# Appendix B

## Pump System Certified – Level 2
## Body of Knowledge

This Appendix provides the additional body of knowledge topics upon which the Pump System Certified – Level 2 examination for certification is based. The examination will include topics covered in Mandatory Appendix A as well as the following additional knowledge topics:

**B-1 Introduction to Pumps (2%)**

No additional topics covered in PSC Level 2. Refer to Mandatory Appendix A for body of knowledge topics.

**B-2 Pump Performance Curves and Power Consumption (4%)**

a) Compare and contrast fixed speed and variable speed pump curves.
b) Identify parallel and series pump curves

**B-3 Pump Systems (9%)**

a) Describe considerations in determining Net Positive Suction Head (NPSH) margin
b) Explain how flow requirements are determined for simple and complex application examples
c) Calculate NPSHA and NPIPA based on site conditions and liquid properties
d) Describe the nature of Newtonian and non-Newtonian liquids
e) Calculate complex friction loss through pipes, valves, fittings by gathering information, variable data and for multiple fittings/pipe
f) Understand the use of the Darcy Weisbach Equation and the Hazen Williams Equation
g) Apply Bernoulli's Equation relative to flow through pipes, nozzles, etc.
h) Describe system transients during pump start-up and shut-down
i) Calculate a system curve for simple systems
j) Describe tools used to calculate system curves for complex or variable systems

**B-4 Rotodynamic Pump Designs and Types (14%)**

a) Explain impeller trimming methods
b) Describe balance methods, grades, and applicability for different impeller and pump designs
c) Describe types of pump casings and discharge collectors and their applicability to application requirements
d) Identify and describe the characteristics of regenerative turbine, self-priming, sealless pumps, multi-stage, slurry, and special effect pumps
e) Identify design considerations of each RD pump type
f) Describe and explain the configurations and purposes of double casing pumps (barrel/can pumps)
g) Describe shaft and column stretch and why it is important to consider
h) Compare and contrast specific speed and suction specific speed
i) Describe factors that will affect pump attainable efficiency
j) Calculate suction specific speed
k) Discuss design considerations when there is potential for reverse flow through the pump
l) Identify and explain location and role of the cutwater area of volute
m) Describe radial thrust, the causes, and mitigation strategies
n) Describe axial thrust, the causes, and mitigation strategies, including momentum change
o) Describe shaft deflection and stress, the causes, and mitigation strategies
p) Describe pump design factors that effect rolling element bearing life and what the L10 bearing life calculation represents
q) Describe lateral and torsional critical speed

r) Explain the use of suction inducers and their application considerations
s) Calculate fluid temperature rise
t) Describe the purpose of a self-priming pump

**B-5 Positive Displacement Pump Designs and Types (7%)**

a) Explain factors that affect positive displacement pump efficiency
b) Explain starting and low speed operation considerations of PD pumps being constant torque devices
c) Describe self-priming characteristics of PD pumps
d) Describe single acting, double acting, triplex, multiplex, etc.
e) Describe the purpose of Air Operated Diaphragm (AOD) pump
f) List various names for metering pumps
g) List metering pump types (diaphragm, piston, plunger, solenoid operated etc.)
h) Explain nature and purpose of turndown ratio of metering pumps
i) Discuss design fit or running clearances between the pumping element
j) Explain factors that affect pump slip
k) Discuss unbalance forces and how they change with operating speed
l) Compare and contrast design features of timed and untimed rotary pumps

**B-6 Pump Components and Accessories (5%)**

a) Explain lubrication and cooling methods for packing
b) Compare and contrast bearing lubrication methods, lubricants, and support systems
c) Explain and describe the various types of pump bases
d) Explain the purpose for external and internal coatings on pump components and/or pumping units
e) Apply coupling selection and sizing methods
f) Describe variable speed drive train devices
g) Describe advanced mechanical seal types
h) Describe thrust bearing location relative to the coupling
i) Discuss and identify seal plans
j) Describe the purpose of flywheels and their effect on the rotating element
k) Discuss common system accessories used in reciprocating pumps
l) Discuss gear sets and their use in pumping
m) Discuss non-VFD variable speed drives

**B-7 Drivers and Drives (5%)**

a) Explain impact of speed-torque curves on motor selection for RDs and PDs
b) Explain locked rotor torque
c) Explain service factor and how it is used
d) Explain power factor
e) Explain allowable starts per hour for across the line and reduced voltage starts
f) Explain precautions for altitude considerations for drivers and drives
g) Explain purpose of anti-reverse mechanisms
h) Compare and contrast submersible and immersible motors
i) Explain submersible motor cooling and how it is accomplished
j) Explain lightning and surge protection for motors
k) Explain precautions for Explosion Proof (EXP) designs and hazardous locations
l) Describe features and characteristics of Variable Frequency Drives (VFDs)
m) Explain VFD operating principles
n) Describe VFD controls and applications
o) Cite motor design considerations for use with VFDs (i.e., inverter duty motors)
p) Explain VFD selection and configuration related to constant and variable torque loads
q) Discuss cable length, shielding, grounding, and electromagnetic interference (EMI)
r) Explain line harmonics and filters
s) Discuss the typical uses of direct current (DC) motors with pumps

