

Contents

Page

Foreword	xiii
1.3 Design and application	1
1.3.1 Scope	1
1.3.2 Introduction to pump classifications	1
1.3.2.1 Introduction to pump industry segments and general applications	3
1.3.2.2 Preferred units for pump applications	4
1.3.3 Casings	6
1.3.3.1 Single volute	7
1.3.3.2 Double volute	7
1.3.3.3 Diffuser	7
1.3.3.4 Circular (concentric) casing	8
1.3.3.5 Multistage arrangements	8
1.3.3.5.1 Type BB3 between-bearings axial split volute	8
1.3.3.5.2 Type BB4 between-bearings radial split single case	8
1.3.3.5.3 Type BB5 between-bearings radial split double case volute	9
1.3.3.5.4 Type BB5 between-bearings radial split double case diffuser	9
1.3.3.6 Corrosion allowance for metallic rotodynamic pumps	10
1.3.4 Impellers	11
1.3.4.1 General impeller types	11
1.3.4.2 Single suction	12
1.3.4.3 Double suction	12
1.3.4.4 Multistage pumps	12
1.3.4.5 Enclosed	13
1.3.4.6 Semi-open	13
1.3.4.7 Open	13
1.3.4.8 Special suction impeller (inducer)	14
1.3.5 Mechanical features	14
1.3.5.1 Calculation of radial thrust for volute pumps	14
1.3.5.2 Calculation of axial thrust for impellers	19
1.3.5.2.1 Axial thrust on enclosed impellers	19
1.3.5.2.2 Calculation of axial thrust for semi-open impellers	27
1.3.5.2.3 Calculation of axial force due to momentum change	29
1.3.5.3 Types of bearing arrangements	30
1.3.5.3.1 Impeller overhung from bearings (Type OH)	30
1.3.5.3.2 Impeller mounted between bearings (Type BB)	31
1.3.5.4 Shaft deflection	33

1.3.5.4.1	Description	33
1.3.5.4.2	Typical industry standards	33
1.3.5.5	Guidelines for bearings and lubrication methods	43
1.3.5.5.1	Introduction	43
1.3.5.5.2	Bearing types	43
1.3.5.5.3	Bearing life (horizontal pumps)	45
1.3.5.5.4	Bearing temperature	52
1.3.5.6	Bearing lubrication	52
1.3.5.6.1	Grease	52
1.3.5.6.2	Oil lubrication	53
1.3.5.6.3	Product lubrication	53
1.3.5.6.4	Quality of lubrication (oil flood, ring oil circulating and splash systems)	54
1.3.5.6.5	Improving quantity in oil flood, ring oil circulating and splash systems	55
1.3.5.7	Type of couplings	56
1.3.5.7.1	Offset (flexible or driveshaft)	56
1.3.5.7.2	Limited end float	56
1.3.5.7.3	Gear	57
1.3.5.7.4	Disc	58
1.3.5.7.5	Elastomeric	58
1.3.5.7.6	Speed limitations	58
1.3.5.7.7	Alignment	58
1.3.5.8	Shaft seals	59
1.3.5.8.1	Packed stuffing boxes	59
1.3.5.8.2	Mechanical seals	60
1.3.5.8.3	Seal chambers	63
1.3.5.8.4	Other sealing means	63
1.3.5.8.5	Sealless pumps	63
1.3.5.8.6	Bearing housing sealing	63
1.3.6	Performance, selection criteria	66
1.3.6.1	System requirements	66
1.3.6.1.1	Pump performance curve versus system curve	66
1.3.6.1.2	Predicting pump performance after impeller diameter change	67
1.3.6.1.3	System pressure limitation	69
1.3.6.1.4	Operation away from the best efficiency point	69
1.3.6.2	Minimum flow	70
1.3.6.3	Net positive suction head	70
1.3.6.3.1	NPSHA corrections for temperature and elevation	70
1.3.6.3.2	NPSH margin considerations	71
1.3.6.3.3	NPSH requirements for pumps handling hydrocarbon liquids and water at elevated temperatures	71

