

**Weatherability of
Thermoplastic Piping
Systems
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Foreword

WEATHERABILITY OF THERMOPLASTIC PIPING SYSTEMS

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The purpose of this technical report is to provide information on the weather resistance of the basic plastic materials used in commercial plastic piping systems.

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WEATHERABILITY OF THERMOPLASTIC PIPING SYSTEMS

1.0 INTRODUCTION

Thermoplastic polymers, like many other materials, are affected by weathering, which is a general term used to cover the entire range of outdoor environmental conditions. However, plastic piping made of thermoplastics that incorporate appropriate weathering protection have been used successfully in various outdoor applications and have provided many years of service. For piping systems that are intended for prolonged outdoor exposure, a material composition must be selected with the necessary weather resistance for the specific conditions involved. Most thermoplastic piping has sufficient weather resistance to withstand normal exposure that occurs before installation. In some instances, this time period can be as long as several years.

Thermoplastic polymers have definitive characteristics regarding weather deterioration: Some are inherently resistant while others are less resistant. The weatherability of all thermoplastics can be improved by the incorporation of select additives. The combination of the basic thermoplastic polymer with these select additives results in a finished material that is generally termed a thermoplastic compound.

This report covers the structure and inherent weather resistance of the basic thermoplastic polymers used in commercial thermoplastic piping and discusses the weather resistance of those thermoplastic compounds that are in established use. Much of the discussion focuses on the effects of ultraviolet radiation exposure, as this is generally the weathering factor with the greatest impact on the performance of thermoplastic piping.

2.0 FACTORS INFLUENCING WEATHERING

When making a determination for the suitability of a particular plastic material for either outside storage or long term above ground service, the environment surrounding the piping material must be considered. A brief description of the more important environmental parameters follows:

2.1 Sunlight

Sunlight contains a significant amount of ultraviolet radiation. The ultraviolet radiation that is absorbed by a thermoplastic material may result in actinic degradation (i.e., a radiation promoted chemical reaction) and the formation of heat. The energy may be sufficient to cause the breakdown of the unstabilized polymer and, after a period of time, changes in compounded materials.

Thermoplastic compounds that will be exposed to ultraviolet radiation should be made with additives that are properly suited to stabilize the compound for such conditions.

2.2 Temperature

First, thermoplastic compounds are exposed to manufacturing heat histories where high temperature is present during the production of the final products. Thermal stabilizers are incorporated to protect the thermoplastic compound against these heat histories in order to maintain appropriate and applicable thermoplastic compound cell classifications.

In addition to manufacturing temperature exposures, there are daily ranges of temperature that vary considerably with season, prevailing climate, and location or orientation of pipe. Heat from solar radiation can significantly raise the temperature of directly exposed products, depending on the pipe location and color. Such extremes of temperature over an extended period can potentially cause physical damage to the thermoplastic compounds, if not properly protected. Therefore, it is important that heat stabilizers be incorporated into the thermoplastic compound to offset the deleterious effects of outdoor high temperature exposures and manufacturing processes. Note, it should be remembered that chemical reaction rates increase exponentially as the temperature increases.

2.3 Moisture

Rain and humidity are the two main contributors of moisture, with humidity having the greater overall effect. In general, humidity contributes a moist continuum in constant contact with the material to produce hydrolysis, leaching, etc. Rain produces a washing and impacting action.

Note: Exposure to moisture is not typically a concern for “most” thermoplastics compounds. Some thermoplastic compounds may be more hygroscopic in nature (i.e. polyamides). These compounds may become a concern when installed in extremely humid conditions or direct water contact. For more information, the reader is referred to the manufacturer’s literature.

2.4 Wind

Wind acts as a carrier of impurities such as dust, gases and moisture that can contribute to weathering effects. Similarly, the absence of wind can allow the accumulation of air contaminants, as in smog areas, which could contribute significantly to the weathering of a material.

2.5 Gases

The nature and quantity of environmental gases vary widely. In industrial areas especially, some corrosive gases may be present, that can result in chemical action on some materials.

2.6 Location

The geographical location is also a factor. Less effects are produced where there are less sunlight hours per year and where the radiation is less intense. For example, a specific period of exposure in Arizona is more detrimental than in New Hampshire due to the obvious extra hours of UV (ultraviolet) exposure and, less obviously, to the higher ambient temperatures encountered.

3.0 WEATHERING RESISTANCE OF BASIC THERMOPLASTIC POLYMERS

Some polymers are inherently quite resistant to weathering, others less so, and some deteriorate quite rapidly. For the purpose of this discussion, only those polymers commonly used in piping applications are presented.