**B-8 System Design Considerations (9%)**

a) Compare and contrast system design for fixed and variable operating conditions
b) Explain how end-use equipment establishes flow demand(s)
c) Identify typical codes and regulations that apply to pump systems
d) Describe system plans and information required for pump specification
e) Explain control methods and associated instrumentation
f) Discuss application considerations for flooded suction and suction lift
g) Describe importance of free surface intake and inlet piping design on pump performance and reliability
h) Explain submergence and its effect on pump system design
i) Explain role of outlet piping velocity in system design
j) Describe system considerations that affect the applied pump nozzle loads
k) Discuss when pressure pulsation control is needed and the devices that are used
l) Discuss safety design considerations for the system to protect equipment, environment, and people
m) Explain purposes of a Programmable Logic Controller (PLC) and a Human-Machine Interface (HMI)
n) Identify and use system process flow, mechanical, electrical, instrumentation, isometric drawings, and associated symbols.
o) Identify and define various communication protocols
p) Describe purpose of seismic analysis
q) Identify when water hammer (hydraulic transient) is more prone to occur and when mitigation should be considered

**B-9 Varying the Pump Operating Point (5%)**

a) Describe advantages and disadvantages of various methods used to control and change the operating point
b) Explain implications of various curve shapes, including curve with dip and curve with droop
c) Explain application of control curves when using variable speed control
d) Analyze various application scenarios to determine the most suitable control
e) Discuss control strategies used to stage parallel pumps when using variable speed control
f) Describe common applications for parallel and series pumping

**B-10 Pump Selection and Specification (9%)**

a) Explain strategies for pump selection to meet various design conditions (i.e., minimum flow condition / maximum flow condition)
b) Explain duration diagram (flow rate versus time)
c) Explain how to establish flow/head requirements based on a duration diagram
d) Select pump type and configuration
e) Select types of drivers, couplings, bearings, mechanical seals or packing, baseplate, sensors and controls, communication protocols and devices, etc.
f) Determine suitable testing requirements
g) Perform interpretation of specifications, sizing and selection of the pump system components
h) Describe different liquid characteristics and their effect on pump performance and selection. (e.g., specific gravity or density, viscosity, vapor pressure, solids, entrained gas, pH, etc.)
i) Compare and contrast North American and ISO pump characteristics
j) Discuss types of corrosion (general, pitting, crevice, galvanic, erosion)
k) Explain real world pump operation uncertainty vs specified performance
l) Discuss common materials of construction for wet end parts and the factors affecting their selection

**B-11 Testing (7%)**

a) Calculate pump total head
b) Explain associated measurement uncertainties
c) Describe mechanical integrity test

d) Describe vibration test
e) Explain procedures, test arrangements and possible modifications required to complete the performance tests
f) Describe equipment and methods used to determine the pump tested values per applicable standards
g) Discuss procedures, and test arrangement to complete hydrostatic pressure testing
h) Explain laboratory instrument calibration and frequency
i) Select instrumentation to meet required measurement uncertainty
j) Describe tests specific to slurry pumps
k) Describe motor tests
l) Describe sound testing methods
m) Describe motor performance and integrity tests
n) Describe string test (complete unit wire-to-water testing, including the pump, drive train, motor, and VFD as applicable)
o) Explain model testing (of large pumps)
p) Describe NPSH and NPIP tests
q) Describe Maximum Allowable Working Pressure (MAWP) and its use in hydrostatic tests
r) Explain how NPIPR is determined for positive displacement pumps

**B-12 Pump Installation, Commissioning, and Startup (7%)**

a) Identify and discuss pipe and tube connection designs and sealing methods
b) Explain and identify suitable pump foundation, grouting and anchoring as applicable for the installation
c) Describe and evaluate elements of proper free surface intake and pump suction piping, and understand what problems can occur if not done properly
d) Describe elements of proper pump discharge piping
e) Define and explain importance of verifying that nozzle loads are within acceptable limits, considering thermal, mechanical, and pressure forces
f) Describe process of aligning drivers and various pump configurations
g) Describe limitations of instrumentation and test setup for field testing
h) Explain priming methods

**B-13 Maintenance (5%)**

a) Describe contents of installation operation and maintenance manual and pre-shutdown checklists including personnel, data collection, system settings, and planned sequence of actions
b) Explain how to determine if a pump is operating according to its required flow rate and head or pressure
c) Identify allowable limits for vibration, temperature, power, etc.
d) Describe typical maintenance monitoring and adjustment if applicable for mechanical seals and packing
e) Document dimensions of wear surfaces and check per Instruction and Operation Manual (IOM)
f) Perform methods for alignment of driver and pump shaft
g) Explain practices for short- and long-term storage of pumps
h) Perform inspection steps during operation
i) Explain condition monitoring
j) Describe calibration of instruments
k) Explain condition based maintenance
l) Explain metrics used to describe the pump or a population of pumps reliability or availability (e.g., Mean Time Between Repair [MTBR])
m) Describe the current state and uses of the Internet of Things (IoT) and Industrial Internet of Things (IIoT) for machinery monitoring and maintenance

**B-14 Troubleshooting (6%)**

a) List causes of abnormal noise
b) List causes of high seal temperature and failures
c) List cause of high bearing temperature and failures
d) List cause of lube oil leakage
e) List causes of pump overheating or seizure
f) Describe potential causes of water hammer.
g) Discuss failure modes of valves, drives, drivers, and other system components
h) Identify and provide solutions to insufficient pressure
i) Describe elements and process of root cause failure analysis

**B-15 Pump System Optimization and Analysis (2%)**

No additional topics covered in PSC Level 2. Refer to Mandatory Appendix A for body of knowledge topics.

**B-16 Markets and Applications (4%)**

a) Discuss market influences and trends / considerations