Internal Fusion Bead Hydraulics

The unique joining technology employed on Fusible PVC™ pipe systems creates a 'bead' on the inside and outside of the pipe cross-section at the location of the thermal butt-fusion joint. This bead is typical for any butt fused thermoplastic and projects into the flow path on the interior of the pipe. Underground Solutions (UGSI) is often asked about the effect a bead has on the flow characteristics of a pipeline. This technical bulletin will discuss these effects and the recommendation for leaving the internal bead in place in most cases.

Executive Summary

Pressure and flow loss for a beaded Fusible PVC™ joint is comparable to that of other conventional PVC joining technologies, including bell and spigot type joints.

By studying the minor losses incurred at the joints of PVC piping systems using common hydraulic flow theories, it is shown that the industry accepted and advocated design methodology of using a 'c' factor of 150 for PVC piping systems (Hazen-Williams method for computing system headloss), indeed is conservative enough to cover the actual minor losses of a system at the joints of the system. This fact holds true for bell and spigot systems, as well as Fusible PVC™ systems. In order to make a qualitative and rational judgment on this issue, three common pipe sizes were used; 8 inch, 16 inch, and 24 inch DR 25 sized PVC pipe; and three common velocities reflecting a normal range of the operation of pressure water and wastewater systems were chosen; 2 feet per second (fps), 5 fps, and 10 fps. Minor and major losses were also quantified for three different types of joints; common bell and spigot joints, Fusible PVC™ fusion bead joints, and Fusible PVC™ fusion bead joints that have had the bead removed after the assembly of the joint. The results of these three types of PVC systems were quantified and compared to a blanket design using a 'c' factor of 150, which is commensurate with current industry practice.

The results of this study verify the concept that a 'c' factor of 150, used in the design of PVC piping systems, including both bell and spigot and Fusible PVC™ joining technology, is adequate and conservative enough to predict the pressure and flow loss incurred at the joints of all of these systems.

Hydraulic Analysis

Non-Pressure Flow

In non-pressure applications, such as sanitary sewer or storm water collection systems, the bead will not detrimentally influence the flow capacities of the pipeline, as we will discuss in more detail below. However, during times of low flow, the ability for the bead to cause pooling behind itself, and subsequent solids deposition, can be a valid concern. It is only for these types of non-pressure installations that the need to remove the inside bead of fusion joints is considered.

Pressure Flow

In pressure flow situations, such as potable water distribution systems or force main applications, the internal bead has no adverse effects on the flow characteristics of the pipeline. Several industry standard assumptions and the Hazen-Williams methodology for pressurized fluid flow will be employed through common PVC pipe joint configurations and systems to support this position.

Three joint configurations are presented to show the impact, or lack thereof, across a range of diameter sizes and operating parameters. Three types of joint configurations will be addressed; a fusion joint with the bead left intact, a fusion joint with the bead removed, and a traditional bell and spigot joint. These three joint configurations will be evaluated per three varying fluid velocities and subsequent flow volumes; 2 feet per second (fps) flow, 5 fps flow, and 10 fps flow. Finally, each joint configuration will be evaluated for three separate diameter and thickness sizes; 8 inch Ductile Iron Pipe Size (DIPS) DR 25, 16 inch DIPS DR 25, and 24 inch DIPS DR 25.

Fusible PVC™ pipe has the same PVC plastic physical properties as conventional bell and spigot systems. The only difference is the joining technology employed by each. The friction coefficient, or ‘c’ factor, utilized in the Hazen-Williams predictive flow model for pressure flow in pipes is identical for both systems. However, the joints for each system, along with the flow path anomaly that they represent are different. **Figure 1** below shows a typical cross-section of an 8 inch DIPS DR 25, Fusible PVC interior bead at a fusion joint, **Figure 2** shows a typical cross-section of an 8 inch DIPS DR 25, Fusible PVC interior bead REMOVED at a fusion joint, while **Figure 3** shows a typical cross-section of an 8 inch DIPS DR 25 bell and spigot joint. Since the pipe systems are identical, except at the joints, this is where the focus of defining the minor losses incurred at each type of joint has been concentrated.

