

Contents

Page

Foreword	vii
2.3 Design and application	1
2.3.1 Scope	1
2.3.1.1 Preferred units for pump applications	1
2.3.1.2 Specific speed and suction specific speed	1
2.3.1.3 Introduction to pump classifications	5
2.3.2 Impeller types	5
2.3.3 Mechanical features	7
2.3.3.1 Radial thrust	7
2.3.3.2 Axial thrust	8
2.3.3.3 Shafting	14
2.3.3.4 Open lineshaft and enclosed lineshaft	15
2.3.3.5 Types of bearing bushings and spacing	18
2.3.3.6 Lubrication systems	19
2.3.3.7 Shaft seals	19
2.3.3.8 Nozzle loading	25
2.3.3.9 System piping and foundation	25
2.3.3.10 Reed frequency	25
2.3.3.11 Motor/Driver interface	26
2.3.4 Pump performance, selection criteria	31
2.3.4.1 Pumping system requirements	31
2.3.4.2 Pump versus system curves	31
2.3.4.3 System pressure limitation	32
2.3.4.4 Reverse runaway speed	32
2.3.4.5 Water (hydraulic) hammer analysis	32
2.3.4.6 Start-up and shut-down analysis	33
2.3.4.7 Pump and motor speed torque curves	34
2.3.4.8 Predicting pump performance after speed of rotation or impeller diameter change	36
2.3.4.9 Determining operating range, series and parallel operation	38
2.3.4.10 Range of operation	39
2.3.4.11 Continuous, intermittent, and cyclic service	40
2.3.4.12 Operation away from BEP flow	40
2.3.4.13 Intake design and submergence	41
2.3.4.14 Suction piping and cans	42
2.3.4.15 Net positive suction head available (NPSHA)	42
2.3.4.16 NPSHA corrections for temperature and elevation	44
2.3.4.17 NPSH margin considerations	46
2.3.4.18 NPSH requirements for pumps handling hydrocarbon liquids and water at elevated temperatures	46
2.3.4.19 Effects of handling viscous liquids	47
2.3.4.20 Losses	47
2.3.5 Sound levels (dBA)	50
Appendix A Pump classification and general application information	51
A.1 Introduction to pump classifications	51
A.2 Two-phase flow: Liquids with gas	51
A.3 Effect of gas on performance	51
A.4 Vertical pumps used as hydraulic turbines	54
A.5 Rotative speed considerations	57

Appendix B	Materials	60
B.1	Corrosion and erosion in vertical turbine pumps.	60
B.2	Protective coatings	61
B.3	Materials for rotodynamic vertical pumps	62
Appendix C	Motors/Drivers.	63
C.1	Introduction	63
C.2	Driver types.	63
C.3	Electric motors	65
C.4	Variable-speed drives	75
C.5	Gears	76
C.6	Deceleration devices.	76
Appendix D	Bibliography	77
Appendix E	Index	79

Figures

2.3.1a	— Included rotodynamic vertical pump types	2
2.3.1b	— Excluded rotodynamic vertical pump types	3
2.3.2a	— Enclosed impeller	6
2.3.2b	— Semi-open impeller	6
2.3.2c	— Axial flow impeller (propeller)	6
2.3.2d	— Double suction impeller	6
2.3.2e	— Inducer	7
2.3.3.2a	— Enclosed impeller plain top shroud	8
2.3.3.2b	— Semi-open impeller	8
2.3.3.2c	— Enclosed impeller with back ring and bypass holes	8
2.3.3.2d	— Enclosed end of shaft at suction	9
2.3.3.2e	— Shaft sleeve through packing or mechanical seal	9
2.3.3.2f	— Shaft sleeve through pressure breakdown bushing	9
2.3.3.2.2	— Experimental thrust coefficient C	12
2.3.3.2.4	— Axial thrust versus rate of flow curves	14
2.3.3.4a	— Open lineshaft, product-lubricated, vertical turbine pump	16
2.3.3.4b	— Enclosed lineshaft, oil-lubricated, vertical turbine pump	16
2.3.3.4c	— Open lineshaft	17
2.3.3.4d	— Enclosed lineshaft	17
2.3.3.7.1a	— Mechanical seal classification by arrangement	20
2.3.3.7.1b	— Mechanical seal classification by design	20
2.3.3.7.3a	— Unbalanced, external seal	22
2.3.3.7.3b	— Internal seal arrangement	22
2.3.3.7.3c	— Special seal arrangement.	23
2.3.3.7.4a	— Stuffing box for low to intermediate pressure service.	23
2.3.3.7.4b	— Stuffing box with injection.	24
2.3.3.10a	— Typical vibration signature of discharge head/driver support with driver.	26

2.3.3.10b — Reed frequency is close to the maximum range of operating rpm	27
2.3.3.10c — Reed frequency is close to the minimum range of operating rpm	27
2.3.3.11.4a — Solid shaft motor	29
2.3.3.11.4b — Hollow shaft motor	29
2.3.3.11.4c — Head shaft coupling, rigid style, for hollow shaft motor	29
2.3.3.11.5a — Flanged adjustable coupling, rigid style	31
2.3.3.11.5b — Flanged adjustable spacer coupling, rigid style	31
2.3.4.2 — Pump performance versus system curve	32
2.3.4.7a — Torque versus speed - metric units	35
2.3.4.7b — Torque versus speed - US customary units	36
2.3.4.8 — Impeller with angled outside diameter	37
2.3.4.9a — Series operation	39
2.3.4.9b — Parallel operation	39
2.3.4.10 — Operating range	40
2.3.4.14 — Suction cans (barrels) with vents	43
2.3.4.18a — NPSHR reduction for pumps handling hydrocarbon liquids and high-temperature water (metric units)	48
2.3.4.18b — NPSHR reduction for pumps handling hydrocarbon liquids and high-temperature water (US customary units)	49
A.1 — Overhung pump types and classifications	52
A.2 — Between-bearings pump types and classifications	53
A.3 — Vertically suspended pump types and classifications	53
A.4 — Effect of gas on pump performance	54
A.5 — Turbine characteristics for pumps with $n_s < 50$ (2500)	55
A.6 — Turbine performance	56
A.7 — Recommended maximum operating speeds for single suction pumps (metric units)	58
A.8 — Recommended maximum operating speeds for single suction pumps (US customary units)	59
C.1 — Typical torque–speed curves for NEMA design AC motors	70
C.2 — Torque–speed curves for design A, B, C, D for AC motor	71
 Tables	
2.3.1.1 — Principal symbols	4
C.1 — Drivers – functions and parameters for selection	63
C.2 — Common electric motor enclosure types (Source: NEMA MG 1)	67
C.3 — Definition of first numeral in IP classification system	68
C.4 — Definition of second numeral in IP classification system	68