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

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PPI TN-44

1. INTRODUCTION

The operational service life of a piping system depends on many factors. Resistance to disinfectants is one of these factors. Polyethylene (PE) pipes intended for potable water applications contain additives to provide resistance to the long term oxidizing effects of water disinfectants. Research programs conducted on PE piping compounds resulted in the development of a model that projects the performance of PE pipes in chlorinated (i.e. free chlorine and chloramine) potable water distribution and transmission systems.[1]

The model is based on testing in accordance with ASTM F2263, "Test Method for Evaluating the Oxidative Resistance of Polyethylene (PE) Pipe to Chlorinated Water" and projects the performance of PE pipes due to specific end use conditions. PE pipe compounds intended for potable water applications are classified for oxidative resistance in accordance with ASTM D3350. The oxidative resistance categories include CC1, CC2 and CC3 (highest performance).

CC1, CC2 and CC3 PE pipe compounds provide long term resistance to disinfectants in most potable water service applications. Table 1 shows a selection of utility specific conditions and the resultant resistance to disinfectants of pipes produced from PE4710 CC1 compounds.

Table 1: Resistance to Disinfectants at Selected Utilities for AWWA C906 Pipe

	Average US Utility	Indiana Utility-1	Indiana Utility-2	North Carolina	California Utility-1	California Utility-2
Disinfectant type		Chloramine	Chlorine	Chlorine	Chloramine	Chlorine
Average Disinfectant Residual (ppm)		1.6	1.4	0.9	1.9	0.9
Average pH		7.7	8.8	8.6	9.0	7.9
Estimated ORP (mV)[2]	650	650	740	680	650	750
Average Annual Water Temperature (^oF)[3]	57	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)	70	70	70	70	65	77
Projected Oxidative Resistance under the specific operating conditions (years)	>100	>100	>100	>100	>100	>100

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

[1] Jana Technical Report, "JP 916: Jana Mode 3 Shift Functions", March 2012
[2] Oxidative Reduction Potential (ORP) is a measure of the ability of a chemical substance to oxidize.
[3] The Average Annual Water Temperature (AAWT) is a weighted average of the daily water temperature, not the highest temperature observed in the system.

2. 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.

1. 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 – CC1, CC2, or CC3

2. 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

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

Figure 1

Temperature Factor F_{Temp}

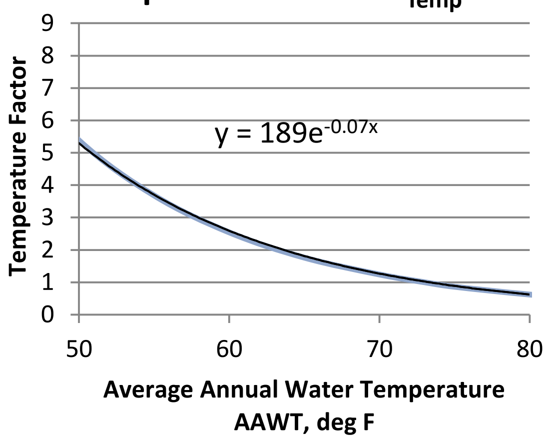
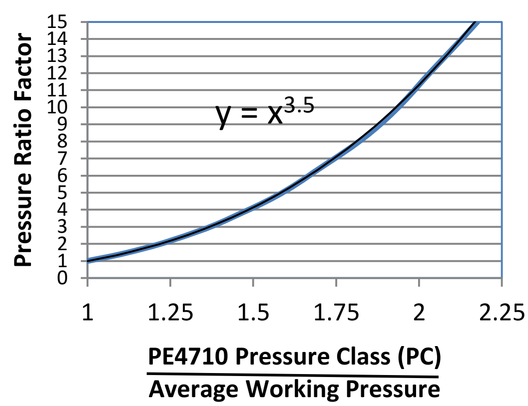


Figure 2

Pressure Ratio Factor, F_{Press}



This may also be used for PE3608, and will be conservative

Table 2: Water Quality Factor – F_{WQ}[4]

		Average Water pH										
		6.5	**6.75**	**7**	**7.25**	**7.5**	**7.75**	**8**	**8.25**	**8.5**	**8.75**	**9**
Average Disinfection with Chlorine Residual (ppm)	**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}[5]

Chlorine Category	Material Factor, F_{Mat}
CC1	0.16
CC2	0.45
CC3	1.0

Table 4: Pipe Size Factor – F_{Size}

Nominal Pipe Size	Size Factor, F_{Size}
4”	1.0
>4”	Data Under Development[6]; use 1.0 as a conservative value

[4] The Water Quality Factor, FWQ 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.

[5] Resins categorized as CC2 and CC3 are readily available.

[6] 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”, a separate document is being prepared.