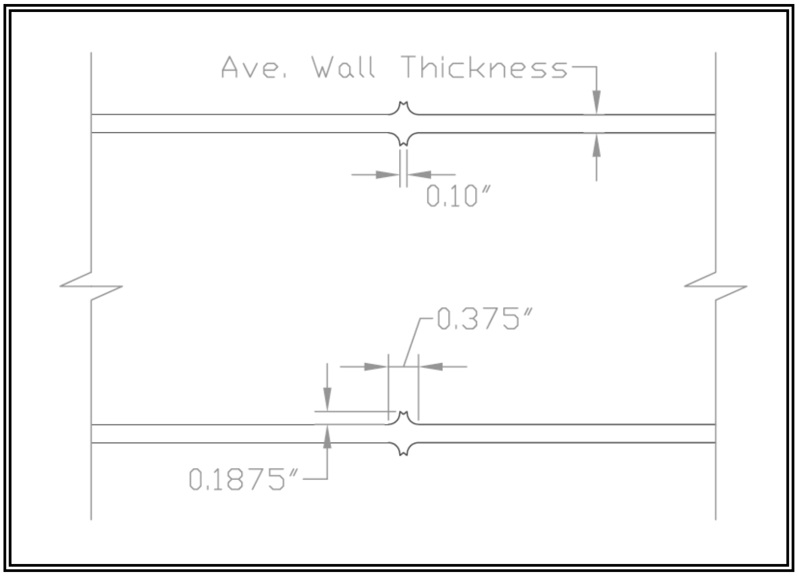

Figure 1 – Typical 8” DR 25 C900 (DIPS) Assembled Fusible PVC™ Fusion Joint

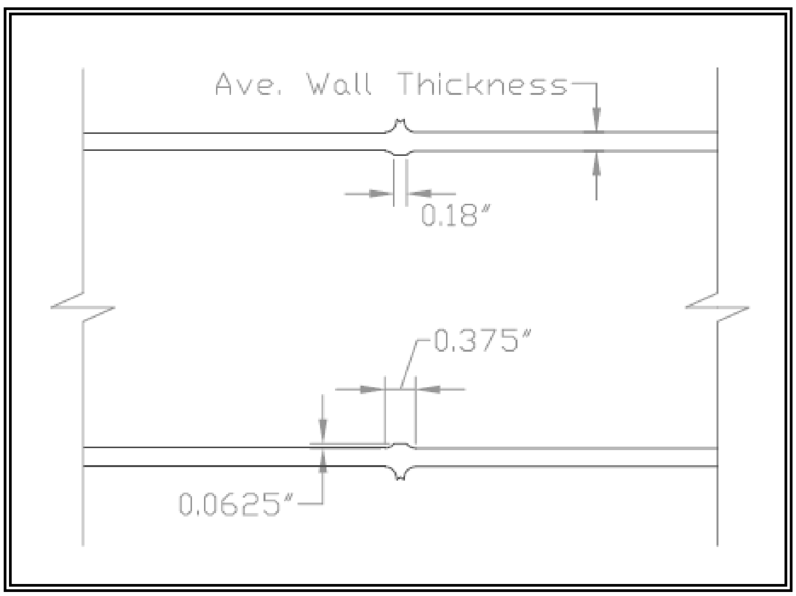

Figure 2 – Typical 8” DR 25 C900 (DIPS) Assembled Fusible PVC™ Fusion Joint with the Bead Removed

