Uni-Bell PVC Pipe News

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15 Year Old PVC Sewer Pipe Passes The Tests Of Time

by Dennis E. Bauer
Association Engineer

While PVC sewer pipe isn't the only sewer pipe, it certainly is the sewer pipe of choice. You have told us that tighter joints, longer lengths, ease of construction and superior performance are all part of your preference for PVC.

As an industry, we felt you would be interested in learning just how good your decision was to specify PVC sewer pipe from a durability standpoint. We will endeavor within this article to provide a report card, if you will, of the pipe's ability to withstand the soil environment as well as the sewage effluent.

Numerous testimonials to PVC's superior long-term performance are available from users throughout North America. However, they have neither the time, budget nor inclination to dig-up perfectly good PVC sewer pipe to test its durability. The members of the Uni-Bell PVC Pipe Association appreciate your business and think it very prudent to provide such technical information in support of your selection of PVC.

A decision was made in 1988 to locate and remove sufficient PVC sewer pipe to test in accordance with ASTM D 3034, "Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings." The pipe was to be one of the earliest gasketed SDR 35 sewer pipes manufactured in accordance with this standard.

ASTM D 3034 was originally published in 1972. Therefore, the oldest pipe, if installed in 1972 and excavated in 1988, would be 16 years old. Certainly an adequate period of time to formulate opinions on long-term durability.

There were prerequisites, in addition to it being gasketed SDR 35, established upon which a specific site selection would be based. One of the requirements was that the line chosen be at least 10 years old. It should also be a sanitary sewer application, with common slopes, depth of cover and operating conditions. A final prerequisite was that the project selected be one for which initial installation documentation was available. This requirement would insure an ability to objectively review the changes with time in the pipe performance as well as durability.

Site Selection

In researching the records for older PVC sewer locations, the City of Dallas, Texas, turned up. Because Dallas has used PVC sewer pipe for many years, a number of sites could be considered. We were interested in knowing what the initial deflections were and the installation requirements that produced them.

Thank goodness we were working with the City of Dallas. They keep very good records, in very good order. And, they were very patient in leading us through them.

Further review led to a 10 inch diameter gasketed SDR 35 PVC sewer line on the north side of Dallas, which had been installed in May of 1973. The City had plan and profiles of the project with embedment description as well as a report on initial deflections. Depths of burial ranged from 8 to 10 feet with a planned slope of 0.80 percent. By tapping the collective memory of local manufacturer's representatives, we learned that the manufacturer of this pipe had completed an initial installation report as well. This site had everything we required.

But, would the City be willing to cooperate with us on a research project requiring the removal of an active PVC sewer line from beneath a City street. The Dallas Water Utilities

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The 10-inch PVC is removed from Dallas.

Batavia Breaks Ground With North America's Largest Diameter PVC Pressure Pipe Installation

The City of Batavia, New York, has come a long way since its first municipal sewers were installed in 1903. They were, of course, clay tiled. Problem was, the materials had breakage and leaky joints after installation.

Batavia's Director of Public Works and City Engineer, Dennis Larson, explains, "This city is built on a flat bog with an unusually high water table. That plus the fact we have numerous hot soil areas contributed to reduced life spans for some of our force mains. In addition, maintenance costs escalated due to leakage problems on the gravity clay tile lines."

As a result, in more recent years, Larson's engineering team began to include polyvinyl chloride (PVC) pipe in its tendering specifications. The reasons are sound: PVC is unaffected by corrosion; PVC is smooth-walled and, as such, offers less resistance to waste buildup which can dramatically reduce flow capacities.

Now in and around Batavia there are miles and miles of PVC gravity sewer pipes ranging in size from 6-ins. to the large 24 and 30-in. diameter mains.

So, it was to PVC that Batavia turned recently. The project: To provide large diameter PVC pressure pipe for a new 4,900 foot sewer force main capable of moving all effluent in the city from a new central pumping station to an also new treatment plant.

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The 30-inch PVC pressure pipe is installed.

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AWWA Approves C900 Update; Copies Available In April

The American Water Works Association has recently completed work on the update to AWWA C900, "Standard for Polyvinyl Chloride (PVC) Pressure Pipe, 4 In. Through 12 In. for Water Distribution."

C900-89 has completed all review and approval levels and now awaits only publishing. AWWA association staff currently project that the standard update will be available for purchase sometime in April.

American Water Works Association procedures provide for the review and update of all AWWA standards by the committee of jurisdiction every five years. This ensures appropriateness as well as accuracy. The major change to C900-89, deletion of provision for iron-pipe-size and solvent welded products, helps demonstrate the wisdom of the requirement. Although always included in C900, these two product types have never been commercially available.

Copies of C900-89 will be available for purchase directly from AWWA at 6666 W. Quincy Ave., Denver, CO 80235.

AWWA Board of Directors Approves PVC Transmission Pipe Standard

The American Water Works Association's (AWWA's) Board of Directors has culminated a four year, standard development effort by approving a standard for PVC transmission pipe. The new standard became effective on December 1, 1988. The designation for this standard is AWWA C905.

AWWA C905 standardizes PVC transmission pipes in nominal diameters ranging from 14 inches through 36 inches. Both IPS and CI outside dimensioned products are included in the AWWA standard.

To enhance design efficiency at least four different wall thicknesses are provided for each nominal diameter. The specific dimension ratios (DR's) in AWWA C905 are 18, 21, 25, 26, 32.5 and 41.

Quality Assured C905

PVC pipes manufactured and tested in compliance with AWWA C905 are capable of providing trouble free, longer life performance than the conventional pipe products they are certain to displace. Performance assurance begins with stringent material requirements for both pipe and gaskets. Workmanship of the highest quality is also a C905 requirement.

Pipe quality is further evaluated through a series of finished product tests that include dimensional checks, pipe flattening, immersion in anhydrous acetone, joint tightness and hydrostatic pressure testing of each length of pipe, including the joint.

Purchasers of AWWA C905 PVC pipe may specify that the manufacturer furnish an affidavit that all pipe conform to the requirements of C905. In addition, Underwriters Laboratories (UL) certification is available for C905 pipe. Water quality is assured through certification by the National Sanitation Foundation (NSF).

State-of-the-Art PVC Design

Design criteria for PVC transmission pipe are included in Appendix A of AWWA C905. These criteria represent the latest advances in PVC pipe engineering. The allowable design stress for C905 pipe is conservatively established to accommodate over a trillion years of continuous service. A service life that cannot be compromised by aggressive water or corrosive soil environments.

AWWA C905 provides for pressure ratings (PR's) ranging from 100 psi (689 kPa) up to 235 psi (1620 kPa). Surge pressures are properly accommodated on a case-by-case basis in the working-pressure rating (WPR). The appropriate equations are included in C905.

The design safety factor of 2.0 recommended in AWWA C905 equals or exceeds that found in other non-PVC AWWA pipe standards. An even larger safety factor of 3.2 is provided for instantaneous total system pressure.

External load design is equally conservative but usually not design limiting for PVC transmission pipe.

Exemplary Performance

While AWWA C905 represents a major standardization advancement, larger diameter PVC pressure pipes are not new to North America. The first larger diameter (nominal 18 inch diameter) PVC transmission pipe was installed in 1967. Since that time a steadily increasing number of installations and applications have followed. Most notably, all of the larger diameter PVC transmission pipe installations throughout North America are performing successfully.

Prior to AWWA's approval of C905, our own Uni-Bell recommended standard, i.e. UNI-B-11, provided specifiers with an interim product standard.

Obtaining Your Copy

Our readers are encouraged to obtain a copy of AWWA C905 either directly from AWWA or from Uni-Bell. For your copy, compliments of Uni-Bell, return the coupon (or a copy thereof) located on page 2 of this issue. You are also invited to request a free copy of our *Handbook Supplement* covering large diameter pressure pipe design and selection. This supplement includes useful hydraulic information specific to PVC pipe complying with AWWA C905.

FREE

Please send me the following information (check information desired):

❑ AWWA C900 ... *see article this page*

❑ AWWA C905 ... *see article this page*

❑ Handbook Supplement ... *see article this page*

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Chairman's Message

James K. Rash

by James K. Rash
Uni-Bell Board Chairman

Last year, this column spoke of increasing PVC pipe prices and the need to develop performance value in the market place.

This year, we are seeing a continuation of this trend with some clear signs that PVC pipe is coming into its own as a "product of choice."

During the past year, the awareness of all water consumers has raised due to the EPA regulations on lead. This raised awareness placed increased demands on water systems as the public is now crying for purity. Fortunately, PVC piping offers the consumer the opportunity to receive water from the tap as pure as when it left the originating water source.

PVC pipe is the most heavily regulated product in the piping industry. Included in the many product standards is adherence to the National Sanitation Foundation standards on taste and odor; the only piping product that meets this requirement. As environmental pressures mount, the quality conscious consumer will look to our standard of quality as the yardstick.

Thus, our industry has the unusual opportunity of benefiting from environmental pressure. Nevertheless, change is slow and it will take some time for the general populace to fully appreciate the performance value of PVC pipe. We still need to sell our product attributes.

AWWA Appoints PVC Committee

Recognizing the ever-increasing role polyvinyl chloride (PVC) pipe is experiencing in the water works industry, the American Water Works Association (AWWA) last year announced a committee split.

The Thermoplastic Pressure Pipe Committee had long served as the responsible committee for all PVC and polyolefin products (polyethylene and polybutylene) PVC now represents sufficient market to warrant a specific committee. Therefore, in June of '88, AWWA Standards Council did vote to split the committee into two new committees. The result is the new PVC Pipe and Fittings Committee and the Polyolefin Pipe and Fittings Committee.

Mr. Joe Richard, who served as Vice-Chairman of the Thermoplastic Pressure Pipe Committee, has been named to chair the PVC Committee. Chief engineer for the City of Baton Rouge, Louisiana, Joe is no stranger to PVC. Consumer experience comes to him from his duties at the City of Baton Rouge. General interest expertise is available both through his previous affiliation with the consulting firm of Owen and White and from his continued work as an expert witness in private consultation cases. Producer perspective is also well represented in Joe's resume by previous employment with a PVC pipe producer and his one time role as chairman of the Uni-Bell Technical Committee. Truly Mr. Richard comes to the chair having walked a mile in everyone's shoes!

One other facet of the split is to open the membership to include more specific expertise. AWWA Governing Documents provide that all committees must represent an equal balance in membership from the three categories alluded to earlier: consumer, general interest and producer. The Thermoplastic Pressure Pipe Committee constantly struggled with the compromise of seating enough members to adequately represent all products in all facets of use in all membership categories versus seating numbers of members which were unwielding and an obstacle to consensus.

