Containing Thrust Forces in Municipal Pipelines: An Integral Joint Restraint System for PVC Pressure Pipe

Shah Rahman[1], Michele Diamond[2]

ABSTRACT

Bell-and-spigot gasket-joint thermoplastic pipes such as Polyvinyl Chloride (PVC) are widely used in pressure applications for potable water distribution and transmission, and sewer force mains. The thrust forces which result at joints due to changes in the direction of flow or changes in the diameter size of a pipeline must be counterbalanced to prevent joint separation. This is accomplished using either concrete thrust blocks or joint restraint devices, or a combination of the two. In the past fifteen years, use of joint restraints in PVC pipes has increased significantly while the use of concrete thrust blocks has lowered. In many parts of the US, both are used in tandem. Traditional joint restraints, "lug-type restraints," are external to a piping system and must be fitted on the outside of the joint, exposing the device to in-situ soils, which makes it susceptible to corrosion. Assembly is also time consuming and prone to human error. When using joint restraints only, without thrust blocks, it is usually necessary to also restrain one or more pipe-to-pipe joints on either side of the fitting. The number of pipe joints or the length of pipe to be restrained on either side of the appurtenance can be calculated based on several parameters. The next generation of joint restraints for PVC pipe-to pipe and ductile iron fitting-to- PVC pipe connections are internal to the system. The BullDog™ joint is integral to a PVC pipe bell and is intended for pipe-to-pipe joints, while the fitting-to-pipe restraint is a self-restraining gasket, called the MJ Filed Lok®. These devices are easier to assemble than traditional alternatives and much less susceptible to corrosion. Basic design of joint restraints, outlined in the American Water Works Association (AWWA) *Manual M23*, *PVC Pipe - Design and Installation* are discussed and the importance of ASTM F1674, *Standard Test Method for Joint Restraint Products for Use with PVC Pipe,* in the selection of joint restraint products, is explained. Finally, a case history of a recent installation of the BullDog™ and the MJ Field Lok-PV® at the City of Richardson, Texas is presented.

INTRODUCTION

Hydrostatic and hydrodynamic forces that are unbalanced within a pipeline are referred to as thrust forces. Hydrodynamic thrust forces are ignored as they are insignificant due to the range of pressures and velocities that are characteristic of municipal pressure pipe systems (Moser 2001). In municipal applications such as water transmission and distribution and sewer force mains, thrusts occur whenever there is a change in the direction of flow, as is the case when fittings or other appurtenances are adjoined to a pipe, whenever there are changes in the cross sectional area of the pipeline such as at

[1] Vice President – Technical & Municipal Services, S&B Technical Products/Hultec, 1300 E. Berry St., Fort Worth, TX 76119, USA; tel. (817) 923-3344; fax (817) 923-1339; srahman@sbtechprod.com
[2] Project Engineer, RJN Group, Inc. 12160 Abrams Rd., Ste. 400, Dallas, TX 75243, USA; tel. (972) 437-4300; fax (972) 437-2707; mdiamond@rjn.com

reducers, and during the opening and closing of valves and hydrants. Thrust can cause joint separation in bell-and-spigot push-on joints if it is not counter balanced with an equal and opposite reaction force. This is accomplished using either concrete thrust blocks or joint restraints, or a combination of the two. When joint restraints are used by themselves (without thrust blocks) at fitting-to-pipe connections, it is usually necessary to also restrain one or more pipe-to-pipe joints on either side of the fitting. The number of pipe joints or the length of pipe to be restrained on either side of the appurtenance can be calculated based on several parameters.

Both thrust blocks and traditional joint restraints are external to a pipe system and pose several disadvantages. Recently, devices have been introduced for fitting-to-pipe and pipe-to-pipe restraint of PVC lines which are internal to the system. The BullDog™ joint restraint system is integral to the bell of a PVC pressure pipe and is incorporated into the pipe during manufacture. It is used to restrain PVC pipe-to-pipe joints. The MJ Field Lok-PV® is a self-restraining gasket that incorporates a serrated grip ring within a mechanical joint gasket and is designed for restraining ductile iron fitting-to- PVC pipe joints.

MEANS OF CONTAINING THRUST

Concrete Thrust Blocks: Thrust blocks are masses of concrete that transfer and distribute the thrust forces at a point in the pipeline to the surrounding soil structure, preventing the separation of any unrestrained joints. The soil in front of and below a thrust block must be able to resist the thrust in the pipeline using horizontal normal stresses on the active and passive faces of the concrete block, vertical normal stresses on the base of the concrete block, shear stresses on the base of the concrete block, and the weight of the concrete block and soil above it (Thorley et al. 1994), figure 1.

