

Contents

| | |
|--|-----------|
| 1. Introduction | 5 |
| 2. Modern hydronic systems | 6 |
| 2.1 Heating and cooling systems | 6 |
| 2.2 Heat and cooling distribution according to Tichelmann | 10 |
| 2.3 Measuring and setting of hydronic balancing in practice | 11 |
| 2.4 Mounting position | 12 |
| 2.5 Circulation pumps | 13 |
| 2.6 Main distribution and heat generation | 15 |
| 3. Timeline of hydronics in building technology | 20 |
| 4. Basics of thermodynamics | 22 |
| 4.1 Thermal state variables | 22 |
| 4.2 Process variable | 23 |
| 4.3 Calorific state variables | 23 |
| 4.4 Processes | 24 |
| 5. Basics of fluid mechanics | 26 |
| 5.1 Continuity equation (conservation of mass) | 26 |
| 5.2 Bernoulli's equation (conservation of energy) | 26 |
| 5.3 Friction losses of flowing fluids | 27 |
| 5.4 Pressure loss in straight pipelines | 28 |
| 5.5 Pressure loss in pipe fittings and valves | 29 |
| 5.6 Pressure loss in control valves | 30 |
| 6. Hydronic circuits | 32 |
| 7. Circulation pumps | 36 |
| 7.1 Characteristics of centrifugal pumps | 37 |
| 7.2 Pump characteristic curves | 38 |
| 7.3 NPSH (Net Positive Suction Head) | 39 |
| 7.4 Pressure and connection of expansion tanks | 42 |
| 8. System characteristics | 46 |
| 8.1 Closed systems | 46 |
| 8.2 Open systems | 49 |
| 9. Series and parallel connection of system components | 54 |
| 9.1 Series connection | 54 |
| 9.2 Parallel connection | 58 |
| 9.3 Series and parallel connection | 62 |
| 10. Hydronic balancing under design conditions | 68 |
| 11. Pump connections | 74 |
| 11.1 Pumps connected in parallel | 74 |
| 11.2 Pumps connected in series | 81 |
| 12. Pumps and energy efficiency | 86 |
| 12.1 Power consumption and efficiency | 86 |
| 12.2 Annual costs for a pump (constant speed) | 90 |
| 13. Partial load operation in buildings | 94 |
| 14. Heating surfaces and water heating under partial load | 96 |
| 14.1 Heat supply system for room heating systems | 96 |
| 14.2 Internal heat exchangers for heating water | 99 |
| 14.3 External heat exchanger for heating water | 110 |

| | |
|---|------------|
| 15. Heat exchanger characteristics | 112 |
| 16. Control valves | 118 |
| 16.1 Flow characteristics of valves | 119 |
| 16.2 Design of control valves | 122 |
| 16.3 Hysteresis | 124 |
| 17. Characteristics of the controlled system | 126 |
| 18. Heat exchanger ventilation: Partial load performance | 130 |
| 19. Partial load behaviour of heat generators | 138 |
| 19.1 Single-stage heat generator | 140 |
| 19.2 Two-stage heat generator | 164 |
| 19.3 Modulating heat generator | 175 |
| 20. System features of heat generators | 184 |
| 20.1 Solar panels | 184 |
| 20.2 Heat pump as heat generator | 187 |
| 20.3 CHP as heat generator | 191 |
| 20.4 Heating boiler as heat generator | 194 |
| 21. Interplay of group and distribution hydronics | 199 |
| 22. Pump control | 200 |
| 22.1 Methods of controlling a pump | 200 |
| 22.2 Speed-controlled pumps | 204 |
| 23. The effect of hydronics on energy efficiency | 210 |
| 24. Behaviour of systems with variable flow rates | 220 |
| 24.1 Static hydronic balancing in pipelines | 220 |
| 24.2 Static hydronic balancing in risers | 250 |
| 24.3 Tichelmann system | 261 |
| 24.4 Hydronic balancing with automatic differential pressure controller | 267 |
| 24.5 Hydronic balancing with automatic differential pressure controller pipeline | 272 |
| 24.6 Hydronic balancing with automatic differential pressure controller – differential pressure riser | 290 |
| 24.7 Pressure-independent control valve | 292 |
| 24.8 Hydronic balancing with pressure-independent control valve – pipeline (AB-QM/VPI) | 301 |
| 24.9 Hydronic balancing for radiators with pressure-independent thermostat valves (Siemens VPD / Danfoss RA-DV) | 313 |
| 24.10 Comparison of systems for hydronic balancing | 316 |
| 25. Planning | 318 |
| 26. Installation, commissioning and operation | 320 |
| 27. Commissioning of hydronic systems | 321 |
| 28. Annex | 322 |
| Table: Physical characteristics of water (VDI) | 322 |
| Bibliography | 323 |
| Author, Cooperation, Project management, Editors | 324 |
| Formula symbols | 326 |
| Index | 328 |