

## EPCOR'S CONTINUING SUCCESS WITH PVC WATER MAIN PIPE

**Doug Seargeant, P. Eng.**  
EPCOR Water Services Inc.  
Edmonton, Alberta, Canada

### ABSTRACT

*Many utilities experience problems related to corrosion of buried metallic components of their water distribution systems. In seeking non-metallic alternatives to solve these problems, questions concerning the life expectancy of these alternatives are often raised. This paper describes testing of Poly Vinyl Chloride (PVC) pipe material after being in service for more than 25 years in Edmonton. The first use of PVC water main pipe manufactured to AWWA C900 in the City of Edmonton occurred in 1977. The increasing rate of water main failure in the cast iron water main material used previously in the distribution system led the water utility to seek a non-metallic alternative. This initial installation in 1977 quickly led to PVC becoming the material of choice for water distribution piping used for replacement of the deteriorating cast iron piping system as well as for installations in newly developing areas of the city. By the end of 2013, the length of PVC pipe in the City of Edmonton water distribution system was over 1,600 kilometres (1,000 miles) representing 47% of the total length of pipe in the water distribution system. In 1994, a study was undertaken to review the City of Edmonton's experience with respect to the performance of PVC pipe over time and to assess the integrity of material which had been in service for 17 years. In 2005, the decision was made to revisit the methodology used in the 1994 study and look at PVC pipe that had been in service for at least 25 years. This paper summarizes the findings in those studies and provides additional information on EPCOR's water distribution system in Edmonton.*

### INTRODUCTION

The City of Edmonton is the capital city of the Province of Alberta in Canada and is located on the banks of the North Saskatchewan River, the source of its drinking water. Water temperatures in the river vary from 65 °F in the summer to 32.5 °F in the winter, with air temperatures typically varying from +75 °F to -25 °F over the course of the year. Extreme recorded temperatures have varied from +95 °F to -55 °F, but such extremes are quite rare.

From two water treatment plants in Edmonton, water is distributed to the 817,000 residents in Edmonton, as well as more than 60 communities outside Edmonton.

## HISTORY OF WATER MAIN PIPE USE IN EDMONTON

Edmonton's earliest water mains were manufactured from pit (or sand) cast iron or wooden staves. Although the last section of wood stave water main was removed from service in the mid 1990's, some of the thick-walled cast iron pipe installed in 1903, the year in which the water utility was incorporated, continues to provide suitable service in the city, specifically in areas where the corrosion potential of the soil is low.

Prior to the Second World War, Edmonton primarily relied on cast iron for its water main pipe needs. The pipe was manufactured using the pit or sand casting process, and water main breaks were a relatively rare occurrence. After the war, iron pipe manufactured using the spin casting process became commonly available and was used almost exclusively as the city experienced a surge in growth. Based on the reliability of the pit cast iron pipe, a consultant's report on proposed extensions to Edmonton's water works network in 1950 included the following paragraph:

*"The city is fortunate in having practically all the mains 20 inches and smaller of cast iron, which has a very long lifetime, and consequently the leakage from the distribution system is low in comparison to other cities where inferior types of pipes have been laid."*

However, by the mid 1950's some maintenance problems related to corrosion of cast iron pipe were beginning to appear in Edmonton. Yet, it was not the older pipe requiring repair, but rather the pipe installed after 1945. In 1952, 50 breaks on a system of approximately 400 miles of pipe were repaired. By 1965, the system had doubled in length but the annual number of breaks had increased 10 fold to 500. The trend was firmly established and the decision was made to cease using spun cast iron pipe as the material of choice.

Because the failure problem was directly related to corrosion, a non-metallic pipe material was sought and in 1966, the utility began to install asbestos cement pipe, a pipe material used by many utilities at that time, for most of its distribution system growth.

Although this material proved to be more reliable from a failure perspective, health concerns related to working with asbestos in the latter part of the 1970's led to the search for another alternative. As the utility continued to experience an increasing water main break rate of cast iron pipe, which had reached more than 1,000 breaks per year by 1977, it was again determined that the new pipe material had to be non-metallic. The decision to try PolyVinyl Chloride (PVC) water main pipe manufactured to AWWA C900 was made in 1977 and the first sections of PVC pipe were installed in Edmonton later that year.

