

## 6. Chemical Properties

### 6 · 1 Rate of Water and Moisture Absorption

The rate of water absorption is

ASTM—D570, after 24 hours in water 0.23~0.26%

The rate of water and moisture absorption of Iupilon / NOVAREX is as shown in Fig. 6 · 1—1.

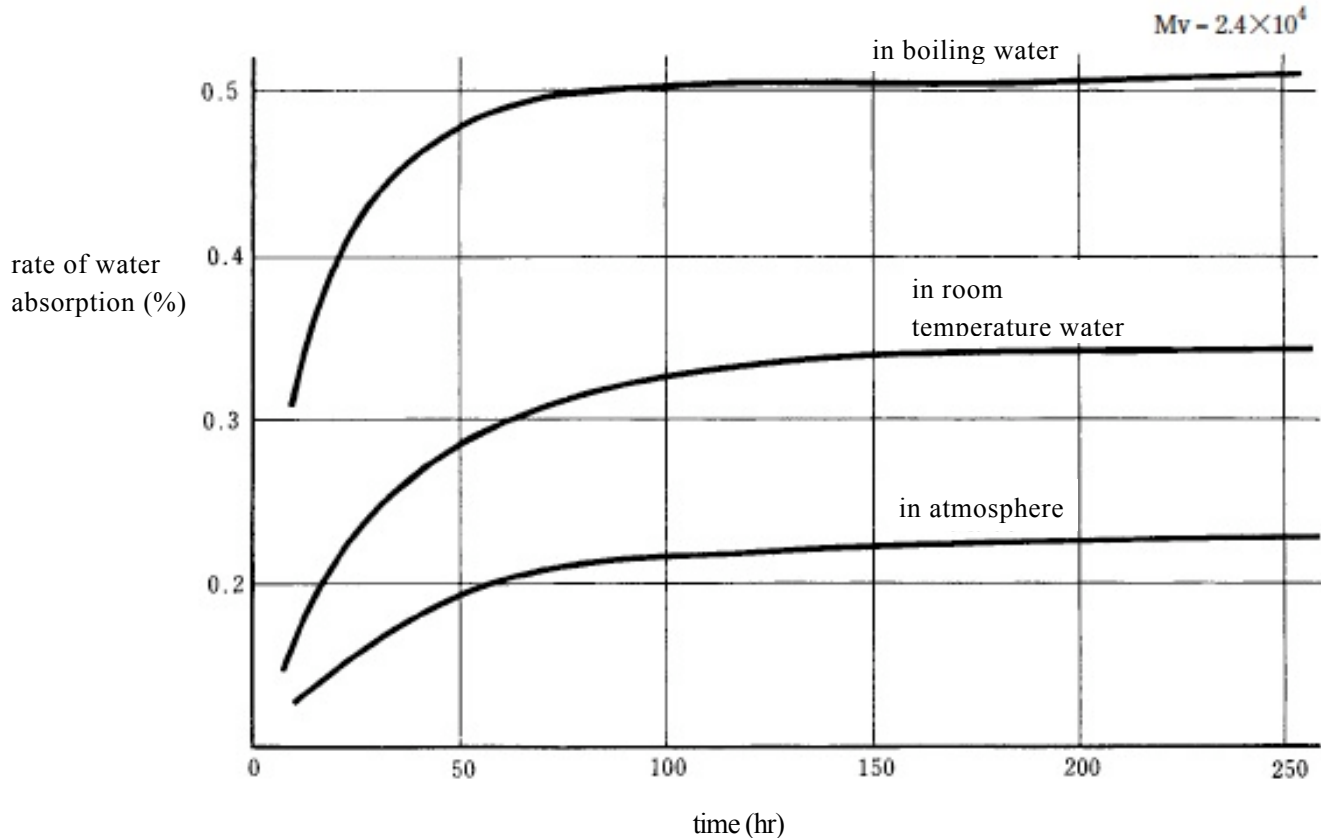


Fig. 6 · 1—1 Water absorption curve of Iupilon / NOVAREX (ASTM-D570)

