Plastics Data File – PMMA (Acrylic)

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1. Introduction

PMMA is one of the earliest polymers and is well known around the world by a variety of trade names Lucite, Oroglas, Perspex and Plexiglas which vary with the country you are in. The original PMMA was seen as a replacement for glass in a variety of applications and is currently used extensively in glazing applications. The material is one of the hardest polymers, rigid, glass-clear with glossy finish and good weather resistance.

A proposed application as automotive windshields was not possible due to the low scratch resistance of the PMMA relative to glass. Despite this PMMA was used extensively as aircraft windows for many aircraft.

My own first involvement with PMMA was in the now famous ‘frozen chicken’ testing: this testing was carried out to investigate the effects of ‘bird strike’ on aircraft windshields (hitting a bird at 600 mph is dangerous to both bird and aircraft). The tests involved defrosted ‘frozen chickens’, a linear accelerator and large sheets of Perspex. You can imagine the rest. We moved on to bullets, small arms, a 40 mm Bofors gun and finally slow indentation – It was worth a Ph. D. so don't laugh too much. We also learnt how to make 'flat lenses' by varying the density of PMMA and overall, what a wonderful material it is.

2. Typical applications

Optics: Dust covers for hi-fi equipment, sunglasses, watch glasses, lenses, magnifying glasses

Vehicles: Rear lights, indicators, tachometer covers, warning triangles

Electrical engineering: Lamp covers, switch parts, dials, control buttons

Office equipment: Writing and drawing instruments, pens

Medicine: Packaging for tablets, pills, capsules, suppositories, urine containers, sterilisable equipment.

Others: Leaflet dispensers, shatter-resistant glazing, shower cubicles, transparent pipelines, illuminated signs, toys.

3. Physical and mechanical properties

General physical properties

PMMA is a glassy polymer with an amorphous structure. It has a density of 1.19 g/cm^3 and has a very low water absorption. The refractive index ranges from 1.49 to 1.51 depending on the type.

Parts made of PMMA have high mechanical strength and good dimensional stability. Other properties include a high Young's modulus and good hardness with low elongation at break. PMMA does not shatter on rupture. PMMA is one of the hardest thermoplastics and is also highly scratch resistant.

Mechanical properties

Property	Approximate Value
Tensile strength	55 - 80 MN/m^2
Tensile Modulus	2-3 GN/m^2
Elongation at Break	<10 %
Flexural Strength	100 - 150 MN/m^2
Notched Impact Strength	< 3 kJ/m^2
Specific Heat	1.25 - 1.7 kJ/kg/°C

Glass Transition Temperature	100˚C
Heat Deflection Temperature	<100˚C
Coefficient of Thermal Expansion	5 - 10 x 10^{-5} /˚C
Long Term Service Temperature	<100˚C
Specific Gravity	1.0 to 1.2
Mould Shrinkage	0.001 - 0.005 m/m
Water Absorption	0.1 - 0.5 % (50% rh)
Transparency	Transparent

4. Thermal, electrical and optical properties

Thermal properties

The thermal stability of standard PMMA is only 65˚C. Heat-stabilised types can withstand temperatures of up to 100˚C. PMMA can withstand temperatures as low as -70˚C. Resistance to temperature changes is very good.

Fire behaviour

PMMA ignites very quickly. It burns with a blue glow, even outside the flame, and crackles with white spurts.

Electrical properties

PMMA has good insulating properties, a high dielectric strength and high tracking resistance. The relatively high surface resistance, however, encourages electrostatic charges on the surface of moulded parts; this can be largely overcome by the use of antistatic agents.

Optical properties

PMMA is naturally transparent and colourless. The transmission for visible light is 92%. The refractive index is 1.492 for PMMA. There are types that transmit UV rays, and types that absorb it almost completely, as a result of which sensitive dyes on painted surfaces behind are protected from fading.

Natural colour

PMMA is crystal clear and has a high surface gloss. It can be produced in all colours, transparent and muted.

5. Chemical resistance properties

General

PMMA is resistant to aliphatic hydrocarbons, cycloaliphatic compounds, fats and oils, and also to dilute acids at temperatures of up to 60˚C.

