GUIDE TO HIGH-TEMPERATURE APPLICATIONS OF NON-POTABLE CROSSLINKED POLYETHYLENE (PEX) PIPE AND TUBING SYSTEMS

PPI TN-52

2024

Plastics Pipe Institute
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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 additional evaluation that is required for PEX pipe and tubing to demonstrate suitability for specific high-temperature applications.

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PPI intends to revise this technical note within five years, or sooner if required, from the date of its publication in response to comments and suggestions from users of the document. Please send suggestions for improvements to the address below. Information on other publications can be obtained by contacting PPI directly or visiting our website.

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This Technical Note, TN-52, was first issued in June 2017 and revised in November 2024.

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1.0 SCOPE

Crosslinked polyethylene (PEX) pipe and tubing conforming to standards such as ASTM F876, ASTM F2788, ASTM F3253, and CSA B137.5 are suitable for typical heating applications including hydronic radiant heating/cooling, hydronic distribution, snow and ice melting, turf conditioning, and geothermal ground heat exchangers at operating temperatures up to and including 180°F (82°C).

There are certain applications that could experience high-temperature exposures above 180°F, such as residential or commercial hydronic distribution systems including high-temperature radiator/baseboard/convector piping, district heating piping, solar thermal collection systems, and certain types of waste heat systems. Some of these systems may operate at fluid temperatures between 180°F and 200°F (93°C).

Some PEX manufacturers allow operating temperatures only up to 180°F and not beyond, whereas other manufacturers may allow operation of their material at temperatures up to 200°F.

Certain brands of PEX tubing are listed with the PPI Hydrostatic Stress Board (HSB) or other third-party certification agencies according to the policies of ASTM D2837 or PPI TR-3 with a "Standard Grade" listing for operation at 200°F and have "**80 psi at 200°F**" marked on the tubing or packaging. However, such a marking does not mean that the material is intended for continuous operation at temperatures up to 200°F. In fact, operating PEX pipe or tubing at temperatures above 180°F may affect its design life.

The intent of this Technical Note is to give guidance to the end user for determining appropriate design life calculations of PEX pipe and tubing for non-potable water at operating temperatures above 180°F. Section 3.0 "Background - PEX Test Methods and Evaluation Techniques" is provided to explain how PEX pipe and tubing are tested to ensure resistance to multiple types of oxidative damage through distinct test procedures and evaluations.

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 nominal tubing size (NTS) or copper tube size (CTS). Product standards ASTM F876, ASTM F3253, 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 nominal pipe size (NPS) or iron pipe size (IPS). "Pipe" may also apply to products where the actual OD matches the nominal size. ASTM F2788 applies to PEX pipe. The terms "pipe" and "piping", as well as "tube" and "tubing", may be used interchangeably in this document.

Note 2: See PPI TN-53 *Guide to Chlorine Resistance Ratings of PEX Pipes and Tubing for Potable Water Applications* for more information on the use of PEX tubing in hot chlorinated potable water applications.

1.1. Definitions specific to this Technical Note

- **Activation energy -** the minimum amount of energy that is required for atoms or molecules to reach a condition in which they can undergo a specific chemical transformation or physical transport
- **Arrhenius equation** - a formula for the temperature dependence using the activation energy for a specific material
- **Design life –** the length of time that a pipe or tubing material is estimated to operate reliably in a standard and approved application
- **Service life –** the length of time that a pipe or tubing material operates while in service
- **Test life –** the length of time that a pipe or tubing sample operates during testing

2.0 REFERENCED STANDARDS

Where all or part of a national or international standard specification by standards development organizations such as ASTM, CSA, ISO, or NSF is incorporated by reference in this technical note, the referenced standard shall be the latest edition and revision.

- ASTM D2837 *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*
- ASTM F876 *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*
- ASTM F2023 *Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Pipe, Tubing and Systems to Hot Chlorinated Water*
- ASTM F2657 *Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing*
- ASTM F2788 *Standard Specification for Metric and Inch-sized Crosslinked Polyethylene (PEX) Pipe*
- ASTM F3253 *Standard Specification for Crosslinked Polyethylene (PEX) Tubing with Oxygen Barrier for Hot- and Cold-Water Hydronic Distribution Systems*
- CSA B137.5 *Crosslinked Polyethylene Tubing Systems for Pressure Applications*
- EN 15632 *District heating pipes – Factory made flexible pipe systems*
- ISO 9080 *Plastics piping and ducting systems - Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation*
- ISO 10508 *Plastics piping systems for hot and cold water installations – Guidance for classification and design*
- ISO 15875 *Plastics piping systems for hot and cold water installations- Crosslinked polyethylene (PE-X)*