Also, the rate of water absorption measured according to JISK6771-1958 was

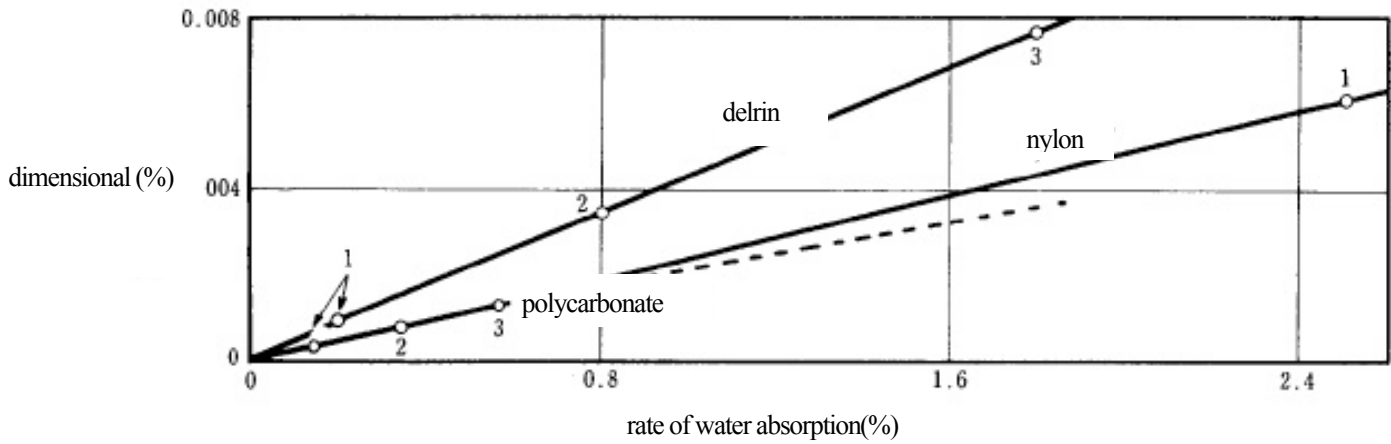
After 24 hours in 50°C water	0.29%
After 24 hours in 75°C water	0.39%

This method of measuring the rate of water absorption is not necessarily based on rate of water absorption of zero.

In view of this, if the moisture of these moisture-absorbed samples is determined by the Karl Fischer method, the coefficient of water absorption becomes about 0.05~0.10% larger than the above values.

The dimensional change of polycarbonate by water and moisture absorption is as shown in Fig. 6 · 1—2.

A comparison with other resins is shown in Table 6 · 1—1, from which it can be seen that the rate of water absorption of Iupilon / NOVAREX is very small and consequently, one of its features is that dimensional change due to this is very small.



1: room temperature, 50% RH, 2: in room temperature water, 3: in boiling water  
 Fig. 6 · 1-2 Dimensional change by water absorption

Table 6 · 1-1 Rate of water absorption of various resins  
 ASTM - D570 (after 24 hours)

Name of substances	Rate of water absorption (%)
Low density polyethylene	< 0.01
Polycarbonate	0.23
Rubber modified PVC	0.07~0.2
Cellulose propionate	1.2~2.8
High impact strength ABS	0.3
High impact strength ethylcellulose	0.8~2.0
Ethylcellulose	1.2~2.0
Soft cellulose acetate	2.3~6.5
Soft cellulose butyrate	0.9~1.3
Rigid cellulose butyrate	1.3~1.8
Cellulose acetate	1.9~4.0
Teflon	0.00
Glass fiber reinforced nylon	0.7~1.4
Polyethylene	0.04~0.08
A B S	0.2
Rigid cellulose acetate	1.6~3.8
Nylon	1.2~2.3
Acrylate	0.2~0.4
Polyacetal	0.41
Polypropylene	< 0.01

## 6 · 2 Gas Permeability

Water vapor permeability of Iupilon film is as shown in Table 6 · 2-1.

Table 6 · 2-1

Film thickness (mm)	Testing method	Rate of water vapor permeability (g/m <sup>2</sup> · day)
0.20	JIS-Z 0208, tempt. 40°C, humidity90%	23.3
0.08	ASTM-E 96-53T, tempt. 50°C, humidity50%	46-57
0.05	ASTM-E 96-53T, tempt. 50°C, humidity 50%	69
0.02	JIS-Z 0208, tempt. 40°C, humidity90%	195

Gas permeability of Iupilon is as shown in Table 6 · 2-2 and Fig. 6 · 2-1. The relation between gas permeability constant and 1/T is shown by the straight line but it has a refractive point between 0~20°C in case of gas with relatively big constant.

