

# Table of Contents

Foreword .....	xv
<b>Chapter • One Introduction, 1</b>	
1.1 Objective.....	1
<b>Chapter • Two Overview, 3</b>	
2.1 Commercial Building Systems .....	3
2.2 Possible Improvements and Considerations .....	3
2.3 Asset Management Overview.....	4
2.3.1 Asset Management.....	5
2.3.2 Life Cycle Costs.....	5
2.3.3 Procurement .....	6
<b>Chapter • Three Pumping Fundamentals and Pump Selection Considerations, 7</b>	
3.1 Pump Selection Considerations and Guide Instructions .....	7
3.2 HI Standards and References.....	9
3.2.1 HI Standards .....	9
3.2.2 HI Pump References .....	10
3.3 Site Conditions .....	14
3.3.1 Installation Space .....	15
3.3.2 Piping Alignments .....	15
3.3.3 Wet Well Depth .....	15
3.3.4 Interior/Exterior Installations .....	16
3.3.5 Power .....	17

3.4 Pump Operational Requirements . . . . .	17
3.4.1 Pump Head . . . . .	17
3.4.2 Rate of Flow Requirements . . . . .	17
3.4.2.1 Pump Flow Rate and Total Head . . . . .	18
3.4.3 Net Positive Suction Head (NPSH) . . . . .	18
3.4.4 Suction and Discharge Requirements . . . . .	19
3.4.5 Efficiency . . . . .	19
3.4.6 Type of Material Pumped . . . . .	20
3.4.6.1 Non-potable Clean Water . . . . .	20
3.4.6.2 Glycol and Water Mixtures . . . . .	20
3.4.6.3 Potable (Domestic) Water . . . . .	21
3.4.6.4 Grey Water . . . . .	21
3.4.6.5 Wastewater . . . . .	21
3.4.7 Additional Requirements . . . . .	21
3.4.7.1 Altitude . . . . .	21
3.4.7.2 Temperature . . . . .	22
3.4.7.3 Speed . . . . .	22
3.4.7.4 Material Selections . . . . .	22
3.4.7.5 Standards and Codes . . . . .	23
3.4.7.6 Operation Time and Frequency of Operation . . . . .	23
3.4.7.7 Vibration Considerations . . . . .	24
3.4.7.8 Testing . . . . .	24
3.4.7.9 Commissioning . . . . .	24

## Chapter • Four **Common System Design Types, 27**

4.1 Open-loop vs Closed-loop Commercial Building Service Applications . . . . .	27
4.1.1 NPSHA Calculation for Open-loop Systems . . . . .	27
4.1.2 NPSHA Calculation for Closed-loop Systems . . . . .	28
4.2 Piping System Characteristics . . . . .	29
4.2.1 Primary-Secondary Pumping . . . . .	29

4.2.2 Advantages of Primary-Secondary Pumping.....	32
4.2.2.1 One Pipe Primary-Secondary .....	33
4.2.2.2 Two Pipe Primary-Secondary .....	33
4.2.3 Primary-Secondary-Tertiary Systems .....	34
4.2.4 Primary-Secondary Pump Selection .....	37
4.2.5 Variable Flow Primary .....	37
4.3 Miscellaneous Equipment.....	38
4.3.2 Expansion Tanks .....	38

## Chapter • Five

### **Common Components in Commercial Building Service Pumping Applications, 39**

5.1. Pump Drivers .....	39
5.1.1 Motor Types.....	39
5.1.1.1 Open Drip-proof (ODP) .....	40
5.1.1.2 Totally Enclosed Fan Cooled (TEFC).....	40
5.1.1.3 Totally Enclosed Nonventilated (TENV) .....	41
5.1.1.4 Weather Protected Types I and II (WPI, WPII) .....	41
5.1.1.5 Explosion-proof Motors (XP) .....	41
5.1.1.6 Submersible Motors.....	42
5.1.1.7 Electronically Commutated Motors (ECM) Motors .....	42
5.1.2 Motor Starting Methods.....	42
5.1.2.1 Across-the-Line or Direct-on-Line (DOL).....	43
5.1.2.2 Reduced Voltage Soft Starters (RVSS) .....	43
5.1.2.2.1 Primary Resistor Starting .....	43
5.1.2.2.2 Autotransforming Starting.....	44
5.1.2.2.3 Part-winding Starting .....	44
5.1.2.2.4 Wye-delta Starting .....	44
5.1.2.2.5 Solid State Starters.....	44
5.2 Variable Frequency Drives (VFDs) .....	44
5.3 Application Consideration (Solid-state Starting Methods).....	45

