# **Contents**

Acknowled	gments	xiii	
About the Authors		xv	
Introduction	n	xvii	
PART I	INTRODUCTION TO BASIC PRINCIPLES OF PUMPS AND HYDRAULICS		
Chapter 1	Basic Fluid Principles	3	
_	Physics	3	
	Matter	3	
	Body	4	
	Energy	5	
	Heat	7	
	Pressure	14	
	Barometer	21	
	Gravity	22	
	Force	26	
	Motion	28	
	Friction	34	
	Work and Power	36	
	Basic Machines	38	
	Lever	40	
	Wheel and Axle	41	
	Pulley	42	
	Inclined Plane	43	
	Screw	44	
	Wedge	45	
	Water	46	
	Properties of Water with Respect to		
	Pump Design	53	
	Pressure at Different Depths	54	
	Compressibility of Water	54	

## iv Contents

	Air	57
	Humidity	57
	Weight of Air	60
	Summary	61
	Review Questions	62
Chapter 2	Principles of Hydraulics	65
	Basic Principles	65
	Hydrostatics	69
	Static Head	70
	Static Lift	70
	Displacement	72
	Buoyancy	73
	Hydrostatic Paradox	76
	Hydrostatic Balance	76
	Hydrodynamics	77
	Dynamic Head	77
	Dynamic Lift	78
	Total Column	84
	Friction of Water in Pipes	84
	Flow of Water	89
	Measurement of Water Flow	89
	Siphon	96
	Flow through Orifices	97
	Specific Gravity	102
	Summary	106
	Review Questions	109
PART II	PUMPS	
Chapter 3	Centrifugal Pumps	113
	Basic Principles	113
	Pumps Having Straight Vanes	114
	Pump Having Curved Vanes	114
	The Volute	115
	Curvature of the Impeller Vanes	117
	Basic Classification	117

_						
C	റ	n	۲P	nt	٠.	v

Single-Stage Pump	118
Multistage Pump	119
Impellers	120
Balancing	123
Construction of Pumps	127
Casing or Housing	127
Impeller	127
Stuffing-Box Assembly	129
Bearings and Housings	129
Shaft Assembly	131
Drive	131
Installation	133
Location	133
Foundation	135
Leveling	135
Grouting	137
Inlet Piping	137
Discharge Piping	138
Pumps Handling High-Temperature	
Liquids	138
Operation	139
Priming	140
Starting the Pump	143
Stopping the Pump	145
Abnormal Operating Conditions	146
Troubleshooting	146
Reduced Capacity or Pressure and	
Failure to Deliver Water	147
Loses Water after Starting	147
Pump Overloads Driver	147
Pump Vibrates	148
Pointers on Pump Operation	148
Maintenance and Repair	149
Lateral End Clearances	149
Parts Renewals	149
Pointers on Assembly	150

## vi Contents

	Corrosion-Resisting Centritugal Pumps	152
	Typical Application — Plating	152
	Corrosion-Resisting Pump Installation	155
	Maintenance	157
	Corrosion-Resisting Pump	
	Troubleshooting	158
	Pump-End Assembly and Disassembly	158
	Good Safety Practices	161
	Impeller Design Considerations	162
	Velocity of Impeller	163
	Total Hydraulic Load or Lift	164
	Velocity Head	164
	Summary	173
	Review Questions	174
Chapter 4	Rotary Pumps	177
_	Principles of Operation	177
	Gear-Type Pumps	177
	Vane-Type Pumps	180
	Piston-Type Pumps	187
	Construction	188
	Gear-Type Pumps	190
	Vane-Type Pumps	199
	Piston-Type Pumps	200
	Installation and Operation	204
	Alignment	204
	Drives for Rotary Gear Pumps	208
	Power for Driving Pumps	208
	Piping	209
	Direction of Rotation	210
	Starting and Operating the Pump	212
	Practical Installation	212
	Types of Gear Pumps	213
	Pressure Relief Valve	215
	Rotary Pump Troubleshooting	216
	No Liquid Delivered	216
	Insufficient Liquid Delivered	217

	Pump Delivers for a Short Period, Then	
	Quits	217
	Rapid Wear	217
	Pump Requires Too Much Power	218
	Noisy Operation	218
	Calculations	218
	Correct Size of Pump	219
	Friction of Water in Pipes	219
	Friction Loss in Rubber Hose	219
	Dynamic Column or Total Load	221
	Dynamic Lift	221
	Dynamic Head	222
	Horsepower Required	224
	Summary	225
	Review Questions	228
Chapter 5	Reciprocating Pumps	229
	Principles of Operation	229
	Lift Pumps	230
	Force Pumps	231
	Self-Priming or Siphon Pumps	239
	Construction	240
	Calculations	243
	Lift	243
	Size of Discharge Pipe	248
	Head	248
	Displacement	250
	Piston Speed	251
	Slip	252
	Capacity	253
	Efficiency	254
	Summary	260
	Review Questions	262
Chapter 6	Special-Service Pumps	265
	Service Pumps	265
	Chemical and Process Pumps	270