Also, the relation between gas permeability of Iupilon and sample thickness is as shown in Table 6 · 2-3. It depends on the kind of gas but shows almost a constant value until the thickness of 300μm except for CO<sub>2</sub>.

Table 6 · 2-2 Gas permeability of Iupilon film (ASTM-D1434)

Temperature (°C)	Gas permeability constant*				
	H <sub>2</sub>	He	N <sub>2</sub>	O <sub>2</sub>	CO <sub>2</sub>
90			20.6		
80			16.2		
70			12.3	46.4	
60	533.	315.	9.7	39.2	210.
50	352.	237.	6.1	31.9	160.
40	208.	197.	4.9	23.8	127.
30	165.	144.	3.2	18.1	103.
20	120.	110.	2.4	14.3	72.
0	62.	77.	1.4	8.4	48.
-10	47.	48.	0.8	5.8	31.
-20			0.4	4.0	
-25				3.3	
-30	34.	34.		2.9	19.
-35	24.	25.		2.3	11.
-40	17.	18.		2.1	5.0
-45	12.	13.		1.3	2.1
-50	7.	8.		1.0	1.3
-55				0.9	
-60				0.8	

\* Unit cm<sup>3</sup> · cm/cm<sup>2</sup> · s · cmHg · 10<sup>11</sup>, pressure difference 1 atm, thickness 50 μ

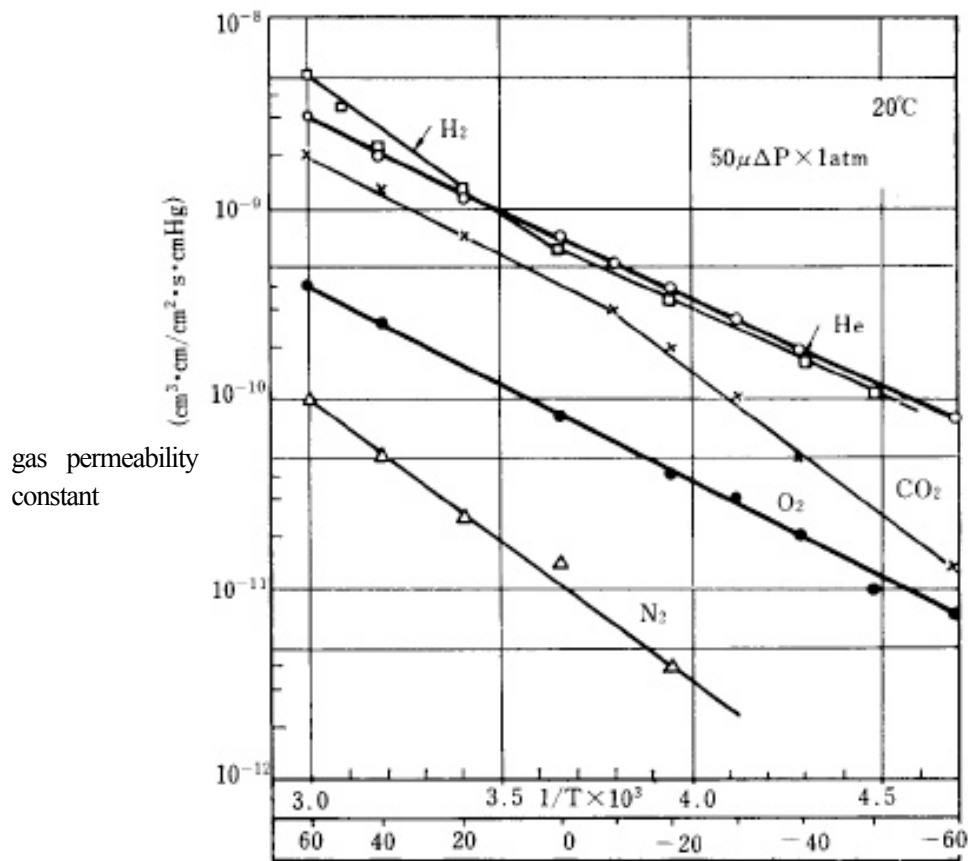


Fig. 6 · 2-1 Gas permeability of Iupilon

The relation between gas permeability of Iupilon and thickness is as shown in Table 6 · 2-3.

