PSAP 1-DAY PSAP EXAM PREPERATION COURSE
BROUGHT TO YOU BY **PUMP SYSTEMS MATTER®**

PUMP SYSTEMS MATTER

Pump Systems Matter

- Pump Systems Matter (PSM) – is a non-profit educational organization established by the Hydraulic Institute, and leading utilities and energy efficiency organizations, to educate the industry on the benefits of pump systems optimization and energy efficiency to improve the bottom-line savings of end-user companies.

- For more information on the Hydraulic Institute, Pump Systems Matter, its member companies and Partners, visit www.Pumps.org

Meet Your Instructor

Rafiq Qutub, M.Eng., P.Eng., PSAP

Rafiq is a process engineer and project manager with GM BluePlan Engineering in Guelph, Ontario, with 13 years of experience in the design and construction of municipal water and wastewater infrastructure with particular expertise in pumping systems. He is experienced in developing PFDs, P&IDs, and PCNs as well as hydraulic modelling in AFT Fathom. Rafiq has been active with the Hydraulic Institute for over 4 years and has served on several committees including the Standards committee for ANSI/HI 9.6.6 – Pump Piping. Rafiq is a certified Pump System Assessment Professional and a licensed Professional Engineer in Ontario. He obtained a Master's Degree in Environmental Engineering and an Advanced Certificate in Environmental Management from the University of Toronto.

Attendee Introductions

- Name
- Company
- Role
- Years of experience
- Intent on taking the PSAP Exam

Course Outline

This course offers 1 day of live virtual instructor-led PSAP certification exam preparation. The course will cover the following:

- Example questions for each knowledge area presented in the exam with in-depth explanations of answers
- An overview of the eligibility requirements, certification process, and how to schedule the exam
- What to expect on the day of the exam
- Live practice exam

PUMP SYSTEMS ASSESSMENT PROFESSIONAL

The certification for pump system professionals

- PSAP certification outlines requirements
- Outlines tasks and knowledge
- Comprehensive exam
- Tests the knowledge of candidates related to knowledge requirements to improve system reliability and efficiency.
- Provides assurance that candidates have experience and knowledge required to conduct pump systems assessments

More Information at:

pumps.org/PSAP

Development of the Certification

- Subject mater experts performed a Job Task Analysis that defined domains, tasks and knowledge requirements to conduct a pump system assessment.
- Examination committee developed a comprehensive exam based on the JTA to test a candidate's knowledge on this subject.

Domain	Weight
Integration and Data Gathering	36%
Data Analysis	46%
Post Assessment	18%

Pump System Assessment - Tasks/Steps

1. Determine if system is amenable to a PSA
2. Obtain and analyze initial information about the pump system (i.e. pre- screening).
3. Define PSA team, roles &responsibilities, project scope and boundary conditions.
4. Visual assessment of the pump system, obtain additional information, and finalize the project scope.
5. Interview stakeholders to answer questions, verify information, and provide additional information.
6. Obtain real-time pump system operation data.
7. Cross-validate the pump system data collected to ensure accuracy.

Pump System Assessment - Tasks/Steps

8. Analyze data based on the project scope and boundary conditions.
9. Interpret the analysis, establish initial findings and options for optimization.
10. Formulate specific recommendations for optimization
11. Prepare PSA report that with sufficient data and prioritized recommendations with costs and benefits.
12. Present the report to stakeholders and assist in the transition from assessment to implementation.
13. Perform post-implementation measurement and verification and generate a report.

Pump System Assessment Knowledge Requirements

1. Pump types (e.g. rotodynamic & positive displacement types)
2. Pump system components (e.g. tanks, valves, pipes, sealing, heat exchangers, couplings, etc.)
3. Pump system component interactions
4. Pump system operating procedures
5. Benefits of pump system optimization
6. Factors that impact pump efficiency and reliability
7. Factors that affect pump system reliability and efficiency
8. Elements of lifecycle costing
9. Basic pump maintenance practices
10. Piping and instrumentation diagrams
11. Isometrics
12. Process flow diagrams
13. Engineering Drawings
14. Key plant personnel needed on the assessment team
15. Roles and responsibilities of an assessment team
16. Field measurement parameters and their acceptable ranges

Pump System Assessment Knowledge Requirements

17. Hydraulic and electrical formulae
18. Measuring devices and their requirements and proper applications
19. Common operating problems and errors
20. Pump and motor performance curves
21. System curves
22. Parameter estimation methods
23. Data and its relationship to reliability
24. Reliability metrics
25. Currently available equipment and technology
26. Industry best practices
27. Basic financial analysis
28. Utility rate structures and incentives
29. Principles and techniques of prioritizing solutions
30. Elements and layout of a pump system assessment report
31. Presentation techniques
32. Techniques for assisting stakeholders in aligning goals and strategies with assessment recommendations
33. Implementation strategies
34. Commissioning

PSAP Certification
Process and Requirements

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PUMP SYSTEMS ASSESSMENT PROFESSIONAL

Becoming PSAP Certified

- Review Program Requirements
- Application and Fee Submittal
- Schedule Exam
- Certification Granted
- Certification Renewal

What's on the exam?

Domain	Weight
Integration and Data Gathering	36%
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Eligibility Requirements

Education

- Applicants are required to possess an undergraduate or graduate degree from a regionally accredited university or college in a STEM or business field and must submit official transcripts.

Experience

- Applicants must have a minimum of three (3) years of professional pump/pumping system experience and must submit contact information of supervisor or client that can verify experience.
- In lieu of an undergraduate or graduate degree, applicants must possess direct industrial or commercial fluid transfer and pumping systems professional experience with five (5) or more years in a field/management position and have completed a minimum of seven (7) pump systems assessments.

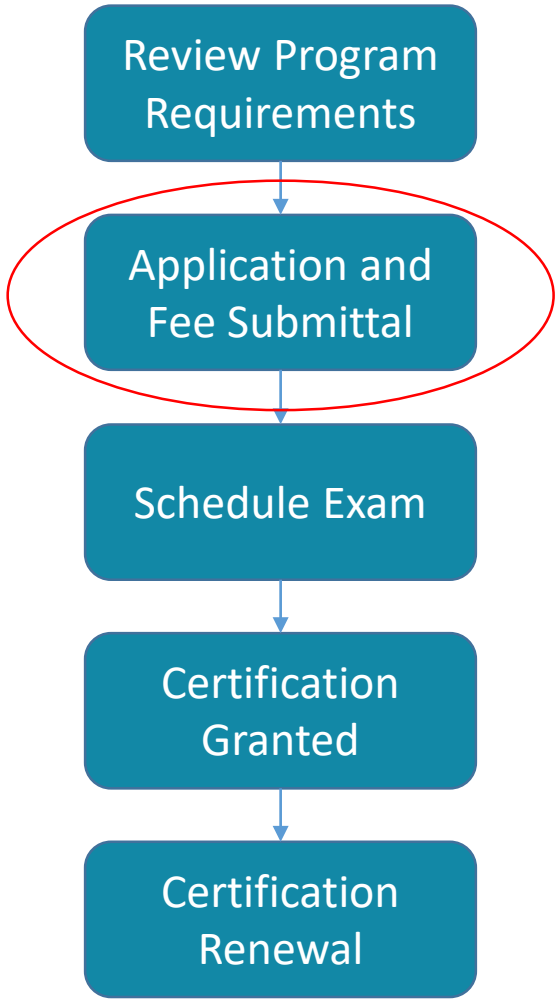
Certification Program Policies

- Complaint Process
- Appeals
- Discipline Process
- Code of Ethics
- Certification Renewal

All certification program policies and requirements are contained in the Candidates Handbook available on the PSAP website: www.pumps.org/PSAP

Pump Systems Assessment Professional Certification

Becoming PSAP Certified



What's on the exam?

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www.pumps.org/PSAP

SECTION 1: GENERAL INFORMATION

Prefix: ☐ Mr. ☐ Mrs. ☐ Ms. ☐ Dr.

Name:

PSAP No.: Cert Expiration Date:

Mailing Address: City:

State/Province: Postal Code: Country:

Email: Phone Number:

Business/Employer Name:

Job Title: Primary Industry:

☐ Please check here if you are requesting special accommodations for your examination. You will be required to submit supporting documentation and must be submitted within the required time frame in advance of your anticipated examination date.

What is your reason for applying for PSAP certification?

☐ Personal Development ☐ Employer Suggestion ☐ Employer Requirement ☐ Other:

SECTION 2: EDUCATION

Applicants must possess an undergraduate or graduate degree in a STEM or business field. Official transcripts (hardcopy or electronic) can be requested from your college or university. This is used to verify your education. In lieu of an undergraduate or graduate degree, applicants must possess at least 5 years of experience and have completed a minimum of seven pump system assessments.

Fill out the information below:

STEM or Business Degree: ☐ Associates ☐ Bachelors ☐ Masters ☐ Doctorate

Field of Study: Year of Graduation:

Name of School Attended:

City: State: Country:

☐ Check here if you are demonstrating more than five (5) years of experience. Note that applicants will have to submit a summary of seven (7) pump system assessment projects that they completed.

SECTION 3: EXPERIENCE

Your current supervisor must sign and attest to the work experience claims made below. If you are self-employed, such as an independent consultant, you can either have a colleague sign or sign yourself. An electronic signature may be used or, you may have your supervisor send an email to psap@pumps.org attesting to the information. If an email is sent, you must have them clearly state who the attestation is for. Applicants may attach a resume to describe pump system experience.

Fill out the information below:

Give a brief description of your pump system experience and typical job duties:

I _____ *(Print Supervisor's Name)* attest that the work experience information presented above by _____ *(Print Applicant's Name)* is accurate to the best of my knowledge.

Supervisor's Name: _____ Job Title: _____

Supervisor Signature: _____ Date: _____

☐ Check here if you are self-employed and signing for yourself

HYDRAULIC INSTITUTE

Certification Agreement

In order to qualify for certification, applicants must agree to each of the following statements. Read the statements carefully, then initial and sign at the bottom. You may use an electronic signature.

1. I agree to comply with and conduct myself in accordance with all HI certification program policies and requirements. In addition, I agree not to provide to any individual or organization in any manner, the specific content of PSAP examination questions or answers to such questions.
2. I agree to comply with and conduct myself in accordance with the PSAP Code of Ethics.
3. I agree to notify HI in a timely manner regarding changes concerning the information provided, including my current name, address, email address, and telephone number.
4. I agree that HI has the right to communicate with any person, government agency, or organization to review or confirm any of the information submitted in conjunction with my application for certification or renewal. Furthermore, I agree to and authorize the release of any information requested by HI for such review and confirmation.
5. I agree that all materials that I submit to HI become the property of HI and that HI is not required to return any of these materials to me.
6. I agree that upon achieving certification status, my name may be posted on the HI certification website as part of an online registry to be created and maintained by HI.
7. I agree that all disputes relating to my application or certification status will be resolved solely and exclusively in accordance with HI certification policies, procedures, and appeals processes.
8. I understand that HI reserves the right to suspend or revoke the certification of any individual who is determined to have failed to uphold or otherwise breached this agreement including any misrepresentations made in application or renewal statements.
9. I agree to return my certificate to HI if for any reason I fail to maintain certification status or if my certificate is revoked.
10. I release and indemnify HI from all liability and claims that may arise related to my PSO and related activities.
11. I hereby release, discharge and indemnify HI, its directors, officers, members, staff, and representatives/agents and consultants from any actions, suits, obligations, damages, claims, or any other action taken in connection with this application and my examination.

_____ I have read and understand all of the policies and procedures described in the Candidate Handbook.

_____ I have read and accept the terms and responsibilities outlined in the Certification Agreement.

_____ I declare that all of the information I have provided is accurate, true, and complete to the best of my knowledge. Furthermore, I understand that any misrepresentation or incorrect information provided to HI can result in disciplinary action, up to and including the suspension of my eligibility for certification.

Print Name	Signature	Date

Certification Fees

Program Fees

	Member	Industry Partner	Non-Member
Examination Fee[1]:	$431.25	$546.25	$575
Re-examination Fee[2]:	$275.00		
Renewal Fee[3]:	$285.00		

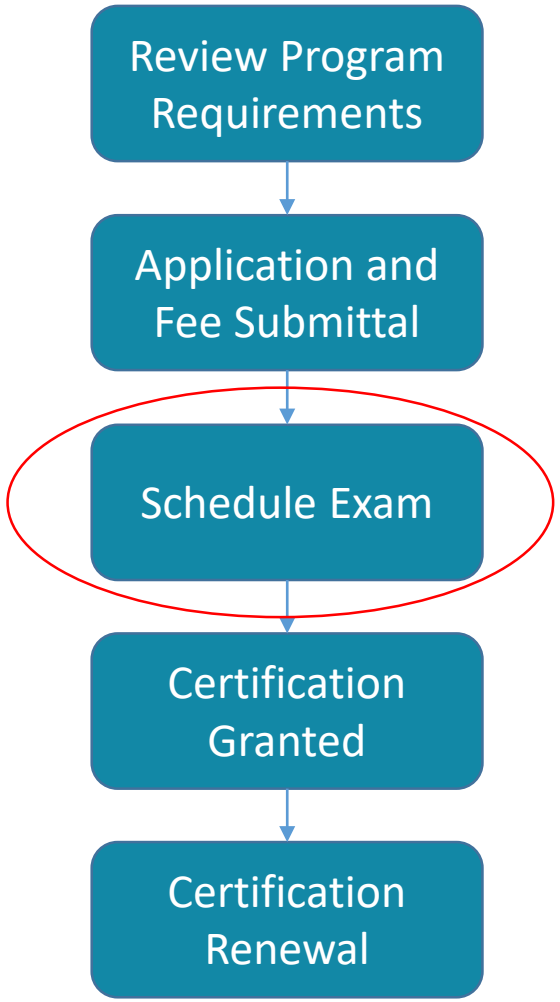
Note 1: Applicants must be a member or an employee of a member of HI in good standing **at the time of their application** to receive the member discount. No refunds will be granted for applicants joining HI after submission of certification application materials. The examination fee includes a $150 non-refundable application fee.

Note 2: Re-examination fees apply to second and third attempts to pass the PSAP examination within the first year of submitting an approved application. See the section titled "Re-examination" for more detail.

Note 3: The Renewal Fee applies at the time a PSAP certified individual submits a recertification application.

Pump Systems Assessment Professional Certification

Becoming PSAP Certified



What's on the exam?

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www.pumps.org/PSAP

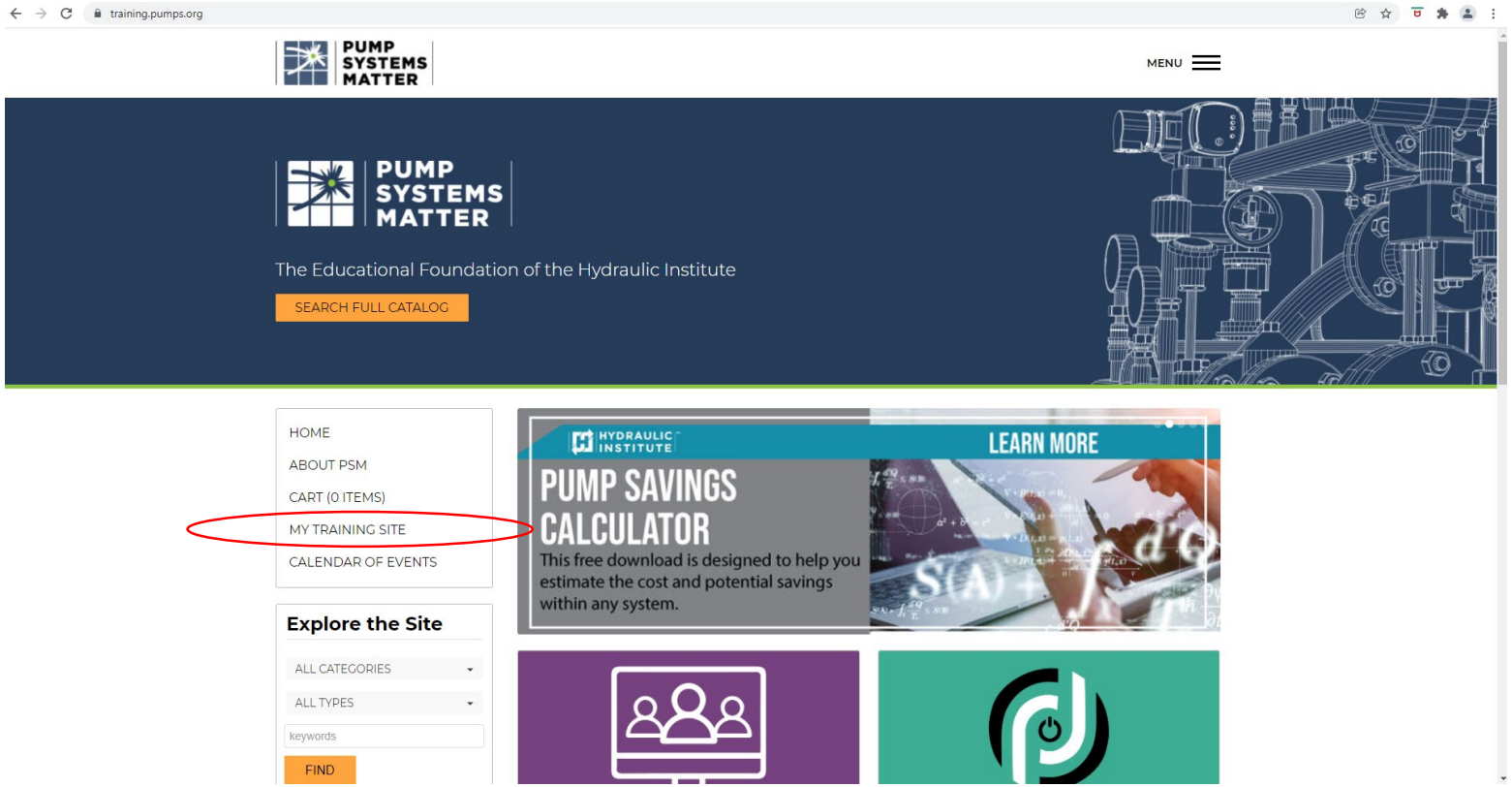
Scheduling a Certification Exam

- All exams are administered online by ProctorU
- ProctorU is a live online proctoring service that allows you to take the certification exam from the comfort of your home.
- Requirements
  - Computer with a Windows or Apple operating system
    - Installation of browser plug-ins required
  - High-speed internet connection
  - Webcam (internal or external)
  - Government issued photo ID
- A formula reference sheet is provided on the exam website.
- Candidates are allowed to use a scientific calculator and a whiteboard to write on. No scratch paper is allowed.

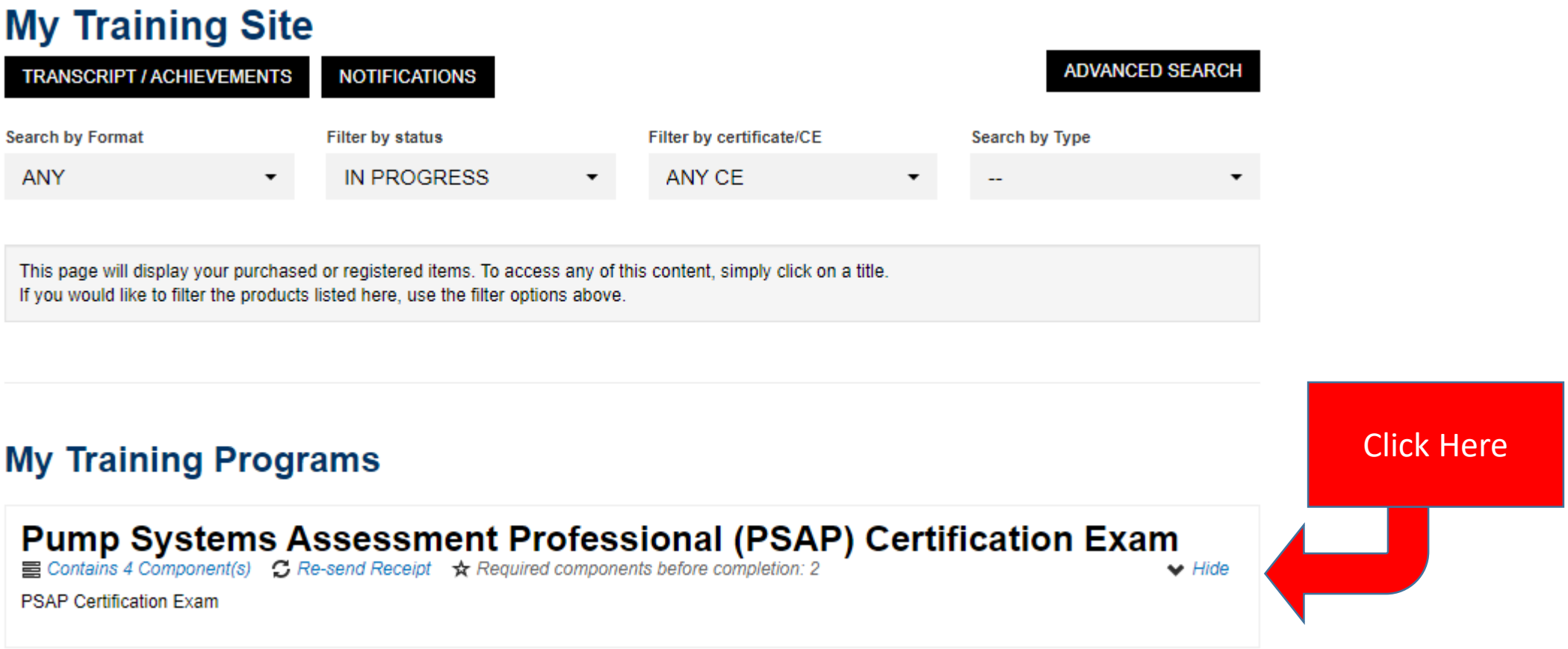
For more information on ProctorU, visit their support website at support.proctoru.com

Scheduling a Certification Exam
Step 1

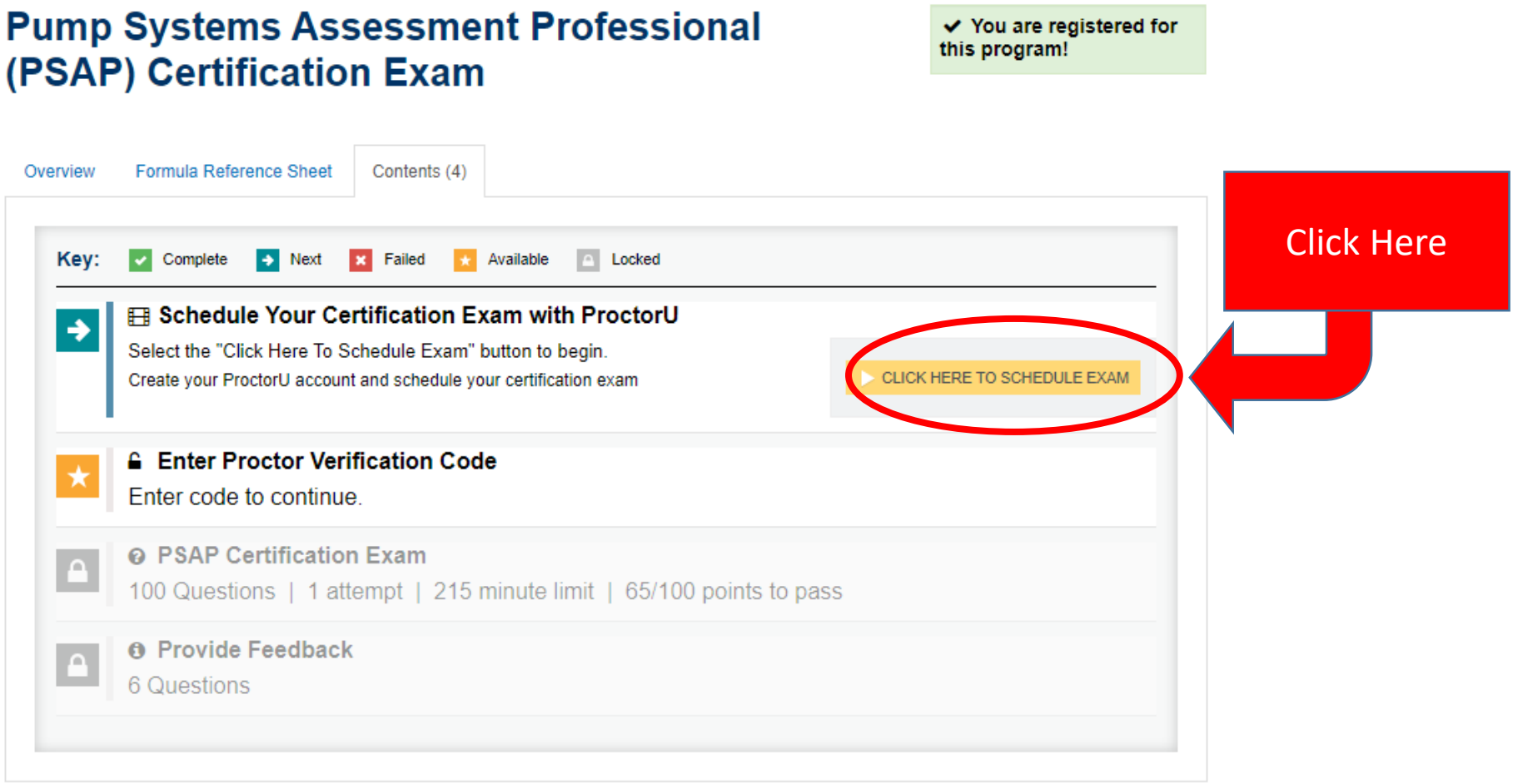
Log-in to your training.pumps.org Account



