



Chemical Compatibility

Sulfone Polymers

Sulfone polymers exhibit varying levels of chemical compatibility, depending upon their polymeric structure and the presence of additives such as glass. Other factors influencing chemical compatibility 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 compatibility 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 are shown in Table 1, rating system as follows:

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

The sulfone polymers tested show excellent resistance to the aqueous solutions of both acids and bases. The aliphatic hydrocarbons have no or little effect on any of the resins tested. The 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 property change. Chlorinated hydrocarbons are shown to attack sulfone resins, with only Radel polyphenylsulfone (PPSU) showing a measure of resistance to them.

STRESS CRACK RESISTANCE

The following tables are a summary of many years of testing of our sulfone polymers. Environmental stress testing was conducted in various chemicals at indicated temperatures, times and concentrations.

To evaluate the resistance of the Udel polysulfone (PSU) and Radel polyphenylsulfone (PPSU) to environmental stress cracking, typical test specimens 127 mm (5 inches) long, 13 mm (.5 inch) wide, 3.2 mm (.125 inch) 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. At lower stress levels, cracking may not occur, but if it does, longer exposure time will be required. 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 room temperature

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: Corresponding Stress

Strain, %	Stress, MPa (psi)			
	Udel P-1700		Radel R-5000	
0.0	0	(0.0)	0	(0.0)
0.2	720	(5.0)	680	(4.7)
0.4	1440	(9.9)	1360	(14.1)
0.6	2160	(14.9)	2040	(4.7)
0.8	2880	(19.9)	2720	(18.8)
1.0	3600	(24.8)	3400	(23.4)
1.2	4320	(29.8)	4080	(28.1)
1.4	5040	(34.7)	4760	(32.8)

While Udel polysulfone (PSU) has good resistance to many materials, Radel polyphenylsulfone (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.

CONCLUSION

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

Table 3: Medical Reagents

Trade Name	Manufacturer	Sulfone Resin	Temperature, °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	Blue	Blue	Green	Green	Green	Green	Green	Green
		Radel R-5000	23	100	1	Blue	Blue	Green	Green	Green	Green	Green	Green
Biotan®	Nouvag	Udel P-1700	23	100	48	Blue	Blue	Green	Green	Green	Green	Green	Green
		Radel R-5000	23	100	48	Blue	Blue	Green	Blue	Grey	Grey	Grey	Grey
Enflurane (Liquid)	Generic	Udel P-1700	RT	100	24	Blue	Grey	Green	Green	Green	Green	Green	Green
		Radel R-5000	RT	100	24	Blue	Blue	Green	Grey	Grey	Green	Green	Green
Fichtan®	Nouvag	Udel P-1700	23	100	48	Blue	Blue	Green	Grey	Green	Green	Green	Green
		Radel R-5000	23	100	48	Blue	Blue	Green	Blue	Blue	Grey	Grey	Grey
Halothane (Liquid)	Generic	Udel P-1700	RT	100	24	Green	Green	Green	Green	Green	Green	Green	Green
		Radel R-5000	RT	100	24	Blue	Blue	Grey	Green	Green	Green	Green	Green
Intralipide®	Pharmaica	Udel P-1700	23	10	72	Blue	Blue	Green	Blue	Blue	Blue	Grey	Grey
		Radel R-5000	23	10	72	Blue	Blue	Green	Blue	Blue	Blue	Grey	Grey
Isoflurane (Liquid)	Generic	Udel P-1700	RT	100	24	Blue	Grey	Green	Green	Green	Green	Green	Green
		Radel R-5000	RT	100	24	Blue	Blue	Green	Grey	Grey	Green	Green	Green
Pliagel® Contact Lens Solution	Alcon Iberhis, S.A.	Udel P-1700	88	100	24	Green	Green	Green	Green	Green	Green	Green	Green
		Radel R-5000	90	100	1	Blue	Blue	Green	Green	Green	Green	Green	Green
Ocufilecon® D + BCHPC	Biomedics	Udel P-1700	110	50	1	Green	Green	Green	Green	Green	Green	Green	Green
		Radel R-5000	110	50	1	Blue	Blue	Green	Grey	Grey	Grey	Grey	Grey
Ocufilecon® D	Biomedics	Udel P-1700	90	100	1	Grey	Green	Green	Green	Green	Green	Green	Green

