

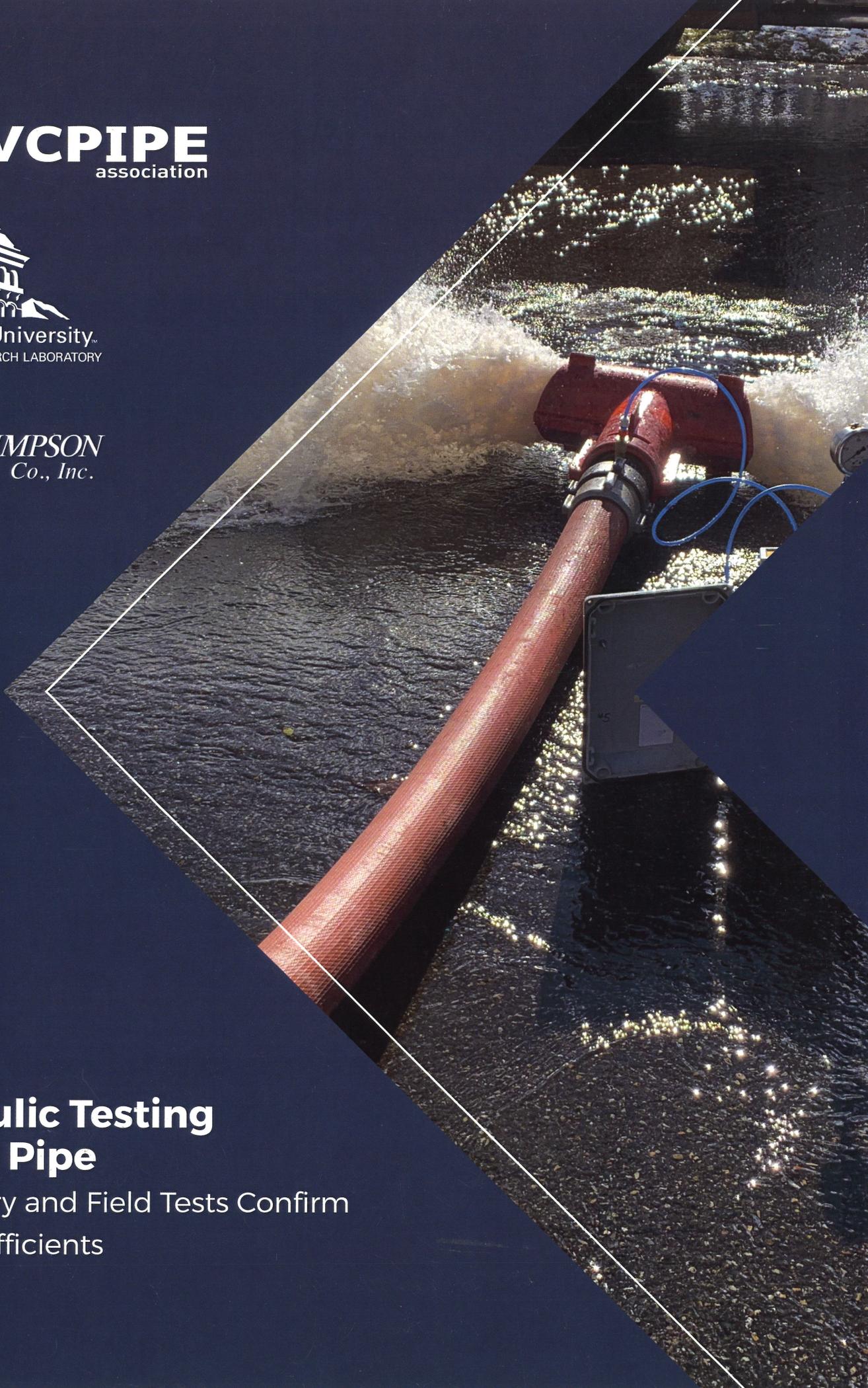


**Utah State University**  
UTAH WATER RESEARCH LABORATORY



## Hydraulic Testing of PVC Pipe

Laboratory and Field Tests Confirm  
Flow Coefficients



# Introduction

## Historical Perspective

In North America most of the hydraulic research on PVC pipes was done in the 1960s and 1970s. These early tests established the following flow factors to be used for PVC pipe hydraulic design:

- ▶ Pressure pipe — Hazen Williams (HW) "C" factor = 150
- ▶ Nonpressure pipe — Manning's "n" number = 0.009

