Polyethylene Plays Vital Role in Conservation

By

Drew L. Wilson

Jim Craig, PE

Chris C. Greggs

McElroy Manufacturing, Inc.
Tulsa Oklahoma

ABSTRACT

This paper provides an overview of the condition of the nations water infrastructure and the need to replace piping systems with materials that do not leak. This report discusses conservation at the root of the problem, detailing percentages of water lost in piping systems due to main line breaks, corrosion and joint leakage. Also discussed is cost analysis of lost revenue due to leakage, leak detection, leak repair, and future estimated repair expenditures. The use of High Density Polyethylene Pipe (HDPE) over the past 35 years in the gas industry is a model of study for a leak free distribution system. It has also pointed the way to the safest, most reliable, affordable and longest lasting water distribution system available. Topics covered include: installation, environmental impact relating to infiltration and seepage, water hammer, the role of heat fused joints as the solution for a monolithic structure.

American Water Works Association
Dedicated to Safe Drinking Water

Copyright © 2002, American Water Works Association. All rights reserved.

INTRODUCTION

Water is never a concern to most people until they turn the faucet on and nothing comes out. This attitude is primarily because the distribution of clean water in the United States of America has been one of the greatest and most efficient achievements of the 20th century. The National Association of Engineers (NAE) ranked clean water distribution fourth in order of importance as having the greatest impact on the quality of life in the U.S.[1] Putting this into perspective, achievements in the water industry rank just under the introduction of the airplane and just above the importance of electronics.

The distribution of clean water is not only a great achievement; it is indeed a crucial requirement. It is a requirement that commands attention to detail and constant study of technologies and techniques that will improve the effectiveness of the system.

It is time to follow the great history of water distribution by exploring the new technologies that will keep the effort of water distribution moving forward. We now have the ability to improve upon the manner in which the world's most valuable resource is delivered.

Clean water deserves a piping system that does not leak. A piping system that is not only the most environmentally safe but will last longer with fewer failures than any other piping system in existence. A piping system that is easy to install, requires little or no maintenance, and is the most economically feasible piping system available. The piping system that boasts these qualities and can insure the future of clean water distribution in the U.S. has one vital component. That component is High Density Polyethylene (HDPE).

THE NEED FOR NEW TECHNOLOGIES

Water conservation is a driving reason for the need to improve our distribution system. There is a consensus of opinion that leaks in the water distribution system are unavoidable. And while incremental improvements to the system have been made over the last 100 years, it is commonly believed that a leak rate of 10 to 15% is a normal acceptable level. Given the materials with which engineers had to work, given the age of the system already installed, and given the expense to repair leaks, it was not possible to strive for a leak proof system. In the past, 10 to15% was the best that could be achieved. Fifty years ago, the technology to achieve a leak proof system, simply did not exist.

But times have changed significantly since then. In the first half of the twentieth century, populations were smaller, labor was cheaper, and water was relatively plentiful. In the United States, the country was growing and most of the infrastructure was fairly new.

Copyright © 2002, American Water Works Association. All rights reserved.

The focus was on industry and expansion. Leaks were simply considered an unavoidable nuisance. The focus today has changed considerably and is now directed more on conservation, cost, and safety. As such, utilities, governmental regulatory agencies, and conservationists are reviewing our distribution systems and paying heavy attention to leaks; and they are finding the costs staggering.

According to the Community Water System Survey,[2] water utilities self reported leak rates average 13%. Many in the industry feel this number is wildly optimistic, and reports that range closer to 20 or 40% percent are abundant. According to one study by the International Water Supply Association, 20 to 30% of water never reaches its intended destination.[3] Whichever number one believes, the effects of such high leakage are taking their toll. For example, the governor of New Jersey has declared a Water State of Emergency for his state. And while this is commonly blamed on the drought conditions in the Northeast, the *Star-Ledger* of Newark reported that the state of New Jersey states their water distribution system has a leak rate of 25%.[4] There is no doubt that, if New Jersey had a leak-proof system, there would be plenty of water for the state even considering the drought conditions.