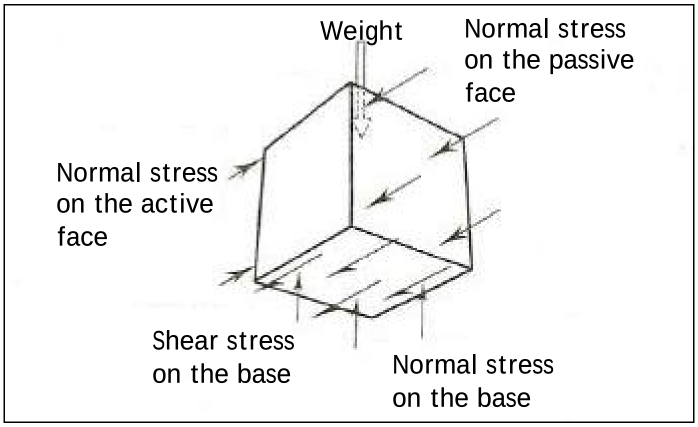

Figure 1: Soil Structure Resistance Components on a Concrete Thrust Block (Thorley et al. 1994)

The bearing surface area of a thrust block is the most critical factor in its design as this area distributes and transfers the resultant thrust forces to the soil mass adjacent to the fitting. The size and shape of a block is determined by the forces to be restrained, the size and type of the pipe fitting or appurtenance, and in-situ soil strength and conditions.

While corrosion resistance is an inherent advantage of non-reinforced concrete thrust blocks, there are several issues that present concerns:

1) Actual replication of a thrust block in the field per the engineer's design – experience shows that most Contractors simply pour a mass of concrete in the location indicated in the plans and rarely ever use forms to replicate the dimensions of the thrust block specified by the engineer.
2) Soil-bearing capability of in-situ soils – the soil must be able to withstand the weight of the mass of concrete without settlement in the long run, so weak soils may not be the ideal location for the placement of a thrust block. Settlement of a block would mean settlement of the pipeline and appurtenances with it. This usually leads to disastrous consequences.
3) Availability of sufficient space for the block(s) - a certain amount of space is required to accommodate a block; this is a particular challenge in developed urban environments.
4) Time required for the concrete to dry before the line can be backfilled – this is usually 24 hours so until the block has dried, the contractor can neither backfill nor hydro-test the installed line.
5) Future excavations in the vicinity of the block – depending on the size of the block, future excavations may be limited as the soil around and underneath the thrust block can not be disturbed.

Joint Restraints: Since their introduction more than forty years ago for use with ductile iron pipes, the acceptance and use of joint restraint devices has steadily increased. PVC joint restraints have been widely used for the last fifteen years. It is estimated that more than half of all municipalities in the US use them today. Figures 2 through 4 show various available joint restraints for PVC systems, most notably the wedge-types and the serrated-types. While joint restraints eliminate many of the problems associated with thrust blocks, they too have their share of disadvantages:

1) They are metallic and external to the pipeline and must be installed on the outside of a pipe joint --- this makes them susceptible to corrosion.
2) Installation is time consuming and subject to human error --- the tightening of nuts and bolts and wedges is an arduous and time consuming task, leading to higher costs for the Contractor as well as the Municipality.
3) The vast majority of joint restraints in North America do not meet the requirements of ASTM F1674, *Standard Test Method for Joint Restraint Products for Use with PVC Pipe*. Devices that do cost double. Most products meet UNI-B-13, which was a less stringent standard from the Uni-Bell PVC Pipe Association but that document was withdrawn in 1996 after publication of ASTM F1674 and is no longer in publication.
4) Devices that use wedges, figure 2, 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. Ultimately, this can undermine the structural

integrity of the pipe and lead to failure or leakage at joints. Uneven tightening of nuts and bolts also leads to joint leakage.

5) Generally, serrated-type products, figure 3, 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.

Figure 2: Wedge-type Joint Restraint for Pipe-to-Pipe and Fitting-to-Pipe Joints (Star Pipe Products 2005, EBAA Iron 2005)

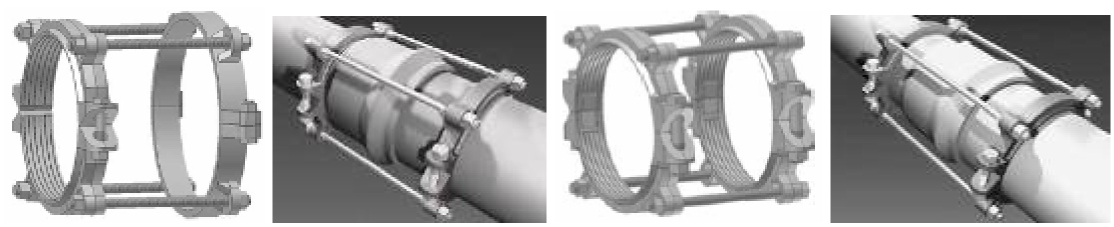

Figure 3: Serrated and Plain Split Ring and Double Serrated Split Ring Pipe-to-Pipe Joint Restraints (EBAA Iron 2005)