3.0 BACKGROUND – PEX TEST METHODS AND EVALUATION TECHNIQUES

It is a basic requirement for most plastic pressure pipes[1] to undergo a hydrostatic pressure test or tests to prove their long-term hydrostatic strength (LTHS) at various temperatures and pressures. "Hydrostatic" simply means constant water pressure inside a pipe. Hydrostatic testing involves testing multiple pipe specimens to ductile failure at various temperatures and pressures; when a dataset of failure times at multiple temperatures and pressures is generated, a ductile failure curve is plotted and evaluated mathematically. This provides a method to predict pipe endurance at the specific operating pressures for each temperature.

Procedures for conducting long-term hydrostatic testing and evaluating the results were originally developed decades ago by groups such as ASTM, ISO, and PPI's Hydrostatic Stress Board (HSB). Today, these LTHS procedures are trusted to predict the long-term hydrostatic capabilities of crosslinked polyethylene (PEX) pipe and tubing, which achieves pressure ratings at various temperatures through extensive hydrostatic strength testing in accordance with the governing standards and policies such as ASTM D2837 and PPI TR-3[2].

The long-term hydrostatic strength of a specific PEX material is independent of any outside environmental factor which could cause degradation or failure. Examples of environmental factors are oxidation from excessive thermal exposure, oxidation from excessive UV exposure, or oxidation from excessive exposure to hot chlorinated water. Therefore, in addition to LTHS testing, in North America, there are standardized testing and evaluation methods to establish the resistance of PEX pipes to oxidation that could be caused by these environmental factors.

For example, mandatory requirements within ASTM F876, ASTM F3253, ASTM F2788, and CSA B137.5 include evaluating the resistance to thermal oxidation through stabilizer functionality testing; ASTM F2657 is the test method used for evaluating the effects of outdoor weathering and ultraviolet (UV) exposure*; and ASTM F2023 is the test method used for evaluating the effects of hot chlorinated water*.

*These tests are mandatory for PEX pipe and tubing intended for potable water applications

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[1] The alternative to a long-term hydrostatic strength (LTHS) test is a long-term hydrostatic pressure-strength (LTHSp) test, usually applied to multi-layer or composite piping products.

[2] PPI TR-3 *Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Hydrostatic Design Stresses (HDS), Pressure Design Basis (PDB), Strength Design Basis (SDB), Minimum Required Strength (MRS) Ratings, and Categorized Required Strength (CRS) for Thermoplastic Piping Materials or Pipe*

3.1. Evaluation Methods for Long-term Hydrostatic Strength (LTHS)

ASTM Test Method D2837 (originally published 1969) contains a procedure for obtaining a long-term hydrostatic strength category based on stress, referred to herein as the hydrostatic design basis (HDB). According to D2837, “The HDB is a material property and is obtained by evaluating stress rupture data derived from testing pipe made from the subject material” and “The LTHS is determined by analyzing stress versus time-to-rupture (that is, stress-rupture) test data that cover a testing period of not less than 10,000 hours and that are derived from sustained pressure testing of pipe made from the subject material. The data is analyzed by linear regression to yield a best-fit log-stress versus log time-to-fail straight-line equation.”

This method utilizes tubing specimens tested at constant temperatures (e.g., 73°F, 180°F, 200°F [23°C, 82°C, 93°C]) with the linear log stress—log time regression line extrapolated to 100,000 hours (11 years). This extrapolated value is called the long-term hydrostatic strength (LTHS) and the categorized value of the LTHS is called the Hydrostatic Design Basis (HDB).

Actual failure data points *are required* to evaluate the long-term hydrostatic strength performance of the material at all temperatures.

When data is analyzed and approved by the PPI’s Hydrostatic Stress Board (HSB), these HDB values can be published in PPI TR-4 *PPI Listing of Hydrostatic Design Basis (HDB), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe*, which is available at www.plasticpipe.org.

The hydrostatic design stress (HDS) is the product of the HDB and the design factor for water, per Equation 1:

Eq. 1 **HDS = HDB x Design Factor**

The HDB for a pressure pipe material must always be determined at 73°F. It is important to note that the PEX Material Designation Code, as shown in the applicable ASTM PEX standards (see Section 4.0), is ONLY determined using the HDB at 73°F.

