POTENTIAL EFFECTS OF ARTIFICIAL LIGHTING ON CROSSLINKED POLYETHYLENE (PEX) PIPE AND TUBING AND RECOMMENDED INSTALLATION PRACTICES

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Foreword

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The purpose of this technical note is to provide information about the potential effects of certain types of artificial lighting on PEX pipe and tubing and to provide recommended installation practices for PEX that is installed in proximity to artificial light sources.

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TABLE OF CONTENTS

Foreword 2
Table of Contents 3
Table of Figures 3
1.0 Introduction 4
2.0 Sources and Types of Artificial Light 4
3.0 Installation Considerations for PEX Pipe and Tubing 5
4.0 Recommendations for PEX Pipe and Tubing Installed in Residential and Light Commercial Applications 6
5.0 Recommendations for PEX Pipe and Tubing Installed in Industrial, Warehousing, and Large Commercial Applications 7
6.0 Conclusion 8
7.0 Additional Resources 9
8.0 References 9
Appendix A: Method Development 10

TABLE OF FIGURES

Figure 1: Recommended setback distance between artificial light source (non-LED) and PEX pipe/tubing in a typical residential or light commercial setting 7
Figure 2: Recommended setback distance between artificial light source (non-LED) and PEX in a typical industrial setting 8

POTENTIAL EFFECTS OF ARTIFICIAL LIGHTING ON CROSSLINKED POLYETHYLENE (PEX) PIPE AND TUBING AND RECOMMENDED INSTALLATION PRACTICES

1.0 INTRODUCTION

Many polymers and plastics are affected by exposure to various forms of natural and artificial light. The effects can manifest themselves as simple color changes (e.g., fading) or as more significant polymer degradation via oxidation or other mechanisms.

The most common form of light exposure is natural sunlight. The electromagnetic energy of sunlight is normally divided into infrared (IR) light, visible light, and ultraviolet (UV) light. Short wavelength UV light has long been recognized as being responsible for most polymer damage. Stabilizers or carbon black are frequently added to polymers intended for outdoor use to protect the materials from deterioration due to the exposure to UV light. For example, the black high-density polyethylene (HDPE) covering on exposed telephone lines is considered to be resistant to UV light for several decades.

Artificial light is primarily used for illumination of indoor living and work areas. Apart from visible light, many forms of artificial light also produce some UV light in their spectra.

Crosslinked polyethylene (PEX) pipe and tubing manufacturers warn against long-term exposure to natural sunlight because of the damaging effects of UV, but is it necessary to protect PEX from long-term exposure to artificial light as well? This Technical Note aims to address this question and to provide recommended installation practices for PEX pipe and tubing in proximity to artificial light sources for long-term and permanent installations.

2.0 SOURCES AND TYPES OF ARTIFICIAL LIGHT

There are numerous technologies used to produce artificial light, but there is a limited selection of lighting types used within typical homes, office buildings, and retail establishments, as well as commercial and industrial buildings. Two of the oldest and most common types of lighting are the incandescent light bulb and the tubular fluorescent bulb. In industrial settings, high-pressure-mercury vapor, high-pressure-sodium (HPS), or metal-halide lighting are often used, though mercury vapor lights were banned in the U.S. as of 2008 and have mostly been replaced with newer technology. More recent developments in artificial lighting are the compact fluorescent light (CFL) and the light emitting diode (LED) lights.

With any of these types of artificial lights, it is possible to produce bulbs with light biased to select portions of the light spectra by using filters, coatings, or special gases (e.g., UV or IR lamps). An example is UV lighting intended for horticultural applications. Because these specialized bulbs are designed to produce either high levels of UV or infrared (IR) heat energy, PEX pipe and tubing must be protected from long-term exposure to these sources of light, and for installation of PEX pipe and tubing in proximity to such lights, users should consult the specific PEX manufacturer for guidance.

Incandescent lights create light by electricity passing through a resistance filament (typically tungsten) which creates light and heat. Very little of the energy used by these bulbs is emitted in the UV range of the light spectrum and historically they have not been of concern as a source of UV.

Tubular fluorescent lights create their light by ionizing mercury vapor in an argon gas. The light created is in the UV portion of the spectrum. Typically, fluorescent tubes have a phosphor coating on the inside of the glass that converts most of the UV light to visible light. However, if there are voids, cracks, or blank areas in the phosphor coating on the inside of the tube, more UV light will escape. In such a circumstance, the fluorescent tube should be replaced for safety reasons.

