

Manual of Water Supply Practices

**M11**

# Steel Pipe— A Guide for Design and Installation

Fifth Edition



American Water Works  
Association

M11

# Steel Pipe—A Guide for Design and Installation

Fifth Edition

Errata April 2018 Incorporated



**American Water Works  
Association**

Manual of Water Supply Practices—M11, Fifth Edition

## Steel Pipe—A Guide for Design and Installation

Copyright © 1954, 1972, 1983, 1991, 2000, 2012, 2017 American Water Works Association

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information or retrieval system, except in the form of brief excerpts or quotations for review purposes, without the written permission of the publisher.

### Disclaimer

The authors, contributors, editors, and publisher do not assume responsibility for the validity of the content or any consequences of its use. In no event will AWWA be liable for direct, indirect, special, incidental, or consequential damages arising out of the use of information presented in this book. In particular, AWWA will not be responsible for any costs, including, but not limited to, those incurred as a result of lost revenue. In no event shall AWWA's liability exceed the amount paid for the purchase of this book.

Project Manager: Melissa Valentine  
Cover Art: Melanie Yamamoto  
Production: Stonehill Graphics.  
Manuals Specialist: Sue Bach

---

### Library of Congress Cataloging-in-Publication Data

Names: Dechant, Dennis, author. | Bambei, John H., Jr., author. | American Water Works Association.

Title: M11--steel water pipe : a guide for design and installation / by Dennis Dechant and John Bambei.

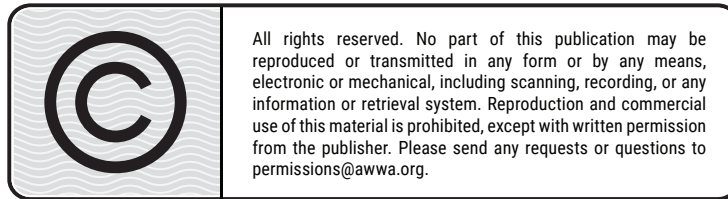
Other titles: Steel water pipe | Guide for design and installation | Steel pipe--design and installation.

Description: Fifth edition. | Denver, CO : American Water Works Association, [2017] | Originally published as: Steel pipe--design and installation. 1964. | Includes bibliographical references.

Identifiers: LCCN 2017002001 | ISBN 9781625762092

Subjects: LCSH: Water-pipes--Design and construction--Handbooks, manuals, etc. | Pipe, Steel--Design and construction--Handbooks, manuals, etc.

Classification: LCC TC174 .D365 2017 | DDC 628.1/5--dc23 LC record available at <https://lccn.loc.gov/2017002001>



ISBN 978-162576-209-2  
eISBN 978-1-61300-408-1

Printed in the United States of America  
American Water Works Association  
6666 West Quincy Avenue  
Denver, CO 80235-3098  
[awwa.org](http://awwa.org)



# Contents



List of Figures, vii

List of Tables, xi

Preface, xiii

Acknowledgments, xv

<b>Chapter 1</b>	<b>History, Uses, and Physical Characteristics of Steel Pipe</b> .....	<b>1</b>
	History, 1	
	Uses, 2	
	Chemistry, Casting, and Heat Treatment, 3	
	Mechanical Characteristics, 7	
	Analysis Based on Strain, 12	
	Ductility in Design, 13	
	Effects of Cold Working on Strength and Ductility, 14	
	Brittle Fracture Considerations in Structural Design, 16	
	References, 18	
<b>Chapter 2</b>	<b>Steel Pipe Manufacture and Testing</b> .....	<b>21</b>
	Manufacture, 21	
	Materials, 23	
	Testing—Coil and Plate, 24	
	Testing—Formed Pipe, 24	
	References, 25	
<b>Chapter 3</b>	<b>Hydraulics of Pipelines, Water Hammer, and Pressure Surge</b> .....	<b>27</b>
	Hydraulic Formulas, 27	
	Calculations, 35	
	Water Hammer and Pressure Surge, 39	
	Checklist for Pumping Mains, 42	
	General Studies for Water Hammer Control, 43	
	Allowance for Water Hammer, 43	
	Pressure Rise Calculations, 44	
	Economical Diameter of Pipe, 44	
	Air Entrapment and Release, 44	
	Good Practice, 45	
	References, 45	
<b>Chapter 4</b>	<b>Determination of Pipe Wall Thickness</b> .....	<b>49</b>
	Internal Pressure, 50	
	Allowable Stress, 51	
	Handling Check, 52	
	Corrosion Allowance, 52	
	External Pressure—Exposed or Submerged Pipe, 52	