Table 6 · 2-3 Relation between gas permeability of Iupilon and thickness

Thickness ( $\mu\text{m}$ )	Gas permeability constant*			
	H <sub>2</sub>	N <sub>2</sub>	O <sub>2</sub>	CO <sub>2</sub>
50	120.	2. 4	14. 3	72
100	109.	2. 5	14. 2	56
200	105.	2. 3	12. 2	26
300	105.	2. 4	12. 8	24
600	114.		9. 1	

\* Unit  $\text{cm}^3 \cdot \text{cm}/\text{cm}^2 \cdot \text{s} \cdot \text{cmHg} \cdot 10^{11}$ , pressure difference 1 atm, tempt. 20°C

The values of water vapor and gas permeability for other resins are shown in Table 6 · 2—4.

Table 6 · 2—4

	Rate of water vapor permeability *	Gas permeability constant **			
		H <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>	CO <sub>2</sub>
Polyethylene	4. 3	10. 07	3. 47	1. 22	12. 5
Mylar	9. 5	0. 80	0. 04	0. 008	0. 20
Polyvinyl chloride	22. 1	3. 8	0. 78	0. 28	1. 78
Nylon	43. 8	1. 0	5. 8	2. 79	0. 31
Polystyrene	45	33. 1			10. 5

\* ASTM · E96—53T, temperature 37. 8°C, water in cup, outside humidity 0%, unit g/m<sup>2</sup> · day/0. 1mm

\*\* Temperature 30°C, unit cm<sup>3</sup> · cm/cm<sup>2</sup> · s · cmHg · 10<sup>10</sup>

### 6 · 3 Chemical Resistance

Chemical resistance of Iupilon / NOVAREX at room temperature and 75°C is shown in Table 6 · 3—2.

As Iupilon / NOVAREX is a polyester, there is a limit to resistance against alkaline chemicals as they cause hydrolysis of the ester bond. As a general rule, it has a strong tendency of swelling and dissolving in aromatic hydrocarbons and chlorinated hydrocarbons.

Also, the ester bond is broken at high temperature by alcohols and phenols.

At a high temperature (60~100°C), it is degraded when left standing for a long time even in pure water, as mentioned in paragraph 4 · 6 and in view of this, the effect on chemical resistance at 75°C can not be overlooked.

As a general rule, the phenomenon of stress cracking or solvent corrosion is present in plastics, by which cracks are formed when it comes in contact with some solvent or its vapor under stress.

Precaution must be taken as this phenomenon is also present in Iupilon / NOVAREX. Solvents to which Iupilon / NOVAREX is particularly sensitive when under stress are carbon tetrachloride, hexane, acetone and alcohols, and some examples are given in Fig. 6 · 3—1.

Also, the limiting tensile strain at which stress cracking is produced by carbon tetrachloride, acetone and hexane is 0.5, 0.35 and 0.8%, respectively, while compression strain does not cause such stress cracking.

In addition, it is known that wide-range substances, for example plasticizers, grease, rubber, and various oils etc. also cause the solvent corrosion, and some examples are given in Table 6 · 3—1.

It is necessary to test the solvent corrosivity of the used substance at the time of design of practical articles.