The *elevated temperature HDB* establishes the Hydrostatic Design Basis for the specific material at chosen higher temperatures. The procedures of ASTM Test Method D2837 are still employed, using actual test temperatures of 180°F (82°C) or 200°F (93°C) or another test temperature as desired.
Elevated temperature HDB values are published in PPI TR-4 for PEX materials which have been tested at those temperatures. Certain plumbing and mechanical codes require PEX tubing to be pressure-rated for 100 psig (gauge pressure) at 180°F, so this pressure rating is considered mandatory and is based on hydrostatic testing as described above.

Note 3: PEX listings at 200°F should be considered within the context of this Technical Note.

3.2. Stabilizer Functionality Test for Long-term Thermal Stability

Like most plastic piping materials, PEX materials include stabilizers to guard against various types of degradation. To ensure the reliability of the material in high-temperature applications, product standards ASTM F876, ASTM F3253, ASTM F2788, and CSA B137.5 require that PEX pipe or tubing undergoes the “stabilizer functionality” test to demonstrate each specific PEX material’s ability to withstand long-term high-temperature conditions.

This test requires a specific stress at a given temperature for a set amount of time. There are two (2) options for testing:

- 3,000 hour (125 day) test at 248°F (120°C) and hoop stress of 101.5 psi (0.7 MPa), or
- 8,000 hour (333 day) test at 230°F (110°C) and hoop stress of 406 psi (2.8 MPa)

This is a single time-point pass/fail test that does not generate a regression curve. It is not necessary for manufacturers to test specimens to failure, which may take thousands of hours beyond the minimum requirements.

3.3. Evaluation Methods for Outdoor Weathering Exposure (including Ultraviolet)

Each PEX pipe and tubing manufacturer publishes an ultraviolet (UV) exposure time limit for its tubing based on the UV resistance of that tube as determined in accordance with ASTM Test Method F2657 (originally published 2007) and the requirements published in ASTM F876, ASTM F3253, ASTM F2788, and CSA B137.5.

This test method outlines the requirements for specimen size and preparation, exposure orientation, minimum UV exposure energy, and post-exposure testing and reporting. Central Arizona is used as the basis of the natural exposure time limits, as it represents the worst-case North American location for UV solar radiation energy.

For PEX pipe and tubing intended for use in potable water plumbing applications, UV-exposed samples are re-tested for chlorine resistance in accordance with ASTM F2023 and must show no significant reduction in the extrapolated time-to-failure. For pipe and tubing *not intended* for use in potable water applications, such as those intended for heating or geothermal applications, UV-exposed samples are re-tested according to the stabilizer functionality test in accordance with ASTM F876 and must show no significant reduction in the resistance to long-term high-temperature conditions.

ASTM F2657 ensures that all manufacturer claims of UV-resistance are evaluated in a consistent manner which is empirically derived.

3.4. Evaluation Methods for Oxidative Resistance to Potable Hot Chlorinated Water

To ensure the reliability of PEX pipe or tubing systems in potable hot chlorinated water applications, product standards ASTM F876, ASTM F2788, and CSA B137.5 require that all PEX tubing intended for use with potable water have a minimum extrapolated time-to-failure when tested in accordance with ASTM Test Method F2023 (originally published in 2000). The minimum extrapolated time-to-failure is 50 years, when evaluated at various operating conditions.

Note 4: See PPI TN-53 *Guide to Chlorine Resistance Ratings of PEX Pipes and Tubing for Potable Water Applications* for more information on the use of PEX tubing in hot chlorinated potable water applications.

4.0 THE PEX MATERIAL DESIGNATION CODE

The PEX Material Designation Code, per the applicable ASTM standards, is the abbreviation for the material - PEX - followed by four digits.

The first digit refers to chlorine resistance in one of four categories, when tested in accordance with ASTM Test Method F2023 and evaluated in accordance with the applicable ASTM product standard (e.g., F876):

- A digit “0” indicates the PEX pipe or tubing either has not been tested for chlorine resistance or does not meet the minimum requirement for chlorine resistance.
- 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% of the time at 73°F (23°C).
- A digit “3” indicates 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% of the time at 73°F (23°C).
- A digit “5” indicates 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).

Digits “2” and “4” are reserved for potential future categories.

