chemical resistance

of polyethylene resins

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CHEMICAL RESISTANCE

While polyethylene resins have generally been found to be resistant to physical and chemical attack, and permeation to most liquids, some aromatic, cyclic and higher aliphatic hydrocarbon solvents are highly mobile through polyethylene resins. It is for this reason that polyethylene is not recommended for packaging these chemicals. The permeation rate will tend to decrease with an increase in resin density and part wall thickness.

Chemical environmental effects on polyethylene can be divided into three categories: stress-cracking, plasticization and oxidation. Of these three groups, only oxidation is a chemical reaction. The other two are physical reactions.

Permeability

In packaging, the rate of permeation is an important parameter. With the increase in density of the polymer and thickness of the formed part, the permeation rate will tend to decrease (Table I). However, various liquid hydrocarbons permeate quite readily even through denser resins and thicker formed parts, and are not recommended for storage in polyethylene containers (Table III).

Chemical resistance

Polyethylene resins have generally been found to exhibit chemical resistance and inertness. In general, polyolefins have also been found to be fairly inert to inorganic chemicals and insoluble in most organic solvents at room temperatures. Chlorinated hydrocarbons, however, will dissolve or soften (plasticize) the resins below 100°C. Polar solvents, such as water, alcohols, acids, esters and ketones, have generally been found to have little or no effect. Exceptions are indicated in Tables II, III and IV.

Stress-cracking agents

Certain surface-active materials (surfactants) can accelerate the cracking of polyethylene when it is under stress, although they appear to have no chemical effect on the resin. This accelerated form of stress failure is called environmental stress-cracking or ESC. Although all polyethylene resins are subject to stress-cracking, some grades are more resistant to it than others. A resin's resistance to stress-cracking is termed its environmental stress crack resistance or ESCR.

An ESC failure is also dependent on the amount of stress imposed on the polyethylene. Therefore, the design of the plastic part is a very important factor for long-term serviceability. With proper mold and part design to minimize molded-in stresses and the selection of a resin grade most suitable for the intended application, even severe stress cracking agents may be packaged.

Plasticizers

Certain types of chemicals are absorbed to varying degrees in polyethylene. This results in swelling, weight gain, softening and some loss of yield strength. Yet they appear to cause no actual chemical degradation of the resin. Some chemicals, such as benzene or other aromatic hydrocarbons, have a strong plasticizing effect. Some plasticizers are volatile enough that when removed from contact with the polyethylene part, the part will dry out and return to its original condition with no impairment of physical properties.

Oxidizers

Oxidizers are the only group of chemicals known to be capable of chemically degrading polyethylene. While the chemical effects that even strong oxidizers have on polyethylene may be gradual and may not be measurable over the short-term, if long-term exposure to these chemicals is expected, the degradation effects can become significant. The following chemicals are examples of strong oxidizers that are unsuitable for long-term exposure to polyethylene resins:

- Fuming nitric acid
- Fuming sulphuric acid
- Aqua regia
- Wet chlorine gas
- Liquid bromine

The information supplied above is of a general nature and should not be considered as a definitive source. The suitability of polyethylene resin for any packaging application depends on a number of variables. These include, but are not limited to, the nature and concentration of the material to be packaged, the expected service temperature and stress, the duration of exposure, whether it is intermittent or continuous, and environmental conditions such as outdoor storage.

Because all these variables play important roles, it must be recognized that standard laboratory tests can only serve as a guide to the packaging of chemicals in polyethylene. The suitability of any packaging system must be determined by extensive testing carried out under conditions which closely approximate those expected in service.

Testing

The actual behaviour of formed articles manufactured from polyethylene resins will only exhibit itself under certain conditions of use, exposure, and the type and concentration of the substance to which it will be exposed. The American Society of Testing and Materials (ASTM) has adopted a standard test method for ESCR of ethylene resins (ASTM test method D1693-70). Standardization for ESCR is a prerequisite. The preparation of the compression molded test specimen for the above procedure is conducted in accordance with ASTM method D1928, procedure "C". The test results from the compression molded specimen may not necessarily reflect the properties of articles fabricated by extrusion, injection, roto and blow molding. It is therefore recommended to repeat the exposure and conditions of actual use on the final packaging containers.

