Weatherability of Thermoplastic Piping Systems

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Foreword

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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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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 in various outdoor applications and have given many years of service. For those piping systems that are intended for continuous outdoor exposure, a material composition must be selected that has 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 ingredients. The combination of the basic thermoplastic polymer with these select ingredients results in the 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 compounding ingredients. Thermoplastic materials that are to be exposed to ultraviolet radiation for long periods of time should be made from plastic compounds that are properly stabilized for such conditions.

2.2 Temperature

The daily range of temperature varies considerably both with season and location and can be quite large. Heat from solar radiation can raise the temperature of directly exposed materials as much as 60°F higher than ambient, depending on the pipe color. Such extremes of temperature over an extended period can cause physical damage to the polymer. Therefore, it is important that heat stabilizers be incorporated into the compounding ingredients in order to offset the deleterious effects of high temperature. In addition, 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.

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 gases vary widely but, in industrial areas especially, gases are present which 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 weather, 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 (Figure 1)

Polyethylene (PE), polypropylene (PP), and polyvinyl chloride (PVC) all have the same 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 (CH_3) group for PP, and chlorine (Cl) for PVC. With UV stabilization, these polymers give good long-term 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 polybutadiene content. The carbon-carbon double bond (C=C), which is responsible for the elastomeric behavior of the rubber, is extremely sensitive to UV energy. This energy causes oxidation and crosslinking that modifies the materials rubbery behavior to one of a more brittle nature. Degradation from weathering starts at the surface and results 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 (acrylonitrile-butadiene-styrene) pipe. Carbon black is the most common UV stabilizer used for extended outdoor applications.

4.0 WEATHERING OF POLYETHYLENE (PE) PIPE

The basic polyethylene polymer has limited outdoor life. However, most polyethylene pipe manufactured today contains an ultraviolet stabilization package. For typical outdoor storage, ultraviolet stabilized non-black systems are satisfactory, but for prolonged outdoor use, polyethylene 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). Carbon black acts as a UV absorbent and screens 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 in the polyethylene (3).

ASTM material standard D 3350 requires a minimum concentration of 2 percent carbon black. It has been demonstrated that this amount of well-dispersed very fine particle carbon black is sufficient protection for continuous outdoor service.

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 (4).

Some PP piping is protected from ultraviolet radiation by the inclusion of carbon black in the compound. 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 and particle size, concentration and dispersion in the compound. A concentration of two percent generally results in the best resistance (5).

It should be noted that PP piping is available manufactured from both carbon black and non-carbon black UV stabilized compounds. Applications that are not subject to outdoor exposure, such as indoor plumbing applications, may successfully utilize non-black PP piping. Non-black PP pipe should not be installed above ground outdoors where it would be continuously exposed to ultraviolet light or sunlight.

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 to be a very highly weatherable product, as can be seen in siding, windows, and furniture. These PVC compounds use PVC resin, UV screens and other weather resistant ingredients.

7.0 WEATHERING OF ACRYLONITRILE-BUTADIENE-STYRENE (ABS)

ABS pipe usually contains carbon black to provide protection from sunlight. The effects of ultraviolet radiation are substantially reduced in pipe so protected and permit the use of ABS pipe 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.

Prolonged exposure of such plumbing vents has not affected their performance. Close examination has shown that only a very thin surface layer of the pipe has been affected by sunlight, even after several years' exposure.

No adverse effects have been found 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. Generally speaking, the first effect of weathering will be a slight discoloration of the pigment resulting in a chalky surface or whitening of the coloration.

Plastic compounds that have been adversely affected by weathering will 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 hot plate welded (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 temperatures and other environmental conditions encountered in the specific application.

The service life of plastic 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 D 1435, "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 used as criteria.

11.0 ACCELERATED WEATHERING

A number of devices are used to simulate outdoor exposure. These employ mercury sunlamps, carbon arcs, xenon arcs or a combined fluorescent sunlamp-black light. ASTM Standard Practices D 4329 (11), D 1499 (12) and D 2565 (13) cover the latter three.

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

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 difference.

However, in spite of this lack of correlation with outdoor exposure, accelerated testing is an extremely useful tool for comparing the relative aging resistance of materials and rapidly screening out 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.

$$-\left[-CH_2 - CH_2 -\right]_n -$$

Polyethylene

$$-\left[-CH_2 - CH\left(CH_3\right)-\right]_n -$$

Polypropylene

$$-\left[-CH_2 - CH\left(CL\ \right)-\right]_n -$$

Polyvinyl chloride

$$-\left[-CH_2 - CH\left(C_6H_5\right)-\right]_n -$$

Polystyrene

FIGURE 1

12.0 REFERENCES

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