The second digit refers to UV resistance in one of four categories, when tested in accordance with ASTM Test Method F2657 and evaluated in accordance with ASTM F876:

- A digit “0” indicates the PEX tubing either has not been tested for UV resistance or does not meet the next category for UV resistance.
- A digit “1” indicates the PEX tubing meets the requirements for 1 month UV resistance.
- A digit “2” indicates the PEX tubing meets the requirements for 3 months UV resistance.
- A digit “3” indicates the PEX tubing meets the requirements for 6 months UV resistance.

Testing for chlorine resistance and outdoor weathering resistance (UV) is not required for non-potable applications. A digit of “0” for either of those properties is acceptable for non-potable applications. The minimum designation code for PEX tubing for many non-potable applications is “0006”.

The third and fourth digits of the PEX Material Designation Code refer to the Hydrostatic Design Stress (HDS) for water at 73°F in hundreds of psi, with tens and units of measure omitted (e.g., 630 psi = “06”).

Examples of PEX material designation codes are shown below:

- PEX0006 - No chlorine rating, no UV rating, 630 psi HDS rating
- PEX1206 - Code “1” for chlorine, Code “2” for UV, 630 psi HDS rating
- PEX3106 - Code “3” for chlorine, Code “1” for UV, 630 psi HDS rating
- PEX5306 - Code “5” for chlorine, Code “3” for UV, 630 psi HDS rating

5.0 PEX MATERIALS IN APPLICATIONS WITH INTERMITTENT USE AT TEMPERATURES ABOVE 180°F AND UP TO 200°F

Certain applications of PEX pipes in heating systems may expose the material to temperatures up to 180°F for a limited number of hours per year, and the remainder of their lifetime at lower temperatures. Even a high-temperature (e.g., 180°F) radiator heating system is highly unlikely to operate 100% of the time, due to intermittent heating demand and temperature cycling.

Many modern hydronic heating systems operate at a range of fluid temperatures, rather than always operating at their highest temperature, to increase system efficiency and reduce operational cycling, using a heating control strategy known as outdoor reset control, whereby the supply fluid temperature is “reset” and modulated based on outdoor air temperature and heating demand.

The most demanding hydronic heating or energy transfer systems may operate at temperatures above 180°F and up to 200°F for a limited number of hours per year, when heating demand is at its highest or peak level.

For PEX materials to demonstrate the capability to withstand intermittent operation at temperatures above 180°F and up to 200°F, they must be tested for two separate capabilities: stabilizer functionality and sustained operation at 200°F.

The mandatory stabilizer functionality test is a single time-point test (3,000 or 8,000 hours, depending upon selected test temperature and stress; see Section 3.2) that verifies the resistance of a PEX material to thermal degradation for a minimum time duration. These test requirements were developed to demonstrate that a PEX material will meet or exceed the expected exposure to temperatures at or above 180°F over a typical design life without thermal oxidative failure.

Certain brands of PEX tubing are listed with the PPI HSB or other third-party certification agencies according to ASTM D2837 and/or PPI TR-3 for operation at 200°F and may have "**80 psi at 200°F**" marked on the tubing. Such a listing indicates suitability for intermittent use at temperatures above 180°F and up to 200°F. However, a marking of "**80 psi at 200°F**" on the pipe **does not mean** that the PEX material is intended for continuous operation at temperatures up to 200°F. In fact, operating PEX at continuous temperatures above 180°F could impact its service life.

Since some hydronic heating systems will operate intermittently at temperatures up to 200°F, typical temperature distribution profiles have been established to approximate the operation over a typical design lifetime (e.g., 50 years) of the PEX material.

These temperature distribution profiles are established by ISO 15875 (and by reference ISO 10508) and EN 15632, which establish the design life at 50 years and 30 years, respectively. These standards show different temperature distribution profiles (shown as classes) that represent different applications where the piping system is anticipated to operate at different temperatures over its intended lifetime. Each of the classes represents a different temperature profile (see ISO 10508 for further information) based on a specific application (e.g., district heating, radiant floor heating, high temperature radiators). Typical temperature distribution profiles can be seen in **Table 1** and **Table 2** of **Appendix A**.

However, if PEX pipe is intended to be used in an application operating above 180°F and up to 200°F continuously, then further evaluation of the thermal oxidative resistance of the pipe needs to be taken into consideration in accordance with Section 6.0 of this Technical Note. This is a design process that the pipe manufacturer can perform based on specific test data for their material.

In addition, PEX pipe or tubing should not be installed in a heating system that is designed to operate at temperatures above 200°F for any duration of time.