Scheduling a Certification Exam
Step 2

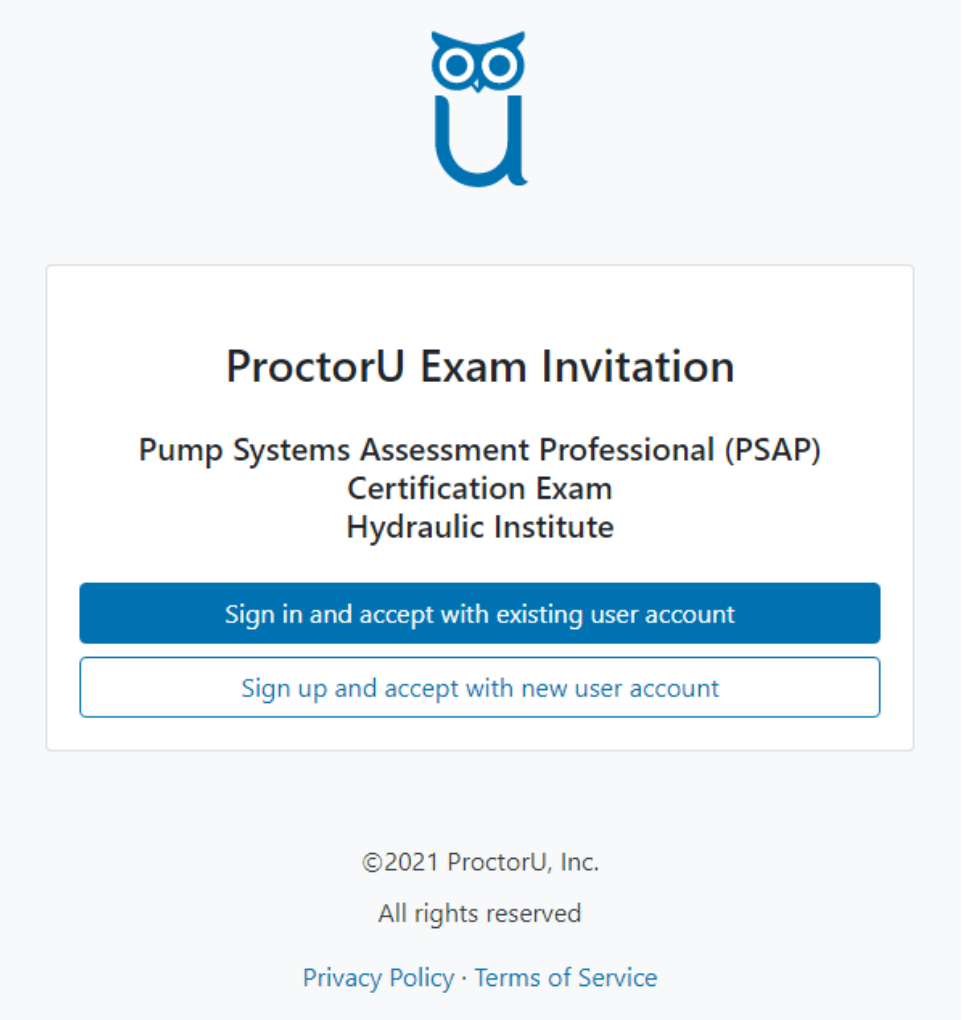


Scheduling a Certification Exam
Step 3

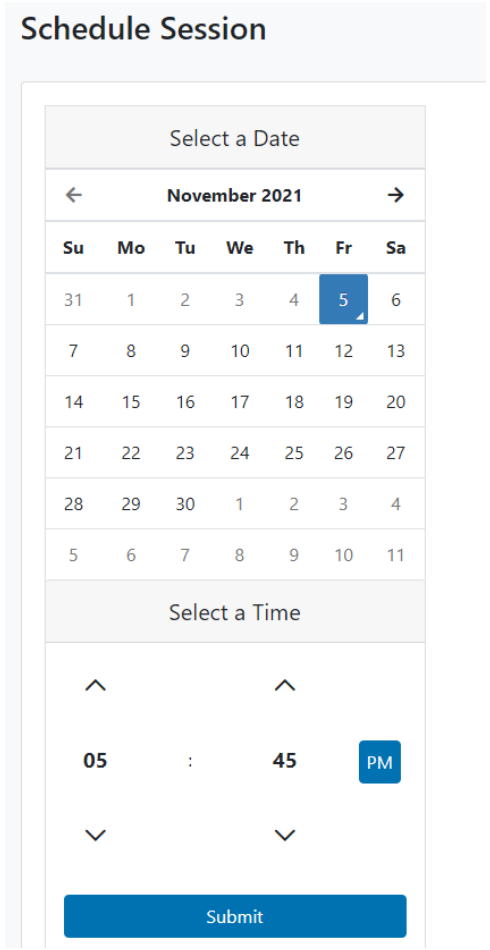


Scheduling a Certification Exam
Step 4

Sign-in to ProctorU account or create new account



Scheduling a Certification Exam
Step 5



Please select a date and time on the left. Once you have selected a date and time, please click Submit.

Steps to Take Before Exam Day

- **Pick Your Browser:** Download either Chrome or Firefox and make sure you're using the latest version.
- **Download the ProctorU Extension:** Select the one for your chosen browser: Chrome or Firefox.
- **Scheduling:** Schedule your exam.
- **Check Your Equipment:** Test your equipment to make sure your system is compatible with ProctorU. Click here to see a full list of requirements.
- **Find an acceptable space to take your exam:** The environment needs to be quiet, well- lit, and away from other people. The workspace area needs to be free of any materials not allowed on the exam. It's required to use a hard surface for a workspace rather than a bed or couch.
- **Become familiar with materials allowed/needed for your exam:** You can review a full list here outlining what ProctorU requires as well as a note about resources permitted by your instructor or exam facilitator.
- **Coordinate accommodations with your exam facilitator:** If you require any special accommodations such as additional time, additional breaks, etc., you'll need to follow these guidelines prior to your exam day.

Exam Day: What to Expect

Before Logging In To Take Your Exam:

- Have a government-issued I.D. ready and be located in a private, well-lit room with no one else around you.
- Clear your workspace from all materials except those allowed by HI.
  - Formula reference sheet
  - Scientific calculator
  - Whiteboard to write on. No scratch paper is allowed.
- Close all third-party programs and unplug any secondary monitors.
- Remove any non-religious head coverings.
- Make sure you've downloaded the ProctorU extension for either Chrome or Firefox.

What Happens During the Exam Launch Process?

The exam launch process will likely take between 8 to 10 minutes unless you experience technical difficulties. This time is not subtracted from the time you're allowed in your exam.

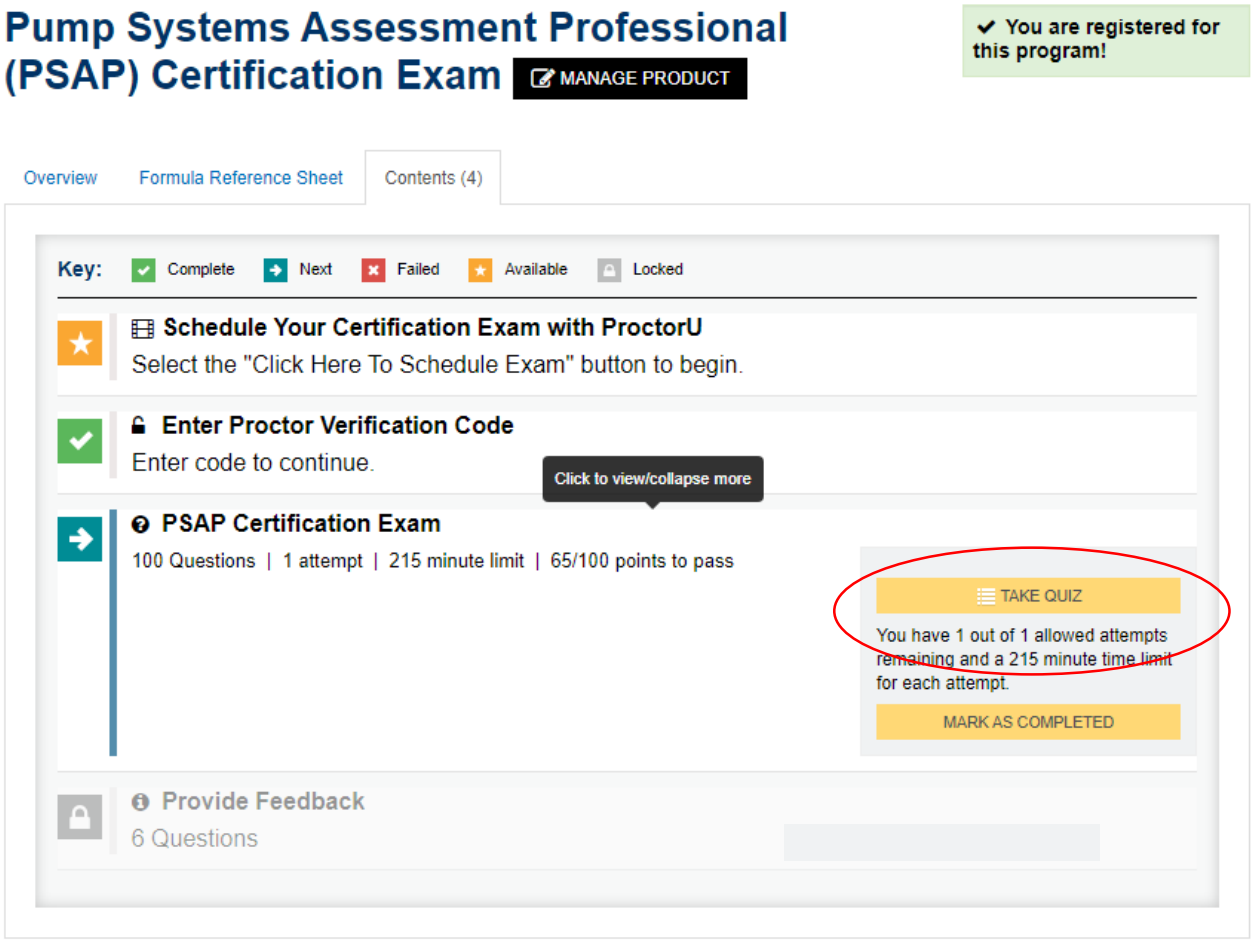
- Log in to your ProctorU account 2-3 minutes before your scheduled appointment and click Start Session when the countdown timer reaches 0:00:00.
- **Pre-checks:** If you don't already have the ProctorU extension, you'll be prompted to download it. The browser will prompt you to share your screen, a required part of being proctored online.
- **Photos & Authentication:** You'll take a photo of yourself as well as your I.D. for identity verification purposes.
- **Chatbox download:** You will be prompted to download and run a LogMeIn Rescue applet file that will bring up a chat box allowing you to text with your proctor.
- **Proctor Connection & Confirmations:** Your proctor will greet you and guide you thorough a series of system checks.

What Happens During the Exam Launch Process?

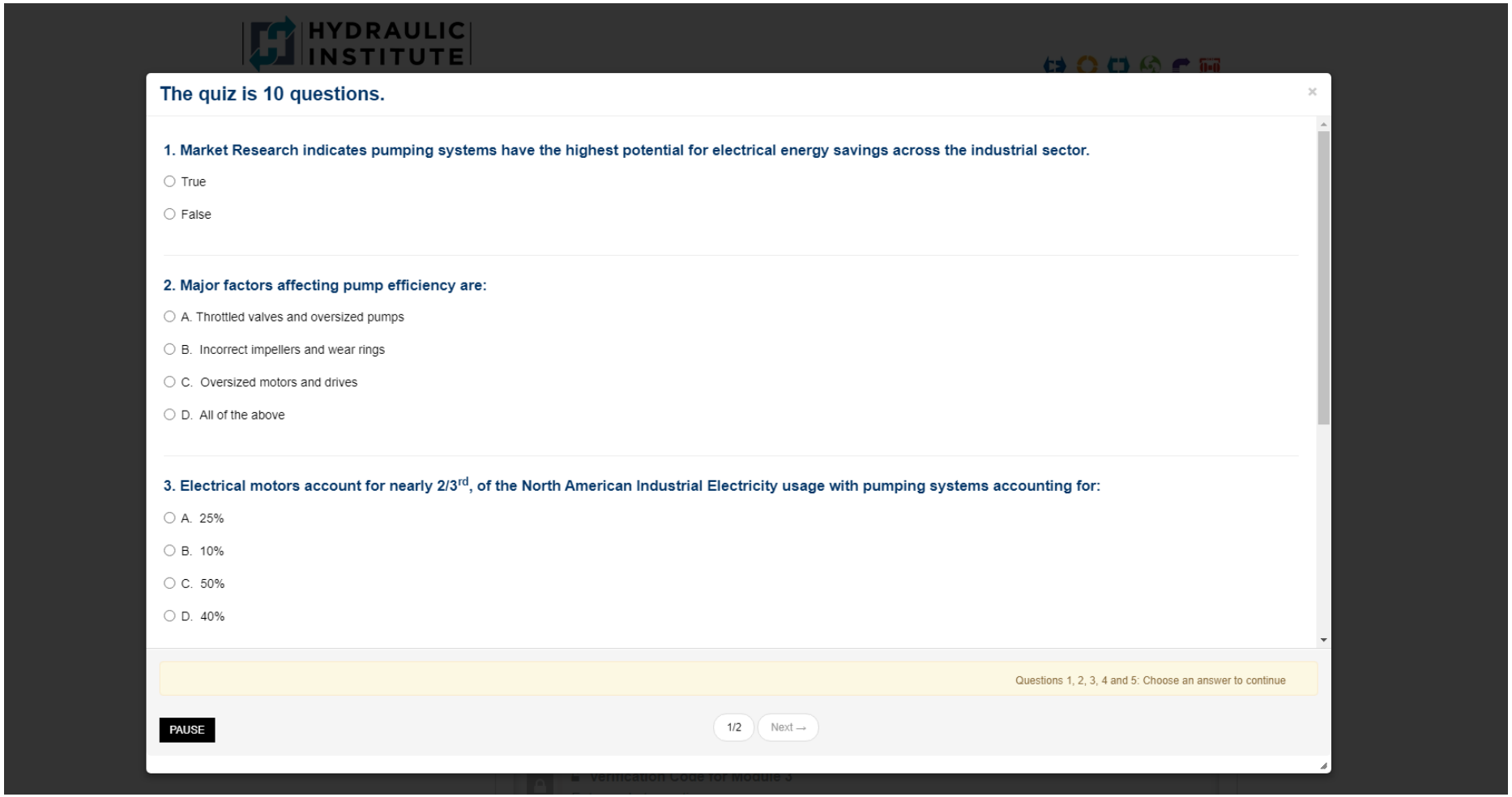
- **Remote System Check:** Your proctor will ask to take remote control of your mouse and keyboard via the LogMeIn Rescue applet in order to make sure no unpermitted programs are running. You will be able to see everything that your proctor is doing during this step, and it is impossible for them to access any files without your knowledge.
- **Camera Pan:** Your proctor will ask you to show the 4 walls of your room as well as your desk space via your webcam. You may or may not also be asked to show your computer monitor by using a mirror or cellphone camera. Lastly, your proctor will make sure your cell phone is out of reach.
- **Navigating to the Exam & Password Entry:** Your proctor will then direct you into exam site so that he or she can unlock your exam.
- **Take Your Exam:** Your proctor will release control of your computer and you'll begin your exam when you're ready.

NOTE: Your webcam view and your screen will be recorded through the duration of your exam.

Example of Exam Site



Example of Exam Site



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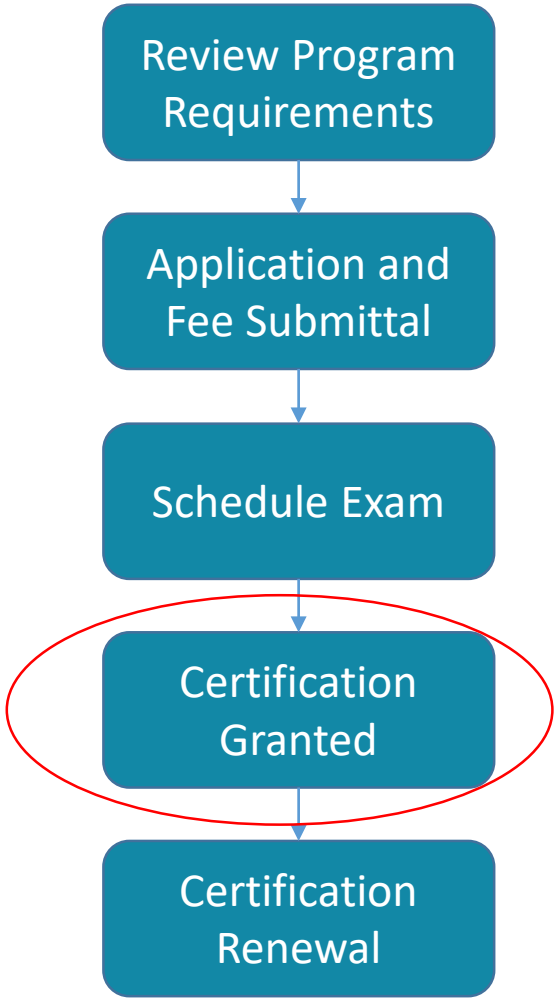
Steps to Take When Exam is Completed

- **Alert the proctor when finished BEFORE submitting:** Prior to submitting your exam, let your proctor know through the chat box that you're finished. They will oversee the submission process. You may also be required to clear a white board or tear up any scratch paper that was used during the exam.
- **Review results:** If your exam results are made available immediately, you may review them for as long as you'd like.
- **Log out of your exam site and browser:** After reviewing your results, your proctor must observe you log out of the exam website and close out of *all* browser tabs.
- **Close out of ProctorU chat box:** This will end your session with ProctorU. Once the chat box closes, you'll be invited to complete a customer satisfaction survey.

Pump Systems Assessment Professional Certification

Becoming PSAP Certified



What's on the exam?

Domain	Weight
Integration and Data Gathering	36%
Data Analysis	46%
Post Assessment	18%

John Doe, PSAP

Pump Systems Assessment Professional Certification

Becoming PSAP Certified

- Review Program Requirements
- Application and Fee Submittal
- Schedule Exam
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- Certification Renewal

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Certification Renewal Requirements

- Certificates are only valid for three (3) years.
- Must submit renewal applications forms
- All PSAP certified individuals will be required to achieve a total of 30 PDHs within the three (3)year certification period.

PDU category	Description of policy	PDU points allowed
Participation in formal education/training programs provided on PSO topics	This option includes courses, seminars, and workshops on PSO-related issues.	One (1) PDU per each hour of instruction. Certified individuals must achieve at least 8 PDUs in this category during the three-year renewal period.
Self-directed learning	This category includes reading articles and books or watching instructional videos on PSO issues.	One (1) PDU per each hour of self-directed learning. Note: Certified individuals may earn a maximum of 10 hours in this category in a three-year period.
Creating new PSO knowledge or content	Examples in this category include authoring articles, books, newsletters, etc. PDUs are also awarded for serving as faculty at various learning events.	One (1) PDU is awarded for each hour of activity spent in these activities.
Volunteer service	Examples in this category include serving as a volunteer for HI or its regional chapters, working on PSO related meetings, or assisting the certification process.	One (1) PDU is awarded for each hour of volunteer service. Certified individuals may earn a maximum of 10 hours in this category in a three-year period.
PSO professional work experience	Full-time employment as a PSO professional for a minimum of one (1) year.	Five (5) PDUs are awarded for each full year of

Getting Involved as a Certified Professional

- Non-members get complimentary access to the HI Industry Partner Program
- Get involved with HI committee
  - Contribute to the advancement of your profession
  - Network with your peers in your field
- Educate the future with training
  - Become an instructor for HI courses and webinars
- Share your knowledge and experiences
  - Write articles and present case studies

PSAP 1-Day Exam Preparation
1 Hour Sample Test and Sample Questions

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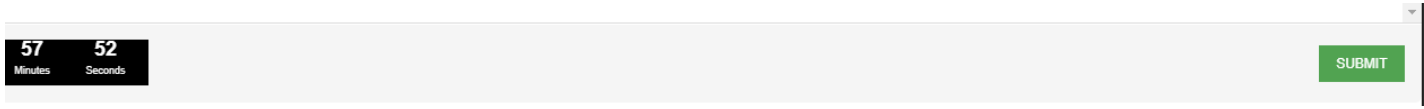
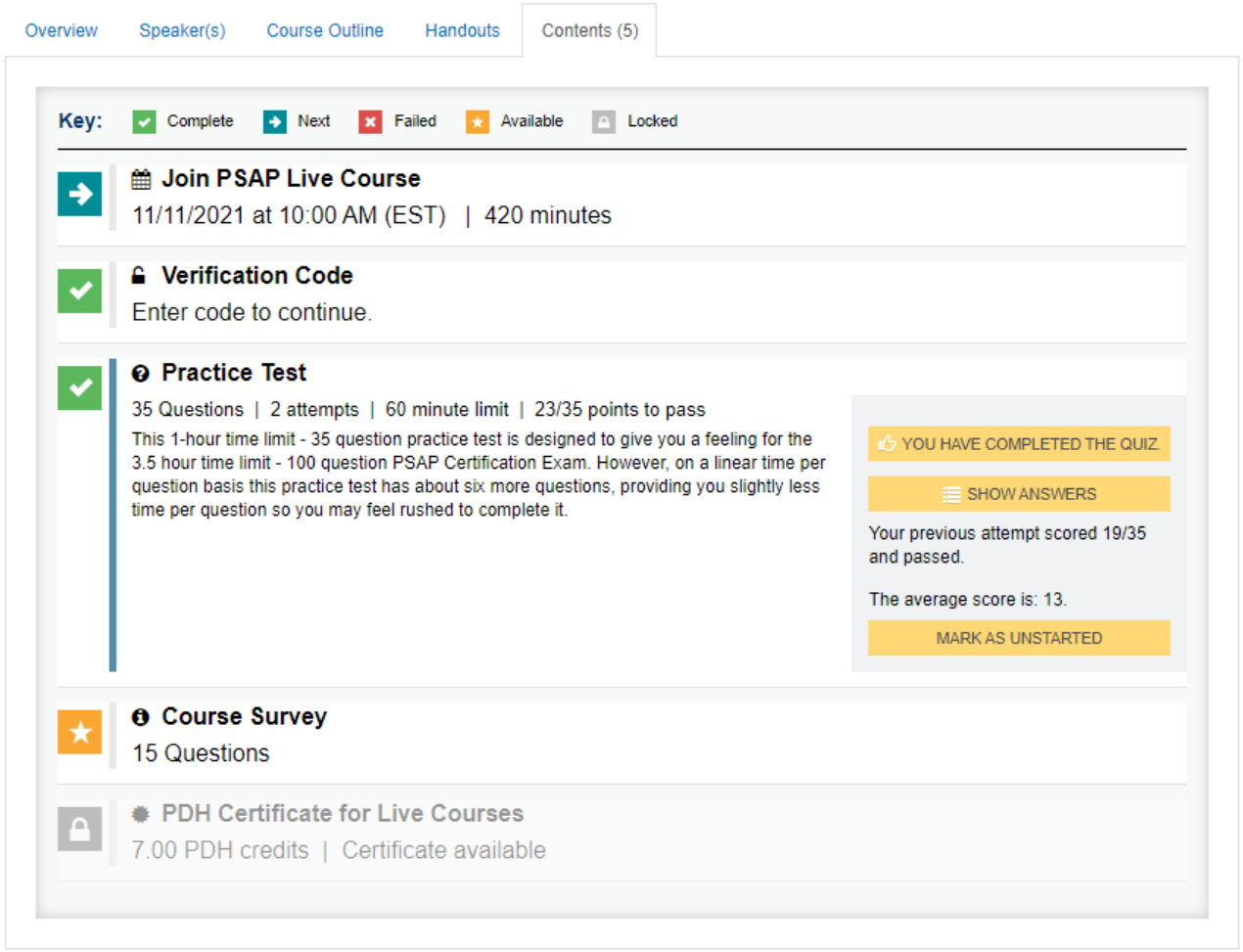
How to access sample test

- Login at training.pumps.org
- Go to my training
- Select PSAP Exam Prep
- Enter Verification Code PSAPSEP2022
- Complete Practice Test
  - Use non-programmable calculator
  - Closed notes
  - Use equation sheet provided
- Once complete hit “submit”



Sample Test Review

We will review all of the questions in detail. As we do that you can review you answers by clicking “SHOW ANSWERS”.



SAMPLE TEST

Verification Code – PSAPSEP2022

Time Limit – 1hour.

** Do Not Proceed Until the Completion of the Sample Test*

Sample Test - D1 T3 K14

1. For a level 3 assessment, which of the follow personnel would not be required on the assessment team ?

a. Site energy efficiency engineer

b. Maintenance manager

c. Process engineer

d. Maintenance technician

1. Answer:

d. Maintenance Technician

A technician generally would not be needed for an assessment because the assessment team typically will not be building or disassembling pumps on site. Past maintenance data will be important, but is better to be provided by the maintenance manager.

Sample Test - D2 T7 K18

2. Which flowmeter would not be used with a non-conductive liquid?

a. Transit-time ultrasonic

b. Turbine

c. Electromagnetic

d. Vortex

2. Answer:

c. Electromagnetic

An electromagnetic flowmeter requires a liquid that conducts electricity. The other flowmeters listed would not be limited by a non-conductive liquid.