	Good Practice, 55	
	References, 55	
<b>Chapter 5</b>	<b>External Loads on Buried Pipe.....</b>	<b>57</b>
	Earth Load, 57	
	Live Loads, 58	
	Construction Loads, 58	
	Extreme External Loading Conditions, 59	
	Predicting Deflection, 61	
	Cement Enhanced Soils, 66	
	Trench Components, 66	
	Special Considerations for Buried Pipe, 66	
	References, 68	
<b>Chapter 6</b>	<b>Pipe Joints.....</b>	<b>73</b>
	Bell-and-Spigot Joint With Rubber Gasket, 73	
	Circumferential Fillet Welds for Lap Joints, 75	
	Expansion and Contraction—General, 78	
	Flanges, 79	
	Couplings, 81	
	Insulating Joints, 83	
	Connection to Other Pipe Material, 84	
	Alternate Joints, 84	
	References, 84	
<b>Chapter 7</b>	<b>Fittings Design, Appurtenances, and Miscellaneous Details.....</b>	<b>87</b>
	Designation of Fittings, 87	
	Miter End Cuts, 88	
	Elbows, 88	
	Calculation of Resultant Angle of a Combined Angle Bend, 90	
	Reducers, 91	
	Reinforcement of Outlets, 91	
	Outlet Design Examples, 96	
	Outlet and Collar/Wrapper Connection, 109	
	Crotch Plate Design for Outlets and True Wyes, 109	
	Crotch-Plate Design, 109	
	Nomograph Use in Radial Outlet and Wye-Branch Design, 110	
	Crotch-Plate Connections, 114	
	True Wye Design, 122	
	Design of Ellipsoidal Heads, 125	
	Testing of Fittings, 126	
	Joint Harnesses, 126	
	Anchor Rings, 143	
	Anchor Ring Design, 149	
	Outlets, 155	
	Blowoff Connections, 155	
	Manholes, 156	
	Air-Release Valves and Air/Vacuum Valves, 156	
	Miscellaneous Connections and Other Appurtenances, 157	
	Layout of Pipelines, 157	
	Good Practice, 158	
	References, 158	

<b>Chapter 8</b>	<b>Thrust Restraint for Buried Pipelines.....</b>	<b>161</b>
	Thrust Forces, 161	
	Hydrostatic Thrust, 161	
	Thrust Resistance, 163	
	Thrust Blocks, 163	
	Thrust Restraint With Welded Or Harnessed Joints for <i>pA</i> Horizontal Thrust, 165	
	Gasketed Joints With Small Deflections, 166	
	Thrust Restraint With Welded Or Harnessed Joints for Horizontal Bends, 168	
	Small Vertical Deflections With Joints Free To Rotate, 170	
	Thrust Restraint With Welded Or Harnessed Joints for Vertical Bends, 171	
	References, 171	
<b>Chapter 9</b>	<b>Pipe on Supports.....</b>	<b>173</b>
	Saddle Supports, 173	
	Pipe Deflection As Beam, 178	
	Methods of Calculation, 178	
	Gradient of Supported Pipelines To Prevent Pocketing, 179	
	Span Lengths and Stresses, 179	
	Design Example, 180	
	Ring Girders, 183	
	Ring-Girder Construction for Lowpressure Pipe, 183	
	Installation of Ring Girder Spans, 184	
	References, 185	
<b>Chapter 10</b>	<b>Principles of Corrosion and Corrosion Protection .....</b>	<b>187</b>
	General Corrosion Theory, 187	
	Typical Corrosion Cells, 189	
	Corrosivity Assessment, 195	
	Internal Corrosion Protection, 199	
	Atmospheric Corrosion Protection, 199	
	External Corrosion Protection, 200	
	References, 206	
<b>Chapter 11</b>	<b>Protective Coatings and Linings .....</b>	<b>209</b>
	Requirements for Good Pipeline Coatings and Linings, 209	
	Selection of the Proper Coating and Lining, 210	
	Available Coatings and Linings, 211	
	Coating and lining Application, 213	
	Good Practice, 214	
	References, 214	
<b>Chapter 12</b>	<b>Transportation, Installation, and Testing.....</b>	<b>217</b>
	Transportation and Handling of Coated Steel Pipe, 217	
	Installation of Pipe, 219	
	Anchors and Thrust Blocks, 227	
	Steel Tunnel Liners and Casing Pipe, 228	
	Rehabilitation of Pipelines, 229	
	Horizontal Directional Drilling, 231	
	Subaqueous Pipelines, 232	