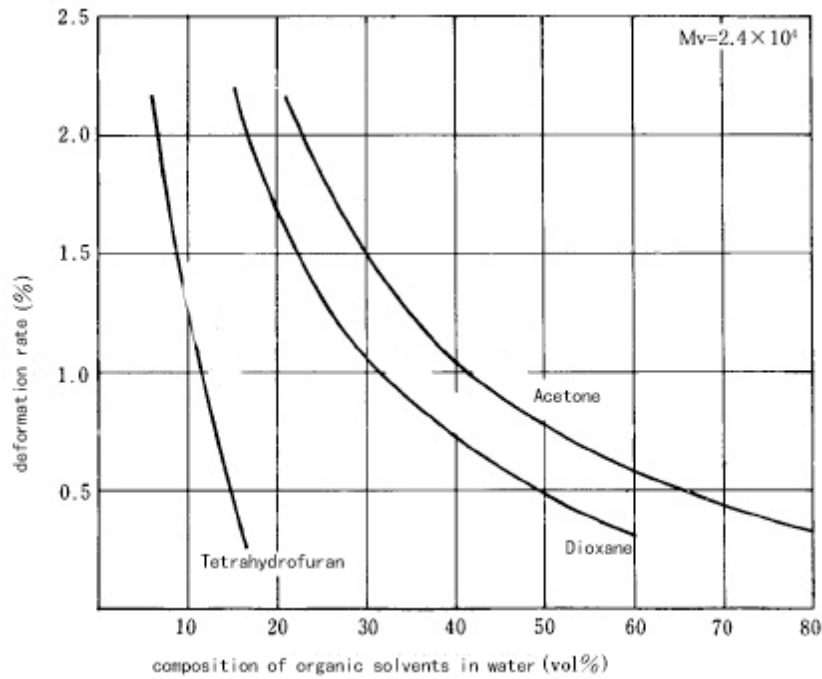


Fig. 6 · 3-1 Solvent cracking curve under stress of Iupilon / NOVAREX  
(Temp. 25°C, test piece 152 × 12. 7 × 6. 4mm)

A combination of flexural strain that does not produce crack and solvent composition was plotted for the case the product was immersed in mixed solvents of various compositions for 1 minute in a condition various flexural strains were given.

Table 6 · 3-1 Solvent corrosion of Iupilon [Unit MPa (kgf/cm<sup>2</sup>)

Substances	Solvent corrosion		Substances	Solvent corrosion	
	R. T	75°C		R. T	75°C
Flexible PVC (with 60% plasticizer)	7. 8	3. 9 (40)	Cutting oil (Komirogen)	29. 4 (300)	3. 9 (40)
Grease (Albania No. 2)	33. 3 (340)	9. 8 (100)	Cutting oil (Komirogen 30% aqueous solution)	29. 4 (300)	7. 8 (80)
Grease (Albania No. 2 low temp. use)	8. 8 (90)	15. 7 (160)	Cutting oil (Dromas oil B)	29. 4 (300)	3. 9 (40)
Grease (beacon No. 325)	33. 3 (340)	15. 7 (160)	Cutting oil (Dromas oil 60%aqueous solution)	29. 4 (300)	7. 8 (80)
Grease (silinon SH7071)	25. 5 (260)	7. 8 (80)	Salad oil	16. 7 (170)	7. 8 (80)
Natural rubber	24. 5 (250)	7. 8 (80)	Antifungal oil (PA-50)	29. 4 (300)	16. 7 (170)
Neoprene rubber (A)	8. 8 (90)	3. 9 (40)	Antifungal oil (Taiana)	19. 6 (200)	8. 8 (90)
Neoprene rubber (B)	21. 6 (220)	7. 8 (80)	Antifungal oil (CRC-36)	21. 6 (220)	3. 9 (40)
Butyl rubber			Sealant (A)		

Ethylene propylene rubber	12. 7 (130)	3. 9 (40)	Sealant (B)	29. 4 (300)	7. 8 (80)
Silicon rubber (A)	32. 4 (330)	15. 7 (160)	Epoxy cast agent	20. 6 (210)	3. 9 (40)
Silicon rubber (B)	25. 5 (260)	15. 7 (160)	Silicon cast agent		11. 8 (120)
Rock materials	3. 9 (40)	3. 9 (40)	Blank	39. 2 (400)	22. 6 (230)

Testing method: Let the substance touch the part where maximum flexural stress is generated by constant strain method, and leave it at normal temperature for 48 hours, at 75°C for 3 hours, then calculate the strain quantity that crack is not generated and convert it to stress.

Table 6 · 3—2 Chemical resistance of Iupilon / NOVAREX at room temperature and 75°C

Size of test piece : 63.5mm length, 12.7mm width, 3.2mm thickness

Strength before tes: Tensile strength 58.1MPa (592khf/cm<sup>2</sup>), Izod impact strength (with notch) 910J/m

Figures in ( ) indicate values at 75°C and all are values after immersion for 30 days.