Compact fluorescent lights are like fluorescent tubes, but they are often designed to install in locations where incandescent bulbs might be used. As with the tubular fluorescent bulbs, the light emitted is in the UV spectrum, but the phosphor coating on the inside of the glass changes this to visible light, with a small component of the spectrum being in the UV region. Some CFLs have a single-glass-envelope, while others have a dual-envelope, whereby that second glass envelope further reduces UV emissions.

Light emitting diode lighting is one of the more recent developments in artificial lighting, and these lights have little-to-no UV component in their spectrum. This technology uses comparatively little energy to produce an amount of light equivalent to an incandescent bulb. Because of their long life, high luminous efficiency, and the range of LED products now offered, LED lighting is emerging in all types of applications, both residentially and commercially, and is likely to be the primary artificial light source in the future.

3.0 INSTALLATION CONSIDERATIONS FOR PEX PIPE AND TUBING

All PEX pipe and tubing produced according to industry standards such as ASTM F876 [1], ASTM F2788 [2], AWWA C904 [3], and CSA B137.5 [4] which are approved for use in hot- and cold-water plumbing applications in the U.S. and Canada must demonstrate a minimum UV resistance, even though these materials are not designed or intended for outdoor usage. ASTM F876, ASTM F2788, and CSA B137.5 require a minimum UV resistance of 1 month when tested according to ASTM F2657 [5] and evaluated in accordance with the requirements of these standards.

This level of minimum UV resistance provides only limited protection against UV radiation and is intended to protect these materials from incidental exposure to UV during installation.

Therefore, in situations where PEX is installed in indoor locations that exposes it to long-term exposure to artificial UV, the effects of this exposure to artificial light sources which may contain a UV component must be considered.

Since most indoor surfaces reflect only small amounts of UV radiation incident upon them (e.g., concrete reflects only 10% of the UV incident upon it), the primary consideration is for light directly emitted by the light source upon the PEX pipe.

Irradiance, which is a measure of the power of light per unit area, and illuminance, which is a measure of the visible light per unit area, both decrease with distance from the light source according to the Inverse-Square Law [6]. Thus, the setback distance that a PEX pipe is installed from direct exposure to a given light source is of critical importance to the amount of UV radiation to which the PEX will be exposed during its lifetime.

Consideration should also be given to the heat generated by some types of artificial light, if PEX pipe and tubing is to be installed in proximity to these light sources, regardless of whether the light is incident on the PEX.

4.0 RECOMMENDATIONS FOR PEX PIPE AND TUBING INSTALLED IN RESIDENTIAL AND LIGHT COMMERCIAL APPLICATIONS

While it is difficult to address all types of artificial light and all installations from the perspective of possible impacts of artificial light on PEX, fluorescent lights, either tubular versions or single-envelope CFLs are of most concern in residential and commercial applications, as these lights have the highest component of UV emissions. Therefore, the following recommendations are based on the use of fluorescent lights; other types of lights, such as incandescent or LED lights, will be of less concern and closer distances may be used. Assumptions of daily exposure are stated in the examples below. However, the actual daily exposure for each installation will vary, and calculations can be performed by the user for those specific situations.

Considering the UV irradiance of these artificial light sources when used in residential and light commercial settings, and when assuming a maximum of twelve (12) hours per day of usage, it is recommended that PEX pipe be installed at a setback distance of no less than 36 inches (91 cm) from direct incidence from the artificial light sources (see Appendix A for the calculation used to derive this distance). See **Figure 1**.

