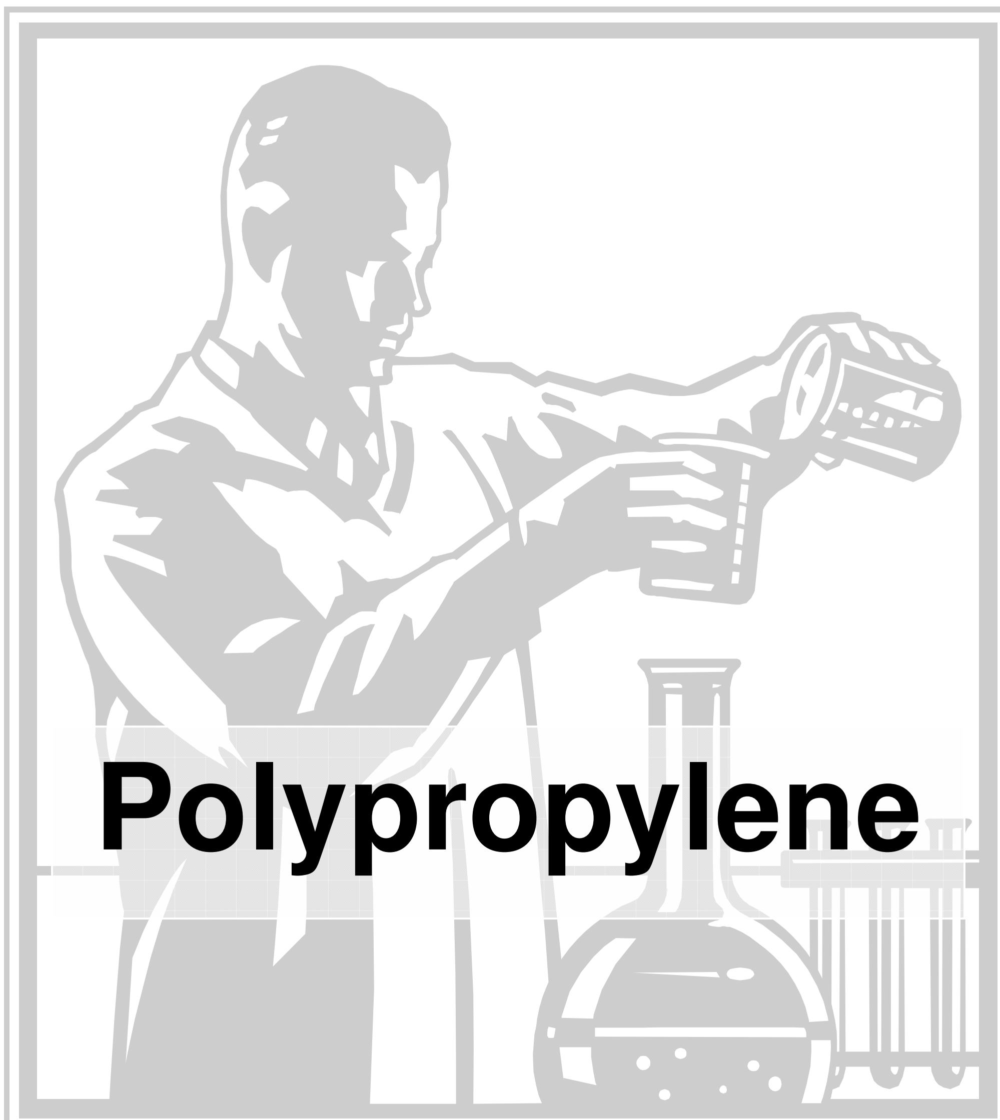
Flexible Geomembrane Tech-Facts



Polypropylene

POLYPROPYLENE GEOMEMBRANES

An extremely tough sheet and containment security from thermally welded seams

Product Information

For over two decades there has been a specialising in the development and manufacture of high performance, unsupported and scrim reinforced geomembranes for critical containment applications. With hundreds of millions of square feet installed world wide, floating covers, liners and caps are helping to safeguard valuable natural resources the world over.

Why Polypropylene?

This membrane is based on cataloy process polypropylene, a highly flexible form of the same base material found in today's car bumpers and side mouldings. Specified for its outstanding toughness, the polymer is manufactured so it can be calendered in flexible sheets. Its toughness makes it an ideal base polymer for use in rugged geomembrane applications. In addition to its toughness, polypropylene has many other important characteristics that make it ideally suitable for critical containment applications.