Name of chemicals	Change in weight %	Change in tensile strength %	Impact value J/m	Change in appearance
<b>Inorganic salts</b>				
Sodium chloride 15% (15%)	+0. 14 (+0. 22)	-4. 4 (+1. 52)	890 (-)	No change Small number of cracks
Sodium sulfide 15% (15%)	+0. 13 (+0. 15)	-5. 4 (+3. 55)	930 (-)	No change Haze on surface, small number of cracks
Potassium chloride 15%	+0. 14	-3. 2	950	No change
Potassium nitrate 15% 1 (15%)	+0. 15 (+0. 21)	-3. 6 (+1. 18)	920 (-)	No change Small number of cracks
Potassium dichromate 15% (15%)	+0. 15 (+0. 31)	-2. 9 (-0. 7)	950 (-)	No change Small number of cracks
Calcium chloride 15% (15%)	+0. 14 (+0. 15)	-4. 4 (+0. 7)	930 (-)	No change Small number of cracks
Sodium sulfate 10%	(+0. 25)	(+1. 5)	(-)	Small number of cracks
<b>Inorganic acids</b>				
Hydrochloric acid 35% (15%)	+0. 13 (+0. 18)	-8. 5 (+2. 4)	56 (-)	Cracks Cracks
10% (5%)	+0. 10 (+0. 38)	-2. 7 (+1. 5)	920 (-)	No change Cracks
Sulfuric acid 98%	-	-	-	Whiten, dissolve
90%	+5. 16	-1. 9	890	Milk white
85%	-0. 17	-5. 4	910	No change
80%	-0. 30	-4. 1	920	No change
(80%)	(-0. 78)	(+1. 5)	(-)	No change
50%	-0. 13	-3. 0	860	No change
(50%)	(-0. 10)	(+3. 6)	(-)	No change
10%	-0. 13	-6. 0	880	No change'
(10%)	(+0. 19)	(+0. 8)	(-)	No change
Nitric acid 60%	+1. 41	-9. 2	920	Discolor to yellow
(60%)	(-)	(-)	(-)	Shape destroyed

Orthophosphoric acid	30%	+0. 25	-6. 6	640	Discolor to yellow
	(30%)	(+1. 06)	(-7. 9)	(-)	Opaque, yellow
	10%	+0. 14	-2. 0	910	No change
	(10%)	(+0, 33)	(0)	(-)	Transparent yellow
	100%	-0. 25	+0. 8	960	No change
	(100%)	(-0. 12)	(+3. 2)	(-)	Transparent light yellow
	10%	+0. 09	-3. 4	900	No change
	(10%)	(+0. 24)	(+2. 7)	(-)	Cracks

Name of chemicals	Change in weight %	Change in tensile strength %	Impact value J/m	Change in appearance
Chromic acid 10%	+0. 25	-3. 7	950	No chang
Hydrogen fluoride conc.	+1. 42	-9. 3	1000	No charge
Sulfuric acid 50 vol%	+5. 02	-19. 0	88	Dissolve
Nitric acid 50 vol%				
Sulfuric acid 300g	+0. 14	-4. 4	920	No change
Chromic anhydride 150g				
Water 1. 5l				
<b>Inorganic alkali</b>				
Sodium carbonate 15%	+0. 13	-3. 2	870	No change
(15%)	(-0. 79)	(+2. 0)	(-)	Cracks
Sodium hydroxide (10%)	(-2. 92)	(-1. 4)	(-)	Surface haze cracks
5%	+0. 03	-4. 4	950	No change
(5%)	(-0. 17)	(-0. 8)	(-)	Surface haze cracks
1%	+0. 05	-4. 6	990	No change
Milk of lime 10%	+0. 04	-5. 1	970	No change
(5%)	(-0. 46)	(+2. 7)	(-)	Cracks
<b>Organic acids</b>				
Acetic acid 100%	+3. 25	-7. 3	660	Turbid
70%	+0. 15	-2. 0	990	No change
(70%)	(+0. 86)	(-40. 5)	(-)	Turbid
50%	+0. 14	-4. 7	970	No change
(50%)	(+0. 64)	(-33. 5)	(-)	Turbid
10%	+0. 21	-4. 1	950	No change
(10%)	(+0. 48)	(-44. 1)	(-)	Cracks
Formic acid 97%	+1. 92	-12. 7	970	No change
70%	+0. 68	-6. 4	920	No change
(70%)	(+1. 91)	(-77. 5)	(-)	Cracks
(40%)	(+0. 86)	(-75. 7)	(-)	Cracks
10%	+0. 28	-4. 7	950	No change
Maleic acid 10%	+0. 07	-4. 1	920	No change
Benzoic acid 10%	+0. 21	-6. 6	990	No change
Lactic acid 10%	+0. 09	-1. 4	930	No change
(10%)	(+0. 23)	(+4. 9)	(-)	Cracks
1%	+0. 15	-4. 4	920	No change
Oxalic acid (30%)	(+0. 25)	(+2. 7)	(-)	Cracks
10%	+0. 12	-4. 1	940	No change