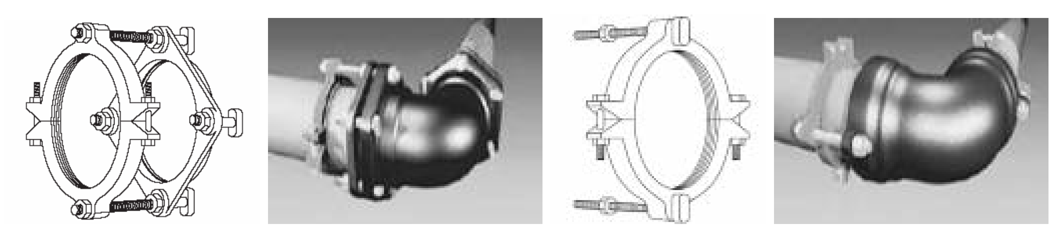

Figure 4: Serrated-type PVC Pipe-to-Ductile Iron Mechanical Joint Fitting and to DI Fitting with Restraining Ear (EBAA Iron, 2005, Star Pipe Products 2005)

JOINT RESTRAINT DESIGN THEORY

To properly design a pressure pipeline, it is necessary to understand the basic theory of thrusts and variables and parameters that counterbalance it. While a detailed explanation for design purposes is outside the scope of this paper, the American Water Works Association (AWWA) Manual of Water Supply Practices, M23, *PVC Pipe – Design and*

Installation should be consulted for reference. Much of the discussion below is obtained from M23.

Figure 5 is used to explain forces in a horizontal bend. The total thrust (or unbalanced forces) at the bend can be described by:

$$\mathbf{T = 2PA \sin \Delta/2} \qquad (1)$$

Where, **T** = resultant thrust force, lb
P = internal pressure, psi
Δ **=** angle of deflection, degrees
A = internal area (based on diameter of sealing element), in^2
The internal area A is based on the maximum inside diameter of the sealing element, the gasket. In the case of joints in a pipeline where the gasket is seated within the bell, the internal area A is based on the pipe outside diameter at the joint.

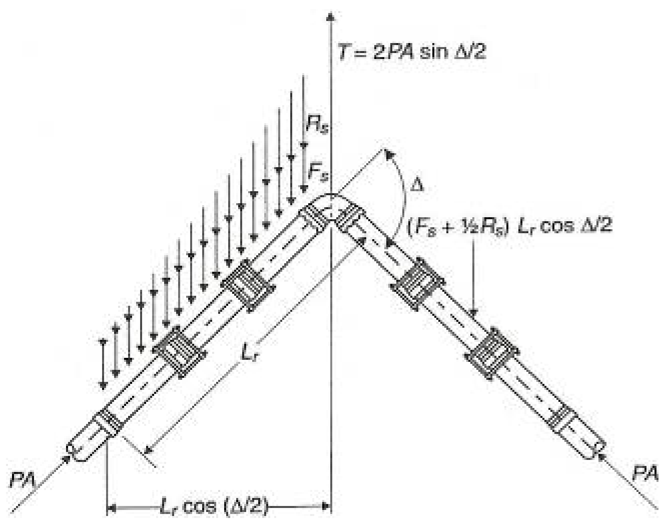

Figure 5: Resultant Frictional and Passive Pressure Forces on a Pipe Bend (*AWWA M23, PVC Pipe – Design and Installation*)

In straight lengths of a buried pipeline, thrust forces at any given joint is counterbalanced by equal and opposite reactions from adjacent joints. Frictional resistance between the pipe and surrounding soils also provides some counter force to the thrusts. However, when the direction of flow changes as in the horizontal bend shown in figure 5, forces on adjacent joints do not balance each other but combine to create a resultant force that tends to push the bend away from the pipeline. The size of this thrust force is directly proportional to the angle Δ.

When using thrust restraints only, without concrete blocks, the pipeline behaves as its own thrust block, transferring the resultant thrust forces to the surrounding soils by itself. In a properly designed pipeline using joint restraints only, the following parameters balance thrust forces:

1) bearing strength of the soil, $R_{s,}$ and
2) frictional resistance between the pipe and soil, F_s

In the example shown in figure 5, resistance to thrust is generated by the passive resistance of the soil as the fitting tries to move, developing resistance in the same way as a concrete thrust block. Additionally, friction between the pipe and the soil generates resistance to joint separation.

L_r is the length of pipe along which resistance is provided by the passive resistance, R_s, and soil friction resistance, F_s. This is the length of pipe which has to be restrained. The number of joints to be restrained is calculated by dividing L_r by the length of a segment of pipe. L_r will vary by the size of the pipe, the soil type, trench type, depth of bury, maximum anticipated pressures in the line, and a number of other parameters. In some instances, less than one full length of pipe will have to be restrained, so it suffices to only restrain the fitting-to-pipe connections on both ends of the fitting.

$$\mathbf{L_r = \frac{PA \tan(\Delta/2)\,(SF)}{F_s + 1/2Rs}} \qquad (2)$$

Where, $\mathbf{L_r}$ = Length of the pipeline to be restrained
SF = factor of safety
$\mathbf{F_s}$ = pipe to soil friction, lb/ft
$\mathbf{R_s}$ = bearing resistance of soil along pipe, lb/ft

Details on the calculation of both F_s and R_s can be found in AWWA Manual of Water Supply Practices, M23.