Sample Test - D1 T2 K6

3. The volumetric efficiency of a rotary pump can be increased by

a. Increasing the differential pressure

b. Lowering the liquid density

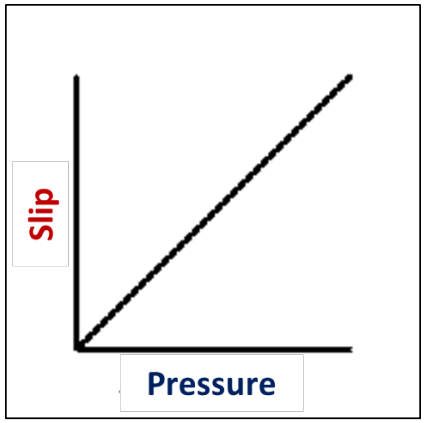
c. Lowering the liquid viscosity

d. Increasing the liquid viscosity

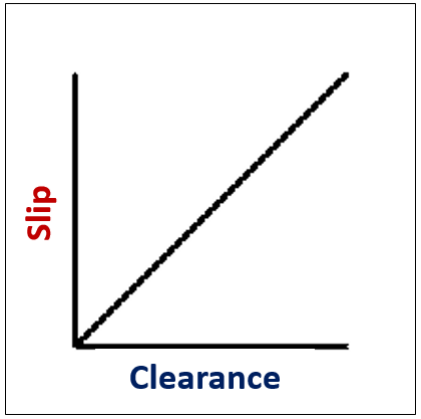
3. Answer:

d. Increasing the liquid viscosity

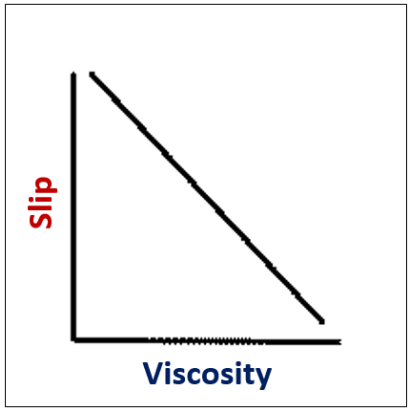
In rotary pumps, volumetric efficiency is a function of the slip, which is the internal volumetric leakage from high pressure to low pressure. The leakage is reduced when the clearance is tightened, the differential pressure is reduced, or when the viscosity is increased.



Slip increases directly with pressure



Slip increases directly with clearance



Slip has inverse relationship with viscosity

4. For the system shown, what is the total head for a pump with the following measurements:

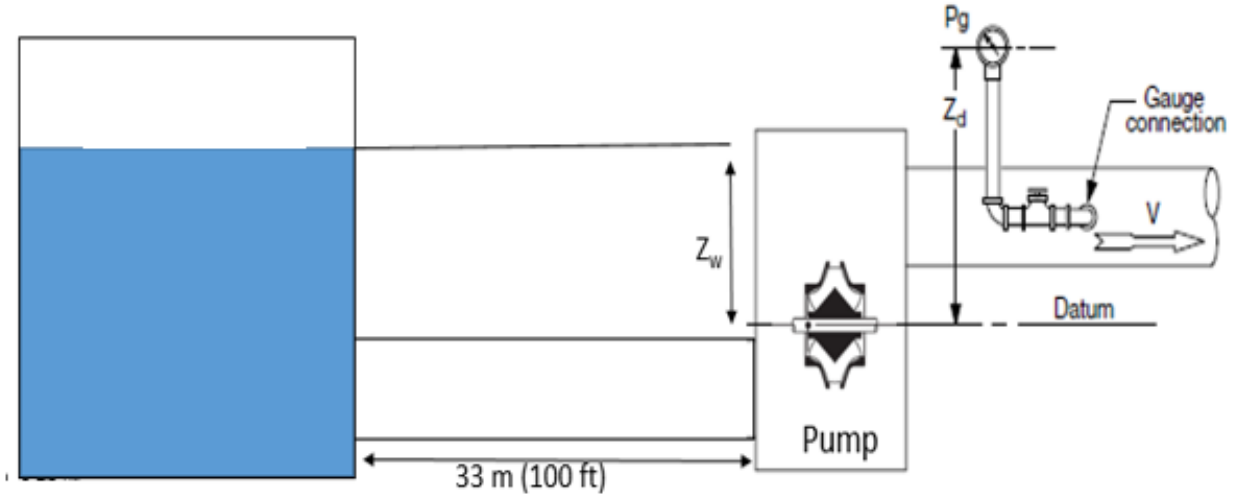
- **Discharge (outlet) pressure of 100 kPa (14.5 psig),**
- **Tank pressure of 50 kPa,absolute (7.25 psia)**
- **Atmospheric pressure of 100 kPa,absolute (14.5 psia)**
- **Inlet & outlet pipe velocity of 5.06 m/s (16.6 ft/s)**
- **liquid is oil with density of 798.6 kg/m^3 (49.85 lbm/ft^3) = Specific gravity of 0.8**
- **Inlet pipe friction head loss of 1.8 m (5.9 ft)**
- **Zw = 1 m (3.28 ft)**
- **Zd = 1.5 m (4.92 ft)**

a. 19.1 meters (62.7 feet)

b. 21.4 meters (70.2 feet)

c. 22.7 meters (74.6 feet)

d. 24.5 meters (80.4 feet)



4. Answer: c. 22.7 meters (74.6 feet)

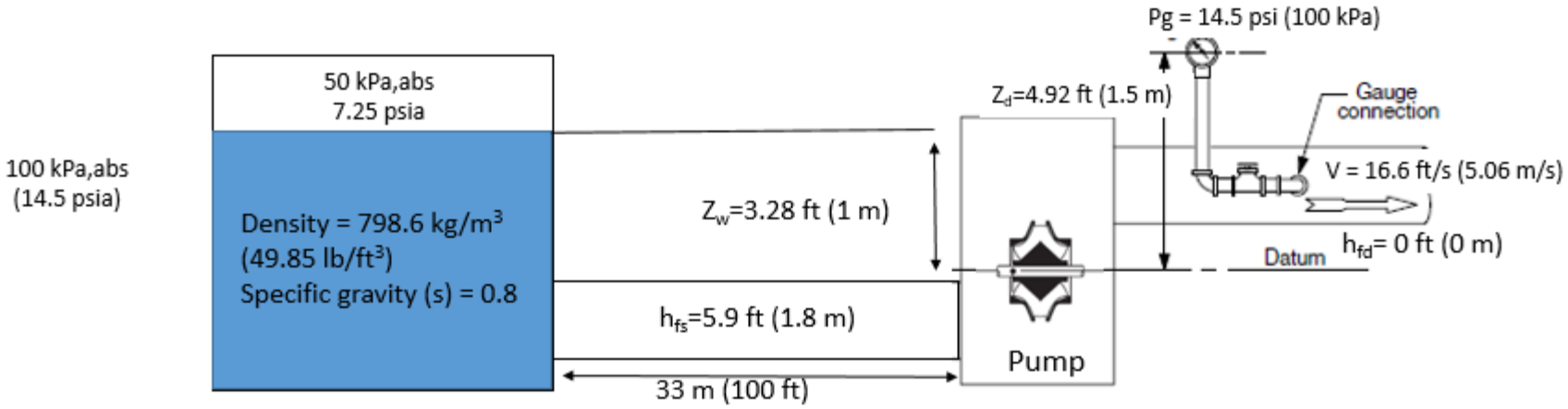
$$H = (Z_d + h_{fd}) - (Z_w - h_{fs}) + \frac{(P_{gd} - P_{gs})}{(\rho \cdot g)} + \frac{v_d^2 - v_s^2}{2 \cdot g}$$

Metric

- $H = (1.5 + 0) - (1 - 1.8) + \frac{(100+100-50)\times 1000}{(798.6\times 9.81)} + \frac{(5.06^2 - 0^2)}{2\times 9.81}$
- $H = 1.5 + 0.8 + 19.1 + 1.3 = 22.7\ m$

US Units

- $H = (4.92 + 0) - (3.28 - 5.9) + \frac{(14.5+14.5-7.25)\times 2.31}{0.8} + \frac{(16.6^2 - 0^2)}{2\times 32.2}$
- $H = 4.92 + 2.62 + 62.8 + 4.28 = 74.6\ ft$



Sample Test - D1 T6 K16

5. In general what speed class of equipment would measuring bearing housing vibration in peak to peak displacement be most applicable?

a. Less than 600 RPM

b. 1500 RPM - 1800 RPM

c. 2400 RPM - 3600 RPM

d. Above 3600 RPM

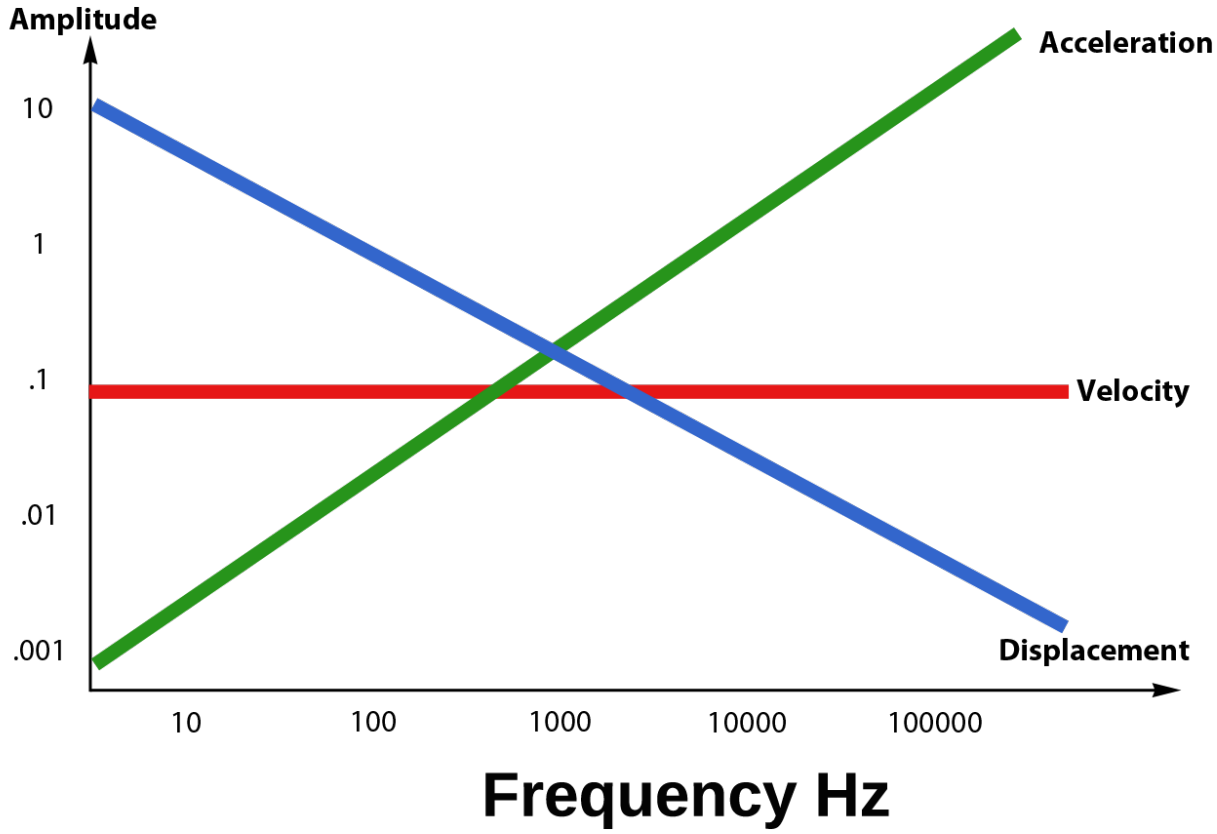
5. Answer:

a. less than 600 RPM

As a function of speed (frequency Hz) displacement sinusoidal vibration amplitude is larger at low frequency for a constant velocity compared to a higher frequency at the same velocity. This makes the measurement of displacement more impactful at low speeds.

$$Diplacement = \frac{Velocity}{2 \cdot \pi \cdot frequncy}$$

For reference low RPM pump equipment has a peak to peak displacement requirement in ANSI/HI 9.6.4 in addition to overall velocity RMS



Sample Test - D2 T9 K23

6. Which of the liquids with the stated properties would have the highest temperature rise from the inlet to the outlet of a pump under the same total head and efficiency?

a. Specific heat = 2.54 kJ/kg-K (0.61 Btu/lbm-F), Specific gravity 0.75

b. Specific heat = 3.0 kJ/kg-K (0.72 Btu/lbm-F), Specific gravity = 0.4

c. Specific heat = 3.5 kJ/kg-K (0.84 Btu/lbm-F), Specific gravity = 0.6

d. Specific heat = 4.16 kJ/kg-K (1.0 Btu/lbm-F), Specific gravity = 1.0

6. Answer:

a. Specific heat = 2.54 kJ/kg-K (0.61 Btu/lbm-F), Specific gravity 0.75

Since it's the same total head and the question states the efficiency is the same it means the volumetric flow has not changed either. Any change in power imparted to the liquid due to specific gravity will cancel out with the proportional change in mass flow rate due to specific gravity.

Specific heat is a measure of the relative energy input required to increase the liquid temperature. Therefore, the specific heat is the only variable that needs to be considered, and the lowest specific heat will result in the largest temperature rise.

A convenient equation relates temperature rise to the total head and pump efficiency:

$$\text{(metric units)}\ \Delta t = \frac{H}{102 \times C_p}\left(\frac{1}{\eta} - 1\right)$$

$$\text{(US customary units)}\ \Delta t = \frac{H}{778 \times C_p}\left(\frac{1}{\eta} - 1\right)$$

Where:

Δt = temperature rise through the pump, in °C (°F)

H = total developed head at flow being considered, in m (ft)

778 = constant

102 = constant

C_p = specific heat of the liquid at pumping temperature, in kJ/(kg·K) (Btu/[lb·°F])

η = efficiency of the pump at flow being considered, expressed as a decimal

Sample Test - D2 T9 K17

7. A positive displacement pump, is pumping a liquid with 1.15 specific gravity (1148 kg/m^3, 71.66 lb/ft^3), at 3,000 gpm (681 m^3/hr) and a pumping efficiency of 85%. The process requires an increased flow so the speed is planned to be increased from 1200 rpm to 1400 rpm. At the higher flow rate the total differential pressure is 105 psi (724 kPa). Assuming the efficiency is unchanged what size motor is needed to drive the pump at the new speed without going over rated power?

a. 150 hp (110 kW)

b. 200 hp (150 kW)

c. 250 hp (185 kW)

d. 300 hp (225 kW)

7. Answer:

d. 300 hp (225 kW)

$$New\ flow\ rate = 3000\ gpm \times \frac{1400\ rpm}{1200\ rpm} = 3500\ gpm\ (795\ \frac{m^3}{h})$$

Calculate using pressure

$$P(kW) = \frac{Q\left(\frac{m^3}{h}\right) \times \Delta p(\text{kPa})}{3600 \times \eta}$$

$$P(kW) = \frac{795\left(\frac{m^3}{h}\right) \times 724(\text{kPa})}{3600 \times 0.85} = 188\ kW$$

$$P(\text{hp}) = \frac{Q(gpm) \times \Delta p(\text{psi})}{1714 \times \eta}$$

$$P(\text{hp}) = \frac{3500(gpm) \times 105(\text{psi})}{1714 \times 0.85} = 252\ hp$$

Calculate using head

$$P(kW) = \frac{Q(\frac{m^3}{s}) \times \text{H(m)} \times \rho(\frac{kg}{m^3}) \times g(\frac{m}{s^2})}{1000 \times \eta}$$

$$P(kW) = \frac{\frac{795}{3600}\left(\frac{m^3}{s}\right) \times \frac{724 \times 1000}{1148 \times 9.81}(\text{m}) \times 1148\left(\frac{kg}{m^3}\right) \times 9.81\left(\frac{m}{s^2}\right)}{1000 \times 0.85} = 188\ kW$$

$$P(\text{hp}) = \frac{Q(gpm) \times \text{H(ft)} \times s(-)}{3960 \times \eta}$$

$$P(\text{hp}) = \frac{3500(gpm) \times \frac{105 \times 2.31}{1.15}(ft) \times 1.15(-)}{3960 \times 0.85} = 252\ hp$$

Sample Test - D2 T7 K22

8. Without any direct method for measuring flow rate, what is the best method for estimating the pump capacity for a mixed flow pump when a pump curve is available?

a. Differential pressure and volumetric tank drawdown over a known time period

b. Differential pressure and pump input power measurement

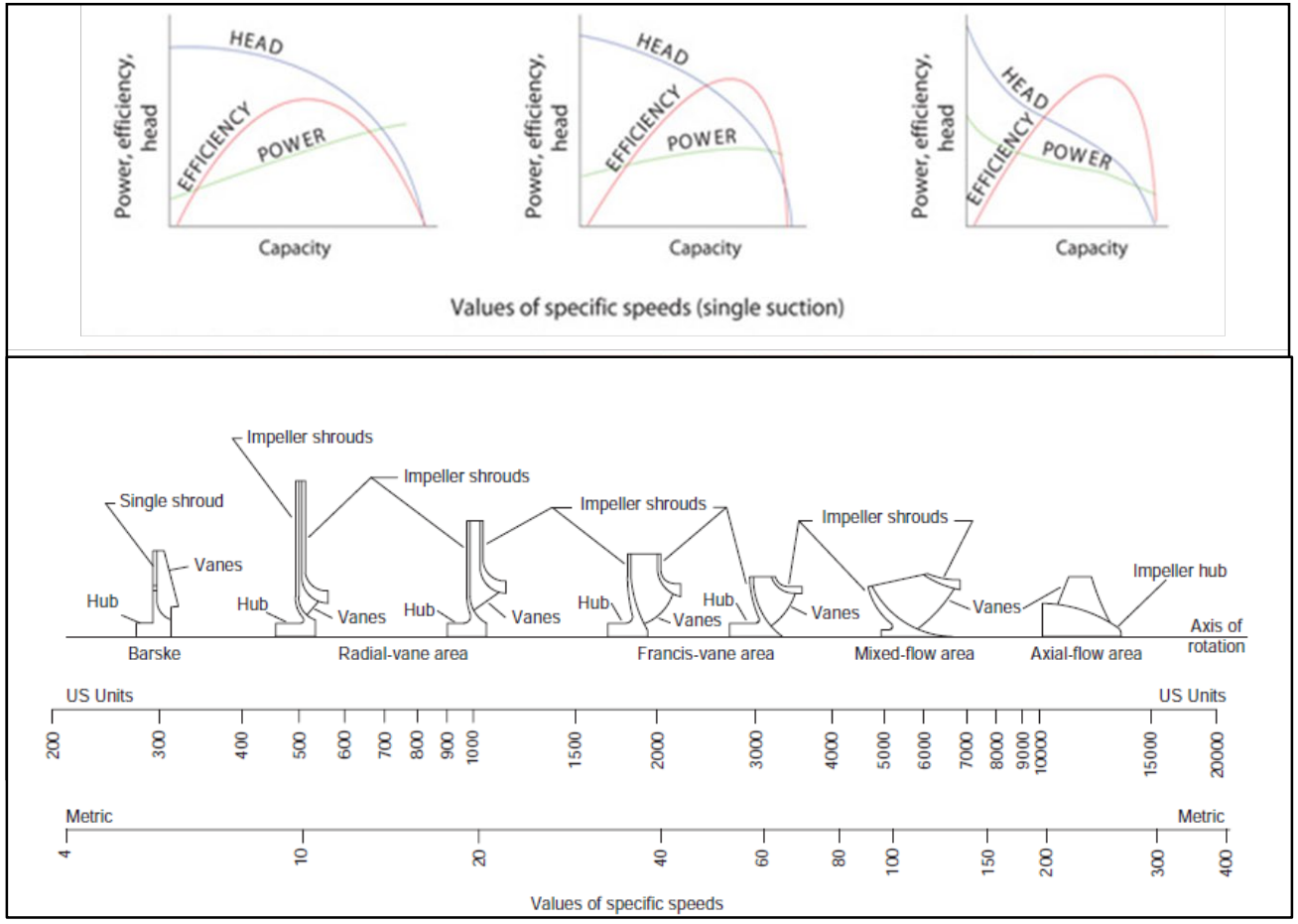
c. Pump input power and volumetric tank drawdown over a known time period

d. Differential pressure and liquid temperature rise from inlet to outlet

8. Answer:

a. Differential pressure and volumetric tank drawdown over a known time period

For a mixed flow pump, the power versus flow curve is often flat and may invert as a function of flow. Mixed flow pumps will have relatively low head compared to their flow rate making temperature rise across the pump very low except for at very low flow conditions. The tank draw down over time is a good way to determine average flow rate, while monitoring differential pressure as a secondary variable to monitor if the total head is changing over time.



Sample Test - D3 T12 K31

9. In a pump system assessment report where data was logged every five minutes for two months, where is the best place for the complete set of logged data be included.

a. Executive Summary

b. Data Appendix

c. Objective & Scope

d. Data analysis

9. Answer:

b. Data Appendix

Of the sections within a PSA report the data appendix would be most appropriate for large amounts of data that can be included for completeness. Large amounts of data would clutter the executive summary, objective and scope, and while useful for data analysis, smaller sets of important data or summary portions of the data would be better for presentation in the data analysis section.

PSA Report Sections

1. Executive Summary
2. Introduction including facility information
3. Assessment objectives and scope
4. Description of systems studied and system deficiencies
5. Assessment data collected
6. Data analysis
7. Annual baseline O&M, downtime, production loss, etc. costs
8. Performance improvement opportunities and prioritization
9. Implementation steps
10. Data appendices

Sample Test - D2 T8 K4

10. When centrifugal pumps are operated in series, which of the following is a consideration for the first pump when the second pump is turned on?

a. Increased suction pressure

b. Increased discharge pressure

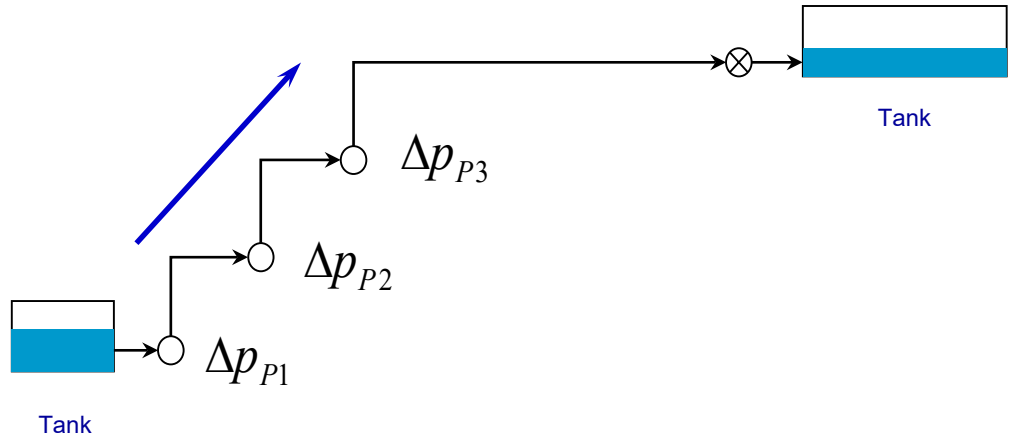
c. Lower power consumption

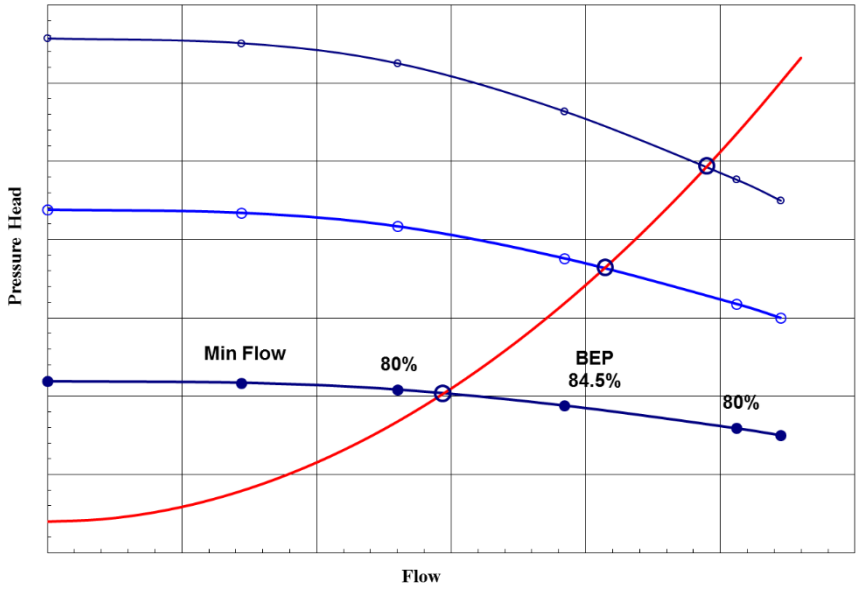
d. Lower NPSH margin

10. Answer:

d. Lower NPSH margin

When subsequent pumps are turned on in series the total system flow rate will increase. This will result in a lower inlet pressure and lower NPSH margin for the first pump.





PUMP SYSTEMS MATTER

Sample Test - D1 T2 K19

11. Which is not a design consideration when using an expansion joint (flexible piping connection) between the pump discharge and the system piping

a. Thermal expansion of the piping

b. Pressure thrust force reaction

c. Isolation from system vibration

d. Elimination of piping anchors

11. Answer:

d. Elimination of piping anchors

In addition to other reasons, flexible piping joints are used to accommodate thermal expansion and potentially isolate the pump from the system. However, these expansion joints being flexible means there will be pressure reaction force that needs to be considered, and will not eliminate the need for appropriate consideration of piping anchors to carry this reaction force.