- UV resistance for outstanding weatherability in exposed applications.
- No plasticisers to leach out and cause embrittlement or cracking.
- Low coefficient of thermal expansion and contraction provides excellent dimensional stability and lay-flat characteristics.
- Does not environmental stress crack (ASTM D1693)
- Highly flexible for easy conformance to earth contours.
- Scrim reinforcement provides enhanced tear and puncture resistance.
- Excellent chemical resistance to most industrial effluents
- Available in both potable water and industrial grades in various thicknesses.
- Potable water grade membrane is NSF-61 listed.

Large panel factory fabrication creates blankets up to 25,000 square feet (2,300m^2) that are shipped to job sites and field seamed using reliable wedge or hot-air welding technology.

Polypropylene Geomembranes have low maintenance requirements. The membrane remains heat-weldable throughout its installation life. Any mechanical damage can usually be repaired by hand using an in-house maintenance crew, thereby eliminating the need for costly transport of equipment and repair technicians to remote locations.

It meets all Government requirements for contact with drinking water, including NSF-61, in addition to international standards such as WRC (British Water Regulation Commission).

Polypropylene has also been tested in accordance with all applicable ASTM, FTM, NSF and GRI test methods.

POLYPROPYLENE TECHFACTS

Environmental Stress Crack Resistance (ESCR)
and thermal behaviour

Documented History of ESC

Past and present failures of exposed semi-crystalline geomembranes due to the environmental stress cracking (ESC) phenomenon are well documented. Exposure of some HDPE materials to low stress levels will lead to slow crack propagation, especially if the crack was initiated by surface cuts or scratches, seam area grinding, or folds in the geomembrane. Slow crack growth may take years to develop, thus making it difficult to predict true service life of HDPE geomembranes. Polypropylene Geomembranes (PP), however, although a member of the polyolefin family as polyethylene, are *not* susceptible to environmental stress cracking.

GRI/GM5 Testing

The Geosynthetic Research Institute has developed a test method (GRI/GM5), which consists of subjecting notched specimens of geomembrane to a constant load in the presence of a surface-active agent at elevated temperatures. Samples of Polypropylene Geomembrane have been tested using GRI/GM5, referred to as the "Notched Constant Load Environmental Stress Crack Resistance Test", with no failures reported in an aggressive soap solution (5% soap solution skimmed from surface of 52% black liquor effluent obtained from a paper processing facility.)

In this test, ASTM D638 type IV dumbbell specimens were notched to produce a hinge thickness at 80% of the nominal thickness of the test specimen. The specimens were attached to hooks on the test apparatus and immersed into the soap solution and maintained at a constant elevated temperature (50°C) and concentration. Test specimens were loaded at various percentages of their room temperature yield stress at increments of 5%. The yield stress of the material were then measured according to ASTM D638 and plotted as percent yield vs. time-to-failure to determine the transition time between ductile and brittle modes of failure.

No failures, surface cracking or notch propagation were observed under 200X magnification in the Polypropylene samples. However, HDPE and VLDPE exposed to the same black liquor solution both indicated premature failure.

Other Thermal Considerations

Polypropylene Geomembranes can be used in a variety of applications involving exposure to elevated temperature solutions, such as those found in black liquor processing effluent ponds.

The melting point of Polypropylene resin as measured by differential scanning calorimetry (DCS) is approximately 160°C, as compared to 130°C for HDPE and 115°C for VLDPE. The broad melt transition range for Polypropylene allows the material to be used in installations requiring resistance to elevated temperature.

POLYPROPYLENE TECHFACTS

Thermal Seamability and Repairability

Melt Transition Range
It is estimated that nearly 90% of all geomembrane leaks occur at the field seam area. Ease of thermal seamability in a geomembrane, as well as the reliability of the resulting seam, is directly related to the *melt transition range* of the base polymer. The wider the range, the less chance of error on the part of the thermal welding equipment operator and the leaks that could result from partial or “cold” welds.

Polypropylene Melt Characteristics
Polypropylene Geomembranes (PP) have a wide melt transition temperature range as compared to polyethylenes. As measured by differential scanning calorimetry (DSC) figure 1 illustrates the approximate melt transition temperature range for Polypropylene, HDPE and VLDPE. The advantage of the wider melting transition observed in the case of Polypropylene as compared to the HDPE is clearly demonstrated by the thermal seaming characteristics of these two materials.