**Chapter • Six**  
**Example Commercial Building in Chicago, 47**

6.1 Typical System Types .....	47
6.1.1 Chilled Water.....	48
6.1.2 Geothermal .....	48
6.1.3 Plumbing and Water Systems .....	48
6.1.4 Fire Protection.....	49
6.1.5 Other systems.....	49

**Chapter • Seven**  
**HVAC Pumping Systems, 51**

7.1 Heating Systems.....	51
7.1.1 Hot Water Heating .....	51
7.1.1.1 General System Overview.....	51
7.1.1.2 Standards and Codes .....	51
7.1.1.3 Pump Features and Considerations.....	51
7.1.1.4 Pump Characteristics .....	52
7.1.1.5 Pump Types.....	52
7.1.2 Steam Heating Systems .....	52
7.1.2.1 General System Overview.....	52
7.1.2.2 Standards and Codes .....	53
7.1.2.3 Pump Features and Considerations.....	53
7.1.2.4 Pump Characteristics .....	54
7.1.2.4.1 Condensate Pumps .....	54
7.1.2.4.2 Condensate Return Units .....	54
7.1.2.4.3 Boiler Feed Pump Units .....	55
7.1.2.4.4 Vacuum Condensate Return Units .....	56
7.1.2.4.4.1 Faster System Heating .....	56
7.1.2.4.4.2 More Even Heating .....	56
7.1.2.4.4.3 Faster Condensate Return .....	56
7.1.2.4.4.4 Lifting of Low Returns .....	57
7.1.2.5 Pump Types.....	57

7.2 Cooling Systems .....	57
7.2.1 Chilled Water Systems .....	57
7.2.1.1 General System Overview .....	57
7.2.1.2 Standards and Codes .....	58
7.2.1.3 Pump Features and Considerations .....	58
7.2.1.4 Pump Characteristics .....	58
7.2.1.5 Pump Types .....	59
7.2.2 Condenser/Cooling Tower Systems .....	59
7.2.2.1 General System Overview .....	59
7.2.2.2 Standards and Codes .....	60
7.2.2.3 Pump Features and Considerations .....	60
7.2.2.4 Pump Characteristics .....	60
7.2.2.5 Pump Types .....	61
7.2.3 Waterside Economizer .....	61
7.2.3.1 General System Overview .....	61
7.2.3.2 Standards and Codes .....	63
7.2.3.3 Pump Features and Considerations .....	63
7.2.3.4 Pump Characteristics .....	63
7.2.3.5 Pump Types .....	63
7.3 Hydronic System Balance .....	64
7.3.1 Chemical Metering Pumps (Water Treatment) .....	65
7.3.1.1 Chemical Metering Pumps .....	65
7.3.1.2 Pump Features and Considerations .....	65
7.3.1.3 Typical Chemicals used for the Treatment of Water .....	65
7.3.1.4 Pump Characteristics .....	66
7.3.1.5 Pump Types .....	66

**Chapter • Eight**  
**Plumbing Pumping Systems, 67**

8.1 Pressure Booster .....	67
8.1.1 General System Overview .....	67
8.1.1.1 Required Flow Rate for a Water Supply System .....	68
8.1.1.2 Probability of All Fixtures Being Used Simultaneously ..	68

