GUIDE TO CHLORINE RESISTANCE RATINGS OF PEX PIPES AND TUBING FOR POTABLE WATER APPLICATIONS

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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 (PPI). These members have shown their commitment to developing and improving quality products by assisting standards development organizations in the development of standards, and also by developing design aids and reports to help engineers, code officials, specifying groups, contractors and users.

The purpose of this technical note is to provide information to the end user regarding the use of PEX tubing in chlorinated potable water applications.

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1.0 SCOPE

The intent of this Technical Note is to give guidance to plumbing system designers, installers and specifiers for understanding chlorine resistance ratings as applied to crosslinked polyethylene (PEX) pipes and tubing for potable water applications, and to describe the effects of using PEX pipes and tubing in operating conditions beyond these published ratings.

This Technical Note is provided to explain how PEX pipe conforming to standard ASTM F2788[1] and PEX tubing conforming to standards ASTM F876[2] and CSA B137.5[3] may be used safely in potable hot- and cold-water distribution systems, within the specific limits discussed within this document. This Technical Note is also intended to clarify that the typical hydrostatic pressure and temperature ratings for PEX tubing (e.g. 160 psi @ 73°F, 100 psi @ 180°F) are not to be confused with the operating conditions which are anticipated in hot chlorinated potable water systems.

As a Guide for users of PEX systems, this document explains ASTM Test Method F2023 in detail, and identifies the four categories of chlorine resistance ratings which are defined within product standards ASTM F876, ASTM F2788, and CSA B137.5.

The Technical Note also differentiates between residential and commercial plumbing systems and explains that continuous recirculation of hot chlorinated water through PEX pipe or tubing at commercial temperatures above 140°F (60°C) is beyond the intended application of the standard chlorine ratings as defined in those standards listed above.

However, the fact that the chlorine ratings outlined in those standards do not explicitly cover commercial systems operating above 140°F should not be construed as an indication that PEX is never suitable for those applications. Some PEX products are specifically designed to meet the rigorous requirements of systems with either continuous or intermittent recirculation of water at temperatures exceeding 140°F.

Note 1: For PEX materials, "tubing" refers to products whereby the actual outside diameter (OD) is 1/8 inch larger than the nominal size, and is described as copper tube size (CTS). Product standards ASTM F876 and CSA B137.5 apply to PEX tubing. "Pipe" refers to products whereby the actual OD matches that of steel pipe of the same nominal size and is described as iron pipe size (IPS), or products where the actual OD matches the nominal size. Product standard ASTM F2788 applies to PEX pipe. The terms "pipe" and "piping", as well as "tube" and "tubing", are used interchangeably in this document.

[1] ASTM F2788 *Standard Specification for Metric and Inch-sized Crosslinked Polyethylene (PEX) Pipe*
[2] ASTM F876 *Standard Specification for Crosslinked Polyethylene Tubing*
[3] CSA B137.5 *Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications*

Note 2: See PPI TN-52 GUIDE TO HIGH-TEMPERATURE APPLICATIONS OF NON-POTABLE PEX PIPE AND TUBING SYSTEMS *for explanation of hydrostatic pressure ratings and considerations for use in non-chlorinated water systems operating at temperatures above 180°F (82°C).*

2.0 BACKGROUND - INTRODUCTION TO ASTM F2023 AND NSF/ANSI STD. 61

The plastic piping industry is highly regulated within USA and Canada with systems of codes, standards and third-party certifications which are extremely rigorous with regards to tubing materials (ingredients), production controls, and finished products. For PEX tubing and materials, chlorine resistance is tested and evaluated in accordance with ASTM F2023 "*Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Pipe, Tubing and Systems to Hot Chlorinated Water"*.

ASTM International is a not-for-profit organization and one of the largest voluntary standards developing organizations in the world. They provide a forum for the development and publication of international voluntary consensus standards for materials, products, systems and services.

A standard specification is a document that has been developed and established through ASTM's consensus principles and which meets their requirements of procedures and regulations. Full consensus standards are developed with the participation of stakeholders with an interest in their development and use. Many PEX producers and PPI members are also members of ASTM International.

