LONG-TERM RESISTANCE OF AWWA C906 POLYETHYLENE (HDPE) PIPE TO POTABLE WATER DISINFECTANTS

PPI TN-44

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(Refer to PPI website to ensure the use of the most current version)

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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 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 general information about the history of the development of high-density polyethylene (HDPE) pipe and the various standards which apply to these products. The technical note may also be used as a guide for selecting appropriate standard specifications for users and specifiers.

The PPI has prepared this technical note as a service to the industry. The information in this report is offered in good faith and believed to be accurate at the time of its preparation but is offered "as is" without any express or implied warranty including WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. Additional information may be needed in some areas, especially regarding unusual or special applications. Consult the manufacturer or material supplier for more detailed information. A list of member manufacturers is available on the PPI website. PPI does not endorse the proprietary products or processes of any manufacturer and assumes no responsibility for compliance with applicable laws and regulations.

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1. INTRODUCTION

On March 23, 2021, the AWWA 263 Committee (American Water Works Association) reached consensus and approved revisions to ANSI/AWWA C906-15[1]. The updated standard was published and became effective on November 1, 2021. For potable water applications, AWWA C906-21 requires the use of only PE4710 (HDPE) compounds with the highest oxidative resistance performance class, CC3.

This Technical Note provides guidance on the use of HDPE in potable water piping systems with chlorine or chloramine as a secondary disinfectant. The use of Chlorine dioxide (ClO_2) as a secondary disinfectant is not covered by this technical note. At this time, HDPE is not recommended in applications with ClO_2 as a secondary disinfectant because further research is needed.

2. BACKGROUND

The operational service life of a piping system depends on many factors. Resistance to disinfectants is one of these factors. HDPE pipes intended for potable water applications contain additives to provide resistance to the long-term oxidizing effects of water disinfectants. Research programs conducted on HDPE piping compounds resulted in the development of a model that projects the performance of HDPE pipes in chlorinated (i.e. free chlorine and chloramine) potable water distribution and transmission systems.[2]

The model is based on accelerated testing of many HDPE compounds in accordance with ASTM F2263[3]; the model allows the user to project the performance of HDPE pipes operating at specific end-use conditions.

HDPE pipe compounds specified for potable water applications are categorized for oxidative resistance performance in accordance with ASTM D3350[4] and based on ASTM F2263 testing. Per the current AWWA C906-21, the required oxidative resistance category is CC3. As such, PPI TN-44 guidance is also based on the use of the highest category HDPE compounds, CC3.

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[1] AWWA C906-21, *Polyethylene (PE) Pressure Pipe and Fittings, 4 In. Through 65 In. (100 mm Through 1,650 mm), for Waterworks, Denver, CO*
[2] Jana Technical Report, "JP 916: Jana Mode 3 Shift Functions", March 2012
[3] ASTM F2263, *Test Method for Evaluating the Oxidative Resistance of Polyethylene (PE) Pipe to Chlorinated Water, West Conshohocken, PA*
[4] ASTM D3350, *Standard Specification for Polyethylene Plastics Pipe and Fittings Materials, West Conshohocken, PA*

3. SPECIFYING THE HDPE PIPE COMPOUND

For potable water applications, the designer/owner should specify the use of a PE4710 CC3 compound in accordance with AWWA C906-21.

4. CASE STUDIES

Table 1 (below) shows case studies for six utilities operating at specific conditions using the methodology described below. In all these applications, AWWA C906-21 PE4710 CC3 pipe is projected to provide at least 100-year resistance to chlorine and chloramine residual disinfectants. Refer to www.HDPEapp.com for this analysis.

Table 1: Resistance to Residual Disinfectants using PE4710 CC3 for AWWA C906-21 Pipe

US and Canadian Utilities	**Ontario**	**Indiana Utility-1**	**Indiana Utility-2**	**North Carolina**	**California Utility-1**	**California Utility-2**
Disinfectant type*	Chlorine	Chloramine	Chlorine	Chlorine	Chloramine	Chlorine
Average Disinfectant Residual (ppm)	1.1	1.6	1.4	0.9	1.9	0.9
Average pH	7.5	7.7	8.8	8.6	9.0	7.9
Estimated ORP (mV)[5]	775	650	740	680	650	750
Average Annual Water Temperature (^{o}F)[6]	59	57	54	68	61	64
Pipe DR and Pressure Class, PC (psi)	DR21 PC100	DR21 PC100	DR21 PC100	DR21 PC100	DR21 PC100	DR21 PC100
Average Working Pressure (psig)	100	70	70	70	65	77
Projected Oxidative Resistance under the specific operating conditions	≥100 years					

*In 2014, it was "estimated that approximately 30% of municipal water utilities use monochloramine for residual disinfection … and that number is expected to increase to 60% as more-stringent DBP [Disinfectant By-Product] regulations go into effect…". Ref: Nagisetty, R., Rockaway, T. and Willing, G., *Drinking Water Quality Concerns from Chloramine-Induced Degradation of Elastomeric Compounds*, AWWA Journal, Sep. 2014.