	Hydrostatic Field Test, 233	
	References, 234	
<b>Nomenclature</b>	.....	<b>237</b>
<b>Glossary</b>	.....	<b>245</b>
<b>Appendix A</b>	<b>Pipe Deflection-Improving Embedment Versus Increasing Cylinder Thickness</b> .....	<b>249</b>
<b>Appendix B</b>	<b>Harness Ring Assembly Design Example</b> .....	<b>251</b>
	References, 265	
<b>Appendix C</b>	<b>Harness Rod Placement When Using Multiple Couplings to Accommodate Vertical Differential Settlement</b> .....	<b>267</b>
<b>Appendix D</b>	<b>Design of Steel Water Pipelines in Geohazard Areas</b> .....	<b>269</b>
	References, 271	
<b>Appendix E</b>	<b>Useful Equations and Conversions</b> .....	<b>273</b>
	Equations, 273	
	Conversions, 281	
<b>Index</b>		<b>283</b>
<b>List of AWWA Manuals</b>		<b>291</b>

# Figures

- 1-1 Steel pipe penstock on bridge, 3
- 1-2 Stress-strain curve for steel, 8
- 1-3 True stress-strain for steel, 8
- 1-4 Stress-strain curves for carbon steel, 10
- 1-5 Plastic and elastic strains, 10
- 1-6 Actual and apparent stresses, 11
- 1-7 Determination of actual stress, 11
- 1-8 Experimental determination of strain characteristics, 13
- 1-9 Effects of strain hardening, 15
- 1-10 Effects of strain aging, 15
- 1-11 Transition curves obtained from Charpy V-notch impact tests, 18
  
- 2-1 Schematic diagram of process for making spiral-seam pipe, 22
- 2-2 U-ing and O-ing straight-seam double-fusion-welded pipe, 22
- 2-3 Schematic diagram for making plate pipe, 22
- 2-4 Schematic representation of the sequence of operations performed by a typical machine for making electric-resistance-welded tubes from steel strip, 23
- 2-5 Cross section through weld point, 23
- 2-6 Electric-resistance welding using high-frequency welding current, 23
- 2-7 Electric-resistance welding by induction using high-frequency welding current, 23
  
- 3-1 Solution of the Hazen-Williams formula (based on  $V = 1.318Cr^{0.63}s^{0.54}$  for  $C = 140$ ), 29
- 3-2 The Moody diagram for friction in pipe, 31
- 3-3 Solution of Manning flow formula for  $n = 0.011$ , 33
- 3-4 Solution of Scobey flow formula for  $K_s = 0.36$ , 34
- 3-5 Resistance coefficients of valves and fittings for fluid flows, 38
- 3-6 Surge wave velocity chart for water, 40
  
- 4-1 Typical pipeline and hydraulic grade profiles for gravity flow, 50
- 4-2 Typical pipeline and hydraulic grade profiles for pumped flow, 50
  
- 5-1 Vertical stress under an imposed area load, 61
- 5-2 Trench detail, 65
  
- 6-1 Common pipe field joints: Bell-and-spigot rubber gasket joints (A, B, and C) and field-welded joints (D–G), 74
  
- 7-1 Basic elbow dimensions, 89
- 7-2 General outlet configurations, 91
- 7-3 Common outlet configuration terminology, 92
- 7-4 Collar and wrapper, 94
- 7-5 Generic sectional view of reinforcement of outlets in welded steel pipe, 95
- 7-6 Scale drawing of the resulting geometry of double outlet, 107
- 7-7 Configurations and welding for outlet not requiring reinforcement, 110

- 7-8 Configurations and welding for outlet requiring reinforcement, 110
- 7-9 One-plate wye, 111
- 7-10 Three-plate wye, 111
- 7-11 Two-plate wye, 111
- 7-12 Nomograph for selecting reinforcement plate depths of equal-diameter pipes, 112
- 7-13 *N* factor curves, 113
- 7-14 *Q* factor curves, 113
- 7-15 Selection of top depth, 115
- 7-16A Two-plate integral crotch-plate connections, 116
- 7-16B Two-plate external crotch-plate connections, 116
- 7-17 Wye-branch plan and layout, 117
- 7-18 Plate configurations for third-plate design, 117
- 7-19 Illustration of one-plate design, 118
- 7-20 Site illustration of two-plate design, 120
- 7-21 True-wye plan, 122
- 7-22 Plate configurations for a true wye, 123
- 7-23 Common handling and shipping lifting hole configurations, 125
- 7-24 Approximation of an ellipsoidal head, 125
- 7-25 Harness lug and ring detail, 137
- 7-26 Anchor ring, 143
- 7-27 Tapping main under pressure, 156
  
