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Chemical Resistance of Sulfone Polymers

Sulfone polymers exhibit varying levels of chemical resistance, depending upon their polymeric structure and the presence of additives such as glass. Other factors influencing chemical resistance include the reagent, reagent concentration, temperature, exposure time and whether the polymer is under stress. Stress may be induced by an external load during use or residual internal stress may result from the processing of the material. Residual processing stresses can usually be minimized by adjusting processing conditions. It is necessary to evaluate resistance in both the unstressed and stressed modes because some reagents which have no effect on the unstressed plastic may cause cracking when stressed.

Immersion Testing (No External Load)

To evaluate native chemical resistance, test specimens were immersed in a variety of common reagents for seven days at room temperature. The results shown in Table 1 are based on the following rating system:

E = Excellent: Little or no effect

G = Good: No serious loss of properties

F = Fair: Some negative effects, some useful properties

P = Poor: Severe attack or rupture

All sulfone polymers tested show excellent resistance to the aqueous solutions of both acids and bases. Aliphatic hydrocarbons have no or little effect on any of the resins tested. Aromatic hydrocarbons are shown to cause property degradation. Oxygenated reagents must be evaluated individually, because some of them attack the polymers aggressively and some cause almost no change in properties. Chlorinated hydrocarbons are shown to attack sulfone resins, with only Radel® PPSU showing a measure of resistance to them.

Stress Crack Resistance

The following tables summarize many years of testing of Solvay's sulfone polymers, which include:

- Radel® PPSU (polyphenylsulfone)
- Acudel® modified PPSU
- Veradel® PESU (polyethersulfone)
- Udel® PSU (polysulfone)

Environmental stress testing was conducted in various chemicals at indicated temperatures, times and concentrations.

To evaluate the resistance of the Udel® PSU and Radel® PPSU to environmental stress cracking, typical test specimens 127 mm (5 in.) long, 13 mm (0.5 in.) wide, 3.2 mm (0.125 in.) thick were clamped to curved fixtures. The radius of the fixture induces a strain in the specimen. From the tensile modulus of the material, the corresponding stress was calculated as shown in Table 2. The reagents were then applied to the central portion of the fixtured test specimen. At 24-hour intervals, the specimens were examined for evidence of attack and rated.

Green indicates no visible effect caused by the reagent under the conditions listed, red indicates the material has experienced stress cracking, and gray indicates no data at that condition.

The variables of importance in environmental stress cracking are temperature, stress level, time and reagent. If a reagent causes stress cracking at a given time, temperature and stress level, the following generalizations usually apply. Cracking generally does not occur at lower stress levels, but can appear when exposed for a longer time. Higher temperatures generally speed cracking. Diluting the reagent may or may not eliminate stress cracking, depending upon the reagent.

Table 1: General indication of chemical resistance 7-day immersion at 23 °C (73 °F)

Reagent	Radel® PPSU	Acudel® modified PPSU	Veradel® PESU	Udel® PSU
n-Butane	E	E	E	G
Iso-Octane	E	E	E	G
Benzene	F	F	P	P
Toluene	F	F	P	P
Ethanol	E	E	E	G
Methyl ethyl ketone	P	P	P	P
2-Ethoxyethanol	G	F	P	P
1,1,1 Trichloroethane	G	F	P	P
Carbon tetrachloride	E	G	G/E	P
Hydrochloric acid (20 %)	E	E	E	E
Acetic acid (20 %)	E	E	E	E
Sulfuric acid (20 %)	E	E	E	E
Sodium hydroxide (10 %)	E	E	E	E

Table 2: Strain and corresponding stress

	Stress [psi (MPa)]	
Strain [%]	Udel® P-1700	Radel® R-5000
0.0	0 (0.0)	0 (0.0)
0.2	720 (5.0)	680 (4.7)
0.4	1,440 (9.9)	1,360 (14.1)
0.6	2,160 (14.9)	2,040 (4.7)
0.8	2,880 (19.9)	2,720 (18.8)
1.0	3,600 (24.8)	3,400 (23.4)
1.2	4,320 (29.8)	4,080 (28.1)
1.4	5,040 (34.7)	4,760 (32.8)

Conclusion

Tables 3 through 8 report the results of the environmental stress cracking testing for reagents used in medical applications, several high-performance greases, common disinfectants, anti-spotting agents, and selected inorganic reagents and organic reagents.