COLOR KEY

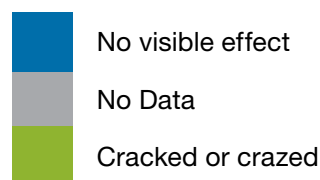


Table 4: Greases

Trade Name	Manufacturer	Sulfone Resin	Temperature, °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 572/300	Kluber	Radel R-5000	150	100	168								

Table 5: Disinfectants

Trade name	Manufacturer	Sulfone Resin	Temperature, °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								

Table 5: Disinfectants Continued

Trade name	Manufacturer	Sulfone Resin	Temperature, °C	Concentration, %	Time, hr	Applied Strain, %							
						0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
H.A.C.	ICI Pharma	Udel P-1700	23	1	72	Blue	Blue	Blue	Blue	Grey	Grey	Green	Green
		Radel R-5000	23	1	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Habitane®	ICI Pharma	Udel P-1700	23	1	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
		Radel R-5000	23	1	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Harvey's Vapo-Steril®	Barnstead/ Thermolyne	Udel P-1700	135	100	6.6	Green	Green	Green	Green	Green	Green	Green	Green
		Radel R-5000	135	100	6.6	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Lysetol® FF	Schulke & Mayer	Udel P-1700	23	4	72	Blue	Blue	Blue	Blue	Grey	Grey	Green	Green
		Radel R-5000	23	100	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Neodisher® Mielclear	Dr. Weigert	Udel P-1700	85	0.07	72	Blue	Blue	Blue	Blue	Grey	Grey	Green	Green
Neodisher® Dental	Dr. Weigert	Udel P-1700	85	0.3	72	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey
Neodisher® A8	Dr. Weigert	Udel P-1700	80	5	72	Green	Green	Green	Green	Green	Green	Green	Green
		Radel R-5000	80	5	72	Blue	Blue	Blue	Blue	Blue	Grey	Grey	Green
S&M Labor	Schulke & Mayer	Udel P-1700	23	1	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
		Radel R-5000	23	1	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Sagrotan®MED	Schulke & Mayer	Udel P-1700	23	0.5	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
		Radel R-5000	23	0.5	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Secumatic® FHZ	Henkel	Udel P-1700	90	0.5	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Secumatic® FNP	Henkel	Udel P-1700	60	0.3	144	Blue	Blue	Blue	Blue	Blue	Green	Green	Green
		Radel R-5000	60	0.3	144	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Secumatic® FRE	Henkel	Udel P-1700	60	0.5	144	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey
		Radel R-5000	60	0.5	144	Blue	Blue	Blue	Blue	Blue	Green	Green	Green
Secumatic® FORTE	Henkel	Udel P-1700	23	0.5	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
		Radel R-5000	23	0.5	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Sokrena®	Dr. Bode & Co.	Udel P-1700	60	2.5	72	Blue	Blue	Blue	Blue	Grey	Grey	Grey	Grey
		Radel R-5000	60	2.5	72	Blue	Blue	Blue	Blue	Grey	Grey	Grey	Grey