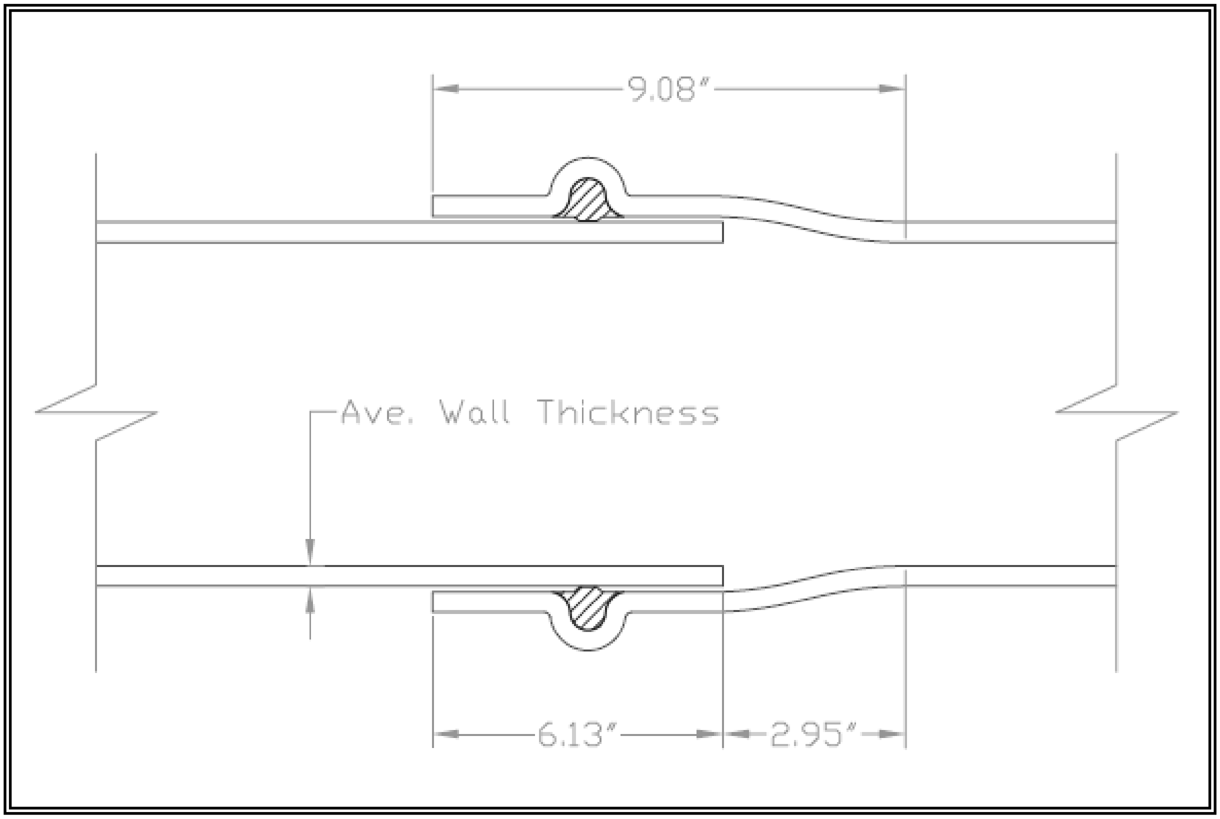

Figure 3 – Typical 8" DR 25 C900 (DIPS) Assembled Bell and Spigot Joint
Joint Characteristics

The fusion bead does not grow linearly in dimensionality along with the pipe diameter, so the dimensionality of the bead will vary according to pipe size. Similarly, the joint configurations that contain the fusion bead removed, as well as the bell and spigot joints will also be reflective of this fact. The flow characteristics of the bell and spigot joint, and that of bell and spigot piping in general are taken from the Uni-bell Handbook of PVC Pipe[2].

In order to simplify the hydraulics associated with the fusion bead, no fusion bead, and the bell and spigot joint, the following has been assumed[1,2].