TABLE I - Molecular Parameters

Property	Density	Molecular weight	Molecular weight dist.
Chemical resistance	↑	↑	-
Permeability	↓	↓	-
ESCR	↓	↑	-
Tensile strength	↑	↑	-
Stiffness	↑	↑	↓
Toughness	↓	↑	↓
Melt strength	-	↑	↑

Guide to Tables II, III, IV

LDPE	Low density, 0.910 to 0.925 g/cm³	HDPE	High density, 0.941 to 0.965 g/cm³	P	Plasticizing, solvating substances
MDPE	Medium density, 0.926 to 0.940 g/cm³	I	Appears to be inert, no known effects	S	Stress-cracking substance
		N	Not recommended	X	Suspect stress-cracking substance
		O	Oxidizing substances	V	Variable resistance, conditions dependent

TABLE II - Foodstuff and miscellaneous

		LDPE		MDPE		HDPE	
		23° C	60° C	23° C	60° C	23° C	60° C
S	Acetic acid (10%)	I	I	I	I	I	I
	Ascorbic acid (10%)	I	I	I	I	I	I
	Beer	I	I	I	I	I	I
X	Butter	I	I	I	I	I	I
XP	Camphor oil	N	N	N	N	V	-
S	Cider	I	I	I	I	I	I
	Coffee	I	I	I	I	I	I
S	Cola concentrates	I	I	I	I	I	I
X	Corn oil	I	I	I	I	I	I
S	Cottonseed oil	I	I	I	I	I	I
	Dextrin (sat'd)	I	I	I	I	I	I
	Dextrose (sat'd)	I	I	I	I	I	I
S	Ethyl alcohol	I	I	I	I	I	I
S	Fish solubles	I	I	I	I	I	I
	Fructose (sat'd)	I	I	I	I	I	I
X	Fruit pulp	I	I	I	I	I	I
	Glucose	I	I	I	I	I	I
	Grape sugar (sat. aq.)	I	I	I	I	I	I
	Milk	I	I	I	I	I	I
	Molasses	I	I	I	I	I	I
S	Shortening	I	I	I	I	I	I
S	Soap solution (any conc)	I	I	I	I	I	I
S	Starch solution	I	I	I	I	I	I
P	Tallow	I	V	I	V	I	-
S	Vanilla extract	I	I	I	I	I	I
	Vinegar	I	I	I	I	I	I
S	Whisky	I	I	I	I	I	-
X	Wines	I	I	I	I	I	I
	Yeast	I	I	I	I	I	I

TABLE III – Organic Substances

		LDPE		MDPE		HDPE	
		23° C	60° C	23° C	60° C	23° C	60° C
S	Acetaldehyde (100%)	V	N	V	N	V	N
S	Acetic acid (60%)	I	V	I	V	I	V
X	Acetic Anhydride	N	N	N	N	N	N
XP	Amyl acetate (100%)	I	I	I	I	I	I
SP	Amyl alcohol (100%)	N	N	N	N	N	N
P	Amyl chloride (100%)	N	N	N	N	V	-
SP	Aniline (100%)	I	N	N	N	N	V
XP	Aromatic hydrocarbons	N	N	N	N	N	N
XP	Benzene	N	N	N	N	N	N
	Benzoic acid (all conc)	I	I	I	I	I	I
S	Butanediol (10%)	I	I	I	I	I	I
S	Butanediol (60%)	I	I	I	I	I	I
S	Butanediol (100%)	I	I	I	I	I	I
XP	n-Butyl acetate (100%)	V	N	V	V	I	V
S	n-Butyl alcohol (100%)	I	I	I	I	I	I
P	Butyric acid (conc)	N	N	N	N	N	N
S	Castor oil (conc)	I	I	I	I	I	I
XP	Chlorobenzene	N	N	N	N	N	N

Guide to Tables II, III, IV

LDPE	Low density, 0.910 to 0.925 g/cm³	HDPE	High density, 0.941 to 0.965 g/cm³	P	Plasticizing, solvating substances
MDPE	Medium density, 0.926 to 0.940 g/cm³	I	Appears to be inert, no known effects	S	Stress-cracking substance
		N	Not recommended	X	Suspect stress-cracking substance
		O	Oxidizing substances	V	Variable resistance, conditions dependent

TABLE III – Organic Substances continued...