ASTM Specification F2023 was first published in 2000 with contributions from many PEX tubing manufacturers, testing laboratories, consultants, and certifying bodies. The test conditions of ASTM F2023, with respect to the end-use operating temperature and pressure, have never been revised. Additionally, the very aggressive water quality required in ASTM F2023 (i.e., a minimum oxidative reduction potential [ORP] of 825 mV) has not been changed.

ASTM F2023 has proven to be a stringent and reliable test method for evaluating chlorine resistance of PEX tubing, setting very high thresholds for various levels of performance. Across the global piping industry, no weaknesses with this test method have been discovered. In fact, this ASTM test method is the standard recognized throughout the world for evaluating chlorine resistance of PEX tubing.

The Scope of ASTM F2023 reads as follows:

> "1.1 This test method describes the general requirements for evaluating the long-term oxidative resistance of crosslinked polyethylene (PEX) pipe or tubing in hot chlorinated water. The pipe or tubing used in such testing is produced in accordance with specifications, such as ASTM Standard Specification F876 or Specification F2788/F2788M. This test method outlines the requirements of a pressurized flow-through test system, typical test pressures, test-fluid characteristics, failure type, and data analysis.

> "1.2 Guidelines and requirements for test temperatures, test hoop stresses, and other test criteria have been established by prior testing of PEX pipe or tubing produced by the three most common commercial methods of crosslinking: silane, peroxide, and electron-beam. Other related system components that typically appear in a PEX hot-and-cold water distribution system can be evaluated with the PEX pipe or tubing. When testing PEX pipe or tubing and fittings as a system, it is recommended that the anticipated end-use fitting type(s) and material(s) be included in the test circuit since it is known that some fitting types and materials can impact failure times. Specimens used shall be representative of the piping product(s) and material(s) under investigation."
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Since the mid-2000s, testing according to ASTM F2023 is a mandatory requirement for all PEX cold- and hot-water plumbing tubing, as per tubing standards ASTM F876 and CSA B137.5. As a result, PEX tubing has proven to be a reliable piping material for chlorinated potable water applications.

Related to drinking water safety, all plastic pipe, tubing and system components must comply with federal regulations. NSF/ANSI Standard 61 *Drinking Water System Components - Health Effects* is the legally-recognized national standard in the United States and Canada for evaluating the human health effects of drinking water materials, components and devices, and ensuring that approved materials are safe for drinking water. NSF Standard 61 defines "drinking water" as "water intended for human consumption". An analogous term is "potable water".

NSF Standard 61 includes three temperature-based categories for testing and certification of PEX:

- **"Cold water application:** A product application that is intended to result in continuous exposure to water of ambient temperature. Products are tested for an end-use temperature of 23 ± 2°C (73 ± 4°F)."
- **"Domestic hot water application:** A product application that is intended to result in continuous or intermittent exposure to water that has been raised from ambient temperature. Intermittent exposure is defined as any hot water contact that is not continuous. Products are tested for an end-use temperature of 60 ± 2°C (140 ± 4°F)."
- **"Commercial hot water application:** A product application that is intended to result in continuous or intermittent exposure to water that has been raised from ambient temperature. Intermittent exposure is defined as any hot water contact that is not continuous. Products are tested for an end-use temperature of 82 ± 2°C (180 ± 4°F)."

When used within this document, the terms "**domestic hot water**" and "**commercial hot water**" will follow these established definitions.

3.0 TEST CONDITIONS OF ASTM TEST METHOD F2023

The test conditions of ASTM Test Method F2023 require that the test fluid has a minimum oxidative reduction potential (ORP) of 825 mV. ORP is a monitoring/control method that provides a measurement of the total oxidizing potential of a solution. For chlorinated water, ORP provides a measurement of the equilibrium of the free-chlorine as a function of pH. For example, third-party test laboratories may use reverse osmosis-purified water with a free chlorine concentration of 4 ppm[4] (4 mg/L) and pH of 6.8, resulting in an ORP of 825 mV or higher.

This represents a very aggressive water quality, which gives conservative results in terms of service life of the pipe. This test procedure is designed to extrapolate the life expectancy of a hot-water plumbing pipe when used at a domestic hot water temperature of 140°F (60°C), and a pressure of 80 psig (0.55 MPa) gauge pressure, considered to be the normal operating limits of domestic hot-water plumbing systems.