For the internal bead at the fusion joint:

1.) Minor Losses will include an entry and exit loss going from the pipe inner diameter (ID) to the constricted flow area of the fusion bead and back to the pipe ID.
2.) Additional head loss will be attained through the constricted area of the fusion bead.
3.) A “C” value of 155 is used for the plastic, as the minimum recommended lab value, determined for PVC plastic.

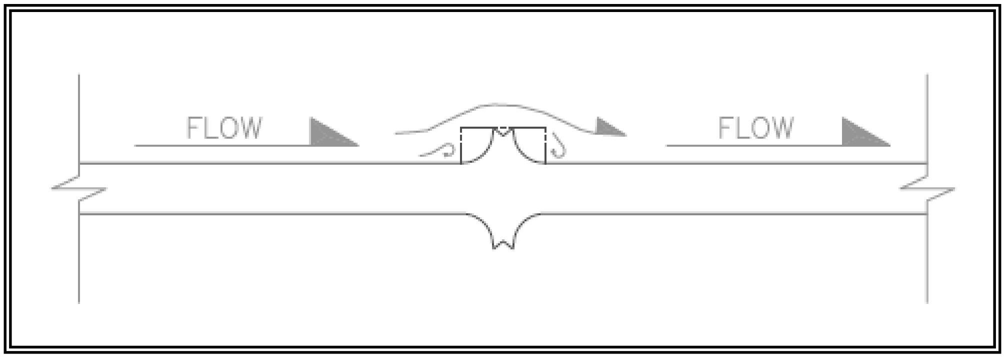

Figure 4 – Hydraulic Representation of Fusion Bead Joint

For the internal bead REMOVED at the fusion joint:

4.) Minor Losses will include an entry and exit loss going from the pipe inner diameter (ID) to the constricted flow area of the fusion bead removal area and back to the pipe ID.
5.) Additional head loss will be attained through the slightly constricted area of where the fusion bead was removed.
6.) A “C” value of 155 is used for the plastic, as the minimum recommended lab value, determined for PVC plastic.

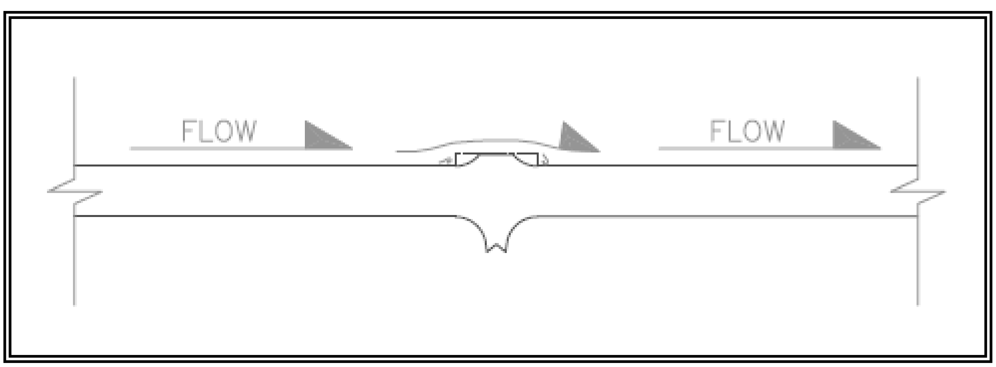

Figure 5 – Hydraulic Representation of Fusion Joint with Bead Removed

For the bell and spigot joint:

1.) Minor losses will include an exit loss from the pipe ID to the bell ID.
2.) Minor losses will also include an entry loss going from the bell ID to the constricted flow area to the pipe ID. The loss coefficient assigned to this entry loss is adjusted per the smooth transition from bell ID to pipe ID, by modeling as a conical diffuser.
3.) Again, a "C" value of 155 is used for the plastic, as the minimum recommended lab value, determined for PVC plastic.

