

Contents

Preface *IX*

1	Diverging Trends before the Twentieth Century	1
1.1	Galileo's Abstraction	1
1.2	Hogs' Bladders in St. Paul's Cathedral	6
1.3	Ballistics	9
1.4	D'Alembert's Paradox	13
1.5	New Attempts to Account for Fluid Friction	15
1.6	Revival of Ideal Fluid Theory	18
1.7	Reynolds's Investigations of "Direct or Sinuous" Flow	22
1.8	Hydraulics and Aerodynamics: A Turn Towards Empiricism	24
1.9	Fluid Mechanics ca. 1900	28
2	The Beginnings of Fluid Dynamics in Göttingen, 1904–1914	31
2.1	Prandtl's Route to Boundary Layer Theory	32
2.2	"Per Experimentum et Inductionem Omnia"	38
2.3	The First Doctoral Dissertations on Boundary Layers	42
2.4	Airship Research	45
2.5	The Discovery of the Turbulent Boundary Layer	49
2.6	The Beginnings of Airfoil Theory	52
3	Aviation and the Rise of Aerodynamics in the First World War	57
3.1	A Symbiotic Relationship	59
3.2	War Contracts	63
3.3	Göttingen Profiles	67
3.4	Max Munk and the Foundation of Airfoil Theory	73
3.5	Theory and Practice in Airplane Design	76

4	The Internationalization of Fluid Mechanics in the 1920s	83
4.1	American Emissaries at Prandtl's Institute	84
4.2	Standardization	91
4.3	International Conferences	96
4.4	Applied Mathematics and Mechanics: A New International Discipline	100
4.5	Internationality in Practice: Max Munk at the NACA	102
5	A "Working Program" for Research on Turbulence	107
5.1	Turbulent Pipe Flow	108
5.2	Prandtl's Research Program on Turbulence	111
5.3	The Mixing Length Concept for the Fully Developed Turbulence	116
5.4	A Kind of Olympic Games	118
5.5	Wind Tunnel Turbulence	124
6	Aerodynamics Comes of Age	129
6.1	How Aerodynamics Became Institutionalized at Technical Universities	129
6.2	Glider Flight	134
6.3	Kármán and Junkers: The Beginnings of Industrial Consulting in Aeronautics	138
6.4	Profile Measurements	142
6.5	Airfoil Theory	148
7	New Applications	153
7.1	Gas Dynamics	154
7.2	Cavitation	162
7.3	Meteorological and Geophysical Fluid Dynamics	167
7.4	The Scope of Fluid Dynamics by the Early 1930s	174
8	Prandtl, Fluid Dynamics and National Socialism	177
8.1	Preparing for War: Increased Funding for Prandtl's Institute	179
8.2	Aeronautical Science as an Instrument of Nazi Propaganda	187
8.3	Goodwill Ambassador	190
9	New Centers	195
9.1	Aachen	196
9.2	Pasadena	201
9.3	Zurich	207

10	Fluid Dynamics on the Eve of the Second World War	213
10.1	Airfoil Theory	213
10.2	Turbulence	220
10.3	Gas Dynamics	228
11	Epilogue	233

Appendix

Abbreviations 243

References 245

Author Index 271

Name Index 275

Subject Index 279