Let us put this into a different perspective by considering the US water distribution system in the aggregate. There are 54,000 water systems in the US processing nearly 34 billion gallons of water per day.[5] A 25% loss ratio is equivalent to 8.4 billion gallons of water every day produced, but never delivered. To have a better understanding of the amount of water involved, consider that about 8 billion gallons of water passes through Hoover Dam and 6.9 billion gallons over Niagara Falls every day. Even using the consensus on acceptable levels of leakage, there is almost as much water leaking from our piping systems on a daily basis, as the amount that pours over Niagara Falls each day.

According to the AWWA *Stats on Tap*, if 100% of the households in the U.S. installed water-saving showers, clothes washers, toilets, dishwashers, baths, faucets and fixed all the household leaks, water use would decrease by 5.4 billion gallons per day. This would translate to dollar volume savings to the consumer of over $4 billion per year.[5] If the 8.4 billion gallons of water that leak from our distribution system each day were not lost, an increase in revenue of $6.2 billion per year could theoretically be realized.

In Europe, the water distribution system is older than that of the U.S. and therefore less efficient. According to Kaj Barlund, Director of the Environment and Human Settlements Division of the United Nations Economic Commission for Europe, "On average between 40 and 60% of water, which is produced, is lost before arriving at the tap."[6] This, in combination with the growing concern of water contamination, causes great concern.

If water can leak out, contaminants can seep in. Leaks in waterlines can cause reservoirs to form that become stagnant and grow bacteria. As long as the pressure is constant these bacteria should not infiltrate the pipe system. As soon as the water pressure drops, exterior water is siphoned into the pipe and pumped directly to the tap.[6]

Copyright © 2002, American Water Works Association. All rights reserved.

It is certain that of this reported water leakage, a small percentage of the water loss is due to fires and flushing water lines. However, the majority of the water loss comes from worn, broken pipes and joints. This is caused by corrosion, aging, ground shift and loading (water hammer).

An AWWA report titled "Reinvesting in Drinking Water Infrastructure Dawn of the Replacement Era" estimates that over the next 30 years $250 billion need to be spent just to replace failing drinking water infrastructure. This figure does not include wastewater infrastructure or new drinking water infrastructure.[7] The Water Infrastructure Network (WIN) released a report in March 2000 that says over the next 20 years, America's water systems should invest $11 billion a year more than current investment levels to meet the national environmental and public health priorities in the Clean Water Act and Safe Drinking Water Act to replace aging and failing infrastructure.[8] In 1997, the U.S. Environmental protection Agency (EPA) submitted the result of a two-year infrastructure needs study to the United States Congress. The EPA reported that $138.4 billion needs to be spent on U.S. water infrastructure just to make it comply with current regulations.[2] There is debate on what the actual expense will be, and more research is needed, but it is agreed upon that the amount is staggering.

Water is a precious commodity. It is more expensive than it has ever been in the history of the world. During the past decade, water rates have increased faster than the Consumer Price Index (CPI) according to the EPA's Community Water System Survey. Rate increases have ranged from 4.9% to 14.8% annually. The CPI over the past several years has been approximately 3%. Telephone service, piped gas, and electricity all had substantially lower rates of increase than the CPI. The only service that had a higher rate increase than water was cable television.[2]

Despite this increase in price to the consumer, many water systems have reported costs that exceed revenues. The percentage of water utilities with deficits (or losses) is higher in smaller systems. More than 25% of publicly owned systems serving up to 50,000 connections reported deficits. The percentage of privately owned systems reporting losses was slightly lower.[2]

U.S. community water systems reported a capital investment of $32.6 billion in the last eight years. Of that amount, 30.6% was spent on repair and replacement of failing infrastructure and 49.9% was spent on expansion. From 1990 through 1994 community water systems replaced 1 million miles of pipe and performed over 360 thousand repairs to mains.[2]

The high cost of premature replacement of failed or leaking pipe systems has a big impact on the economics of distribution systems. For utilities, the water distribution system already has the highest asset-to-revenue ratio. For water utilities in the U.S. the ratio averages about $5 of gross assets (e.g., treatment plant, distribution systems) for

Copyright © 2002, American Water Works Association. All rights reserved.

every $1 of revenue. In comparison, according to the American Gas Association, the asset-to-revenue ratio for gas utilities in 1994 was about $3 to $1.[2] This reflects the high capital investment of water utilities even before spending the money needed for repairs and projected growth.