- 8-1 Hydrostatic thrust *T* applied by fluid pressure to typical fittings, 162
- 8-2 Typical thrust blocking of a horizontal bend, 163
- 8-3 Typical thrust blocking of vertical bends, with bearing-type and gravity-type blocks, 164
- 8-4 Horizontal frictional forces that resist horizontal thrust  $T = pA$
- 8-5 Pipe alignment through a curve, 167
- 8-6 Restraint of thrust at deflected gasketed joints on long-radius horizontal curves, 168
- 8-7 Unbalanced thrust at horizontal bends,  $T = 2pA \sin \Delta/2$ , 169
- 8-8 Unbalanced axial thrust,  $F = pA (1 - \cos \Delta)$  plus unbalanced thrust normal to axial thrust,  $F_2 = pA \sin \Delta$ , 169
- 8-9 Restraint of uplift thrust at deflected joints on long-radius vertical curves, 170
  
- 9-1 Details of concrete saddle: Pipe acting as a self-supporting bridge may rest on suitably padded concrete saddles, 174
- 9-2 Saddle supports for 78-in. pipe, 174
- 9-3 Ring girders provide support for 54-in.-diameter pipe, 174
- 9-4 Expansion joints between stiffener rings, 175
- 9-5 Anchor block, 175
- 9-6 Long-span steel pipe for low pressures, 184
- 9-7 Ring girders on 111-in. pipe, 185
  
- 10-1 Electrochemical corrosion cell, 188
- 10-2 Electrochemical corrosion cell—alkaline flashlight battery, 188
- 10-3 Dissimilar metal corrosion between stainless-steel base metal and carbon steel fasteners, 190
- 10-4 Corrosion cell—dissimilar electrolytes typical of car battery, 190
- 10-5 Galvanic cell on embedded pipe without protective coating, 190

- 10-6 Galvanic cell—pitting action, 191
- 10-7 Corrosion caused by dissimilar metals in contact on buried pipe, 191
- 10-8 Corroding anchor bolt contacting reinforcement is subject to differential pH corrosion in water holding basin, 192
- 10-9 Corrosion caused by new versus old steel pipe, 193
- 10-10 Corrosion caused by cinders, 194
- 10-11 Corrosion caused by dissimilarity of surface conditions, 194
- 10-12 Corrosion caused by dissimilar soils , 194
- 10-13 Corrosion caused by mixture of different soils , 195
- 10-14 Corrosion caused by differential aeration of soil, 195
- 10-15 Stray-current corrosion caused by electrified railway systems, 198
- 10-16 Bonding wire for bell-and-spigot rubber-gasketed joint, 201
- 10-17 Bonding wires installed on sleeve-type coupling, 201
- 10-18 Bonding wires installed on split-sleeve-type coupling, 202
- 10-19 Corrosion monitoring station, 202
- 10-20 Galvanic anode cathodic protection, 203
- 10-21 Cathodic protection—galvanic anode type, 204
- 10-22 Cathodic protection—rectifier type, 205
  
- 12-1 Pipe stulling and bracing configurations, 220
- 12-2 Steel reliner section, 229
- 12-3 Steel reliner assembly view (not to scale), 230
- 12-4 Steel slipliner section being inserted into host pipe with casing spacers, 231
- 12-5 Subaqueous pipeline—assembly and launching, 232
- 12-6 Subaqueous pipeline—positioning by barge, 233
- 12-7 Subaqueous pipeline—floating string positioning, 233
  
- A-1 Comparison of improving pipe embedment versus increasing wall thickness for 48-in. pipe, 250
  
- B-1 Harness lug geometry, 253
- B-2 Harness lug assembly geometry, 254
- B-3 Front harness ring/shell section, 258
- B-4 Back harness ring/shell sections, 260
- B-5 Simplified lug free body diagram, 263
  
- C-1 Harness rod placement for differential settlement across multiple harnessed joints (section view), 268
  
- E-1 Cross-section area of partially full cylinder, 273
- E-2 Measuring radius of curvature, 274
- E-3 Pipe with deflected joints or mitered ends in a long-radius curve, 275
- E-4 Spiral pipe helix angle, 276
- E-5 Vertical deflection of a pipe under its own weight on a flat surface, 277
- E-6 Vertical deflection of pipe full of water without support, 278
- E-7 Various ring deflections of a circular ring under load with rigid bottom arc and no side support, 278
- E-8 Combined Elbows FTQ Location, 279

This page intentionally blank.

