

Ultraviolet (UV) Resistance of PEX Tubing

A presentation by
The Plastics Pipe Institute



Contact

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The Plastics Pipe Institute

PPI Represents All Sectors of the Plastic Pipe Industry

- PPI was formed in 1950 to research and develop test methods for plastic pressure pipes
- Today: Non-profit trade association serving North America, based in Irving, TX

PPI Mission: To advance the acceptance and use of plastic pipe systems through research, education, technical expertise, and advocacy

Members: Over 170 member firms involved with the plastic pipe industry

PPI Website: www.plasticpipe.org

The Plastics Pipe Institute

PPI Building & Construction Division (BCD)

- BCD is focused on plastic pressure pipe and tubing systems used within buildings and on building premises for applications such as plumbing, water service, building supply, fire protection, hydronic heating & cooling, snow & ice melting, district energy heating & cooling, and ground source geothermal piping systems.

BCD Materials: CPVC, HDPE (Geothermal), PEX, PE-RT, PEX-AL-PEX, and PP (PP-R & PP-RCT)

BCD homepage: <https://plasticpipe.org/BuildingConstruction>



Ultraviolet (UV) Resistance of PEX Tubing

Outline

1. Introduction to PEX tubing systems for plumbing applications
2. Effects of UV exposure on PEX tubing – Potential threats
3. PEX plumbing system standards and code compliance
4. Evaluating UV Resistance with ASTM Test Method F2657
5. PPI PEX Labeling Guidelines for UV resistance



1. Introduction to PEX Tubing Systems for Plumbing

Overview

- PEX was introduced for radiant heating in the early 1970s in Europe
- Introduced to USA and Canada in 1980s* for heating and plumbing systems
- PEX is a high-temperature flexible pressure piping system
- PEX tubing systems are used for water service lines, building supply lines, hot- and cold-water distribution, radiant heating & cooling, snow & ice melting, residential fire protection, geothermal ground loops, turf conditioning, district energy and other demanding applications



**[ASTM F876](#), the original PEX tubing standard, was first published in 1984*

Introduction to PEX Tubing Systems for Plumbing

Crosslinked Polyethylene (PEX) Definition

- Formal Definition – “PEX is a polyethylene material that has undergone a change in molecular structure through processing whereby a majority of the polymer chains are chemically linked.”

Source: [ASTM F412](#), [ASTM F876](#)

- “Crosslinking of polyethylene into PEX for pipe and tubing results in improved properties such as elevated temperature strength and performance, chemical resistance, flexibility, and resistance to slow crack growth.” *Source: PPI Technical Note 17*

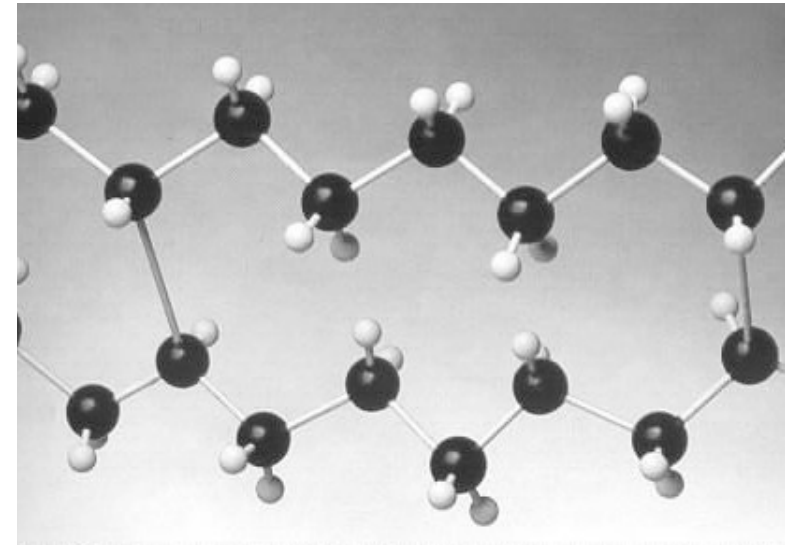


Illustration of a “PEX molecule”

Introduction to PEX Tubing Systems for Plumbing

PEX Tubing Configurations

- PEX tubing is produced in nominal tubing sizes from **3/4** to **4** (copper tube size)
- PEX tubing is available in natural (white) or colors such as red, white, and blue
- PEX tubing is available in coils or straight lengths, depending on the customer preference and application



Courtesy BOW



*Courtesy
REHAU*

Introduction to PEX Tubing Systems for Plumbing

PEX Tubing Production Methods

The three common methods of crosslinking polyethylene into PEX are known as:

- **Peroxide (PEX-a):** *This method employs organic peroxides that generate reactive free radicals that splice PE chains together during extrusion*
- **Silane (PEX-b):** *Involves grafting a reactive silane molecule to the backbone of the polyethylene; crosslinking reaction is completed during moisture-curing in a steam “sauna” or hot-water bath*
- **Electron beam (PEX-c):** *Involves subjecting the extruded PE pipe to a dose of high-energy electrons*
- Letter designations are not related to any type of performance rating system; based on chronological dates
- PEX tubing produced by each of these methods must meet the same technical requirements as specified in the relevant industry standards (e.g., ASTM, AWWA, CSA) and codes (e.g., IPC, NPC, NSPC, UPC)

See [PPI Technical Note 17](#) for more details about each method

Introduction to PEX Tubing Systems for Plumbing

Advantages of PEX Plumbing Systems

- Safety of potable water and long-term reliability
- Resistance to scale and mineral buildup
- Smooth wall, excellent flow characteristics
- Resistance to corrosion, erosion, water disinfectants
- Quiet operation, absorbs pressure surges (water hammer)
- Many fitting and joining options; no flame risk
- Flexibility to facilitate faster installations
- Potential for reduced installation costs
- Better heat retention, less condensation
- Freeze-break resistance (see PPI TR-52)
- Water conservation is assisted with reduced heat loss
- Proven long life, rigorous certifications, highly tested

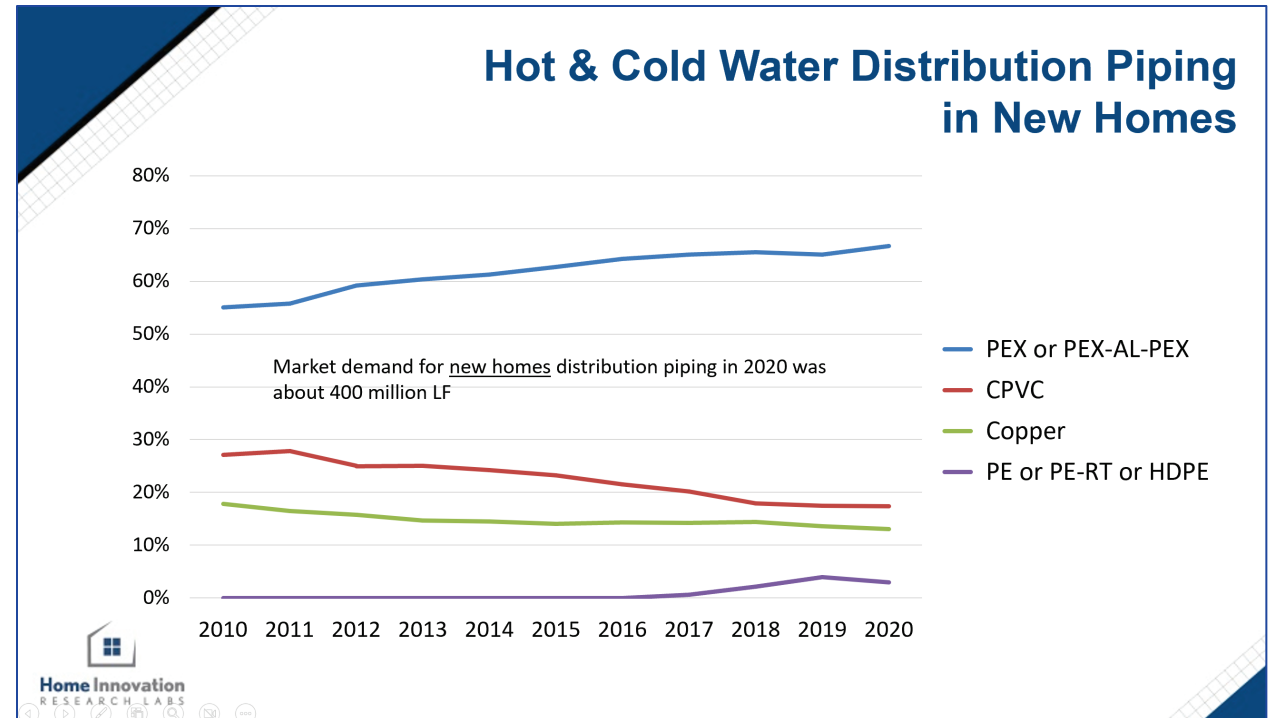


Introduction to PEX Tubing Systems for Plumbing

PEX is a Proven Success

- Since 1997, the usage of PEX tubing in residential plumbing (US) has steadily increased to **over 60%**