Picric acid	2%	+0. 13	-6. 7	960	No change
Petroleum components					
n-Hexane		+0. 07	-5. 4	930	No change
Solvent naphtha					Turbid, swells
Cyclohexane		+0. 07	-4. 4	920	No change
		(-)	(-)	(-)	Dissolve completely

Name of chemicals	Change in weight %	Change in tensile strength %	Impact value J/m	Change in appearance
Petroleum ether	+0. 003	-2. 4	950	No change
Kerosine	+0. 08	-4. 4	930	No change
Ligroin	(-0. 07)	(+0. 2)	(-)	Cracks
(B. P. above 80°C)	+0. 15	-7. 1	970	No change
	(+0. 49)	(-0. 3)	(-)	No change
Benzene	-	-	-	Swell, dissolve
Toluene	-	-	-	Swell, dissolve
Spindle oil	+0. 003	-5. 2	930	No change
Dynamo oil	+0. 003	-5. 9	940	No change
Turbine oil	(-0. 05)	(+2. 0)	(-)	No change
	+0. 003	-4. 7	950	No change
Machine oil	+0. 03	-0. 9	940	No change
Refrigerator oil	(+0. 02)	(+0. 7)	(-)	No change
	+0. 018	+0. 8	970	No change
Marine engine oil	+0. 017	-4. 1	940	No change
Cylinder oil	+0. 007	-2. 9	960	No change
Heavy oil	(+0. 01)	(+0. 7)	(-)	No change
	+0. 07	-1. 7	940	No change
Gasoline (low aromatics)	+0. 009	-1. 9	920	No change
Insulating oil	(-0. 02)	(+1. 9)	(-)	No change
Vegetable oils				
Soy bean oil	+0. 08	-5. 2	930	No change
Peanut oil	+0. 07	-5. 9	930	No change
	(-0. 13)	(+2. 5)	(-)	No change
Caster oil	+0. 08	-4. 4	940	No change
Organic solvents				
Methanol	+1. 47	-21. 5	1000	Cracks on surface
Ethanol	100%	+0. 50	960	No change
	(100%)	(+3. 41)	(-)	Turbid
	(50%)	(+1. 18)	(-)	Cracks
Isopropyl alcohol		(+1. 39)	(-)	No change
n-Butyl alcohol		+0. 12	930	No change
		(+1. 86)	(-)	Whitens to translucent
n-Amyl alcohol		(+2. 69)	(-)	Whitens to translucent
n-Octyl alcohol		(+0. 12)	(-)	No change
Ethylene glycol		-0. 06	910	No change
		(+0. 04)	(-)	No change

Glycerine		-0.07 (+0.06)	-6.9 (+0.5)	960 (-)	No change No change
Ethyl ether		+15.4	-55.7	1000	Milky white
Acetone		-	-	-	Turbid, crumbles
Name of chemicals		Change in weight %	Change in tensile strength %	Impact value J/m	Change in appearance
Methyl ethylketone					Turbid, crumbles
Ethyl acetate					Turbid, swells
Carbon tetrachloride		+7.9	-9.6	960	Turbid
Carbon disulfide		+2.0	-5.4	930	Turbid
Triethanol amine		-0.21	-3.6	910	Cracks on surface
Terpene oil		-0.02 (+1.69)	-3.7 (+2.0)	(-)	No change Translucent turbid
Camphor oil		-0.01 (+1.53)	-4.3 (+0.2)	960 (-)	No change Translucent turbid
Others					
Toilet soap	3%	+0.07	-5.2	960	No change
Neutral soap	3%	+0.07 (+0.25)	-4.9 (+2.7)	960 (-)	No change Cracks
Bleaching powder	2.5%	+0.05	-5.4	970	No change
Hydrogen peroxide	70%	+0.34	-3.9	820	Light yellow, translucent
	30%	+0.15	-0.7	880	Light yellow
Formalin	30%	+0.17 (+0.83)	-4.2 (+4.9)	910 (-)	No change Cracks
Black tea		(+0.27)	(+2.0)	(-)	Cracks
Chlorine		+1.5	-0.2	910	Discolor to yellow