# Tables



- 1-1 Effects of alloying elements, 5
- 1-2 Maximum strain in pipe wall developed in practice, 13
  
- 3-1 Multiplying factors corresponding to various values of  $C$  in Hazen-Williams formula, 29
- 3-2 Kinematic viscosity of water, 32
- 3-3 Multiplying factors for friction coefficient values—base  $n = 0.011$ , , 33
- 3-4 Multiplying factors for friction coefficient values—base  $K_s = 0.36$ , 34
- 3-5 Flow equivalents, 37
- 3-6 Velocity of pressure wave for steel pipe, 41
  
- 5-1 Live-load effect, 59
- 5-2 Newmark vertical influence coefficients, 60
- 5-3 Soil stiffness,  $E'$ , for pipe embedment materials (psi), 63
- 5-4 Comparison of standard density tests, 63
- 5-5 Unified soil classification, 64
  
- 7-1 Recommended reinforcement type based on PDV and outlet type, 93
- 7-2 Multiplier for pressure on the convex side of a head, 126
- 7-3 Tie rod schedule for harnessed joints, 128
- 7-4 Dimensions of joint harness tie rods and lugs for rubber-gasketed joints, 136
- 7-5 Minimum fillet weld size for harness lug assembly and anchor ring attachment, 136
- 7-6 Maximum allowable load per tie rod, 138
- 7-7A Dimensional information for anchor rings (100-psi maximum), 144
- 7-7B Dimensional information anchor rings (150-psi maximum), 145
- 7-7C Dimensional information for anchor rings (200-psi maximum), 146
- 7-7D Dimensional information for anchor rings (250-psi maximum), 147
  
- 8-1 Unit weight of soil,  $\text{lb}/\text{ft}^3$ , based on type of soil and relative compaction, 166
  
- 10-1 Galvanic series of metals and alloys (in seawater) at  $77^\circ\text{F}$ , 191
- 10-2 Soils grouped in order of typical corrosive action on steel, 197
- 10-3 Soil resistivity versus degree of corrosivity, 197
  
- 12-1 Pipe bracing, 219
- 12-2 Bolt torque, 226

This page intentionally blank.

# Preface



This manual provides a review of experience and theory regarding design of steel pipe used for conveying water, with appropriate references cited. The manual provides general and technical information to be used as an aid in the design and installation of steel pipe. It is a discussion of recommended practice, not an AWWA standard calling for compliance with certain specifications. Application of the principles and procedures discussed in this manual must be based on responsible judgment.

This manual was first authorized in 1943. In 1949, Committee 8310D on Steel Pipe, appointed one of its members, Russell E. Barnard, to act as editor in chief in charge of collecting and compiling the available data on steel pipe. The first draft of the report was completed by January 1957; the draft was reviewed by the committee and other authorities on steel pipe. The first edition of this manual was issued in 1964 with the title *Steel Pipe—Design and Installation*.

The second edition of this manual was approved in June 1984 and published in 1985 with the title *Steel Pipe—A Guide for Design and Installation*. The third edition of the manual was approved in June 1988 and published in 1989. The fourth edition of the manual was approved March 2003 and published in January 2004. This fifth edition was approved August 2016.

Major revisions to this fifth edition are (1) reorganization of the chapters to combine similar content in the same chapters; (2) elimination of some tables which were replaced with formulas and examples; (3) changes in aboveground design and examples to more clearly reflect conditions encountered on a water pipeline; (4) addition of a chapter on thrust design; (5) addition to the fittings chapter to include design of true wyes and crosses, design of crotch plates with higher strength steel, expanded elbow stress design in restrained areas, tangential outlet design was clarified, double outlet design was clarified, strength reduction factors for varying steel strengths of outlets was added, PDV values were clarified to 9000 for test and transient pressures, anchor ring design was added, design of ellipsoidal heads was added, and modified joint harness requirements; (6) added suggested bracing for shipping of pipe; (6) updated the flange bolt torque values and table; (7) buckling of buried pipe was clarified (8) weld details for outlets and crotch plates were added; (9) cement enhanced soil was defined and added; (10) design of welded lap joints was expanded; and (11) Appendixes were added for nomenclature, comparison of increase of  $E'$  versus increase of wall thickness, full example of harness ring design, design of harness rod placement for differential settlement, seismic considerations, and useful equations and conversions.