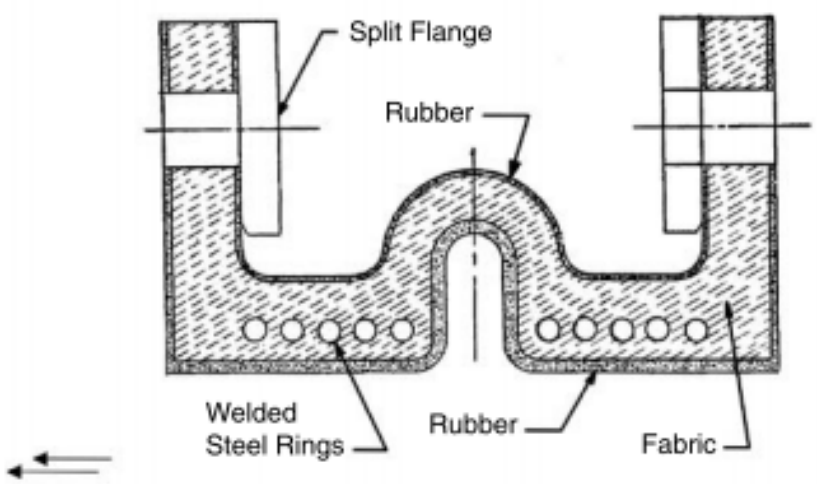


Figure D.2 — Rubber expansion joints

Sample Test - D1 T2 K19

12. Which of the following is the most likely cause of high power consumption in a reciprocating pump

a. Low suction pressure resulting in cavitation

b. A partially closed discharge valve resulting in slightly less flow

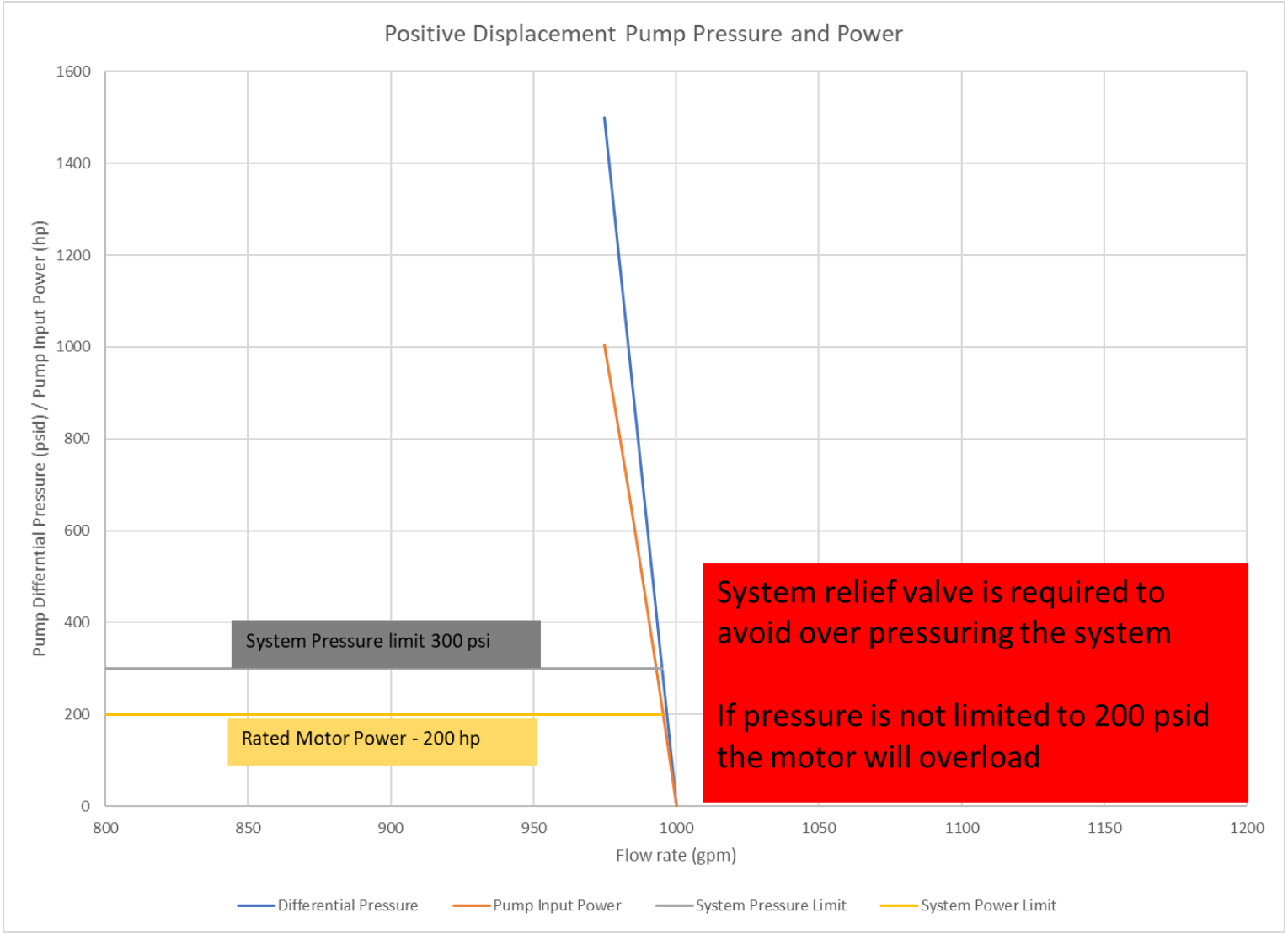
c. A fully open discharge valve resulting in slightly more flow

d. A rise in suction pressure

12. Answer:

b. A partially closed discharge valve resulting in slightly less flow

When dealing with reciprocating pumps a slight decrease in flow rate will result in a large increase in pressure and power consumption.



Sample Test - D2 T9 K1

13. For a 5000 cSt multi-phase liquid, which contains small abrasive solids, which of the following is the most appropriate pump type considering efficiency and reliability?

a. Untimed screw pump with hardened materials

b. Timed screw pump with hardened materials

c. Centrifugal slurry pump

d. Centrifugal solids handling pump

13. Answer:

b. Timed screw pump with hardened materials

The screw pumps would be best for this application compared to the centrifugal pumps because of the high viscosity liquid. Since the fluid is multi-phase and includes abrasives it is important that the screws do not require a fluid film to prevent metal to metal contact. Therefore, a screw pump with a timing gear that maintains a gap between the screws is preferred over the untimed gear pump which relies on the screws meshing with fluid film lubrication from the product to prevent metal to metal contact.

Table 3.0.3a — Capability table – Metric

Pump type	Flow m^3/h	Pressure *bar*	Viscosity *cSt* (×1000)	Solids *cm*	Temps. °C	Dry, Self-priming	Wet, Self-priming	Dry running	Reversible	Abrasive handling	Shear sensitive	Pulseless	Power *kW*
Sliding vane	570	20	220	0.08	200	Y	Y	Y	Y	Fair	Fair	Fair	0.75-190
Piston, axial	70	250	0.44	Clear	60	N	Y	Y	Y (special)	Poor	Poor	Poor	0.75-450
Flexible vane	25	4	22	Clear	90	Y	Y	N	N	Fair	Good	Good	0.15-4
Peristaltic	80	16	44	3.3	80	Y	Y	Y	Y	Excellent	Excellent	Poor	0.1-30
Lobe	1000	28	440	6.35	177	N	Y	Y	Y	Good	Excellent	Fair	0.75-160
Gear, external internal	 180 340	 21 21	 4000 440	 0.08 0.08	 275 275	 Y Y	 Y Y	 Y Y	 Y Y	 Fair Fair	 Poor Poor	 Good Good	 0.37-110 0.37-110
Circumferential piston	140	31	1000	3.2	275	Y	Y	Y	Y	Good	Excellent	Poor	0.75-150
Progressing cavity	850	70	440	9	205	Y	Y	N	Y	Excellent	Excellent	Excellent	0.1-150
Timed screw	5000	104	990	0.08	371	N	Y	Y	Y	Good	Good	Excellent	3.7-1500
Untimed screw	1200	310	220	Clear	275	N	Y	N	Y (special)	Good	Good	Excellent	0.75-750

14. Calculate the Net Positive Inlet Pressure Available for a rotary positive displacement pump in a closed system with the following system data:
- Liquid level above the pump = 3 meters (9.8 feet)
- Suction vessel pressure at top of liquid = 69 kPa,abs (10 psia)
- Friction head loss between the suction vessel and pump = 4.3 meters (14 feet)
- Atmospheric pressure = 101 kPa, abs (14.7 psia)
- Liquid vapor pressure = 51 kPa,abs (7.4 psia)
- Liquid density = 798.6 kg/m^3 (49.8 lb/ft^3) = specific gravity of 0.8
- Suction line velocity head = 1 meter (3.28 ft)
- Suction nozzle inside diameter = 200 mm (8 inch)
- 1 foot = 0.433 psi * specific gravity
- 1 meter = 9.80 kPa * specific gravity

a. 2.1 kPa, abs (0.33 psia)
b. 5.3 kPa (0.78 psia)
c. 7.8 kPa,abs (1.1 psia)
d. 15.6 kPa,abs (2.2 psia)

14. Answer:

c. 7.8 kPa,abs (1.1 psia)

NPIPA is the total suction pressure absolute minutes the absolute vapor pressure referenced to the inlet of the pump.

$$NPIPA = p_{s,absolute} - p_{vp,abs}$$

$$NPIPA = \left[3(m) \times 9.80\left(\frac{kPa}{m}\right) \times 0.8 + 69(kPa, abs) - 4.3(m) \times 9.8\left(\frac{kPa}{m}\right) \times 0.8\right] - 51\ (kPa, abs) = 7.8\ kPa, abs$$

$$NPIPA = \left[9.8(ft) \times 0.433\left(\frac{psi}{ft}\right) \times 0.8 + 10(psia) - 14(ft) \times 0.433\left(\frac{psi}{ft}\right) \times 0.8\right] - 7.4\ (psia) = 1.1\ psia$$

Since the pressure is given at the surface of the liquid level there is no need to consider velocity head

15. Estimate the pump input power for a close-coupled pump based on the following motor nameplate and measured data:

-Full load current: 86 Amps (rated nameplate)

-Rated motor power: 75 horsepower (55 kW)

-Rated voltage: 480 Volts

-Measured current (average three phase): 80 Amps

-Measured voltage (average three phase): 440 Volts

-Full load motor efficiency: 92% efficiency

-75% load motor efficiency: 90% efficiency

a. 58 hp (43 kW)
b. 64 hp (47 kW)
c. 70 hp (52 kW)
d. 75 hp (55 kW)

15. Answer:

b. 64 hp (47 kW)

Based on the information provided the pump input power can be estimated as follows:

- Correct measured amperage to rated voltage: 80 A * (440 V / 480 V) = 73.3 A
- Estimate % FLA based on corrected amperage = 73.3 A / 86 A = 85.2% full load
- Since the % FLA is above 75% with a given efficiency we should not expect large variations in motor efficiency or power factor to influence our estimate if we use motor rated output power.
- Estimate motor output power based on percent FLA = 85.2% * 75 hp (55 kW) = 63.9 hp (46.9kW)

Sample Test - D2 T8 K21

16. Pump total head is measured to be 500 ft at 2000 gpm, and the static head is determined to be 100 ft based on measured tank levels. The impeller is then trimmed, and the new total head is 400 ft at 1500 gpm; however, the static head levels could not be measured, and the pipe size and valves remained constant. What is the static head, and friction head after the impeller was replaced?

a. 175 ft (static), 225 ft (friction)

b. 140 ft (static), 260 ft (friction)

c. 200 ft (static), 200 ft (friction)

d. 100 ft (static), 300 ft (friction)

16. Answer:

a. 175 ft (static), 225 ft (friction)

The friction head for the original configuration is the total head minus the static head

$$h_{f,original} = H - h_s = 500\ ft - 100\ ft = 400\ ft$$

Understanding that friction head changes proportional to the square of flow rate, the friction head for the trimmed impeller can be calculated.

$$h_{f,trimmed} = h_{f,original} \cdot \left(\frac{flow_{trim}}{flow_{original}}\right)^2 = 400\ ft \cdot \left(\frac{1500\ gpm}{2000\ gpm}\right)^2 = 225\ ft$$

The static head for the trimmed impeller case can now be calculated by subtracting the total head from the friction head

$$h_{s,trimmed} = H_{trimmed} - h_{f,trimmed} = 400\ ft - 225\ ft = 175\ ft$$

Sample Test - D2 T9 K24

17. A mean time between repair (MTBR) measurement program is started on January 1st, and there are 3000 pieces of equipment. For the first three months of the program there are 75, 40, and 100 repairs respectively. Assuming 31 days in January, 28 days in February, and 31 days in March, what is the 12 month cumulative MTBR for January, January - February and January - March?

a. 41 months, 51 months, and 41 months

b. 40 months, 52 months, and 45 months

c. 38 months, 44 months, and 42 months

d. 31 months, 41 months, and 32 months

17. Answer:
a. 41 months, 51 months and 41 months is the correct answer

MTBR is the number of pumps divided by the total number of repairs multiplied by time.

For January the MTBR is calculated as follows:

- January MTBR = (3000 pumps / 75 pump failures) x (31 days / 365 days) x 12 months = 40.8 months

For January - February the MTBR is calculated as follows:

- January – February MTBR = (3000 pumps / (75 + 40) pump failures) x ((31 + 28) days / 365 days) x 12 months = 50.6 months

For January – March the MTBR is calculated as follows:

- January – March MTBR = (3000 pumps / (75 + 40 + 100) pump failures x ((31 + 28 + 31) days / 365 days) x 12 months = 41.3 months

Sample Test - D2 T7 K7

18. What is the average specific energy consumption for a pumping system that operates at 12 hours per day at 227 m^3/h, 30.5 m, and 85% combined pump/motor/VFD efficiency, and 4 hours per day at 90.8 m^3/h, 12.2 m, and 80% combined pump/motor/VFD efficiency? Assume the fluid has a specific gravity of 1.0.

a. 0.079 kWh/m^3

b. 0.091 kWh/m^3

c. 0.13 kWh/m^3

d. 0.20 kWh/m^3

18. Answer:

b. 0.091 kWh/m^3

Specific energy consumption is the measure of energy usage per volume required by the system

The energy usage for each period can be calculated as follows:

- kWh (12 hour period) = (227 m^3/h / 3600 s/h x 30.5 m x 1.0) / (0.1022 x 85%) x 12 h = 266 kWh
- kWh (4 hour period) = (90.8 m^3/h / 3600 s/h x 12.2 m x 1.0) / (0.1022 x 80%) x 4 h = 15.1 kWh
- Total kWh = 266 +15.1 = 281.1 kWh

In this case the system requires a volume of 2724 m^3 in a 12 hour period, and 363.2 m^3 in a 4 hour period for a total of 3087 m^3 the 16 hour period.

The specific energy in kWh/m^3 is equal to 281.1 kWh / 3087 m^3 = 0.091 kWh/m^3; therefore “b” is the correct answer

Sample Test - D1 T1 K2

19. Which of the following application would a single split mechanical seal be best applied?

a. Overhung sewage pump with driver mounted vertically
b. Overhung flexibly coupled crude oil pump in horizontal configuration
c. ANSI type overhung pump
d. Controlled-volume metering pump dosing chemicals

19. Answer

a. Overhung sewage pump with driver mounted vertically

The best answer here is the overhung sewage pump with vertically mounted motor (“a”) because split mechanical seals are applied for easy maintenance, and are applied when slight leakage of the process fluid will not be hazardous to personnel or the environment. Wastewater generally is not hazardous if slight leakage occurs, and the split design would be beneficial for maintenance so that the vertical motor would not need to be lifted to replace the seal.

The other pump types listed would not be suitable for slight leakage based on their applications, and would not have the maintenance benefit of not having to lift the vertical motor.

Sample Test - D2 T8 K17

20. For a column of water that is 100 meters (328 ft), that has a specific gravity of 1.0 (998.2 kg/m^3) (62.31 lb/ft^3), what is the static pressure at the midpoint of the column height.

a. 400 kPa (58 psig)

b. 450 kPa (65 psig)

c. 490 kPa (71 psig)

d. 550 kPa (80 psig)

20. Answer

c. 490 kPa (71 psig)

Pressure is the product of density, gravitational acceleration and head.

The head above the mid-point is 50 meters (164 ft).

Metric: 490 kPa = 50 m * 9.81 ($m/s^{2)}$ * 998.2 (kg/m^3 / 1000 (pa/kPa)

US: 71 psi = 164 ft * 62.31 (lbm/ft^3) / 144 (in^2/ft^2)

For US units: Acceleration due to gravity cancels out because pressure is in lbf and density is in lbm.

This can also be calculated using the 2.31 conversion constant, 71 psi = 164/2.31.

Sample Test - D1 T4 K2

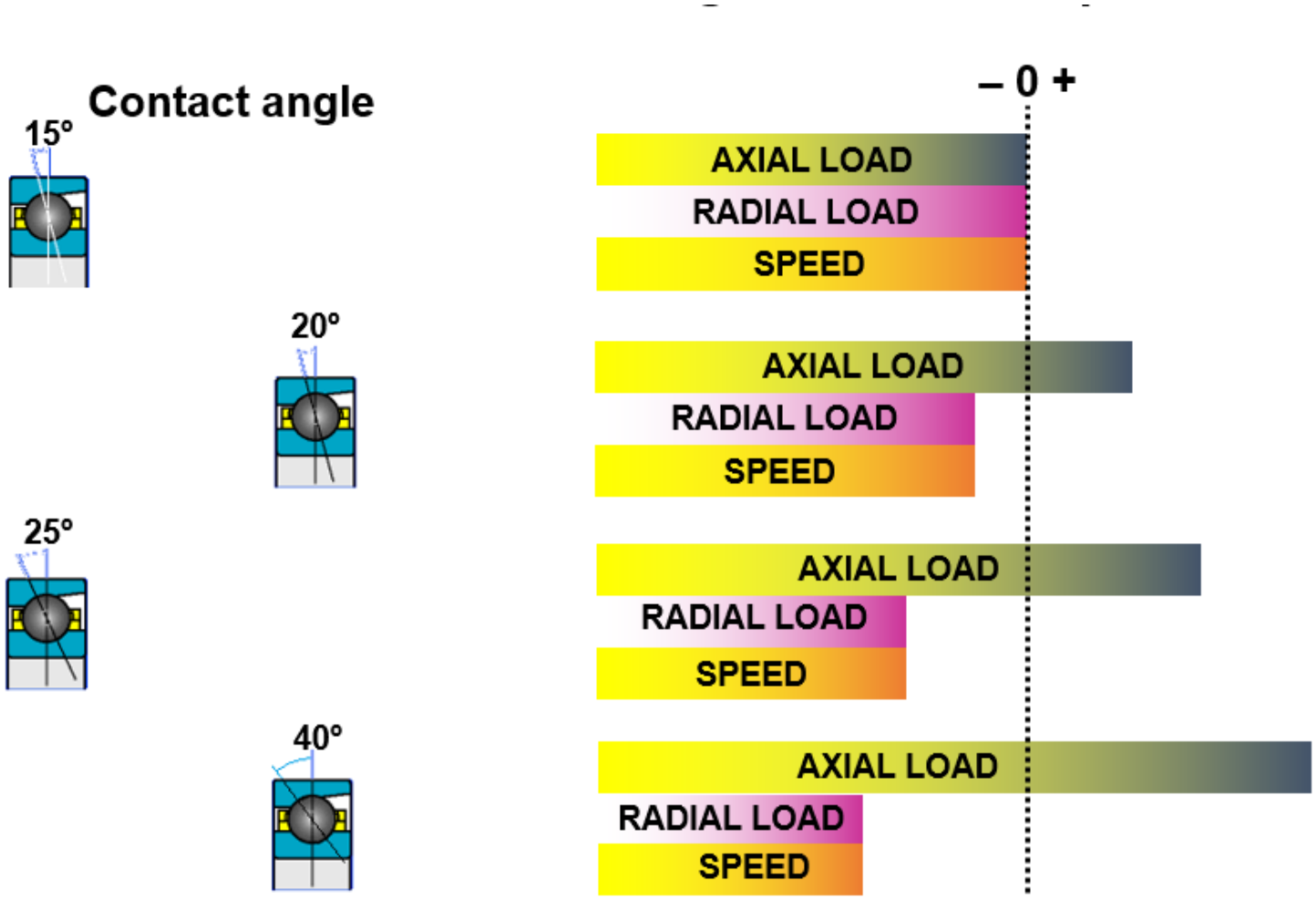
21. For an angular contact ball bearing, which contact angle will carry the highest radial load?

a. 15 degree
b. 20 degree
c. 25 degree
d. 40 degree

21. Answer

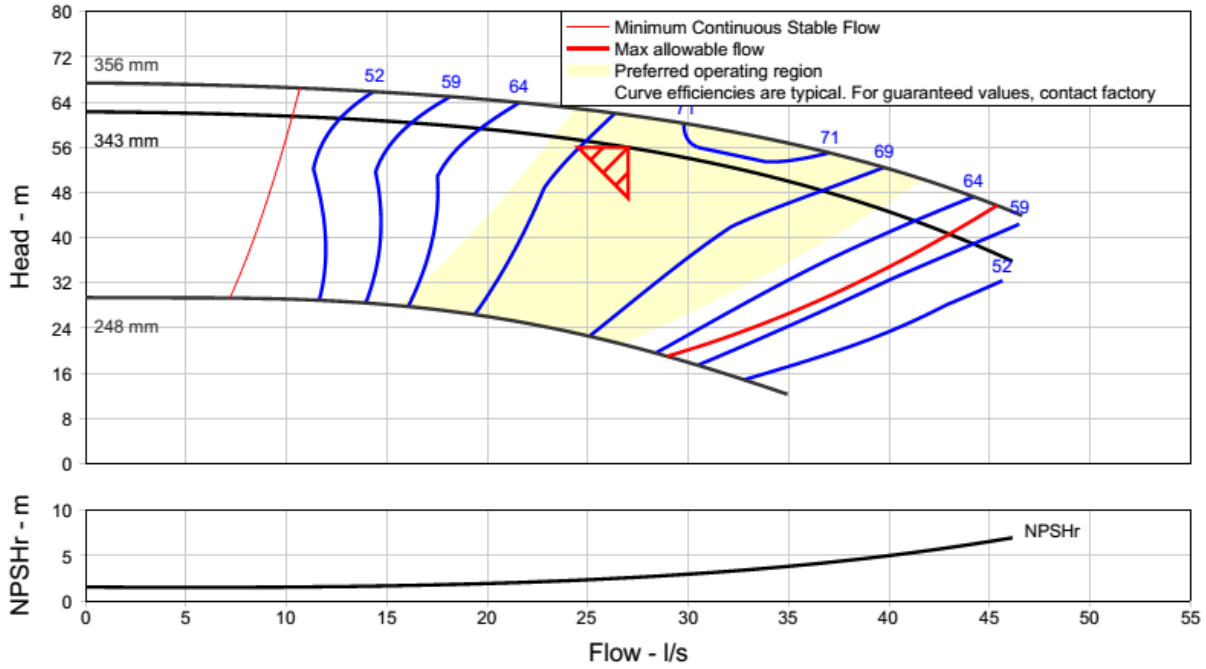
a. 15 degree

The correct answer is “a”. The axial thrust capability increases as the contact angle increases, but the radial thrust and speed capability decreases as the contact angle increases.



22. Calculate the NPSH margin and NPSH margin ratio for a water pump system operating at 27 L/s at 56 m total head with the following recorded parameters:

- **Suction Pressure gauge reading immediately before the pump = 70 kPa**
- **Discharge Pressure gauge reading immediately downstream of the pump = 671 kPa**
- **Velocity head is negligible**
- **Suction and discharge pressure gauges are at the same elevation at the pump centerline**
- **Suction pipe diameter = 350 mm**
- **Discharge pipe diameter = 350 mm**
- **Atmospheric pressure = 101 kPa**
- **Water density = 998 kg/m3**
- **Water vapor pressure = 2.3 kPa**
- **Pump curve attached**



22. Continued

a. NPSH margin = 65.9 m, NPSH margin ratio = 27.4
b. NPSH margin = 14.8 m, NPSH margin ratio = 6.9
c. NPSH margin = 4.5 m, NPSH margin ratio = 2.8
d. NPSH margin = 7.6 m, NPSH margin ratio = 4.0

22. Answer

b. NPSH margin = 14.8 m, NPSH margin ratio = 6.9

The NPSH margin is the difference between the NPSHA and the NPSHR (or NPSH3). The NPSHA margin ratio, on the other hand, is the ratio of the NPSHA over the NSPHR (or NPSH3). The first step in the calculation is to determine the NSPHA. Because NPSHA is a suction related parameter, the discharge pressures and discharge pipe diameter are irrelevant. The equation for calculating the NPSHA is:

$$NPSHA = h_{atm} + h_s - h_{vp}$$

The first term, h_{atm}, is the atmospheric pressure expressed in meters of head. We are given the atmospheric pressure in kilopascals (kPa). To convert the value into meters, the following formula is used:

$$h_{atm} = \frac{p_{atm}}{(\rho \cdot g)}$$

Where,

P_{atm} is the atmospheric pressure in Pascals (1 kPa = 1000 Pa)

ρ is the dentistry of water = 998 kg/m3

g is the acceleration due to gravity, which is equal to 9.807 m/s^2 in SI units.

Therefore, h_{atm} = 101 x 1000 / (998 x 9.81) = 10.3 m

22. Answer Continued

The second term, *hs*, is the total suction head, which is comprised of the suction gauge head, suction velocity head, and elevation from the suction gauge to the datum

$$h_s = h_{gs} + h_{vs} + z_s$$

The question indicates that the velocity head can be ignored, and that the pressure gauges are at the same elevation at the pump centerline. Therefore, the h_{vs} and z_s terms can be ignored. In other words, there is no need for velocity head or elevation correction for the suction pressure reading in this specific case. Therefore, we just need to convert the suction pressure from kPa to head in meters. Using the same conversion above:

$$h_s = h_{gs} = \frac{p_{gs}}{(\rho \cdot g)} = 70 \text{ x } 1000 \text{ / } (998 \text{ x } 9.81) = 7.2 \text{ m}$$

Finally, the vapor pressure is given, so it needs to be converted into meters:

$$h_{vp} = 2.3 \text{ x } 1000 \text{ / } (998 \text{ x } 9.81) = 0.24 \text{ m}$$

The NPSHA for the system is therefore:

$$\text{NPSHA} = 10.3 + 7.2 - 0.24 = 17.3 \text{ m}$$

The next step is to determine the NPSHR for the pump. Since the pump curve is given, the NPSHR can be read directly for the duty point at 27 L/s. at that duty point, the NPSHR is approximately 2.5 m.