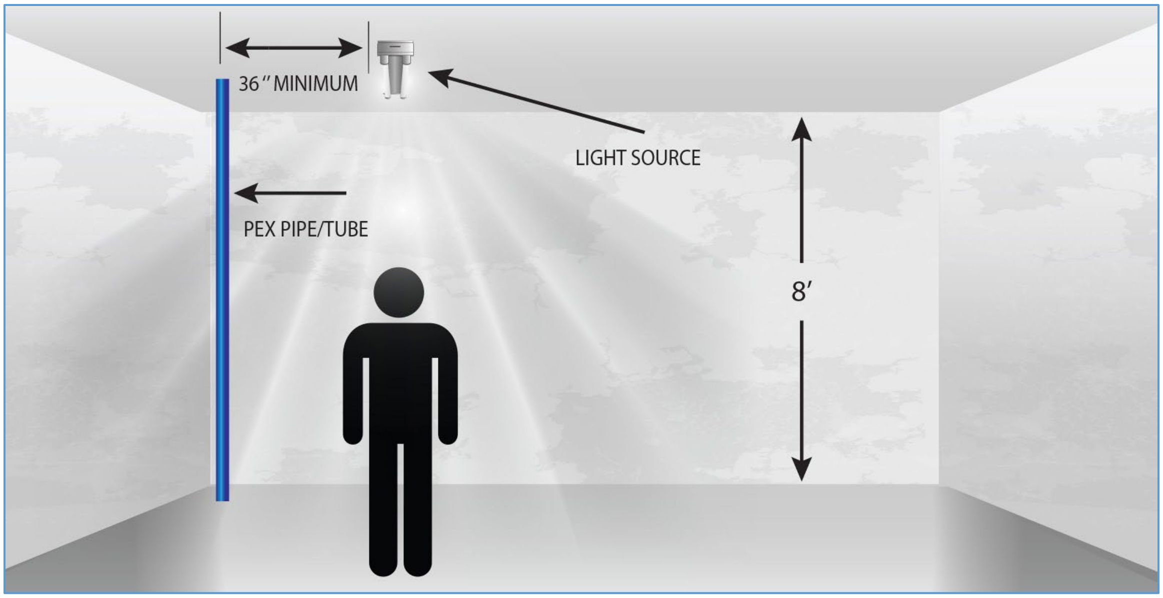

Figure 1: Recommended setback distance between artificial light source (non-LED) and PEX pipe/tubing in a typical residential or light commercial setting

When PEX pipes must be installed closer than 36 inches (91 cm) from direct incidence to an (non-LED) artificial light, a layer of exterior protection, such as protective sleeving or a pipe insulation that is compatible with the PEX material, should be installed.

5.0 RECOMMENDATIONS FOR PEX PIPE AND TUBING INSTALLED IN INDUSTRIAL, WAREHOUSING, AND LARGE COMMERCIAL APPLICATIONS

For industrial/manufacturing, warehousing, and large commercial applications, such as those with ceiling heights in excess of 20 feet (6.1 m), artificial light sources are often fluorescent, metal-halide or LED. In these applications, the distance from the light source to the lighted working area is significantly greater, and the types of light sources employed produce proportionally higher luminous efficiency (Lumen/watt) to achieve the same illuminance value at the working level. Proportionally higher UV irradiance can also be expected.

In addition, these facilities often lack natural lighting, and artificial light sources may be utilized 24 hours per day. Thus, for PEX pipes installed in such commercial or industrial applications, assuming 24 hour per day usage, it is recommended that they be installed at a setback distance of no less than 30 feet (9.1 meters) from direct incidence by the (non-LED) artificial light source (see Appendix A for the calculation used to derive this distance).

For PEX pipes installed closer than 30 feet from direct incidence to an artificial light, a layer of exterior protection, such as protective sleeving or a pipe insulation that is compatible with the PEX material, should be installed. See **Figure 2.**