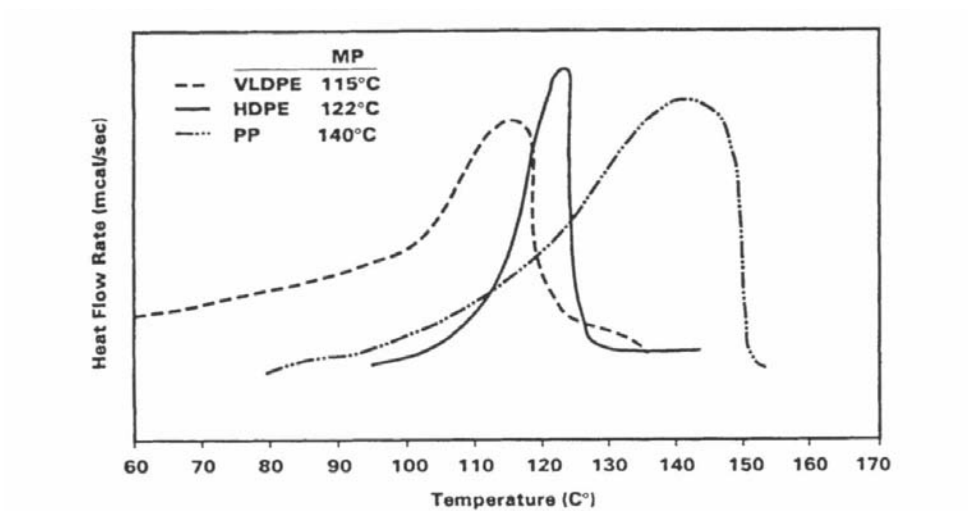


Figure 1. ***Approximate melt transition temperature range for three geomembrane materials.***

Seam Fabrication and Testing
A seam fabrication and testing programme was carried out at an independent laboratory in an effort to determine the approximate seaming window for 1.15mm (45-mil) reinforced Polypropylene, 1.0mm (40-mil) VLDPE and 1.5mm (60-mil) HDPE. All materials were thermally welded with a wedge welder. The seam equipment temperature was varied while equipment speed, pinch roller pressure and sheet temperature of 23℃ (72℉) were kept constant.

Figure 2 illustrates the differences in the thermal seaming window for all three geomembranes. Clearly, the Polypropylene geomembrane exhibits the widest welding temperatures window at 204°C while still maintaining a quality weld with no failures when tested in the peel mode.

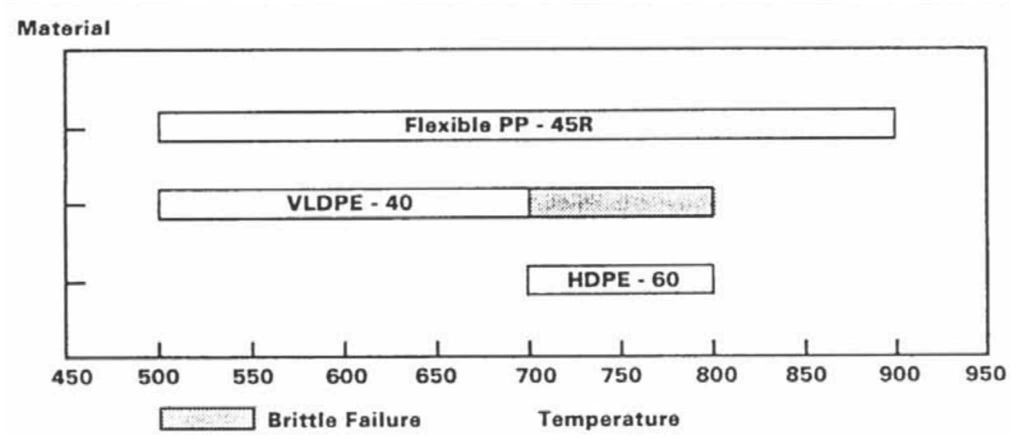


Figure 2. ***Approximate thermal seaming (wedge welder) temperature window comparison.***

Peel strength testing was also carried out for reinforced Polypropylene when seamed at a much lower ambient temperature of 7.2°C . Even at this lower temperature, Polypropylene exhibited a wide welding temperature window of 200°C and consistently strong seams. In all cases, specimens failed at the seam edge in a Film Tear Bond (FTB) mode of failure with no indications of bonded seam area failures.