1.3.6.3.4	Limitations for use of chart for net positive suction head reduction	72
1.3.6.3.5	Instruction for using chart for net positive suction head reduction	73
1.3.6.3.6	Use of chart for net positive suction head reduction for liquids other than hydrocarbons or water	73
1.3.6.4	Suction performance considerations.	73
1.3.6.5	Determination of operating duty point.	76
1.3.6.5.1	Series and parallel operation	76
1.3.6.5.2	Continuous, intermittent, and cyclic service	76
1.3.6.6	Liquid temperature rise in a rotodynamic pump	76
1.3.6.6.1	Temperature rise calculation.	76
1.3.6.6.2	Minimum flow in a pump due to temperature rise.	78
1.3.6.7	Efficiency prediction method for rotodynamic pumps	80
1.3.6.8	Effects of handling viscous liquids	80
1.3.6.9	Startup and shutdown.	80
1.3.6.9.1	Starting with closed discharge valve.	80
1.3.6.9.2	Starting with open discharge valve (mixed flow and axial flow type pumps)	81
1.3.6.9.3	Shutdown	81
1.3.6.10	Reverse runaway speed	81
1.3.6.11	Water (hydraulic) hammer	81
1.3.6.12	Pump liquid temperature limits on end suction pumps	81
1.3.6.13	Intake design	82
1.3.6.14	Pump and motor speed-torque curves	82
1.3.7	Noise levels.	91
1.3.7.1	Estimation of sound pressure levels.	91
1.3.8	Baseplates – introduction	94
1.3.8.1	Functional requirements	94
1.3.8.2	Baseplate types	94
1.3.8.2.1	Grouted baseplate	96
1.3.8.2.2	Nongrout-type baseplate	96
1.3.8.2.3	Pregouted baseplate	97
1.3.8.2.4	Soleplate	98
1.3.8.2.5	Freestanding baseplate	99
1.3.8.2.6	ASME B73 and ISO 2858 standard baseplates	99
1.3.8.2.7	Nonmetallic baseplates.	101
1.3.8.2.8	Oil pipeline skid type baseplate	103
1.3.8.2.9	Offshore skid type baseplate	104
1.3.8.2.10	Three-point mount baseplate	104
1.3.8.3	Tolerancing	106
1.3.8.4	Stress and rigidity requirements	106
1.3.8.5	Coupling alignment.	107

1.3.8.6	Shims and fasteners	107
1.3.8.7	Lifting requirements	107
1.3.8.8	Miscellaneous criteria	107
Appendix A	Introduction to pump classifications, industry segments, and general applications	109
A.1.3.1	Pump classifications	109
A.1.3.2	Pump industry segments and general service applications	109
A.1.3.2.1	General service applications	112
A.1.3.2.2	Transfer pumping	112
A.1.3.2.3	Booster service	113
A.1.3.2.4	Pumps used as hydraulic turbines	113
A.1.3.2.5	Dry pit (nonclog) pumps	116
A.1.3.2.6	Self-priming pump applications	118
A.1.3.2.7	Two-phase pumping applications	121
Appendix B	Other configurations	125
B.1.3	Introduction to Appendix B	125
B.1.3.1	Regenerative turbine pumps	125
B.1.3.1.1	Principle of operation	125
B.1.3.1.2	Definitions and terminology	126
B.1.3.1.2.1	Bucket (impeller channels)	126
B.1.3.1.2.2	Circulatory flow	126
B.1.3.1.2.3	Dam	127
B.1.3.1.2.4	Discharge	127
B.1.3.1.2.5	Impeller	128
B.1.3.1.2.6	Side channels (flow-through area)	128
B.1.3.1.2.7	Side clearance	128
B.1.3.1.2.8	Suction	128
B.1.3.1.2.9	Teeth	128
B.1.3.1.3	Application	128
B.1.3.1.4	Design	128
B.1.3.1.4.1	Performance changes	128
B.1.3.1.4.2	Change in head at constant speed	128
B.1.3.1.4.3	Change in flow at constant speed	128
B.1.3.1.4.4	Change in speed	128
B.1.3.1.4.5	Efficiency	129
B.1.3.1.4.6	Special characteristics	129
B.1.3.1.5	Special maintenance	130