The newly seated PVC Pipe and Fittings Committee does currently have positions available for both consumer and general interest, qualified in experience with PVC pipe and fittings. Those qualified applicants willing to serve should offer their desire and background in writing to Mr. Dewey Dickson, Chairman of AWWA Standards Council, with copy to Mr Joe Richard as below:

Mr. Dewey Dickson
JM Montgomery Engineers
P.O. Box 7009
Pasadena, CA 91109

Mr Joe Richard
1068 Colonial Drive
Baton Rouge, LA 70806

Uni-Bell offers its sincere appreciation for those who served so unselfishly for so long on the Thermoplastics Committee. We now join the entire water works Industry in also offering our best wishes to the new PVC Committee.

Batavia

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The current 14-in. ductile iron main together with the present treatment plant will be phased out of service.

For the new line, specified as pressure pipe, the Uni-Bell member company recommended its 30-in. SDR 25, introduced to the marketplace in 1987. The pipe meets all industry standards including AWWA C905, "Polyvinyl Chloride (PVC) Water Transmission Pipe, Nominal Diameters 14 In. Through 36 In.," and UNI-B-11, "Recommended Standard Specification for Polyvinyl Chloride (PVC) Water Transmission Pipe (Nominal Diameters 14-36 Inch)," and with 32-in. OD, is the largest diameter (PVC pressure) water transmission pipe made in North America.

"We felt confident in choosing it, largely on the basis of slickness and flow characteristics, and its heavier wall," notes Larson. "Very simply, we were looking for the very best pipe for the job."

Pressure rated at 165 psi, SDR 25 weighs 86.58 lbs/ft and has a wall thickness of 1.280 ins. The design flow rate is 10.608 USgpm and the friction loss rating is only 0.200 ft/100 ft.

According to Larson, the city "has no way to bypass the line. A breakdown would mean a complete shutdown of the system. Consequently, the pipe must perform."

Installation of the new Batavia force main started in mid-May, 1988. It was completed on schedule by September 1. Now tested and ready for use, the force main awaits completion of the treatment plant sometime in 1990.

Bryan Smith of the consulting engineering firm of Tallamy, Van Kuren, Gertis and Associates, Orchard Park, New York, is equally optimistic about the successful, long-term operation of the system. As the resident engineer on the project, Smith anticipates, "No problems whatever," with the unique new force main. One reason is the track record of all of the PVC pipe previously installed in the city. "We have used a lot of Uni-Bell member company PVC pipe with no instances of pipe failure," he says. In the past year, Batavia installed close to 24,000 feet of PVC pipe for gravity sewers, including an additional 2,500 feet of the same 30-in. pipe.

Smith makes his second point by referring to test results for the pressure force main. "Although normal use pressures in the line will be 30-40 psi, we tested it at 100 psi and held that pressure for four successive days. There were no leaks."

The new PVC force main has a capacity of 22 million gals per day. The system is designed for an average flow rate of 6 million gals/day. Peak design capacity is 22 million gals/day.

Smith rates the lower coefficient of friction in the pipe as crucial. "This means reduced calcification, less buildup," he says. The city's Larson agrees, and goes further by siting PVC's corrosion resistance. "In some areas, ductile iron would have been sufficient. But in many hot spots you get the double problem of internal and external corrosion. Neither is much of a factor with PVC. We have a lot of faith in that pipe."

Smith likes it for one other reason--the high water table in Batavia. "Average depth below the surface grade is only eight feet. The force main was installed at 10 foot depths. You can readily see the potential for problems," he says. But not with the PVC pipe. Since it is pressure-rated (including the gaskets), it can withstand higher internal and external pressures--even when it sits continuously below the water table.

As for cost, Smith maintains PVC generally comes to 20 percent less than the rival materials. "Actual installation savings were even greater," suggests Keith Wilkinson, Jr., President of Alden Excavating Inc., Cowlesville, New York. Wilkinson's company put in every foot of the large diameter force main "at a conservative estimate of 25 percent in cost savings versus ductile iron."

The 20-foot length of 30-inch PVC is handled with light-weight equipment.

The company averaged 150 feet of pipe installed daily (in 8 hour days). "We initially figured on 75 feet per day due to the number of cuts we had and the numerous tight working areas. These numbers speak for themselves. They left us absolutely delighted in the job," Wilkinson says. That's not all. Wilkinson expressed appreciation for the PVC gasket system as well. "We had a lot of changes in direction, at least 20, and some were as much as 90°, both vertically and horizontally. We went under railroad tracks and bridges, and even under the Tonawanda Creek. All of those bends and no leaks. Not one."

Wilkinson is quick to point out how easy PVC pipe is to work with, even large diameter. "Lengths come together nicely, cutting is fast, the pipe is light and easy to handle and we were able to get away with using much lighter equipment and less labor. It was a pleasure," he says.

"On top of all this," adds Dennis Larson, "there wasn't one delivery problem or delay. We evaluated the pipe carefully to start with, and now that the job is completed, we are confident we made the right choice."

Dual PVC Force Main Relieves Pembroke Pines, Florida

The City of Pembroke Pines, Florida, has been growing at a rapid pace the last few years, and expectations are that it will continue growing rapidly into the future.

When the City recently annexed a 20 square mile area, known as the Western Service Area (WSA), there were some utility concerns which required immediate attention. The most crucial concern involved an existing sewage treatment plant which was servicing a small community at the extreme west end of the WSA. The plant was undersized to meet future demands and was producing effluent which didn't meet current state standards.

The city turned to Berry & Calvin Inc., Consulting Civil Engineers, from nearby Hollywood, Florida, for assistance in determining the best alternative for meeting both the current and future sewage treatment needs. Edward J. Dvorak, a Project Manager with Berry & Calvin, was selected to head up the design as he had completed Pembroke Pines' master plan for the WSA.

One factor which complicated the design was the fact that the WSA was largely undeveloped. This meant a significant difference between current and future flow demands, which were estimated at 310 gpm and 5210 gpm, respectively. A computer generated model of the system revealed that a dual force main (8" force main along side gradually increasing 10" to 24" force

main) was the most economical alternative. Mr. Dvorak stated that, "A twin force main offers the opportunity to phase the usage. A smaller diameter main operating with a large diameter main allowed efficient pumping at the current relatively low flows as well as the ability to handle future increased flows. Pipeline velocities are maintained within the smaller force main until increased flows require us to open up portions of the larger main."

The force main would deliver the sewage approximately eight miles to the Pembroke Pines treatment facility. The design analysis revealed that approximately 198 feet of head (86 psi) would be required to pump the sewage over this distance. Two pumps in series with a wet well arrangement were designed to meet this requirement.

When it came time to select the pipe material, "we wanted to get the most economical product which would provide long-term service," stated Mr. Dvorak. The contractor was allowed to select either PVC, ductile iron or concrete cylinder pipe for the project. PVC pressure pipe was provided by the contractor in the following diameters and quantities:

6"	-	195'
8"	-	37,917'
10"	-	7,678'
12"	-	1,587'
14"	-	10,534
16"	-	5,253
18"	-	8,561
20"	-	8,322'
24"	-	2,115
Total	-	82,162'

All of the 6 - 12" was DR 18 (Pressure Class 150 psi) and the 14 - 24" was DR 25 (Pressure rated 165 psi).

Ed Dvorak, the City of Pembroke Pines, as well as many other cities in Broward County, Florida, had specified 6 through 12" PVC pressure pipe meeting the requirements of AWWA C900, Polyvinyl Chloride (PVC) Pressure Pipe, 4 In. Through 12 In., for Water, for a number of years before this project. However, they had not used large diameter (14 and above) before. After thoroughly reviewing the Uni-Bell standard (UNI-B-11), "Recommended Standard Specification for Polyvinyl Chloride (PVC) Water Transmission Pipe (Nominal Diameters 14-36 Inch)," as well as the material qualities, Mr Dvorak found that, The large diameter PVC had the same physical characteristics and

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15 Year Old PVC Sewer Pipe Passes Tests Of Time

This quiet neighborhood is the site of PVC research.

Utah State University receives the PVC sewer pipe.

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Department was very interested. They believed the research would greatly benefit their information base as well as the user community in general. To them this was an opportunity. In fact, the City of Dallas Water Utilities Department would act as the contractors for the Uni-Bell sponsored project.

The Pre-Excavation

Before excavating the line and sending it to the laboratory for testing, we wanted to know how well it was currently operating. City crews reported that there were no recorded instances of maintenance on this line in its 15 years of service. The following five steps summarize the pre-excavation protocol.

- Depth of flow measurement
- TV the line
- Clean the line
- Pull a deflection mandrel through the line
- Re-TV the line

Dallas Water Utilities had set up a mobile recording device to measure depths over a seven day period. Depth of flow over the seven days ranged from a low of approximately one inch to a high of three inches of depth.

The Dallas utility crew, which televised the line, explained that they no longer televise their PVC sewer lines, as a part of scheduled maintenance, because experience had shown there was little to see. After viewing the video of the 245 foot long section of PVC pipeline, we see their point. The interior did not look brand new, but it looked awfully clean for 15 years of service.

The line was then cleaned with a water jetting device before the deflection mandrel was pulled. Both the City and manufacturer's initial installation reports indicated that deflections ranged from two to five percent over the length of the line. They both had used deflectometers to measure over the entire length. We were prepared to pull a 5 percent deflection mandrel (a go/no go testing device) through the line. Unfortunately, the outlet structure of the manhole invert was built up with concrete to the point that we could not wedge the five percent mandrel through into the pipe. No problem, we have another manhole downstream. Wrong. The inlet structure there was also built up.

The next move was to try a 7 1/2 percent mandrel, which is the industry recommended allowable deflection limit. With much effort and manipulation it was wedged through the upstream manhole outlet structure. The pipe easily passed the 7 1/2 percent mandrel.

The line was retelevised in order to see what difference, if any, the jet cleaning made on the line. There were some minor noticeable changes. Of special advance note is the fact that after the pipe was removed, the interior could be easily cleaned with water and a small amount of elbow grease. *(Editor's Note: When you attend the American Water Works Association Convention in L.A., stop by our booth and see an actual sample.)*

The Excavation

On a sunny and warm December morning (1988), Uni-Bell staff met the Dallas excavation/replacement crew on site. The street had been marked and the asphalt cut prior to our arrival.

Before removal of any overburden could proceed, we would place a device in the PVC sewer pipe to maintain in-situ deflection over a two foot length. This was accomplished by yours truly, who spent several unforgettable moments inverted in the manhole. By maintaining the deflection in this section, the actual long-term structural properties of the material could be calculated.

The asphalt was removed and a nuclear densometer, operated by a Dallas utility consultant, was calibrated and used to measure soil density just below the surface and then again three feet down. The densities ranged from 82 percent to 92 percent along the length of the trench.

Terra-Mar Consulting Engineers, a Dallas-based firm which specializes in geo-technical evaluations, was retained to classify and define the native trench soil as well as the embedment material. The final backfill material, which was placed from approximately four to six inches above the pipe to about one foot below the pavement, was classified as CH material, described as "Dark gray to tan clay with calcareous modules and limestone fragments."