Polypropylene Seaming Advantages

Polypropylene resin, by virtue of its low crystallinity and basic composition, allows a broad process temperature range. The relative ease of thermal welding over a wide range of seaming equipment temperatures is a great advantage to the installation contractor. It provides an added measure of security to the overall project when compared to geomembranes having much narrower welding windows (melt transition ranges). This is especially important in critical containment applications. Polypropylene Geomembrane can be welded by all thermal methods without surface preparation other than cleaning the seam area of any residual dirt or other contaminants. Unlike extrusion welding, no grinding is required, even for detail work around appurtenances or sumps.

No Stress Cracking in Polypropylene Geomembranes.

Another advantage of Polypropylene Geomembranes is their low coefficient of Linear Thermal Expansion (COLTE), which results in minimal residue stress at the seam area during thermal seaming. It has been widely reported concern for other olefinic geomembranes where a high degree of thermal expansion will manifest itself in higher levels of residual stress at the seam area. This has contributed to the stress cracking phenomena found in HDPE geomembranes.

Ease of Repair.

Polypropylene does not cross-link with age. In addition, there is no need for surface grinding prior to making a repair seam. The material can thus be repaired readily in the field, even after many years of service, using the same thermal welding methods as those employed during installation. Repair processes are simple and generally require only hand held hot air gun and roller with little or no surface preparation other than cleaning the seam area of residual dirt or other contaminants.

POLYPROPYLENE TECHFACTS

Chemical Resistance

An Engineered Approach

A common practice in the containment industry today is to select a geomembrane based on the highest degree of chemical resistance, frequently exclusive of other physical properties or application-based selection criteria. A more engineered approach is to balance the chemical resistance against other key factors that must be satisfied in order to meet all the requirements of the specific project. These may be such factors as sub-grade conformance and puncture resistance, ease of installation, thermal seamability, environmental stress crack resistance, dimensional stability during extreme temperature changes, UV resistance etc.

Polypropylene – The Best of Both Worlds

Polypropylene Geomembranes combine the best of both worlds. They have exceptional physical properties as well as excellent chemical resistance. This makes Polypropylene ideally suited for a wide range of buried and exposed containment applications without sacrificing key performance characteristics.

Because it is part of the polyolefin family (as is HDPE), Polypropylene is resistant to a broad range of chemicals, making geomembranes made from Polypropylene suitable for containing a wide range of industrial effluents, municipal waste-water and waste leachates.

Organic Solvent Testing

In an independent laboratory test, the chemical resistance of a 1.0mm (40-mil) Polypropylene geomembrane was tested against saturated solutions of a variety of organic solvents. Upon reaching equilibrium, (i.e. no further organic absorption in the polymer), the sheet samples were tested for physical property changes. The results are shown in Table 1. The data indicates no significant detrimental effect on the Polypropylene sheet samples after exposure to a variety of organics.

EPA 9090 Geomembrane Immersion Test

In the EPA9090, a geomembrane immersion test, no discernable loss of physical properties was noted when Polypropylene was exposed to a municipal leachate obtained from the Delaware Solid Waste Landfill in Sandtown, Delaware. The test was conducted at two temperatures, 23°C and 50°C. In this test, various critical properties were monitored over four months of sheet sample immersion in the leachate with little or no change in physical/mechanical properties.

Project-Specific Chemical Testing important

Obviously, the degree of chemical attack on any material will be influenced by a number of factors and their interaction. Project-specific chemicals or mixture of chemicals, in the concentrations and temperatures found in the actual application, must be tested against the geomembrane system that will contain them.

Table 1. Resistance of Polypropylene to Saturated Aqueous-Organic Solutions

Solution	Concentrate (ppm)	Weight Gain (%)	Tensile Yield (Mpa)	Tensile Break (Mpa)	Ultimate Elongation
Control			8.00	23.50	840
Water		0.10	8.70	22.30	800
2%NaCL	2000	0.10	7.80	22.00	815
MEK	1000	0.18	8.70	21.40	775
TCE	475	2.00	8.00	25.00	835
O-Xylene	150	1.10	7.80	22.60	840
Toluene	475	2.25	7.20	20.00	775
+2%NaCL	475	2.50	7.60	20.00	765

Notes: 1. 120 day immersion data, Matrecon Inc.
2. 1 Mpa = 145 psi.