Therefore, the NPSH margin is = 17.3 m – 2.5 m = 14.8 m, NPSH margin ratio is = 17.3 m / 2.5 m = 6.9 (dimensionless)

Both values are considered ample and well above the minimum recommended margins.

23.Which of the options listed is most reasonable flow velocity for a piping system carrying solids laden liquids such as raw wastewater?

a. 0.3 m/s (1 ft/s)
b. 1.5 m/s (4.9 ft/s)
c. 5.0 m/s (16 ft/s)
d. 8.0 m/s (26 ft/s)

23. Answer

b. 1.5 m/s (5 ft/s)

In general, maintaining a low velocity reduces friction losses in the system and reduces overall energy requirements. However, for liquids containing solids, it is important to maintain a minimum scouring velocity in the piping system to prevent the deposition and subsequent hardening of solids in piping, which could cause significant headloss or even plugging problems. A flow range between 1.0 m/s and 2.5 m/s is considered reasonable for solids-laden liquids such as wastewater.

Answer a) is too low, which would likely result in solid deposition over time. Answer (C) may be acceptable but is considered at the higher end and would waste energy. Answer (d) is a very excessive velocity, which results in a significant head loss. Therefore, answer b) is considered the most reasonable answer.

Note higher velocities than this may be required for different solids bearing liquids, such as slurries.

24. A close-coupled ambient water pump has a design point of 1,000 gpm at 45 ft of head and 75% pump efficiency. The maximum duty point for this pump is 3,000 gpm at 15 ft total head and 60% pump efficiency. If the motor efficiency is assumed constant at 90% for both duty points, what is the required motor rating for this application with a motor with a 1.15 service factor?

a. 15 hp
b. 20 hp
c. 25 hp
d. 30 hp

24. Answer

b. 20 hp

The pump power input is calculated by the following equation:

$$P = \frac{Q \cdot H \cdot s}{3960 \cdot \eta}$$

Where Q is the flow rate in GPM, H is the total head in ft, η is the hydraulic efficiency, and s is the specific gravity. Since this is an ambient water pump, s = 1.0. We calculate the pump power input requirement at the design point as well as the maximum duty point to determine the maximum pump input power:

- P1 = 1000 x 45 x 1 / (3960 x 0.75) = 15.1 hp
- P2 = 3000 x 15 x 1 / (3960 x 0.60) = 18.9 hp

In this case, maximum power is governed at the highest flow rate. Therefore, a maximum pump power input of 18.9 hp is required.

The next motor size available from the list is 20 hp, which makes “b” the most suitable answer. Note that there is no need to divide by the motor efficiency, because the rated horsepower of a motor is the guaranteed motor output, which is also equal to the pump input power. The question did not state if operation in the service factor is acceptable, but even if it was the 15 hp motor would not be sufficient for the 18.9 hp duty point.

Sample Test - D1 T1 K5

25. Which is not a reason to conduct an assessment on a pumping system?

a. High operating hour system with company global initiative to save energy
b. Operator identifies energy intensive system with poor reliability, but management is not currently supporting optimization projects
c. Critical service that experienced unexpected downtime
d. System with large power load, and throttling control valves

25. Answer

b. Operator identifies energy intensive system with poor reliability, but management is not currently supporting optimization projects

An assessment should only be done if there is management and organizational support. There are many people within the organization that will need to be involved in the assessment, an investment in resources are required to conduct the assessment, and financial support will be need to upgrade the system. Without top level support and communication to all stakeholders, the assessment will likely fail.

26. Which of the following activities is the responsibility of the assessment team when performing a Level 2 assessment?

a. Collecting data from installed instrumentation that is required to develop the pump system assessment report
b. Installing instruments and data logging variable operating conditions
c. Completing a design review of the selected equipment versus the system requirements, without having to measure actual operating conditions
d. Performing measurement and validation in the pre-assessment phase of the pump systems assessment

26. Answer

a. Collecting data from installed instrumentation that is required to develop the pump system assessment report

A level 2 assessment requires measurement of system parameters over a finite time span and is typically conducted on systems that have little or well known variability.

A level 2 assessment will result in an assessment report with analysis and recommendations related to the data gathered.

Sample Test - D1 T2 K26

27. If a pump has an NPSH3 of 6 m, and requires the greater of the NPSH margin ratio of 1.1 or 1 meter (m) minimum NPSH margin, what NPSHA is required?

a. 5.4 m
b. 6 m
c. 6.6 m
d. 7 m

27. Answer

d. 7 m

NPSH margin is the absolute value above the NPSH3, and margin ratio represents the percent above the NPSH3 that is required. The question states a margin ratio of 1.1 or a minimum margin of 1 m is required. To figure out which governs we need to multiply the NPSH3 by 1.1 and compare it to the NPSH3 plus one meter.

NPSH3 = 6 m

NPSH Margin ratio method = 6 m * 1.1 = 6.6 m NPSHA

Minimum Margin method = 6 m + 1 m = 7 m NPSHA

Since the minimum margin method is larger NPSHA it governs.

Sample Test - D2 T9 K3

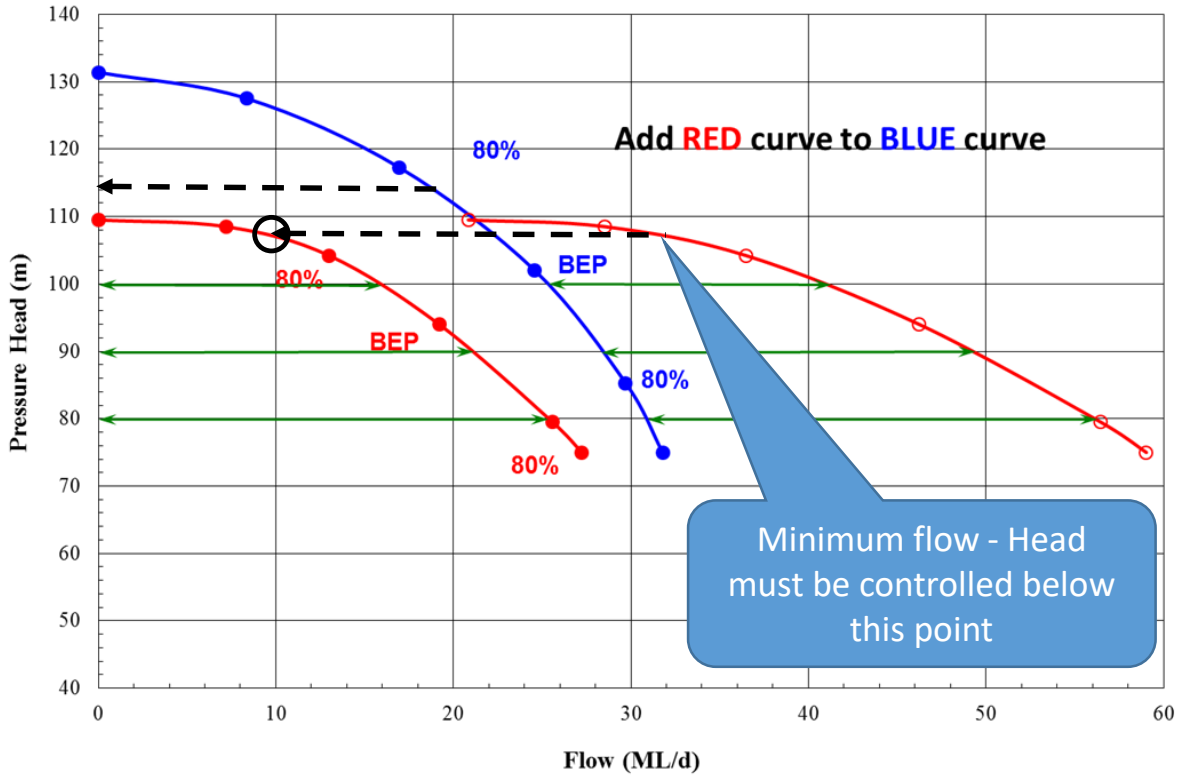
28. Two pumps were purchased for the same rated point and supplied with the same impeller trim and rotating speed to be operated in parallel. The published pump curves are fairly flat, and no certified performance testing was conducted. The system curve is mostly dominated by static head intersecting the parallel pump curves 10% past their minimum flow. The seal has a Plan - 02 arrangement. One pump is experiencing frequent seal failures, whereas the other pump is experiencing no issues. The seal failure analysis shows evidence of dry running. What is the most likely cause of the seal failures?

a. The seal flush line is clogged
b. The frictional drag on the seal faces is too high.
c. The pumps are operating off their curves providing insufficient seal pressure.
d. The pump is operating below its minimum flow condition

28. Answer:

d. The pump is operating below its minimum flow condition

When operating pumps in parallel, care should be given to the shape of the pump curves and ensuring that the pump curves have nearly equivalent heads. If there is a high static head system and one of the pump supplied is producing a lower head, it is possible for the lower head pump to run below minimum flow.



Sample Test D3 T10 K8

29. What portion of the life cycle cost is typically low, but in critical service applications without full redundancy, can be the largest component of the life cycle cost

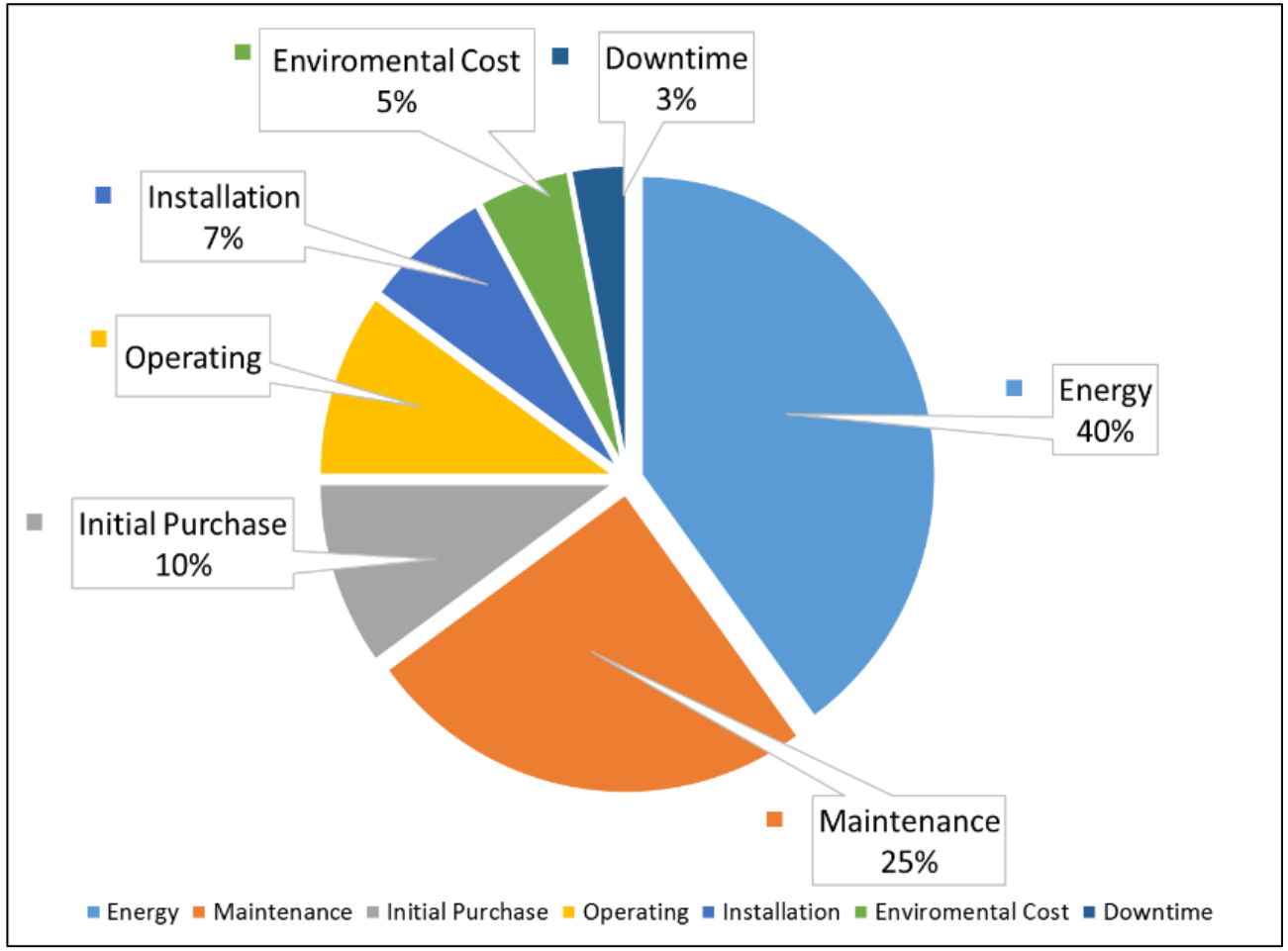
a. Environmental and safety costs
b. Energy costs
c. Installation cost
d. Lost production (down time)

29. Answer

d. Lost production

Energy and maintenance are typically the largest portion of the pump life cycle cost. However, lost production due to down time can be a huge cost for applications that rely on a pump to make a product (i.e. electric power). If a critical application like this experiences unplanned failures without sufficient redundancy in place, the cost of the lost production can far exceed any other cost item.

Environmental costs could also be unexpectedly high in certain applications, but was not the best answer in this case because the question was specific to critical application and lack of redundancy.



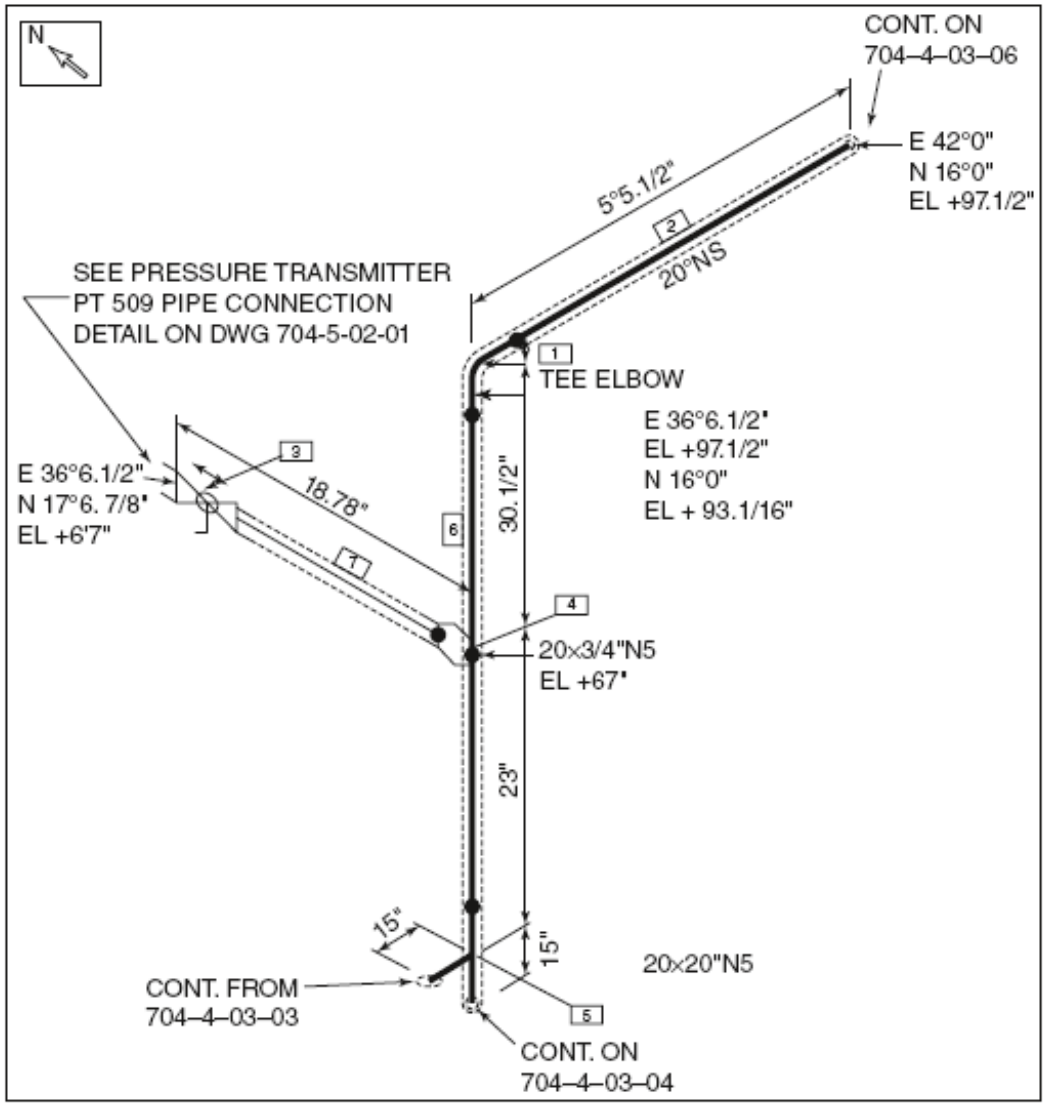
Sample Test - D1 T5 K11

30. What type of drawing would be best for gathering pipe size and lengths?

a. Isometric drawing
b. Piping & Instrumentation Diagram
c. Process flow diagram
d. Pipe length diagram

30. Answer
a. Isometric drawing

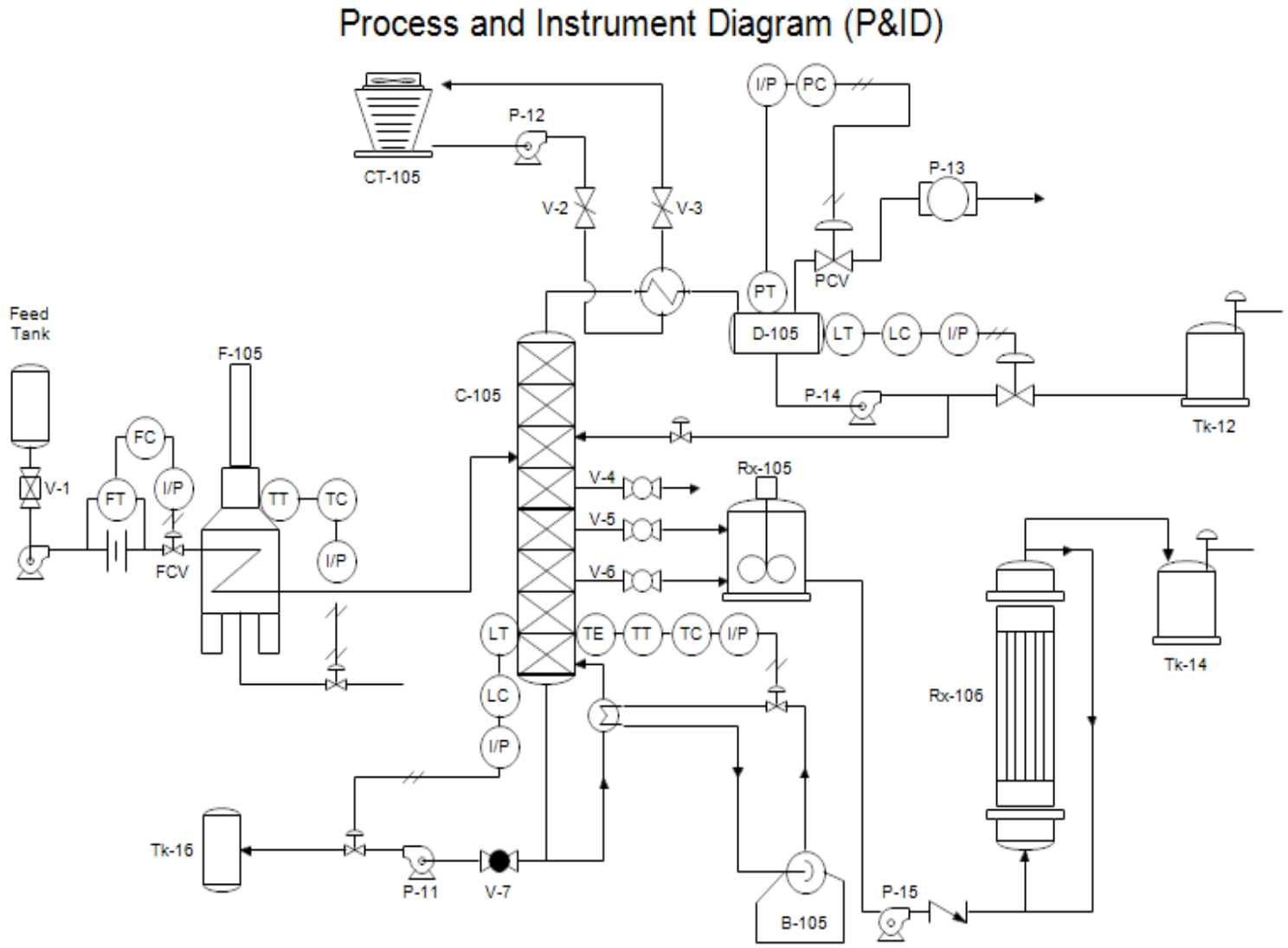
Isometric drawings provide a realistic view of the piping from three sides. Location and direction are provided on the drawing to properly orient equipment and piping in the process. By reviewing the isometric drawing, the assessment professional can determine the actual length of process piping, size of the piping, fittings, and elevation of the piping and the process components. This is very important when developing piping system models to accurately determine process values, such as pressure at specific locations or flow through specific sections of the system. Additionally it is important to review isometric drawings when identifying where to take measurements such as flow rates to ensure flowmeters can be installed properly and that the desired process flow is being measured.



Sample Test - D1 T2 K10

31. In the diagram provided, which pump provides cooling water to a heat exchanger

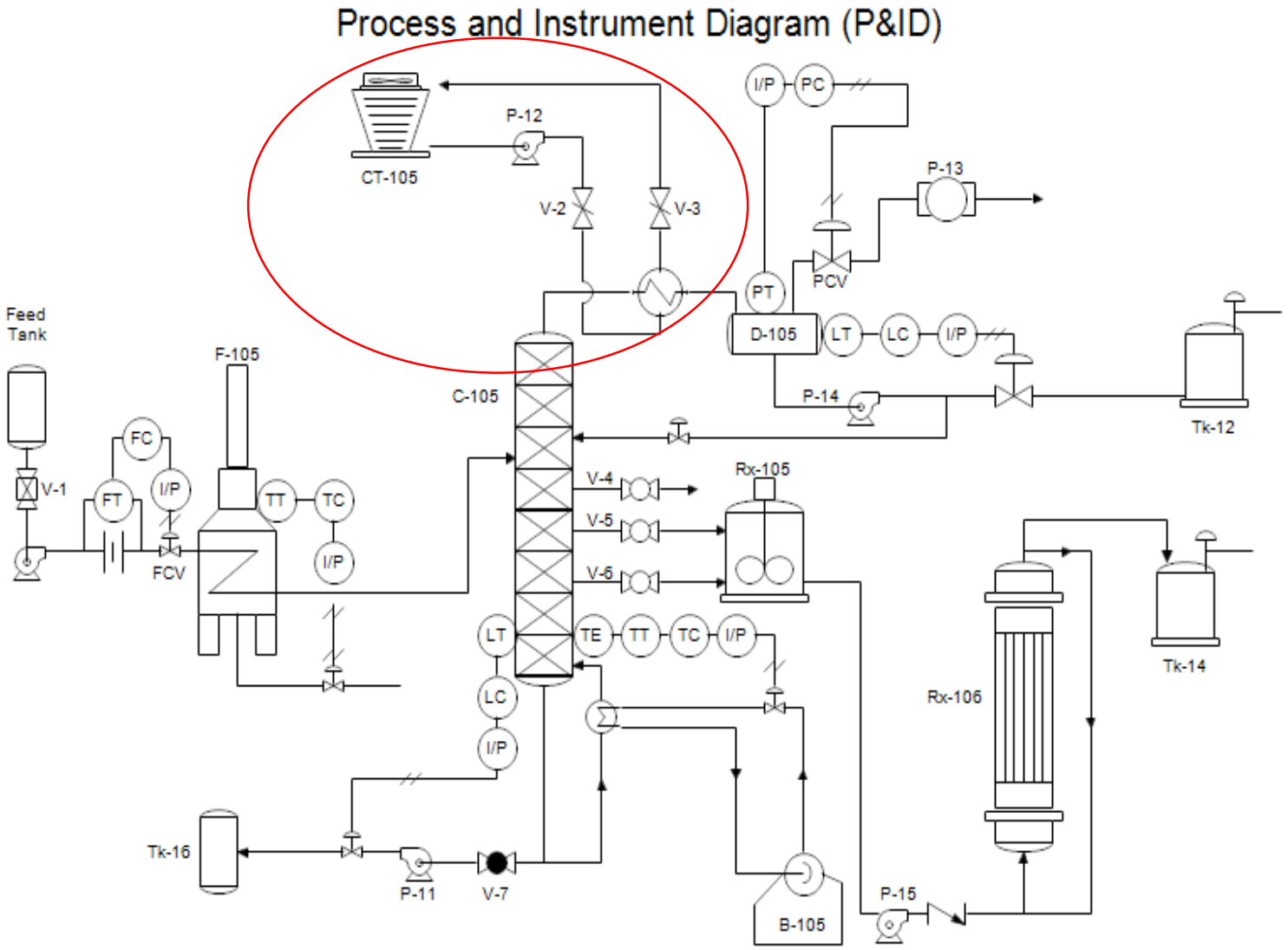
a. P-11
b. P-12
c. P-14
d. P-15



31. Answer

b. P-12

In the diagram “CT-105” is a cooling tower, which reduces the temperature of cooling water by evaporation. Pump “P-12” takes cooling water suction from the cooling tower reservoir and discharges through a process heat exchanger where heat is added and then back to the top of the cooling tower where the heat is exchanged and the cycle continues.