3.1 Polyethylene, Polypropylene, and Polyvinyl Chloride

Polyethylene (PE), polypropylene (PP), and polyvinyl chloride (PVC) all have a similar basic structure as shown in Figure 1. They all have a backbone of carbon-to-carbon bonds with various side components: hydrogen (H) for PE, a methyl (CH₃) group for PP, and chlorine (Cl) for PVC. With addition of UV stabilization additives, these polymers can be protected to provide extended service in outdoor applications. The ability to withstand exposure to weathering conditions is dependent on the type of UV stabilization and the amount of UV exposure.

3.2 ABS (Acrylonitrile-Butadiene- Styrene) Terpolymers

Impact-modified styrenic polymers such as ABS (acrylonitrile-butadiene-styrene) terpolymers are very sensitive to oxidation, essentially because of the butadiene content. The carbon-carbon double bond (C=C) from butadiene, which is responsible for the elastomeric behavior of the rubber moieties in the material, is extremely sensitive to UV energy. This energy causes oxidation and crosslinking that modifies the material's rubbery behavior that is responsible for its impact resistance to one of a more brittle nature. Degradation from weathering starts at the surface and may propagate through the bulk material, resulting in a rapid loss of mechanical properties such as ultimate elongation, toughness, and impact strength.

To avoid degradation, ABS is frequently protected by the inclusion of carbon black in the formulation. The addition of sufficient carbon black can make these polymers very weather resistant, as evidenced by the good field history of black ABS pipe. Carbon black is the most common UV stabilizer used for extended outdoor applications.

4.0 WEATHERING OF POLYETHYLENE (PE) PIPE

Some natural or unstabilized polyethylene have limited outdoor life. However, most polyethylene pipe manufactured today contains an ultraviolet stabilization package. These are broken into two basic types of stabilization:

UV radiation diffuser – carbon black

UV radiation absorber–Hindered Amines Light Stabilizer (HALS)

Polyethylene pipe that does not contain carbon black, such as yellow gas pipe, would typically contain some chemical UV stabilizers – such as a hindered amine light stabilizer (HALS) - to protect the pipe from the effects of UV radiation. For typical outdoor storage these ultraviolet absorber-stabilizer systems can provide the “non-black” colored piping adequate protection for exposures of 3 years or more. The manufacturer should be contacted for specific UV performance information.

For prolonged outdoor use, polyethylene pipe should be formulated with a minimum of 2 percent finely dispersed carbon black. Incorporating carbon black in polyethylene compounds greatly increases their weather resistance (1, 2). Due to the absorptive properties of the carbon black, it acts as an UV diffuser and protects the polyethylene from damaging ultraviolet radiation. The aging resistance imparted by the carbon black depends upon its type, particle size, concentration, and degree of dispersion and distribution in the polyethylene (3). ASTM standard D3350 requires a minimum concentration of 2 percent carbon black. It has been demonstrated that this amount of well-dispersed very fine particle carbon black grade, such as N-550, provides sufficient protection for continuous outdoor service for more than 50 years (1)..

5.0 WEATHERING OF POLYPROPYLENE (PP) PIPE

Pigmented (non-black) polypropylene (PP) pipe, like pigmented (non-black) polyethylene pipe, has a limited life when stored outdoors. The outdoor storage life of non-black polypropylene should be limited to a total of three months unless the pipe is covered or otherwise protected from sunlight.

Some PP piping is protected from ultraviolet radiation by the inclusion of carbon black in the compound or an outside layer on the piping with carbon black incorporated. Polypropylene's weatherability, like polyethylene's, is greatly enhanced by the incorporation of carbon black. The degree of weatherability imparted by the carbon black depends upon its type, particle size, concentration and dispersion or distribution in the compound. A concentration of two to three percent carbon black in PP pipe generally results in good weathering resistance (4).

6.0 WEATHERING OF POLYVINYL CHLORIDE (PVC) PIPE

Generally, standard PVC pipe grade materials covered under ASTM D 1784 (such as PVC 1120 - cell classification 12454) include sufficient UV screen, usually titanium dioxide (TiO_2), to be stored outdoors for at least one year. Special care must be given to ensure that PVC pipe used in outdoor applications has been formulated to be a highly weather resistant product. Otherwise, it may not deliver equally satisfactory performance outdoors.

PVC materials can be compounded with a suitable amount of TiO_2 and a sufficient level of other stabilizers to be a very highly weatherable product (5), as can be seen in siding, windows, and furniture. These PVC compounds contain PVC resin, UV screens, stabilizing additives, and other weather resistant ingredients.