Approved Chemical Resistance List

Polypropylene Geomembranes exhibit resistance to a wide range of aggressive chemicals. This performance property can be of critical importance in various containment environments. The following is a list of chemicals approved for use in contact with Polypropylene Geomembranes. Restrictions are that chemical temperature as it is applied to the geomembrane is not to exceed 51°C.

It is important to note that the degree of attack on any material is influenced by a number of variable factors including dilution of the chemical, temperature, aeration, velocity of flow, duration of exposure, stability of the fluid, possible chemical reaction, with other compounds being held in the same pond, size of the area under attack, geometry of the test sample etc. Therefore, this list is offered as a guide only. Before specifying Polypropylene geomembranes for a liner or floating cover application we advise that you test the material under actual or simulated service conditions.

A
ACETAMIDE
ACETIC ACID
ACETONE
ACID MINE WATER
ALCOHOL AMYL
ALCOHOL ETHYL
(ETHANOL)
ALUMINIUM CHLORIDE 10%
ALUMINIUM FLUORIDE
ALUMINIUM NITRATE
ALUMINIUM SULPHATE 10%
ALUMINIUM
CHLOROHYDROXIDE WET
AMMONIA 100% ANHYDROUS
AMMONIA AQUEOUS
AMMONIA CARBONATE
AMMONIUM BIFLORIDE
AMMONIUM CHLORIDE
SATURATED
AMMONIUM HYDROXIDE
AMMONIUM NITRATE
AMMONIUM SULPHATE 10%
AMMONIUM SULPHITE
ANTIMONY TRICHLORIDE
ARSENIC ACID
ASPHALT
B
BARIUM CARBONATE
BARIUM CHLORIDE SATURATED

BARIUM CHLORIDE 30%
BARIUM HYDROXIDE
BARIUM SULPHIDE
BEER
BEET SUGAR LIQUOR
BLACK LIQUOR
BRINE
BUTYRIC ACID 5%

C
CALCIUM CARBONATE
CALCIUM CHLORIDE
CALCIUM CHLORIDE SATURATED
CALCIUM HYDROXIDE 20%
CALCIUM HYPOCHLORITE 100%
CALCIUM NITRATE
CALCIUM SULPHATE
CALCIUM SULPHITE
CALCIUM DIOXIDE
CALCIUM MONOXIDE
CALCIUM PHOSPHATE
CARBONIC ACID
CASTOR OIL
CHLOROACETIC ACID
CITRIC ACID CONCENTRATED
CITRIC ACID DILUTE
COPPER CHLORIDE
COPPER CYANIDE
COPPER FLUORIDE
COPPER NITRATE
COPPER SULPHATE
COTTONSEED OIL
CUPRIC CHLORIDE<2%
CYANIC ACID

D
DETERGENTS 20%
DIETHYLENE GLYCOL

E
ETHYL ALCOHOL
ETHYL SULPHATE
ETHYLENE DIAMINE
ETHYLENE GLYCOL (DIHYDROX-ETHANE)
ETHYLENE OXIDE

F
FERRIC CHLORIDE<1%
FLUOBORIC ACID
FORMALDEHYDE (FORMALIN)
FURAN

G
GALLIC ACID
GELATIN
GLUCOSE
GLYCERIN (GLYCEROL)
GLYCOLIC ACID (HYDROXY ACETIC)
GLYCOL (ETHYLENE GLYCOL)

H
HEXAMINE
HYDROCHLORIC ACID 20%
HYDROCYANIC ACID
HYDROFLUORIC ACID 35%
HYDROFLUOSILICIC ACID
HYDROGEN CHLORIDE GAS DRY
HYDROGEN CYANIDE
HYDROGEN GAS
HYDROGEN PEROXIDE<30%
HYDROGEN SULPHIDE

I
INKS
IODINE
ISOPROPYL ALCOHOL

K
KETONES – ALIPHATIC

L
LPG (PROPANE)
LACTIC ACID (UP TO 70℉)
LANOLINE
LEAD ACETATE
LEAD NITRATE
LEAD SULPHATE
LIME SULPHUR (CALCIUM SULPHIDE)
LIME (CALCIUM OXIDE)
LINSEED OIL