Chlorinated aliphatic hydrocarbons, ketones, alcohols, ethers, esters, aromatics, petrol, spirit, nitrocellulose varnishes and certain plasticisers cause PMMA to swell or produce stress cracks.

A detailed chemical resistance chart is given in Section 11.

The resistance to weathering of PMMA is very good.

Resistance to stress cracking

Stress cracks can be formed by cleaning agents and disinfectants. Certain organic solvents and metal salts can also cause stress cracking.

6. Advantages and limitations

Advantages	Limitations
1. Material is very hard.	1. Brittle under impact conditions and failure is by shattering.
2. Material is clear and can be coloured in any colour from opaque to translucent.	2. Difficult to mould thin-walled products because of poor flow properties.
3. Good weathering resistance.	3. Poor hot-melt strength limits processing methods.
4. Good optical properties.	4. Flow properties make processing slow compared to other materials.
5. High gloss.	5. Does not have significant elastic deformation before failure i.e., goes straight to brittle fracture.
6. Scratch resistant (but not as good as glass because it does scratch - this is why car windscreens are not made from PMMA).	

7. Processing

Injection moulding

Pre-drying is not necessary if a vented cylinder is used but if a normal cylinder is used then PMMA must be processed dry and it is advisable to pre-dry the granules for up to 8 hours at 70 to 100˚C, depending on the type. Surface defects and blisters will form if damp granules are processed.

Processing parameters: The mould temperature should be between 40 and 80˚C, depending on the type. The material temperature should be between 200 and 250˚C. As the temperature rises, molecular orientation and internal stresses decrease, but the risk of sink spots increases.

As a general rule, high injection pressures are needed because of poor flow properties and it may be necessary to inject slowly to get the correct flow. This is particularly important for optical mouldings where visible weld lines will form if the correct parameters are not used. For thick mouldings a high follow-up pressure is needed for a long time (2 to 3 minutes).

Large gates are needed because of the poor flow but hot runners are possible.

Reprocessing is possible if the material has been thoroughly dried and has an opaque colour. Optically good mouldings are not generally possible with regrind even if the regrind is glass clear.

Shrinkage is relatively low: 0.4 to 0.8% depending on the grade used. Avoid wall thicknesses of less than 1 mm.

Extrusion

Extrusion temperatures are between 180 and 250˚C. Metering type screws with a compression ratio of 3:1 are generally recommended. Relatively high molecular weight formulations are used for the extrusion of sheets and profiles. A degassing screw with an L/D ratio of 20 to 30 is best.

Process selector

Processing Method	Applicable
Injection Moulding	Yes
Extrusion	Yes
Extrusion Blow Moulding	Yes It is possible for some grades to be injection blow moulded but the poor hot-melt strength makes extrusion blow moulding difficult and injection blow moulding is generally used
Rotational Moulding	No
Thermoforming	Yes
Casting	Yes
Bending and joining	Yes

8. Finishing

Machining

In order to avoid sticking, the cutting speeds should not be too high. Tools must be sharp, and a cutting coolant should be used. When drilling, the angle of point should be 60 to 90˚. Thin sheets can be broken along a scribed line. High machining speeds can be used if there is sufficient cooling.

Surface treatment

Care should be taken to ensure that the solvents in the lacquer do not attack the PMMA too severely. Petrol or toluene-based lacquers are suitable. Warm storage is recommended before lacquering. Metallising does not cause any problems provided there are no residues of fat or release agent on the surface.

Welding

PMMA can be welded by all the plastics welding processes such as hot-blade, hot-gas, ultrasonic or spin welding.

Bonding

Solvents can cause stress cracks if internal stresses are present in the moulded part, so it is advisable to temper the part at 60 to 90˚C before bonding. Methylene chloride, polymerisation, epoxy resin, contact and impact adhesives are suitable. Adhesion with solvent-based and polymerisation adhesives is better than with contact adhesives.

9. Health and safety

PMMA is odourless and tasteless and physiologically safe.

10. Other information

Identification

Material is easily flammable and burns with a bright flame after ignition source has been removed.

Flame crackles and produces sooty fruity/sweetish smell.

11. Detailed chemical resistance

Important Note:

Whilst we try to ensure that this table is as accurate as possible, we cannot guarantee that the data contained in the tables is accurate for all blends and grades. In all cases the supplier of the material should be contacted to determine the exact chemical resistance of the material.