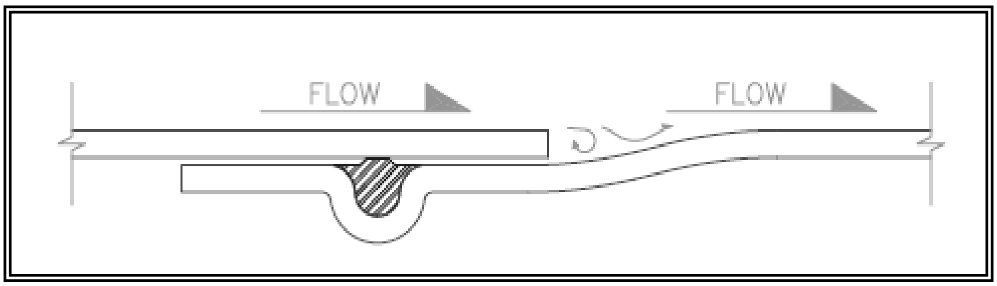

Figure 6 – Hydraulic Representation of Bell and Spigot Joint

Flow Model Comparison

Minor losses of a system are a function of the velocity head of the system. The higher the velocity head, the greater the system losses incurred. With this in mind, a velocity and subsequent flow of a pipe system was chosen at a range befitting the operating parameters of a water distribution system or a force main application. A velocity profile was chosen of 2 fps, 5 fps, and 10 fps to illustrate the difference between velocity heads in the various systems modeled. Also, the overall pipe system, not just the joints, was given a length of 1000 linear feet for comparative purposes. Finally, all of these results were qualified against the standard design practice of the industry and that as advocated by the Uni-Bell Handbook of PVC Pipe, which is to design the system with a c-value of 150, to conservatively account for the minor losses associated with pipe joinery. The comparative results as indicated below, are in reference to an 'ideal' system which includes the flow and headloss attained by a system with no joints, and a 'C'value of 155.

One thing to note for these system comparisons are the number of the joints per system. Fusible PVC with nominal pipe lengths of 40 feet will have roughly 25 joints per 1000 feet of pipe system, while bell and spigot piping, with nominal pipe lengths of 20 feet will have roughly 50 joints per 1000 feet of pipe system. This can be a significant contributing factor to overall system losses.

Total Headloss and Flow-loss Results for the 8 inch DIPS DR 25 calculations:

	Velocity = 2 fps	Velocity = 5 fps	Velocity = 10 fps
Fusion Bead Removed	H_L = <0.001	H_L = 0.002	H_L = 0.010
	Q_L = 0.047	Q_L = 0.134	Q_L = 0.296
Fusion Bead	H_L = 0.002	H_L = 0.011	H_L = 0.044
	Q_L = 0.218	Q_L = 0.622	Q_L = 1.375
Bell and Spigot	H_L = 0.026	H_L = 0.156	H_L = 0.601
	Q_L = 3.225	Q_L = 8.734	Q_L = 18.614
C Value of 150 for Entire Pipeline	H_L = 0.093	H_L = 0.507	H_L = 1.828
	Q_L = 11.230	Q_L = 28.058	Q_L = 56.077

H_L = Headloss, in feet of water, as compared to pipeline with no joints at a 'c' value of 155, which for 2 fps is 1.5 ft (+/-), for 5 fps is 8.1 ft (+/-), and for 10 fps is 29.2 ft (+/-).
Q_L = Flowloss, in gallons per minute, as compared to a pipeline with no joints at a 'c' value of 155, which for 2 fps is 337 gpm (+/-), for 5 fps is 843 gpm (+/-), and for 10 fps is 1,684 gpm (+/-).