This technical note provides a method to determine the resistance to disinfectants for different conditions than those shown above.

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[5] Oxidative Reduction Potential (ORP) is a measure of the ability of a chemical substance to oxidize.

[6] The Average Annual Water Temperature (AAWT) is a weighted average of the daily water temperature, not the highest temperature observed in the system, experienced by the pipe. In situations where the pipes are buried just beneath the pavement, a higher water temperature estimate for the AAWT may be required.

5. DETERMINE THE PIPE DISINFECTANT INDEX (PDI)

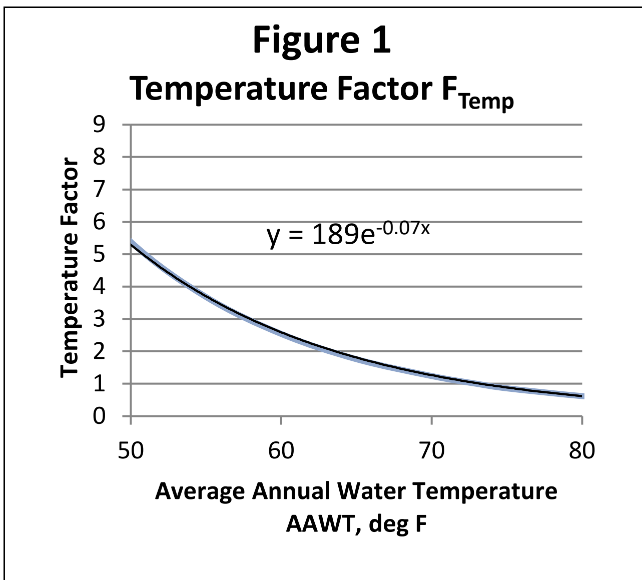
Based on ASTM F2263 test data, a Pipe Disinfectant Index (PDI) has been developed and normalized to reflect resistance to disinfectants. The PDI has been normalized to reflect a resistance to disinfectants of at least 50 years for a PDI ≥ 1, and at least 100 years for a PDI ≥ 2. A PDI ≥1 indicates acceptable service in the presence of disinfectants.

The procedure is outlined below along with figures, curve fit equations, tables and examples.

A. Obtain the following data:
   - Average annual water temperature, AAWT (°F): If AAWT is not available from the water utility Appendix A may also be used to estimate this value.
   - Pipe Pressure Class (PC)
   - Average system working pressure
   - Average Disinfectant residuals (ppm)
   - Average Water pH,
   - Pipe Material Chlorine Category –CC3

B. Determine the following:
   - Temperature Factor, F_{Temp} from Figure 1
   - Pressure Ratio Factor, F_{Press} from Figure 2
   - Water Quality Factor, F_{WQ} = 8.0 for chloramines; for chlorine F_{WQ} refer to Table 2
   - Pipe Material Factor, F_{Mat} from Table 3
   - Pipe Size Factor, F_{Size} from Table 4

C. Calculate the Pipe Disinfectant Index (PDI):
   - PDI = F_{Temp} x F_{Press} x F_{WQ} x F_{Mat} x F_{Size}



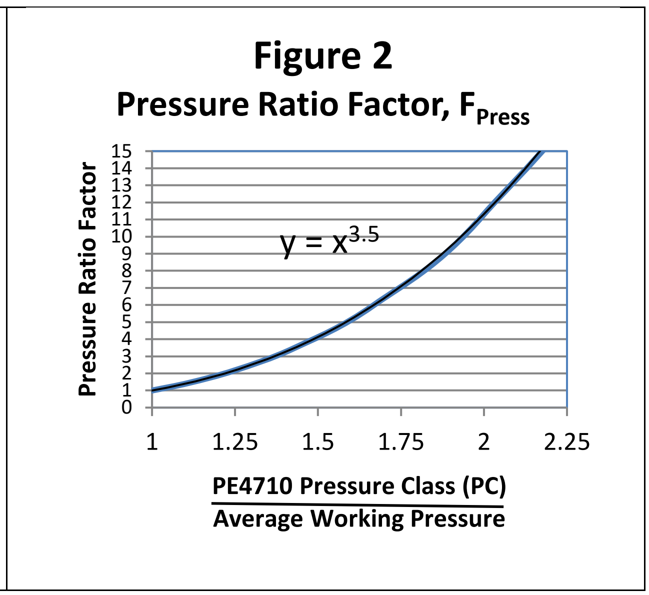


Table 2: Water Quality Factor – F_{WQ}[7]

