POLYETHYLENE RESIN TESTING REQUIREMENTS TO SUPPORT ASTM D2513 UV EXPOSURE LIMITS OF POLYETHYLENE COMPOUND

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Foreword

This technical note was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute. The members have shown their interest in quality products by assisting independent standard-making and user organizations in the development of standards, and also by developing reports on an industry-wide basis to help engineers, code officials, specifying groups, and users.

This technical note has been prepared to provide those responsible for the maintenance of existing HDPE pipelines with suggested general guidelines for the repair of those lines that have been subjected to third party or other unforeseen damage. These guidelines constitute a set of basic operations that have been demonstrated by test and experience to produce satisfactory repairs with commercially available materials. Each specific procedure must be acceptable to, and qualified by, the operator having legal responsibility for the performance of the piping system. This document was not intended to provide system design information. Go to the PPI website at www.plasticpipe.org for different system design documents.

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1.0 Introduction

The objective of this document is to provide testing requirements for Polyethylene (PE) compounds to support recent modifications to the Outdoor Storage Stability section of ASTM D2513. Specifically, those modifications were to show:

(1) Code C (black with 2 % minimum carbon black) PE pipes with 2.0 to 3.0 weight percent of a well dispersed carbon black would be considered stabilized against deterioration from unprotected exposure to UV for not less than 10 years and,
(2) Code E (colored with UV stabilizer) PE pipes would be considered stabilized against deterioration from unprotected exposure to UV for not less than 3 years.

ASTM D3350 uses a letter code to identify PE compound UV resistance properties as follows:

6.2 *Color and Ultraviolet (UV) Stabilizer* – The color and UV stabilization shall be indicated at the end of the cell classification by means of a letter designation in accordance with the following code:

Code Letter	Color and UV Stabilization
A	Natural
B	Colored
C	Black with 2 % minimum carbon black
D	Natural with UV stabilizer
E	Colored with UV stabilizer

ASTM D2513-13 further refines UV resistance as follows:

4.10 *Outdoor Storage Stability* – PE materials shall be Code C or E as defined in Specification D3350. Code C compound shall contain 2.0 to 3.0 percent well dispersed carbon black pigment, and due to the absorptive properties of the carbon black, is considered to be stabilized against deterioration from unprotected exposure to UV for not less than 10 years. Code E materials shall be stabilized and protected against deterioration from unprotected UV exposure for not less than 3 years.

The most recent edition of ASTM D2513 defines the testing requirements for Code C and Code E compounds as follows:

4.10.1 PE compounds designated as Code C containing 2.0 to 3.0 % carbon black shall be considered stabilized against deterioration for not less than 10 years without the need for additional testing.

4.10.2 PE compounds designated as Code E shall be considered stabilized against deterioration from unprotected exposure to UV for not less than 3 years when meeting the following criteria following exposure to actual outdoor (natural sunlight) weathering for up to 3 years in accordance with ASTM Standard Practice D1435 or accelerated weathering in accordance with Practice D2565 and Practice G155 for the equivalent of at least 3 years natural sunlight: (a) all tensile bar specimens tested in accordance with Test Method D638 shall have an elongation at break value greater than 400% indicating the equivalency of the PE material before and after UV exposure against the elongation at break requirement in Specification D3350; and (b) all tensile bar specimens tested in accordance with Test Method D638 shall retain a minimum of 50% of their original elongation at break values. Test data shall be made available from the manufacturer upon request.

It should be noted this technical note applies only to polyethylene pipe materials and compounds. It is unknown if the testing protocols and correlations presented are applicable to other compounds used in gas service such as polyamide, polypropylene, and polyvinylchloride. For crosslinked polyethylene piping materials refer to ASTM F2657 "Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing" and ASTM F876 "Standard Specification for Crosslinked Polyethylene (PEX) Tubing" for applications of this test method.

2.0 Background and Documentation

There are numerous published documents on carbon black and UV exposure protection. It is well known that due to the absorptive properties of carbon black, that PE materials utilizing at least 2.0% carbon black are considered stabilized against deterioration for in excess of 20 years with some studies indicating as much as 50 years. Some examples of those publications are included in the references as items 1-6. Therefore, no additional testing methodology was needed to support the "not less than 10 year claim" for Code C black PE pipes in D2513.

