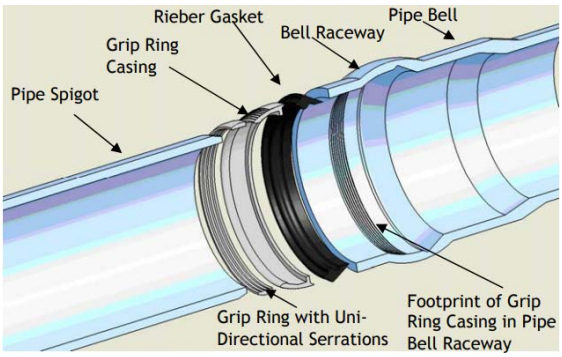


Figure 17.—BullDog™ restrained joint pipe components [30]

MJ Field LOK-PV® Self-Restraining Gasket for Mechanical Joints

The MJ Field LOK-PV® is a self-restraining internal gasket for connecting and restraining ductile iron fittings to PVC pipe. These devices are easier to assemble than external joint restraint alternatives and much less susceptible to corrosion.

This self-restraining gasket (figure 18) is designed for use in mechanical joints (ductile iron fitting-to-PVC pipe joints). Just like the BullDog™, the serrations on the ring are unidirectional, allowing the pipe to go through, but not to be withdrawn. The gland on the PVC pipe is then bolted to the flange on the mechanical fitting.

Figure 18.—Self-restraining gasket [30]

Diamond LOK-21®

Diamond LOK-21® joint restraint for PVC pressure pipe is manufactured in accordance with AWWA C900 [7] in sizes from 4 inch to 24 inch to a DR18 with a pressure rating of 235 psi. It is manufactured to a cast iron outside diameter (CIOD) which ensures the availability of fittings and valves [31].

This restraint system provides uniform circumferential contact and therefore eliminates any concerns over point loading. Since it is a simple push together system, it can reduce installation time. Diamond LOK-21® is well suited for directional drilling operations, for installation through bore casings, and many applications which require joint restraint. Because it is made of PVC, long-term performance can be achieved. The restraint mechanism is located in the bell. It does not require couplings or splines, nuts, bolts and torque wrenches, butt fusion equipment, concrete thrust blocking or solvent cement.

Diamond LOK-21® is tested to twice its pressure rating. All Diamond LOK-21® products utilize the Rieber sealing system technology which provides tremendous

joint integrity under severe construction conditions. Figure 19 shows Diamond LOK-21® retainer and ring assembly.

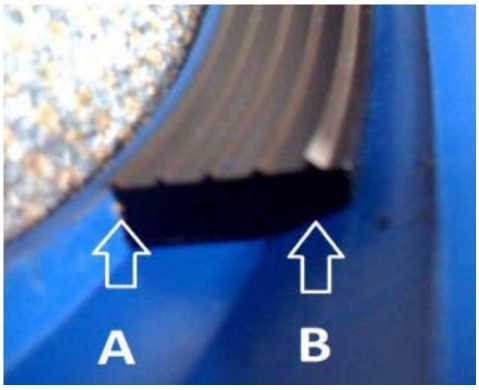


Figure 19.—Diamond LOK-21® retainer and ring assembly [32]

Testing of PVC Joint Restraints

In 1988, the Uni-Bell PVC Pipe Association published UNI-B-13 – Recommended Standard Performance Specification for Joint Restraint Devices for Use with Polyvinyl Chloride (PVC) Pipe [30]. The standard practice required three tests to prove the performance of a restraint device when attached to a PVC pipe joint:

- Burst pressure test to verify the effect of a joint restraint on the short term strength of the pipe.
- 1,000-hour sustained pressure test to ensure the long term strength of the pipe fitted with the restraint.
- Cyclic strength of the pipe and restraint through the one million-cycle test (A cycle is an increase in the internal pressure in a cyclic pressure test specimen from the base pressure to the peak pressure, followed by a decrease in the internal pressure to the base pressure).

The UNI-B-13 standard practice did not specify that the rating of the device had to be at the same pressure rating of the pipe system it was being used on, and it did not require a manufacturer to test all sizes and all pressure ratings. In 1996, ASTM F1674 – Standard Test Method for Joint Restraint Products for Use with PVC Pipe [20] was written with two additional points [30]:

- Every size and every pressure rating of a joint restraint product line must be able to pass the three mentioned tests.
- The product must have the same pressure class as the pipe that it is going to restrain.

