Chemical Resistance of **Arnitel®**

Chemical resistance of any material is a function of the interactions that occur between the polymer and a chemical in contact. The chemical resistance or the lack of it is seen through the swelling of the polymer (dimensional instability), plastisizing (drop in hardness) or chemicals induced cracking like ESC (Environmental Stress Cracking).

Chemical resistance can be readily tested on tensile bars. ESC occurs when stresses in the material relax in the presence of a solvent or non-solvent. ESC is only seen if polymers are in contact with a mixture of chemicals like oil, a brake fluid or an adhesive. Arnitel® U is sensitive to certain acrylic acid compounds, data is available on request. Arnitel® E and Arnitel® P are also suspected to be sensitive to this type of adhesive.

The chemical resistance of Arnitel® has been tested in a large number of chemicals. Testing was performed on tensile test bars according to ISO R462-65 and checked for the percentage elongation under tension. The data is summarized in the following sections.

Weight increase of Arnitel by some chemicals:
The amount of chemical absorbed into the polymer is of major importance to the retention of mechanical properties. If a polymer absorbs high amounts of a chemical, the material will soften. Also it will degrade rapidly with increasing amounts of absorption. In table 1, the uptake of chemicals is displayed for Arnitel E types.

Table 1: Weight gain due to absorption of several chemicals by Arnitel E after six weeks immersion at 23°C.

Chemical substance	EM400	EM460	EL550	EL630	EL740
	wt gain 6 weeks				
Acetic acid 5%	-	-	0.8*	1.2	0.5
Acetic acid	129	68	28*	19	3.5
Acetone	28	-	10*	9.1	6.3
Bleaching lye, 1%	-	-	0.4	-	0.4
Bleaching lye, 12%	-	-	0.2	-	0.2
Cyclo hexane	-	-	5.9	-	0.1
Cyclo hexanone	-	-	20	-	1.3
DOP	-	-	0.8	-	0.01
Ethanol	--	-	4.5*	4.6	0.8
Ethyl acetate	-	-	15*	12	4.7
Ethylene glycol	-	-	0.5	-	0
Formaldehyde	-	-	2.9	-	0.5
Formic acid, 5%	-	-	1.4	-	0.5
Formic acid, 50%	-	-	11	-	2.9
Gasoline (petrol)	-	-	12	-	0.7
Gasoline/methanol (85/15)	65	35	14	11	3.8
Hydrochloric acid, 1%	-	-	0.5	-	0.4
Hydrochloric acid, 10%	-	-	0.4	-	0.3
Peroxide, 3%	-	-	0.4	-	0.3
Peroxide, 10%	-	-	1.7		0.5
Peroxide, 30%	-	-	4.1	-	1.0
Iso-octane	9.0	5.2	2.5*	1.2	0.3
Iso-octane/toluene(70/30)	27	16	9.3*	7.7	0.6
Methanol	-	-	4.7	4.3	-