6.0 PEX MATERIALS IN APPLICATIONS WITH CONTINUOUS USE AT TEMPERATURES ABOVE 180°F AND UP TO 200°F

For hydronic applications of PEX pipe with continuous use at temperatures above 180°F and up to 200°F, further evaluations are required to predict the pipe's service life.

ISO 9080 has a standard extrapolation method that is used for establishing a maximum extrapolation time of a pipe material for operating at temperatures above 180°F and up to 200°F. This extrapolation is calculated from the Arrhenius equation [Equation 2] which uses the long-term, high-temperature test data and the activation energy of the material.

Eq. 2

$$k = Ae^{\frac{-E_a}{RT}}$$

where:

- *k* = rate constant (frequency of collisions resulting in a reaction)
- *T* = absolute temperature
- *A* = pre-exponential factor or Arrhenius factor or frequency factor. Arrhenius originally considered A to be a temperature-independent constant for each chemical reaction. However more recent treatments include some temperature dependence
- E_a = molar activation energy for the reaction
- *R* = universal gas constant

This guideline for determining the design life of a PEX material requires an evaluation of the failure times for the specific PEX material through a long-term, high-temperature hydrostatic test. For such extrapolations, PEX pipe must be tested at a temperature above the intended service temperature, until brittle failure occurs. To determine the design life, pipe samples are tested until Stage III oxidative (i.e., brittle) failures occur; this testing demonstrates the ultimate resistance of the PEX material to thermal oxidative failure.

This testing may take thousands of hours beyond the standard minimum number of test hours required in the ASTM F876 stabilizer functionality test, for example.

After the samples have been tested to failure, the k_e extrapolation factor from ISO 9080 is used to determine the maximum extrapolation time limit of the tubing. The k_e extrapolation factor is a function of the difference between the test temperature (e.g., 110°C [230°F]) and the design temperature of the specific application, (e.g., 88°C [190°F]) in degrees Celsius. **Table 3** of **Appendix B** shows the different extrapolation time limits for PEX pipe based on testing at 230°F and theoretical failure times of 8,000 hours, 12,000 hours, and 16,000 hours.

This type of high-temperature evaluation is very specific to the test data of each PEX material, which is proprietary information to the pipe or tubing manufacturer; all PEX pipe or tubing will not have the same estimated service or design life at a given operating condition. Each pipe or tubing manufacturer must do this calculation on their own, based on their own exclusive dataset.

Therefore, for continuous-use, high-temperature applications operating at temperatures above 180°F and up to 200°F, users should contact the specific PEX pipe or tubing manufacturer to determine whether such conditions are approved for use, and if so, what the effects may be on the pipe or tubing service life.

See **Appendix B** for examples of the impact of continuous high temperatures on specific materials' design lives.

7.0 SUMMARY

PEX pipe and tubing that conforms with ASTM F876, F2788, F3253, and CSA B137.5 has the ability to operate continuously at a pressure up to 100 psi at 180°F or lower, based on mandatory test requirements found within those product standards.

PEX pipe and tubing that is listed as "standard grade" for operation at 200°F and is listed with a pressure rating of 80 psi at 200°F has the ability to operate at temperatures above 180°F and up to 200°F in intermittent operation as described in Section 5.0 of this technical note. For **continuous** use at temperatures above 180°F, PEX pipe must be evaluated in accordance with Section 6.0 of this TN to determine its ability to resist thermal oxidation in these applications.

PEX pipe should not be installed in a heating system that is designed to operate at temperatures **above 200°F** for any significant duration of time.

For PEX piping systems which are intended to operate continuously at temperatures above 180°F and up to 200°F, the specific pipe or tubing manufacturer must be contacted to determine whether such conditions are approved for use, and if so, what may be the effects on material design life.

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

Appendix A – Background Information for Calculating Predicted Design Life based on a Temperature Profile Distribution per Section 5.0

ISO 15875 *Plastics piping systems for hot and cold water installations-Crosslinked polyethylene (PE-X)* defines PEX pipe for hot- and cold-water installations. Identified within this ISO standard are multiple classes of PEX for specific applications, each having their own Miner's Rule calculation to justify the 50-year anticipated design life.

These classes may be thought of as "temperature distribution profiles" based on the anticipation of the accumulated exposures within a pipe's lifetime. In other words, it is assumed that an installed PEX pipe or tubing will be exposed to combinations of temperature exposures no worse than those indicated in the tables below for Class 1 to 5.

For instance, a Class 5 pipe is anticipated to be exposed to the various temperatures shown in **Table 1** for the accumulated service times at each of those temperatures. This is based on how a "high-temperature radiator" piping system would actually be used over a typical 50-year period.