		LDPE		MDPE		HDPE	
		23° C	60° C	23° C	60° C	23° C	60° C
S	Acetaldehyde (100%)	V	N	V	N	V	N
S	Acetic acid (60%)	I	V	I	V	I	V
X	Acetic Anhydride	N	N	N	N	N	N
XP	Amyl acetate (100%)	I	I	I	I	I	I
SP	Amyl alcohol (100%)	N	N	N	N	N	N
P	Amyl chloride (100%)	N	N	N	N	V	-
SP	Aniline (100%)	I	N	N	N	N	V
XP	Aromatic hydrocarbons	N	N	N	N	N	N
XP	Benzene	N	N	N	N	N	N
	Benzoic acid (all conc)	I	I	I	I	I	I
S	Butanediol (10%)	I	I	I	I	I	I
S	Butanediol (60%)	I	I	I	I	I	I
S	Butanediol (100%)	I	I	I	I	I	I
XP	n-Butyl acetate (100%)	V	N	V	V	I	V
S	n-Butyl alcohol (100%)	I	I	I	I	I	I
P	Butyric acid (conc)	N	N	N	N	N	N
S	Castor oil (conc)	I	I	I	I	I	I
XP	Chlorobenzene	N	N	N	N	N	N
XP	Chloroform	N	N	V	N	V	N
	Chlorosulphonic acid (100%)	N	N	N	N	N	N
S	Citric acid (sat'd)	I	I	I	I	I	I
S	Coconut oil alcohols	I	I	I	I	I	I
S	Detergents, synthetic	I	I	I	I	I	I
X	Dibutylphthalate	V	V	V	V	V	V
XP	Dichlorobenzene (o & p)	N	N	N	N	N	N
XP	Diethyl ketone	V	N	V	V	V	V
S	Diethylene glycol	I	I	I	I	I	I
S	Diglycolic acid	I	I	I	I	I	-
	Dimethylamine	N	N	N	N	N	N
XP	Ethyl acetate (100%)	V	N	V	N	V	-
S	Ethyl alcohol (100%)	I	I	I	I	I	I
XP	Ethyl benzene	N	N	N	N	N	N
P	Ethyl chloride	N	N	N	N	N	N
P	Ethyl ether	N	N	N	N	N	N
XP	Ethylene chloride	N	N	N	N	N	N
S	Ethylene glycol	I	I	I	I	I	I
	Formic acid (all conc)	I	I	I	I	I	I
P	Furfural (100%)	N	N	N	N	V	-
XP	Furfuryl alcohol	N	N	N	N	V	-
S	Gallic acid (sat'd)	I	I	I	I	I	I
XP	Gasoline	N	N	V	N	V	V
S	Glycerine	I	I	I	I	I	I
S	Glycol	I	I	I	I	I	I
S	Glycolic acid (30%)	I	I	I	I	I	I
XP	n-Heptane	N	N	N	N	V	V
	Hexachlorobenzene	I	I	-	-	I	-
S	Hexanol, tertiary	I	I	I	I	I	I
	Hydroquinone	I	I	I	I	I	I
S	Inks	I	I	I	I	I	I
S	Methyl alcohol (100%)	I	I	I	I	I	I
XP	Methylene chloride (100%)	N	N	N	N	V	N
P	Mineral oils	V	N	V	N	I	V
PS	Naphtha	V	N	V	N	V	N

Guide to Tables II, III, IV

LDPE	Low density, 0.910 to 0.925 g/cm³	HDPE	High density, 0.941 to 0.965 g/cm³	P	Plasticizing, solvating substances
MDPE	Medium density, 0.926 to 0.940 g/cm³	I	Appears to be inert, no known effects	S	Stress-cracking substance
		N	Not recommended	X	Suspect stress-cracking substance
		O	Oxidizing substances	V	Variable resistance, conditions dependent

TABLE III – Organic Substances continued...