B.1.3.1.5.1	Clean liquids	130
B.1.3.1.5.2	Strainer	130
B.1.3.1.6	Summary.	130
B.1.3.2	Pitot tube pumps.	130
B.1.3.2.1	Nomenclature	130
B.1.3.2.1.1	Description of a pitot tube pump	130
B.1.3.2.1.2	Definitions and terminology.	131
B.1.3.2.2	Design and application	133
B.1.3.2.2.1	Theory.	133
B.1.3.2.2.2	Performance changes.	133
B.1.3.2.2.3	Test standards	133
B.1.3.2.2.4	Special characteristics	135
B.1.3.2.2.5	Special maintenance requirements.	136
B.1.3.3	Sump pumps - introduction.	136
B.1.3.3.1	Description of sump pump type VS4 (line shaft design).	137
B.1.3.3.1.1	Definitions and terminology.	137
B.1.3.3.1.2	Application	140
B.1.3.3.1.3	Performance	140
B.1.3.3.1.4	Special characteristics	143
B.1.3.3.2	Description of sump pump type VS5 (cantilever shaft design)	145
B.1.3.3.2.1	Definitions and terminology.	146
B.1.3.3.2.2	Application	148
B.1.3.3.2.3	Performance	148
B.1.3.3.2.4	Special characteristics	149
Appendix C	Drivers.	153
C.1.3	Introduction to Appendix C	153
C.1.3.1	Electric motors	153
C.1.3.1.1	Motor types	155
C.1.3.1.1.1	AC (alternating-current) single-phase motors.	155
C.1.3.1.1.2	AC polyphase motors	156
C.1.3.1.1.3	Direct current (DC) motors	156
C.1.3.1.2	Electric motor construction	156
C.1.3.1.2.1	Enclosures	156
C.1.3.1.2.2	Degree of protection	157
C.1.3.1.2.3	Cooling methods.	158
C.1.3.1.2.4	Motor bearings	159
C.1.3.1.2.5	Mounting methods and orientation	159
C.1.3.1.3	Performance characteristics	160

C.1.3.1.3.1	Relationship between voltage and current	160
C.1.3.1.3.2	Torque versus speed	160
C.1.3.1.3.3	Efficiency.	161
C.1.3.1.3.4	Power factor	162
C.1.3.1.3.5	Service factor	163
C.1.3.1.3.6	Altitude	163
C.1.3.1.3.7	Frequency.	163
C.1.3.1.3.8	Starting	163
C.1.3.1.4	Classified (or regulated) areas (hazardous atmospheres)	164
C.1.3.1.4.1	Explosion-proof and dust-ignition-proof motors	164
C.1.3.1.4.2	National Electrical Code – Hazardous locations and materials: class, division, group.	165
C.1.3.1.5	Variable-speed power sources for electric motors	166
C.1.3.1.6	Reference Industry Standards	168
C.1.3.2	Engines.	168
C.1.3.2.1	Engine types	168
C.1.3.2.2	Gasoline engines	169
C.1.3.2.3	Diesel engines	169
C.1.3.2.4	Construction	169
C.1.3.2.4.1	Engine mounting.	169
C.1.3.2.4.2	Types of drive connection.	169
C.1.3.2.4.3	Engine cooling	170
C.1.3.2.4.4	Enclosures for engine protection	170
C.1.3.2.5	Engine operation.	171
C.1.3.2.5.1	Speed governing.	172
C.1.3.2.5.2	Engine starting	173
C.1.3.2.5.3	Condition monitoring.	173
C.1.3.2.6	Engine testing and performance considerations.	174
C.1.3.2.7	Package design considerations	174
C.1.3.3	Steam turbine	175
C.1.3.4	Eddy current drives.	176
C.1.3.5	Deceleration devices.	176
C.1.3.6	Variable-speed drives and gears	176