The initial backfill, which was placed from the springline of the pipe to four to six inches above, was classified as SM and described as "Tan silty fine sand with trace fine gravel." The City crew knew we were getting close to the top of the pipe when the backhoe operator struck this sand.

The City requirements called for a "Class B" embedment material when the pipe was originally installed, regardless of pipe material, and still do This would be described as a material basically consisung of sand and gravel. The material which was removed from the bottom of the pipe and from the sides to the springline was classified as SC and described as tan and grayish brown clayey fine to coarse sand with some fine gravel. Because the invert was approximately eight feet deep and the water table was slightly above the crown of the pipe, some of the native clay materials washed into these samples during the excavation process. Obviously, their requirements were sufficient to maintain deflections below 7 1/2 percent.

The water table being above the pipe made for nasty working conditions which were aggravated by rainy weather. This didn't deter the Dallas utility crew. They brought in pumps to lower the water level and uncovered the pipe. Once uncovered, they cut holes in the crown and let the pipe assist in draining.

A total of approximately 40 feet of pipe were required to test in accordance with ASTM D 3034. The 10 inch PVC was removed in two sections, one 33 feet in length and the other 7 feet. A house lateral prevented us from removing one contiguous piece. As the photo on the front page shows, the pipe was covered with mud upon removal. Even so, many of the crew members commented that the pipe looked practically new The mud was washed off, the interior was rinsed and the pipe was cut in lengths convenient for shipment.

The Testing

The pipe was sent to Utah State University's (USU) mechanical engineering department in Logan, Utah USU is recognized as a premiere pipe research facility, which made the choice of laboratories an easy one.

Apparently we didn't clean the interior of the pipe as thoroughly as we could have The folks at USU reported an overly offensive odor upon uncrating the samples We'll blame the user of this pipe he's obviously running smelly stuff through it.

USU tested in accordance with ASTM D 3034, which has requirements for workmanship, diameter dimension, wall thickness dimension, flattening, impact resistance, pipe stiffness, joint tightness, and extrusion quality

Workmanship The requirement states that the pipe and fittings shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions or other injurious defects. The pipe shall be as uniform as commercially practical in color, opacity, density and other physical properties.

After 15 years the PVC pipe passed the requirements. In fact, the report from USU states that, after cleaning with soapy water the appearance was almost like new pipe." Looking like new is one thing, but what about physical properties?

Diameter dimension The average outside diameter when measured in accordance with ASTM D 2122, "Standard Method of Determining Dimensions of Thermoplastic Pipe and Fittings," was found to be two thousandths of an inch under the tolerance.

This minor variation in diameter obviously had no affect on performance With today's computer controlled extrusion equipment, the tolerances can be more easily met today.

Wall Dimension Simply put, the wall thickness exceeded the requirements when measured in accordance with ASTM D 2122. The samples had average wall thickness ranging from 0.307 inches to 0.314 inches. After 15 years of service, the wall thickness, even in the invert, was greater than that required by the standard for new pipe. Granted domestic sewage is not normally very abrasive, but we all know that things go into the system which shouldn't Previous studies have confirmed PVC's high resistance to abrasion.

Pipe Flattening The ASTM requirement states that there shall be no evidence of splitting, cracking or breaking when flattened to 40 percent of the outside diameter. By flattening to 40 percent of O D , the pipe is deflected 60 percent.

The accompanying photo is worth a thousand words. The 15 year old PVC pipe passed the test. There was no embrittlement with time.

Impact Resistance ASTM D 3034 requires that 10 inch diameter pipe withstand 220 ft-lbf when tested in accordance with ASTM D 2444, Standard Test Method for Impact

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Resistance of Thermoplastic Pipe and Fittings by Means of Tup (Falling Weight)." This standard requires that pipe specimens be able to withstand a blow from a missile-shaped falling weight called a tup. The tup is 20-lbs., therefore, an 11 foot drop. This test was meant as a quality control requirement rather than a requirement for field installation. All samples passed, providing further evidence that no embrittlement occurs over time with PVC pipe.

Pipe Stiffness. A minimum of 46 psi is ASTM's requirement for SDR 35. All samples were tested in accordance with ASTM D 2412, "Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel Plate Loading." The average pipe stiffness was 62.8 psi.

Joint Tightness: Within D 3034 is a requirement that the elastomeric gasket joints perform in accordance with ASTM D 3212, "Standard Specification for Drain and Sewer Plastic Pipe Using Flexible Elastomeric Seals." This standard requires that the pipe undergo both an internal pressure and vacuum requirement when axially deflected. The sample passed the test.

Fifteen years later the PVC gasketed joint was leak free. Properly installed PVC sewer pipes comply with a recommended allowable infiltration of 50 gallons per inch of internal diameter per mile per day. Most alternate sewer pipe products cannot meet such low allowable infiltration levels when newly installed, let alone 15 years after installation.

Extrusion Quality ASTM D 3034 requires that the pipe not flake or disintegrate when tested in accordance with ASTM D 2152, "Standard Test Method for Degree of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion." Samples were submerged in anhydrous acetone for the required time and inspected. All successfully passed.

Structural Properties: Within a limited group of users and non-users of PVC there lingers a question concerning long-term structural properties. They would suggest that properties such as tensile strength and modulus of elasticity decrease with time.

We thought you would be interested in seeing what the testing revealed. When the 15-year-old PVC pipe was tested in both the circumferential and longitudinal direction for tensile strength and modulus of elasticity, the adjacent results were obtained.

As you can see, these values are typical of newly manufactured pipe.

The Additional Testing

Remember that we said prior to removing any overburden from the pipe we installed a device which would lock in the long-term deflection. Well, we did this for selfish reasons. By providing USU with this sample, they were able to measure deflections, measure the load required to maintain the deflection and incrementally load the sample to reach the required deflection for determination of pipe stiffness.

The pipe stiffness calculated, at the required deflection, was 65.1 psi. With this value, the modulus of elasticity could be calculated. It had not decreased from those values determined for unrestrained samples.

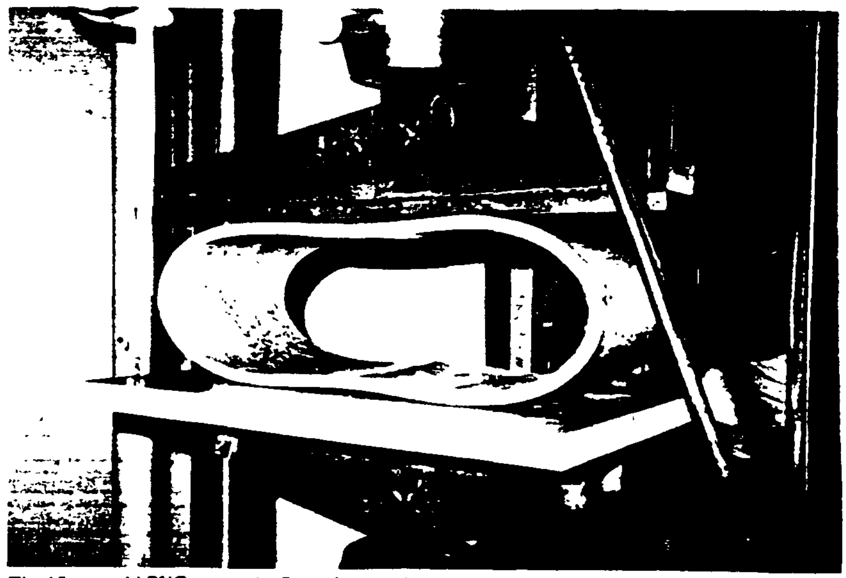
PVC. The Right Stuff

We said early on that this article would serve as a report card on how good your decision to use PVC sewer pipe has been. We would say you get an A+ and go to the head of the class. Your decision has been rewarded with not only superior performance but superior durability as well.

The ASTM D 3034 yardstick limited us to 15 years. Nevertheless, the results give us no reason to suspect any different results would be derived from 150 year old PVC sewer pipe. Based on the fact that the 15 year old PVC passed all the requirements of newly produced pipe, with the singular exception of average O.D., our opinion is that your great, great grandchildren's children will still be serviced by the PVC pipe you specified. We will not be around to see the final report card.

When you evaluate PVC on durability and performance, it dictates your selection.

Editor's Note: A copy of the original report from Utah State University is available from Uni-Bell headquarters in Dallas Texas



The 15-year-old PVC passes the flattening requirement.

CIRCUMFERENTIAL DIRECTION

Specimen Number	Strength (psi)	Modulus (psi)
1	7410	0.376×10^6
2	7600	0.441×10^6
3	7700	0.403×10^6
4	7670	0.430×10^6
AVG.	7600	0.412×10^6

LONGITUDINAL DIRECTION

Specimen Number	Strength (psi)	Modulus (psi)
1	7990	0.449×10^6
2	7980	0.437×10^6
3	8140	0.432×10^6
4	8060	0.458×10^6
AVG.	8040	0.444×10^6

PVC Pipe Time Capsule Preserves City Keepsakes

by Robert Walker

To wrap up Texas' 150th birthday celebration, the City of Richardson, Texas, buried a time capsule to preserve this time period for the future. The capsule, which will not be opened until 2036, during Texas' 200th birthday, contains memorabilia from the sesquicentennial year, photos, messages, business cards and a letter from the Mayor.

To protect these historical documents and artifacts for future generations, the city selected a construction material that would not deteriorate under conditions of burial. The time capsule was made from PVC pipe and was donated to the city by the Richardson Water Department.

When it has to last, specify PVC pipe.

CTL027262

Correction: AASHTO Design Specification Example

In our Summer 1988 edition we reported on the approval of an American Association of State Highway and Transportation Officials (AASHTO) design specification for PVC highway drainage culverts. As part of that article a design example was included.

The design example included both service load design criterion and load factor design criterion. The service load computations were correct but the load factor burial depth limit computation did not take into account γ and β_E factors from AASHTO Design Section 3. The specified load factor design γ and β_E values for flexible culverts are 1.3 and 1.5, respec-tively. These factors multiplied together effectively increase the design load 1.95 times. The result is an allowable burial depth of 18.3 feet when load factor criterion are applied in the example.

Although less conservative, our use of the actual dead load does yield a very safe and conservative burial limit for PVC culverts.

In a related matter the AASHTO Special Liaison Committee for Flexible Culverts has identified an error in the capacity modification factor (ϕ) used in the load factor design method for PVC culverts. The AASHTO Plastic Pipe Task Force inadvertently set the ϕ factor equal to 0.65. The ϕ factor should be 1.0 to be consistent with other AASHTO culvert design sections and to restore consistency between the service load and load factor design methods.

When the ϕ factor is corrected, the allowable burial limit from our previous example computations will be 27 feet using the load factor design method.