		LDPE		MDPE		HDPE	
		23° C	60° C	23° C	60° C	23° C	60° C
S	n-propyl alcohol	I	I	I	I	I	I
XP	Propylene dichloride (100%)	N	N	N	N	N	-
S	Propylene glycol	I	I	I	I	I	I
X	Pyridine	I	-	I	-	I	-
	Resorcinol (sat'd)	I	I	I	I	I	I
	Salicylic acid (sat'd)	I	I	I	I	I	I
	Sodium acetate (sat'd)	I	I	I	I	I	I
S	Stearic acid (100%)	I	I	I	I	I	-
S	Tannic acid (sat'd)	I	I	I	I	I	I
XP	Tetrahydrofuran	N	N	N	N	V	N
XP	Toluene	N	N	N	N	V	V
XP	Trichloroethylene	N	N	N	N	N	N
X	Triethylene glycol	I	I	I	I	I	I
P	Turpentine	N	N	N	N	V	V
	Urea (0-30%)	I	I	I	I	I	I
S	Wetting agents	I	I	I	I	I	I
P	Xylene	N	N	N	N	V	V

TABLE IV – Inorganic Substances

		LDPE		MDPE		HDPE	
		23° C	60° C	23° C	60° C	23° C	60° C
	Air	I	I	I	I	I	I
	Aluminum chloride (all conc)	I	I	I	I	I	I
	Aluminum fluoride (all conc)	I	I	I	I	I	I
	Aluminum sulfate (all conc)	I	I	I	I	I	I
	Alums (all types)	I	I	I	I	I	I
	Ammonia (100% dry gas)	I	I	I	I	I	I
	Ammonium carbonate	I	I	I	I	I	I
	Ammonium chloride (sat'd)	I	I	I	I	I	I
	Ammonium fluoride (sat'd)	I	I	I	I	I	I
	Ammonium hydroxide (10%)	I	I	I	I	I	I
	Ammonium hydroxide (28%)	I	I	I	I	I	I
	Ammonium nitrate (sat'd)	I	I	I	I	I	I
	Ammonium persulphate (sat'd)	I	I	I	I	I	I
	Ammonium sulphate (sat'd)	I	I	I	I	I	I
O	Aqua regia	N	N	N	N	N	N
	Arsenic acid (all conc)	I	I	I	I	I	I
	Barium carbonate (sat'd)	I	I	I	I	I	I
	Barium chloride (sat'd)	I	I	I	I	I	I
	Barium hydroxide	I	I	I	I	I	I
	Barium sulphate (sat'd)	I	I	I	I	I	I
	Barium sulphide (sat'd)	I	I	I	I	I	I
	Bismuth carbonate (sat'd)	I	I	I	I	I	I
	Bleach lye (10%)	I	I	I	I	I	I
	Borax (sat'd)	I	I	I	I	I	I
	Boric acid (all conc.)	I	I	I	I	I	I
	Boron trifluoride	I	I	I	I	I	I
	Brine	I	I	I	I	I	I
O	Bromine (liquid)	N	N	N	N	N	N
	Calcium bisulphide	I	I	I	I	I	I

Guide to Tables II, III, IV

LDPE	Low density, 0.910 to 0.925 g/cm³	HDPE	High density, 0.941 to 0.965 g/cm³	P	Plasticizing, solvating substances
MDPE	Medium density, 0.926 to 0.940 g/cm³	I	Appears to be inert, no known effects	S	Stress-cracking substance
		N	Not recommended	X	Suspect stress-cracking substance
		O	Oxidizing substances	V	Variable resistance, conditions dependent

TABLE IV – Inorganic Substances continued...