Table 6: Anti-Spotting Agents

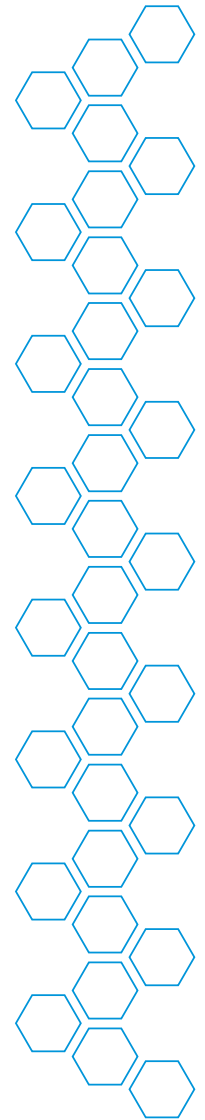
Trade name	Manufacturer	Sulfone Resin	Temperature, °C	Concentration, %	Time, hr	Applied Strain, %							
						0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
Guardian® San	Ecolab	Udel P-1700	95	0.25	72	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey
Neodisher® KRM	Dr. Weigert	Udel P-1700	95	1	72	Blue	Blue	Blue	Blue	Blue	Blue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

Table 7: Inorganic Agents

Trade Name	Sulfone Resin	Temperature, °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	Blue	Blue	Blue	Blue	Grey	Grey	Grey	Grey
	Radel R-5000	75	25/2	120	Blue	Blue	Blue	Blue	Grey	Grey	Grey	Grey
Hydrochloric Acid	Radel R-5000	100	20	24	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Hydrogen Peroxide	Udel P-1700	23	30	72	Blue	Blue	Blue	Blue	Grey	Grey	Green	Green
	Radel R-5000	23	30	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Lithium Bromide	Udel P-1700	100	65	96	Blue	Blue	Blue	Blue	Grey	Green	Green	Green
	Radel R-5000	100	65	96	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Ozone	Udel P-1700	50	2(#)	168	Blue	Blue	Blue	Blue	Grey	Grey	Green	Green
Phosphorus Acid	Udel P-1700	50	30	168	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Potassium Hydroxide	Udel P-1700	120	40	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Sodium Hydroxide	Radel R-5000	100	20	24	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Sodium Hydroxide	Udel P-1700	90	50	96	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green
Sodium Hypochlorite	Udel P-1700	88	12	24	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Sodium Metasilicate	Udel P-1700	149	100	24	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Sulfuric Acid	Radel R-5000	100	50	24	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue

Table 8: Organic Chemicals

Trade Name	Sulfone Resin	Temperature, °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	Grey	Grey	Green	Green	Green	Green	Green	Green	Green
	Radel R-5000	23	100	24	Grey	Grey	Green	Green	Green	Green	Green	Green	Green
Diacetone-alcohol	Udel P-1700	23	100	96	Green	Green	Green	Green	Green	Green	Green	Green	Green
	Radel R-5000	23	100	96	Blue	Blue	Grey	Green	Green	Green	Green	Green	Green
Ethanol Vapors	Udel P-1700	78.5	100	96	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey	Grey
Formaldehyde	Udel P-1700	38	35	168	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Glycerine	Udel P-1700	23	100	1,000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Isopopropanol	Udel P-1700	55	100	72	Blue	Blue	Blue	Grey	Green	Green	Green	Green	Green
Isopropyl Myristate	Udel P-1700	23	100	72	Blue	Blue	Blue	Grey	Grey	Green	Green	Green	Green
	Radel R-5000	23	100	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Nitroglycerine	Udel P-1700	23	1	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey
	Radel R-5000	23	1	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Phenol	Udel P-1700	60	1	24	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey
Polyethyleneglycol	Udel P-1700	23	20	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey
	Radel R-5000	23	20	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey
Polyvinylpyrrolidone	Udel P-1700	90	100	144	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Propylene Glycol (Tyvocor L)	Udel P-1700	110	60	1,000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey
	Radel R-5000	110	60	1,000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey
Propyonic Acid	Udel P-1700	40	99	144	Green	Green	Green	Green	Green	Green	Green	Green	Green
	Radel R-5000	40	99	144	Blue	Blue	Blue	Grey	Green	Green	Green	Green	Green
Sorbic Acid	Udel P-1700	23	100	1,000	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Thiourea	Udel P-1700	35	11	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey
Triethanolamine	Udel P-1700	90	0.01	72	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey	Grey



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