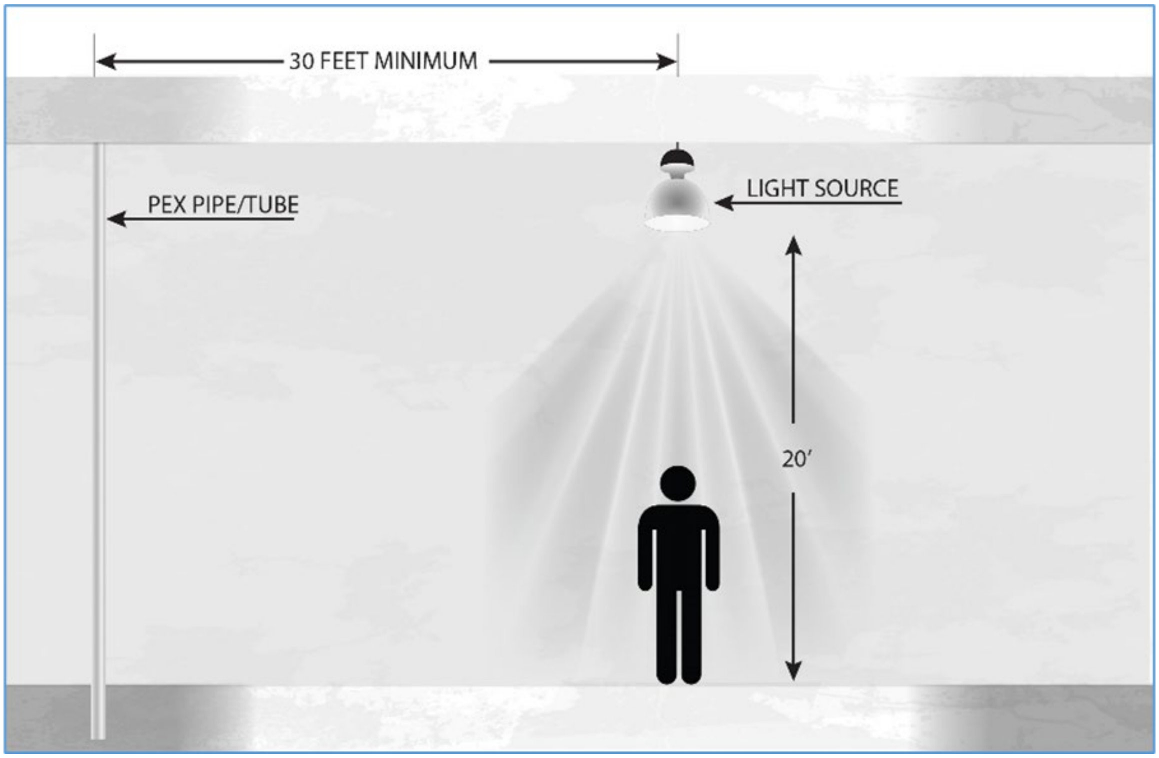

Figure 2: Recommended setback distance between artificial light source (non-LED) and PEX in a typical industrial setting

6.0 CONCLUSION

PEX pipe and tubing may be adversely affected by ultraviolet (UV) emissions from artificial light sources over decades of operation, and while different artificial light sources emit different levels of UV radiation, UV must be considered where PEX pipe and tubing is installed near all artificial light sources. UV irradiance and its harmful effects diminish the further the PEX pipe or tubing is from the artificial light source, so setback distance is a critical consideration. Minimum setback distances of 36 inches (91 cm) for residential and light commercial applications and 30 feet (9.1 m) for industrial/ manufacturing, warehousing, and large commercial applications of are considered reasonable for all types of artificial light sources.

Users are recommended to contact specific PEX manufacturers for more precise recommendations for individual situations.

7.0 ADDITIONAL RESOURCES

- National Electrical Manufacturers Association, *Ultraviolet Radiation from Fluorescent Lamps*, A NEMA Lighting Systems Division Document LSD 7-1999 (R2012, S2020), reaffirmed 2020

- Safari, Dehkordy, Kazemi, Dehghan, and Mahani, *Ultraviolet Radiation Emissions and Illuminance in Different Brands of Compact Fluorescent Lamps*, Research Article, Hindawi Publishing, 2014

8.0 REFERENCES

[1] ASTM F876 *Standard Specification for Crosslinked Polyethylene (PEX) Tubing,* ASTM International

[2] ASTM F2788 *Standard Specification for Metric and Inch-sized Crosslinked Polyethylene (PEX) Pipe,* ASTM International

[3] AWWA C904 *Crosslinked Polyethylene (PEX) Pressure Tubing, 1/2 in. Through 3 in. for Water Service,* American Water Works Association

[4] CSA B137.5 *Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications,* CSA Group

[5] ASTM F2657 *Standard Test Method for Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing*, ASTM International

[6] The inverse square law for electromagnetic radiation describes that measured light intensity is inversely proportional to the distance squared ($d2$) from the source of radiation. https://www.sciencedirect.com/topics/engineering/inverse-square-law#:~:text=The%20inverse%20square%20law%20for,from%20the%20source%20of%20radiation.

Appendix A: Method Development

An approach to estimating the safe distance between certain types of artificial lights and PEX pipes and tubing with a known level of resistance to natural UV light is to quantify the UV irradiance of fluorescent lighting in typical lighting applications and use what is known about the effects of natural Arizona sunlight exposure on PEX pipes and tubing as a reference point for quantitative comparison.

Note 1: ASTM Test Method F2657 requires testing the outdoor weathering and UV resistance of PEX pipes and tubing when exposed to natural sunlight in Central Arizona; this location was selected for this test method as it represents the worst case North American location based on historical data. ASTM F2657 Table 1[1] (below) provides quantitative values for Solar Radiation (MJ/m^2) for various periods of a typical year.

