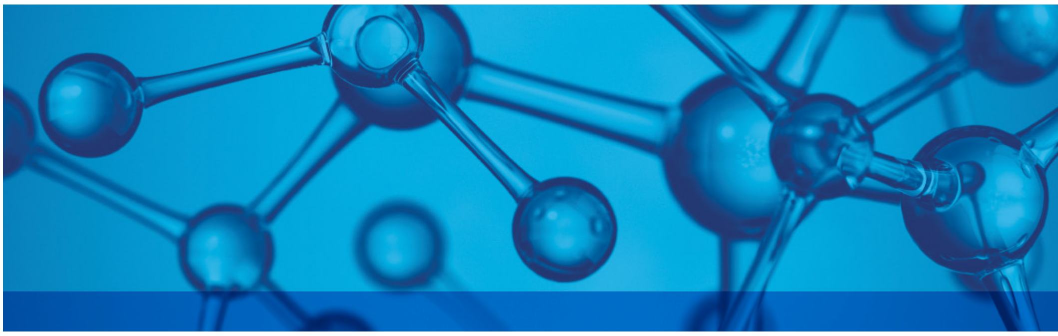

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Ryton® PPS Resistance to Hot Chlorinated Water

Introduction

Many manufacturers want to use plastic materials in components of hot potable water systems. However, there is some concern that residual chlorine in treated water may potentially have detrimental effects on plastic materials. In cooperation with a manufacturer of residential water system components, a study was undertaken to demonstrate the suitability of Ryton® PPS (polyphenylene sulfide) for such service. The performance of Ryton® PPS compounds compared to other high temperature engineering thermoplastics was also evaluated.

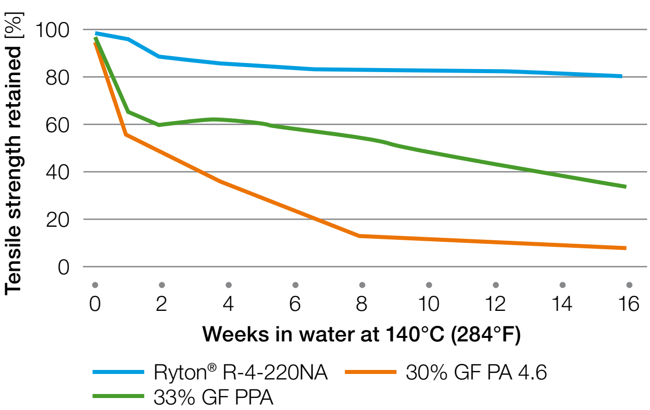
Previous water immersion tests had shown Ryton® PPS to be very resistant to chemical attack by hot chlorinated water. For a more extensive circulating water study, two Ryton® PPS compounds were chosen for evaluation along with other materials. Ryton® R-4-220NA is a 40 % glass fiber reinforced PPS compound, specially formulated to provide exceptional mechanical integrity during long-term service in hot water. Ryton® R-7-120BL is a more economical glass and mineral filled PPS compound that also exhibits excellent long-term mechanical integrity in hot water.

Hot Water Immersion Testing

Elevated temperature immersion tests have shown that PPS polymer is not attacked by hot water. These tests involved total immersion of standard test specimens in hot water for a period of time, and stress testing after exposure to determine retention of mechanical strength. For example, after exposure to 93 °C (200 °F) water for twelve months, unfilled Ryton® PPS retained over 90 % of original tensile strength. The slight drop in tensile strength was likely due to thermal aging rather than chemical attack, and similar retention of mechanical strength after hot water exposure was observed at temperatures up to 149 °C (300 °F). Many other polymers, such as polyamides (nylons) and polyesters, will actually be hydrolyzed in hot water; the polymer chain is broken down and the plastic material is degraded.

Glass fiber reinforced PPS compounds, however, may be adversely affected by hot water compromising the adhesion between the glass fibers and the polymer matrix. For example, after exposure to 85 °C (185 °F) water for twelve months, Ryton® R-4 (40 % glass reinforced PPS) retained only 59% of original tensile strength. But Ryton® R-4-220NA/BL and Ryton® R-7-120NA/BL are exceptionally resistant to this mode of attack. After exposure to 140 °C (284 °F) water for sixteen weeks, Ryton® R-4-220NA and Ryton® R-7-120NA both retained over 80 % of original tensile strength. Figure 1 compares the tensile strength retention of three different materials in tests where superheated water (140 °C, 284 °F) and thin specimens (1.6 mm, 0.062 inch) were used to achieve an accelerated effect. It is important to note that within the first four weeks of exposure to the superheated water, permeation of Ryton® R-4-220NA, and the resultant detrimental effects, had reached an equilibrium state, and no significant reduction in mechanical strength was observed after that time. Ryton® R-7-120NA showed similar behavior in such tests. In contrast, nylon (PA 4.6) and polyphthalamide (PPA) showed progressive material degradation due to the polymers being hydrolyzed.

Figure 1: Hot water immersion test results



Immersion tests have also shown Ryton® PPS to be essentially unaffected by low concentrations of aqueous chlorine. When exposed to 0.7 % (7000 ppm) aqueous chlorine at room temperature for three months, Ryton® R-4 retained 99 % of original flexural strength. When exposed to 0.26 % (2600 ppm) aqueous chlorine at 82 °C (180 °F) for three months, Ryton® R-4 retained 78 % of original flexural strength. These effects were essentially no different from the effects of pure water.