July 2004

Methylenechloride	-	-	155*	78	39
Methyl-ethyl ketone	-	-	12	-	6.4
Nitric acid, 1%	-	-	0.5	-	0.4
Nitric acid, 10%	-	-	2.0	-	0.4
Perchloro ethylene	-	-	27	-	2.6
Phosphoric acid, 1%	-	-	0.5	-	0.4
Phosphoric acid, 10%	-	-	0.4	-	0.3
Potassium chlorate, 10wt%	-	-	0.4	-	0.3
Sodium hydrolgensulphite, 10wt%	-	-	1.3	-	0.4
Sodium hydroxide, 10%	0	0	0.5*	0.3	0.2
Sodium hydroxide, 50%	0	0	0	0.02	0
Sulphuric acid, 1%	-	-	0.5	-	0.4
Sulphuric acid, 10%	-	-	0.3	-	0.4
Sulphuric acid, 30%	0	0	0	0.2	0.15
Sulphuric acid, conc.	-	-	**	**	**
Super gasoline (petrol)	-	-	11	-	0.6
Teepol solution, 25%	-	-	0.5	-	0.3
Terpentine	-	-	5	-	0.1
Tetrachloro methane	172	97	45	27	1.3
Ureum, 10wt%	-	-	0.3	-	0.3
Xylene	86	48	21	14	1.6
Zinc chloride, 10wt%	-	-	0.4	-	0.3
ASTM oil no.1	1.6	0.51	0.6	0.3	0.1
ASTM oil no.3	15	6.6	3.8	0.9	0.05
Crude oil	19	10	6.6	2.5	0.1
Esso Turbo oil 2380	13	4.5	2.5	0.5	0.1
Esso turbo oil 2389	18	7.2	3.7	0.8	0.1
Heavy oil (Diesel)	-	-	7.1	-	-
Kontol K147	-	-	14	-	-
Kontol KW1936	-	-	4.4	-	-
Lockheed brake fluid	-	-	5.4	3.9	0.1
Nalfloc A320 (10% in water)	-	-	0.4	-	-
Nalfloc V914	-	-	13	-	-
Nalfloc V3804	-	-	**	-	-
Nalfloc V3656	-	-	0.4	-	-
Nalfloc V935	-	-	3.7	-	-
Petroleum	-	-	5.6		-
Skydrol LD	32	18	11	3.1	0.05
Skydrol 500B	37	20	13	3.5	0.05
X-tol XT 48	-	-	13	-	-

* Sample is tested for four weeks in the solvent. ** Sample dissolves in the solvent.

Table 2: Effect of chemical on weight increase of Arnitel PL380/PL580 after two and six week's immersion at 23°C or 60°C. This data is also valid for the extrusion versions, Arnitel PM381 and PM581.

Chemical substance	PL380	PL380	PL380	PL380	PL580	PL580	PL580	PL580
	wt gain 2 weeks 23°C	wt gain 2 weeks 60°C	Wt gain 8 weeks 23°C	Wt gain 8 weeks 60°C	wt gain 2 weeks 23°C	wt gain 2 weeks 60°C	wt gain 8 weeks 23°C	Wt gain 8 weeks 60°C
Acetic acid 10%	15	9	17	9	5	4	6	4
Acetone	35	-	-	-	13	-	13	-
Ammonia 10%	10	-	-	-	2	-	4	-
ASTM oil 1	2	4(100°C)	8	13(100°C)	0.3	1.6(100°C)	0.3	1.6(100°C)
ASTM oil 3	7	13(100°C)	8	13(100°C)	1.6	1.2(100°C)	5.2	2.7(100°C)
DOT-4 (brake fluid)	17	27(100°C)	17	-	6	14	13	-

July 2004

Calcium Chloride 10%	3	2	3	2	1	1	1	1
Ethanol	28	38	29	-	8	14	8	11
Ether	22	-	21	-	8	-	8	-
Ethyl acetate	52	-	53	-	16	14	17	-
Ethylene glycol	2	2	2	3	-	-	-	-
Gasoline leaded (super)	22	31	23	54	9	11	9	16
Gasoline unleaded	24	27	25	31	9	11	9	12
Glysantin (cooling fluid)	2	3	-	-	1	2	1	2
GML0003 (oil)	65	-	-	-	19	21	-	-
Heavy oil (diesel oil)	13	16	13	17	4	7	6	7
Hydrochloric acid 10%	22	5	-	-	1	1	2	-
Hydrogen peroxide 30%	24	-	-	-	10	-	6	-
Nitric acid 10%	25	-	-	-	7	-	9	-
Palatinol (transformer oil)	40	-	-	-	6	17	11	-
Perchloro ethylene	86	120			27	34	27	34
Phosphoric acid 30%	22	6	25	8	2	1	4	2
Sodium hydroxide 10%	57	55	-	-	-2	-33	-14	-
Sulphuric acid 30%	26	-	-	-	1	1	1	-
Tetrachloride	121	-	-	-	36	32	36	
Toluene	71	-	-	-	21	27	21	27
Trichloro ethylene	208	270	-	-	57	67	58	67
Zinc chloride 10%	8	3	8	3	2	2	3	1

The data on weight increase can be used to calculate the degree of swell of Arnitel in the solvent. The way chemicals effect the mechanical property varies from one to another, but is more or less related to the amount of the chemical absorbed by the polymer.