We hope we have clarified the proper application of AASHTO's design criteria. To obtain a copy of AASHTO's Design Section 18 entitled "Soil-Thermoplastic Pipe Interaction Systems," you may [illegible] AASHTO General Offices, [illegible] North Capitol Street N.W., Suite 225, Washington DC 2[illegible]

Uni-Bell Welcomes New Members

Symbol of Excellence
Uni-Bell
MEMBER
UNI-BELL PVC PIPE ASSOCIATION

The Uni-Bell PVC Pipe Association is a non-profit technical and educational organization headquartered in Dallas, Texas, which provides information regarding the specification and use of gasketed PVC pipe products, for use in water, sewer, drainage and irrigation applications. The Association is made up of manufacturers committed to providing quality products and service to the PVC pipe industry. Formed in 1971, Uni-Bell offers technical service, research and development data and support in standards development.

Uni-Bell is proud to be directly affiliated with quality producers of gasketed PVC pipe, PVC fittings, PVC resin and PVC compound micro ingredients. The following companies have distinguished themselves as responsible new Associate member companies. Uni-Bell member companies benefit from a philosophy that top quality pipe, service and technology all go hand in hand. The following Uni-Bell member companies serve the PVC pipe industry and their customers with quality products, professional personnel and Uni-Bell technical expertise.

BFGoodrich

B.F. Goodrich Canada Inc. is Canada's largest domestic producer of vinyl resins and compounds. The company's plants are located across Canada in Shawinigan, Quebec; Niagara Falls, Ontario; and Scotford, Alberta. BFG Canada is a subsidiary of the BFGoodrich Company headquartered in Akron, Ohio.

Strong demand for PVC products in Canada has resulted in the growth of an established customer base for B.F. Goodrich resins and compounds. To meet demand, the company is expanding its manufacturing capacity.

Customers of BFG Cana have "state-of-the-art" knowledge of PVC processing, with an emphasis on technology and high quality goods.

B.F. Goodrich has met the challenge of keeping pace with its customers' demands for quality and innovation through the introduction of comprehensive Statistical Quality Control (SCQ) and Statistical Process Control (SPC) in its plants. Improvements to existing proven resins and the introduction of new resins offering improved processing and physical properties are ongoing.

The company has the advantage of being able to supply suspension resins from its Niagara and Shawinigan plants. Its Scotford, Alberta, facility is one of the largest and most modern mass resin plants. The flexibility of having both major types of PVC resins provides customers with access to the best resin for their application and process.

Canada has been favored with abundant supplies of natural resources. Large gas fields and salt deposits provide reliable supplies of the basic raw materials for PVC (ethylene and chlorine).

On Canadian minds in 1989 and beyond will be the ramifications of the Free Trade Agreement. By and large, the PVC industry looks forward to the exciting opportunities presented in a North American marketplace.

Organizations such as Uni-Bell, which have been operating in Canada and the U.S for some time, have actively demonstrated that both countries share similarities which transcend the border.

B.F Goodrich Canada Inc. is pleased to be joining Uni-Bell at this time and looks forward to meaningful participation.

The Vinyl Institute

A Division of The Society of The Plastics Industry, Inc.

The Vinyl Institute is a trade association representing the leading U.S. manufacturers of polyvinyl chloride (PVC) and vinyl chloride monomer (VCM), the raw material from which PVC is derived. Member companies include Air Products and Chemicals, Inc., Borden Chemicals and Plastics, CertainTeed Corporation, Dow Chemical Co., Georgia Gulf Corporation, BFGoodrich Co., Occidental Chemical Corporation, PPG Industries, Inc., Shintech Inc. and Vista Chemical Co. European and Canadian PVC interests are represented as well by associate memberships held by the Vinyl Council of Canada and European Vinyls Corporation.

In 1987, a new class of membership was established to enable U.S. companies that manufacture adjuvants or other raw materials that are used in the manufacture, compounding or fabrication of PVC to participate in Institute programs as affiliated members. Current affiliate members are **GE Specialty Chemicals, Kaneka Texas Corporation, Lucidol Division of Pennwalt Corporation, M & T Chemicals Inc., Rohm and Haas Co. and Witco Corporation.**

Founded in November 1982 as an operating division of the Society of the Plastics Industry, Inc., the Vinyl Institute's first major objective was to correct misconceptions and erroneous allegations by marketplace competitors about the performance of PVC pipe and conduit in fires. During its first two years, the Institute launched a massive coordinated campaign involving research, development of educational programs for firefighters, communications and public relations that has successfully helped to confirm the safety of vinyl products.

Today, this responsiveness continues in VI activities. As the voice of the PVC industry, the Institute aggressively and responsibly promotes the continued development of the vinyl industry by:

- Educating the public about the safety and performance of vinyl.
- Sponsoring health and environmental research to assure the safe use of vinyl products.
- Development of market-place opportunities for expanded uses of vinyl.
- Fostering programs and communications with other industry groups (Domestic and international trade associations).

For the past two years, the Vinyl Institute has helped support a cooperative program with Uni-Bell PVC Pipe Association to expand the use of large diameter pipe. More recently, the VI has embarked on a pro-active program to help in creating expanded market for PVC in packaging, electrical materials and piping applications. An integral part of these programs is the development of informational brochures, technical information papers and a generic advertising campaign aimed at reaching influential purchasing decision makers.

Headquartered in Wayne, New Jersey, the Vinyl Institute is governed by an executive board representing all member companies and is managed by an executive director.

Corma Inc

10 McLEARY COURT CONCORD (TORONTO)
ONTARIO CANADA L4K 2Z3
TELEPHONE (416) 669-9397 TELEX 06-964583

Corma Inc. was established in 1973 to develop, manufacture and market plastic corrugated pipe productions systems, which were available only in Europe at that time.

Taking this opportunity, we wish to introduce you to Corma, the largest supplier of corrugated production systems in the world, with its head office and manufacturing facilities located in Canada. In its Research and Development Department, Corma is continuing technological innovation, citing that its commercial growth is directly related to its R. & D.

Corma designs and builds complete corrugator systems for the production of corrugated plastic tubing and pipe for automotive wire harness conduit, electrical conduit, medical respirator tubing, swimming pool hoses, underground cable ducting, drainage, irrigation piping, sewer and culverts.

These end pipe products are manufactured on Corma equipment in either blow or vacuum forming, with a pipe size range from 3 mm I.D. to 1200 mm O.D.

The four corrugated systems allow the pipe processor to manufacture a single-wall, double-wall or spiral wound pipe. In addition, the newest sanitary sewer pipe system, the Ultra-Rib System. This recent advancement in pipe design is ideally suited for PVC as there is no fusion of pipe layers required.

The Ultra-Rib pipe is a smooth pipe with radial reinforcing ribs and is produced from only a single layer of plastic. The unique profile of Ultra-Rib pipe gives it a very high crush and impact strength, still the pipe remains very light and requires about half the material to produce than other comparable pipes.

Corrugated Plastic pipe can be made from almost all blow and vacuum forming plastics, such as PE, PP, PVC thermoplastic rubber, nylon, teflon, etc.

Corma also builds, as part of the system, dies and downstream equipment including such items as watertank aftercoolers, haul-off and pipe dry-off stations, rotary cutters and slitters for drainage pipes.

An ever expanding company, Corma offers its customers the best and latest of knowledge in corrugated pipe production.

Uni-Bell

PVC Pipe News

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Dallas Installs First 18-Inch PVC Circumferentially-Ribbed Sewer Pipe

While small diameter circumferentially ribbed PVC sewer pipe has been installed throughout the United States, only recently has it been manufactured in 18 inch diameter. Eight through fifteen inch has been produced for some time by this innovative technology, which offers pipe having a seamless uniform cross-sectional wall, radial ribs (circumferential), which are perpendicular to the axis of the pipe, a smooth interior for excellent flow characteristics and an integral bell and gasket joint.

During the spring of 1988, Haukos Construction Company of Dallas, Texas, installed 5,320 feet of the Uni-Bell member company 18 inch PVC sewer pipe on the Ash Creek relief interceptor project for the City of Dallas.

Much of the trench was cut through solid rock. Haukos Construction was able to move quickly by using their trenching machine. It is fitted with an 18 foot boom and was able to cut a 30 inch wide trench. This along with the light weight of the PVC pipe insured a timely completion.

Mr. Don Haukos, President and owner of Haukos Construction Company was pleased with the pipe's lightweight (134 pounds per 13 foot length). Mr. Haukos said, "This allowed economical hand installation, saving on the cost of equipment needed to handle heavier pipe." He also said he liked the radial rib construction which gave the pipe extra stiffness and allowed it to be cut anywhere. "This rib construction allows me to cut the pipe to the length I need, reposition the gasket and push the pipe together--no need to bevel cuts anymore. This is a real time saver."

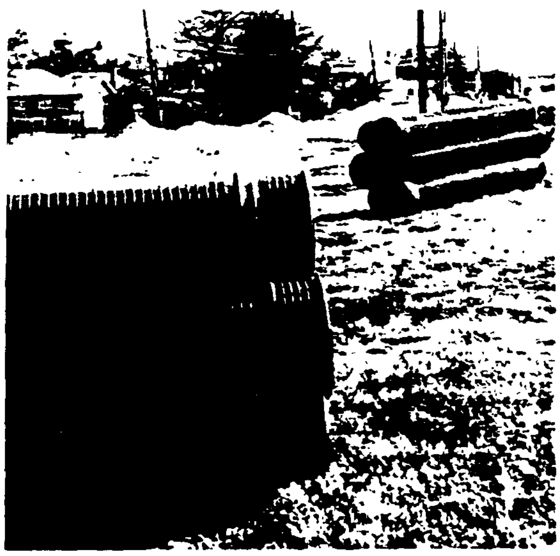
Part of the job required pushing 53 feet of the 18 inch PVC pipe through a solid rock bore under Peavy Road. According to Mr. Haukos, "We pushed the pipe through the bore with ease. Then we pressure grouted the opening between the O.D. of the pipe and the bore hole. It worked slick as a whistle."

There were 11 manhole sections on the project. Each manhole employed an "A-Lok" connection for water tightness. This connection was fast and simple to make using the smooth manhole adaptor furnished by the manufacturer.

The radially ribbed PVC pipe was installed in accordance with the standard City of Dallas installation specifications. The bedding and haunching material was 3/4 inch crushed stone, which was placed 4 inches under the pipe to 2 1/4 inches above the springline. Sand was used as initial backfill and placed 12 inches over the pipe. Native material was then placed in the ditch to original ground level.

After installation was complete, all sections successfully passed both an air test and deflection test. Mr. Haukos stated, "Since the line was in a street which required repaving, the City of Dallas televised the entire line with no problems."

The trenching machine speeds up construction.


The ribbed sewer pipe awaits installation.


The light-weight PVC is manhandled.

COME SEE US At A.W.W.A! Booths 838 & 840

The American Water Works Association (AWWA) annual conference and exposition this year will be held in Los Angeles California, June 18-22. Uni-Bell and its member companies will be there in a big way to celebrate the conference premiere of C905, "POLYVINYL CHLORIDE (PVC) WATER TRANSMISSION PIPE, NOMINAL DIAMETERS 14 IN. THROUGH 36 IN." The newest technology in non-pressure PVC piping will also be on display.