Hot Circulating Water Testing

In a more elaborate test program, pump housings molded from a variety of materials were evaluated for resistance to chemical attack by dilute aqueous chlorine at elevated temperatures. These tests involved continuously circulating hot chlorinated water through the pump housings, and then examining them for evidence of chemical attack as well as testing them for retention of mechanical integrity. The materials evaluated included:

- Ryton® R-4-220NA
- Ryton® R-7-120BL
- 33 % glass filled polyphthalamide (PPA)
- 35 % glass filled nylon HTN
- 30 % glass filled nylon 6,6
- 10 % glass filled and 20 % glass filled Styrene/Maleic Anhydride Copolymers (SMA)

The pump housings were mounted on a test rack, with chlorinated water (5 ppm chlorine at pH 7) circulating through them in series at a rate of 6.8 L/min (1.75 gpm), a temperature of 90 °C (194 °F), and 1.4 bar (20 psi) internal pressure. The temperature was higher than potential service conditions, but was selected to accelerate the effects of chlorinated water exposure in combination with fluid flow and internal pressure. Multiple pump housings of each material were put on test and taken off test at periodic intervals, and burst tests were conducted to evaluate retention of mechanical integrity over time.

The SMA compounds were eliminated after 780 hours due to insufficient creep properties when leaks developed at the seals between the pump housings and the bases. The nylon 6,6 and HTN were eliminated after about 1100 hours due to erosion of material from the internal walls of the pump housings. PPA also showed progressive erosion of material from the internal walls within 1100 hours, but testing was continued. The Ryton® PPS compounds showed no evidence of material degradation, but a superficial white layer formed on the internal surfaces of the pump housings. Closer examination did not find any degradation beyond the surface "scale."

Surface Scaling

A superficial white layer (less than 0.1 mm thick) formed on the internal surfaces of the Ryton® PPS pump housings. Scanning Electron Microscopy (SEM) examination of the inner surfaces of exposed Ryton® PPS pump housings showed that the small amount of scaling was only on the surface and did not go into the depth of the wall.

No cracking was observed beneath the white surface layer. Elemental analysis of the white coating found it to be primarily comprised of carbon, oxygen, aluminum, phosphorus, and sodium. No sulfur was detected, as would be expected in PPS degradation products. The aluminum likely arose from aluminum components of the test fixture. The source of the other elements was likely the phosphate containing pH buffer and/or other additives in the water.

Inner Wall Erosion

Pump housings that had been on test for 1,100 hours were sectioned, examined by microscopy, and the wall thickness measured at the same three selected positions on each part. The measurements for each of the positions, A, B, and C, are shown in Table 1. Examination of the cross sections showed that three of the materials had been attacked during the test, as evidenced by a reduction in wall thickness and the presence of cracks and holes in the material. Ryton® R-4-220NA had apparently not been attacked during the test, and suffered no measurable erosion in wall thickness. Nylon 6,6 showed the greatest degree of erosion, while PPA and HTN showed lesser degrees of erosion.

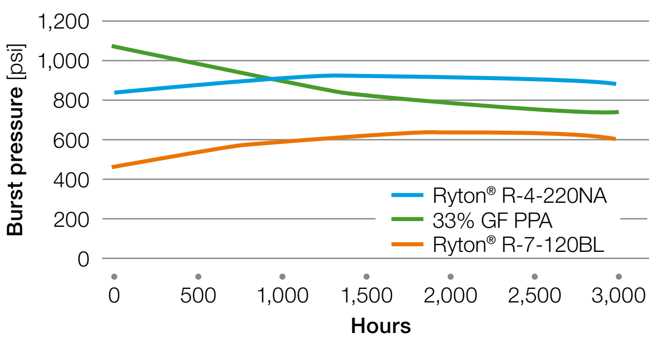
Table 1: Wall thickness measurements after exposure to flowing hot chlorinated water
1.75 gpm, 5 ppm chlorine, 90 °C, 1,100 hours

Material	Wall Thickness [mm]		
	Pos. A	Pos. B	Pos. C
Ryton® R-4-220NA	2.9	2.9	2.9
35 % GF Nylon HTN	2.5	2.7	2.7
33 % GF PPA	2.2	2.5	2.5
30 % GF Nylon 6,6	1.0	1.8	1.8

Burst Testing

Pump housings were periodically removed from the test fixture and burst tested. General trend lines from the burst test results over time are shown in Figure 2. PPA suffered a progressive loss in strength, likely due to erosion of the inner wall of the pump housing. The Ryton® PPS compounds did not show any loss in burst strength. Results were more scattered for the Ryton® R-7-120BL, with some failures attributed to non-ideal molding conditions.

Figure 2: Pump housing burst pressure vs. duration of hot chlorinated water exposure
Chlorinated water, 5 ppm, 90 °C, 1.75 gpm



Conclusion

The testing of pump housings indicated that Ryton® PPS is the best choice among the materials tested for applications requiring exposure to hot chlorinated water. Its combination of high temperature creep resistance and resistance to polymer degradation provided superior mechanical integrity. SMA showed inadequate elevated temperature creep resistance, while nylon, HTN, and PPA all suffered progressive material degradation. Ryton® R-4-220NA meets the requirements of NSF Standard 61 and BS 6920 for use in potable water systems. This makes Ryton® R-4-220NA an excellent choice for components of hot potable water systems. Still, adequate testing under conditions as close as possible to actual service is always recommended to ensure the success of any application.

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