ASTM Standards F876, F3253, F2788, and CSA B137.5 do not utilize such temperature profile assumptions. However, North American PEX manufacturers with full datasets for each of the tests described within this Technical Note can calculate expected design lives for their PEX products at given pressure and temperature conditions.

Table 1 shows the different classes and their accumulated service times at each temperature.

Table 1: ISO 15875 Classification Tables using Miner's Rule

Class 1: Hot water supply (140°F)	
Temperature °F	Accumulative Service Time Years
140	49
Followed by	
176	1
Followed by	
203*	100 hours

Class 2: Hot water supply (158°F)	
Temperature °F	Accumulative Service Time Years
158	49
Followed by	
176	1
Followed by	
203*	100 hours

Class 4: Underfloor heating and low temperature radiators	
Temperature °F	Accumulative Service Time Years
68	2.5
Followed by	
104	20
Followed by	
140	25
Followed by	
158	2.5
Followed by	
212*	100 hours

Class 5: High-temperature radiators	
Temperature °F	Accumulative Service Time Years
68	14
Followed by	
140	25
Followed by	
176	10
Followed by	
194	1
Followed by	
212*	100 hours

*As demonstrated through the excessive pressure-temperature test found with ASTM F876, F2788, F3253, and CSA B137.5, PEX tubing has the capability to operate at temperatures slightly above 200°F for short durations of time, including short-term exposure of up to 100 hours with operating temperatures up to 203°F or 210°F, as anticipated in the classes evaluated within ISO15875.

EN 15632 *District heating pipes-Pre-insulated flexible pipe systems* defines pre-insulated pipe for district heating applications. Identified within this EN standard is a class system using Miner's Rule calculation to justify a 30-year anticipated design life at higher operating temperatures than anticipated in ISO 15875.

The table below shows a summary of this class and the accumulated service time at each temperature.

Table 2: EN 15632 Classification Table using Miner's Rule

Temperature °F	Accumulative Service Time Years
176	29
Followed by	
194	1
Followed by	
203*	100 hours

Appendix B – Background Information for Calculating Predicted Design Life per Section 6.0

The examples in **Table 3** show the maximum extrapolation time limits for different temperatures when testing has been performed at 230°F (110°C) for 8,000 hours, 12,000 hours, and 16,000 hours. The test data shown below is a theoretical example that does not reflect the capabilities of a particular PEX formulation. Each manufacturer is responsible for generating their own test data to predict design life for their materials/s in various applications.

Table 3: Extrapolation Factor (k_e) Applied for Multiple Test Times of PEX Tubing

	Test data for 8,000 hours		Test data for 12,000 hours		Test data for 16,000 hours	
Continuous Operating Temperature °F	Test Time (hours)	Maximum Extrapolated Design Life in Years	Test Time (hours)	Maximum Extrapolated Design Life in Years	Test Time (hours)	Maximum Extrapolated Design Life in Years
165	8,000	33.1	12,000	49.7	16,000	66.2
175	8,000	18.2	12,000	27.2	16,000	36.3
185	8,000	10.2	12,000	15.2	16,000	20.3
195	8,000	5.8	12,000	8.7	16,000	11.6
200	8,000	4.4	12,000	6.6	16,000	8.8

Note 5: The k_e extrapolation factors in **Table 3** were derived using the Arrhenius equation in the same manner as **Table 1** in ISO 9080. However, the values in **Table 3** above were not categorized as they are in **Table 1** of ISO 9080. Instead, the values shown in **Table 3** were specifically calculated for the temperatures shown in the table.

Example of Predicting Service Life for Continuous Use Applications for Theoretical PEX Materials

A university campus is installing an underground district heating system that will operate continuously at 195°F (90°C) to supply hot water for hydronic heating systems in various buildings.

- *PEX Manufacturer X* has tested their PEX at 230°F (110°C) for 8,000 hours as required by the ASTM stabilizer functionality test, and then stopped the test without failures. *PEX Manufacturer X* is able to extrapolate the design life of their pipe to **5.8 years** at **195°F**, as test data is only available to 8,000 hours.
- *PEX Manufacturer Y* has tested their PEX at 230°F (110°C) until failure, which happened to be at 16,000 hours (approximately 2 years). *PEX Manufacturer Y* can extrapolate the design life of their PEX to **11.6 years** at **195°F** based on the test data and the ISO 9080 evaluation.