- Source: HIRL Builders Practices Report, Sept. 2021



2. Effects of UV Exposure on PEX – Potential Risks

Physical Effects of Excessive Sunlight / Ultraviolet (UV) Exposure

- The long-term performance of PEX can be damaged by excessive **ultraviolet (UV) radiation** from sunlight, especially when tubing is then used in chlorinated hot-water systems after exposure
- **Excessive** UV exposure may make the PEX tubing become more susceptible to oxidative failure when exposed to hot chlorinated water
- **Excessive** ultraviolet (UV) radiation exposure has the potential to reduce the lifetime of PEX tubing

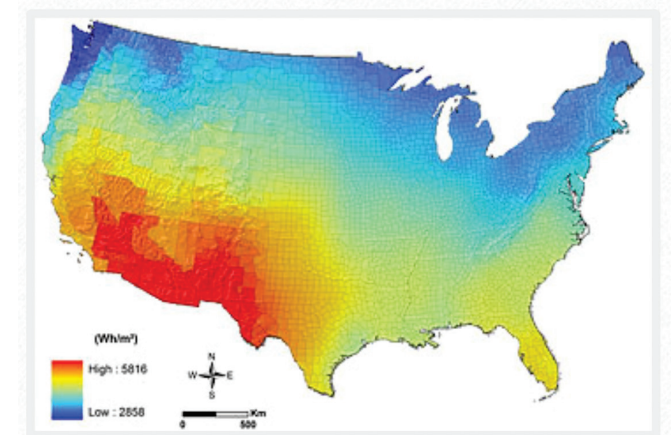
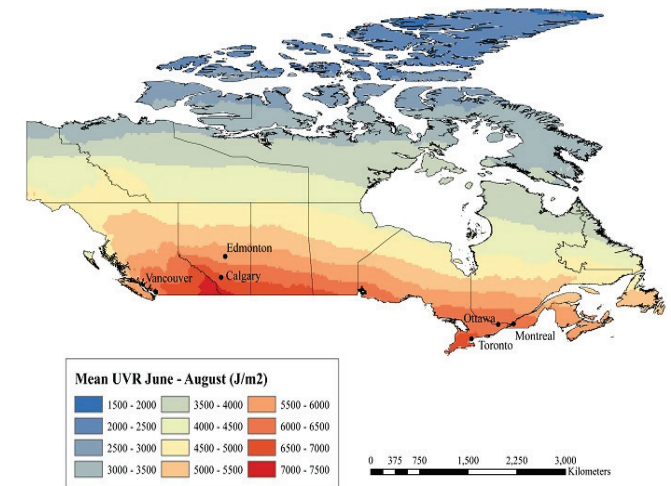
From ASTM F876:

- *3.2.7.3 Discussion – “PEX tubing is not designed for outdoor use. Data from short-term exposure testing in accordance with this test method can be used to judge the relative performance of PEX tubing stored outdoors for short periods of time prior to installation completely shielded from sunlight”*

Effects of UV Exposure on PEX – Potential Threats

UV Exposure: Varying Intensity Across North America

- Actual UV intensity varies greatly across the US and Canada
- The risk of UV overexposure varies based on location
- Example Map (Canada): *Mean ultraviolet radiation for June through August, Canada, 1980-1990*
- <https://www150.statcan.gc.ca/n1/daily-quotidien/170517/mc-b001-eng.htm>
- Example Map (US): *County Level UV Exposure Data for the Continental United States*
- <https://gis.cancer.gov/tools/uv-exposure/>



Effects of UV Exposure on PEX – Potential Threats

Excessive Sunlight / Ultraviolet (UV) Exposure due to Outdoor Storage

- PEX should not be stored outdoors or installed with excessive exposure to sunlight

Solution:

- Wholesalers and installers should keep PEX tubing stored indoors in the original packaging prior to installation, for protection against UV/ sunlight and other potential hazards

Storing PEX tubing outdoors is not permitted!



Effects of UV Exposure on PEX – Potential Threats

Excessive Sunlight / Ultraviolet (UV) Exposure due to Outdoor Installation

- PEX should not be stored outdoors or installed with excessive exposure to sunlight

Solution:

- Installers need to sleeve PEX tubing when installed outdoors to protect it against UV/sunlight and other potential hazards

Direct outdoor exposure is not permitted!



