

HYDRAULICS OF PIPELINES

**PUMPS, VALVES, CAVITATION,
TRANSIENTS**

J. PAUL TULLIS

Professor of Civil and Environmental Engineering
Utah State University



A Wiley-Interscience Publication

JOHN WILEY & SONS

New York Chichester Brisbane Toronto Singapore



CONTENTS

Nomenclature	ix
Preface	xiii
1. Basic Concepts and Equations of Fluid Flow	1
1.1 Classification of Flow / 1	
1.2 Fluid Properties / 3	
1.3 Basic Equation / 9	
1.4 Fluid Friction / 15	
1.5 Minor Losses / 23	
1.6 Introduction to Cavitation / 25	
1.7 Introduction to Hydraulic Transients / 25	
2. Design of Pipelines	29
2.1 Feasibility Study / 29	
2.2 Economic Analysis / 31	
2.3 Pipe Materials / 41	
2.4 Pressure Class of Pipe / 42	
2.5 Hydraulic Design / 44	
3. Pumps	53
3.1 Pump Hydraulics / 54	
3.2 Pump Selection / 63	
3.3 Pump Operation / 73	

3.4 Suction Piping / 75	
3.5 Hydraulics of Pumping Pits / 76	
3.6 Cavitation in Pumps / 78	
4. Valves	81
4.1 Control Valves / 81	
4.2 Hydraulic Characteristics / 87	
4.3 Valve Selection and Sizing / 99	
4.4 Pressure-Regulating Valves / 107	
4.5 Check Valves / 111	
4.6 Air Valves / 114	
5. Fundamentals of Cavitation	119
5.1 Types of Cavitation / 119	
5.2 Effects of Cavitation / 120	
5.3 Origin of Cavitation / 121	
5.4 Damage Mechanism / 124	
5.5 Suppressing Cavitation / 125	
5.6 Cavitation Parameters / 126	
5.7 Evaluating Cavitation Limits / 127	
5.8 Scaling and Scale Effects / 129	
6. Cavitation Data for Valves	133
6.1 Cavitation Design Criteria / 133	
6.2 Experimental Data / 138	
6.3 Scale Effects / 144	
6.4 Controlling Cavitation / 152	
7. Cavitation Data for Orifices, Nozzles and Elbows	167
7.1 Orifice Scale Effects / 167	
7.2 Zones of Cavitation Damage / 170	
7.3 Nozzles and Sudden Enlargements / 172	
7.4 Multihole Orifices / 173	
7.5 Long-Radius Elbows / 175	
7.6 Comments on Size Scale Effects / 177	
8. Fundamentals of Hydraulic Transients	185
8.1 Definitions / 186	
8.2 Basic Transient Equation / 188	
8.3 Pressure-Wave Propagation Without Friction / 190	
8.4 Instant and Effective Value Closure Time / 193	
8.5 Wave Propagation With Friction / 196	

8.6 Wave Speed / 197	
8.7 Influence of Air on Wave Speed / 202	
9. Numerical Solution of Transients	205
9.1 Method of Analysis / 205	
9.2 Equation of Motion / 206	
9.3 Equation of Continuity / 207	
9.4 Method of Characteristics / 209	
9.5 Finite Difference Solution / 210	
9.6 Simple Boundary Conditions / 214	
9.7 Basic Waterhammer Program / 216	
9.8 Additional Boundary Conditions / 227	
9.9 Surge Analysis / 231	
9.10 Controlling Transients / 233	
9.11 Complex Piping Systems / 239	
10. Column Separation and Trapped Air	243
10.1 Column Separation / 243	
10.2 Air Release During Column Separation / 247	
10.3 Trapped Air / 250	
Appendix A. Conversion Factors	255
References	257
Index	263