The AWWA Manual M23, PVC Pipe – Design and Installation Manual of Water Supply Practices [33], clearly states

> *Only joint restraint devices manufactured and tested for use in PVC pressure piping systems should be considered. All devices should be required to conform to ASTM F1674.*

The test method based on this standard explains the following aspects [21]:

- Describes a procedure for qualifying the performance of joint restraint products for use on PVC pressure pipe systems.
- Determines the long-term effect of a joint restraint product on PVC pipe.

- Addresses restraint products that are rated at the full pressure capacity of the PVC pipe on which they are used.

- Determines the performance of a joint restraint product on PVC pipe subjected to cyclic pressure surges.

The external mechanical joint restraint products fabricated by the various manufacturers identified in this report were tested according to ASTM F1674 on various pipe sizes, conforming to the requirements of AWWA for different types of PVC pipes. However, these pipe restraints have disadvantages as follows [30]:

- They are metallic and external to the pipeline and must be installed on the outside of a pipe joint. Therefore, they are susceptible to corrosion.

- Installation is time consuming and subject to human error (for example the pipe does not centered correctly inside the restrainer or coating damages during installation process without special care).

- The vast majority of joint restraints in North America do not meet the requirements of ASTM F1674.

- Devices that use wedges subject the pipe wall to point loading due to over-tightening of wedges. Even torque-off bolts commonly cause deformities in the walls of PVC pipe. This can lead to failure or leakage at joints. Uneven tightening of nuts and bolts also leads to joint leakage.

- Serrated-type products are incapable of sustaining internal pressures as high as those products that meet ASTM F1674 , making the system subject to the possibility of leakage and failure in the future. The rods in particular play a role in the failure mechanism of these devices.

Pipe internal joint restraints meet all the requirements of ASTM F1674 and do not have the disadvantages of the mentioned external mechanical joint restraints.

Long Term Burst Strength of PVC Pipe with Joint Restraint

The literature review found little test data to address the long term performance of joint restraints. One study by EBAA on their MEGALUG® mechanical joint restraints is described below. No long term testing was found on the newer internal joint restraint systems.

EBAA conducted a long term proof testing program on the 2000PV mechanical joint restraints for PVC pipe over a three year period starting in 1990. EBAA tested PVC pipe rated for 150 psi service for 1,000 hours (42 days) at the

sustained pressure of 500 psi which is the same requirement listed in AWWA C900 [7] for the pipe itself. Samples of various sizes were tested at 500 psi at different times. After the 1,000 hour mark was reached, the samples were kept at the same 500 psi pressure for 10,000 hours (417 days). After successful completion of 10,000 hours, samples were removed and inspected. The inspection of the samples showed that the MEGALUG® had caused no damage of any kind to the pipe. The pressure in the remaining samples was taken from the 500 psi sustained pressure and the pressure was increased until failure. The results are shown in table 16. It was found that the 2000PV test sections held at hoop stress levels of 4000 psi and above for over 20,000 hours indicated no detrimental effect of the MEGALUG® mechanical restraint on the PVC pipe.

Table 16.—Results of the Long Term Burst Tests [34]

Pipe Size (in)	Pipe Class	Sustained Hoop Stress (psi)	Time at Sustained Pressure (hr)	Ultimate Hoop Stress at Failure (psi)
3	SCH140	3,250	6,381	8,430
4	DR18	4,250	24,682	8,449
6	DR18	4,250	21,237	9,223
6	SDR17	4,000	21,260	8,512
10	DR18	4,250	21,260	8,585

The minimum required burst stress for all the tested pipe is 6,400 psi. The typical ultimate hoop stress at failure for a quick burst test specimen is typically around 7,650 psi; however, no control specimens were tested as part of this study. In another study, a different pipe (believed to be similar) burst at a pressure of 860 psi or 7,310 psi hoop stress. The results in Table 16 suggest that after 21,260 hours at a pressure of 500 psi, the ultimate hoop strength increased by seventeen percent (8,550 psi vs. 7,310 psi). EBAA claims that these results indicate that PVC pipe is capable of becoming stronger over time. EBAA also concludes that these results show that the 2000PV does not affect the PVC pipe in an adverse manner, and that the EBAA 2000PV is safe and reliable in the long term.