8.1.1.3 Pump Head Requirement .....	69
8.1.1.4 Design Considerations for Retrofit Applications .....	69
8.1.2 Standards and Codes .....	70
8.1.2.1 International Plumbing Code (IPC) .....	70
8.1.2.2 ASHRAE Energy Standard 90.1 .....	70
8.1.3 Pump Features and Considerations .....	70
8.1.4 Pump Characteristics .....	70
8.1.5 Pump Types .....	70
8.2 Hot Water Recirculation .....	71
8.2.1 General System Overview .....	71
8.2.2 Standards and Codes .....	72
8.2.3 Pump Features and Considerations .....	72
8.2.4 Pump Characteristics .....	72
8.2.5 Pump Types .....	73
8.3 Wastewater .....	73
8.3.1 General System Overview .....	73
8.3.2 Standards and Codes .....	75
8.3.3 Pump Features and Considerations .....	75
8.3.3.1 Fluids Handled .....	75
8.3.3.2 Variables that Impact Wastewater Pump Selection .....	76
8.3.4 Wastewater Pump Characteristics .....	78
8.3.4.1 Materials .....	78
8.3.4.2 Operation .....	78
8.3.5 Wastewater Pump Types .....	78
8.4 Grey Water .....	79
8.4.1 General System Overview .....	79
8.4.2 Standards and Codes .....	80
8.4.3 Pump Features and Considerations .....	80
8.4.4 Pump Characteristics .....	80
8.4.5 Pump Types .....	81
8.5 Elevator Pit Pumps .....	81
8.5.1 General System Overview .....	81
8.5.2 Standards and Codes .....	81
8.5.3 Features and Considerations .....	82
8.5.4 Pump Characteristics and Types .....	82

**Chapter • Nine**  
**Renewables/Energy Recovery, 83**

9.1	Introduction . . . . .	83
9.2	Geothermal Systems (ground source heat pumps [GSHPs]) . . . . .	84
9.2.1	General System Overview . . . . .	84
9.2.2	Standards and Codes . . . . .	84
9.2.3	Pump Features and Considerations . . . . .	84
9.2.3.1	Open-loop System . . . . .	85
9.2.3.2	Closed-loop System . . . . .	85
9.2.4	Pump Characteristics . . . . .	85
9.2.5	Pump Types . . . . .	86
9.3	Solar Domestic Hot Water (DHW) Heating . . . . .	86
9.3.1	General System Overview . . . . .	86
9.3.2	Standards and Codes . . . . .	87
9.3.3	Pump Features and Considerations . . . . .	87
9.3.4	Pump Characteristics . . . . .	88
9.3.5	Pump Types . . . . .	88
9.4	Condenser Heat Recovery . . . . .	88
9.4.1	General System Overview . . . . .	88
9.4.2	Standards and Codes . . . . .	89
9.4.3	Pump Features and Considerations . . . . .	89
9.4.4	Pump Characteristics . . . . .	90
9.4.5	Pump Types . . . . .	90
9.5	Rainwater Harvesting . . . . .	90
9.5.1	General System Overview . . . . .	90
9.5.2	Standards and Codes . . . . .	92
9.5.3	Pump Features and Considerations . . . . .	92
9.5.4	Pump Characteristics . . . . .	92
9.5.5	Pump Types . . . . .	92

**Chapter • Ten  
Fire Protection, 95**

10.1.1 General System Overview . . . . .	95
10.1.2 Standards and Codes . . . . .	95
10.1.3 Pump Features and Considerations . . . . .	96
10.1.4 Pump Characteristics . . . . .	97
10.1.5 Pump Types. . . . .	100

**Chapter • Eleven  
Swimming Pool and (Decorative/Feature) Fountains, 103**

11.1 Swimming Pools . . . . .	103
11.1.1 General System Overview . . . . .	103
11.1.2 Standards and Codes . . . . .	103
11.1.3 Pump Features and Considerations. . . . .	104
11.1.4 Pump Characteristics. . . . .	104
11.1.5 Pump Types . . . . .	105
11.2 (Decorative/Feature) Fountain Pumps . . . . .	106
11.2.1 General System Overview . . . . .	106
11.2.2 Standards and Codes . . . . .	106
11.2.3 Pump Features and Considerations. . . . .	106
11.2.4 Pump Characteristics. . . . .	106
11.2.5 Pump Types . . . . .	107

**Appendix A  
Select Pump Construction Drawings, 108**

**Appendix B  
Materials of Construction, 119**

**Appendix C  
Coupling Selection, 123**