To address the Code E (colored with UV stabilizer) PE pipes, a PPI task group of industry experts was formed. This task group collected testing methodology from several PE resin companies that produce grades used for the Code E PE pressure pipe production, reviewed industry practices and several technical documents.

UV exposure only affects the surface layer of a plastic pipe. The compound inside the pipe wall is protected by the surface layer. Pipe that is not sufficiently UV stabilized (C or E designation) may undergo molecular chain degradation from UV exposure. As a result, PE materials may lose toughness and become brittle or become more susceptible to slow crack growth failure. Elongation at break is a very sensitive parameter to molecular weight and molecular degradation. The Task Group found it was proper to use at a minimum ASTM D638 tensile strength at yield and elongation at break testing as an effective means to evaluate the effects of UV exposure.

UV exposure can be accomplished via artificial and natural means. Howard and Gilroy at Bell Telephone Laboratories published a paper in 1969 that covered natural and artificial UV testing of PE. This paper also included information on various carbon black sizes and the resultant PE UV resistance.[7] It was determined that for artificial exposure, testing in a weatherometer in accordance with ASTM D2565 (cycle 2 with daylight filters) and ASTM G155 (with intermittent spray with irradiance of 0.35 $W/m^2/nm$ at 340 nm wavelength and 63 °C) was appropriate and widely used. A paper published at Eurotec 2011 on UV rating methods for injection molding PE grades concluded that the Xenon Arc method for accelerated UV testing gave the best correlation with outdoor exposure testing.[8]

There are numerous methods to test UV resistance, which include outdoor exposure and accelerated laboratory testing methods. Most test methods include exposing tensile bars to a UV source and then performing ASTM D638 tensile testing at specified intervals of UV exposure (typically at 1,000 hour increments). The tensile testing is usually performed on two types of PE tensile bars – Type IV and Type V. For reference, Type IV tensile bars have dimensions of 115 mm (4.5 ”) minimum length, 19 mm (0.75 ”) minimum width and a thickness of 3.2 ± 0.4 mm (0.13 ± 0.02 ”). Type V tensile bars have dimensions of 63.5 mm (2.5 ”) minimum length, 9.53 mm (0.375”) minimum width and the same thickness as Type IV bars. Both bars are referenced in ASTM D638 and with a thickness of 3.2 ± 0.4 mm (0.13 ± 0.02”) would correspond to ASTM D2513 pipes sizes of at least 1” IPS DR11.0 and 1” CTS tubing.

Publications show various UV radiance levels throughout the world and published equations may be used to calculate the projected lifetime of a PE product based on the desired UV rating of the material and annual solar radiation for a geographical area. Studies have shown that HDPE exposed to Xenon Arc yields approximately 4.4 times the acceleration of outdoor exposure in Florida.[8] Therefore, around 2000 hours Xenon Arc testing would equal about 1 year outdoor exposure in Florida. Other geographical areas such as Southern California would have a correlation of about 1250 hr exposure to Xenon Arc equaling about 1 year outdoor exposure and Southern Canada would have a correlation of about 1000 hrs Xenon Arc exposure equaling about 1 year outdoor exposure.

Several different PE industry applications use pass/fail criteria for a material or compound as 50 % retention of the initial tensile elongation at break after 3000-6000 hours of UV exposure.[9] And, ASTM D3350 requires a minimum of 400 % elongation at break for the compound before UV exposure.

3.0 Conclusions

Based upon industry published studies on the UV protection provided by carbon black, the PPI task group concluded that ASTM D2513 for Code C PE plastic pipes were stabilized for at least 10 years exposure was supported by numerous published documents and that no further testing methodology needed to be developed. The PPI task group concluded that for artificial UV exposure ASTM D638 tensile bars for Code E yellow pipe PE grades should be UV exposed per ASTM D2565 (Cycle 2 with daylight filters) along with ASTM G155 (with intermittent spray for an irradiance of 0.35 $W/m^2/nm$ at 340 nm wavelength at 63 °C). The UV exposed (by accelerated Xenon Arc or outdoor exposure) tensile bars should have a minimum 50 % retained elongation at break and retain the applicable ASTM D3350 tensile strength at yield of the original compound cell classification. It is proposed that such a testing methodology would demonstrate performance for the requirements of ASTM D2513 outdoor storage stability for Code E grades.

4.0 References

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