To support these conclusions, Reclamation proposes additional testing to address pipe wall deformations, stress concentrations, and the potential for long-term creep.

Potential Installation Issues with Mechanical Joint Restraints

Figure 20 shows a brand new MEGALUG® 2006PV mechanical joint restraint manufactured by EBAA. Pictures in this figure are taken immediately after the nut is sheared off by applying torque with no environmental exposure. The following issues could be observed while the product was stored and prior installation in the filed:

- Insufficient coating coverage (most likely due to poor surface preparation before coating application)
- Corrosion
- Pinholes in the coating
- Coating removal due to nut shear-off process

Coating damage can also happen during installation and environmental exposure to soil while in service. This could lead to corrosion and therefore release of pressure on the mechanical joint restraints. Figure 21 shows the failed mechanical joint restraints used for Pine Ridge Oglala Sioux Tribe Reservation Pipe. These mechanical joint restraints were installed 7 to 8 years prior to failure. The cause of failure is coating damage and corrosion due to exposure of bare metal to the soil. These mechanical joint restraints could not be cathodically protected due to lack of continuity. Special care is needed in both application of the coating on a well surface prepared mechanical joint restraints and their installation.

Figure 20.—Sheared-off nut and remaining hex nut; corrosion seen inside nut and on the hex nut. In addition, pinholes in the coating and insufficient coating coverage observed at various areas on the hex nut.

Figure 21.—Failed mechanical joint restraint used for Pine Ridge Oglala Sioux Tribe Reservation Pipe (7 to 8 years in service). Coating damage and corrosion seen at different locations.

Summary / Recommendations

As listed in this report, there are multiple products available from multiple manufacturers offering both external and internal restrained joints for PVC pipe. HDPE also has a variety of pipe restraint products as well for transitioning from HDPE pipe to other mechanical joints. This literature search found limited testing on the joints restraint systems, especially the larger sized joint restraint products. In addition, the long term effects on both the pipe wall and the restraint itself have not had extensive testing.

Since external mechanical joint restraints have been used in Reclamation for restraining plastic pipe to pipe or metallic fittings to plastic pipe, testing should be conducted to verify the manufactures statements. The testing will be conducted in accordance to ASTM F1674 [20] and follow all the requirements of AWWA for different types and sizes of PVC and HDPE pipes. Longer testing time frames could be performed to test creep by applying static load on the pipe with mechanical joint restraints hanging vertically. This is because the grips can slip or plastically deform the pipe near a bend due to the hydrostatic forces or tensile type loads. These tests are additional tests to the burst testing recommended by the ASTM standard.

The next generation of joint restraints for PVC pipe that are internal to the system should also be tested. The results of the tests between external and internal restrained joints should be compared to determine the long term effects of both joints.

References

[1] American Society for Testing and Materials. 2014. ASTM A536 – Standard Specification for Ductile Iron Castings.

[2] American Water Works Association . 2017. AWWA C111/A21.11 – Rubber Gasket-Joints for Ductile Iron Pressure Pipe and Fittings.

[3] American Water Works Association . 2011. AWWA C153 – Ductile-Iron Compact Fittings.

[4] Denver Water. Material Specification for Mechanical Joint Restraint. Engineering Standards 14th Edition, ERRATA 7. Accessed July 2017 from https://www.denverwater.org/sites/default/files/2017-05/ms-29.pdf.

[5] EBAA IRON. Accessed July 2017 from http://www.ebaa.com/.

[6] EBAA MEGA-BOND. Accessed July 2017 from http://ebaa.com/files/pdf/brochures/Brochure.MEGA-BOND.pdf.

[7] American Water Works Association . 2016. AWWA C900 – Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 in. through 60 in. (100 mm through 1,500 mm).

[8] American Society for Testing and Materials. 2015. ASTM D2241 – Standard Specification for Polyvinyl Chloride (PVC) Pressure-Rated Pipe (SDR Series).

[9] American Society for Testing and Materials. 2012. ASTM D2774 – Standard Practice for Underground Installation of Thermoplastic Pressure Piping. 2012.

[10] 2000 PV MEGALUG® Product Brochure. Accessed July 2017 from http://www.ebaa.com/files/pdf/brochures/Brochure.2000PV.pdf.