Sample Test - D2 T8 K20

32. Which of the following is not published on the motor characteristic curve

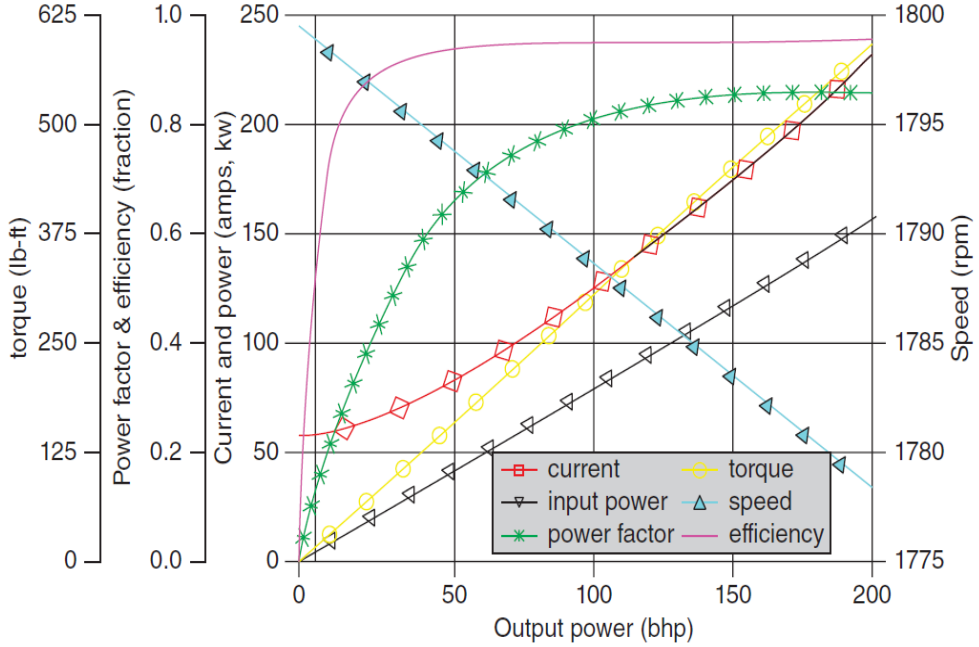
a. Power factor
b. Current
c. Speed or slip
d. Reactive power

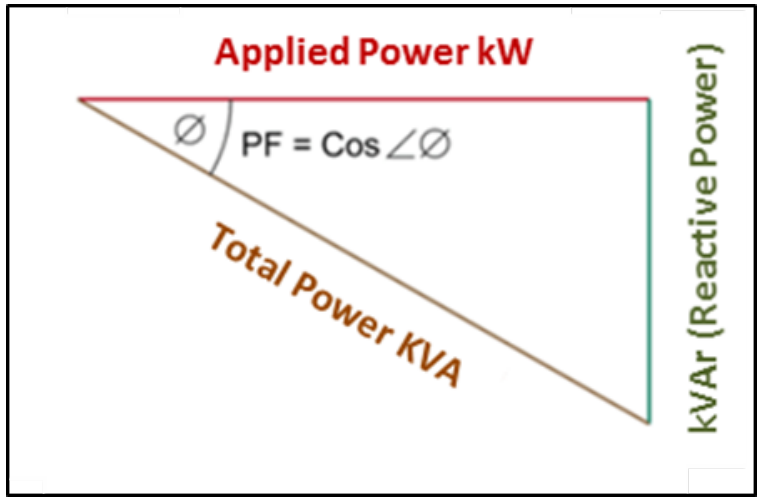
32. Answer
d. Reactive power

A motor characteristic curve plots the following as a function of motor output power.

- Current,
- Power factor,
- Input power
- Efficiency
- Torque
- Slip or speed

However, reactive power is not published on the motor characteristic curve. Reactive power is related to the power factor and applied or input power so it could be calculated based on the motor characteristic curve.





Sample Test - D2 T9 K2

33. In a pump with packing what is the purpose of the lantern ring?

a. Compress the packing so it seals on the shaft
b. Provide a hard surface to minimize wear
c. Liquid injection for cooling
d. To separate particles from the injection liquid

33. Answer
c. Liquid injection for cooling

Packing is a material that is compressed against the pump shaft (usually hardened surface or sleeve), to seal the pumped liquid. However it requires some leakage to cool and lubricate the packing and sleeve. Some design have a lantern ring, which provides a method of injecting flush liquid to the packing.

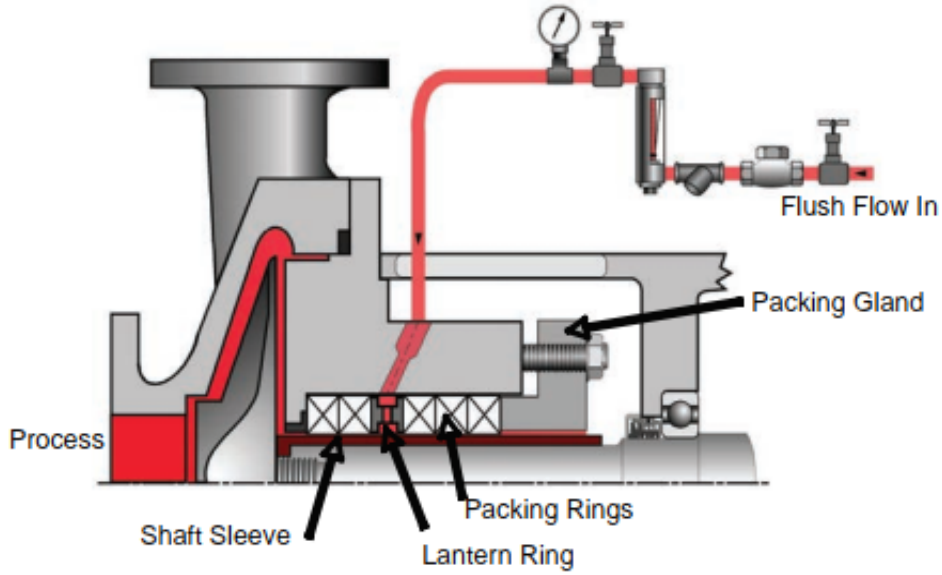


Figure D.2: Lantern ring injection arrangement

34. When an equipment upgrade will have a payback period around 10 years, what type of financial analysis will help determine if the investment meets the company's hurdle rate?

a. Simple payback method
b. Net present value method
c. Internal rate of return method
d. Interest rate accrued method

34. Answer
c. Internal rate of return method

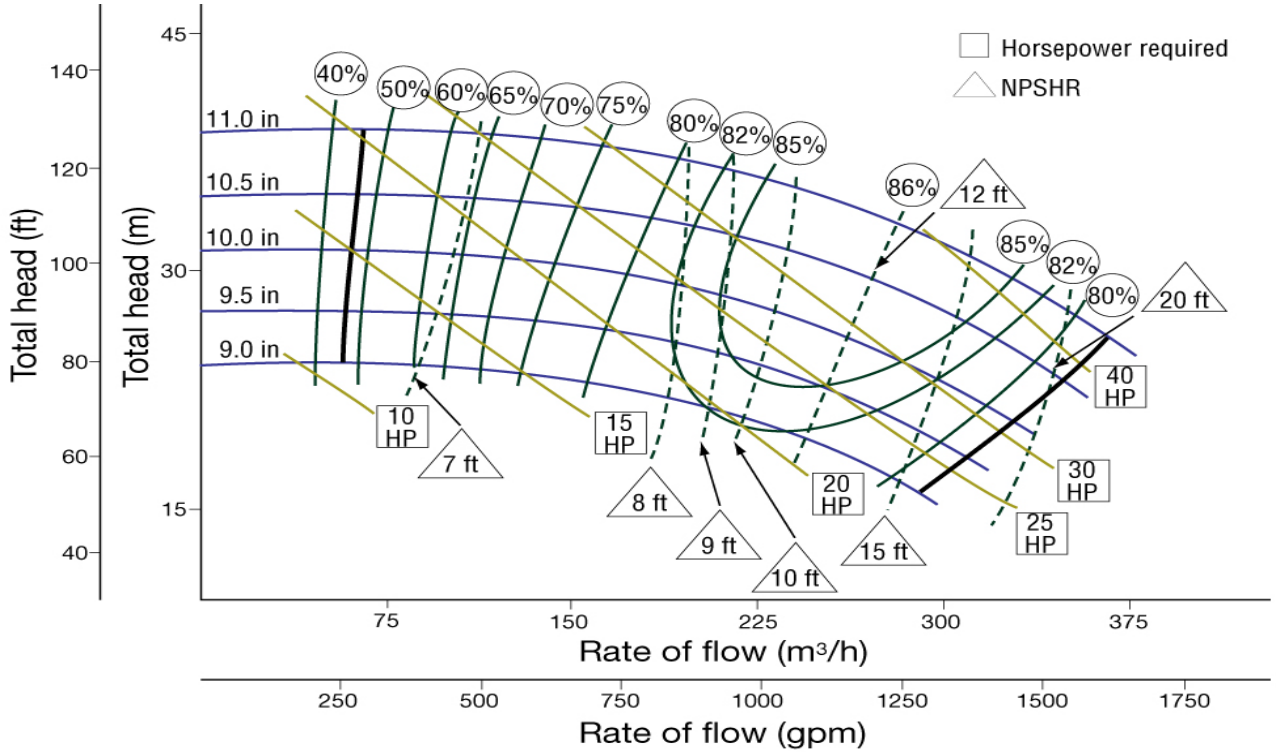
When financially justifying an optimization upgrade a simple payback is the easiest to understand, but generally are only approved if there is very shot payback period. Many times an optimization project can be a good investment even if it takes much longer to payback. Companies will set a hurdle rate for investments, above which they will consider it a good investment. The hurdle rate is the minimum internal rate of return (IRR) for an investment to proceed.

Optimize to save energy and eliminate valve and seal maintenance			
Discount Rate	5.0%		
Upgrade	New Efficient Motor	New VFD+motor	New Pump to Match Normal Point
Period	Cash flow	Cash flow	Cash flow
0	$ (5,000)	$ (10,000)	$ (11,000)
1	$ 600	$ 2,200	$ 2,500
2	$ 600	$ 2,200	$ 2,500
3	$ 600	$ 2,200	$ 2,500
4	$ 600	$ 2,200	$ 2,500
5	$ 600	$ 7,200	$ 7,500
6	$ 600	$ 2,200	$ 2,500
7	$ 600	$ 2,200	$ 2,500
8	$ 600	$ 2,200	$ 2,500
9	$ 600	$ 2,200	$ 2,500
10	$ 600	$ 7,200	$ 7,500
IRR (%)	3.5%	25.1%	25.3%
NPV ($)	($349.48)	$13,309.54	$14,563.37
Simple Payback (Years)	8.3	3.1	3.1

Sample Test - D1 T4 K20

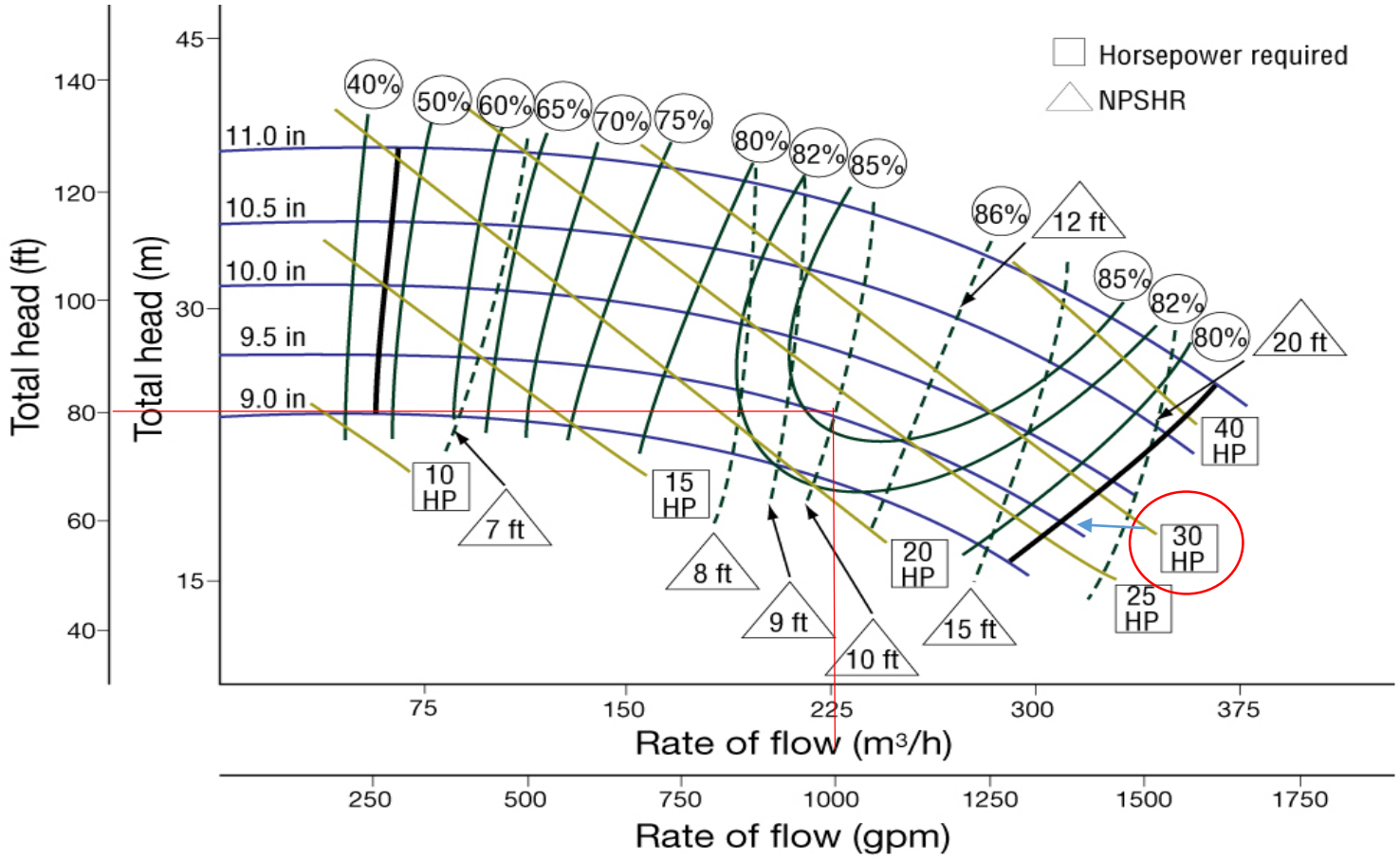
35. For the pump curves shown, if the design point is 1000 gpm (225 m³/hr) and 80 ft (24.5 m), what horsepower motor is required to cover the end of curve condition for the closest impeller trim listed?

a. 20 hp
b. 25 hp
c. 30 hp
d. 40 hp



35. Answer

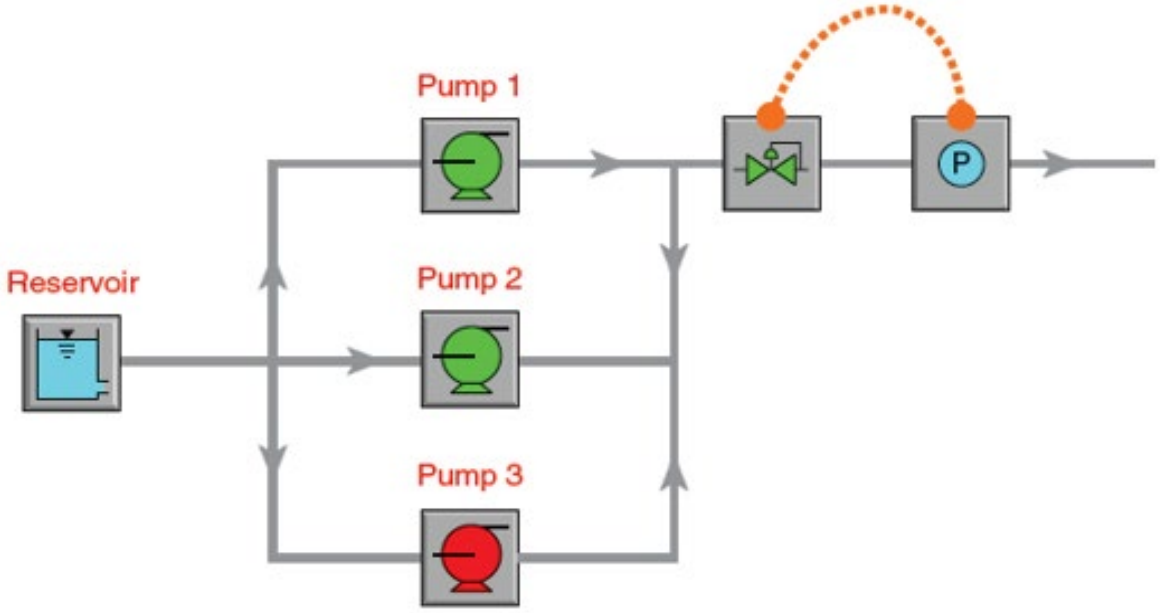
d. 30 hp



D1 T2 K7

36. The control valve in the system below is normally operating 90% - 100% open (20 hours), but for two hours twice per day (four hours total) it regulates flow by closing to 20% open. What is the opportunity to save energy by optimizing this system?

a. Reduce the pump speed twice per day, allowing the control valve to operate more closed
b. Increase the pump speed twice per day, allowing the control valve to operate more open
c. Reduce the pump speed twice per day, allowing the control valve to operate more open
d. Reduce the pump speed during normal operation, allowing the control valve to operate more open



36. Answer:
c. Reduce the pump speed twice per day, allowing the control valve to operate more open

Increasing the valve open position and lowering the pump head to decrease the head loss across the valve is an opportunity to save energy. Increasing the pump speed would not achieve this, and reducing the pump speed during normal operation would not provide significant savings because the valve is already 90% - 100% open. Therefore, answer c is the best selection.

D1 T4 K20

37. The total head developed by a rotary pump is directly proportional to

a. System Head

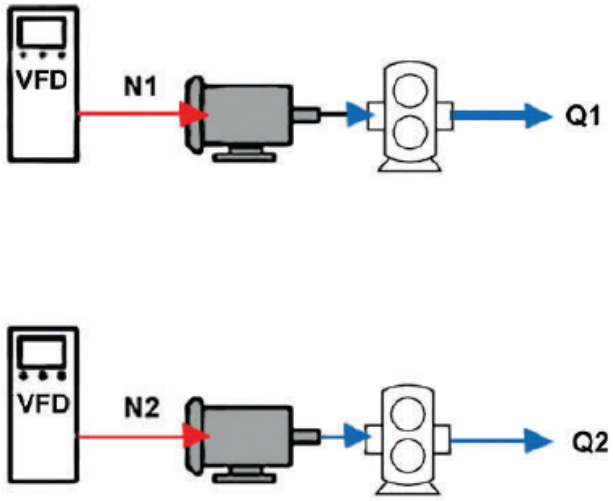
b. Pump Speed

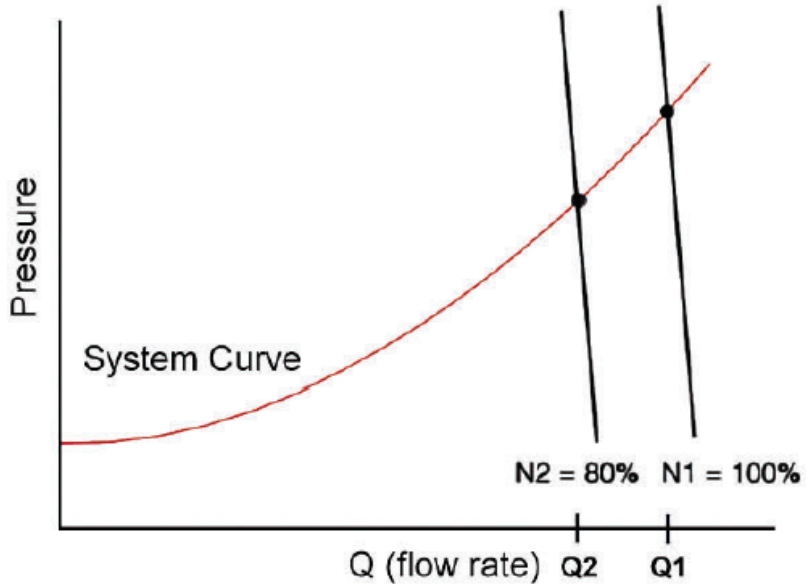
c. Slip

d. Flow Rate

37. Answer:
a. System Head

Positive displacement pumps will operate at a differential pressure that is relatively independent of flow, speed and slip. The item that sets the pump differential pressure is the system head.





38. Which of the following is the BEST method of direct, nonintrusive flow measurement in a system with significantly aerated and multi-phase liquid?

a. Doppler ultrasonic

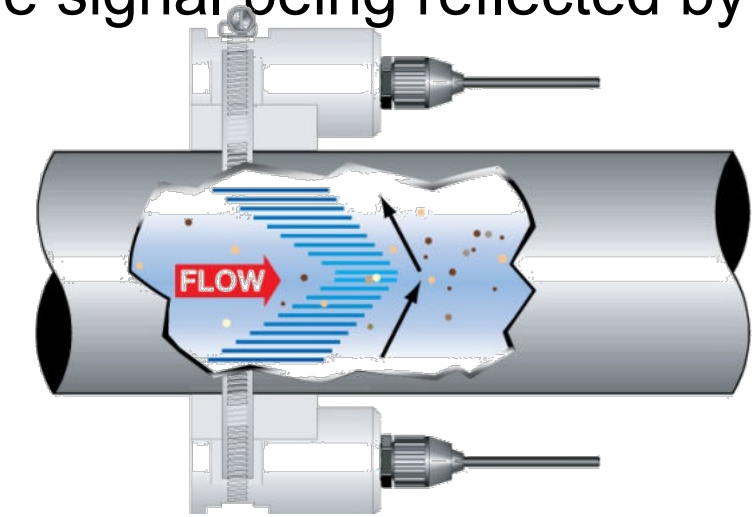
b. Transit-time ultrasonic

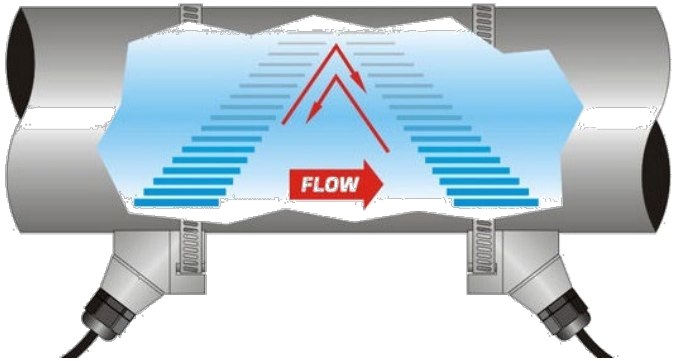
c. Orifice plate

d. Venturi

38. Answer:
a. Doppler ultrasonic

The ultrasonic flowmeters are the non-intrusive designs listed. Since the fluid is significantly aerated the transit time flow meter will likely have its signal dispersed as it travels to the receiving transducer and back. However, the Doppler technology works based on the signal being reflected by particles or bubbles within the stream.





39. The flow from a centrifugal pump in a closed loop circulating system is regulated to be constant by a flow control valve. If the control valve continually opens wider from 45% to 60% over a five year period, what is most likely the cause?

a. Pump internal clearances have worn

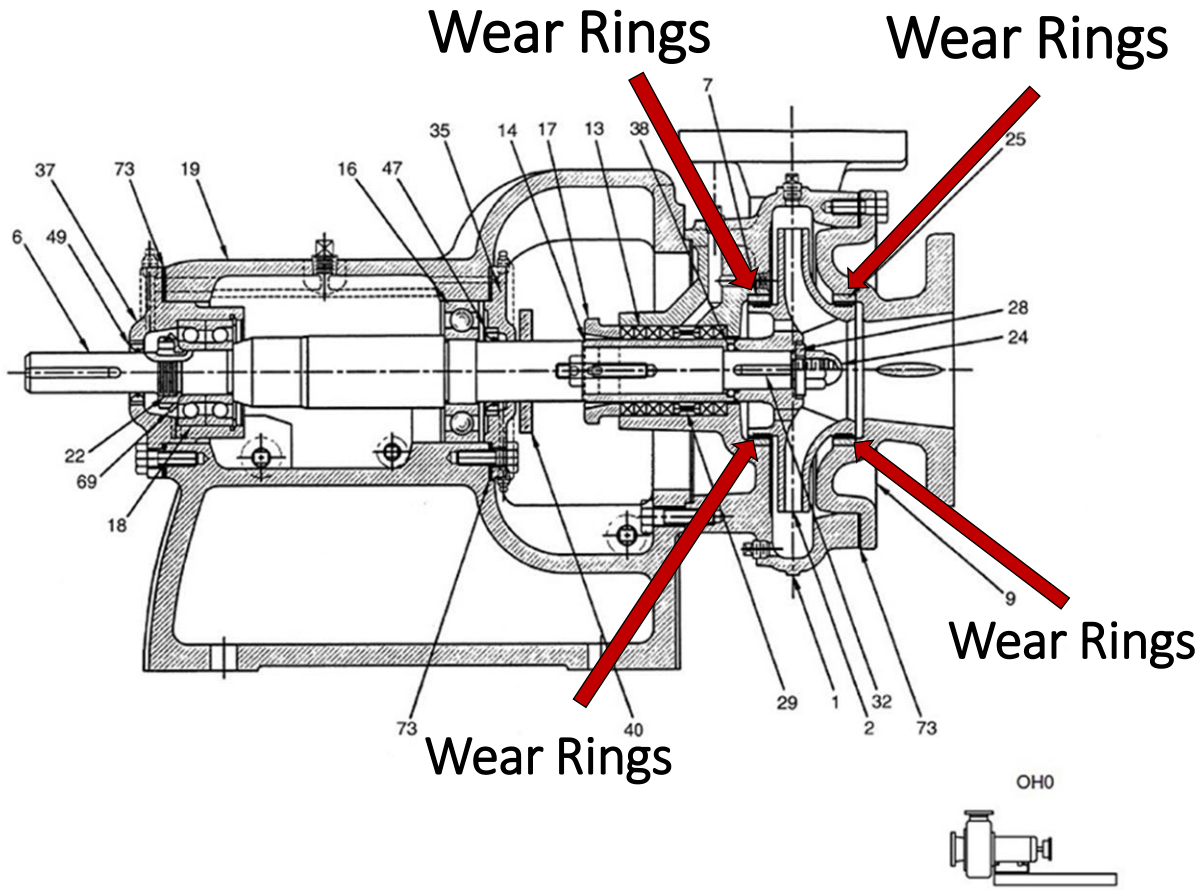
b. The level in a discharge tank has increased

c. The suction pressure has decreased

d. A minimum flow line valve has been shut

39. Answer:
a. Pump internal clearances have worn

Since the increase in valve position has been gradual over a five year span, it is likely that it is due to a gradually lowering pressure from the pump as the result of gradual wear. The other items listed, would not likely result in a gradual change in valve position.