3. *EXAMPLES*

Example 1: 24” DIPS DR21 (PC100) PE4710 CC1 category
Average Annual Water Temperature, AAWT = 64^{o}F
Average Chlorine disinfection residual = 0.9ppm
Average water pH = 7.9
Average working pressure = 77psi

- From Figure 1, for T = 64°F, $\underline{F_{Temp} = 2.1}$
- From Figure 2, $\frac{PC}{WP} = \frac{100}{77} = 1.3$, $\underline{F_{Press} = 2.5}$
- From Table 2, for pH7.9 and 0.9ppm, select pH8 and 1.0ppm $\underline{F_{WQ} = 3.4}$
- From Table 3, for CC1, $\underline{F_{Mat} = 0.16}$
- From Table 4, for Pipe Size >4” $\underline{F_{Size} = 1}$
- Calculate Pipe Disinfection Index, PDI
  $\rightarrow$ PDI$=F_{Temp} \times F_{Press} \times F_{WQ} \times F_{Mat} \times F_{Size}$
  $\rightarrow$ PDI $=2.1 \times 2.5 \times 3.4 \times 0.16 \times 1 = \mathbf{2.9}$

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

Example *2*: 12” IPS DR17 (PC125) PE4710 CC2 category
Average Annual Water Temperature, AAWT = 78^{o}F
Average Chlorine disinfection residual = 0.7ppm
Average water pH =7.5
Average working pressure = 100psi

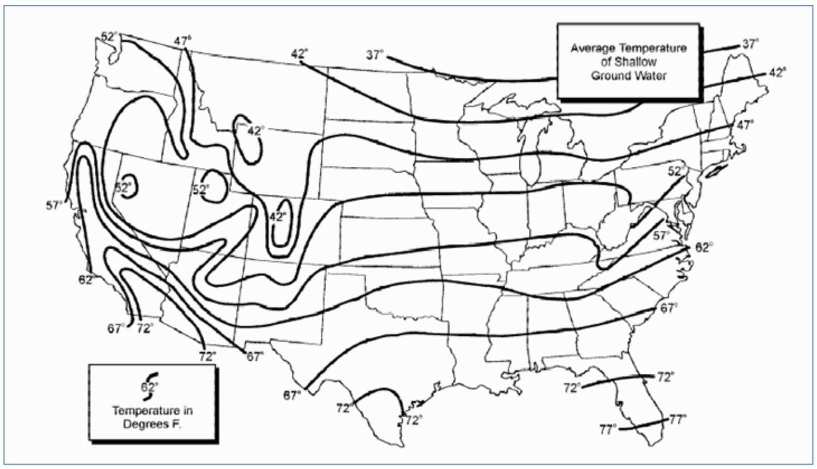
- From Figure 1, for T = 78°F, $\underline{F_{Temp} = 0.8}$
- From Figure 2, $\frac{PC}{WP} = \frac{125}{100} = 1.25$ $\underline{F_{Press} = 2.2}$
- From Table 2, for pH7.5, chlorine 0.7ppm $\underline{F_{WQ} = 2.9}$
- From Table 3, for CC2, $\underline{F_{Mat} = 0.45}$
- From Table 4, for Pipe Size >4” $\underline{F_{Size} = 1}$
- Calculate Pipe Disinfection Index, PDI
  $\rightarrow$ PDI$=F_{Temp} \times F_{Press} \times F_{WQ} \times F_{Mat} \times F_{Size}$
  $\rightarrow$ PDI $=0.8 \times 2.2 \times 2.9 \times 0.45 \times 1 = \mathbf{2.3}$

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

Appendix A

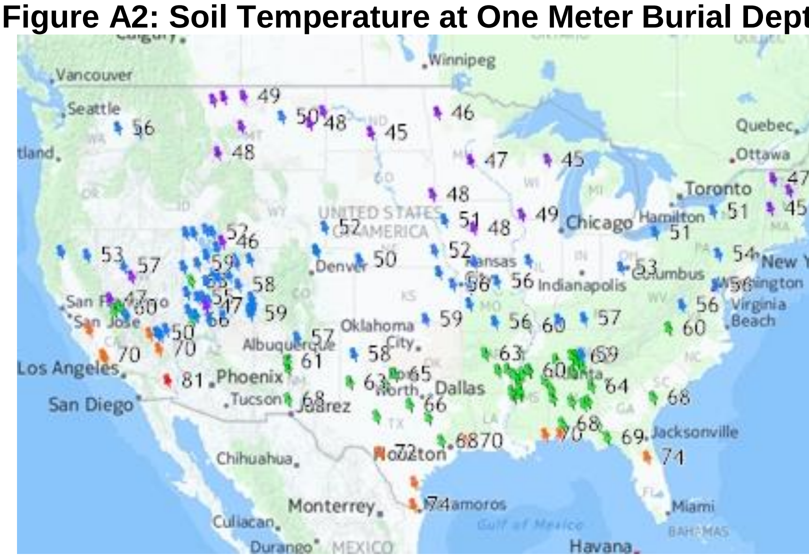
The average annual ground temperature at the pipe's burial depth may be used to estimate the value.[7] Figure A1 provides ground temperature data at typical pipe burial depths. Figure A2 represents recent data from USDA regarding annual average soil temperature at selected observation points throughout 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).

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