Table 1: Total UV (TUV) Energy per Monthly Time Period[A]

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

[A] Solar 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

In this case, the only assumptions are:

1) Fluorescent lights are on 24 hours a day, and
2) The spectral distribution of UV from sunlight is similar to the spectral distribution of UV emitted by fluorescent light.

Irradiance is a measure of the power of light per unit area, generally expressed in Watts per square meter (W/m^2). Widely available sources indicate that, while UV irradiance from CFLs is low and varies by brand and design, it is detectible and can be significant over a long period of time.

[1] Extracted, with permission, from ASTM F2657 *Standard Test Method for Outdoor Weathering Exposure of Crosslinked Polyethylene (PEX) Tubing*, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org

Illuminance of artificial lighting, which is measured in Lux (Lumen/m^2) is an important factor to consider. Recommended illuminance levels vary by application, but the U.S. Occupational Health & Safety Administration (OSHA) recommends approximately 750 Lux for warehouse lighting, and the Illuminating Engineering Society (IES) recommends slightly lower values for working areas in the home. Research by Safari et al, 2014, found UV irradiance values of single-envelope CFLs to be on the order of 0.03 to 0.07 W/m^2 at an illuminance of approximately 750 Lux.

For lighting in a typical residential setting, the distance from the light source to the work area is usually taken to be between 20 to 40 inches (50 to 100 cm), so the illuminance and irradiance are measured at that distance.

PEX that has been tested in natural Arizona sunlight according to ASTM Test Method F2657 and shown to meet a 1-, 3-, or 6-month requirement has demonstrated no statistically significant effect from that UV exposure. It is possible to compute the effective irradiance for that ”no effect” exposure from the Total UV (TUV) energy and the respective Exposure Time (1, 3, or 6 months) and compare that with the irradiance of CFL lighting.

For 1-month Arizona sunlight exposure defined in terms of total UV energy by ASTM F2657, the effective irradiance is calculated as follows:

- TUV Energy (from Table 1 of ASTM F2657[5]) = 40 MJ/m^2 = 40 x 10^6 J/m^2
- Exposure time = 1 month = 30 days = 2.592 x 10^6 seconds
- Effective Irradiance = TUV Energy/Exposure Time = 40 x 10^6 / 2.592 x 10^6 = 15.4 W/m^2

Using the UV irradiance value for the typical CFL to be 0.07 W/m^2 from the above-referenced research, it is found that the ratio of UV irradiance of Arizona sunlight to UV irradiance of CFL is a ratio of 15.4/0.07 or 220:1. In other words, the UV irradiance of sunlight is 220 times greater than that of artificial light.

Given 1-month (30 day) exposure in sunlight, this translates to an artificial light exposure time that would be 220 times greater than sunlight exposure time, so 220 x 30 days, or 18.1 years. This result suggests that 18 years of 24/7 exposure to UV from typical CFL lighting at an illuminance of 750 Lux (achieved at approximately 30 inches setback) would have ”no effect” on a PEX pipe with a 1-month UV rating according to the requirements of ASTM F876 when tested in accordance with ASTM F2657.

Since a typical residential application is likely to be limited to 12 hours per day of light exposure, such a PEX pipe will see ”no effect” after 36 years of non-continuous 12-hour per day exposure to the same light source.

Assuming a PEX pipe service life of 50 years, to calculate the setback distance required for ”no effect” after 50 years of non-continuous 12-hour per day exposure, the inverse-square law is used as follows:

- 50 years/36 years = $x^2/30^2$
- x (in inches) = $(30^2 * 50/36)^{1/2}$
- x = 35.4 inches, rounded to 36 inches

For the same PEX pipe in a commercial or industrial setting with irradiance and illuminance at the working level assumed to be similar to the above, but where setback distance from the light to the lighted work area is typically greater (as much as 18 feet) and assuming usage to be continuous (24/7/365), the calculated setback distance required for ”no effect” after 50 years of continuous 24/7/365 exposure for this greater setback, using the inverse-square law is:

- 50 years/18 years = $x^2/18^2$
- x (in feet) = $(18^2 * 50/18)^{1/2}$
- x = 30 feet

The same approach as above can be used to determine the minimum setback distance for PEX pipe and tubing under short-term storage conditions in a warehouse. In this case, if one assumes a storage period of no more than 6 months (0.5 years), the calculated setback distance required for “no effect” after 6 months of continuous 24/7 exposure is:

- 0.5 years/18 years = $x^2/18^2$
- x (in feet) = $(18^2 * 0.5/18)^{1/2}$
- x = 3 feet