To sum up the situation, water loss in the distribution system is high. The U.S. needs to invest billions to solve this problem. A significant number of utilities are losing money and the price of water has been increased far above the CSI. If the water that leaks through the distribution system were delivered, it would translate to billions in revenue and contribute strongly to conservation. A lot of money is being spent on infrastructure and much more is needed. If current methods that use outdated technologies continue, the result will be exactly what the water companies find themselves experiencing right now; high maintenance cost coupled with a system that delivers only 60% to 85% of the billable resource. It is a situation that can only be solved through one of two options.

a. Increase the price of water to pay for ongoing maintenance
b. Decrease water loss and the costs of maintenance

Consumers have already seen price increases in excess of the CPI. A far more preferable way to address the problem would be to reduce cost.

This paper addresses solving the problem of water loss by implementing a leak proof, distribution-system made of HDPE. HDPE will far outlast the materials that are in use today and drastically lower the huge amount of expense needed for maintaining water infrastructure due to constant repair as well as future capital expenses to rebuild the system.

The decisions made right now on how to solve the water distribution problems, will have a direct impact on the health, economy and well being of millions of Americans. The U.S. is now at a crossroads. The problem can be attacked by continuing to patch existing lines and installing the same materials that are causing the problem now; or the problem can be solved by implementing the new technologies that are now available and have been proven to create the only leak free, maintenance free piping system in existence.

The legacy left behind will be under the scrutiny of future generations. Hopefully it will be one similar to past achievements in water distribution and rank as one of the greatest accomplishments of the 21st century.

HDPE HAS A PROVEN TRACK RECORD

The use of HDPE over the past 35 years in the gas industry is a proven model for a leak free distribution system. High standards and strict regulation to avoid gas leaks led to the development of the piping technologies that are now in use in the gas industry. Safety was the key concern that sparked the improvement. From a safety standpoint, a leak in a gas line can cause fire, explosions or death. Although a leak in a water line may not cause death, there is the growing evidence that back siphoning can cause contamination.

Copyright © 2002, American Water Works Association. All rights reserved.

If health and safety were not a concern at all, it would still be smart to take advantage of the improvements in a piping system that delivers 100% of the resource, costs less to maintain and in many cases is less expensive to install.

According to 1999 Gas Facts there are 380,000 miles of HDPE main gas lines[9] and over 28 million service lines in the U.S.[10] 90% of all new underground gas pipe installed today is HDPE.[9] Of the HDPE lines, there is an average of fewer than 10 leaks a year caused by something other than third party damage.[11] These figures demonstrate the confidence that the gas industry places on the suitability of HDPE as a leak proof gas distribution pipe material.

Besides the leak proof qualities of PE, another reason the gas industry is using it in 90% of new installation is that installation cost can be about half the cost steel pipe with cathodic protection. In a gas utilities survey conducted by Pipeline & Gas Journal in December of 2001, price per foot to install 2-inch HDPE ranged from $1.25 to $25.18 and $5 to $26 for 6-inch. Steel main installation costs ranged from, $4.60 to $66.23 for 2-inch and $8 to $88.75 for 6-inch.[12]

The majority of gas companies that responded to the survey stated that programs are in place to remove and replace all cast iron and bare steel mains. Most are replacing them with PE. Expenditures associated with repairing old iron and steel lines that leak are excessive. A gas company in Illinois serving 845,000 customers reported spending $1,950 per leak repair. The company also indicated that it expected to spend $900,000 on leak detection and repair efforts for the following year. One gas utility with 198,000 customers indicated spending $300,000 to $500,000 per year to find and repair leaky mains. To realize significant cost savings, a gas company in Salt Lake City, UT with 720,000 customers has already removed and replaced all cast iron and bare steel in its existing system.[12]

In the U.S., HDPE has piggy backed its way into the municipal water market on the back of trenchless technologies. Most of the time, PE is just used where there is a high chance for failure of conventional materials, like a river bore or highway crossing. This is because PE is tough and flexible and with butt-fused joints, there is little chance of separation upon pull back when boring or sliplining.