The ease of installation made the pipe material a popular choice with construction staff. In just a few short years, PVC became the material of choice for all water distribution piping in Edmonton. As available pipe diameters increased, ECPOR continued to try

larger and larger pipe. At this time, PVC water main pipe up to 900 mm in diameter operates successfully in Edmonton's water distribution system. Approximately 45% of the overall water distribution system in Edmonton today is comprised of PVC pipe.

Earlier, it was noted that the decision to stop installing cast iron pipe was made in 1965, due to an increasing failure rate. However, the failure rate of that pipe material continued to increase and by the mid 1980's, customer dissatisfaction with the lack of reliability of a distribution system experiencing more than 1,600 breaks per year led to a focused program to replace the cast iron pipe network with PVC. Since 1985, slightly more than 50% of the original cast iron pipe network has been replaced and the annual number of water main breaks has decreased from 1,670 in 1985 to 278 in 2013. But as recently as 2013, more than 90% of all water main breaks in Edmonton still occurred on cast iron pipe, even though by length, cast iron pipe is less than 20% of the overall network. By comparison, in 2013, EPCOR had to excavate PVC pipe two times to repair a problem, despite the fact that, by length, approximately 45% of the network is comprised of PVC pipe.

## **PERFORMANCE REVIEWS**

EPCOR has reviewed the performance and condition of the PVC pipe in its network in Edmonton on more than one occasion. In all cases, EPCOR has not received any financial consideration from an outside party, but has accepted in-kind support in the form of quality control testing assistance from a local PVC pipe manufacturer, due to the requirement of specialised testing equipment. All third-party tests were witnessed by a staff member of EPCOR.

Between 1993 and 1996, AWWA C900 DR 18 PVC pipe was used in a Trench Backfill Study undertaken jointly between EPCOR and the National Research Council of Canada (NRC). Over the length of a city block, vertically parallel sections of PVC water main pipe were installed at depths of 3 feet and 8 feet of cover in 7 different backfill materials. Strain gauges were installed on the pipes and temperatures were measured over the course of a number of years at various depths in each of the different backfill materials. All readings were tracked in real time through telecom connections to the NRC offices in Ottawa, Ontario.

In late 1996, the water flow in the pipe with 3 feet of cover was stopped. Through the winter months, temperatures dropped to well below the freezing point, and temperature measurements at the shallow-bury pipe indicated the water in that section of pipe had frozen, expanding the plastic pipe. Based on information from the strain gauges attached to the pipe, the NRC predicted the water main had expanded to the point of failure, due to the magnitude of expansion. The pipe was exhumed in the summer of 1997 with no visible damage. Testing confirmed the pipe was able to meet the performance requirements expected of new DR 18 PVC pipe, including a burst test result of more than 1,000 psi.

In 1994, two sections of pipe from the original 1977 installation of AWWA C900 DR 18 PVC pipe were exhumed and taken to the laboratory for analysis. The diameters of the sections of pipes tested were 8 and 10 inches. Prior to removal of pipes, one of the pipes of each diameter was successfully tapped with  $\frac{3}{4}$ , 1 and  $1\frac{1}{2}$  inch direct taps while under pressure. The pipes then were put through the same quality control testing used for new pipes when they come off the assembly line. All pipes exceeded the minimum test requirements, after providing 17 years of reliable service. In this case, the DR 18 pipe failed at a pressure slightly under 1,000 psi during the burst test.

A similar project was undertaken in 2005, this time using PVC pipe with 25 years of service life experience. Once again, the results showed the pipe able to meet or exceed the expectations placed on new pipe.

In 2013, a slightly different approach was used for evaluation of PVC pipe removed from the distribution system after 25 years of service. In addition to the standard quality control tests undertaken in previous reviews, some sections of the pipe were sent to a specialty laboratory for long-term cyclical pressure testing in an effort to ascertain an estimate of remaining service life. Work on that project continues and although results to date are encouraging, no definitive conclusions have yet been reached. Incidentally, the quick burst test pressure capability of this 25 year old PVC pipe exceeded 1,000 psi.

EPCOR has good records of water main performance in Edmonton. In an effort to normalize a comparison of the performance of the three major pipe materials currently in use in Edmonton, a comparison of statistics related to the first 36 years of service for each material is shown below.