Effects of UV Exposure on PEX – Potential Threats

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Solution:

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Effects of UV Exposure on PEX – Potential Threats

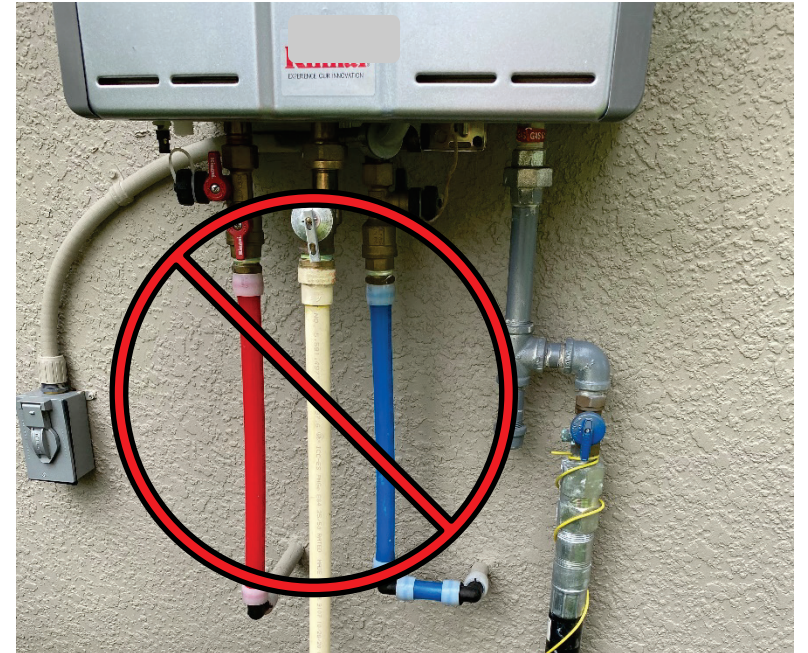
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Direct outdoor exposure is not permitted!



Effects of UV Exposure on PEX – Potential Threats

Excessive Sunlight / Ultraviolet (UV) Exposure due to Delays in Construction

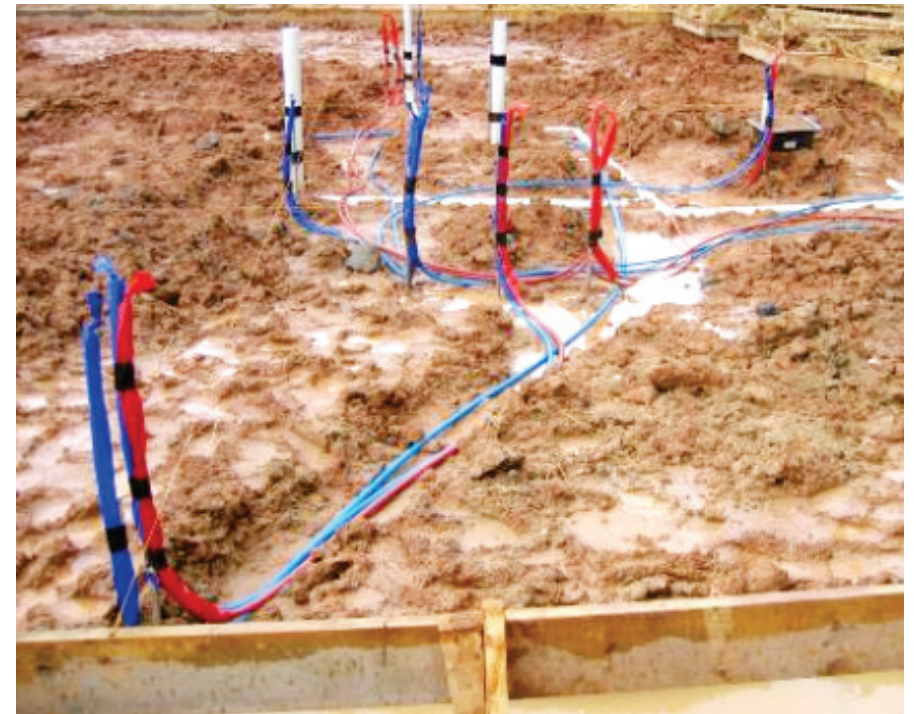
- Installed tubing should not be left exposed due to bad weather or other unforeseen construction delays

Solution:

- Installers need to cover installed PEX tubing with UV-blocking material (e.g., an opaque tarp or bags) if construction delays may result in excessive exposure time



If these plumbing pipes are not embedded in concrete within the approved UV exposure time, they should be covered with protective tarps



Effects of UV Exposure on PEX – Potential Threats

Excessive Sunlight / Ultraviolet (UV) Exposure due to Delays in Construction

- Installed tubing should not be left exposed due to bad weather or other unforeseen construction delays

Solution:

- Installers need to cover installed PEX tubing with UV-blocking material (e.g., an opaque tarp or bags) if construction delays may result in excessive exposure time



If these radiant heating pipes are not embedded in concrete within the approved UV exposure time, they should be covered with protective tarps



Protecting PEX Against UV Exposure – Solutions

Creating a UV-resistant PEX tubing material is achieved through various methods:

- Formulations: Add UV Stabilizers or carbon black into the PEX compound (material)
- Special stabilizers can inhibit degradation of the polymer by continuously and cyclically removing free radicals that are produced by photo-oxidation of the polymer



Courtesy Viega

Protecting PEX Against UV Exposure – Solutions

Creating a UV-resistant PEX tubing material is achieved through various methods:

- Coatings: Add UV-blocking and UV-absorbing barrier layers to the exterior of the PEX wall to protect the tubing itself

In section 4 of this presentation, we'll explain how the UV resistance of PEX tubing is measured and evaluated using an ASTM test method



Courtesy REHAU

3. PEX Plumbing System Standards and Code Compliance

PEX Tubing and System Standards

- There are three primary standards for PEX tubing and systems in North America:
 - ASTM F876 *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*
 - ASTM F877 *Standard Specification for Crosslinked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems*
 - CSA B137.5 *Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications*
- Model plumbing codes such as IPC, NSPC, UPC, and the NPC of Canada refer to these standards



PEX Plumbing System Standards and Code Compliance

PEX Tubing Standards

- ASTM F876 and CSA B137.5 establish capabilities and test requirements for tubing, such as:
 - Dimensions
 - Degree of crosslinking
 - Quick burst pressures
 - Long-term pressure ratings
 - Chlorine resistance
 - **Outdoor weathering and UV resistance**
 - Excessive pressure-temperature capability
 - Hot-bend and cold-bend tests
 - Marking requirements
 - Even more...



PEX Plumbing System Standards and Code Compliance

Three Key PEX Tubing Properties with Categories for Performance

1. Chlorine Resistance
2. Outdoor Weathering Exposure (UV) Resistance
3. Hydrostatic Design Stress (HDS), related to pressure ratings

- Performance categories are defined in [ASTM F876 TABLE 1](#) “Thermoplastic Tubing Material Designation Code Cells for SDR9 PEX”



F876 – 22a

TABLE 1 Thermoplastic Tubing Material Designation Code Cells for SDR9 PEX

	PEX	1	1	0	6
Material	↑				
Chlorine Resistance (75% at 73°F and 25% at 140°F)		↑			
Minimum UV Resistance (1 month)			↑		
HDS at 23°C (630 psi)				↑	↑

PEX Plumbing System Standards and Code Compliance

Mandatory Chlorine and Outdoor Weathering/UV Resistance

- ASTM F876 requires minimum digit of ‘1’ for chlorine resistance for all PEX intended for potable water (6.9)
- ASTM F876 requires minimum digit of ‘1’ for UV resistance for all PEX intended for potable water (6.10)

- In other words, ASTM F876 requires a minimum **1-month** UV resistance for all PEX intended for potable water (PEX material code of ‘**1106**’)

- *Excerpt from **ASTM F876-22a**:*

6.9 Oxidative Stability in Potable Chlorinated Water Applications—PEX tubing intended for use in the transport of potable water shall have a minimum extrapolated time-to-time failure of 50 years and comply with the requirements for a first digit of “1” or higher in the PEX Tubing Material Designation Code when tested and evaluated in accordance with **7.11**.

6.10 Oxidative Stability in Outdoor Weathering Exposure (UltraViolet)—PEX tubing intended for use in the transport of potable water shall comply with the requirements for a second digit of “1” or higher in the PEX Tubing Material Designation Code when tested and evaluated in accordance with Test Method **F2657** where the decreased average failure time is less than or equal to 21 %.

4. Evaluating UV Resistance using ASTM F2657

ASTM Test Method F2657

- ASTM Standard Test Method F2657 provides PEX manufacturers with a recognized test method for establishing proven UV resistance
- First published in 2007
- Latest edition 2021



Designation: F2657 – 21

Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing¹

This standard is issued under the fixed designation F2657; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method describes the procedure for exposing crosslinked polyethylene (PEX) tubing produced in accordance with Specification F876 to natural (sunlight) ultraviolet (UV) radiation and evaluating the effects of the exposure. This test method outlines the requirements for specimen size and preparation, exposure orientation, minimum UV exposure energy, post exposure testing and reporting.