The shipment of HDPE pipe grows every year. A major reason for the growth of plastic pipe, according to *Plastic Piping Handbook*, *McGraw-Hill*, is the cost savings in installation, labor and equipment as compared to traditional piping materials.[13]

EUROPEAN MARKET

Copyright © 2002, American Water Works Association. All rights reserved.

The growth of HDPE pipe in Western Europe shows that the market has nearly doubled in volume since 1985.[14] The growth began as a direct result of the success obtained from experience using HDPE in the gas industry. The high level of reliability with HDPE resulted in water and sewer applications taking advantage of the material. This has also been contributing to the overall increase of HDPE since 1990. The prediction to 2005 shows even further growth expected in water and industrial applications of PE.[14]

One reason for HDPE gaining acceptance in water distribution was the poor service record of other piping materials previously used in water distribution. Recent studies by The University of East London confirm a relatively high level of PVC and Iron failures. Iron pipelines show 203.7 failures per 1000km and PVC-U pipelines show 156.6 failures per 1000km.[15] The United Nations Economic Commission for Europe estimates the economic cost of these leakages for the whole region at about $10 billion a year in terms of clean water wasted alone.[6]

HDPE now plays a prominent role in water distribution in the UK. In 2000, an analysis of the pipe installed by the water companies in the UK, France, Italy, Spain and Germany, carried out by the Corporate Development Consultants (CDC), shows that the majority of pipe now installed below 300 mm, about 12 inches diameter, is HDPE.[14]

The popularity of HDPE in the natural gas industry has played a significant role in the growth of the plastic pipe industry. It has also led the way for HDPE to enter the water distribution market, which is also driving up shipments.

HDPE SOLUTION

Perhaps heat-fused joints are the key to the success of HDPE. A totally fused HDPE system is truly a monolithic structure. Heat fusion produces a leak free joint that is stronger than the pipe itself. In essence, there is no joint. With a permanently sealed pipeline, nothing can enter or exit the pipeline unless it is cut open by third party damage. HDPE does not rust or corrode and has a very low flow resistance. HDPE piping systems resist attack from corrosive soils. The smooth wall of HDPE makes the transport of water more efficient and effective. It also has a high resistance to scale or build-up and does not rupture at sub-zero temperature conditions.

HDPE greatly reduces the impact of water hammer. As the speed of the water increases, the pressure exerted on the piping system and fittings increases. Because water is non-compressible, the force increases as the velocity of the water is suddenly reduced. This causes a backpressure wave called “water hammer,” or “hydraulic transient” as used more recently. The instantaneous elasticity of polyethylene pipe significantly reduces the shock wave speed, the associated pressure surge, and contributes to faster dissipation of the surge event. In addition, HDPE pipe can withstand intermittent surges up to 200% of the design pressure of the pipe system. In this manner HDPE pipe has a “built in” allowance, which not only allows surges but also dampens the magnitude of the event.

Copyright © 2002, American Water Works Association. All rights reserved.

As a result all the components of a piping system will be subjected to a significantly lower surge when HDPE is utilized. This will also result in a longer life for the system.

The flexibility of HDPE is unequaled in comparison to any other piping material. It flexes with the shifting ground instead of breaking and can be bent at a radius of 25 times the diameter of the pipe. The pipe can follow natural contours as in cul-de-sac operations and transition smoothly around obstacles. This can reduce or eliminate the number of fittings, couplings and restraint blocks that would be required in most piping applications.