TECHNICAL STANDARDS

Standards for the performance of joint restraint products are there to ensure that neither the short term nor the long term hydrostatic or structural capabilities of the pipe are lowered by the thrust restraint devices being used with them. 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*. The standard required three tests to prove the performance of a restraint device when attached to a PVC pipe joint:

1) Burst pressure test to verify the effect of a joint restraint on the short term strength of the pipe,
2) 1000-hour sustained pressure test to ensure the long term strength of the pipe fitted with the restraint, and
3) cyclic strength of the pipe and restraint through the one million-cycle test.

There were two key things that this standard did not require of manufacturers --- it 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. Essentially, a manufacturer could run the tests on one particular size and claim that other pressure rated devices of that size met UNI-B-13. Or, they could run the tests on one specific pressure rated device and claim that all other sizes of that pressure rating met the requirements of UNI-B-13. This standard, though published by a trade association and not a formal standardization organization such as ASTM, became the only existing formal performance guide for PVC pipe thrust restraint manufacturers and municipal engineers for almost a decade. UNI-B-13 was updated in 1992 and 1994.

In 1996, UNI-B-13 was utilized to write a more stringent standard: ASTM F1674, *Standard Test Method for Joint Restraint Products for Use with PVC Pipe*. In that same year, UNI-B-13 was officially withdrawn and publication ceased. All manufacturers were given a two year period to change markings on their joint restraint product lines and gain compliance with the new ASTM standard. Unfortunately, ten years later, there continues to be products manufactured to the UNI-B-13 standard which are still accepted at numerous municipalities throughout North America. Two major additional points added to ASTM F1674 made it more rigorous than UNI-B-13:

1. Every size and every pressure rating of a joint restraint product line must be able to pass the three tests (manufacturers can no longer extend standard compliance to all sizes and pressure rated products simply by passing the tests for one size and/or one pressure rating)
2. The product must be of the same pressure class as the pipe that it is going to restrain

It is important for specifications engineers to understand these differences. The M23 Manual of Water Supply Practices 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" (AWWA 2002).

PRODUCT INNOVATIONS

To overcome various problems associated with concrete thrust blocks and lug-type external joint restraints, research and development has given rise to a new generation of joint restraint devices for pipes and appurtenances that alleviate time consuming installation processes as well as corrosion. Two of these products are discussed below.

BullDog™ Integral Joint Restraint System: This joint is designed for pipe-to-pipe connections and meets all the requirements of ASTM F1674. The current version is designed for integration into pipes manufactured to AWWA C900 standard, diameters 4-inch (100 mm) through 12-inch (300 mm). The mechanism consists of a metal casing that sits adjacent to the Rieber gasket[3] in the bell; the casing is molded into the "raceway" of the bell during pipe belling. A C-shaped grip-ring with several rows of uni-directional serrations is manually inserted into the casing after the pipe has been hydro-tested following belling. Both casing and grip rings are made of ductile iron. When the pipe

[3] See Session 8A technical paper titled PVC Pipe Jointing: The Rieber System in North America, by Rahman, S. and Bird, W.

arrives at a jobsite, the pipe bell already contains the casing with the grip ring inserted in it. Figure 6 is a cross-sectional drawing of the components of the joint.
`

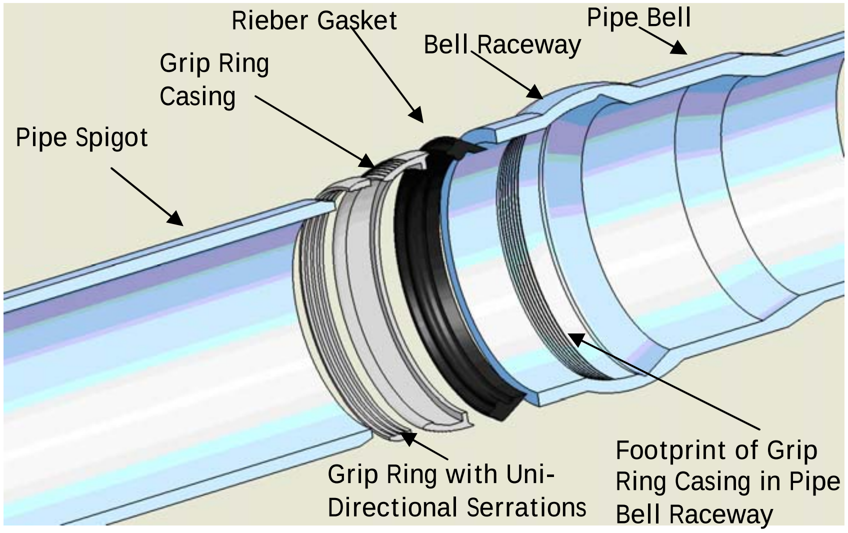

Figure 6: BullDog™ Restrained Joint Pipe Components

In the field, the joint is assembled like a regular push-on joint --- the spigot is pushed into the bell up to the insertion mark. Figure 7 shows a cross section of the joint after assembly.