Effect on mechanical properties

Automotive related chemicals:

Arnitel E analogues were tested in some oils at 23°C and 100°C. The corresponding data are depicted in table 3 and 4

Table 3: Effect of six weeks at 23°C in oil on the elongation at break for Arnitel E.

	EM400	**EM460**	**EL550**	**EL630**	**EL740**
ASTM oil 1	98	101	104	93	105
ASTM oil 2	107	-	-	-	-
ASTM oil 3	92	98	98	89	103
Crude north sea oil	95	97	89	92	97
ESSO TURBO OIL 2380	95	100	93	91	102
ESSO TURBO OIL 2389	93	98	89	95	103
Skydrol LD	85	96	89	86	103
Skydrol 500B	83	90	85	84	103

The same work was performed at 100°C to see the effects. These effects are depicted in table 4.

Table 4: Effect of six weeks at 100°C in oil on the elongation at break for Arnitel E.

Chemical	**EM400**	**EM460**	**EL550**	**EL630**	**EL740**
ASTM oil 1	100	110	107	91	33
ASTM oil 2	108	-	-	-	-
ASTM oil 3	86	91	100	89	74
crude north sea oil	96	99	93	87	103

July 2004

ESSO TURBO OIL 2380	84	94	102	98	103
ESSO TURBO OIL 2389	88	86	98	93	98
Skydrol LD	**	**	74	86	103
Skydrol 500B	**	**	**	**	103
Tranself 80B	-	-	78	-	-

** Polymer swollen and cracked

Some other oil types were tested at different conditions. The test results are shown in table 5.

Table 5: Effect of some oils after six weeks at elevated temperatures (elongation at break).

	23°C	**80°C**	**80°C**	**80°C**
	EL550	**EL550**	**EL630**	**EL740**
Antar LV Cx grease	90	-	-	-
Antar LV R30 grease	90	-	-	-
Cameron 530 oil (only 60C)	-	94	101	98
Kontol K147	95	-	-	-
Kontol KW1936	104	-	-	-
Ford brake fluid	100	76	-	-
Lockheed brake fluid	100	3	86	109
Nalfloc A320, 10% in water	106	-	-	-
Nalfloc V3804	99	-	-	-
Nalfloc V3656	*	-	-	-
Nalfloc V935	105	-	-	-
X-tol XT 48	92	-	-	-

* Sample embrittles completely.

The effect of Molikote 7401 Power steering oil was tested for seven days at 125°C on Arnitel EM400. Elongation at break was at 40% of the original value. Elongation of Arnitel EM400 in Shell Helix 10W40 for six weeks at 130°C showed retention of 98%. The weight increased by 9%. EL550 was tested for seven days in ASTM oil 2 at 90°C. Elongation remained at the original level.
Since thermal degradation of oil results in an increase in the concentration of carboxylic acid groups, using an acid scavenger will increase the lifetime of Arnitel in oil. Carboxylic acid groups increase the speed of degradation and the sensitivity towards hydrolysis.

Also the resistance against some fuel types has been tested and the data is depicted in table 6.

Table 6: Effect of several types of gasoline on the elongation at break for Arnitel E after immersion for six weeks at 23°C.

	EM400	**EM460**	**EL550**	**EL630**	**EL740**
Gasoline(petrol)	-	-	84	-	104
Gasoline/methanol (85/15)	-	-	83	80	108
Super gasoline (petrol)	-	-	82	-	-
Gasoline/methanol(85/15)	75	81	83	80	108
i-octane/toluene (70/30)	89	94	93	89	92
Heavy oil (diesel)	-	-	91	-	-

Additional experiments were performed with Arnitel EL630. The polymer was tested in gasoline/methanol 85/15 and 60/40 at 60°C under pressure (4 bar). The results are depicted in table 7.