40. A pump with a 75 horsepower electric motor is operating 6000 hours per year with an average of 26 kW motor input power, power factor of 0.6 and motor efficiency of 82%. To supply the same pump load, what would be the simple payback be by replacing the 75 horsepower motor with a 40 horsepower model that was 94.1% efficient and operated at a power factor of 0.85? The cost of electricity is $0.10 per kWh, demand charge is $8/kW the, and the local utility provided a $500 incentive for energy efficiency savings and $300 incentive for reduced demand, and the motor acquisition and installation cost was $7500. Assume the total plant kW is reduced by the kW savings.

a. 2.4
b. 3.0
c. 3.8
d. 4.1

40. Answer:
b. 3 years

- Motor input power (original) = 26 kW
- Pump input power (original) = 26 kW * 0.82 = 21.3 kW
- Motor input power (upgraded) = 21.3 kW / 0.941 = 22.6 kW
- Annual Savings = (26 kW - 22.6 kW) * 6000 h * 0.1 $/kWh = $2000
- Annual Demand Savings = (26 kW – 22.6 kW)* 8 $/kW * 12 months = $325
- Simple payback = ($7500-$500-$300) / ($2000 + $325) = 2.9 years

D1 T2 K6

41. Which of the following is not a primary consideration in setting the low flow side of a pumps Allowable Operating Region (AOR)

a. Pressure loading on the impeller

b. Size of the pump

c. Reduced efficiency

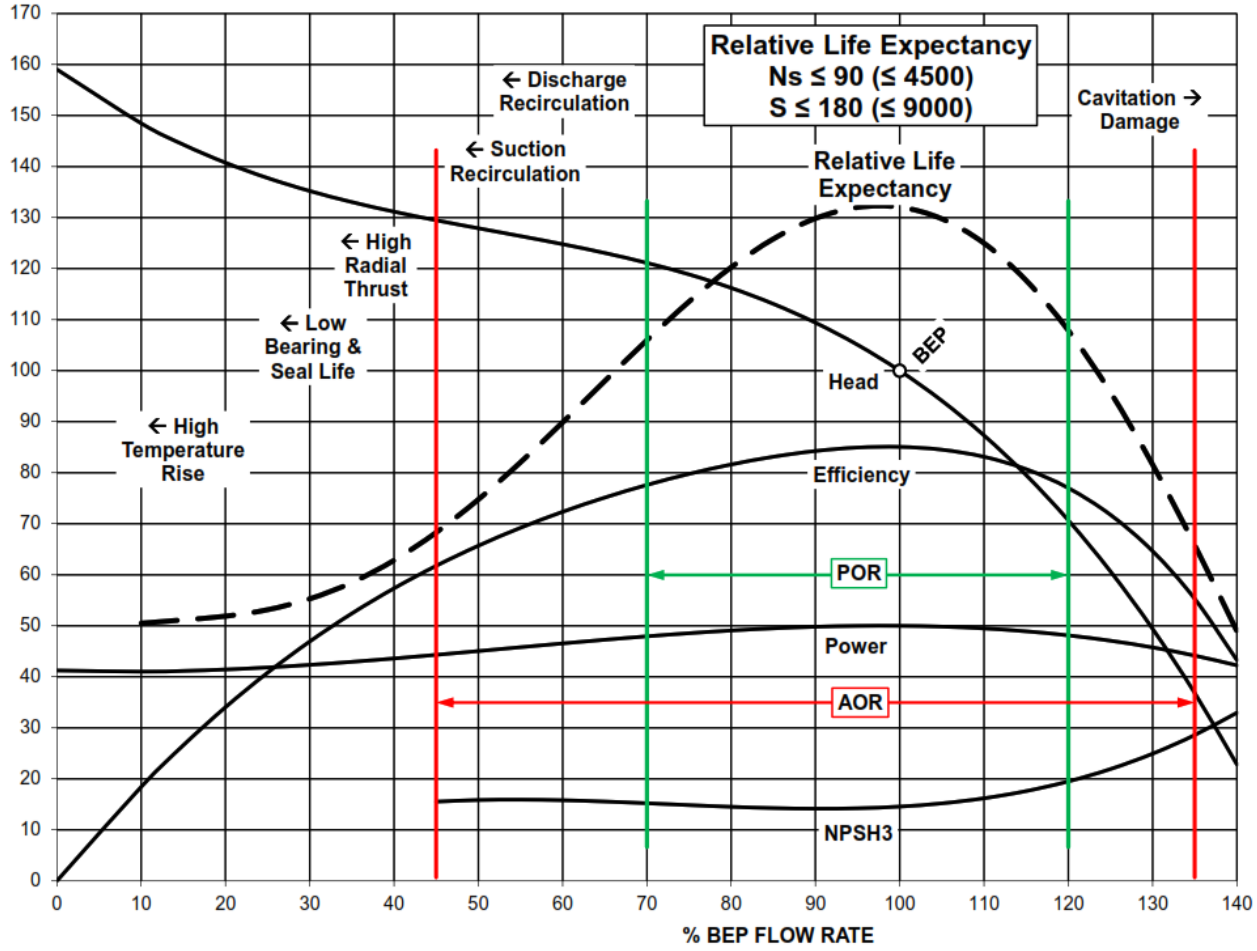
d. High liquid temperature rise

41. Answer:
c. Reduced efficiency

POR is a range of flows to either side of predicted BEP which Hydraulic efficiency and the operational reliability of the pump are not substantially degraded

AOR is a wider range of rates of flow, outside the POR, over which the service life of a pump is acceptable. Considerations include but are not limited to:

- Hydraulic loading (radial & axial)
- Temperature rise
- Vibration & noise
- Power & head curves
- NPSH margin
- Suction & discharge recirculation



42. What sealing arrangement is most appropriate for a volatile and hazardous liquid pump at 200 F (95 C) and 750 psi (5200 kPa) suction pressure.

a. Unbalanced elastomeric bellows type mechanical seal

b. Balanced split type pusher mechanical seal

c. Unbalanced metal bellows type mechanical seal

d. Balanced elastomeric bellows type mechanical seal

42. Answer:
d. Balanced elastomeric bellows type mechanical seal

A balanced seal is a configuration in which the fluid closing forces on the seal faces have been modified design of the closing area and the opening area to limit the closing force and friction at the seal faces.

For the 750 psi suction pressure the closing force will be high so a balanced seal is needed. Of the options listed the balanced split seal would not be an option for a volatile liquid and would not meet the pressure requirements due to the split design. For these reasons answers d is the best selection.

Seal Type	Pusher	Non-pusher	Balanced	Unbalanced	Max. Pressure (kPag / psig)	Temperature Range (Deg. C / Deg. F)
Elastomeric bellows		X		X	2070 / 300	-40 to 205 / -40 to 400
Elastomeric bellows		X	X		6900 / 1000	-40 to 205 / -40 to 400
Metal bellows		X		X	2070 / 300	-75 to 425 / -100 to 800
O-ring secondary seal	X			X	1380 / 200	-40 to 260 / -40 to 500
O-ring secondary seal	X		X		6900 / 1000	-40 to 260 / -40 to 500
Polymer secondary seal	X			X	1380 / 200	-75 to 260 / -100 to 500
Polymer secondary seal	X		X		5070 / 750	-75 to 260 / -100 to 500
Stationary slurry	X		X		2670 / 400	-40 to 205 / -40 to 400
Split seal	X		X		1380 / 200	-40 to 205 / -40 to 400
Dual gas seal	X		X		2070 / 300	-40 to 260 / -40 to 500
Dual gas seal		X	X		1725 / 250	-40 to 260 / -40 to 500

Reference HI Mechanical Seals for Pumps Guidebook

D1 T1 K3

43. Which of the following is the most important design or application consideration for a reciprocating pump to operate reliably

a. Discharge piping configuration

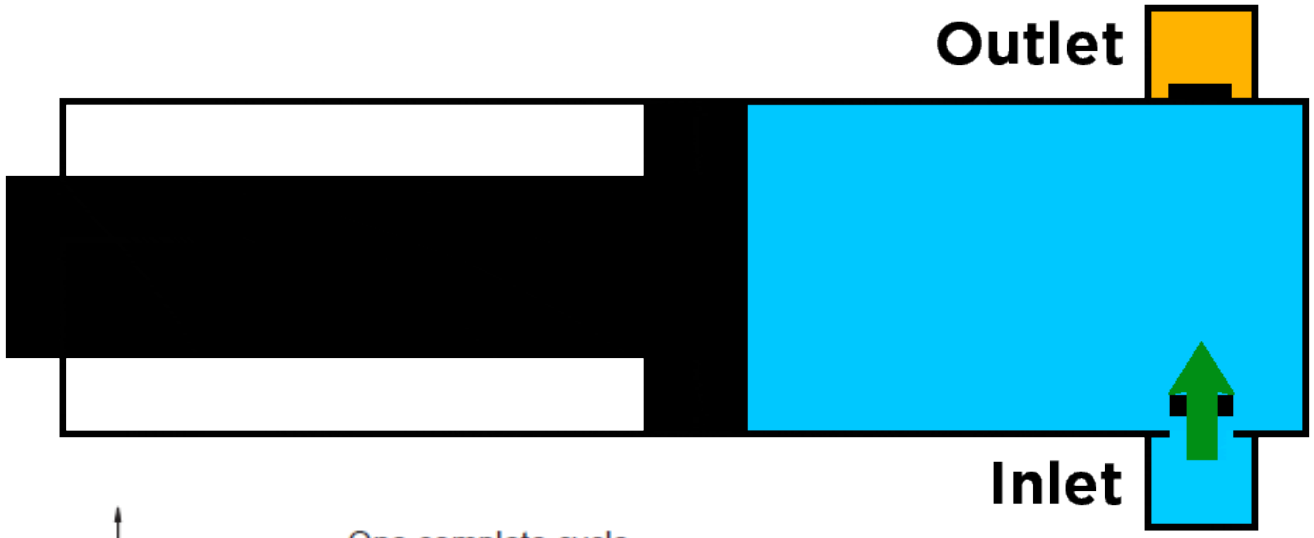
b. Suction piping configuration

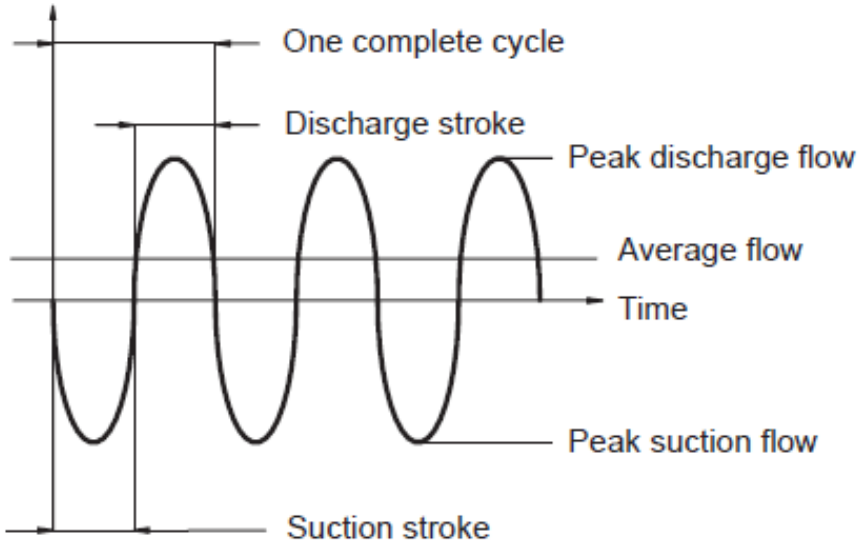
c. Low viscosity liquid

d. High viscosity liquid

43. Answer:
b. Suction piping configuration

Improper suction piping design is the most common design issue that affects a reciprocating pumps operation and reliability because through their pumping action the liquid must accelerate with every rotation of the shaft. This results in a pulsating pressure and an acceleration head loss that contributes to vaporization of the liquid in the suction pumping when the friction loss and acceleration head causes the suction pressure to drop below the liquid vapor pressure. To limit this, care must be take in the suction piping design to limit the length, increase the diameter, and consider suction stabilizers, and consider the acceleration head loss when calculating the Net Positive Inlet Pressure Available.





44. Which item is the primary reason positive displacement pumps are used in metering/dosing applications

a. Performance and efficiency is less effected by various liquid properties

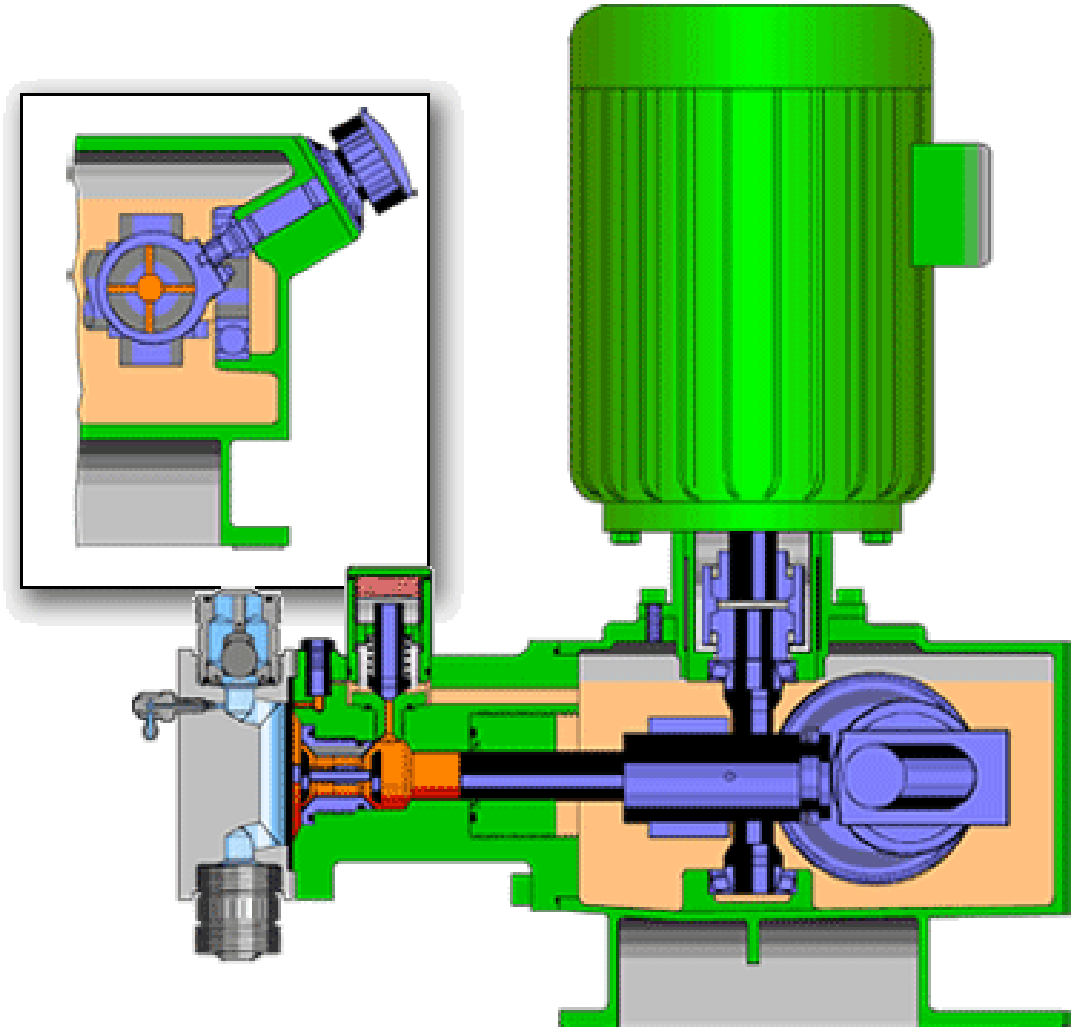
b. Their flow is easily metered with use of a bypass valve

c. A consistent volume is delivered with each shaft rotation

d. Pulsating flow generated from reciprocating pumps is not a problem in metering applications

44. Answer:
c. A consistent volume is delivered with each shaft rotation

Positive displacement pumps are used in metering applications because they deliver a relatively constant volume with every revolution of the shaft independent of the differential pressure. Reciprocating designs can be equipped with a displacement adjustment to fine tune volume delivered.



D1 T4 K3

45. Relative to maximizing the pump suction pressure, which type of valve would be least appropriate in the suction line of a pump

a. Globe valve

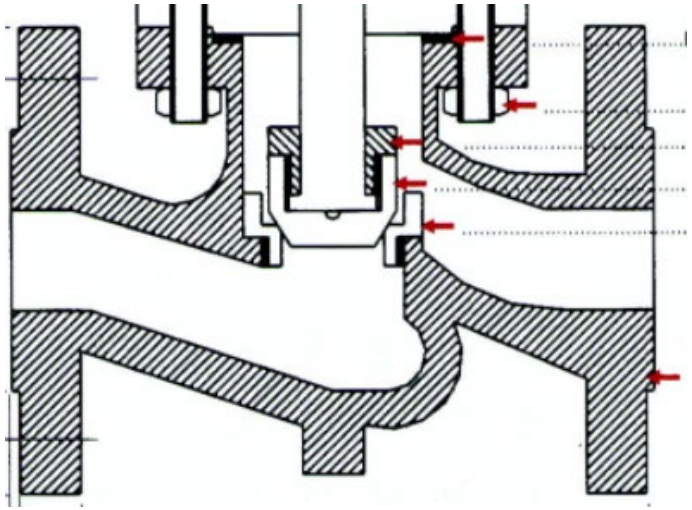
b. Butterfly valve

c. Full port ball valve

d. Gate valve

45. Answer:
a. Globe valve

Globe valves are designed to have a more linear Cv as a function of valve position making them a good choice for controlling or regulating flow; however, the design has more torturous path for the flow to travel when it is 100% open. This results in a higher head loss than the other valves, making it the lease appropriate for the suction piping.



46. Which is the best valve selection for control purposes?

a. 60% open with 10 psi differential at rated condition

b. 25% open with 10 psi differential at rated condition

c. 50% open with 1 psi differential at rated condition

d. 25% open with 1 psi differential at rated condition

46. Answer:

a. 60% open with 10 psid at rated condition

Generally controllability for the valve suffers below 10% open and above 80% open. Control valves should be selected so they are within their controllable position at the rated condition with some minimal additional pressure drop, so that if there is a need, the valve can open and provide additional flow to the system. In this example answer “a” would be the best selection because it offers so additional minimal pressure drop at 60% open, but enough so that additional flow beyond the rated could be achieved. The other options “b, c, and d” are oversized for the application, and require additional throttling to achieve controllability.

47. A pump motor is rated for 50 hp, is 95% efficient, and has a service factor of 1.25. During the assessment, motor input power readings of 35 kW, 40 kW, 42 kW, 45 kW, 47 kW, 50 kW and 55 kW were recorded. What readings are in the motors service factor?

a. 35 kW, 40 kW, and 42 kW

b. 40 kW, 42 kW, and 45 kW

c. 45 kW, 47 kW, and 50 kW

d. 47 kW, 50 kW, and 55 kW

47. Answer:
b 40 kW, 42 kW, and 45 kW

The motor input power readings are in kW so the rated motor in hp needs to be adjusted for the motor efficiency and converted to kW.

Rated motor input power (kW) = 50 hp x (1/95%) x (0.746 kW/hp) = 39.2 kW

Once the rated motor input kW is know the service factor can be applied

39.2 kW x 1.25 = 49.1 kW

39.2 kW to 49.1 kW service factor for the motor

Since the service factor for the motor is between 39.2 and 49.1 kW, the 35 kW, 50 kW and 55 kW readings are not within the motor's service factor. Therefore, answer "b" 40 kW, 42 kW, and 45 kW is correct

48. A batch process operates 12 times a day. Each batch operates for 1 hour and is then off for 1 hour. The batch process was not available for two weeks in March, and two weeks in November due to unexpected maintenance. What is the availability of the batch process for a 52 week period?

a. 50%

b. 74%

c. 92%

d. 94%

48. Answer:

c. 92%

Availability is defined as the number of days the process is available divided by the number of days the process is to be operated per year expressed as a percent.

In this case the batch is scheduled to operate 52 weeks per year, which equates to 365 days.

The process was only available for 48 weeks in the 52 week period, which equates to 337 days.

By definition the availably is the ratio of these two numbers expressed as a percent.

Availability (%) = 337 days / 365 days = 92%

49. A pump's discharge pressure varies between 90 and 100 psig. What range of bourdon tube pressure gauge should be selected for the application?

a. 0 – 100 psig

b. 0 – 110 psig

c. 0 – 150 psig

d. 0 – 200 psig

49. Answer:
c. 0 – 150 psig

For bourdon tube pressure gauges the steady pressure is generally limited to 3/4 of the full scale and 2/3 of the full scale for fluctuating readings, but can be operated to the full range for short time periods.

This question did not indicate if the 90 - 100 psig would be steady or fluctuating, so a worst case should be assumed.

Based on the above, “c” 0 – 150 psig would be the best range because the 100 psig measurement 2/3 of the full scale.

Applications

- Fire sprinkler systems
- Suitable for all media that will not obstruct the pressure system or attack copper alloy parts

Product Features

- UL-listed (UL-393), United States and Canada
- Factory Mutual (FM) approved
- Reliable and economical

Bourdon Tube Pressure Gauge Type 111.10SP

Specifications

Design
EN 837-1 & ASME B40.100

Sizes
4" (100 mm)

Accuracy class
± 3/2/3% of span (ASME B40.100 Grade B)

Ranges
0/80 psi (5,5 bar), retard to 250 psi (17 bar), air
0/300 psi (20 bar), water
0/400 psi (28 bar), water
0/600 psi (40 bar), water

Working pressure
Steady: 3/4 of full scale value
Fluctuating: 2/3 of full scale value
Short time: full scale value

Operating temperature
Ambient: -40°F to 140°F (-40°C to 60°C)
Media: 140°F (+60°C) maximum

Temperature error
Additional error when temperature changes from reference temperature of 68°F (20°C) ±0.4% of span for every 18°F (10°K) rising or falling.

Bourdon tube
Material: copper alloy
C-shape

Pressure connection
Material: copper alloy
1/4“ NPT lower mount (LM)

Movement
Copper alloy

Dial
White aluminum with stop pin; black and red lettering

Pointer
Black aluminum

Case
Black polycarbonate

Window
Snap-in clear polycarbonate

Approvals
UL listed (UL-393)
Factory Mutual

D2 T7 K17

50. What is the head loss for a fitting that is 8 inch (203 mm) inside diameter with 1000 gpm (227 m^3/h) and a K value of 0.5?

a. 0.22 ft (0.07 m)
b. 0.32 ft (0.10 m)
c. 0.42 ft (0.13 m)
d. 0.52 ft (0.16 m)

50. Answer

b. 0.32 ft (0.10 m)

Head loss is calculated by $h_L = K \cdot \frac{V^2}{2 \cdot g}$

This question requires that pipe area ($A = \pi \cdot r^2$) is calculated, and velocity is then calculated based on the volumetric flow rate.

For US units an equation is provided so that area does not need to be calculated, this means the student does not need to convert flow rate to ft^3/s to calculate velocity from the area.