Since friction-factor testing for PVC pipe in North America took place more than 50 years ago, the Uni-Bell PVC Pipe Association (PVCPA) decided to engage in a two-pronged test program: (1) laboratory testing of new pipe and (2) field testing of installed pipe. PVCPA contracted with Utah State University (USU) to:

- ▶ Perform hydraulic-flow testing at the University's Utah Water Research Laboratory (UWRL)
- ▶ Oversee field testing of installed PVC pressure pipe

## Research Program

Research goals were to:

- ▶ Measure hydraulic coefficients for pressure and nonpressure applications
- ▶ Determine if established coefficients were conservative compared to established values

Laboratory testing was performed at UWRL in Logan, UT, and overseen by Research Professor Steven Barfuss who is Associate Director of UWRL. Field testing was performed in West Valley City, UT, by M.E. Simpson Co., Inc., and witnessed by Research Professor Barfuss.

The results of both tests are summarized in Table 1. The procedures and testing undertaken are discussed in detail in the rest of this report. Test results for Darcy-Weisbach " $f$ " are provided in Tables 1, 4, and 5, but are not discussed in the rest of this document.

TABLE 1: RESULTS OF LABORATORY AND HYDRAULIC FIELD TESTING ON PVC PIPE		
Pipe Age	Pipe Size	Friction Factor Results
New	6"	HW "C" = 154 - 161 Manning's "n" = 0.0085 - 0.0070 Darcy " $f$ " = 0.012 - 0.017
New	12"	HW "C" = 150 - 157 Manning's "n" = 0.0094 - 0.0077 Darcy " $f$ " = 0.011 - 0.017
46 Years	8"	HW "C" = 164

<b>TABLE 2: DIMENSIONS FOR 6-INCH PVC PIPE</b>				
<b>Section</b>	<b>ID 1 (in)</b>	<b>ID 2 (in)</b>	<b>ID 3 (in)</b>	<b>Average ID (in)</b>
1	5.88	5.85	5.88	5.87
2	5.88	5.87	5.85	5.87
3	5.85	5.88	5.89	5.87
Overall Average ID (in)				5.87
Average Flow Area (in <sup>2</sup> )				27.10
Average Flow Area (ft <sup>2</sup> )				0.19

<b>TABLE 3: DIMENSIONS FOR 12-INCH PVC PIPE</b>				
<b>Section</b>	<b>ID 1 (in)</b>	<b>ID 2 (in)</b>	<b>ID 3 (in)</b>	<b>Average ID (in)</b>
1	11.69	11.65	11.65	11.66
2	11.63	11.68	11.65	11.65
3	11.60	11.68	11.68	11.65
Overall Average ID (in)				11.65
Average Flow Area (in <sup>2</sup> )				107.00
Average Flow Area (ft <sup>2</sup> )				0.74

## Results

Test results for the friction coefficient tests are shown in Table 4 for 6-inch PVC pipe and in Table 5 for 12-inch pipe. Darcy "f," Manning's "n," and Hazen-Williams "C" are listed in each table. Flow velocities were 2 feet per second and greater as shown. The coefficient results for these tests vary with increasing Reynolds number, which is consistent with the Moody Diagram and other theoretical calculations.

TABLE 5: TEST RESULTS FOR 12-INCH PVC PIPE

Run No.	Flow Volume (cfs)	Flow Velocity (fps)	Inlet Reynolds Number	Friction Loss (ft of H <sub>2</sub> O)	Friction Loss (psi)	Hydraulic Slope (ft/100 ft)	Darcy "f"	Hazen-Williams "C"	Manning's "n"
1	1.5	2.0	126,000	0.23	0.10	0.10	0.017	150	0.0094
2	2.5	3.4	217,000	0.59	0.26	0.27	0.015	153	0.0089
3	3.5	4.8	304,000	1.10	0.48	0.50	0.014	154	0.0086
4	4.5	6.1	393,000	1.75	0.76	0.79	0.013	155	0.0084
5	5.7	7.7	493,000	2.66	1.15	1.21	0.013	155	0.0082
6	6.7	9.1	581,000	3.57	1.55	1.62	0.012	156	0.0081
7	7.9	10.6	679,000	4.74	2.06	2.15	0.012	156	0.0080
8	8.8	11.9*	761,000	5.83	2.53	2.65	0.012	157	0.0079
9	10.0	13.5*	861,000	7.30	3.16	3.31	0.012	157	0.0078
10	10.9	14.7*	943,000	8.64	3.75	3.92	0.011	157	0.0078
11	12.0	16.3*	1,040,000	10.40	4.49	4.72	0.011	157	0.0078
12	13.5	18.2*	1,170,000	12.80	5.55	5.81	0.011	157	0.0077