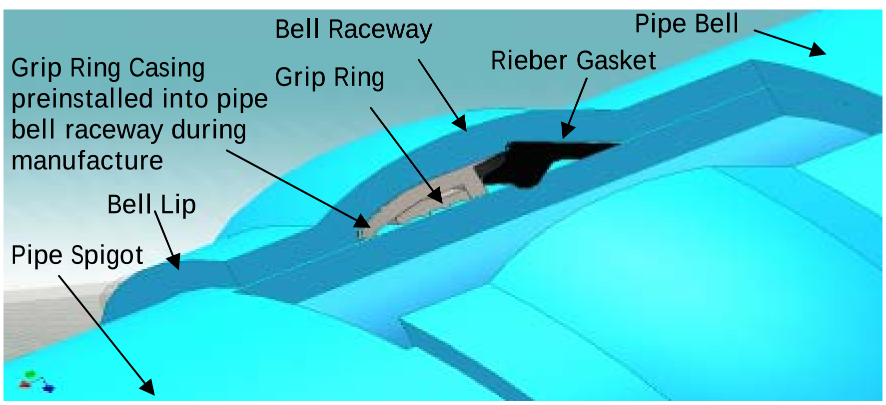

Figure 7: Cross Section of Installed BullDog™ Joint

The uni-directional serrations on the grip ring only allow entry of the spigot through it but do not allow its withdrawal. Any opposing movement of the spigot once it is inserted through the grip-ring causes the serrations in the ring to “bite” circumferentially and uniformly onto the spigot wall. The grip ring is designed to be 10/1000 of an inch smaller than the outside-diameter of the adjoining spigot; this ensures a snug fit as the spigot is pushed through the ring. Once the pipe is put into service, expansion of the spigot and its backward movement as a result o 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% of the wall thickness (per AWWA). Sealing of the joint is carried out by the Rieber gasket. The gasket also prevents the fluid within the pipeline from coming into contact with the restraint mechanism (grip ring and casing).

Finite Element Analysis: Results of finite element analysis (FEA) to measure stress concentrations in the pipe bell raceway, simulated for a 12-inch diameter joint is shown in figure 8 (Quesada, 2006). Analysis is based on a nonlinear 2D computer model simulation considering the high strain and contact with friction. The rubber gasket is not shown in the analysis because it is considered only as a sealing element and will not have any effect on stresses in the joint.

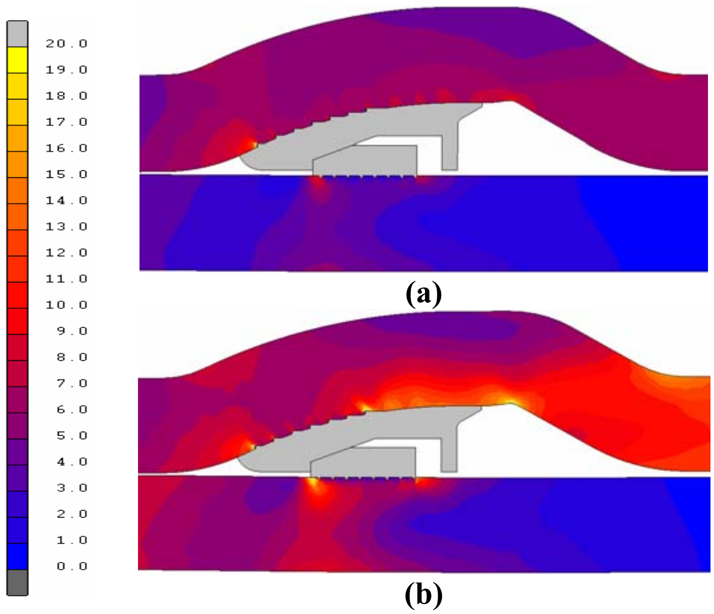

Figure 8: Von Mises Stresses at 122 psi; Stresses at 244 psi (*Quesada, 2006*)

Stresses in the pipe are measured at an interval pressure of 122 psi (0.84 MPa) and 244 psi (1.68 MPa), figure 8a and 8b. The simulation is such that internal pressure generates traction between the spigot and bell. At 122 psi, this is a mix of residual stress from the bell contraction against the casing and stress from fluid pressure traction. Spots of the bell showing traces of an orange color, figure 8a, indicate higher stress concentrations at those points. At 244 psi, figure 8b, stresses generated from fluid pressure and traction dominate. Expansion of the bell at these high pressures cause residual stresses between the grip-ring casing and pipe bell raceway vanish. Some stress concentration can be observed around the serrations on the casing and the grip ring. This stress concentration tends to even out and to re-distribute to the other serrations. The high stress concentrations in the radius on top of the gasket result due to the thinner walls in this area.

The major advantages of the integral joint over traditional external restraints include:

1) Installation costs are negligible since there are no nuts and bolts or wedges to tighten. It is no different from a regular gasket-joint PVC pipe.
2) Human errors such as over-tightening or under-tightening of nuts and bolts or wedges eliminate the possibility of joint leakage or point loading of the pipe wall.
3) The possibility of corrosion of the restraint mechanism is dramatically reduced. Casing and grip ring are coated with a water-based rubber toughed phenolic resin. If the metallic casing is exposed to ground water or soils entering through the gap between the bell-lip and the spigot, protection is provided by the coating.
4) The joint meets all requirements of ASTM F1674.