R = Resistant, LR = Limited Resistance, NR = Not Recommended, ND = No Data

Chemical	Resistance		
	20˚C	60˚C	100˚C
Acetaldehyde	ND	ND	ND
Acetic acid (10%)	R	R	ND
Acetic acid (glac./anh.)	ND	ND	ND
Acetic anhydride	ND	ND	ND
Aceto-acetic ester	ND	ND	ND
Acetone	ND	ND	ND
Other ketones	ND	ND	ND
Acetonitrile	ND	ND	ND
Acetylene	ND	ND	ND
Acetyl salicylic acid	ND	ND	ND
Acid fumes	ND	ND	ND
Alcohols	ND	ND	ND
Aliphatic esters	ND	ND	ND
Alkyl chlorides	ND	ND	ND
Alum	ND	ND	ND
Aluminium chloride	ND	ND	ND
Aluminium sulphate	ND	ND	ND
Ammonia, anhydrous	ND	ND	ND
Ammonia, aqueous	ND	ND	ND
Ammonium chloride	ND	ND	ND
Amyl acetate	ND	ND	ND

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Chemical	Resistance		
	20˚C	60˚C	100˚C
Aniline	ND	ND	ND
Antimony trichloride	ND	ND	ND
Aqua regia	ND	ND	ND
Aromatic solvents	ND	ND	ND
Ascorbic acid	ND	ND	ND
Beer	ND	ND	ND
Benzaldehyde	ND	ND	ND
Benzene	ND	ND	ND
Benzoic acid	ND	ND	ND
Benzoyl peroxide	ND	ND	ND
Boric acid	ND	ND	ND
Brines, saturated	ND	ND	ND
Bromide (K) solution	ND	ND	ND
Bromine	ND	ND	ND
Bromine liquid, tech.	ND	ND	ND
Bromine water, saturated aqueous	ND	ND	ND
Butyl acetate	ND	ND	ND
Calcium chloride	ND	ND	ND
Carbon disulphide	ND	ND	ND
Carbonic acid	ND	ND	ND
Carbon tetrachloride	ND	ND	ND
Caustic soda & potash	ND	ND	ND
Cellulose paint	ND	ND	ND
Chlorates of Na, K, Ba	ND	ND	ND
Chlorine, dry	ND	ND	ND
Chlorine, wet	ND	ND	ND

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	20˚C	60˚C	100˚C
Chlorides of Na, K, Ba	ND	ND	ND
Chloroacetic acid	ND	ND	ND
Chlorobenzene	ND	ND	ND
Chloroform	ND	ND	ND
Chlorosulphonic acid	ND	ND	ND
Chromic acid (80%)	ND	ND	ND
Citric acid	ND	ND	ND
Copper salts (most)	ND	ND	ND
Cresylic acids (50%)	ND	ND	ND
Cyclohexane	ND	ND	ND
Detergents, synthetic	ND	ND	ND
Emulsifiers, concentrated	ND	ND	ND
Esters	ND	ND	ND
Ether	ND	ND	ND
Fatty acids (>C6)	ND	ND	ND
Ferric chloride	ND	ND	ND
Ferrous sulphate	ND	ND	ND
Fluorinated refrigerants	ND	ND	ND
Fluorine, dry	ND	ND	ND
Flourine, wet	ND	ND	ND
Fluorosilic acid	ND	ND	ND
Formaldehyde (40%)	ND	ND	ND
Formic acid	ND	ND	ND
Fruit juices	ND	ND	ND
Gelatine	ND	ND	ND
Glycerine	ND	ND	ND