While Udel® PSU has good resistance to many materials, Radel® PPSU provides the best resistance to environmental stress cracking of the sulfone polymers. Because the glass-fiber-reinforced grades of the sulfone polymers have higher moduli, they deflect less (lower strain) under the same load and therefore have more resistance to environmental stress cracking.

Since each application has its 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 best simulate the function of the component or system in its intended use. For example, the resistance to aqueous caustic solutions has become increasingly important in the medical field as the use of strong solutions of sodium hydroxide has become one of the preferred methods for disinfection.

Table 3: Medical reagents

Trade Name/ Manufacturer	Sulfone Polymer	Temp. [°C]	Concentration [%]	Time [hr]	Applied Strain [%]							
					0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
Polymacon/ Allergan	Udel® P-1700	23	100	1	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	1	●	●	●	●	●	●	●	●
Biotan®/ Nouvag	Udel® P-1700	23	100	48	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	48	●	●	●	●	●	●	●	●
Enflurane (liquid)/ Generic	Udel® P-1700	23	100	24	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	24	●	●	●	●	●	●	●	●
Fichtan®/ Nouvag	Udel® P-1700	23	100	48	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	48	●	●	●	●	●	●	●	●
Halothane (liquid)/ Generic	Udel® P-1700	23	100	24	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	24	●	●	●	●	●	●	●	●
Intralipide®/ Pharmaica	Udel® P-1700	23	10	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	10	72	●	●	●	●	●	●	●	●
Isoflurane (liquid)/ Generic	Udel® P-1700	23	100	24	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	24	●	●	●	●	●	●	●	●
Pliagel® contact lens solution/ Alcon Iberhis, S.A.	Udel® P-1700	88	100	24	●	●	●	●	●	●	●	●
	Radel® R-5000	90	100	1	●	●	●	●	●	●	●	●
Ocufilcon® D + BCHPC/ Biomedics	Udel® P-1700	110	50	1	●	●	●	●	●	●	●	●
	Radel® R-5000	110	50	1	●	●	●	●	●	●	●	●
Ocufilcon® D/ Biomedics	Udel® P-1700	90	100	1	●	●	●	●	●	●	●	●

Table 4: Greases

Trade Name/ Manufacturer	Sulfone Polymer	Temp. [°C]	Concentration [%]	Time [hr]	Applied Strain [%]							
					0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
Dow Corning 200/ Dow Corning	Udel® P-1700	100	100	168	●	●	●	●	●	●	●	●
	Radel® R-5000	100	100	168	●	●	●	●	●	●	●	●
Molycote® 111/ Dow Corning	Udel® P-1700	120	100	168	●	●	●	●	●	●	●	●
	Radel® R-5000	120	100	168	●	●	●	●	●	●	●	●
QS-7508/ Dow Corning	Udel® P-1700	100	100	168	●	●	●	●	●	●	●	●
Krytox® GPL-225/ Dupont	Radel® R-5000	180	100	24	●	●	●	●	●	●	●	●
Polylub® GLY 151/ Kluber	Udel® P-1700	140	100	168	●	●	●	●	●	●	●	●
Unisilikone® TK/ Kluber	Radel® R-5000	150	100	168	●	●	●	●	●	●	●	●