7.0 WEATHERING OF ACRYLONITRILE-BUTADIENE-STYRENE (ABS)

ABS pipe usually contains sufficient carbon black to provide protection from sunlight. The effects of ultraviolet radiation are substantially reduced in black pipe which enables its use in outdoor applications. The largest outdoor use is probably plumbing vent pipes of drain, waste and vent (DWV) systems that are fully exposed to all climatic conditions.

No adverse effects have been reported from other weather conditions such as wet or cold, or from geographical location where the intensity of ultraviolet radiation varies. Non-black ABS compounds are not recommended for outdoor service.

8.0 EFFECTS OF WEATHERING

The effects of weathering can vary from a complete loss of tensile strength and reduction of ductility to slight surface degradation that does not detract from performance but still indicates oxidation is occurring. Generally speaking, the first effect of weathering typically may be a slight discoloration of the pigment resulting in a chalky surface or whitening of the coloration.

Thermoplastic compounds that have been adversely affected by weathering are expected to exhibit a reduction in tensile strength and ductility. In all cases, surface degradation must be removed in order to allow the plastic compound to be heat fused or solvent bonded. The pipe and fitting manufacturer's recommended heat fusing or bonding procedures should be consulted.

9.0 DESIGN CONSIDERATIONS

The following statements on weathering characteristics of plastic piping compounds may be used for guidance on piping systems utilizing these materials. The weathering statements are appropriate for piping systems that have been designed to withstand the UV radiation, increased temperatures and other environmental conditions encountered in specific applications.

The service life of thermoplastic pipe exposed simultaneously to weathering and external stresses may be greatly reduced by acceleration of chemical and physical changes (6, 7). For example, unstressed control specimens of various polyethylene compounds required considerably longer time to show signs of degradation from natural ultraviolet light than did specimens exposed in the form of bent strips subjected to high stresses (8, 9).

10.0 NATURAL WEATHERING

Most natural weathering studies are conducted in accordance with ASTM D1435, "Standard Practice for Outdoor Weathering of Plastics" (10). The intensity of solar radiation, of course, varies widely with the geographical location and time of year. (One year's exposure in New Jersey, for example, does not give the same degree of aging as a year's exposure in Florida or Arizona). A month's exposure in July or August at any location is not the same as a month's exposure during December or January. Even at one location, the variation in solar radiation from year to year can be as great as the total radiation for a whole month. Therefore, even a year as a unit for timing exposure is variable and cannot be used for direct comparison of samples, unless they were exposed during the same period.

However, data and case histories from severe locations, where radiation is intense, enable users to properly design for applications at less severe locations. Change in tensile properties, color change, brittleness temperature and other significant properties are commonly used as criteria.

11.0 ACCELERATED WEATHERING TESTING

A number of devices are used to simulate outdoor exposure. These devices employ mercury sunlamps, carbon arcs, xenon arcs or a combined fluorescent sunlamp-black light. ASTM Standard Practices D4329 (11), D1499 (12) and D2565 (13) cover the latter three, respectively.

None of these tests can be absolutely correlated with outdoor exposure. The reasons for this lack of correlation include:

1. The extreme variations in outdoor environment.
2. The radiation spectrum does not exactly duplicate the solar spectrum.
3. Temperatures and temperature ranges differ from outdoor conditions.
4. Humidity differences.
5. Other Environmental factors, like exposure to pollution or salt.

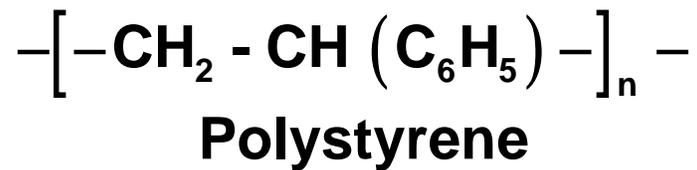
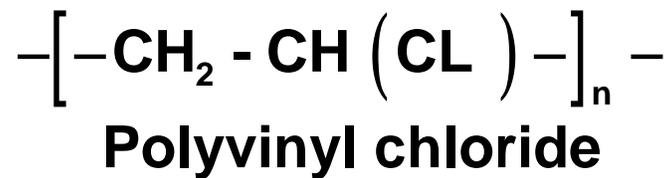
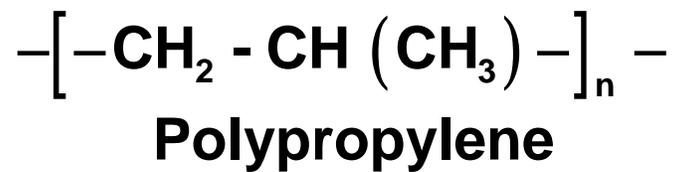
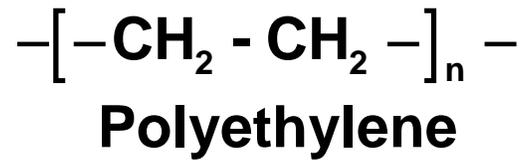
However, in spite of this lack of perfect correlation with outdoor exposure, accelerated testing is a very useful tool for comparing the relative aging resistance of materials and for quick screening to identify materials that have a poor resistance. The same criteria of change in properties and appearance used to evaluate natural weathering are used for accelerated tests.

