

Contents

Acknowledgments	xvii
Introduction	xix
Abbreviations	xxv
1 Power in an Agricultural Economy: The Rural Water Mill	1
Numbers, Kinds, and Distribution	1
Role in Pioneering Development	6
Bread: The Fundamental Need	8
Sawmills and Shelter	15
Fulling and Carding Mills	21
Tanneries	25
Public Support of Water Mills	28
Growth in Numbers	36
Mills and the Market Economy	41
Water Mills in Western Europe	44
The Decline of Water Milling	47
Contributions of the Water Mill	49
2 The Traditional Technology	51
Dams, Millponds, and Races	54
Hydraulic Prime Movers: The Waterwheels	60
A Wheel in a Class by Itself	71
Wheels with Horizontal Shafts	83
A Technology of Wood	88
The Millwright's Craft	91
The Millwright's Companion	94
Milling Practice in the Colonial Period	104
From Water Milling to Waterpower	111
3 The Geographical Basis and Institutional Framework	114
The Geographical Determinants	116
Patterns of Millstreams and Waterpowers	118
Topography and Power Potential	119
Rainfall, Runoff, and Streamflow	122
Natural Regulators	126
Regional Power Potentials	130
The Law of Watercourses	139

Navigation Rights and the Milling Interests	142
Milldams and Fisheries	144
Farmers versus Flowage Rights	146
The Public Character of Water Mills	148
Conflict of Interests: Mills versus Mills	151
Difficulties in Coordination	155
4 Mill and Factory Villages: Grass Roots Industrialization	159
Power Sources in Perspective	161
Conditions Controlling the Choice of Power	163
Manufacturing as a Condition of Growth	169
Mill Seats as a Condition of Manufacturing	172
A Factor in the Growth of Towns	174
Waterpower and the Industrial Village	178
The Ubiquity and Variety of Waterpowers	181
River Systems and Patterns of Industrial Location	185
The River Basin: Basic Unit of Power Supply	189
Representative Drainage Basins in New England	191
The Merrimack, Connecticut, and Hudson River Valleys	194
Regional Variations in Waterpower Supply and Use	201
5 The First Industrial Cities	204
Breaking New Ground at Lowell	205
Engineering and Management Tasks	207
Power Supply: Evolution of Control	211
Small Industry: The Outsiders	217
The Lowell Achievement and Influence	221
Waterpower and Paper	227
Flour, Lumber, and the Falls of Saint Anthony	233
Power Developments in the South	242
Waterpower for Sale: The Overall Dimensions	247
6 Management of a Great Waterpower: The Proprietors of	
the Locks and Canals on the Merrimack	251
The Supply Canal Network	255
Enlargement of the Canal System	261
The Balance Sheet	268
Maintenance and Management	273
Shortcomings of the Supply System	276
Management of the Upstream Reservoirs	279
Shortage and Surplus	282
Steam Power	287
Discontent and Dissent	289

7	The Hydraulic Turbine	292
	Operating Criteria	293
	Changing Industrial Requirements	298
	Reaction Wheels	299
	Tub Wheel to Turbine	305
	Samuel Howd and the Inward-Flow Wheel	313
	Birth of the True Turbine	318
	The Turbine Reaches America	322
	Contributions of Boyden and Francis	328
	Who Invented the “Francis” Turbine?	338
8	A Generation of Declining Use and Advancing Technology	343
	The Stock-Pattern Turbine Industry	347
	James Emerson and the Holyoke Testing Flume	350
	The Mixed-Flow Turbine	359
	Designer-Builders of the Mixed-Flow Turbine	363
	Improving Efficiency at Part Gate	374
	Advances in Setting, Governing, and Positioning	378
	The American Stock-Pattern Turbine	385
	Influence of Hydroelectricity	388
	Turbine Design after Niagara	391
	Innovations in Western Mining States	396
	From the Hurdy-Gurdy to the Tangential Waterwheel	400
	In Brief Summation	413
9	The Transmission of Power through Millwork	416
	From Gristmill to Flouring Mill	421
	Variations in Transmission Requirements	431
	Power Distribution in Textile Mills	432
	Power Transmission in Mining	448
	New Conditions and New Needs	449
	British Innovations in Millwork	450
	The Shafting Revolution of Fairbairn and Lillie	456
	The New System in the United States	459
	The American Contribution: Belting in Main Drives	462
	Millwork Fittings and Equipment	471
	The Limitations of Millwork	478
10	The Decline of Direct-Drive Waterpower	481
	Factors in the Change	482
	Urbanization and Power Supply	485
	Regional and National Trends	488
	Power Trends by Major Industries	490

Motive Power and Two Economies	495
Traditional Industries in Decline	496
Unutilized and Underutilized Waterpowers	498
Expedients for Enlarging Power Supply	499
Irregularities in Streamflow	504
Storage Reservoirs	509
Auxiliary Steam Power	514
Comparative Costs of Steam Power and Waterpower	516
An Indictment Agreed Upon	529
A New Contender for Stream Use	530
Epilogue	536
Appendixes	
1. Grain-Milling Practices among the American Indians	545
2. Survivals: The Tub Mill	548
3. List of Ironwork for Gristmill	553
4. The Tenth Census Reports on Waterpower	556
5. Tidal Power along the Atlantic Seaboard	559
6. Data on Streamflow	562
7. James B. Francis on Estimating the Power of a Stream	564
8. The Franklin Institute's Experiments on Waterwheels	567
9. Comparison of a Boyden Turbine and the Burden Overshot Wheel	569
Index	575