Table 7: Effect of gasoline/methanol mixtures at 60°C on Arnitel EL630 (elongation at break).

	Gasoline/methanol 85/15	**Gasoline/methanol 60/40**
Reference	450	450
4 days	469	480
7 days	526	525
21 days	34	475
42 days	19	*

July 2004

* Complete embrittlement of the test bars.

Finally the effects of FAM/methanol was tested 85/15 mixtures at 120°C was tested on 58 micron Arnitel EL550 films. The film's thickness increased to 170 micron, elongation at break increased from 180% to 430% in the parallel direction and from 60 to 340% in the perpendicular direction. Materials shrunk for 25 and 40% respectively.
In the presence of natural gas condensate, no effects were noticed after seven days at 80°C
Arnitel PM581 is a copper stable grade, specially developed for tubes and hoses, and is very stable against all types of hydraulic oil. Examples are shown in table 8.

Table 8: Data on the oil resistance of Arnitel® PM581.

	2 weeks 100°C	**8 weeks**
ASTM oil 1	102	105
ASTM oil 3	100	102

Table 9 shows the data on retention tensile strength for Arnitel PL380 and Arnitel PL580. These data are also valid for the extrusion versions, Arnitel PM381 and PM581

Chemical substance	**PL380**	**PL380**	**PL380**	**PL380**	**PL580**	**PL580**	**PL580**	**PL580**
	2 weeks 23°C	2 weeks 60°C	8 weeks 23°C	8 weeks 60°C	2 weeks 23°C	2 weeks 60°C	8 weeks 23°C	8 weeks 60°C
Acetic acid 10%	97	92	92	80	96	95	90	89
Acetone	72	-	-	-	83	-	82	-
Ammonia 10%	62	-	-	-	93	-	86	-
ASTM oil 1	98	98(100°C)	97	89(100°C)	100	102(100°C)	100	105(100°C)
ASTM oil 3	96	95(100°C)	97	89(100°C)	101	100(100°C)	103	102(100°C)
DOT-4 (brake fluid)	86	0(100°C)	85	-	94	86	86	-
Calcium Chloride 10%	99	100	98	96	95	95	95	95
Ethanol	87	76	82	-	89	92	86	91
Ether	92	-	88	-	88	-	93	-
Ethyl acetate	75	-	68	-	84	70	83	-
Ethylene glycol	99	99	97	93	-	-	-	-
Gasoline leaded (super)	85	77	85	61	87	92	95	90
Gasoline unleaded (eurosuper)	83	78	85	80	91	87	92	91
Glysantin (cooling fluid)	98	95	-	-	100	104	111	104
GML0003 (oil)	62	-	-	-	81	82	-	-
Heavy oil (diesel oil)	91	88	89	78	99	96	98	96
Hydrochloric acid 10%	68	0	-	-	99	99	88	
Hydrogen peroxide 30%	47	-	-	-	88	-	0	-
Nitric acid 10%	56	-	-	-	88	-	43	-
Palatinol (transformer oil)	78	-	-	-	96	90	93	-
Perchloro ethylene	71	62	-	-	87	85	85	42
Phosphoric acid 30%	97	82	85	60	94	94	92	93
Sodium hydroxide 10%	35	44	-	-	116	116	0	-
Sulphuric acid 30%	61	-	-	-	95	97	88	-

July 2004

Tetrachloride	70	-	-	-	90	23	90	-
Toluene	52	-	-	-	81	83	79	79
Trichloro ethylene	34	24	-	-	77	78	65	71
Zinc chloride 10%	101	97	98	92	94	95	95	92

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The chemical resistance against bases is quite good. Only at higher temperatures will degradation take place. Even in a hydrolysis stabilised Arnitel, stabilisation against base induced degradation can not be prevented. The data are depicted in table 10.