2. Referenced Documents

- 2.1 *ASTM Standards*:²
- D1435 Practice for Outdoor Weathering of Plastics
 - D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
 - D1600 Terminology for Abbreviated Terms Relating to Plastics
 - F412 Terminology Relating to Plastic Piping Systems
 - F876 Specification for Crosslinked Polyethylene (PEX) Tubing

Evaluating UV Resistance using ASTM F2657

UV Resistance: Evaluation using ASTM F2657

- UV resistance of PEX is evaluated according to ASTM Test Method F2657
- Natural exposure is based on worst-case North American location near **Phoenix, AZ**
- 3.2.6.1 Discussion - *UV Energy for Central Arizona was selected as it represents the worst-case North American location based on a 4-year average of 1998 through 2001. This information was provided by Atlas Material Testing Technology LLC. (ASTM F2657)*



Evaluating UV Resistance using ASTM F2657

UV Resistance: Evaluation using ASTM F2657

- UV resistance of PEX is evaluated according to ASTM Test Method F2657
- Test samples must be exposed to **Total UV (TUV) Energy** as defined in **Table 1**

- Required UV exposures are based on historical values

- Each month of the year is different

- A month in Phoenix may be equivalent to 2 to 3 months in other locations (e.g., a northern location)

- *See Table 1 of F2657*

Nominal Exposure Time Period	TUV Solar Radiation MJ/m ²	Highest Consecutive UV Month Range
1 month	40	June
2 months	80	May-June
3 months	119	May-July
4 months	154	May-August
5 months	187	April-August
6 months	218	April-September
7 months	246	March-September
8 months	270	March-October
9 months	289	February-October
10 months	307	February-November
11 months	324	January-November
12 months	339	January-December

^ASolar UV radiation is based on Central Arizona 5° off horizontal for the 4 year period of 1998 through 2001 as reported by Atlas and Testing and Technology LLC.

Evaluating UV Resistance using ASTM F2657

UV Resistance: Evaluation using ASTM F2657

- PEX tubing samples are mounted outdoors, facing **South**
- Samples are left outdoors until the desired amount of UV exposure is accumulated (e.g., 30 days, 90 days)
- The actual UV exposure is measured daily for each set of test samples
- Outdoor weathering is also an aspect of this text

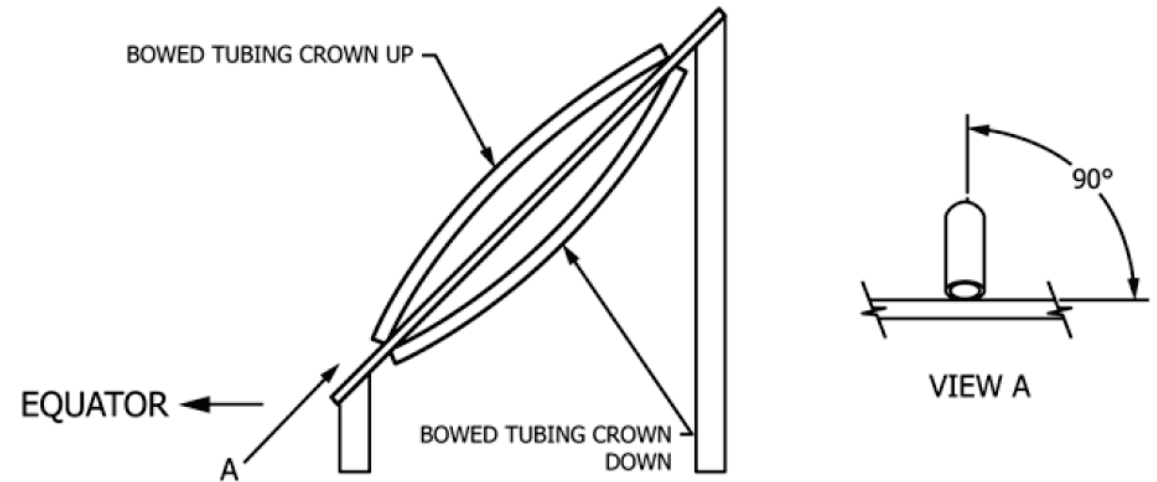


FIG. 2 Bowed Tubing Racking

Fig. 2 from ASTM F2657

Evaluating UV Resistance using ASTM F2657

UV Resistance: Evaluation using ASTM F2657

- After exposure, chlorine testing (using ASTM F2023) is performed on exposed samples to detect any degradation in performance, as compared with new tubing that was not exposed to sunlight
- Each PEX tubing manufacturer must have its tubing tested and evaluated according to ASTM F2657

Sec. 9 from ASTM F2657

9. Post UV-Exposure Testing

9.1 Test UV-Exposed Specimens generated in Section 8 to either 9.2 or 9.3. When required, test non UV-exposed specimens in accordance with 9.4.

9.2 *Oxidative Resistance Testing to Test Method F2023*—test the exposed specimens at one temperature and pressure condition in accordance with Test Method F2023. Test all specimens to failure. All failures shall be Stage III brittle oxidative failures. See Specification F876.