So come see the latest and allow us to renew our good friendships at the exposition in booths 838 & 840.

The Effects Of Deflection On Sewer Hydraulics

by Robert Walker, P.E.

Nearly every hydraulics handbook and wastewater engineering textbook include sections dealing with circular pipes. Many empirical equations have been developed to provide solutions to circular pipe flow problems. Blasius, Chezy, Colebrook, Darcy, Fanning, Hazen-Williams, Kutter, Manning, Moody, Morris, Scobey, Streeter, Stricker and Weisback are some of the more prominent names associated with circular pipe hydraulic evaluations. Thus, the design engineer has easy access to methods appropriate for dealing with circular pipe hydraulics, i.e., flow capacity, headloss, flow velocity, etc.

Buried flexible pipes, however, are engineered to deflect. A flexible pipe's ability to deflect offers two major structural benefits; 1) significant stress reduction brought about by improved load distribution around the pipe's circumference and 2) superior resistance to cracking or breaking that in turn prevents costly leakage. Such deflections also result in some deviation from a pipe's original circular cross-section. If the deflection is large, the change in cross section may alter the hydraulic characteristics of a pipe enough to warrant evaluation.

In this article the influence that pipe deflection will have upon the discharge capacity of an initially circular pipe is evaluated. Both full flow and partially full situations are considered.

Elliptical Cross Section

The amount of deflection and the profile of a pipe's deflected cross section will depend upon the pipe's embedment, loading and stiffness. The ellipse most closely models the cross section profile observed in buried PVC pipelines. A practical analysis requires that it be assumed the pipe will deflect to form a pure ellipse.

Figure 1 shows the cross section geometry of a circle and an ellipse. Using polar coordinates the following equations define a circle.

$x = R \cos \theta$
$y = R \cos \theta$

Where: R = radius of a circle
θ = angle of the radius with the x axis

The following equation also applies:

$$x^2 + y^2 = R^2$$

Using the same notation, the following equations define an ellipse:

$x = a \cos \theta$
$y = b \cos \theta$

Where: a = half the length of the long (horizontal) axis
b = half the length of the short (vertical) axis.

An ellipse will also satisfy the following equation.

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

Elliptical Circumference

For a deflected pipe, the values of a and b must be fixed so that the circumference of the ellipse (deflected pipe) and the original circle (undeflected pipe) are equal. A circle's circumference (C_c) is simply:

$$C_c = 2\pi R$$

The determination of an elliptical circumference is not so simple. The length of an elliptical curve can be calculated using the following integral:

$$L(i,j) = \int_i^j \sqrt{1 + y_1^2}\, dx$$

Where: $L(i,j)$ = elliptical arc length between boundaries i and j
y_1 = derivative of the function $y = f(x)$

For an ellipse:

$$y_1 = -\frac{bx}{a\sqrt{a^2 - x^2}}$$

Therefore, the arc length for an ellipse becomes:

$$L(i,j) = \int_i^j \sqrt{\frac{a^4 - (a^2 - b^2)x^2}{a^2(a^2 - x^2)}}\, dx$$

Simplification of this expression can be accomplished by introducing the numerical eccentricity:

$$e = \frac{\sqrt{a^2 - b^2}}{a}$$

It is possible to substitute x = sin θ and use the boundaries i = - π/2 and j = π/2 (half ellipse) yielding the following equation for the elliptical circumference (C_e):

$$C_e = 2a \int_{1/2\pi}^{-1/2\pi} \sqrt{1 - e^2 \sin^2 \theta}\, d\theta$$

The above integral is known as the "elliptical integral" and cannot be solved with elementary functions. Numerical solution requires using a computer to handle the large number of calculations needed.

Elliptical Deflection

For a deflected pipe, the original pipe circumference (C_c) will always equal the elliptical circumference (C_e).

$$C_c = C_e$$

Using this constraint, the values of a and b for a deflected pipe can be calculated. The values of a and b that correspond to various deflections are provided in Table 1 for R = 1.

Figure 2 diagrams the above deflections so that you can get a better physical idea of what these deflections imply.

Elliptical Pipe Hydraulics

To calculate the discharge capacity of a completely or partially filled elliptical pipe requires calculation using the "elliptical integral." As with any pipe, determination of the flow capacity requires calculation of the hydraulic radius and the area of the wetted cross section flow.

Figure 3 depicts the cross section of a partially full deflected pipe. The wetted perimeter part ACB of the elliptical perimeter can be calculated by defining the boundaries as

$i = -\pi/2$
$j = \propto$

Then the wetted perimeter is calculated:

$$C_{wp} = 2a \int_{-\pi/2}^{\propto} \sqrt{1 - e^2 \sin^2 \theta}\, d\theta$$

Where C_{wp} = the wetted perimeter of an ellipse.

The area of the elliptical segment AOB can be calculated as follows:

$$AOB_{ellipse} = \int_i^j S^2\, d\theta$$

Where S = the elliptical radius"

The equation for the radius squared at angle θ for an ellipse is:

$$S^2 = \frac{b^2}{1 - e^2 \cos^2 \theta}$$

The area of the elliptical segment can now be written as:

$$AOB_{ellipse} = \int_{-\pi/2}^{\propto} \frac{b^2}{1 - e^2 \cos \theta}\, d\theta$$

The wetted area can be calculated by simply subtracting the triangular area ABO from the area of the elliptical segment. The area of the triangle is:

$$ABO_{triangle} = (S \sin \propto)(S \cos \propto)$$

(Please turn to Page 9)

Table 1

Values of a and b, when R = 1

Pipe Deflection	a/b	a	b
0%	1.00	1.00	1.00
2.5%	1.05	1.024	0.975
5%	1.10	1.047	0.952
10%	1.20	1.089	0.907
20%	1.50	1.188	0.792
30%	1.80	1.260	0.700

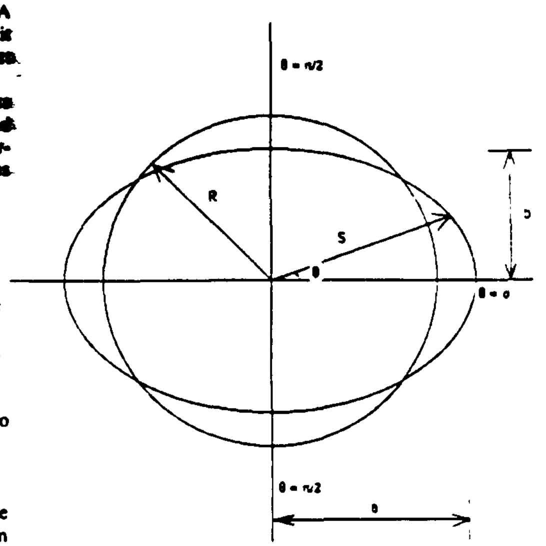


Figure 1 Elliptical vs. Circular Geometry

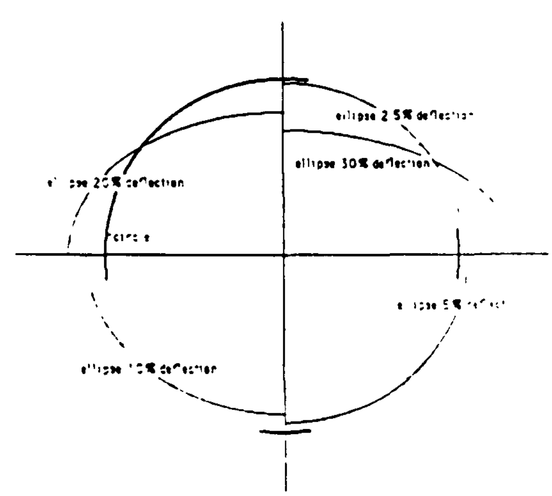


Figure 2 Elliptical Segments That Correspond With Specific Pipe Deflections

The Effects Of Deflection On Sewer Hydraulics

(Continued from Page 8)

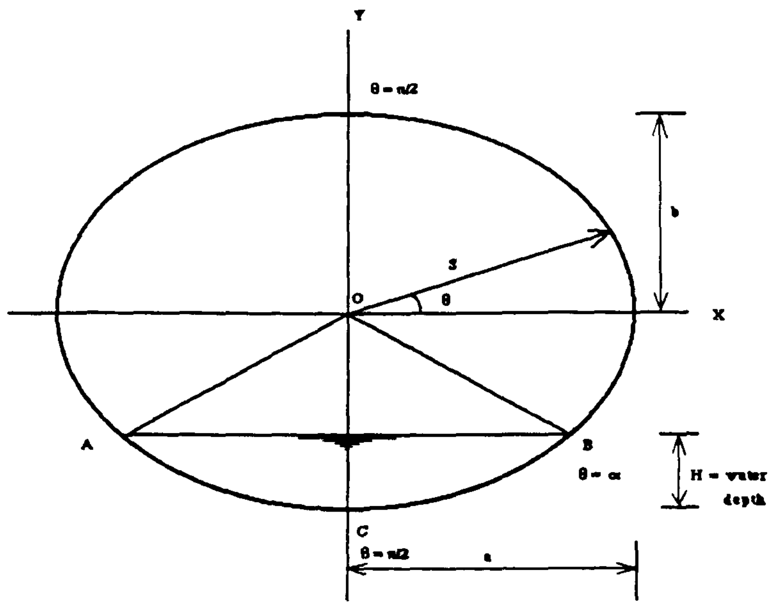


Figure 3: Cross Section of a Partially Full, Deflected Pipe

A single equation for the wetted area can now be written as follows:

$$A = \int_{-\pi/2}^{\alpha} \frac{b^2}{1 - e^2\cos^2} \, d\theta - \frac{b^2}{1 - e^2\cos^2\alpha} \sin\alpha \cos\alpha$$

Using this equation for the wetted area (A) and the previously derived equation for the elliptical wetted perimeter (C_{wp}), the hydraulic radius can be calculated.

$$r = A/C_{wp}$$

Where r = the hydraulic radius of the wetted cross section of the deflected pipe.

Simple trigonometry provides that the water depth (H) is determinant by the following relationship:

$$H = b - b\sin\alpha$$

Application of these equations, together with those from common hydraulic textbooks, enable us to compute the discharge capacity of either completely or partially filled deflected pipelines.

Calculation Results

A computer can be used to calculate the discharge capacities for various pipe deflections and flow depths. **Figure 4** graphically summarizes the results. As expected, discharge capacity is greatest with an undeflected pipe. However, the influence of the deflection on hydraulic discharge capacity is not significant until deflection exceeds 10 percent, i.e., less than 2 percent discharge capacity reduction for pipe deflected 10 percent.

To more clearly depict the percentage discharge capacity reductions, Figure 5 was developed. The graph shows that for deflections larger than 10 percent, the reduction in discharge capacity may be significant. The degree of significance will depend upon the amount of deflection and how closely the selected pipe size came to meeting the maximum discharge requirements for the pipeline.