		LDPE		MDPE		HDPE	
		23° C	60° C	23° C	60° C	23° C	60° C
	Calcium oxide (saturated)	I	I	I	I	I	I
	Calcium sulphate	I	I	I	I	I	I
	Carbon dioxide (all conc)	I	I	I	I	I	I
	Carbon disulphide						
	Carbon monoxide	N	N	N	N	N	N
P	Carbon tetrachloride	I	I	I	I	I	I
	Carbonic acid	N	N	N	N	V	N
O	Chlorine (100% dry gas)	I	I	I	I	I	I
O	Chlorine liquid	V	N	V	N	-	-
	Chlorine water (2% sat'd sol'n)	N	N	N	N	N	N
	Copper chloride (sat'd)	I	I	I	I	I	I
	Copper cyanide (sat'd)	I	I	I	I	I	I
	Copper fluoride (2%)	I	I	I	I	I	I
	Copper nitrate (sat'd)	I	I	I	I	I	I
	Copper sulphate (sat'd)	I	I	I	I	I	I
	Developers, photographic	I	I	I	I	I	I
	Diazo salts	I	I	I	I	I	I
	Disodium phosphate	I	I	I	I	I	I
S	Emulsions, photographic	I	I	I	I	I	I
	Ferric chloride (sat'd)	I	I	I	I	I	I
	Ferric nitrate (sat'd)	I	I	I	I	I	I
	Ferrous chloride (sat'd)	I	I	I	I	I	I
	Ferrous sulphate	I	I	I	I	I	I
	Fluoboric acid	I	I	I	I	I	V
	Fluosilicic acid (conc)	I	V	I	V	I	-
	Fluosilicic acid (32%)	I	I	I	I	I	I
	Hydrobromic acid (50%)	I	I	I	I	I	I
	Hydrochloric acid (all conc)	I	I	I	I	I	I
	Hydrocyanic acid (sat'd)	I	I	I	I	I	I
	Hydrofluoric acid (40%)	I	I	I	I	I	I
	Hydrofluoric acid (60%)	I	I	I	I	I	I
	Hydrogen (100%)	I	I	I	I	I	I
	Hydrogen chloride (dry gas)	I	I	I	I	I	I
	Hydrogen sulphide	I	I	I	I	I	I
	Hypochlorous acid (conc)	I	I	I	I	I	I
O	Iodine (in KI sol'n)	V	N	V	N	V	-
	Lead acetate (sat'd)	I	I	I	I	I	I
	Lead nitrate	I	I	I	I	I	I
	Magnesium carbonate (sat'd)	I	I	I	I	I	I
	Magnesium chloride (sat'd)	I	I	I	I	I	I
	Magnesium hydroxide (sat'd)	I	I	I	I	I	I
	Magnesium nitrate (sat'd)	I	I	I	I	I	I
	Magnesium sulphate (sat'd)	I	I	I	I	I	I
	Mercury	I	I	I	I	I	I
	Nickel chloride (conc)	I	I	I	I	I	I
	Nickel nitrate (sat'd)	I	I	I	I	I	I
	Nickel sulphate (conc)	I	I	I	I	I	I

Guide to Tables II, III, IV

LDPE	Low density, 0.910 to 0.925 g/cm³	HDPE	High density, 0.941 to 0.965 g/cm³	P	Plasticizing, solvating substances
MDPE	Medium density, 0.926 to 0.940 g/cm³	I	Appears to be inert, no known effects	S	Stress-cracking substance
		N	Not recommended	X	Suspect stress-cracking substance
		O	Oxidizing substances	V	Variable resistance, conditions dependent

TABLE IV – Inorganic Substances continued...