MJ Field Lok-PV® Self Restraining Gasket for Mechanical Joints: This self restraining gasket, figure 9a, is another innovation that has been available on the market for over a year. At the time of the writing of this paper, more than 70,000 units had been sold. It is specifically designed for use in mechanical joints (DI fitting-to-PVC pipe joints), in lieu of the traditional external restraints shown in figures 2 and 4.

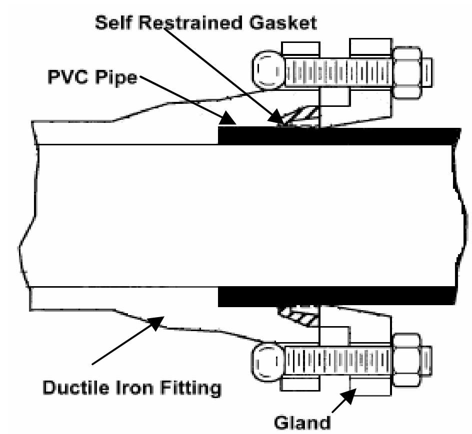

Figure 9a, b: Self-restraining Gasket; Cross-Sectional View After Installation

This restraining device has two components – a serrated C-ring, similar to the one discussed in the previous section, and a rubber gasket. The C-ring is inserted into a groove on the inside wall of the rubber gasket, forming a snug fit between the rubber and the ring. Installation involves inserting the self-restraining gasket into the mouth of a ductile iron mechanical fitting. The adjoining piece of PVC pipe is fitted with a gland, and then inserted through the ring and into the mouth of the mechanical fitting. Just like the BullDog™, the serrations on the ring are uni-directional, 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. Tightening of the flange and the gland cause the gasket to become compressed, forming a seal at the joint, and simultaneously, the serrations embed themselves into the outside wall of the pipe, figure 9b.

This device has passed the Underwriter Laboratories (UL) certification and is currently available in 4-inch (100 mm) through 12-inch (300 mm) sizes. The MJ Field Lok-PV®

eliminates the need to use lug-type restraints such as those shown in figures 2 and 4. It is easier to assemble and does not cause point loading as is the case with wedge-type restraints.

CITY OF MCKINNEY, TX CASE HISTORY

The first PVC pressure pipe with BullDog™ joint restraint systems was installed in late August 2006 at the City of McKinney, Texas, as part of the City's annual program to replace substandard water mains. Also utilized in this project was the MJ Field Lok-PV® self restraining gasket for mechanical joints. McKinney is located approximately 30 miles north of Dallas, has a population of approximately 100,000 people, and is the fastest growing city in North America. In a 2005 Dallas Morning News survey of retail growth in the Dallas-Ft. Worth area (which has more than 50 cities), McKinney placed second in retail construction (454,000 sq. ft.) and highest retail occupancy levels (98.3 percent). McKinney was the only city to place in the top five in each category.[4] The City's consulting engineer, RJN Group, Inc., based in Dallas, first brought the joint restraint products to the City's attention as a viable option for use on the Substandard Water and Sewer Main Replacement Phase III Project. The Contractor on the job was RKM Utility Services, also based in Dallas.

Project Details: Approximately 1,110 linear feet of 8-inch PVC was designed to replace an existing 6-inch cast iron pipe which served a residential community of 18 homes. Due to customer complaints, the City performed tests that identified red water in the system. The existing cast iron pipe had been corroding; therefore the City had to move the rehabilitation of this line to its priority list. To further hasten the priority of the rehab, the Public Works department had already begun street repaving in the area and wanted to move to Finch St next. So not to have to patch up the street a second time, nor delay the Streets Department, the City decided to move quickly onto this water main replacement.

The 8-inch water main was designed to connect at the intersection of Graves and Bonner with an 8-inch tee, then to the west on Bonner towards another intersection at Finch St. where it branches off both to the north and south. Each end of the north-south branches were designed to connect to the existing 6-inch main to complete the loop. To accomplish this without disturbing the current service of the 6-inch line, the alignment of the new 8-inch line was offset 3 feet from the existing line, and at each tie-in, two 45 degree bends and a reducer was installed to connect the 8-inch back to the 6-inch line, figure 10.

Also, near the bends and reducers, tee connections were utilized to tie in the existing perpendicular lines connecting into the main, as well as fire hydrants. With so many fittings located at these reducing points, the need for restraints to balance the resultant thrust force became necessary. Although the pressure in the pipes during normal operations is only expected to be 75 psi, small diameter PVC pressure pipe is not heavy enough to counter balance all of these forces loaded in the areas and therefore needed to be restrained.