These calculations and the resultant graphs can be used to determine the hydraulic significance of anticipated or actual pipe deflections. Normally, the very minor or insignificant hydraulic influences of PVC pipe deflection are more than offset by PVC's smoother interior waterway and fewer joints. Longer pipe lengths and smooth walls combine to afford lower hydraulic friction which yields higher flow velocity and increased discharge capacity.

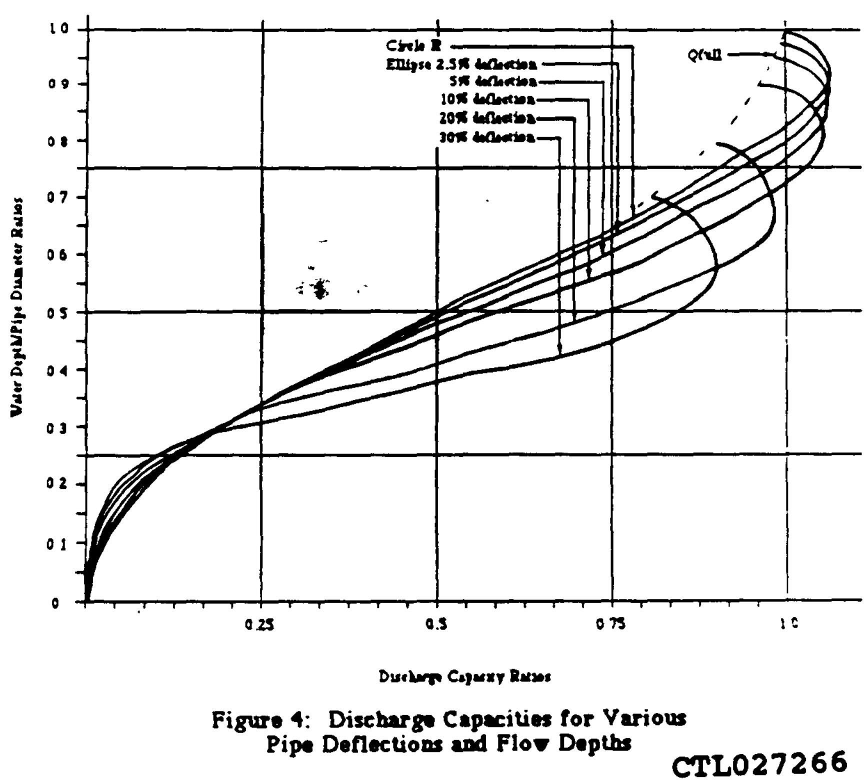


Figure 4: Discharge Capacities for Various Pipe Deflections and Flow Depths

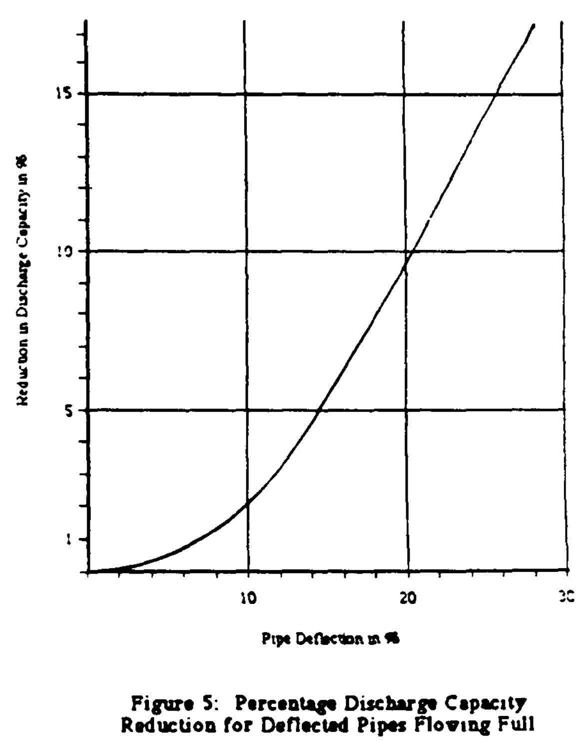


Figure 5: Percentage Discharge Capacity Reduction for Deflected Pipes Flowing Full

PVC Force Main Design Is Key To Long-Term Performance

By Dennis E. Bauer
Association Engineer

PVC has fast become the designer's choice for sewage force mains. PVC has gained a reputation as a superior performer for this application. Excellent flow characteristics, Hazen & Williams C = 150, a non-corrosive nature and system economy are just a few of the reasons PVC has received such high regard.

As with all engineered facilities, sound design is the key to economic long-term performance of PVC force mains. Particular attention must be given to the key design variables.

We quite regularly receive questions concerning proper design of PVC force mains. We appreciate the interest and hope the following design example provides answers to some of your questions.

SYSTEM DESIGN CONDITIONS

Given: 7,500 feet of 12" cast iron O.D. PVC pressure pipe meeting the requirements of AWWA C900, "AWWA Standard for Polyvinyl Chloride (PVC) Pressure Pipe, 4 In. Through 12 In., for Water," is to be used for a sewage force main. Sewage at a maximum future rate of 1400 g.p.m. will be transmitted through the line approximately 1.42 miles to a manhole as shown in Figure A.

The main has been designed such that the pumps will start and stop five times per hour. The main will be constructed in the southern midwest U.S. with an average frost depth of 2.0 feet. It will be placed below urban streets for a majority of its length.

Purpose of Design: To determine the appropriate dimension ratio (DR) requirements of the PVC pipe to be used.

INTERNAL PRESSURE CONSIDERATIONS

The key design variable for PVC pipe used in pressure applications is generally internal pressure. While force mains generally have very low internal pressures, they cycle on and off several times per hour. This creates surge conditions. These conditions are aggravated by air and hydrogen sulfide gas which may build up between the intermittent flow conditions. Therefore, fatigue may often be the critical design variable for force main design.

Step 1: Determine velocity for maximum flow.

See Table 41 (Flow Friction Loss, AWWA C900) of the Uni-Bell *Handbook of PVC Pipe: Design and Con-struction*, page 231 of 2nd edition.

At 1400 gpm, the velocity is as given below:

DR	Velocity fps
14	4.559
18	4.217
25	3.919

Step 2: Determine pressure required to pump to the manhole (P_p).

From Figure A we determine the elevation difference is 45 feet. Therefore, pressure required to overcome the elevation difference (P_e) = 45 ft x 0.433 psi/ft. P_e = 19.5 psi.

Pressure to overcome friction losses in the line (P_f) may be determined by multiplying the pressure drop values given in Table 41 of the aforementioned *Handbook* by the length of the line as follows:

DR	Pressure Drop psi/100 ft	Length of Main (100 ft)	P_f (psi)
14	0.224	75	16.8
18	0.185	75	13.9
25	0.155	75	11.6

Fitting and valve losses have not been calculated for this example. They may be converted to equivalent pipe length and represent a relatively small portion of the 7500' main. (See Figure 37, page 225 of the aforementioned *Handbook* for equivalent lengths.)

Pressure required to pump the sewage to the manhole (Pp) equals P_e + P_f.

DR	P_e (psi)	P_f (psi)	P_p (psi)
14	19.5	16.8	36.3
18	19.5	13.9	33.4
25	19.5	11.6	31.1

Obviously, the total pressures along the line are well below the pressure capability of DR 25 (PC 100). But because velocities are higher than the 2.0 fps which is accounted for in AWWA C900 and there are several surge cycles per hour, we must check surge pressures.

Step 3 Determine the surge pressures (P_s) associated with the maximum change in velocity (ΔV). In this example, it is assumed that no surge control devices are incorporated into the design. Therefore, the maximum change in velocity (ΔV) is taken to be the maximum velocity. Surge control devices should be provided. Water hammer or surge can cause serious damage to the system if not adequately considered. Additional savings in pipe material costs may be obtained by including surge control devices such as slow closing valves, pump flywheels, surge relief tanks and pressure relief valves. Air and vacuum relief valves should also be included in the system. These devices reduce surge pressures by reducing the change in velocity (ΔV). Surge pressures are calculated by multiplying the wave velocity (a) by the maximum change in velocity and dividing by gravity (g) as shown in the following equation: P = aV/2.31 g. For more information see pages 115 through 119 of the *Handbook*.

The maximum surge associated with an instantaneous change in velocity of 1 fps, for the various DR's, is listed in both the *Handbook* and AWWA C900 and may be used to determine the maximum surge as follows:

DR	Ps* (ΔV = 1.0 fps) (psi)	ΔV (fps)	Ps** (psi)
14	19.8	4.559	90.3
18	17.4	4.217	73.4
25	14.7	3.919	57.6

*See Section A.3.3 of AWWA C900

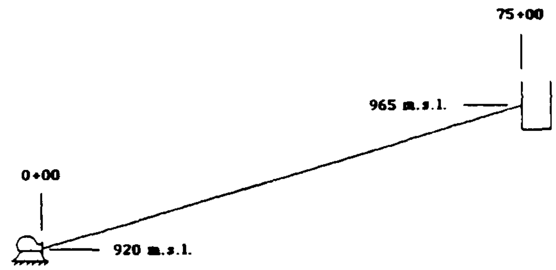
**Surge pressure obtained by multiplying P_s @ ΔV = 1.0 fps times the maximum ΔV.

Obviously, the surge pressures may represent the largest portion of internal pressure the line will experience if they are not designed out of the system.

Step 4: Determine the peak internal pressure (P_I) the line may experience.

$$P_I = Pp + P_s$$

FIGURE A



DR	Pressure Class (psi)	PP (psi)	Ps (psi)	PI (psi)
14	200	36.3	90.3	126.6
18	150	33.4	73.4	106.8
25	100	31.1	57.6	88.8

These total pressures represent those which would be experienced very near the pump station. Pressure to pump (Pp) would be reduced incrementally along the line. In this particular example, there is a uniform decrease in working pressure from (Pp) to zero gauge at the manhole, due to the constant slope of the line.

The surge pressure (P_s) is much less predictable in regard to precisely where along the line it will decrease. Air or other compressible gasses can aggravate the surge. This is why it is important to design the system to relieve surge.

We see that (P_I) is well below the pressure class of each of the respective DR's. We also realize that in accordance with AWWA C900 DR's 14, 18 and 25 have a built-in allowance for surge based on an instantaneous change of velocity of 2.0 fps. This adds an additional 39, 35 and 29 psi, respectively, pressure capability to each. Now we have a basis to begin a check for adequacy in fatigue.

Fatigue phenomena are well known and commonly considered in the design of piping systems regardless of the piping material. Only in liquid transport systems where severe cyclic surging is anticipated is fatigue failure considered to be a potential performance limit. Various empirical design methods can then be used to accommodate cyclic surging. As research on the subject continues, understanding of the fatigue failure phenomena is expanding. Consequently, design treatment to accommodate cyclic surging and "cyclic fatigue" is being refined.