Color Key

- ● No visible effect
- ● No data
- ● Cracked or crazed

Table 5: Disinfectants

Trade Name/ Manufacturer	Sulfone Polymer	Temp. [°C]	Concentration [%]	Time [hr]	Applied Strain [%] 0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
Aldetex®-28/ ICI Pharma	Udel® P-1700	23	100	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	72	●	●	●	●	●	●	●	●
Aseptisol®/ Dr. Bode & Co.	Udel® P-1700	23	2.5	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	2.5	72	●	●	●	●	●	●	●	●
Bomix® / Dr. Bode & Co.	Udel® P-1700	23	3	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	3	72	●	●	●	●	●	●	●	●
Bodephen®/ Dr. Bode & Co.	Udel® P-1700	23	3	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	3	72	●	●	●	●	●	●	●	●
CIDEX®/ Johnson & Johnson	Udel® P-1700	23	100	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	72	●	●	●	●	●	●	●	●
CIDEX®/ Johnson & Johnson	Udel® P-1700	60	100	24	●	●	●	●	●	●	●	●
Dettol®/ Rechitt & Colemann	Udel® P-1700	23	5	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	5	72	●	●	●	●	●	●	●	●
Gigasept® FF/ Schulke & Mayer	Udel® P-1700	23	15	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	15	72	●	●	●	●	●	●	●	●
Grotanat®/ Schulke & Mayer	Udel® P-1700	23	4	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	4	72	●	●	●	●	●	●	●	●
H.A.C./ ICI Pharma	Udel® P-1700	23	1	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	1	72	●	●	●	●	●	●	●	●
Habitane®/ ICI Pharma	Udel® P-1700	23	1	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	1	72	●	●	●	●	●	●	●	●
Harvey's Vapo-Steril®/Barnstead/ Thermolyne	Udel® P-1700	135	100	6.6	●	●	●	●	●	●	●	●
	Radel® R-5000	135	100	6.6	●	●	●	●	●	●	●	●
Lysetol® FF/ Schulke & Mayer	Udel® P-1700	23	4	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	72	●	●	●	●	●	●	●	●
Neodisher® Mielclear/Dr. Weigert	Udel® P-1700	85	0.07	72	●	●	●	●	●	●	●	●
Neodisher® Dental/ Dr. Weigert	Udel® P-1700	85	0.3	72	●	●	●	●	●	●	●	●
Neodisher® A8/ Dr. Weigert	Udel® P-1700	80	5	72	●	●	●	●	●	●	●	●
	Radel® R-5000	80	5	72	●	●	●	●	●	●	●	●
S&M Labor/ Schulke & Mayer	Udel® P-1700	23	1	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	1	72	●	●	●	●	●	●	●	●
Sagrotan® MED/ Schulke & Mayer	Udel® P-1700	23	0.5	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	0.5	72	●	●	●	●	●	●	●	●
Secumatic® FHZ/ Henkel	Udel® P-1700	90	0.5	72	●	●	●	●	●	●	●	●
Secumatic® FNP/ Henkel	Udel® P-1700	60	0.3	144	●	●	●	●	●	●	●	●
	Radel® R-5000	60	0.3	144	●	●	●	●	●	●	●	●
Secumatic® FRE/ Henkel	Udel® P-1700	60	0.5	144	●	●	●	●	●	●	●	●
	Radel® R-5000	60	0.5	144	●	●	●	●	●	●	●	●
Secumatic® FORTE/ Henkel	Udel® P-1700	23	0.5	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	0.5	72	●	●	●	●	●	●	●	●
Sokrena®/ Dr. Bode & Co.	Udel® P-1700	60	2.5	72	●	●	●	●	●	●	●	●
	Radel® R-5000	60	2.5	72	●	●	●	●	●	●	●	●

Table 6: Anti-spotting agents

Trade Name/ Manufacturer	Sulfone Polymer	Temp. [°C]	Concentration [%]	Time [hr]	Applied Strain [%]							
					0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
Guardian® San/ Ecolab	Udel® P-1700	95	0.25	72	●	●	●	●	●	●	○	○
Neodisher® KRM/ Dr. Weigert	Udel® P-1700	95	1	72	●	●	●	●	●	●	○	○
Neodisher® Mediklar/ Dr. Weigert	Radel® R-5000	60	0.5	168	●	●	●	●	●	●	●	●
Sekumatic® FDR/ Henkel	Radel® R-5000	60	1	168	●	●	●	●	●	●	●	●
SU 932/ SU-System	Udel® P-1700	70	5	144	●	●	●	●	○	○	○	○
	Radel® R-5000	70	5	144	●	●	●	●	○	○	○	○
Teux® FD50/ Woelner Werke	Udel® P-1700	70	1	144	●	●	●	●	●	●	●	●
	Radel® R-5000	70	1	144	●	●	●	●	○	○	○	○
TOPAX® P3 67/ Henkel	Udel® P-1700	70	10	168	●	●	●	●	○	○	○	○
	Radel® R-5000	70	10	168	●	●	●	●	○	○	○	○