# viii Contents

	Pumps for Medical Use	273
	Pumps for Handling of Sewage	274
	Other Special-Service Pumps	275
	Magma Pumps	276
	Sump Pumps	276
	Irrigation Pumps	281
	Diaphragm-Type Pumps	282
	Open-Diaphragm Pump	284
	Advantages of Diaphragm Pumps	284
	Shallow-Well and Deep-Well	
	Pumps	287
	Rubber Impeller Pumps	296
	Principles of Operation	297
	Marine Applications	297
	Tubing Pumps	298
	Basic Principle of Operation	299
	Lubricating the Tubing	301
	Variable Speed	301
	Types Available	301
	Air Driven Pump	311
	Multi-Tube Pumps	311
	Chemical Pumping	312
	Summary	312
	Review Questions	313
PART III	HYDRAULICS	
Chapter 7	Hydraulic Accumulators	317
	Basic Construction and Operation	317
	Types of Accumulators	318
	Weight-Loaded	319
	Spring-Loaded Accumulators	324
	Air- or Gas-Type Accumulators	324
	Shock Absorbers or Alleviators	331
	Air and Vacuum Chambers	334
	Air Chambers	334
	Vacuum Chambers	335

Contents	ix

	Accumulator Circuits	338
	Summary	342
	Review Questions	344
Chapter 8	Power Transmission	345
	Hydraulic Drives	345
	Basic Operating Principles	346
	Tangential Acceleration	348
	Tangential Deceleration	351
	Types of Hydraulic Drives	352
	Fluid Drive	352
	Hydraulic Drive	356
	Twin-Disk Hydraulic Drive	357
	Hydraulic Torque Converter	358
	Hydrostatic Transmission Systems	359
	Hydraulic Adjustable-Speed Drive	367
	Farm Tractor Applications	368
	Pumps for Robots	371
	CCS Systems	378
	Summary	381
	Review Questions	382
Chapter 9	Hydraulic Power Tools	383
-	Hydraulic Circuits	383
	Hydraulic Motors	385
	Types of Hydraulic Motors	389
	Hydraulically Controlled Circuits	394
	Combination Pump and Control Valve Unit	394
	Remote Directional Control Valves	395
	Operation of a Cylinder on a Machine Tool	
	Circuit Elements	398
	Operation of the Hydraulic Circuit	402
	Summary	403
	Review Questions	403
Chapter 10	Hydraulic Cylinders	405
•	Nonrotating Cylinders	405
	Names of Parts	407

## x Contents

	Force Developed in Nonrotating	
	Cylinders	415
	Installation	418
	Eccentric Loads	421
	Causes of Failure	422
	Repair and Maintenance	423
	Rotating Cylinders	424
	Names of Parts	424
	Installation	428
	Failure	430
	Repair and Maintenance	430
	Summary	432
	Review Questions	432
Chapter 11	Control Valves	435
	Pressure Controls	437
	Pressure Relief	437
	Sequence	438
	Pressure Reducing	439
	Counterbalance and Unloading	440
	Operating Signals	441
	Flow Controls	441
	Needle	444
	Noncompensating	444
	Compensating	445
	Directional Controls	447
	Summary	450
	Review Questions	451
Chapter 12	Hydraulic Control Valve Operators	453
	Pressure-Control Valve Operators	453
	Flow-Control Valve Operators	454
	Directional Control Valve Operators	456
	Manual Operators	456
	Solenoid Operators	460
	Mechanical Operators	463
	Pilot Operators	465

Contents	хi
----------	----

	Summary Review Questions	468 469
PART IV	FLUIDS, LINES, AND FITTINGS	
Chapter 13	Hydraulic Fluids	473
1	Petroleum-Base Fluids	473
	Synthetic-Base Fluids	473
	Quality Requirements	474
	Maintenance	475
	Change of Fluids in a Hydraulic System	476
	Selection of a Hydraulic Fluid	477
	Specific Weight	477
	Viscosity	478
	Saybolt Universal Viscosimeter	478
	Viscosity Problems	480
	Viscosity Index	480
	Lubricating Value	481
	Pour Point	481
	Oxidation and Contamination	481
	Hydraulic Filters	482
	Mobile-type Hydraulic Filter Units	485
	Summary	488
	Review Questions	488
Chapter 14	Fluid Lines and Fittings	491
-	Rigid Pipe	491
	Semi-Rigid (Tubing)	492
	Manufacturing Process	495
	Other Types	497
	Installation of Tubing	498
	Flexible Piping (Hose)	499
	Manifolds	505
	Summary	507
	Review Questions	507
Appendix A	Pump Resources	509

# xii Contents

Appendix B	Oils and Fluids
Appendix C	Latest Pumps Available
Index	

511513531