## Contents

### Part 1
**Principles of the Fluid Dynamic Design of Packed Columns for Gas/Liquid Systems**

1 **Introduction** .......................................................... 11  
  1.1 General Information on Packed Columns .............................. 11  
  1.2 Development of Packed Columns and Their Significance in Rectification and Absorption Technology ............................ 14  
  1.3 Brief Overview of Existing Monographs and/or Complex Reviews on Packed Column Design .............................................. 17  
  1.4 Conclusion Chapter 1 ............................................. 21  

2 **Two-Phase Flow and Operating Range** ............................. 25  
  2.1 Hydraulic Processes in Packed Columns ................................ 25  
  2.2 Flooding Point ....................................................... 29  
    2.2.1 Flooding Mechanisms ........................................... 29  
    2.2.2 Droplet Formation in Packed Columns ............................. 31  
    2.2.3 Literature Overview – Status of Knowledge ..................... 34  
    2.2.4 New Model of Suspended Bed of Droplets (SBD) for Determining Gas Velocity \( u_{VH} \) at Flooding Point .................. 44  
    2.2.5 Conclusions Chapter 2.2 ...................................... 88  
  2.3 Determining Column Diameter ....................................... 93  
  2.4 Lower Loading Line .................................................. 93  
    2.4.1 Conclusions Section 2.4 ...................................... 94  

3 **Pressure Drop of Dry Packed Columns** ............................... 123  
  3.1 Introduction ............................................................ 123  
  3.2 Law of Resistance for Single-Phase Flow in Packed Columns ........ 123  
    3.2.1 Determining the Resistance Coefficient \( \psi \) for Pall Rings ......... 127  
    3.2.2 Determining the Resistance Coefficient for Other Random Packings ................................................................. 131  
    3.2.3 Determining the Resistance Coefficient \( \psi \) for Structured Packings ................................................................. 133
3.3 Introducing a Channel Model Based on Partially Perforated Channel Walls .......................................................... 140
3.3.1 Determining the Resistance Coefficient for Non-perforated Packing Elements ........................................ 142
3.3.2 Determining the Pressure Drop in Single-Phase Flow – Final Equation ............................................... 143
3.3.3 Evaluation of Results .............................................. 143
3.4 Conclusions Chapter 3 ............................................. 145

4 Pressure Drop of Irrigated Random and Structured Packings .......................................................... 175
4.1 Introduction and Literature Overview .......................................................... 175
4.1.1 Significance of Pressure Drop for Packed Column Design .......................................................... 175
4.1.2 Literature Overview .................................................. 176
4.2 Liquid Hold-Up .......................................................... 183
4.2.1 Basic Terms ...................................................... 184
4.2.2 Static Liquid Hold-Up ............................................ 184
4.2.3 Dynamic Liquid Load Below the Loading Line .......... 185
4.2.4 Analysing the Influence of Various Parameters on Liquid Hold-Up, Based on Literature Data .............................. 188
4.2.5 Test Method, Systems and Packing Elements .......................................................... 190
4.2.6 Experimental Results ............................................. 190
4.2.7 Conclusions Section 4.2 ........................................... 204
4.3 Model for Determining the Pressured Drop of Irrigated Random and Structured Packings, Based on the Known Resistance Coefficient \( \psi \) for Single-Phase Flow and the Dimensionless Pressure Drop \( \Delta p/\Delta p_0 \) .......................................................... 207
4.3.1 Deriving the Model .............................................. 207
4.3.2 Comparing Calculated and Experimental Values for Laminar Liquid Flow, \( \text{Re_L} < 2 \) .............................................. 209
4.3.3 Determining the Parameter \( C_B \) for Turbulent Liquid Flow .......................................................... 211
4.3.4 Comparing Calculated and Experimental Values for Turbulent Liquid Flow .............................................. 214
4.3.5 Conclusions Section 4.3 ........................................... 223

5 Pressure Drop of Irrigated Random and Structured Packings Based on the Law of Resistance for Two-Phase Flow .......................................................... 247
5.1 Introduction .......................................................... 247
5.2 Deriving the Model for Determining the Pressure Drop of Irrigated Random and Structured Packings .......................................................... 247
5.3 Law of Resistance \( \psi_{VL} = f(\text{Re_L}) \) for Packed Columns with Two-Phase Flow – Deriving the Model .......................................................... 248
5.4 Deriving the Equation for the Calculation of the Pressure Drop of Irrigated Random Packings .......................................................... 249
5.5 Comparing Calculated and Experimental Values Throughout the Entire Operating Range of Packed Columns .......................................................... 250
5.6 Evaluation of Results .................................................. 250
6 Fluid Dynamics of Packed Columns for Gas/Liquid Systems – Summary of Results ........................................................... 275
6.1 General Information .............................................................. 275
6.2 Determining the Flooding Point .............................................. 281
6.3 Liquid Hold-Up at Flooding Point ........................................... 282
6.4 Pressure Drop and Liquid Hold-Up ........................................... 282
  6.4.1 Pressure Drop Below the Loading Line ................................ 283
  6.4.2 Liquid Hold-Up Below the Loading Line ............................. 284
  6.4.3 Pressure Drop and Liquid Hold-Up in the Range Between the
       Loading Line and the Flooding Point .................................. 285
  6.4.4 Pressure Drop at Flooding Point ..................................... 286
6.5 Pressure Drop Calculation Acc. to the $\psi_{VL}$ Model Presented
       in Chapter 5 ............................................................. 287
6.6 Notes on Tables Containing Technical Data of Random and Structured
       Packings as Well as Model Parameters $\psi_{FL}/\psi_{FL,m}$ for Determining
       Flooding Point and Pressure Drop ..................................... 287
6.7 Validity Range of Correlations .............................................. 288
6.8 FDPAK Programme for Fluid Dynamic Design of Columns with
       Modern Random and Structured Packings ............................. 289
  6.8.1 Programme Information .................................................. 289
  6.8.2 Conclusions ............................................................... 295

Part 2
Principles of the Fluid Dynamic Design of Packed Columns for Liquid/Liquid Systems

7 Basic Principles of Packed Column Design for Liquid/Liquid Systems ........ 315
  7.1 Introduction ........................................................................ 315
  7.2 Two-Phase Flow and Operating Ranges .................................. 317
    7.2.1 Dispersed Phase Hold-Up in Packed Columns Containing
           Random and Structured Packings .................................. 317
    7.2.2 Droplet Diameter ....................................................... 324
  7.3 Determining the Flooding Point ........................................... 327
    7.3.1 Introduction .................................................................. 327
    7.3.2 Rising and Falling Velocity of Droplets in Packings –
           New Model ................................................................. 331
    7.3.3 Modified Flooding Point Diagram [15] ............................ 333
    7.3.4 Model for Determining the Specific Flow Rate of the Dispersed
           Phase at Flooding Point for Liquid/Liquid Systems ........... 335
  7.4 Conclusions ........................................................................ 338

Index ....................................................................................... 351
Fluid Dynamics of Packed Columns
Principles of the Fluid Dynamic Design of Columns for Gas/Liquid and Liquid/Liquid Systems
Mackowiak, J.
2010, XXI, 355 p., Hardcover
ISBN: 978-3-540-88780-5