		LDPE		MDPE		HDPE	
		23° C	60° C	23° C	60° C	23° C	60° C
O	Nitric acid (70%)	I	V	I	V	I	V
O	Nitric acid (95-98%)	N	N	N	N	N	N
	Photographic solutions	I	I	I	I	I	I
	Plating solutions for:						
S	Brass	I	I	I	I	I	I
S	Cadmium	I	I	I	I	I	I
S	Copper	I	I	I	I	I	I
S	Gold	I	I	I	I	I	I
S	Lead	I	I	I	I	I	I
S	Nickel	I	I	I	I	I	I
S	Silver	I	I	I	I	I	I
S	Tin	I	I	I	I	I	I
S	Zinc	I	I	I	I	I	I
	Potassium bicarbonate (sat'd)	I	I	I	I	I	I
	Potassium bromide (sat'd)	I	I	I	I	I	I
	Potassium carbonate	I	I	I	I	I	I
	Potassium chlorate (sat'd)	I	I	I	I	I	I
	Potassium chloride (sat'd)	I	I	I	I	I	I
	Potassium chromate (40%)	I	I	I	I	I	I
	Potassium cyanide (sat'd)	I	I	I	I	I	I
	Potassium dichromate (40%)	I	I	I	I	I	I
	Potassium ferri/ferro cyanide (sat'd)	I	I	I	I	I	I
	Potassium fluoride	I	I	I	I	I	I
	Potassium hydroxide (conc)	I	I	I	I	I	I
	Potassium nitrate (sat'd)	I	I	I	I	I	I
	Potassium perchlorate (10%)	I	I	I	I	I	I
	Potassium permanganate (20%)	I	I	I	I	I	I
	Potassium persulphate (sat'd)	I	I	I	I	I	I
	Potassium sulphate (conc)	I	I	I	I	I	I
	Potassium sulphide(conc)	I	I	I	I	I	I
	Potassium sulphite (conc)	I	I	I	I	I	I
	Sea water	I	I	I	I	I	I
	Selenic acid	I	I	I	I	I	I
	Silver nitrate solution	I	I	I	I	I	I
	Sodium benzoate (35%)	I	I	I	I	I	I
	Sodium bicarbonate (sat'd)	I	I	I	I	I	I
	Sodium bisulphate (sat'd)	I	I	I	I	I	I
	Sodium bisulphite (sat'd)	I	I	I	I	I	I
	Sodium borate	I	I	I	I	I	I
	Sodium bromide (dilute)	I	I	I	I	I	I
	Sodium carbonate (conc)	I	I	I	I	I	I
	Sodium chlorate (sat'd)	I	I	I	I	I	I
	Sodium chloride (sat'd)	I	I	I	I	I	I
	Sodium cyanide	I	I	I	I	I	I
	Sodium dichromate (sat'd)	I	I	I	I	I	I
	Sodium ferri/ferro cyanide (sat'd)	I	I	I	I	I	I
	Sodium fluoride (sat'd)	I	I	I	I	I	I
	Sodium hydroxide (conc)	I	I	I	I	I	I
	Sodium hypochlorite	I	I	I	I	I	I
	Sodium nitrate	I	I	I	I	I	I

Guide to Tables II, III, IV

LDPE	Low density, 0.910 to 0.925 g/cm³	HDPE	High density, 0.941 to 0.965 g/cm³	P	Plasticizing, solvating substances
MDPE	Medium density, 0.926 to 0.940 g/cm³	I	Appears to be inert, no known effects	S	Stress-cracking substance
		N	Not recommended	X	Suspect stress-cracking substance
		O	Oxidizing substances	V	Variable resistance, conditions dependent

TABLE IV – Inorganic Substances continued...

		LDPE		MDPE		HDPE	
		23° C	60° C	23° C	60° C	23° C	60° C
	Sodium chloride (sat'd)	I	I	I	I	I	I
	Sodium cyanide	I	I	I	I	I	I
	Sodium dichromate (sat'd)	I	I	I	I	I	I
	Sodium ferri/ferro cyanide (sat'd)	I	I	I	I	I	I
	Sodium fluoride (sat'd)	I	I	I	I	I	I
	Sodium hydroxide (conc)	I	I	I	I	I	I
	Sodium hypochlorite	I	I	I	I	I	I
	Sodium nitrate	I	I	I	I	I	I
	Sodium sulphate	I	I	I	I	I	I
	Sodium sulphide (sat'd)	I	I	I	I	I	I
	Sodium sulphite (sat'd)	I	I	I	I	I	I
	Stannous chloride (sat'd)	I	I	I	I	I	I
	Sulphuric acid (1-50%)	I	I	I	I	I	I
	Sulphuric acid (70%)	I	V	I	V	I	V
	Sulphuric acid (80%)	I	N	I	N	I	N
	Sulphuric acid (96%)	V	N	V	N	V	N
	Sulphuric acid (98% - conc)	V	N	V	N	V	N
	Sulphuric acid (fuming)	N	N	N	N	N	N
	Sulphurous acid	I	I	I	I	I	I
X	Titanium tetrachloride (sat'd)	N	N	N	N	N	-
	Trisodium phosphate (sat'd)	I	I	I	I	-	-
	Water	I	I	I	I	I	I
	Zinc bromide (sat'd)	I	I	I	I	I	I
	Zinc carbonate (sat'd)	I	I	I	I	I	I
	Zinc chloride (sat'd)	I	I	I	I	I	I
	Zinc oxide (sat'd)	I	I	I	I	I	I
	Zinc stearate	I	I	I	I	I	I
	Zinc sulphate (sat'd)	I	I	I	I	I	I

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