Step 5: Check for adequacy in fatigue

Empirical equations developed by H. W. Vinson can be used in the conservative estimation of cyclic surge limits for typical PVC pressure piping systems. If the approximate number of cycles (C') which will be sustained in the life of the system is known, the required design peak hoop stress (S') can be calculated using the following equation:

$$S' = \left(\frac{5.05 \times 10^{21}}{C'}\right)^{0.204}$$

S' = Required design peak hoop stress, psi
C' = Anticipated number of cycles in life of system.

We are given that there are 5 on/off cycles per hour. This equals 10 surges per hour. If we select a 50 year design life, the anticipated number of cycles may be determined.

C' = 10/hr x 24 hrs/day x 365 days/yr x 50 years = 4,380,000 cycles

$$S' = \left(\frac{5.05 \times 10^{21}}{4.38 \times 10^{6}}\right)^{0.204}$$

$$S' = 1{,}182.0 \text{ psi}$$

Having determined the required design peak hoop stress, we may now calculate the required dimension ratio (DR), which equals outside diameter (O.D.) divided by minimum

(Continued on Page 11)

TABLE 1 - CALCULATED DEFLECTIONS OF BURIED AWWA C900 PVC PIPE
Deflection (Percent) for Highway H20 and Railway E80 Loads

Height of Cover →	2'		4'		6'		8'		10'		12'		15'		20'		25'	
Live Load →	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E8
E' Value	DR 14 Pressure Class 200																	
200	0.5	2.1	0.45	1.63	0.48	1.55	0.55	1.34	0.62	1.19	0.75	1.16	0.94	1.22	1.25	1.40	1.56	1 67
400	0.5	1.93	0.42	1.49	0.44	1.42	0.50	1.22	0.57	1.09	0.68	1.07	0.86	1.11	1.14	1.29	1.43	1.53
700	0.44	1.72	0.37	1.33	0.39	1.26	0.45	1.09	0.51	0.97	0.61	0.95	0.76	0.99	1.01	1.14	1.27	1.36
1000	0 40	1.54	0.34	1.19	0.35	1.13	0 40	0.98	0.46	0.87	0.55	0.85	0.69	0.89	0.91	1.03	1.14	1.23
E' Value	DR 18 Pressure Class 150																	
200	1.1	4.2	0.9	3.28	0.97	3.11	1.1	2.69	1.25	2.40	1.51	2.34	1.89	2.45	2.51	2.82	3.14	3.37
400	0.92	3.58	0.78	2.77	0.82	2.63	0.93	2.27	1.06	2.03	1.28	1.98	1.59	2.07	2.12	2.39	2.65	2 84
700	0.74	2.91	0.63	2.24	0.66	2.13	0.75	1.84	0.86	1.64	1.03	1.60	1.29	1.68	1.72	1.93	2.15	2.31
1000	0.63	2.44	0.53	1 89	0.56	1.79	0 63	1.55	0.72	1.38	0.87	1.35	1.09	1.41	1.44	1 63	1 81	1 94
E' Value	DR 25 Pressure Class 100																	
200	2.3	9.0	2.0	6.96	2.05	6.60	2.34	5.71	2.66	5.10	3.21	4.97	4.01	5.19	5.32	5.99	6.67	7 15
400	1.6	6.47	1.41	5.0	1.47	4.75	1.68	4.10	1.91	3.66	2.30	3.57	2.88	3.73	3.82	4.31	4.79	5 14
700	1.17	4.55	0.99	3.52	1.04	3.34	1.18	2.88	1.35	2.58	1.62	2.51	2.03	2.63	2.69	3.03	3.37	3 61
1000	0.9	3.51	0.76	2.71	0.80	2.58	0.91	2.23	1 04	1.99	1.25	1.94	1.56	2.03	2.08	2.34	2.60	2 79

See pages 158-169 of the *Handbook* for derivation of the equations used to complete Table 1.

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Back To Basics: Pipe Stiffness Fundamentals

by Dave Eckstein
Technical Director

Each *PVC Pipe News* we make an ardent effort to stay topical with subject matter. Your input to us has prompted the development of this new feature, "Back to Basics." Here, each edition we plan to take an in-depth look at some fundamental aspect of PVC pipe design.

Keeping pace with changing times and needs, the PVC Industry is ever introducing new applications and product lines. This updating requires a firm foundation in design basics for the novice and the seasoned PVC pipe designer alike.

This edition we examine the very beginnings in PVC non-pressure pipe design:

Pipe Stiffness in a Flexible Conduit

The relative flexibility or stiffness of a pipe has long been recognized as critical in determining the reaction of pipe to its environment, as well as, the environment to the pipe.

Pipe stiffness is defined as:

$$P.S. = F/\Delta y$$

Where: P.S. = pipe stiffness, psi
F = force, per unit length, lbs/in.
Δy = change in y axis, in.

The pipe stiffness is then a rating of the deflection performance under load. Pipes with relatively high stiffnesses will 1) deflect less under a constant load, or 2) require a higher load to produce a constant deflection. The converse is true for pipes of relative low stiffness.

In order to have values standardized for use in design and to compare different pipes, one of the variables in stiffness determination (force or deflection) must be set. Historically, the standards have set deflection as the constant and defined a value of 5 percent of the original outside diameter.

The American Society for Testing and Materials (ASTM) Standard D2412, "Standard Test Method for External Loading Properties of Plastic Pipe by Parallel-Plate Loading," delineates test protocol and calculation method for determining the standard pipe stiffness value for plastic pipe. Immediately evident from the standard's title is the verification that this is a pipe only parameter. Test specimens are placed in a parallel-plate loader with no side support.

To best understand the test and, therefore, the parameter it defines, a look at units is in order. Although commonly expressed in psi, stiffness is most accurately expressed as pounds per inch-inch. Pipe stiffness is produced by deflecting a sample to 95 percent of its original vertical outside diameter. The pounds force to produce the deflection is noted and divided both by the inches of travel representing the deflection and the inches of length of the sample.

Example. Take a one foot long sample of 100 inch inside diameter pipe. Say the force to reach 5 percent deflection is one half ton, the pipe stiffness is:

$$P.S. = F/\Delta y = \frac{.5\ \text{tons}}{(100\ \text{inches} \times 5\%)\ (1\ \text{foot})}$$

$$= \frac{1000\ \text{lbs.}}{5 \times 12\ \text{in}^2}$$

$$= 16.67\ \text{psi}$$

Likewise, take a six inch sample of 8" ASTM D3034, SDR 35 sanitary sewer pipe. The pipe stiffness is defined in standard D3034 as 46 psi. Calculate the minimum force required in the D2412 testing to meet minimum pipe stiffness.

$$P.S. = F/\Delta y$$

$$46\ \text{psi} = \frac{F/\Delta y}{(\text{I.D.} \times 5\%)\ (6\ \text{inches})}$$

$$46\ \text{psi} = \frac{F}{[8.4 - 2(.24)]\ .05 \times 6}$$

$$F = 46\ \text{psi} \times 2.376\ \text{in}^2$$

$$F = 109.3\ \text{pounds}$$

Mathematically, pipe stiffness can be expressed as:

$$P.S. = \frac{EI}{0.149r^3}$$

Where: E = Modulus of tensile elasticity of the pipe material, psi.
I = Moment of Inertia per unit length, in^3
r = Mean radius of the pipe, inches

Stiffness physically is a function of the strength of the material from which the pipe is made (E) and the configuration in which it is manufactured (I and r). Let's look separately at these variables and its current direction within the pipe industry.

RAW MATERIAL

Pipe grade compounds for non-pressure applications today range in modulus of elasticity (E) from 400,000 psi to about 560,000. The PVC resin used in the making of all these compounds is basically the same. It is the compounding, both the additives themselves and the technology with which they are combined, that make the difference in end product performance.

Due to several changes in the non-pressure pipe markets of late, it has become more feasible to compound specifically to that market. Resin costs, improved performance additives, compounding technology and larger non-pressure markets are among the factors involved. More and more the users will be seeing compounds specifically geared to the end use.

Virtually any aspect of change to physical properties carries with it the possibility of consequence, positively or negatively, to some other aspect. It is imperative then to monitor all aspects when changes are made. Regulatory-wise that is accomplished by standardizing the allowable compounds to be used by specification of cell classification. The cell classification defines physical property ranges in many areas of performance, therefore, providing the check and balance required. It should be noted that it is this reasoning that has defeated some recent attempts to legislate additive levels or filler content, in favor of sticking with cell class specification. Additionally, the filler content approach ignores the technology of compounding and leaves the user open to the risk of an incompetent compounder and closed to the advantages of a competent one. Only cell classification places "as compounds" performance requirements.

CONFIGURATION

The configuration component of pipe stiffness is governed by the moment of inertia (I) and the mean radius (r). Configuration or shape design is not new to structural analysis of any kind including pipe. The trend for the past few years, however, has certainly been one of increasing attention to this facet of stiffness. The result of this attention has been an assortment of product lines manufactured in profile wall configurations. The intent, as before, is to offer the same stiffness with less material (as compared with solid wall pipe) in the case of sanitary sewer pipe. The profile configurations also can offer a more cost effective performer for new markets, for example lower stiffness pipes for storm drain applications.

For illustration purposes, a trip back to my high school physics class is in order. All those years ago in Des Moines, Iowa, we were told to hold a piece of paper (8 1/2 x 11 variety) cantilever by one of the short ends. Our not so lovely assistant, my parents having viewed my grade school performance had sentenced me to an all boys school, was instructed to place a quarter on the far end. (Unlike the experiments on TV, go ahead and try this one at home.) The obvious result was that paper isn't very good at the structural requirements of quarter holding.

Now we were instructed to take the same piece of paper and alternately fold approximately 1" strips up and down across the width. Re-enactment of the quarter placement proved structurally far superior in this configuration. Same material, more structurally efficient profile.

The analogy to pipe holds good one more step in that there was additional work required to manufacture the profile. In pipe also, the economics of profile are normally in excess of that for solid wall. Diameter, required stiffness, material savings, extrusion cost, etc., all become variables which ultimately dictate overall selection.

Having reviewed the mechanism of pipe stiffness and the variables involved and their role, the user can better judge the appropriateness of different product prototypes for different end use applications. The present and future hold many new opportunities for the PVC pipe industry. Opportunities that both the Industry and the users are anxious for us to accept.

Pipe stiffness and its role in buried pipe performance? Maybe next time, or how about HDB determination in pressure pipe or something else? Let me hear from you!

Force Main

(Continued from Page 10)

wall thickness (t), by using a form of the ISO equation.

$$DR = \frac{2S'}{P} + 1$$

DR = dimension ratio
S' = required design peak hoop stress, psi
P = peak internal pressure (P_I), psi

Peak internal pressure is dependent upon change in velocity in a given DR. We will check the adequacy of the largest DR, lowest pressure class, first.