Note 3: Other known disinfecting systems (chlorine dioxide, ozone, and chloramines) are currently used for protection of potable water; however, free-chlorine is by far the most common system in use today. For information about the relative oxidative aggressiveness of chloramines and free chlorine on PEX, please refer to PPI Statement A at www.plasticpipe.org.

Product standards ASTM F876, ASTM F2788, and CSA B137.5 require that PEX pipe and tubing intended for use in the transport of potable water have a minimum extrapolated time-to-failure of 50 years when tested and evaluated in accordance with ASTM Test Method F2023. Testing is typically conducted with multiple specimens of nominal ½ inch SDR 9 PEX tubing at temperatures and pressures in accordance with ASTM F2023.

For example, specimens are typically tested at two (2) test stress levels at each of a minimum of three (3) test temperatures (often set at 239°F, 221°F, 203°F [115°C, 105°C, 95°C]), with at least two specimens at each test condition for a minimum of 12 data points.
Tests employ hot chlorinated water flowing through the PEX test specimens. PEX specimens are connected with typical adapter fittings which are approved for use with PEX, such as crimp ring fittings or cold-expansion fittings.

[4] The US EPA sets a maximum disinfectant level of 4.0 parts per million (ppm) within water distribution systems.

4.0 EVALUATION

While ASTM F2023 specifies the requirements for analyzing test specimens, conducting regression analysis and calculating time-to-failure extrapolations, the actual performance requirements for PEX pipe and tubing are found within product standards ASTM F876, ASTM F2788, and CSA B137.5. In addition, those standards cover the basic requirements for PEX tubing such as dimensions, degree of crosslinking, hydrostatic sustained pressure strength, hydrostatic burst pressure, bent-tube sustained pressure requirements, stabilizer functionality testing, etc. PEX pipe and tubing for drinking water applications is required to have a minimum extrapolated time-to-failure of 50 years when tested in accordance with ASTM F2023 and evaluated in accordance with ASTM F876, ASTM F2788 or CSA B137.5. Continuous recirculation, timed recirculation and traditional domestic conditions are evaluated by ASTM F2023 and categorized within those standards as part of the Thermoplastic Pipe Material Designation Code (MDC)[5].

The first number of the MDC refers to chlorine resistance in one of four categories:

- A digit “0” indicates that the PEX pipe or tubing either has not been tested for chlorine resistance or does not meet the minimum requirement for chlorine resistance. This tubing does not meet minimum requirements for potable water.
- A digit “1” indicates the PEX pipe or tubing has been tested and meets the applicable ASTM PEX standard requirement for minimum chlorine resistance at the end use condition of 25% of the time at 140°F (60°C) and 75% at 73°F (23°C). This is sometimes referred to as the Traditional Domestic application, hot up to 6 hours/day.
- A digit “3” indicates that the PEX pipe or tubing has been tested and meets the applicable ASTM PEX standard requirement for minimum chlorine resistance at end use condition of 50% of the time at 140°F (60°C) and 50% at 73°F (23°C). This is sometimes referred to as the Timed Recirculation application, hot up to 12 hours/day.
- A digit “5” indicates that the PEX pipe or tubing has been tested and meets the applicable ASTM PEX standard requirement for minimum chlorine resistance at end use condition of 100% of the time at 140°F (60°C). This is sometimes referred to as the Continuous Recirculation application, hot up to 24 hours/day.

Beyond these four standard chlorine categories, the data generated when testing PEX pipe and tubing to ASTM F2023 allows for evaluations of extrapolated times-to-failure at other operating conditions, including other pressures and temperatures, within the guidelines of F2023. For example, a laboratory may apply the regression analysis generated from the F2023 data set for a particular PEX formulation, as well as Miner’s Rule for other situations of multiple temperatures, to determine an extrapolated time-to-failure for a specific application.

[5] See ASTM F412 for full explanation of the thermoplastic pipe material designation code. For PEX tubing, the material designation code includes the abbreviation for the material, PEX, followed by four numerals.

5.0 SIGNIFICANCE OF CHLORINE RESISTANCE RATINGS ON THE APPLICATION

The Thermoplastic Pipe Material Designation Code (MDC) is required to be printed on all PEX tubing, indicating the chlorine resistance, as well as other performance indicators such as UV resistance and long-term hydrostatic design strength.

