

# Effects of Chlorinated Water on Plastic-Based Water Delivery Systems

Chlorinated water remains one of the most significant advancements in public health. This practice dramatically improves our quality of life by giving us the assurance that we get clean, safe drinking water when we turn on the tap in public places, at work or in our homes.

For that reason, over 98 % of water treatment facilities in the U.S. disinfect water with chlorine and chlorine-based products. This type of disinfectant offers numerous advantages over other systems, including high germicidal potency, economy and efficiency. Chlorine also has a lasting residual effect throughout the entire water distribution system. This must be taken into consideration when selecting materials to construct water delivery systems.

Residual chlorine in water systems combined with elevated temperatures can produce an oxidizing environment. Since many metals and plastics are susceptible to oxidation and oxidizing agents, this condition can dramatically shorten the service life of components made from these materials.

## Historical Background

In the late 1960s, the plumbing industry began to use polyacetal resin, primarily in fittings, because of the material's reasonable hydrolytic stability at moderate temperatures, high crystallinity, low creep and relatively low water absorption. By the mid 1970s, however, it became apparent that some problems existed with using polyacetal resin in chlorine environments. Despite this information, millions of homes were constructed by the end of the decade that used polyacetal fittings to connect polybutylene pipe. Within a few years, many of these homes had leakage problems caused by the failure of the polyacetal fittings.

Although polyacetal has some limitations, other plastics have enjoyed many years of success in plumbing applications. For example, polyvinylchloride (PVC) has been used for over 40 years in cold water applications such as water distribution, DWV (drain, waste and vent), sewer and irrigation systems.

Chlorinated polyvinylchloride (CPVC) is well-suited for both hot and cold water delivery systems. Since its introduction in 1960, over 2 billion feet of CPVC pipe have been installed in single-family dwellings, condominiums, buildings, apartments and hotels. CPVC has proven that a potable water delivery system made completely from plastic can be both viable and reliable. A notable limitation of CPVC is that it is a rigid system that requires solvent welding of fittings and joints.

Cross-linked polyethylene (PEX) is another viable choice for all-plastic hot and cold potable water systems. PEX systems have been thoroughly tested in aggressive chlorinated water environments and delivered an outstanding performance. In Europe, PEX has been used successfully for 25 years in radiant floor heating and plumbing systems. A significant advantage of a PEX system over other piping systems is that it is a flexible tubing delivery system that does not require heat or solvents for assembly.

Historically, PEX systems were assembled using brass or copper fittings. More recently, many of these systems have been assembled using fittings made from sulfone polymers, providing a reliable all-plastic alternative to CPVC systems.

## Sulfone Polymers

Several independent testing labs have studied the chlorine resistance of sulfone polymers. One such study conducted by Materials Performance, Inc. reported that sulfone-based polymers showed very good resistance to prolonged chlorine exposure at elevated temperatures. Another study conducted by the American Water Works Association (AWWA) specifically reported that Udel® polysulfone (PSU) is largely impervious to both chlorine and chloramines[1].

Udel® PSU has successfully replaced metals such as brass, copper and stainless steel in a variety of plumbing applications. With its 15-year history of proven performance in fittings for pressurized hot water plumbing applications, Udel® PSU provides an attractive alternative to brass fittings, which are prone to corrode especially in areas where the water is chlorinated and has a low pH.

Udel® PSU has a 20-year history of proven performance in dip tubes for water heaters, which is a very aggressive environment. Udel® PSU is also used to manufacture faucet components because of its excellent hydrolytic and dimensional stability, as well as its resistance to mineral buildup and corrosion.

Radel® polyphenylsulfone (PPSU) has enjoyed similar success in replacing metals in plumbing applications. It offers the same impressive performance features as Udel® PSU, plus it offers enhanced chemical resistance and exceptional mechanical toughness. Acudel® modified PPSU provides an intermediate cost/performance balance between Udel® PSU and Radel® PPSU.

Udel®, Acudel® and Radel® sulfone polymers are FDA and NSF compliant and recognized by many other regulatory bodies as being suitable for use with hot, potable water.

## Evolution of Test Methods

The historical results of using plastics in chlorine environments make it clear that materials need to be evaluated for chlorine and hot water resistance before use. The ensuing material testing progressed through a number of stages that are highlighted briefly in the following text.

Most plastic components can withstand long-term exposure to low-temperature water – 54 °C (130 °F) or lower – under weak oxidizing conditions. However, when the water temperature is increased and maintained at or above 60 °C (140 °F) in the presence of chlorine-based additives, there are significant differences in the long-term performance of the various plastics.

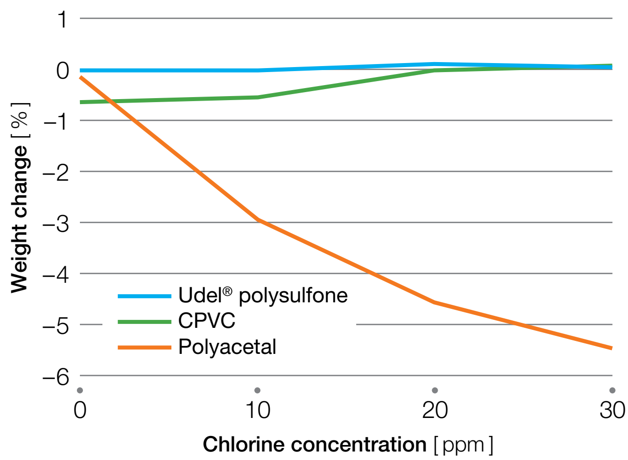
### Static Water Testing

Initial testing that studied the chlorine resistance of polymers at elevated water temperatures was conducted in a static water environment. In this method, samples were placed in containers with a test solution of hot water and chlorine that was changed regularly but not circulated. Tests were conducted over a 6-month period at a variety of chlorine levels.