Evaluating UV Resistance using ASTM F2657

UV Resistance: Four (4) Categories of Performance

- ASTM F876 defines four levels of UV performance:

0 = Not tested or not rated

1 = 1 month minimum UV resistance

2 = 3 months minimum UV resistance

3 = 6 months or more minimum UV resistance

- Digit '**1**' is the **Minimum** requirement for PEX plumbing tubing according to ASTM F876

*Portion of Table 1
from ASTM F876*

Property	Standard	0	1	2	3	4	5	6	7	8	9
Chlorine Resistance	F2023	Not tested or rated	75 % at 73°F and 25 % at 140°F	Reserved	50 % at 73°F and 50 % at 140°F	Reserved	100 % at 140°F	...	...	...	...
Minimum UV Resistance	F2657	Not tested or rated	1 month	3 months	6 months	...	...	...	...	...	...

Evaluating UV Resistance using ASTM F2657

Achieving UV Resistance Certification for PEX Tubing (Example):

- If *Manufacturer X* wants to claim **6-month UV resistance** for their blue potable PEX, they must:

1. Submit the blue potable PEX samples to test lab (e.g., third-party certifier)
2. Lab exposes samples to UV exposure equivalent to **6 months radiation** (218 MJ) according to F2657
3. After exposure, lab performs chlorine testing on samples to ensure that performance is maintained, as compared with *unexposed* samples of the same PEX material
4. If chlorine test result is satisfactory, then **6-month** UV resistance claim is verified



That PEX would earn a '3' for UV Resistance in the **Material Designation Code** (e.g., "x306")

5. PPI PEX Labeling Guidelines

PPI TN-32 *UV Labeling Guidelines for Crosslinked Polyethylene (PEX) Tubing and Pipe*

- PPI TN-32 provides recommended UV labeling guidelines for PEX manufacturers
- *Originally published in 2004, latest edition 2017*
- **Sample label language:**

CAUTION

- The long-term performance of PEX will be damaged by excessive UV radiation from sunlight.
- Do not store unprotected PEX outdoors.
- Keep PEX stored indoors in the original packaging prior to installation for protection against UV/sunlight and other potential hazards.
- To prevent UV damage, ensure that exposure to sunlight during installation does not exceed the maximum recommended UV exposure time of **X** days.
- UV damage is not visible to the naked eye, but will degrade the material and may reduce its service life.



UV Labeling Guidelines for
Crosslinked Polyethylene (PEX)
Tubing and Pipe

TN-32

2017

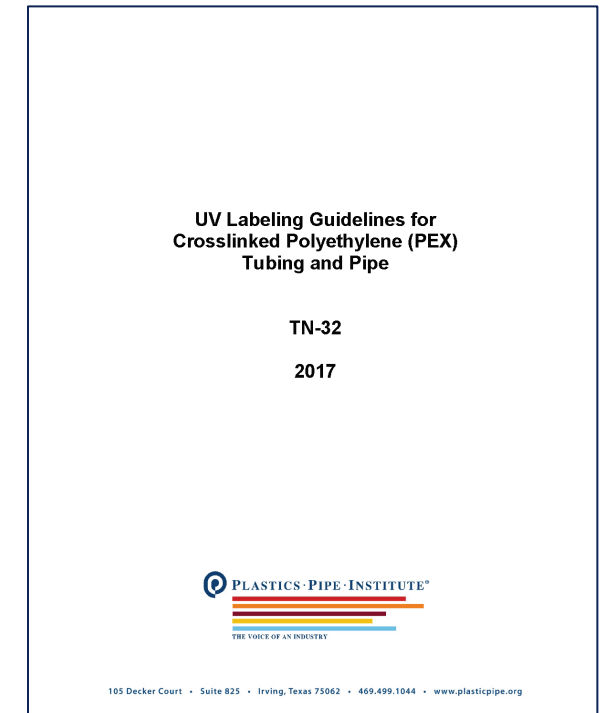
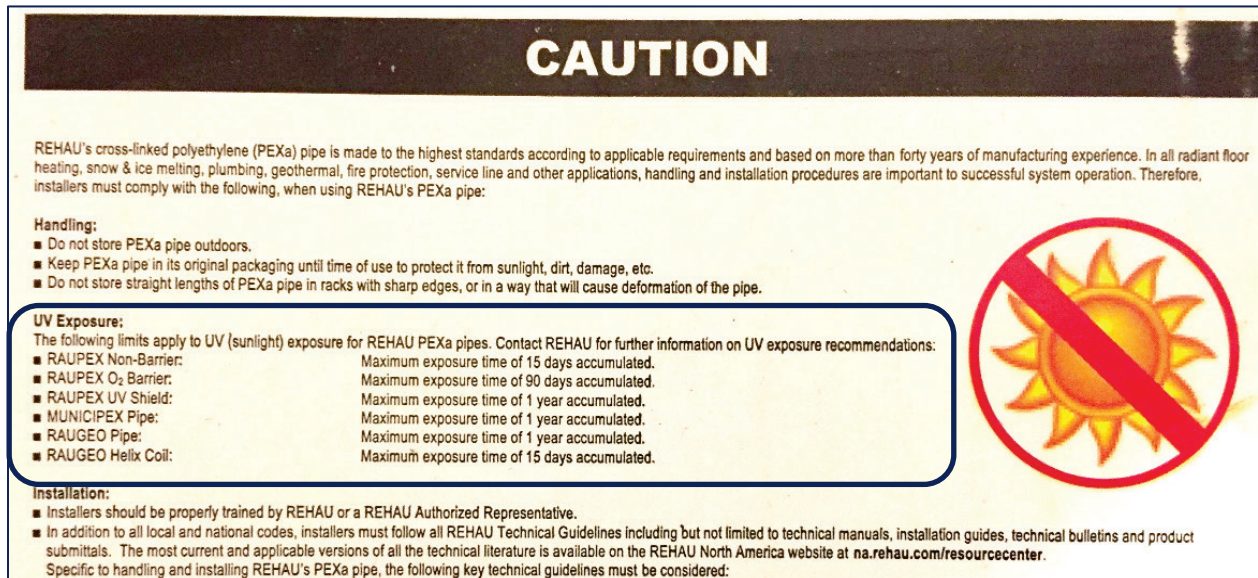