A very reliable index of weather resistance is provided by intensified natural sunlight testing stations. These test stations use an equatorial mount that follows the sun and also concentrates the sun's rays by a battery of mirrors. The sun's spectrum is used and the accompanying heat generated is controlled with air and water streams. Results are obtained in approximately one seventh of the time required in natural exposure. Reference numbers 14, 15, 16, 17 in Section 12.0 may be consulted for further information on this subject.

12.0 SUMMARY

In summary, the effects of weathering on thermoplastic piping systems is a well understood phenomenon that has been studied extensively. Therefore, performance limitations can be addressed and potential failure can be avoided. Consulting the appropriate manufacturer can help resolve or clarify any design or exposure limitations and expectations. The UV radiation and potential temperature effects on weathering of various thermoplastic piping systems can be controlled and minimized by properly selecting suitable manufacturing material and the final product cell classifications to achieve a high degree of confidence in the understanding of the performance expectations of these various thermoplastics.

FIGURE 1



13.0 REFERENCES

1. Gilroy, H. M., "Polyolefin Longevity for Telephone Service," ANTEC '85, pp. 258-260.
2. Whitney, Lynn, C., "Specifying Carbon Blacks for UV Light Protection," Plastics Engineering, (December 1988), pp. 29-33.
3. Wallder, V. T., Clarker, W. J., DeCoste, J. B., and J. B. Howard, "Weathering Studies on Polyethylene," Industrial and Engineering Chemistry Vol 42, No. 11, pp. 2320-2325.
4. Handbook of PE Pipe, Plastics Pipe Institute, Washington, DC, 1976.
5. Houle, J., "UV Exposure Has No Practical Effect on PVC Pipe", March 20, 2013. PVCPIPE Technical Blog. <https://www.uni-bell.org/blogs/technical-blog/uv-exposure-has-no-practical-effect-pvc-pipe>
6. Quackenbos, H. M. and Samuels, H., "Practical Problems for Predicting Weathering Performance," Modern Plastics Vol. 44, No. 8, (April 1967), p. 143.
7. Gary, V. E. and Cadoff, B. C., "Experimental Techniques for the Evaluation of the Effects of Weathering on Plastics," Modern Plastics, Vol. 44, No. 8 (April 1967), p. 219.
8. Kaufman, F. S., Jr., "Evaluating Weathering of High Density PE," Modern Plastics, Vol. 44, No. 8 (April 1967), p. 146.
9. Newland, G. C. and Tamblyn, J. W., "Weathering of Polyolefins Under Stress," Polymer and Engineering Science (July 1965), pp. 148-151.
10. ASTM D 1435-94, "Standard Practice for Outdoor Weathering of Plastics," American Society for Testing and Materials, Philadelphia, PA, 1985.
11. ASTM D 4329-92, "Standard Practices for Operating Light and Water Apparatus (Fluorescent UV and Condensation Type) for Exposure of Plastics," American Society for Testing and Materials, Philadelphia, PA, 1984.
12. ASTM D 1499-92a, "Standard Practice for Operating Light and Water Exposure Apparatus (Carbon-Arc Type) for Exposure of Plastics," American Society for Testing and Materials, Philadelphia, PA, 1984.
13. ASTM D 2565-92a, "Standard Practice for Operating Xenon ArcType Light Exposure Apparatus With and Without Water for Exposure of Plastics," American Society for Testing and Materials, Philadelphia, PA, 1988.

14. DeBlieu, I. K. and Zerlaut, G. A., "Weathering of Plastics and Plastics Piping; Real Time and Accelerated Outdoor Exposure Testing," American Gas Association Distribution/Transmission Conference, May 1984.
15. "Engineering Plastics", Engineering Materials Handbook, Vol. 2, 1988, pp 575-580.
16. Modern Plastics Encyclopedia. Vol. 67, No. 11, p. 216, McGraw-Hill Publishing Co., New
17. Palermo, E. F., "New Outdoor Storage Requirements in ASTM D 2513," AGA Plastic Materials Committee Workshop, February 1987.