[11] American Water Works Association . 2013. AWWA C605 – Underground Installation of Polyvinyl Chloride and Molecularly Oriented Polyvinyl Chloride Pressure Pipe and Fittings.

[12] 2200PV MEGALUG® Product Brochure. Accessed July 2017 from http://www.ebaa.com/files/pdf/brochures/Brochure.2200.pdf.

[13] 15MJ00TD Tru-Dual® Product Brochure. Accessed July 2017 from http://www.ebaa.com/files/pdf/brochures/Brochure.15MJ00TD.pdf.

[14] 2000 SV MEGALUG® Split Restraint Product Brochure. Accessed July 2017 from http://www.ebaa.com/files/pdf/brochures/Brochure.2000SV.pdf.

[15] 15MJ00 Split Serrated Restraint Product Brochure. Accessed July 2017 from http://www.ebaa.com/files/pdf/brochures/Brochure.15MJ00.pdf.

[16] 19MJ00 and 1900 Split Serrated Restraint Product Brochure. Accessed July 2017 from http://www.ebaa.com/files/pdf/brochures/Brochure.19MJ00.pdf.

[17] 65MJ00 Split Serrated Restraint Product Brochure. Accessed July 2017 from http://www.ebaa.com/files/pdf/brochures/Brochure.65MJ00.pdf.

[18] American Water Works Association . 2015. AWWA C906 – Polyethylene (PE) Pressure Pipe and Fittings, 4 in. through 65 in. (100 mm through 1,650 mm), for Waterworks.

[19] HDPE Restraint Product Brochure. Accessed July 2017 from http://www.ebaa.com/files/pdf/brochures/Brochure.HDPE.pdf.

[20] American Society for Testing and Materials. 2011. ASTM F1674 – Standard Test Method for Joint Restraint Products for Use with PVC Pipe.

[21] Uni-Flange® Series 1500 "Circle Lock" Product Catalog. Accessed July 2017 from http://www.fordmeterbox.com/catalog/u/ujpeg.pdf.

[22] RomaGrip. Accessed July 2017 from http://www.romac.com/Submittals/RESTRAINT/romagrip-pvc-3-12-sub.pdf.

[23] EZ Grip. Accessed July 2017 from http://sipindustries.com/dwlpdf/EZGripPVC.pdf.

[24] ONE-LOK™ SLCE for PVC Pipe. Accessed July 2017 from http://www.argco.com/pdf/techdata/one_lok_wedge_restraint_TechData.pdf.

[25] ONE-LOK™ and PV-LOK™ for HDPE Pipe. Accessed July 2017 from http://www.sigmaco.com/product/restraint-product-for-high-density-polyethylene-pipe-hdpe/.

[26] American Water Works Association. 2015. AWWA C213 – Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings.

[27] Smith-Blair Cam-Lock™ Product Brochure. Accessed July 2017 from http://smith-blair.com/assetts/pdf/product_brochures/pb_120.pdf.

[28] Stargrip® Series 4000 Product Catalog. Accessed July 2017 from http://www.starpipeproducts.com/pdf/joint%20resraint/submittals/4000_submittal-1702.pdf.

[29] TUF Grip™ Series 2000 Product Catalog. Accessed July 2017 from http://www.tylerunion.com/upl/downloads/catalog/products/tufgrip-2000-tlp-domestic-submittal-ae602d34.pdf.

[30] Rahman, S., and M. Diamond. 2006. Containing Thrust Forces in Municipal Pipelines: An Integral Joint Restraint System for PVC Pressure Pipe. Accessed July 2017 from http://hultec.co.za/downloads/BULLDOG_INTEGRAL_JOINT_RESTRAINT_SYSTEM_S_Rahman.pdf.

[31] LOK-21™ Features and benefits. Accessed July 2017 from http://www.dpcpipe.com/assets/pdf/prod/B2017/9_13.pdf?v=1.

[32] Diamond LOK-21™ Assembly Information. Accessed July 2017 from http://www.dpcpipe.com/assets/pdf/prod/Lok21_AssemblyGuide.pdf.

[33] American Water Works Association. 2002. AWWA Manual M23 – PVC Pipe – Design and Installation. Second Edition.

[34] EBBA IRON Connections. Long Tem Burst Strength of PVC Pipe and the 2000PV. Accessed July 2017 from http://www.ebaa.com/files/pdf/connections/Connections.PV-02.pdf.