[4] City of McKinney website, www. mckinneytexas.org

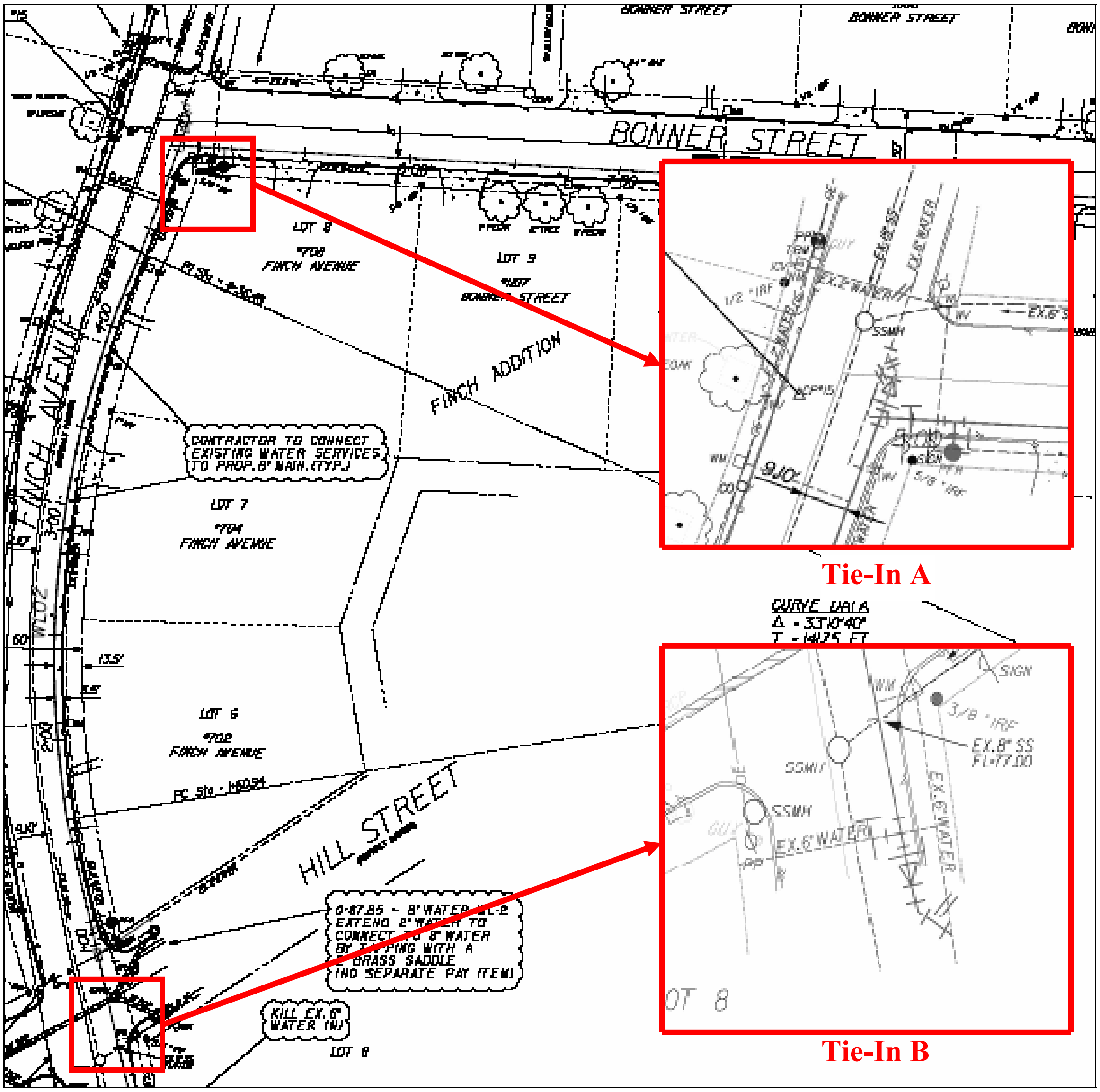

Figure 10: Plan Drawing of Bonner-Finch Project

In keeping with the practices of the City of McKinney, all joints exposed to thrust forces on this project were originally designed to utilize both joint restraints and concrete thrust blocks. In the DFW Metroplex, Contractors usually use joint restraints only at the fitting-to-pipe connections on both sides of a fitting, and then pour a block of concrete behind each fitting. While this eliminates the need to utilize pipe-to-pipe joint restraints, all the disadvantages of concrete thrust blocks accompany the process. Furthermore, the lug-type joint restraints also present their set of disadvantages during installation. In a nut shell, the methods are time- consuming, subject to human error and add to the overall cost of a project. Once engineers at RJN became aware of the BullDog™ and MJ Field Lok-PV® restraints, it was decided, after consultation with the City, that these products would be used at the two tie-in's in lieu of lug-type restraints and concrete thrust blocks.

This would be the first time that the BullDog™ PVC pipe-to-pipe restraint would be used.

Using the principles of designing a system with joint restraints only, discussed previously in this paper, the lengths (or number of joints) of pipe to be restrained, L_r, beyond an appurtenance-to-pipe connection were calculated which eliminated the use of concrete thrust blocks altogether. MJ Field Lok-PV® self restraining mechanical gaskets were used in lieu of the lug-type restraints at appurtenance-to-pipe joints and BullDog™ joints were used at pipe-to-pipe joints beyond the appurtenance-to-pipe connections. Figure 11 shows assembly of tie-in A, while figure 12 shows tie-in B. Joint types that were restrained included fitting-to-pipe, valve-to-pipe, reducer-to-pipe, and pipe-to-pipe.