Appendix D	Bibliography	177
Appendix E	Index	179
Figures		
1.3.1	— Rotodynamic (centrifugal) pump types	2
1.3.3.1	— Single volute casing	7
1.3.3.2	— Double (dual) volute casing	7
1.3.3.3	— Diffuser casing	7
1.3.3.4	— Circular (concentric) casing	8
1.3.3.5.1	— Type BB3 between-bearings axial split multistage pump	8
1.3.3.5.2	— Type BB4 between-bearings radial split single case multistage pump	9
1.3.3.5.3	— Type BB5 between-bearings radial split double case multistage volute pump	9
1.3.5.5.4.1	— Type BB5 between-bearings radial split double case multistage pump with stacked in-line diffuser construction	10
1.3.5.5.4.2	— Type BB5 between-bearings radial split double case multistage pump with back-to-back diffuser construction	10
1.3.4.1	— General impeller types	11
1.3.4.2	— Single suction impeller	12
1.3.4.3	— Double suction impeller	12
1.3.4.5	— Enclosed impeller	13
1.3.4.6	— Semi-open impeller	13
1.3.4.7	— Open impeller	13
1.3.4.8	— Inducer	14
1.3.5.1a	— Additional sketch to illustrate D_2 and b_2	15
1.3.5.1b	— Single volute radial thrust distribution	15
1.3.5.1c	— Single volute	16
1.3.5.1d	— Radial thrust factor for single volute with various specific speeds	16
1.3.5.1e	— Double volute	17
1.3.5.1f	— Radial thrust factor for double volute with various specific speeds	17
1.3.5.1g	— Circular (concentric) casing	18
1.3.5.1h	— Radial thrust factor for circular (concentric) casing typical for specific speed 20 (1000)	18
1.3.5.2.1a	— Pressure distribution on enclosed impeller	19
1.3.5.2.1b	— Pressure distribution on enclosed impeller shrouds for various specific speeds	21
1.3.5.2.1c	— Thrust calculation example (metric units) for enclosed impeller with plain back shroud	22
1.3.5.2.1d	— Impeller with back ring	23
1.3.5.2.2a	— Semi-open impeller with a full back shroud	27
1.3.5.2.2b	— Semi-open impeller with a scalloped back shroud	27
1.3.5.2.2c	— Cross section of semi-open impeller showing diameter locations	28
1.3.5.3.1	— Overhung impeller pump	30
1.3.5.3.2	— Impeller between bearings	31

1.3.5.3.2.1 — Pressure distribution on between-bearings double suction enclosed impeller	32
1.3.5.3.2.2 — Horizontal between-bearings axially split multistage pump	32
1.3.5.4.2.4a — Overhung impeller	34
1.3.5.4.2.4b — Between-bearings single stage pump - method of calculating shaft deflection neglecting coupling weight	38
1.3.5.5.2.2a — Sleeve bearings	44
1.3.5.5.2.2b — Type BB4 multistage radial split single casing pump with ball and roller bearings	45
1.3.5.8.1a — Stuffing box without lantern ring	59
1.3.5.8.1b — Stuffing box with lantern ring	59
1.3.5.8.2.1a — Mechanical seal classification by arrangement	61
1.3.5.8.2.1b — Mechanical seal classification by design	61
1.3.5.8.6.1 — Types of bearing housing shaft seals	64
1.3.5.8.6.3a — Lip seal	65
1.3.5.8.6.3b — Lip seal with secondary V-ring	65
1.3.5.8.6.8 — Bearing isolator	66
1.3.6.1.1a — Pump performance curve versus system curve	66
1.3.6.1.1b — Variable speed curve	67
1.3.6.1.2a — Impeller with straight outside diameter	68
1.3.6.1.2b — Impeller with angled outside diameter	68
1.3.6.1.2c — Trimming only the impeller vane	69
1.3.6.3.5a — NPSHR reduction for pumps handling hydrocarbon liquids and high-temperature water (metric units)	74
1.3.6.3.5b — NPSHR reduction for pumps handling hydrocarbon liquids and high-temperature water (US customary units)	75
1.3.6.5.1a — Pumps operating in series	76
1.3.6.5.1b — Pumps operating in parallel	76
1.3.6.14a — Torque curve	84
1.3.6.14b — Evaluation of pump torque versus speed (metric units)	85
1.3.6.14c — Evaluation of pump torque versus speed (US customary units)	86
1.3.6.14d — Plotting torque versus speed (metric units)	87
1.3.6.14e — Plotting pump torque versus speed (US customary units)	90
1.3.7.1a — Combining sound pressure	92
1.3.7.1b — dBA correction for impeller trim and percent BEP operation	93
1.3.8.2.1a — Grouted baseplate, fabricated steel	96
1.3.8.2.1b — Grouted baseplate, cast iron	97
1.3.8.2.2 — Nongrout baseplate	97
1.3.8.2.3 — PregROUTed baseplate	98
1.3.8.2.4 — Soleplate	99
1.3.8.2.5a — Freestanding baseplate	100
1.3.8.2.5b — Baseplate mounting springs with slide bearing	100
1.3.8.2.6.1 — ASME B73.1 pump and baseplate	100