Table 7: Inorganic agents

Trade Name	Sulfone Polymer	Temp. [°C]	Concentration [%]	Time [hr]	Applied Strain [%]							
					0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
Acetic/Sulfuric acid mixture	Udel® P-1700	75	25/2	120	●	●	●	●	○	○	○	○
	Radel® R-5000	75	25/2	120	●	●	●	●	○	○	○	○
Hydrochloric acid	Radel® R-5000	100	20	24	●	●	●	●	●	●	○	○
Hydrogen peroxide	Udel® P-1700	23	30	72	●	●	●	●	○	○	●	●
	Radel® R-5000	23	30	72	●	●	●	●	●	●	○	○
Lithium bromide	Udel® P-1700	100	65	96	●	●	●	●	○	●	●	●
	Radel® R-5000	100	65	96	●	●	●	●	●	●	●	●
Ozone	Udel® P-1700	50	2(#)	168	●	●	●	●	○	○	●	●
Phosphorus acid	Udel® P-1700	50	30	168	●	●	●	●	●	●	●	●
Potassium hydroxide	Udel® P-1700	120	40	72	●	●	●	●	●	●	●	●
Sodium hydroxide	Udel® P-1700	100	20	24	●	●	●	●	●	●	○	○
	Radel® R-5000	90	50	96	●	●	●	●	●	●	●	●
Sodium hypochlorite	Udel® P-1700	88	12	24	●	●	●	●	●	○	○	○
Sodium metasilicate	Udel® P-1700	149	100	24	●	●	●	●	●	●	●	○
Sulfuric acid	Radel® R-5000	100	50	24	●	●	●	●	●	●	○	○

Table 8: Organic agents

Trade Name	Sulfone Polymer	Temp. [°C]	Concentration [%]	Time [hr]	Applied Strain [%] 0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
1-Butylamine	Udel® P-1700	23	100	24	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	24	●	●	●	●	●	●	●	●
Diacetone-alcohol	Udel® P-1700	23	100	96	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	96	●	●	●	●	●	●	●	●
Ethanol vapors	Udel® P-1700	78.5	100	96	●	●	●	●	●	●	●	●
Formaldehyde	Udel® P-1700	38	35	168	●	●	●	●	●	●	●	●
Glycerine	Udel® P-1700	23	100	1,000	●	●	●	●	●	●	●	●
Isopopanol	Udel® P-1700	55	100	72	●	●	●	●	●	●	●	●
Isopropyl myristate	Udel® P-1700	23	100	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	100	72	●	●	●	●	●	●	●	●
Nitroglycerine	Udel® P-1700	23	1	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	1	72	●	●	●	●	●	●	●	●
Phenol	Udel® P-1700	60	1	24	●	●	●	●	●	●	●	●
Polyethyleneglycol	Udel® P-1700	23	20	72	●	●	●	●	●	●	●	●
	Radel® R-5000	23	20	72	●	●	●	●	●	●	●	●
Polyvinylpirrolidone	Radel® R-5000	90	100	144	●	●	●	●	●	●	●	●
Propylene glycol (Tyvocor® L)	Udel® P-1700	110	60	1,000	●	●	●	●	●	●	●	●
	Radel® R-5000	110	60	1,000	●	●	●	●	●	●	●	●
Propyonic acid	Udel® P-1700	40	99	144	●	●	●	●	●	●	●	●
	Radel® R-5000	40	99	144	●	●	●	●	●	●	●	●
Sorbic acid	Udel® P-1700	23	100	1,000	●	●	●	●	●	●	●	●
Thiourea	Udel® P-1700	35	11	72	●	●	●	●	●	●	●	●
Triethanolamine	Udel® P-1700	90	0.01	72	●	●	●	●	●	●	●	●

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