M
MAGNESIUM BISULPHATE
MAGNESIUM CARBONATE
MAGNESIUM CHLORIDE
MAGNESIUM HYDROXIDE
MAGNESIUM NITRATE
MAGANESIUM SULPHATE
MALEIC ACID
MANGANESE CHLORIDE
MERCURIC CHLORIDE
MERCURIC CYANIDE
METHYL ACETONE
METHYL ALCOHOL (METHANOL)
METHYL ETHYL KETONE (TO 70℉)
MILK & ITS BY-PRODUCTS

MONOCHLOROACETIC ACID

N
NICKEL CHLORIDE
NICKEL NITRATE
NICKEL SULPHATE
NITROGEN
N-OCTANE

O
OILS ANIMAL
OILS OLIVE
OILS VEGETABLE
OXALIC ACID

P
PENOSULPHONIC ACID
PHOTOGRAPHIC SOLUTIONS – DEVELOPERS
PHOTOGRAPHIC SOLUTIONS – (HYPO ACID FIXING BATHS)
PLATING SOLUTIONS:
- BRASS
- CADMIUM
- CHROME
- COPPER
- GOLD
- LEAD
- NICKEL
- SILVER
- TIN
- ZINC

POTASSIUM ALIMINIUM SULPHATE (ALUM)
POTASSIUM BICARBONATE
POTASSIUM BICHROMATE
POTASSIUM BROMIDE
POTASSIUM CARBONATE
POTASSIUM CHLORATE
POTASSIUM CHROMATE
POTASSIUM SYANIDE
POTASSIUM DICHROMATE
POTASSIUM FERRICYANIDE
POTASSIUM FERROCYANIDE
POTASSIUM HYDRATE
POTASSIUM NITRATE
POTASSIUM OXALATE
POTASSIUM SULPHATE
POTASSIUM SULPHIDE
POTASSIUM SULPHITE
PROPYL ACETATE
PROPYL ALCOHOL (PROPANOL)
PROPYLENE CHLOROHYDRIN
PROPYLENE GLYCOL
PYRIDINE

R
RESORCINOL
ROSIN
SALT BRINE – SODIUM CHLORIDE SOLUTION
SEA WATER
SEWAGE
SILICONE OIL
SILVER BROMIDE
SILVER CYANIDE
SKYDROL 500 & 7000
SOAP SOLUTIONS
SODIUM ACETATE
SODIUM BENZOATE
SODIUM BICARBONATE
SODIUM BICHROMATE
SODIUM BISULPHATE
SODIUM BISULPHITE
SODIUM BORATE (BORAX)
SODIUM BROMIDE
SODIUM CARBONATE (SODA ASH)
SODIUM CHLORATE
SODIUM CHLORITE 5% (TO 158℉)
SODIUM CHLORIDE
SODIUM CHROMATE
SODIUM CITRATE
SODIUM CYANIDE
SODIUM DICHROMATE
SODIUM FERRICYANIDE
SODIUM FLUORIDE
SODIUM HYDROXIDE 10%
SODIUM HYPOCHLORITE
SODIUM HYPOSULPHITE
SODIUM METASILICATE
SODIUM NITRATE
SOIDUM PERBORATE
SODIUM PHOSPHATES
SODIUM SILICATE (WATER GLASS)
SODIUM SULPHATE
SODIUM SULPHIDE
SODIUM SULPHITE
SODIUM THYOSULPHATE (HYPO)
SODIUM TETRABORATE (BORAX)
STARCH
SUGARS & SYRUPS
SULPHUR
SULPHURIC ACID (10%)
SULPHUROUS ACID

T
TALL OIL
TALLOW
TANNIC ACID
TARTARIC ACID
TETRAPHOSPHORIC ACID
TRIETHYLENE GLYCOL
TRIETHYL PHOSPHATE
TRIPHENYL PHOSPHATE
TRIPHENYL PHOSPHITE
TRIPROPYLENE GLYCOL

U
UREA
URINE

V
VASELINE
VINEGAR

W
WHISKEY
WHITE LIQUOR PULP MILL
WHITE SPIRIT
WINE
WOOD PULP

Y
YEAST

Z
ZINC CARBONATE
ZINC CHLORIDE
ZINC CYANIDE
ZINC NITRATE
ZINC STEARATE
ZINC SULPHATE

Ultraviolet Resistance

Ultraviolet Resistance
Ultraviolet (UV) radiation is one of the most damaging components of the suns rays. Each year thousands of products fail because these invisible rays can break down chemical bonds in a material's polymer chains and weaken it. Once this breakdown starts, it is not unusual for other elements to accelerate the loss of integrity. Additionally, ultraviolet radiation can cause certain components to migrate out of the base product, i.e. plasticisers out of a polyvinyl chloride (PVC) membrane, leaving it brittle, subject to mechanical damage or cracking.