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PPI PEX Labeling Guidelines

PPI TN-32 *UV Labeling Guidelines for Crosslinked Polyethylene (PEX) Tubing and Pipe*

- PPI TN-32 provides recommended UV labeling guidelines for PEX manufacturers
- *Originally published in 2004, latest edition 2017*
- **Actual example of “UV Caution label” on PEX packaging:**



Additional Information

More PEX Plumbing Information

- See **PEX Plumbing DESIGN GUIDE**
- **Ch. 3** educates about the need for UV caution

Free download:

- PPI Building & Construction Division
www.plasticpipe.org/buildingconstruction
- Home Innovation Research Labs
www.homeinnovation.com

Chapter 3 – MATERIAL PROPERTIES

Ultraviolet (UV) Resistance

Like most plastics, the long-term performance of PEX is affected by exposure to sunlight. Although most PEX pipes have some UV resistance, they are not intended for use outdoors where they are exposed to the sun. PEX pipes should be used indoors unless they are buried in earth or properly protected from direct sunlight.

Indirect (diffused) and reflected sunlight also emit UV radiation. This radiation can be blocked by blocking sleeve or pipe insulation as approved by the manufacturer.

Each PEX pipe manufacturer publishes a maximum recommended UV exposure time based on the UV resistance of that pipe as determined by testing to ASTM Test Method F2657 and the requirements published in the Material Designation Code. The basis of the exposure time limits, as it represents the maximum recommended UV exposure time for UV energy. Exposed pipes are then re-tested to ASTM F2023 and must show no significant reduction in pipe strength.

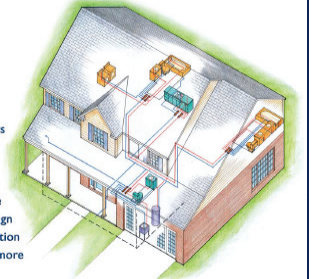
ASTM F876 has four categories for UV resistance, representing various levels of UV resistance ranging from untested: to 6 months continuous exposure, as listed in the Material Designation Code. See Chapter 9 for explanations of Material Designation Codes. Do not allow PEX pipes to be over-exposed beyond these limits.

- “Ensure that accumulative exposure time to sunlight during storage and installation does not exceed the maximum recommended UV exposure limit as indicated by the manufacturer.”

DESIGN GUIDE

Residential PEX Water Supply Plumbing Systems

Second Edition



Caution

- Do not store PEX pipes outdoors.
- Keep PEX pipes in original packaging until time of installation.
- Ensure that exposure to sunlight during installation does not exceed the maximum recommended UV exposure time as recommended by the manufacturer.

Ultraviolet (UV) Resistance of PEX Tubing

Conclusions

1. PEX plumbing systems are well proven, safe, and very reliable
2. Overexposure to sunlight/UV is a potential threat to PEX tubing
3. PEX system standards require UV resistance to protect users
4. UV resistance is evaluated according to ASTM F876 & F2657
5. PPI provides suggested PEX Labeling Guidelines



Ultraviolet (UV) Resistance of PEX Tubing



For questions, contact PPI:

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