Average Disinfection with Chlorine Residual (ppm)	Average Water pH										
	6.5	**6.75**	**7**	**7.25**	**7.5**	**7.75**	**8**	**8.25**	**8.5**	**8.75**	**9**
0.5	2	2.1	2.3	3	3.9	6.1	10	10	10	10	10
0.7	1.5	1.7	2	2.4	2.9	3.8	5	6.9	9.8	10	10
1	1.2	1.3	1.5	1.7	2.1	2.6	3.4	4.6	6.1	8.9	10
1.5	1	1.1	1.2	1.4	1.6	2	2.6	3.4	4.4	6.4	9.1
2	0.8	1	1.1	1.2	1.4	1.8	2.3	3	3.9	5.7	8.2
2.5	0.8	0.8	0.9	1.1	1.3	1.6	2	2.7	3.5	4.9	7.2
3	0.8	0.8	0.9	1.1	1.3	1.5	1.9	2.5	3.2	4.4	6.4
4	0.7	0.7	0.8	0.9	1.1	1.3	1.7	2.2	2.7	3.8	5.5
If the pH and residual Chlorine values are in-between the values shown above, select F_{WQ} by rounding the value of residual chlorine and/or pH to the nearest tabulated number.											

Table 3: Pipe Material Factor – F_{Mat}

Chlorine Category	Material Factor, F_{Mat}	Allowed in AWWA C906-21
CC1	0.16	No
CC2	0.45	No
CC3	1.0	Yes

Table 4: Pipe Size Factor – F_{Size}

Nominal Pipe Size	Size Factor, F_{Size}
4”	1.0
>4”	Data Under Development[8]; use 1.0 as a conservative value

[7] The Water Quality Factor, F_{WQ} has not been determined for HDPE pipes used in the presence of chlorine dioxide as a secondary disinfectant. The use of chlorine dioxide as a secondary disinfectant is rare and estimate to be used in <1% of U.S. water utilities.

[8] The effect of disinfectants is known to decrease as the pipe diameter increases and wall increases. The size factor will be greater than 1.0, so model projection is conservative for sizes larger than 4”. However, the specific value is currently undetermined. For pipes < 4”, see PPI TN-49.

6. EXAMPLES

Example 1: 24” DIPS DR21 (PC100) PE4710 CC3 category
Average Annual Water Temperature, AAWT = 64°F
Average Chlorine disinfection residual = 0.9ppm
Average water pH = 7.9
Average working pressure = 77psi

- From Figure 2, for T = 64°F, $\underline{F_{Temp} = 2.1}$
- From Figure 3, $\frac{PC}{WP} = \frac{100}{77} = 1.3,$ $\underline{F_{Press} = 2.5}$
- From Table 2, for pH7.9 and 0.9ppm, select pH8 and 1.0ppm $\underline{F_{WQ} = 3.4}$
- From Table 3, for CC3, $\underline{F_{Mat} = 1.0}$
- From Table 4, for Pipe Size >4” $\underline{F_{Size} = 1}$
- Calculate Pipe Disinfection Index, PDI
  $\rightarrow$ $\text{PDI}=F_{Temp} \times F_{Press} \times F_{WQ} \times F_{Mat} \times F_{Size}$
  $\rightarrow$ $\text{PDI} = 2.1 \times 2.5 \times 3.4 \times 1.0 \times 1 = 17.9$

<u>Example 1 Result</u>: PDI ≥ 2, therefore the pipe is resistant to the disinfectant conditions for at least 100 years.

Example *2*: 12” IPS DR17 (PC125) PE4710 CC3 category
Average Annual Water Temperature, AAWT = 78°F
Average Chlorine disinfection residual = 0.7ppm
Average water pH =7.5
Average working pressure = 100psi