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Chemical	Resistance		
	20˚C	60˚C	100˚C
Glycols	ND	ND	ND
Glycol, ethylene	ND	ND	ND
Glycolic acid	ND	ND	ND
Hexamethylene diamine	ND	ND	ND
Hexamine	ND	ND	ND
Hydrazine	ND	ND	ND
Hydrobromic acid (50%)	ND	ND	ND
Hydrochloric acid (10%)	ND	ND	ND
Hydrochloric acid (conc.)	ND	ND	ND
Hydrocyanic acid	ND	ND	ND
Hydrofluoric acid (40%)	ND	ND	ND
Hydrofluoric acid (75%)	ND	ND	ND
Hydrogen peroxide (30%)	ND	ND	ND
Hydrogen peroxide (30 - 90%)	ND	ND	ND
Hydrogen sulphide	ND	ND	ND
Hypochlorites	ND	ND	ND
Hypochlorites (Na 12-14%)	ND	ND	ND
Iso-butyl-acetate	ND	ND	ND
Lactic acid (90%)	ND	ND	ND
Lead acetate	ND	ND	ND
Lead perchlorate	ND	ND	ND
Lime (CaO)	ND	ND	ND
Maleic acid	ND	ND	ND
Manganate, potassium (K)	ND	ND	ND
Meat juices	ND	ND	ND
Mercuric chloride	ND	ND	ND

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Chemical	Resistance		
	20˚C	60˚C	100˚C
Mercury	ND	ND	ND
Methanol	ND	ND	ND
Methylene chloride	ND	ND	ND
Milk products	ND	ND	ND
Moist air	ND	ND	ND
Molasses	ND	ND	ND
Monoethanolamine	ND	ND	ND
Naptha	ND	ND	ND
Napthalene	ND	ND	ND
Nickel salts	ND	ND	ND
Nitrates of Na, K and NH3	ND	ND	ND
Nitric acid (<25%)	ND	ND	ND
Nitric acid (50%)	ND	ND	ND
Nitric acid (90%)	ND	ND	ND
Nitric acid (fuming)	ND	ND	ND
Nitrite (Na)	ND	ND	ND
Nitrobenzene	ND	ND	ND
Oils, diesel	ND	ND	ND
Oils, essential	ND	ND	ND
Oils, lubricating + aromatic additives	ND	ND	ND
Oils, mineral	ND	ND	ND
Oils, vegetable and animal	ND	ND	ND
Oxalic acid	ND	ND	ND
Ozone	ND	ND	ND
Paraffin wax	ND	ND	ND
Perchloric acid	ND	ND	ND

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	20˚C	60˚C	100˚C
Petroleum spirits	ND	ND	ND
Phenol	ND	ND	ND
Phosphoric acid (20%)	R	R	ND
Phosphoric acid (50%)	R	R	ND
Phosphoric acid (95%)	ND	ND	ND
Phosphorous chlorides	ND	ND	ND
Phosphorous pentoxide	ND	ND	ND
Phthalic acid	ND	ND	ND
Picric acid	ND	ND	ND
Pyridine	ND	ND	ND
Salicyl aldehyde	ND	ND	ND
Sea water	ND	ND	ND
Silicic acid	ND	ND	ND
Silicone fluids	ND	ND	ND
Silver nitrate	ND	ND	ND
Sodium carbonate	ND	ND	ND
Sodium peroxide	ND	ND	ND
Sodium silicate	ND	ND	ND
Sodium sulphide	ND	ND	ND
Stannic chloride	ND	ND	ND
Starch	ND	ND	ND
Sugar, syrups & jams	ND	ND	ND
Sulphamic acid	ND	ND	ND
Sulphates (Na, K, Mg, Ca)	ND	ND	ND
Sulphites	ND	ND	ND
Sulphonic acids	ND	ND	ND

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	20˚C	60˚C	100˚C
Sulphur	ND	ND	ND
Sulphur dioxide, dry	ND	ND	ND
Sulphur dioxide, wet	ND	ND	ND
Sulphur dioxide (96%)	ND	ND	ND
Sulphur trioxide	ND	ND	ND
Sulphuric acid (<50%)	ND	ND	ND
Sulphuric acid (70%)	ND	ND	ND
Sulphuric acid (95%)	ND	ND	ND
Sulphuric acid, fuming	ND	ND	ND
Sulphur chlorides	ND	ND	ND
Tallow	ND	ND	ND
Tannic acid (10%)	ND	ND	ND
Tartaric acid	ND	ND	ND
Trichlorethylene	ND	ND	ND
Urea (30%)	ND	ND	ND
Vinegar	ND	ND	ND
Water, distilled.	ND	ND	ND
Water, soft	ND	ND	ND
Water, hard	ND	ND	ND
Wetting agents (<5%)	ND	ND	ND
Yeast	ND	ND	ND
Zinc chloride	ND	ND	ND