Examples of Material Designation Codes found on PEX tubing:

- PEX 1306
- PEX 3206
- PEX 5006

As stated in Section 3.0, the end-use operating conditions for temperature and pressure as evaluated by ASTM F2023 are 140°F (60°C) and 80 psig (0.55 MPa) gauge pressure, considered to be the normal operating limits of domestic hot-water plumbing systems. Data indicates that most domestic plumbing systems operate at temperatures less than 140°F, with water less aggressive than that used in ASTM F2023, and at system pressures lower than 80 psig.

Note 4: Flow velocities for hot-water distribution piping should follow applicable plumbing codes.

6.0 EFFECTS OF EXCESSIVE OPERATING CONDITIONS ON POTABLE HOT-WATER PIPING

PEX pipe and tubing should be used in plumbing systems operating within the guidelines of Categories 1, 3, or 5 listed in Section 4.0 and as defined within product standards ASTM F876, ASTM F2788, and CSA B137.5.

Frequent or continuous exposure to water conditions beyond those used in ASTM Test Method F2023 (i.e., aggressive water quality with an ORP above 825 mV and/or pressures above 80 psig and/or temperatures above 140°F) may cause premature oxidation and eventual brittleness of the PEX material, reducing its ability to meet long-term requirements. Conversely, infrequent or sporadic exposure to such operating conditions may have little effect on PEX pipe or tubing, with regards to its anticipated lifetime.

For operating conditions beyond the specified end-use conditions of the respective PEX standards, users should contact the specific pipe or tubing manufacturer to determine whether such conditions are approved for use.

Note 5: See PPI TN-52 GUIDE TO HIGH-TEMPERATURE APPLICATIONS OF NON-POTABLE PEX PIPE AND TUBING SYSTEMS *for explanation of hydrostatic pressure ratings and considerations for use in non-chlorinated water systems operating at temperatures above 180°F (82°C).*

7.0 RESOURCES FOR DOMESTIC POTABLE WATER SYSTEM DESIGN

PEX manufacturer installation instructions provide good pipe sizing parameters and installation practices that should be referenced prior to the design of a potable water PEX system.

When designing potable water plumbing systems, several industry resources are available to assist designers:

- *Design Guide: PEX Water Supply Plumbing Systems* is a joint publication of PPI, PPFA, ICC and NAHB Home Innovations Research Labs. It addresses topics such as material properties, code acceptance, joining methods, types of systems, design, performance data, and installation.
  - http://plasticpipe.org/publications/pex-handbook.html
- *BCD Plastic Pressure Pipe Design Calculator* is a software tool that aids in designing PEX tubing systems for applications such as plumbing, water service, and fire protection. The tool includes functions to calculate Pressure/Head Loss, Pipe Weight/Volume, Thermal Expansion/Contraction, Hydraulic Shock and Expansion Arm/Loop design. It utilizes dimensional data from ASTM International and CSA Group industry standards for these materials, as well as data generated from various PPI research projects.
  - www.plasticpipecalculator.com
- BCD's continuing education course *Designing PEX Plumbing Systems to Optimize Performance and Efficiency* explains piping design methods that can provide faster delivery of hot-water to fixtures, improve overall system efficiency, optimize use of materials, and improve installation efficiency.
  - http://plasticpipe.org/building-construction/bc-courses.html
- American Society of Plumbing Engineers (ASPE) heat loss method of sizing of Hot Water Recirculation Systems
  - ASPE Plumbing Engineering Design Handbook – Volume 2, Chapter 6 – Domestic Water Heating Systems , 2014-2015 V2: www.aspe.org
- IAPMO IS 31-2014, *Installation Standard for PEX Tubing Systems for Hot- and Cold-water Distribution*
  - IAPMO 2015 Uniform Plumbing Code (UPC) Appendix I

8.0 SUMMARY

Thanks to the many benefits of PEX pipe and tubing materials and the associated fittings and system components, it has become common for engineers, builders and plumbers to employ PEX potable water systems for drinking water applications.

However, for operating conditions beyond the typical "domestic hot" temperature of 140°F (60°C) and/or system pressure of 80 psig (0.55 MPa), users should contact the specific PEX pipe or tubing manufacturer to determine whether such conditions are approved for use.

The PPI Building & Construction Division and member companies may be reached through our website www.plasticpipe.org.