HDPE's toughness and ability to withstand tremendous force, has been proven by its ability to survived major earthquakes such as those that occurred in Kobe, Japan in 1995. No other piping system survived the earthquake in Kobe unscathed.[14]

The cost of installing pipe in the ground is the most expensive aspect of the overall project. The cost of the pipe and fittings on a large project is possibly less than 10% of the total installed cost.[14]

There are many old leaking pipes that are expensive to repair. In many instances it is not necessary to excavate and remove the entire line to replace it. HDPE lends itself for renovation by insertion into old leaking pipelines by slip-lining, pipe-bursting, pipe-splitting and inreaming with very little digging required. These techniques can result in significant reductions in installation costs compared to other materials that require open cut and removal and disposal of damaged pipe.

The unique material characteristics of HDPE allow it to be introduced into a water system through a variety of different construction methods in 40/50-foot sections or in spools of up to 1,000 feet. Coiled pipe has been determined to save an additional $1 a foot in installation cost by the Institute of Gas Technology. All fittings, and repair valves are available for transition to any other materials. In many cases these installations can be made without opening a trench because HDPE is the preferred material for trenchless technologies. One municipality in Colorado saved $25 million off their maintenance budget in one year just by lowering asphalt repair expenses by using horizontal directional drilling under roads.[16]

HDPE is lighter than most other piping materials and does not require the handling equipment used by the heavier materials. Even in large diameter pipe, HDPE still has a significant weight advantage over metallic or cement pipe. Cutting, joining and installing HDPE is far simpler than the same procedures for other materials. At today's labor rates, the increased productivity is vital to the overall piping system cost.

In Mexico City trenchless technologies are being used to replace asbestos cement pipes with HDPE. In 1997 the city was losing 37% of its water due to leaks in the infrastructure. By 1999 leakage is estimated to have fallen to 32%. A 5% improvement in two short years is commendable.[17]

Copyright © 2002, American Water Works Association. All rights reserved.

Perhaps the most significant advantage HDPE has over other piping materials is the savings gained over the extended lifetime of the piping system. The asset value to any water utility of its distribution system significantly depends upon its operating lifetime. Lifetime expectations should play a major role when selecting materials for a pipe system.

People incorrectly quote that the minimum working life expectancy of HDPE is 50 years. This quote comes from the accounting basis that the construction costs of the pipeline can be written off over a period of fifty years at a rate of 2% per annum.[18]

The results of long-term failure tests carried out on pipes under elevated internal hydrostatic pressure show that the HDPE pipe materials available today have a reliable service life of more than 100 years. The test states that real HDPE pipelines should be capable of lasting much longer than the test pipes because the load placed on the test pipe is much higher than normal load conditions. It should also be considered that pipelines are usually laid underground and are better protected against environmental influences than the test specimens.[18]

To have a full understanding of the economic benefits of HDPE one must view the system as a long-term investment. To compare HDPE with other materials solely on price per linear foot of raw material is a fallacy of economic comparison. Other items should be taken into consideration like the savings associated with collecting on 100% of the billable resource, lower installation cost, or having a maintenance free system that has a longer life.

A software package developed in the UK called WATERFOWL was written to aid rehabilitation planning for pipelines on a whole-life costing evaluation. The economic analysis is based on comparing the cost of owning a main in its poor condition over X years, against the cost of performing rehabilitation methods now and owning the main in its improved condition for X years. The analysis assumes that if a new main replaces an old main in poor condition, then the new main will have a burst and leak rate of zero. Therefore the new main will not have the expenses of leak repair.

The main factors considered are:

1. length of main and number of connections
2. number of bursts (leaks) per year
3. number of complaints per year
4. volume of water lost due to bursts
5. volume of water lost due to background leakage
6. marginal cost of water
7. cost of burst detection, location and repair; and
8. cost of customer complaints/compensation payments
9. installation cost
10. capital cost of rehabilitation
11. annual cost of owning the main

Copyright © 2002, American Water Works Association. All rights reserved.

Using the WATERFOWL software package, examples of pipeline systems were outlined in a paper presented at The Construction and Operation of Underground Utilities Conference in 1997[19]. The costs analysis was based on a 1km length of 155-mm bore iron main with a service connection every 10m.