Solvay Specialty Polymers contracted one such study [2] that tested a variety of polymers at 0, 10, 20 and 30 ppm levels of chlorine at 60 °C (140 °F), which is the typical operating temperature of residential hot water systems.The chlorine levels were elevated above the normal potable water levels of 1 ppm to 2 ppm in order to accelerate the effect of chlorine and to enable the use of regression analysis to predict reaction rates at various chlorine levels.

The results of the study showed that the static chlorinated water environment adversely affected some of the polymers. Test samples molded from polyacetal formed a chalk-like scale that flaked off. Those molded from PA 6,6 showed ablation of oxidized polymer from the surface. Both Udel® PSU and CPVC showed very good resistance to hot, chlorinated water, even at high levels of chlorine (see Figure 1).

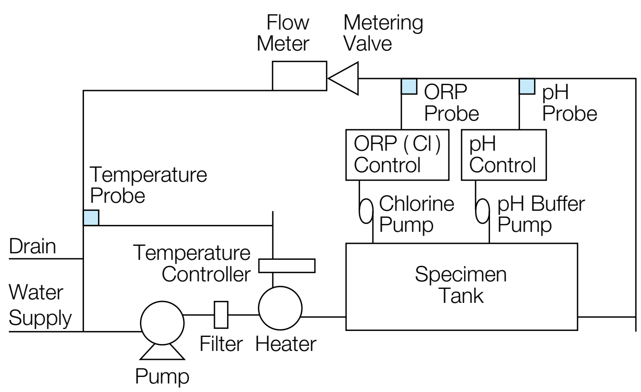
**Figure 1:** Weight change after 6-month exposure to static chlorinated water at 60 °C (140 °F)




### Dynamic Water Testing

The next evolution of chlorine resistance testing introduced a dynamic water environment, which more closely represents actual end-use conditions than static water testing. In this method, samples are subjected to a test solution of hot water and chlorine that circulates continuously in a closed loop system (see Figure 2).

**Figure 2:** Dynamic water test system for evaluating chlorinated water resistance



In a recent Solvay Specialty Polymers study[3], water temperatures ranged from room temperature to 90 °C (194 °F) with chlorine levels at 0 ppm and 5 ppm for a duration of 1,500 hours. Chlorine and pH levels were continuously monitored and adjusted as necessary. Although this chlorine level is closer to typical levels found in municipal water, the continuous water flow and the higher temperature accelerated the effect of chlorine.

Test results, which are summarized in Table 1, confirmed that the sulfone-based products have very good resistance to hot, chlorinated water. CPVC showed a slight but statistically significant weight loss.

**Table 1:** Weight loss of various resins after 1,500 hours of exposure to flowing water at 90 °C (194 °F)

| | Weight Loss[1] [%] | |
|---|---|---|
| | 0 ppm Chlorine | 5 ppm Chlorine |
| Udel® PSU, unfilled | 0.0 | 0.1 |
| Udel® PSU, 20 % glass-filled | 0.0 | 0.0 |
| Radel® PPSU | 0.5 | 0.2 |
| Acudel® modified PPSU | 0.3 | - 0.1 |
| CPVC | - 0.6 | 1.2 |

*[1] Weight changes within ± 0.6 % were not statistically significant.*

## Long-Term Hydrostatic Stress Testing

The piping industry has long recognized the need to evaluate the long-term effect of hydrostatic stress when rating piping systems. Standard testing, however, did not factor in how chlorine additives can affect the service life of potable water delivery systems. Recently, the plumbing industry has recognized the need for a new testing protocol that addresses the effect of chlorine additives.

ASTM addressed this need for improved testing by developing a protocol for determining the chlorine resistance of plastic piping materials. ASTM F2023-2000 specifies that piping systems are to be tested to failure under typical end-use conditions of chlorine levels, pH and pressure. Elevated temperatures are used to accelerate time to failure. Testing is conducted at two hoop stresses at a minimum of three different temperatures. Regression analysis is used to estimate time-to-failure under several conditions.

The new ASTM protocol is a result of the collaboration of plumbing industry leaders to provide appropriate test conditions. At the time of this writing, this protocol is applicable to pipes, but not to the fittings that join them.

## Summary

The test results presented in this document demonstrate that sulfone-based materials have very good resistance to prolonged exposure to chlorinated water at temperatures as high as 90 °C (194 °F). This suggests that these materials could perform well in hot, chlorinated water delivery systems. This is supported by over 15 years of successful performance in the field.

Since each plumbing application has unique performance requirements and design criteria, it is important that specialized testing be conducted by the design engineer to evaluate the resin under conditions that simulate the environment and function of the component in service. The test results reported here are not a substitute for such testing.


[1] *AWWA Research Foundation, "Chloramine Effectson Distribution System Materials", 1993.*

[2] *Solvay Specialty Polymers, "Effects of Chlorinated Water on Thermoplastics".*

[3] *S. Bradely, J. El-Hibri, B. Bersted, W. Bradley, "A Study of the Effect of Chlorinated Water on Engineering Thermoplastics at Elevated Temperatures", ANTEC, pp. 3132-3136, 2000.*



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