Given: DR 25 has a P_I of 89 psi.

$$\text{Therefore}\quad DR = \frac{2S'}{P} + 1$$

$$DR = \frac{2(1182)}{89} + 1$$

$$DR = 27.56$$

Therefore, as long as the PVC pressure pipe product has a DR less than 27.56, it will meet the given requirements of 10 surges per hour for 50 years.

DR 25 is adequate for this example.

In this particular example, a product meeting AWWA C900 was specified. DR 25 is the lowest pressure class available meeting this standard. Lower pressure rated products (higher DR's) which meet ASTM D 2241, "Standard Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)," are available. They may offer a similarly conservative yet more economical design.

In this 7500' project the required pumping pressure (Pp) is reduced uniformly over the length of the project. For DR 25 Pp is 31.1 psi. At the midway point in the line the working pressure will be 0.5 x 31.1 or 15.55 psi. If the peak internal pressure is reduced by 15.55 psi, the required DR becomes:

$$DR = \frac{2(1182)}{89 - 15.55} + 1$$

$$DR = 33.19$$

By calculating the pressure gradient and utilizing an iterative design procedure, one may determine the most economical design while maintaining a given safety factor. See pages 120 to 129 of the aforementioned *Handbook* for further details of cyclic fatigue design.

EXTERNAL LOAD CONSIDERATIONS

External loads are seldom the critical design variable for PVC pressure pipes. However, in a force main application where intermittent flow and severe cyclic surge conditions may exist, which may be either positive or negative, it is appropriate to consider external load.

The above example verified that DR 25 would meet the internal pressure requirements. The external loading will consist of the earth load (dead) and traffic load (live). It is given that the frost depth is approximately two feet and that the line will be buried beneath paved roadways. Therefore, highway (H20) loading with three to four foot of cover is the combined loading which must be considered.

Table 1 (on page 10) lists calculated deflections for C900 PVC pipe under various combined loadings. A check of DR 25 under 2 to 4 foot of cover with an H20 live load reveals

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Pembroke

(Continued from Page 3)

material qualities as the small diameter, such as good flow characteristics and no susceptibility to corrosion." This made PVC an ideal choice for the dual force main.

Construction of the eight mile dual PVC force main began in March of 1987 and was completed on schedule in March of 1988. Phase one of the construction included clearing and demucking along the majority of the length of the proposed route. A tremendous amount of overgrowth existed in the undeveloped areas. Next came the process of demucking. The first three feet of trench was a soft organic material. Following this was the removal of several feet of lime rock. As the photos show, there was a constant battle to keep the ditch dry. The water table is near the surface in South Florida, as you might guess.

The bedding for the pipe consisted of 8 to 12 inches of gravel. This material was brought up to the springline of the PVC pipes. The photos reveal that spacing between the two mains was such that the granular material could be adequately placed in the haunch areas between them. The initial backfill, which consisted of a sandy granular material, was placed to a few inches above the pipes and native final backfill material followed.

Upon completion of the installation the dual force main was pressure tested. The line was required to undergo a 200 psig pressure test for the first half mile from the pump station. The remainder of the line was tested at 150 psig.

The dual PVC force main has been in service just a little under one year now. The smaller force main is now nearly full and the larger force main will be opened soon. According to Mr. Michael F. Estok, Pembroke Pines Director of Public Services, "The line has lived up to our expectations. It is working just fine."

Force Main

(Continued from Page 11)

that the maximum deflection is 2.3 percent, well below the acceptable limit for PVC pressure pipe. It also reveals that this deflection would occur at the minimum depth of cover with the lowest E', worst soil compaction combination, listed in the table. Therefore, if the pipe is installed with class IV material bedding and haunching or better, and at least a slight compactive effort, the external loading is not critical.

PVC pipe, under normal temperature conditions, can withstand a vacuum. However, when a vacuum occurs it acts in addition to the external loads. It will seldom be a critical design variable. For additional information refer to an article entitled, "A Discussion of PVC Pipe Under Vacuum," in our *Summer 1988* issue of the *Uni-Bell PVC Pipe News*.

OTHER CONSIDERATIONS

The same methods commonly used to determine thrust forces in other types of pipe are utilized for PVC. Fittings and valves must be blocked against those forces.

PVC pressure pipe is offered in both IPS and C.I.O.D. regimens. It is currently manufactured in diameters up to 30 inch. It may be incorporated into most existing systems without the necessity for dual inventory of fittings.

PVC pressure pipe offers the physical properties required to withstand both internal pressure and external load. Because it is produced in a range of pressure ratings, cost efficient combinations can be selected by the engineer for specific applications. High safety factors may be maintained without over designing. As can be seen in the example above, cost effectiveness can be achieved without a complicated design procedure.

We hope the example comes in handy. For more information concerning PVC force main design please give us a call.

Pressure Fittings: A Non-Corrosive Connection

Mention PVC to Bob Kreykenbohm and you get much more than his sudden attention. Quite obvious, even on the telephone, is his unbridled enthusiasm for the term. In his position as Water Superintendent for the Sandwich Water District, which provides drinking water to the Cape Cod resort community of Sandwich, Massachusetts, Kreykenbohm is a self-confessed proponent of PVC pipe and fittings.

PVC fittings? "You bet," Kreykenbohm says. "We've just installed 52 of them in about 7 miles of 6-in. and 8-in. water transmission lines and they tested out perfectly. No leaks. Lower cost."

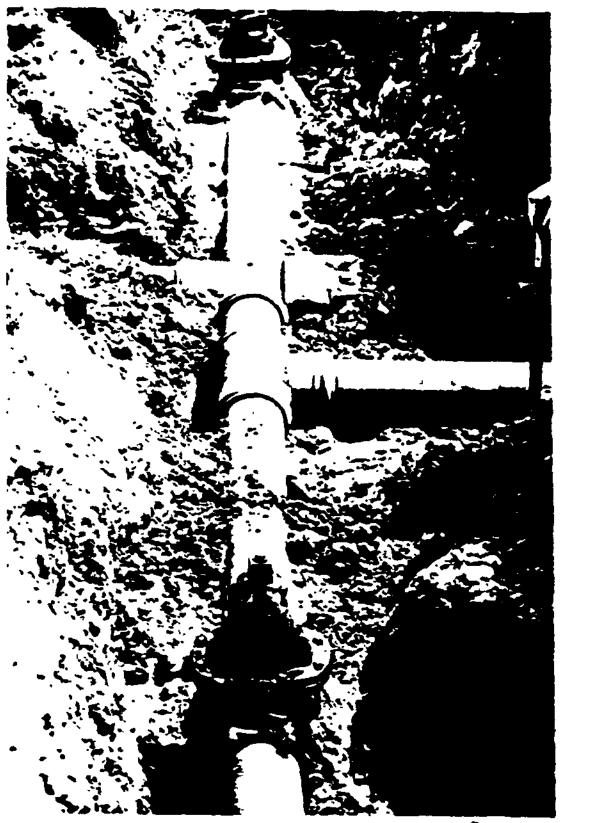
"But then again, that's what we expected, even though I'm told our installation is the very first in North America for these fittings." Several years in development and testing stages, the new PVC fittings are injection molded through a unique technology. The fittings are produced with a hydrostatic design basis (HDB) of 4000 psi comparable to PVC pipe manufactured to meet AWWA C900. The PVC fittings are designed for Class 150 (DR 18) PVC pressure pipe conforming to AWWA C900.

Altogether, 40 6-in. and 12 8-in. fittings were used (both Ts and elbows). The water main, now installed and operating, provides water from gravel pack wells to three different subdivisions at an average pressure of 78 psi. The main, though designed to carry 1,000 gal/min, for fire flow reasons, is averaging "well below" that, according to Kreykenbohm.

"Over the last several years, we have replaced an estimated 2 1/2 miles of 2 - 2 1/2-in. cement-lined wrought iron pipe with PVC in our 125 mile system," he notes. "In all cases, we have upgraded to the larger 6-in. and 8-in. sizes for fireflow purposes."

The big reason the Board of Water Commissioners of the District has readily agreed with Kreykenbohm's recommendations to go almost exclusively with PVC pipe, and now fittings, is cost. Long-term corrosion free service provides added value.

"On a per-foot basis, our costs on this particular installation would range from $16 to $32 per foot. That includes all materials, labor, top cover extras and so on," Kreykenbohm says. "The biggest material savings come at intersections where you have the majority of fittings. I would estimate a 50 percent savings over ductile fittings on the complete project," he notes. But Kreykenbohm's biggest consideration was "the labor factor, where it's not unusual to pay $25 an hour," he points out. In most cases, the District handles its own installation of water mains. The men in charge: Kreykenbohm, along with Assistant Water Superintendent. Dan Mahoney.



PVC pressure fittings complete the project.

"Overall cost of this particular installation was around 25 percent less than ductile," Kreykenbohm says. "A lot of that savings can be attributed directly to the PVC fittings. "Ductile fittings require mechanical joints, and need to be bolted together. This takes time," he reasons. "The PVC fitting joints are virtually identical to the pipe. We simply push fitting and pipe together using a crowbar. Installation is that simple and fast, and there were no leaks," he emphasizes.

Testing of the completed mains was done at 150 psi in several 20-min. stages. Pressure was raised and held for that time, then dropped, then repeated.

The Class 150 PVC fittings offer long-term hydrostatic strength, satisfying all contemporary safety standards for municipal water systems throughout the U.S. and Canada. Quick Burst Strength rating is 755 psi (5.21 MPa) minimum, when tested in accordance with ASTM D1599. Minimum wall thickness of the fitting body is at least 125 percent the wall thickness of Class 150 (DR 18) C900 pipe of the same size. The fittings conform to UNI-B-12, Recommended Standard Specification for Polyvinyl Chloride (PVC) Pressure Fittings," as well as CSA B-137.2, "Poly(Vinyl Chloride) PVC Injection Molded Gasketed Fittings for Pressure Applications."

Kreykenbohm is also counting on other benefits inherent in PVC products. The glass-smooth surface of the pipe and fittings minimizes interior buildup and thereby friction losses. "In my experience over the years all we'll see is maybe a thin film. Periodic flushing, done on a yearly basis, takes care of that." Corrosion is of no concern to Kreykenbohm. The PVC fittings are not subject to galvanic or electrolytic corrosion. No wrappings or coatings were required.

Kreykenbohm foresees no need for regular maintenance of any kind. "The life expectancy of the mains is forever," he says, "and this includes the fittings. In the future as the community grows, the only factor making them obsolete might be fire flow capacity. But that's a long way off. You and I won't be around, that's for sure."

Did the Uni-Bell member company PVC pipe or fittings present any unexpected problems on this job, Kreykenbohm is asked.

His answer is, "None. Deliveries were on time and their on-the-job service support was great. What I like best is, what they say they'll do, they do, that goes from the president on down."

Kreykenbohm interrupts his own comments and pauses: "Oh, there is one thing I want to mention. Their pipe is too slippery. Our laborers walk on it in the trench. I keep thinking someone will slip and fall and get hurt.

"Seriously though," he concludes, "that was my only major concern on the whole job."

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