Geomembrane systems that will be exposed (non-buried) must, therefore, be resistant to the de-grading effects of ultraviolet radiation. Otherwise, cracks or other UV-induced damage could result in total sheet failure and the resulting liabilities associated with such an occurrence.

Weathering Testing
Because some geomembranes resist ultraviolet radiation better than others, a comparison of their weatherability characteristics should be made before final material specification is made. Several tests exist which can predict the characteristics of materials under these conditions. Each has advantages and disadvantages.

Real-Time Testing exposes membrane samples to actual weathering conditions for a designated amount of time – 5, 10 or 15 years. The samples are then taken to a laboratory where they are evaluated for physical properties and overall performance. While this is the most accurate method for testing long-term performance and UV resistance, it is not a realistic primary reference for geomembrane manufacturers because of the length of time required for the test. And since weather conditions and patterns vary in different geographic regions, the test results can vary widely and are not valid across the country.

Xenon-Arc Weatherometer Testing subjects geomembrane samples to a long-arc, water-cooled xenon lamp that operates at a standard 0.35 W/m^2 at 340nm. The light and heat radiance is kept at a pre-determined level through a monitoring device. Geomembrane samples are periodically moistened by a water spray at preset intervals and subjected to temperatures of 80 $\pm$ 3°C (170 $\pm$ 6°F) and to specific ultraviolet light. The procedure is carried out at a preselected dry exposure time and with a combination of light and water spray according to a cycle defined in the standard specification for each generic material.

This test produces the most accurate man-made sunlight of all laboratory test methods. It is also shortest of the accelerated tests, lasting 2000 hours, or 83 days. However, since it has been found that some heat stabilisation packages fail at 2200 hours, testing is done to a minimum of 4000 hours at 80°C (170°F).

A disadvantage of the xenon arc lamp test is its inconsistent UV output. Ultraviolet wavelengths degrade faster than other wavelengths over the life of the lamp, so the UV output slowly and consistently decreases (irradience can be kept constant by increasing the wattage). This weakness also makes it difficult to repeat the test for comparison testing.

EMMAQUA concentrated sunlight (Equatorial Mount with Mirrors for Acceleration with Water) is presently the best alternative to real-time testing for determining the long-term weatherability (UV resistance) of a geomembrane. The test uses a Fresnel-reflecting solar concentrator and 10 flat mirrors to reflect and concentrate natural sunlight onto membrane samples mounted on a target plane. The apparatus automatically follows the sun's movements across the sky, resulting in the maximum amount of sunlight (roughly equivalent to the radiation from eight suns). Excess heat is drawn away from the membrane, and samples are intermittently sprayed with water to simulate the wet/dry cycle that can cause migration of volatile stabilisers and other ingredients from some geomembranes.

The EMMAQUA test is the most realistic and accurate accelerated weather test because it exposes samples to the full spectrum of actual concentrated sunlight. It uses the right combination of testing conditions, including UV light, water, dew, heat and cold to produce degradation comparable to the worst natural weathering conditions. In addition, test results can be converted into a reasonable real-time weathering estimate for a specific geographic region. More importantly, the test results can be repeated and non-simultaneous test results are comparable with a minimum margin of error. The disadvantage of this test is that it takes 18 to 36 months to complete and is fairly expensive.

Testing Polypropylene

Flexible Polypropylene geomembranes are well suited to prolonged outdoor exposure in applications such as floating covers, waste water treatment ponds, solar ponds, fish hatcheries, waste pile covers or industrial evaporation ponds.

Extensive UV resistance testing has been completed and additional analysis is ongoing. At the time of collating this information, *Xenon Arc Weatherometer* (ASTM G26) exposure on the formulations tested exceeds 4000 hours at 80°C (170°F) with no indication of change in appearance or physical properties.

In addition, extensive outdoor exposure testing using the EMMAQUA accelerated aging techniques (ASTM G90) are in progress. At time if printing, Polypropylene geomembranes under test have passed the 2 million Langley (2267 MJ/M_2 UV) mark with no evidence of surface deterioration or colour change.