Table 1 – 8 Inch Diameter

Total Headloss and Flow-loss Results for the 16 inch DIPS DR 25 calculations:

	Velocity = 2 fps	Velocity = 5 fps	Velocity = 10 fps
Fusion Bead Removed	H_L = <0.001	H_L = 0.001	H_L = 0.004
	Q_L = 0.171	Q_L = 0.487	Q_L = 1.076
Fusion Bead	H_L = 0.001	H_L = 0.007	H_L = 0.030
	Q_L = 1.153	Q_L = 3.293	Q_L = 7.288
Bell and Spigot	H_L = 0.023	H_L = 0.138	H_L = 0.826
	Q_L = 22.147	Q_L = 60.658	Q_L = 130.330
C Value of 150 for Entire Pipeline	H_L = 0.043	H_L = 0.237	H_L = 0.853
	Q_L = 41.536	Q_L = 103.744	Q_L = 207.344

H_L = Headloss, in feet of water, as compared to pipeline with no joints at a 'c' value of 155, which for 2 fps is 0.7 ft (+/-), for 5 fps is 3.8 ft (+/-), and for 10 fps is 13.6 ft (+/-).
Q_L = Flowloss, in gallons per minute, as compared to a pipeline with no joints at a 'c' value of 155, which for 2 fps is 1,247 gpm (+/-), for 5 fps is 3,115 gpm (+/-), and for 10 fps is 6,226 gpm (+/-).

Table 2 – 16 Inch Diameter

Total Headloss and Flow-loss Results for the 24 inch DIPS DR 25 calculations:

	Velocity = 2 fps	Velocity = 5 fps	Velocity = 10 fps
Fusion Bead Removed	H_L = <0.001	H_L = <0.001	H_L = 0.002
	Q_L = 0.244	Q_L = 0.693	Q_L = 1.531
Fusion Bead	H_L = <0.001	H_L = 0.005	H_L = 0.020
	Q_L = 2.712	Q_L = 7.748	Q_L = 17.148
Bell and Spigot	H_L = 0.022	H_L = 0.132	H_L = 0.514
	Q_L = 73.416	Q_L = 201.818	Q_L = 434.751
C Value of 150 for Entire Pipeline	H_L = 0.027	H_L = 0.150	H_L = 0.539
	Q_L = 91.346	Q_L = 228.156	Q_L = 455.996

H_L = Headloss, in feet of water, as compared to pipeline with no joints at a 'c' value of 155, which for 2 fps is 0.4 ft (+/-), for 5 fps is 2.4 ft (+/-), and for 10 fps is 8.6 ft (+/-).
Q_L = Flowloss, in gallons per minute, as compared to a pipeline with no joints at a 'c' value of 155, which for 2 fps is 2,743 gpm (+/-), for 5 fps is 6,852 gpm (+/-), and for 10 fps is 13,694 gpm (+/-).

Table 3 – 24 Inch Diameter

Joint Configuration Comparison

The tables above clearly show the comparative results of the systems as described. Generally, the fusion joint with the bead removed reflected the lowest head losses and flow losses, which is as anticipated. This was followed by the fusion joint with bead, and then the bell and spigot joint configuration. Perhaps the most important item of note was the fact that all joint configurations incurred less head loss and flow loss than a conservative system design using a ‘c’ value of 150.

Excluding the joint with the fusion bead removed, the bell and spigot and fusion bead joint configurations reflected head loss and flow loss values ranging from 4% to 95% of the conservative ‘c’ value of 150 design, depending on size of pipe.

Conclusion

The use of a ‘c’ factor of 150, or equivalent friction coefficient per other predictive flow models for PVC pipe is conservative, and adequately accounts for minor losses in a pipeline including those incurred by either internal fusion beads, internal fusion beads removed, or bell and spigot joint configurations. Pipeline designers should feel confident in using such a design factor to adequately estimate head loss and flow loss in their systems, no mater what type of joint is being used. By this reasoning, there is also no reason to remove the fusion bead for a pipe system, due to concerns of head or flow loss in a system.

References:

[1] Fundamentals of Fluid Mechanics, Second Ed. Munson, Young, and Okiishi. John Wiley & Sons; New York, NY, 1994. pp 496-8.

[2] Handbook of PVC Pipe: Design and Construction Fourth Ed. Unibell PVC Pipe Association, Dallas, TX, 2001. p 314.