The results show that despite the relatively high initial capital costs of replacement, the cumulative costs over the life of the system would be lower if total replacement were performed. The cumulative cost of sliplining is recovered in the first 10 to 20% of the life.[19]

It should be noted that if replacement is performed with HDPE that is leak free, has a lower maintenance cost and a longer life expectancy, it can be determined that cumulative cost savings will only increase with time.

CONCLUSION

In the last 100 years, the distribution of water has been a great achievement. Embracing new technologies and striving to improve upon set standards was the catalyst in achieving this. Failing water infrastructure has placed the U.S. at a crossroads. Leaky pipe networks are creating billion dollar problems and wasting one of the most important resources in the world. Clean water not only deserves to be protected, it must be sheltered with a piping system that does not leak. A 15% leak ratio is no longer an acceptable benchmark. It is time to stop patching failing infrastructure with materials that have a short span of reliability and take advantage of the technologies that are now available.

HDPE has been in use for water in Europe, Mexico, Japan, and other countries with a high level of success. It is also gaining acceptance in the U.S., but at a much slower rate.

The rapid adoption of HDPE in many cases was for a specific need. The technologies associated with HDPE have increased safety and reduced leakage. It has been used to reduce contamination, and pipe failures especially in high-risk applications such as road or river bores and earthquake regions. HDPE has demonstrated its cost effectiveness and creative problem solving characteristics. It is time for the U.S. to adopt HDPE on a large scale for the solution of water loss and conservation.

The problem of water loss can be solved with the implementation of a leak proof distribution system. HDPE is the crucial element of this new distribution system and touts abilities and characteristics that are superior to any other piping material in existence. These characteristics can translate into distinct cost and construction advantages over other materials and save billions of dollars while playing a vital role in the conservation of water.

Copyright © 2002, American Water Works Association. All rights reserved.

Acknowledgements:

The authors of this paper would like to thank Richard Gajan, Terry Silkey and Jim Perrault for viewing this paper. The authors gratefully acknowledge support from The AWWA, Plastic Pipe Institute and would also like to thank Ricky A. Ponder, David Willoughby and Rita Tubb for their ongoing work.

Sources:

[1] National Association of Engineers (NAE); Washington, D.C. May 2000.
[2] U.S. Environmental Protection Agency; Office of Ground Water and Drinking Water; Drinking Water infrastructure Needs Survey; National Technical Information Service; Springfield, BA; Jan 1997
[3] Leak Detection Methods For Plastic Water Pipes: Hundaidi, Chu, Wang, and Guan; AWWA; 1999.
[4] The Star-Ledger Newark, NJ Sunday, March 10, 2002.
[5] American Water Works Association; Press Room; *Stats on Tap*
[6] United Nations Economic Commission for Europe; *Interview with Mr. Barlund*.
[7] AWWA: Reinvesting in Drinking Water Infrastructure, *Dawn of the Replacement Era*
[8] Water Infrastructure Network; Water Infrastructure Now 2nd Report, February 2001.
[9] 1999 Gas Facts; 1998 data
[10] 1998 OPS Gas Distribution Annual Report Data
[11] OPS Gas Distribution Incident Data
[12] Pipeline and Gas Journal 36th Pipe Report Nov, 2001
[13] Plastic Piping Handbook; McGraw-Hill; Written by David Willoughby
[14] Plastics Pipes XI; Munich Germany; September 2001; *Polyethylene Pipeline Systems—The big success Story*.
[15] Plastic pipes X; Plastics Pipeline Systems for the Millennium, Goteborg, Sweden September 1998; *Plastic Pipes—Do they have a future for the water industry in the new Millennium*?
[16] Quote from Richard Bond; Maintenance Supervisor, Colorado Springs Utilities
[17] Business Mexico Magazine; Naomi Adelson
[18] Plastic Pipes XI; Munich Germany; September 2001; *Pipeline systems made of plastics: - unlimited working life?*
[19] The Construction and Operation of Underground Utilities Conference; Coventry, UK. February 1997; *Optimizing investment in pipeline systems.*

Copyright © 2002, American Water Works Association. All rights reserved.