- Spun Cast Iron Pipe
  - Mostly installed between 1945 and 1965
  - Years considered: 1946 to 1982 (36 years)
    - 760 miles in service in 1982
    - 17,131 Repairs in years considered
  
- Asbestos Cement Pipe
  - Mostly installed between 1966 to 1980
  - Years considered: 1966 to 2002 (36 years)
    - 762 miles in service in 2002
    - 882 Repairs in years considered
  
- PVC Pipe
  - First installed in 1977
  - Years considered: 1977 to 2013 (36 years)
    - 1,041 miles in service in 2013
    - 141 Repairs in years considered

From the preceding information, it is readily seen that PVC water main pipe has provided a significantly greater reliability of service in the conditions found in Edmonton, with a correspondingly low maintenance cost, when compared to the other pipe materials. In recent years, excavations related to PVC water main pipe have been approximately 1% of the number of excavations on average undertaken over the course of the year for work on water mains in Edmonton, although PVC accounts for 45% of the overall length of pipe in the distribution system. In 2013, only two excavations were required on the more than 1,000 miles of PVC pipe in service.

## **CHALLENGES**

Although the performance record of PVC water main pipe is significantly better than the other materials used in Edmonton, there have been a few issues that have challenged the utility. Many of these types of issues are not limited to PVC water main pipe and are possible to experience with other pipe materials.

Accelerated corrosion-related deterioration of carbon steel bolts on valves and appurtenances connected to non-metallic piping continues to be an issue on both asbestos cement and PVC pipe installations prior to 1988. In 1988, the requirement for these components to be Type 304 stainless steel was added to the specification, but a significant number of appurtenances with the more vulnerable type of bolts remain in the ground on pre-1988 installations.

Some repair excavations have been related to problems at joints between pipes. Gaskets have shifted during the installation process, and although the seal at the gasket is sufficient to pass an initial pressure test, the gasket ultimately moves to the point that a leak develops.

We have experienced some instances of pipes being installed on bedding containing a rock that results in the pipe being exposed to a point load that, over time, results in a split in the PVC pipe.

Some piping installers have used a philosophy that more lubricant applied to the bell and spigot joint gasket during installation will make the job easier, and potentially reduce future problems with joints. However, water quality problems related to taste and odour associated with abusive application of pipe lubricant have been experienced, due to the fact that pipe lubricant solubility in water seems to decrease as water temperature decreases. This problem is more common in Edmonton towards the end of the construction season in the Fall, when water temperatures are decreasing, as noted at the beginning of this paper.

Some piping installers have used a philosophy that more lubricant applied to the bell and spigot joint gasket during installation will make the job easier, and potentially reduce future problems with joints. However, water quality problems impacting taste and odor can result due to an overabundant application of pipe lubricant for these joints which in turn becomes more water soluble as higher water temperatures rise. This problem is more common in Edmonton towards the end of the construction season in the Fall, when water temperatures are decreasing, as noted at the beginning of this paper.

## **SUMMARY**

PolyVinyl Chloride water main pipe, manufactured to AWWA Standards C900 and C905 has been in use in Edmonton for more than 35 years. Characteristics of the pipe material make it easy to install and adapt to a variety of conditions encountered during construction. The corrosion-resistance of the material ensures reliable ongoing service, which contributes to improved customer satisfaction. The un-matched reliability of the pipe material for over 35 years has enabled EPCOR to reduce its annual water main break rate to levels not seen since the early 1960's, when Edmonton's water system was less than 1/3 of the size it is today. This pipe material continues to be the material of choice in EPCOR's water distribution network in Edmonton. Testing PVC pipe and finding little to no degradation over 25+ years provides EPCOR with the assurance that, for the conditions found in Edmonton, PVC is an appropriate water main pipe material choice that will provide ongoing, reliable service for years to come.

## **ACKNOWLEDGMENTS**

The author and EPCOR acknowledge the participation and contributions of the following organizations in testing and studies that were conducted between 1993 and 2013:

- IPEX Inc.
- City of Edmonton
- National Research Council of Canada

Much of the information presented herein has been presented at other industry conferences and in a number of publications since 1998. Some of that information has been updated from its initial presentation to reflect changes that have occurred over time.