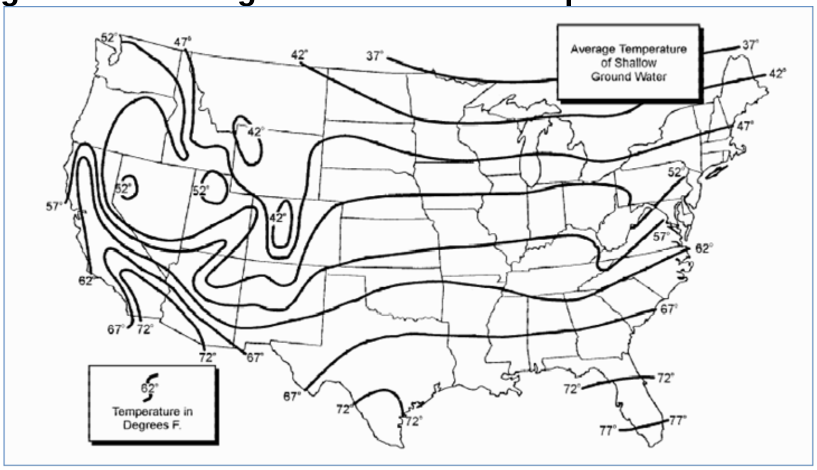
- From Figure 2, for T = 78°F, $\underline{F_{Temp} = 0.8}$
- From Figure 3, $\frac{PC}{WP} = \frac{125}{100} = 1.25$ $\underline{F_{Press} = 2.2}$
- From Table 2, for pH7.5, chlorine 0.7ppm $\underline{F_{WQ} = 2.9}$
- From Table 3, for CC3, $\underline{F_{Mat} = 1.0}$
- From Table 4, for Pipe Size >4” $\underline{F_{Size} = 1}$
- Calculate Pipe Disinfection Index, PDI
  $\rightarrow$ $\text{PDI}=F_{Temp} \times F_{Press} \times F_{WQ} \times F_{Mat} \times F_{Size}$
  $\rightarrow$ $\text{PDI} = 0.8 \times 2.2 \times 2.9 \times 1.0 \times 1 = 5.1$

<u>Example 2 Result</u>: PDI ≥2, therefore the pipe is resistant to the disinfectant conditions for at least 100 years.

Appendix A

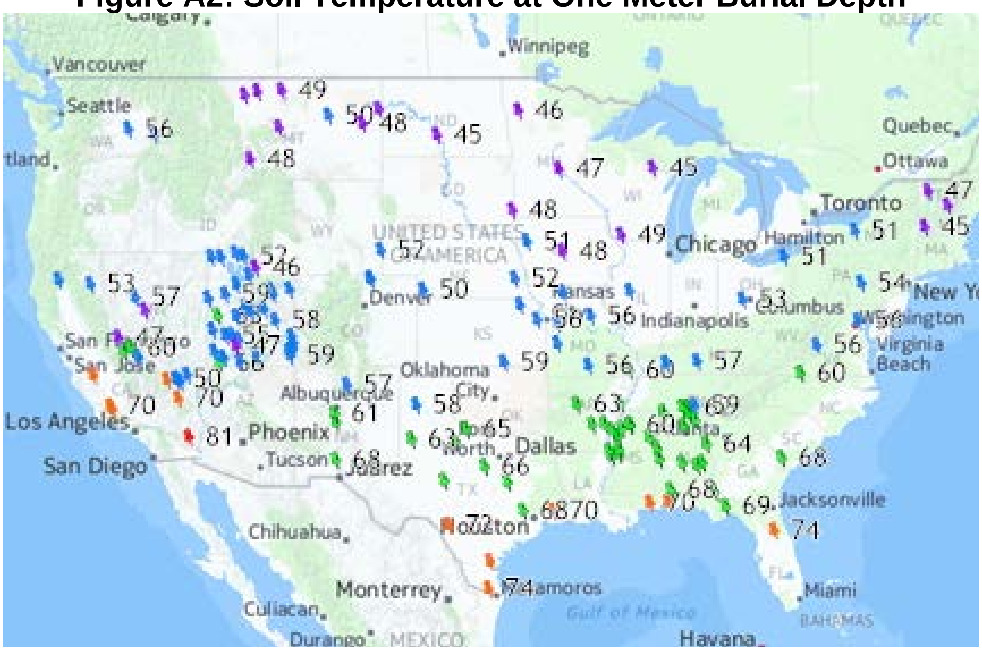
The average annual ground temperature at the pipe's burial depth may be used to estimate the value.[9] Figure A1 provides ground temperature data at typical pipe burial depths. Figure A2 represents recent data from USDA regarding annual average soil temperature at selected observation points throughout the U.S. and is consistent with Figure A1.

Figure A1: Average Annual Water Temperature Guidance



Source: U.S. Environmental Protection Agency (prepared from data included in Collins, W.D., 1925, Temperature of Water Available for Industrial Use in the United States, United States Geological Survey, Water Supply Paper 520-F).

Figure A2: Soil Temperature at One Meter Burial Depth



Source: United States Department of Agriculture (USDA), National Resources Conversation Service (NRCS), Soil Climate Analysis Network (SCAN) data (2014-15).

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9 E.J. Mirjam Blokker and E.J. Pieterse-Quirijns, *Modeling temperature in the drinking water distribution system*, 104 AWWA JOURNAL 11 (2013).