Author’s Note

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Preface

This book addresses those areas of applied hydraulics of special interest to engineers engaged in the fields of water supply and wastewater disposal. The analytical methods employed are developed from first principles with an emphasis on engineering application rather than on mathematical rigour. Parameter correlations are presented in a format appropriate to problem solution by computer.

Chapter 1 reviews fluid properties. Chapter 2 reviews the basic concepts of fluid flow including the application of the principles of continuity, energy and momentum. Chapters 3-6 inclusive, deal with flow in closed conduits. Chapters 7, 8 and 10 deal with open channel flow. Chapter 9 is concerned with dimensional analysis and hydraulic modelling. Chapter 11 deals with pumping systems.
1. **Fluid properties**
   1.1 Introduction
   1.2 Viscosity
   1.3 Surface tension
   1.4 Vapour pressure
   1.5 Thermodynamic properties
   1.6 Compressibility
   1.7 Density
   References

2. **Fluid flow**
   2.1 Introduction
   2.2 Flow classification
   2.3 Fluid acceleration
   2.4 Streamtube and control volume concepts
   2.5 The continuity principle
   2.6 The momentum principle
   2.7 The energy principle
   2.8 Applications of the continuity, energy and momentum principles
      2.8.1 Incompressible flow
      2.8.2 Compressible flow
   2.9 Resistance to fluid flow
   References

3. **Steady flow in pipes**
   3.1 Introduction
   3.2 Categorisation of flow by Reynolds number
   3.3 Hydraulic and energy grade lines
   3.4 Shear stress distribution
   3.5 Laminar pipe flow
   3.6 Turbulent flow in pipes
   3.7 Practical pipe flow computation
      3.7.1 The Darcy-Weisbach and Colebrook-White equations
      3.7.2 Design values for pipe roughness
      3.7.3 Other pipe flow equations
   3.8 Flow of sewage sludge in pipes
      3.8.1 Laminar sludge flow in pipes
      3.8.2 Turbulent sludge flow in pipes
   3.9 Head loss in pipe fittings
      3.9.1 Head losses in valves
      3.9.2 Other pipe fittings
      3.9.3 Head loss in flow of sludge through fittings
   References

4. **Flow in pipe manifolds**
   4.1 Introduction
   4.2 Orifice-type pipe manifold
4.3 Pipe manifold with pipe laterals
4.4 Design of manifold systems
References

5. Steady flow in pipe networks

5.1 Water pipe networks
5.2 Head-discharge relationships for pipes
5.3 Network analysis
5.4 Boundary conditions
5.5 Solution of network equations
  5.5.1 Hardy Cross method
  5.5.2 Simultaneous loop flow correction
  5.5.3 Linearization of network equations
  5.5.4 Convergence of methods
5.6 Worked example: Hardy Cross
5.7 Loop selection
5.8 Initial flow distribution
5.9 Network flow controls
5.10 Analysis of existing distribution systems
5.11 Network analysis by ARTS
References

6 Unsteady flow in pipes

6.1 Introduction
6.2 The continuity equation
6.3 The momentum equation
6.4 Solution by the method of characteristics
  6.4.1 Finite difference formulations
6.5 Boundary conditions

6.5.1 Reservoir
  6.6.2 Pump at upstream end (running at fixed speed)
  6.6.3 Control valve at downstream end.
  6.6.4 Valve at an intermediate location
  6.6.5 Change in pipe size
6.6 Pressure transients due to pump starting and stopping
  6.6.1 Pump characteristics
  6.6.2 Pump cut-out: governing equations for pump node
6.7 Waterhammer control
  6.7.1 Flywheel
  6.7.2 Air vessel
  6.7.3 Surge tank
  6.7.4 Air valves
6.8 Column separation, entrained gas
6.9 Transient pressure limits
6.10 Waterhammer analysis using ARTS
6.11 Examples of waterhammer computation
6.12 Some practical design considerations
6.13 Some relevant material properties
References

7. STEADY FLOW IN OPEN CHANNELS
7.1 Introduction
7.2 Hydraulic resistance to flow
7.2.1 Influence of channel shape on flow resistance
7.3 Computation of uniform flow
    7.3.1 Use of ARTS software
7.4 Specific energy
7.5 Rapidly varied steady varied flow: the hydraulic jump
7.6 Gradually varied steady flow
7.7 Computation of gradually varied flow
    7.7.1 Computation of surface water profile using ARTS software.
7.8 Channel transitions
    7.8.1 Entry flow to closed conduits
References

8. Open channel flow measurement structures
8.1 Introduction
8.2 The broad-crested weir
8.3 The sharp-crested weir
    8.3.1 Rectangular sharp-crested weirs
    8.3.2 V-notch weirs
    8.3.3 The proportional-flow (Sutro) weir
8.4 The critical depth flume
8.5 Sharp-crested orifices
    8.5.1 The circular sharp-edged orifice
    8.5.2 The rectangular sharp-edged orifice
8.6 Selection and design of flow measurement structures
8.7 Flume and weir design using ARTS
References

9. Dimensional analysis, similitude, and hydraulic models
9.1 Introduction
9.2 Dimensionless quantities
9.3 The Buckingham \( \pi \) theorem
9.4 Physical significance of non-dimensional groups
9.5 Similarity requirements in model studies
    9.5.1 Pumps and turbines
    9.5.2 The use of distorted scales
9.6 Concluding comments
Related reading

10. Unsteady flow in open channels
10.1 Introduction
10.2 Basic equations
10.3 Solution by characteristics method
10.3 Numerical computation procedure
10.5 Simplification of the St Venant equations
10.6 Rapidly varied unsteady flow
    10.6.1 Upstream positive surge
    10.6.2 Downstream positive surge
    10.6.3 Upstream negative surge
    10.6.4 Downstream negative surge
References

11. Pumping installations
11.1 Introduction
11.2 Pump types
11.2.1 Positive displacement pumps
11.2.2 Rotodynamic pumps
11.2.3 The air-lift pump
11.2.4 The Archimedean screw pump
11.3 Hydraulics of rotodynamic pump/rising main systems
11.4 Economics of pump/rising main systems
11.5 Pumping station design
  11.5.1 Pump selection
  11.5.2 General layout
  11.5.3 Pump sump design
11.6 Control of pumping

Appendix