Figure 11: Joint Restraints at Tie-In A

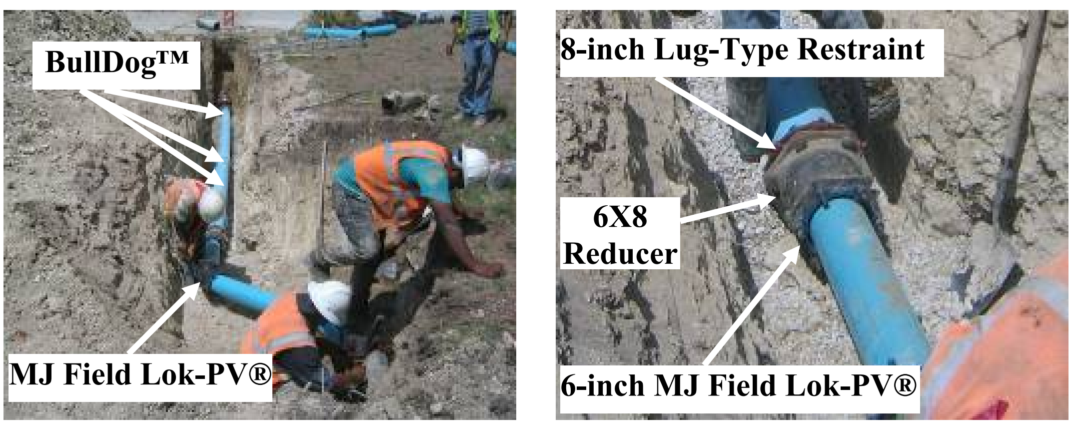

Figure 12: Joint Restraints at Tie-In B

In tie-in B, the Contractor used 8-inch lug-type joint restraints (Ford Meter Box – Uni-Flange®) for 8-inch appurtenance-to-pipe connections, and MJ Field Lok-PV® for all 6-inch appurtenance-to-pipe connections. This afforded an opportunity to directly compare installations of the self restraining gasket versus the lug-type restraints. Clearly, it was advantageous to use the former because it eliminated point loading of the pipe by wedges, and also took less time since there were no wedges to torque. The amount of concrete saved at the conclusion of the construction of the two tie-in's was apparent, figure 13. The savings realized in construction time with the BullDog™ were tremendous. In the absence of this product, it would have taken approximately 45 minutes per joint to install lug-type pipe-to-pipe restraints. The absence of concrete thrust blocks eliminated the need for the blocks to dry before the system could be tested and put into service. Consequently, once the tie-in's were completed, the system was immediately put into service as the remainder of the newly installed 8-inch PVC line was previously chlorinated and passed water-quality testing.

Figure 13: Concrete at the Job Site that was Unused for Thrust Blocks

CONCLUSION

The common problems associated with concrete thrust blocks can be eliminated through the design of systems that use only joint restraints. Traditional lug-type joint restraints, however, are external to pipe joints and are prone to corrosion. It is also labor intensive to assemble them and human error can cause both leakage and failure of the pipe wall through point loading of wedges. The vast majority of traditional joint restraint devices in the market today also do not meet the requirements of ASTM F 1674. Even though they claim to meet UNI-B-13, this document is no longer in publication and was withdrawn in 1996. Municipalities should update their materials specifications to reflect this fact and also become more selective in their choice of allowable joint restraint devices. The BullDog™ and the MJ Field Lok-PV® make up the "next generation" of joint restraint devices, effectively eliminating much of the disadvantages associated with both traditional joint restraints and thrust blocks. The installation and performance of both products at the City of McKinney proved them to be worthy additions to the waterworks industry. The saving realized in installation time was advantageous to the Contractor.

References

American Water Works Association (2002), *Manual of Water Supply Practices M23: PVC Pipe – Design and Installation*, Denver, CO, pp. 42-52.

EBAA Iron, Inc. (2005), product literature

Moser, A. (2001), *Buried Pipe Design*, McGraw-Hill.

Quesada, G. (2006), *Analysis Report – Effect of Dimensional Variations in 12-inch BullDog Joint*, Spoerl & Asociados, San Jose, Costa Rica.

Rahman, S., and R. Watkins (2005), *Longitudinal Mechanics of Buried Pipe: Analysis of Thermoplastic Pipes of Various Joint Types*, Proc. Pipelines 2005: Optimizing Pipeline Design, Operations, and Maintenance in Today's Economy, C. Vipulanandan and R. Ortega, Eds., American Society of Civil Engineers, Reston, VA, pp. 1101-1116.

Star Pipe Products (2005), product literature

Thorley, A., and J. Atkinson (1994), *Guide to the Design of Thrust Blocks for Buried Pressure Pipelines*, Report 128, Construction Industry Research and Information Association, Westminster, London, pp.16-17.