**Notes:**

1. Length of pipe tested: 220.29 feet
2. Date of calibration: 28-Mar-2022
3. Data: water temperature 46°F, unit weight 62.2 pcf, kinematic viscosity  $1.52 \times 10^{-5}$  ft<sup>2</sup>/sec

\*These test runs use velocities that exceed typical designs of municipal pipelines

**Summary of Test Results**

- ▶ Hazen-Williams "C" factor — average value was 159 for 6-inch pipe and 155 for 12-inch
- ▶ Manning's "n" number — average value was 0.0075 for 6-inch pipe and 0.0082 for 12-inch
- ▶ Darcy-Weisbach "f" factor — values ranged from 0.012 to 0.017 for 6-inch pipe and 0.011 to 0.017 for 12-inch

In all cases, results obtained verified the traditional values used for the last 40+ years for PVC pipe hydraulic design. The results also confirmed that these values are conservative.

## Pipe Dimensions

A run of 8-inch PVC pipe between two hydrants was used. Distance between the hydrants was 278 feet. Pipe dimensional information is found in Table 6.

Section	ID 1 (in)	ID 2 (in)	ID 3 (in)	Average ID (in)	Pipe Length (ft)
1	8.0350	8.0005	7.9960	8.01	278
Overall Average ID (in)				8.01	
Average Flow Area (in <sup>2</sup> )				50.40	
Average Flow Area (ft <sup>2</sup> )				0.35	

## Results

Two tests were performed on the same length of pipe. Each test used a different flow velocity to generate additional data. Test information is found in Table 7.

Run No.	Flow Volume (gpm)	Flow Velocity (fps)	Friction Loss (ft of H <sub>2</sub> O)	Friction Loss (ft H <sub>2</sub> O / ft)	Hazen-Williams "C"
1	606	3.86	1.30	0.005	164.2
2	1,370	8.73	5.93	0.021	163.3
Average					163.8

## Summary of Test Results

- ▶ The first test used a velocity of 3.86 fps — HW "C" factor was 164.2
- ▶ The second test used a velocity of 8.73 fps — HW "C" factor was 163.3
- ▶ Average HW "C" factor for the two tests was 163.8, about 9% higher than the recommended design of 150

**FIGURE 4. EXCAVATED SAMPLES OF PVC WATER MAINS FOR DIMENSION MEASUREMENT**



---

## THE IMPORTANCE OF USING CONSERVATIVE FRICTION FACTORS WHEN COMPARING TO OTHER PIPE MATERIALS

Designers should realize that recommended PVC pipe Hazen-Williams “C” = 150 and Manning’s “n” = 0.009 are conservative values compared to test data. In fact, despite using a wide range of flow velocities, every data point in recent research has been at or better than these recommended values. When making comparisons with other materials, it is important to avoid using average values for friction factors for hydraulic design, since average values are not conservative. Users are encouraged to review test data from other pipe materials to understand how their recommended values were obtained. Additionally, it is essential that recommended industry coefficients include any internal pipe-wall or pipe-lining degradation.

### ACKNOWLEDGEMENTS

The PVC Pipe Association expresses its appreciation to the Granger-Hunter Improvement District for allowing hydraulic testing to occur in their water system and also to their employees who actively assisted in making the tests happen.

#### Uni-Bell PVC Pipe Association

The PVC Pipe Association is the North American trade association for gasketed PVC pipe. Since 1971, PVCPA has been the authoritative source for information on PVC water, sewer, and reclaimed water pipe. The Association serves the engineering, regulatory, public health, and standardization communities.

#### Utah Water Research Laboratory

The Utah Water Resources Laboratory is an internationally renowned research institution at Utah State University. Dedicated in 1965, it is the oldest and one of the largest water research laboratories in the United States. The facility includes more than 113,000 square feet of office and laboratory space. UWRL is primarily focused on research in water and irrigation engineering and supports undergraduate and graduate programs in several subject areas.

#### M.E. Simpson Co., Inc.

M.E. Simpson was founded by Marvin Simpson in 1979 with the objective of providing technical services to water utilities throughout the Midwest. Since then, the company has improved distribution system performance for utilities, optimized distribution system data, and increased revenues for water systems throughout the United States.

### REFERENCES

“Laboratory Testing of PVC Pipe Hydraulics,” Water Research Laboratory (2022)

“C Factor Testing of an Installed PVC Water Main (Witness Test),” Water Research Laboratory (2022)

“Report for C-Factor Loss-of-Head Testing in an Installed PVC Water Main,” M.E. Simpson Co., Inc. (2023)