Table 10: Arnitel E stability against bases after six weeks at 23°C.

Testing 23°C	Elongation at break as percentage of the original value.				
Chemical	**EM400**	**EM460**	**EL550**	**EL630**	**EL740**
Bleaching lye, 1%	-	-	90	-	97
Bleaching lye, 12%	-	-	94	-	98
Sodium hydroxide, 10%	100	103	100*	91	100
Sodium hydroxide, 50%	101	101	100*	91	105
Zinc chloride, 10%	-	-	95	-	96

* Immersion only for four weeks.

The resistance towards acids for some Arnitel E grades at 23°C is depicted in table 11.

Table 11: Effects of acidic environments on the elongation at break for Arnitel E.

testing 23°C	Elongation at break as percentage of the original value.				
Chemical	**EM400**	**EM460**	**EL550**	**EL630**	**EL740**
Acetic acid, 5%	-	-	100*	84	100
Acetic acid, 100%	53	77	72*	82	100
Formic acid, 5%	-	-	97	-	72
Formic acid, 50%	-	-	82	-	89
Phosphoric acid, 1%	-	-	85	-	67
Phosphoric acid, 10%	-	-	93	-	94
Hydrochloric acid, 1%	-	-	90	-	91
Hydrochloric acid, 10%	-	-	93	-	92
Nitric acid, 1%	-	-	92	-	97
Nitric acid, 10%	-	-	3	-	97
Sulphuric acid, 1%	-	-	91	-	99
Sulphuric acid, 10%	-	-	86	-	96
Sulphuric acid, 30%	102	105	100*	95	98
Sulphuric acid*	**	**	**	**	**

* Immersion for only four weeks ** complete solution of the polymer

In general, Arnitel E is sensitive towards concentrated acids, especially at elevated temperatures. Diluted acids are less effective, however in these cases degradation also takes place and temperature plays in this case a very important role. Stabilisation against acid degradation is only possible for short-term solutions.

Resistance against organic chemical:

The latter compounds are the organic chemicals, often used in all kinds of materials that have contact with Arnitel E. The resistance of all Arnitel E types against most common organic solvents used are depicted in table 12.

July 2004

Table 12: Resistance of Arnitel E against regular organic solvents after six weeks immersion.

Testing 23°C	Elongation at break as percentage of the original value.				
Common chemicals	**EM400**	**EM460**	**EL550**	**EL630**	**EL740**
Acetone	88	95	93	86	103
Dichloro methane	-	-	**	87	70
Ethanol	-	-	95*	86	103
Ethyl acetate	81	91	95	89	102
Gasoline	-	-	84	-	104
Gasoline/methanol(85/15)	75	81	83	80	108
Super gasoline	-	-	82	-	-
iso-octane	100	100	100	98	97
i-octane/toluene (70/30)	89	94	93	89	92
Tetrachloro methane	60	75	80*	84	100
Xylene	70	80	80*	91	110

* Sample only tested for four weeks. ** Polymer dissolves completely.

All other chemicals have only been tested on Arnitel EL550 and Arnitel EL740. The results are shown in table 13.

Table 13: Effects of several chemicals on Arnitel EL550 and Arnitel EL740 after a residence time of six weeks at 23°C.

	EL550	**EL740**	**EL630**
Cyclohexane	86	98	
Cyclohexanone	76	97	
Dioctyl phthalate	96	102	
Ethylene glycol	89	73	
Formaldehyde	85	98	
Methanol	102	100	97
Methylethyl ketone	76	102	
Potassium chlorate, 10wt%	88	96	
Hydrogen peroxide, 3%	91	98	
Hydrogen peroxide, 10%	**	94	
Hydrogen peroxide, 30%	**	86	
Perchloro ethylene	79	112	
Sodium hydrogensulphite, 10 wt%	98	102	
Sodium sulphate, 10 wt %	95	98	
Teepol solution, 25%	90	91	
Terpentine	93	96	
Ureum, 10 wt%	97	98	

July 2004