1.3.8.2.6.2 — ISO pump and baseplate	101
1.3.8.2.7.1 — Formed polymer baseplate	102
1.3.8.2.7.2 — Polymer concrete base	103
1.3.8.2.7.3 — Pedestal baseplate	103
1.3.8.2.8 — Oil pipeline skid type baseplate	104
1.3.8.2.9 — Offshore skid type baseplate	105
1.3.8.2.10a — Three-point mount type baseplate	105
1.3.8.2.10b — Underside of the three-point mount baseplate (O, P, and Q show the mounting points)	106
A1.3.1.a — Overhung pump types and classifications	110
A1.3.1.b — Between-bearing pump types and classifications	111
A1.3.1.c — Vertically suspended pump types and classifications	111
A1.3.2.4a — Turbine characteristics	114
A1.3.2.4b — Turbine performance	116
A1.3.2.5c — Dry pit pump — overhung foot mounted flexibly coupled horizontal end suction	117
A1.3.2.5a — Dry pit pump — overhung flexibly coupled vertical end suction	117
A1.3.2.5b — Dry pit pump — overhung close coupled vertical end suction	117
A1.3.2.6a — Self-priming pump — construction industry	119
A1.3.2.6b — Self-priming pump — chemical industry	120
A1.3.2.7a — Two-phase pumping applications	121
A1.3.2.7b — Helico-axial multiphase pump	122
A1.3.2.7c — Screw-type multiphase pump	123
A1.3.2.7d — Effect of gas on pump performance	124
A1.3.2.7e — Venting the eye of the impeller	124
A1.3.2.7f — Top suction impeller	124
B1.3.1 — Regenerative turbine pumps types and classifications	125
B1.3.1.1a — Regenerative turbine – impeller between bearings – two stage	126
B1.3.1.1b — Regenerative turbine flow path	127
B1.3.1.4.1 — Regenerative turbine pump performance	129
B1.3.2.1.2.6a — Cross section of pitot tube pump	131
B1.3.2.1.2.6b — Rotating assembly	132
B1.3.2.2 — Pitot tube pump performance	134
B1.3.3.1 — Type VS4 line shaft design sump pump	138
B1.3.3.1.3.4 — Tailpipe and float control	141
B1.3.3.1.3.3 — Rate of flow versus minimum submergence	142
B1.3.3.1.4.4 — Schematic showing vapor-proof/pressurized design	144
B1.3.3.1.4.6 — Alarms and controls	145
B1.3.3.1.4.7 — Applied forces and moments	145
B1.3.3.2 — Type VS5 cantilever shaft design sump pump	147
B1.3.3.2.3.3 — Rate of flow versus minimum submergence	150
B1.3.3.2.4.5 — Applied forces and moments	151
C1.3.1.3.2a — Torque speed curves for NEMA Design AC motors	160

C1.3.1.3.2b — Design A, B, C, D for AC motors	161
C1.3.2.7 — Outline of an internal combustion engine	175

Tables

1.3.2 — Principal symbols	5
1.3.5.5.2.1 — Rolling element bearing types	43
1.3.5.5.3.5 — Life adjustment factors	49
1.3.5.5.3.6 — Oil contamination factor η_c	51
1.3.5.7 — Shaft couplings - functions and parameters for selection	57
1.3.6.12a — Guidelines for minimum and maximum liquid temperature for gray iron, ductile iron, carbon steel, chrome steel, austenitic stainless and duplex stainless steel pumps (°C)	83
1.3.6.12b — Guidelines for minimum and maximum liquid temperature for gray iron, ductile iron, carbon steel, chrome steel, austenitic stainless and duplex stainless steel pumps (°F).	83
1.3.7.1 — Multistage pump sound pressure reductions.	92
1.3.8.1 — Functions of a baseplate and parameters for selection.	95
C1.3.1 — Drivers – functions and parameters for selection	154
C1.3.1.2.1 — Common electric motor enclosure types	157
C1.3.1.2.2a — IP classification system	158
C1.3.1.2.2b — Definition of second numeral in IP classification system	158