The student will need to convert m^3/h to m^3/s by dividing by 3600.

$$V\left(\frac{m}{s}\right) = \frac{\frac{227\ \left(\frac{m^3}{hr}\right)}{3600\ \left(\frac{s}{hr}\right)}}{\pi\left(\frac{0.203}{2}\right)^2} = 1.95\frac{m}{s} \qquad h_L = 0.5 \times \frac{1.95^2}{2 \times 9.81} = 0.10\ m$$

$$V\left(\frac{ft}{s}\right) = \frac{0.4085 \times 1000\ gpm}{8in^2} = 6.4\frac{ft}{s} \qquad h_L = 0.5 \times \frac{6.4^2}{2 \times 32.2} = 0.32\ ft$$

51. Which pump is best for unloading heavy crude with a viscosity of 2000 centistokes that requires 3,000 gpm (680 m^3/hr), and 100 psi (690 kPa) differential pressure?

a. Air operated diaphragm pump
b. Double Case Between Bearing Centrifugal (BB5)
c. Twin screw pump
d. API 610 Overhung Centrifugal (OH2)

51. Answer

c. Twin Screw Pump

The best answer here is the twin screw pump (“c”) due to the viscosity and flow rate requirement of the application. Twin screw pumps are of the positive displacement type and can handle relatively high flow rates (up to ~4500 gpm at this pressure), and will have the highest efficiency at this viscosity. In general positive displacement pumps will be the best option for highly viscous liquids when compared to rotodynamic types listed. The air operated diaphragm pump could pump the liquid, but could not support the high flow rate. The OH2 API pump could support the flow rate and head, but would have significantly reduced efficiency compared to the screw pump at this viscosity. The BB5 pump is a multi-stage higher pressure design that would not be needed for the relatively low pressure.

D2 T9 K18

52. Select the instrument that provides the required accuracy of 0.5% of reading with a measurement of 100, that provides the lowest cost?

a. Accuracy 0.25% full scale, range 0 – 200, price $1,000

b. Accuracy 0.1% full scale, range 0 – 150, price $1,500

c. Accuracy 0.5% full scale, range 0 – 150, price $700

d. Accuracy 0.2% full scale, range 0 – 150, price $1,300

52. Answer

a. Accuracy 0.25% full scale, range 0 – 200, price $1,000

Answer “a” provides the required accuracy at the lowest cost.

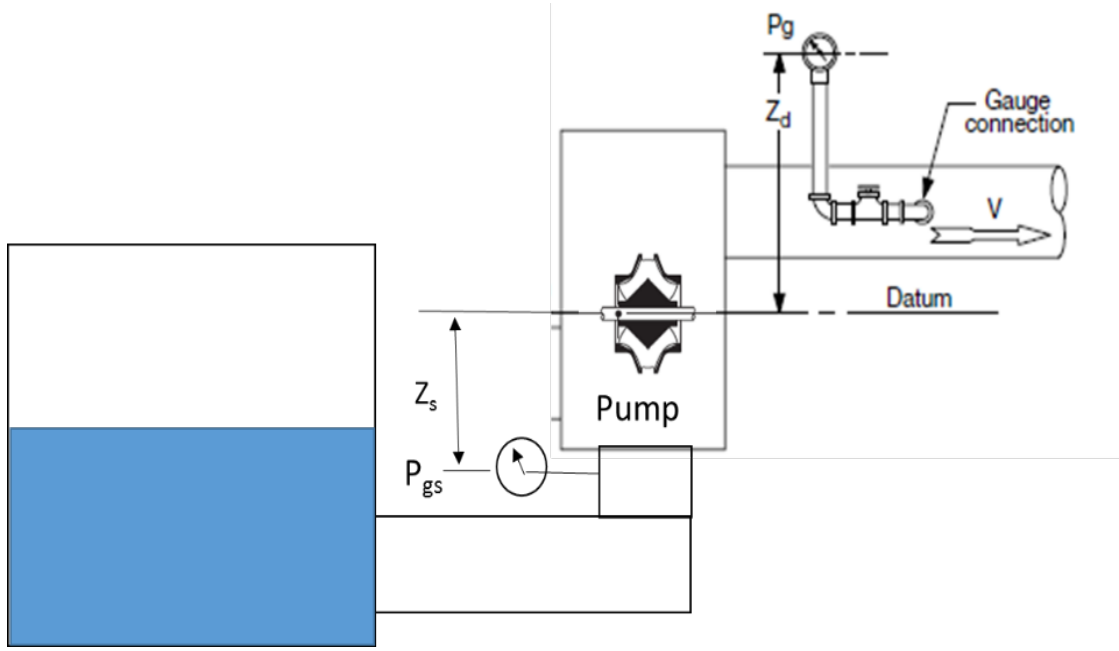
0.25% full scale for a maximum range of 200 will result in 0.5% of reading at a measurement of 100.

- 0.25% * 200 = 0.5
- 0.5/100 = 0.5%

Answers “b” and “d” would provide the required reading accuracy, but cost more, and answer “c” will not meet the accuracy requirement.

53. For the closed system shown what is the NPSHA?

- Density 958 kg/m³ (59.8 lb/ft³), (specific gravity 0.96)
- Pgs = 20.7 kPa (3 psig)
- Flow rate = 0.83 m³/s (29.3 ft³/s)
- Zs = 1 meter (3.28 ft)
- Zd = 2 meters (6.56 ft)
- Pg = 414 kPa (60 psig)
- Atmospheric pressure = 100 kPa abs (14.5 psia)
- Vapor pressure = 99.0 kPa abs (14.4 psia)
- Suction pipe inside diameter = 0.457 meters (1.5 ft)
- Discharge pipe inside diameter = 0.457 meters (1.5 ft)



a. 1.2 meters (4 ft)
b. 2.6 meters (8.4 ft)
c. 3.1 meters (10.2 ft)
d. 4 meters (13.1 ft)

53. Answer
The correct answer is “b”, 2.6 meters (8.4 ft)

Metric units

$$NPSHA = h_{atm} + h_s - h_{vp}$$

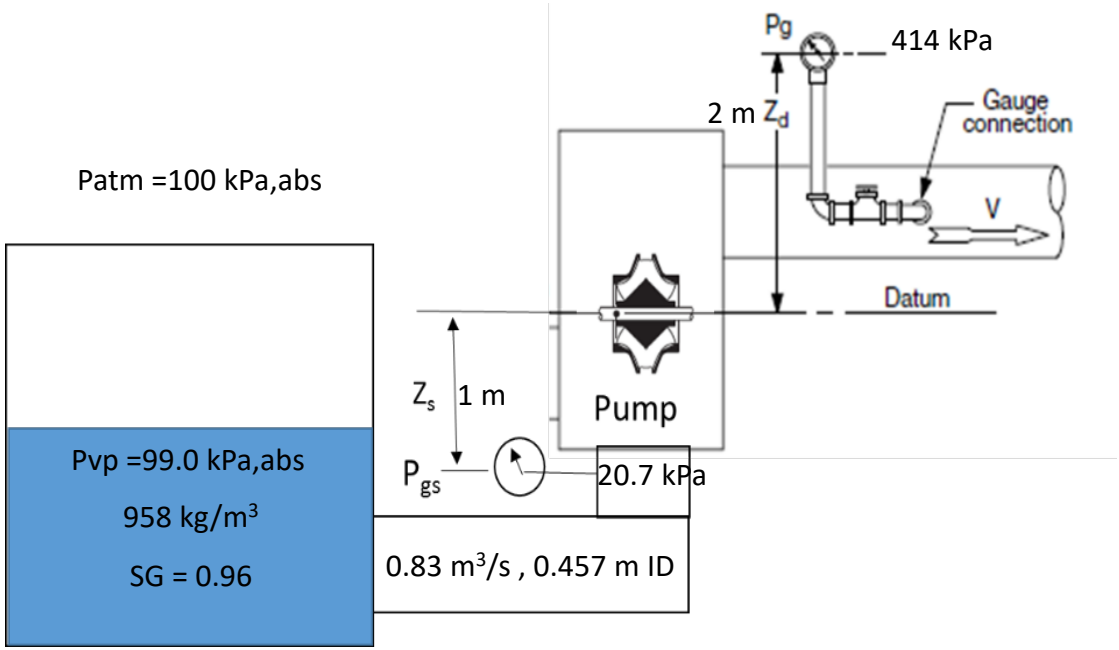
$$h_s = -1 + \frac{20.7 \times 1000}{958 \times 9.81} + \frac{5.06^2}{2 \times 9.81} = 2.51\ m$$

$$h_{atm} = \frac{100 \times 1000}{958 \times 9.81} = 10.6\ m$$

$$h_{vp} = \frac{99\ \times 1000}{958 \times 9.81} = 10.5 m$$

$$NPSHA = 10.6 + 2.51 - 10.5 = 2.6\ m$$

$$V = \frac{0.83\ (\frac{m^3}{s})}{\pi \cdot \left(\frac{0.457}{2}\right)^2\ (m^2)} = 5.06 \frac{\mathrm{m}}{\mathrm{s}}$$



53. Answer (continued)

The correct answer is “b”, 2.6 meters (8.4 ft) US units

US Units

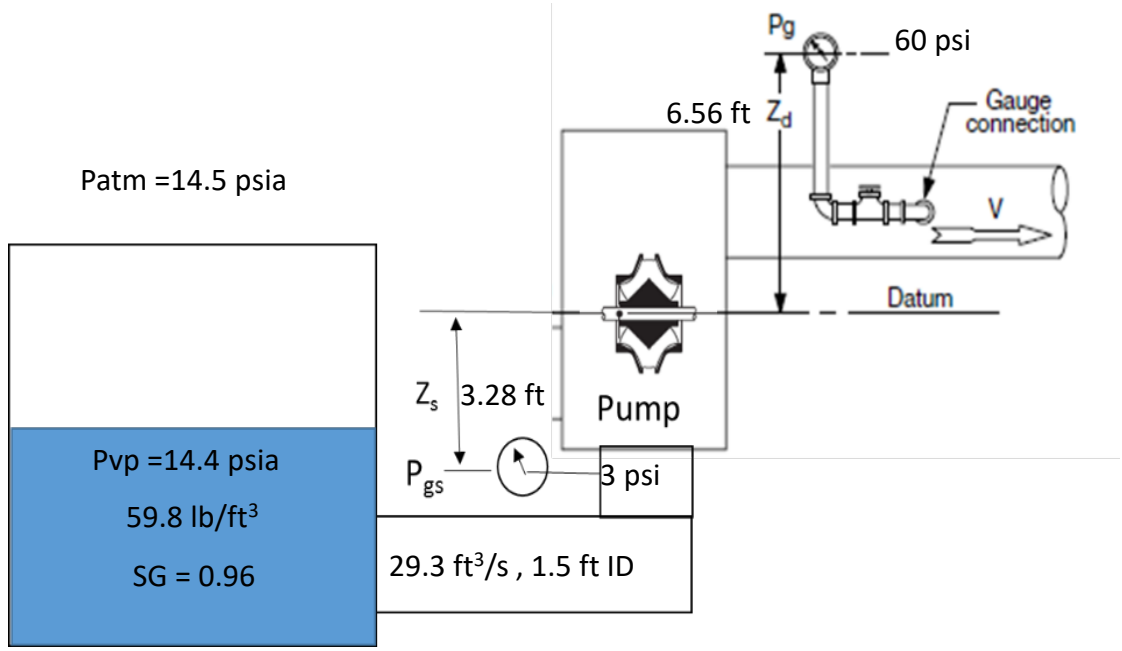
$$h_s = -3.28 + \frac{3 \times 144}{59.8} + \frac{16.6^2}{2 \times 32.2} = 8.22\ ft$$

$$h_{atm} = \frac{14.5 \times 144}{59.8} = 34.9\ ft$$

$$h_{vp} = \frac{14.4 \times 144}{59.8} = 34.7\ ft$$

$$NPSHA = 34.9 + 8.22 - 34.7 = 8.4\ ft$$

$$V = \frac{29.3\ (\frac{ft^3}{s})}{\pi \cdot \left(\frac{1.5}{2}\right)^2 (ft^2)} = 16.6 \frac{\text{ft}}{\text{s}}$$



54. For reduced speed operating considerations, which type of pump would be considered a constant torque load?

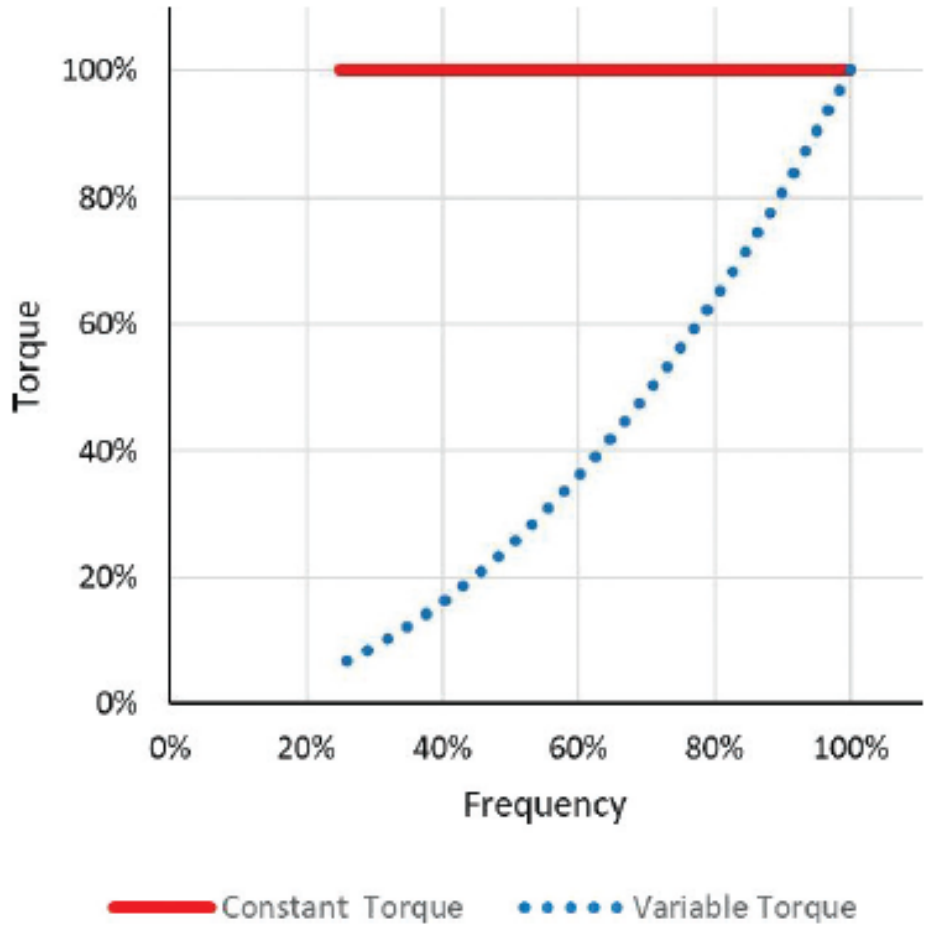
a. High pressure 8000 RPM Between Bearing Centrifugal Pump
b. Axial flow 600 RPM vertically suspended pump
c. Mixed flow 1800 RPM double suction pump
d. 3000 RPM untimed screw pump

54. Answer

d. 3000 RPM untimed screw pump

The correct answer is “d” because the screw pump is the only positive displacement pump type listed. The other three fall into the rotodynamic category that will have reduced head as speed is reduced, but the screw pump is a positive displacement type that can operate at maximum head at reduced speeds.

Note that constant torque loads will be harder to start at low speed due to the torque requirement, therefore, careful consideration of the Motor and VFD is require to ensure the proper sizing, cooling and overload capabilities



55. Which operating condition generally will not cause a pump to operate at lower than expected flow rate?

a. Air entrainment in the liquid
b. Wrong direction of rotation
c. System head higher than expected
d. System head lower than expected

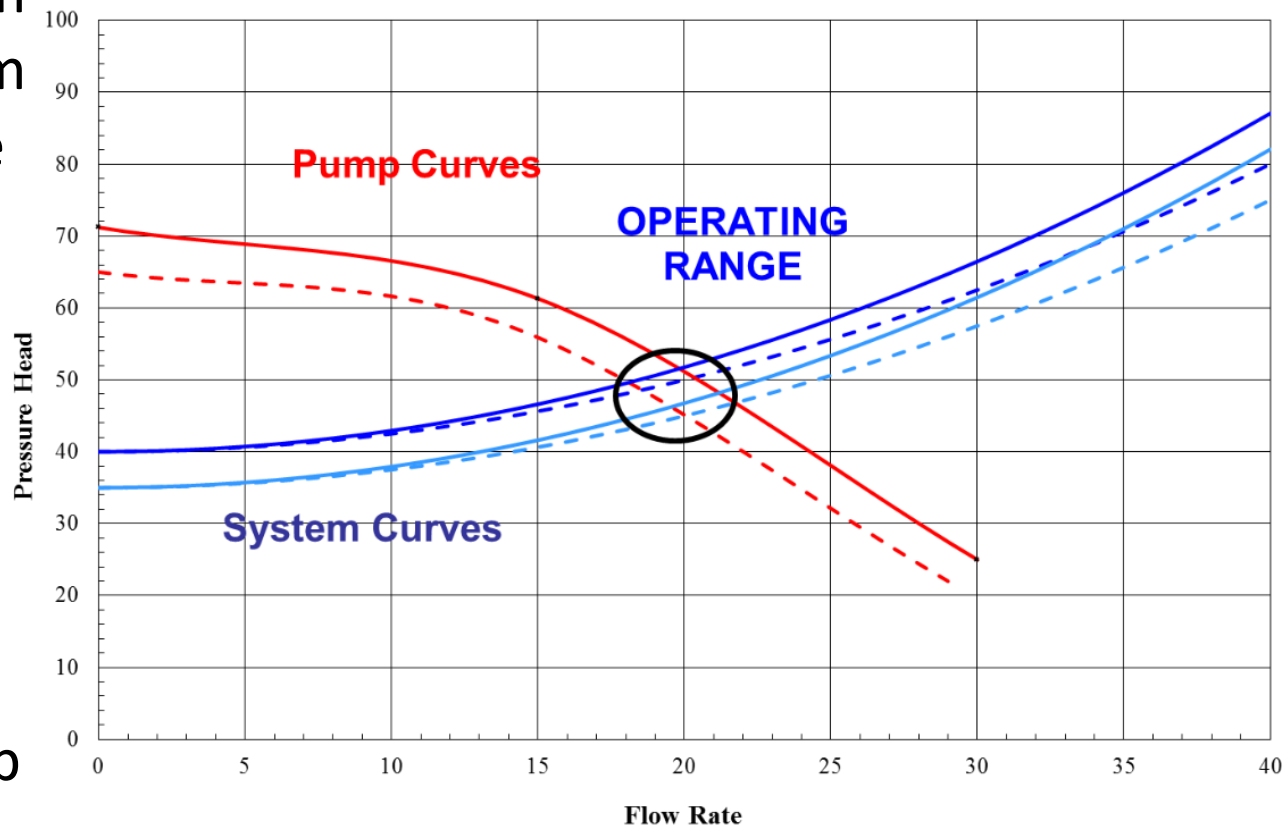
55. Answer

d. System head lower than expected

The correct answer is “d” because low system head will move the intersection of the system curve and the pump’s head capacity to curve to the right, resulting in higher flow rate.

The only caveat to this would be if the flow rate became excessive the suction pressure could not support the NPSHR at the higher flow rate.

The other conditions would reduce the pump flow rate.



56. If the velocity of flow in a section of pipe doubles, then the friction head loss in the system:

a. Drops in half
b. Remains the same
c. Doubles
d. Quadruples

56. Answer

d. Quadruples

The general equation for calculating head loss in piping is:

$$h_f = f \cdot \frac{L}{d} \cdot \frac{v^2}{(2 \cdot g)}$$

Where f is the pipe friction factor, L is the pipe length, d is the pipe inner diameter, v is the average velocity of flow, and g is the acceleration due to gravity. Headloss is related to the square of the velocity term. If the value of v doubles, then the overall head loss term increases fourfold due to the square term. This goes to show the criticality of flow velocity (and therefore proper pipe sizing) in optimizing pumping systems.

57. What is the effect of increasing liquid temperature on the net positive suction head available?

a. Increasing liquid temperature does not impact the NPSHA
b. Increasing liquid temperature increases the NPSHA
c. Increasing liquid temperature reduces the NPSHA
d. It depends on the type of liquid

57. Answer
c. Increasing liquid temperature reduces the NPSHA

Temperature of the liquid affect its vapor pressure. Vapor pressure is related to NPSHA according to the following equation:

$$NPSHA = h_{atm} + h_s - h_{vp}$$

As the temperature of a liquid increases, its vapor pressure also increases. If the vapor pressure increases, the NPSHA correspondingly decreases.

Conversely, vapor pressure decreases as the temperature decreases. One of the ways to improve the NPSHA conditions of the system is to reduce the fluid temperature if feasible. The correct answer is “c”.

58. What is the most cost effective type of instrument for measuring pump head in a Level 2 Assessment?

a. Pressure gauge
b. Pressure switch
c. Pressure transducer
d. Pressure reading is not required for a Level 2 assessment

58. Answer

a. Pressure gauge

A Level 2 assessment is quantitative assessment of pump performance based on a single operating point. Therefore, answer d) is incorrect.

Data recording is required in this case, which typically include the flow, head, and power input to the pump. Among the listed types of pressure instruments, a pressure gauge is the most cost effective and practical instrument.

A pressure switch does not typically provide a continuous reading, and a pressure transducer/transmitter is more expensive to purchase and to install and its normally used for continuous reading.

Therefore, answer a) is the most suitable answer.

59. When reviewing a pump system with operating personnel, which key information gathered from the operator indicates the greatest need for a more detailed review is need?

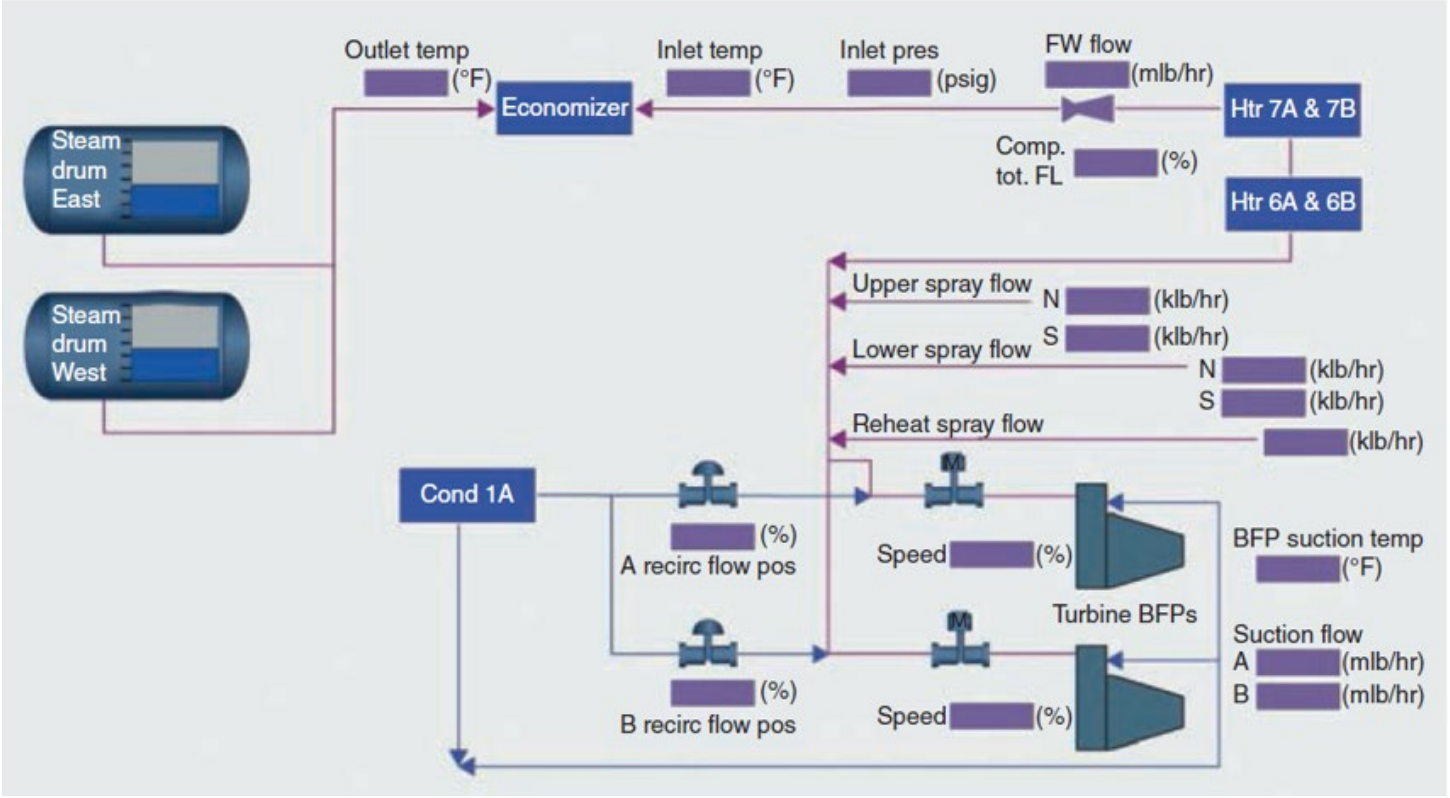
a. The pump bearings are hot, the pump is noisy, and bearing failures occur unexpectedly
b. The pump runs at 70% of maximum speed and is operating in the allowable operating region
c. The discharge valve is 100% open, and the pump speed is 60%
d. The pump operates 50% of the time, and the motor is operating in the service factor

59. Answer
a. The pump bearings are hot, the pump is noisy, and bearing failures occur unexpectedly

The only observation that results in failures is answer a, and red flags such as noise and hot bearings are indicated; therefore, it is the best answer.

60. The image provided is an example of what type of drawing

a. Isometric drawing
b. Piping & Instrumentation Diagram
c. Process flow diagram
d. Engineering drawing



60. Answer
c. Process flow diagram

Process flow diagrams, sometimes referred to as flowsheets, are used in chemical and process engineering. They indicate the general flow of processes and equipment, and display the relationships between major equipment in the plant. It's important to note that process flow diagrams do not show minor details, such as piping details.
Process flow diagrams of a single process will typically include the following:

- Major equipment
- Process piping
- Control valves and other major valves
- Connections with other systems
- Major bypass and recirculation streams
- Operational data, such as temperature, pressure, mass flow rate, density, etc.
- Process stream names

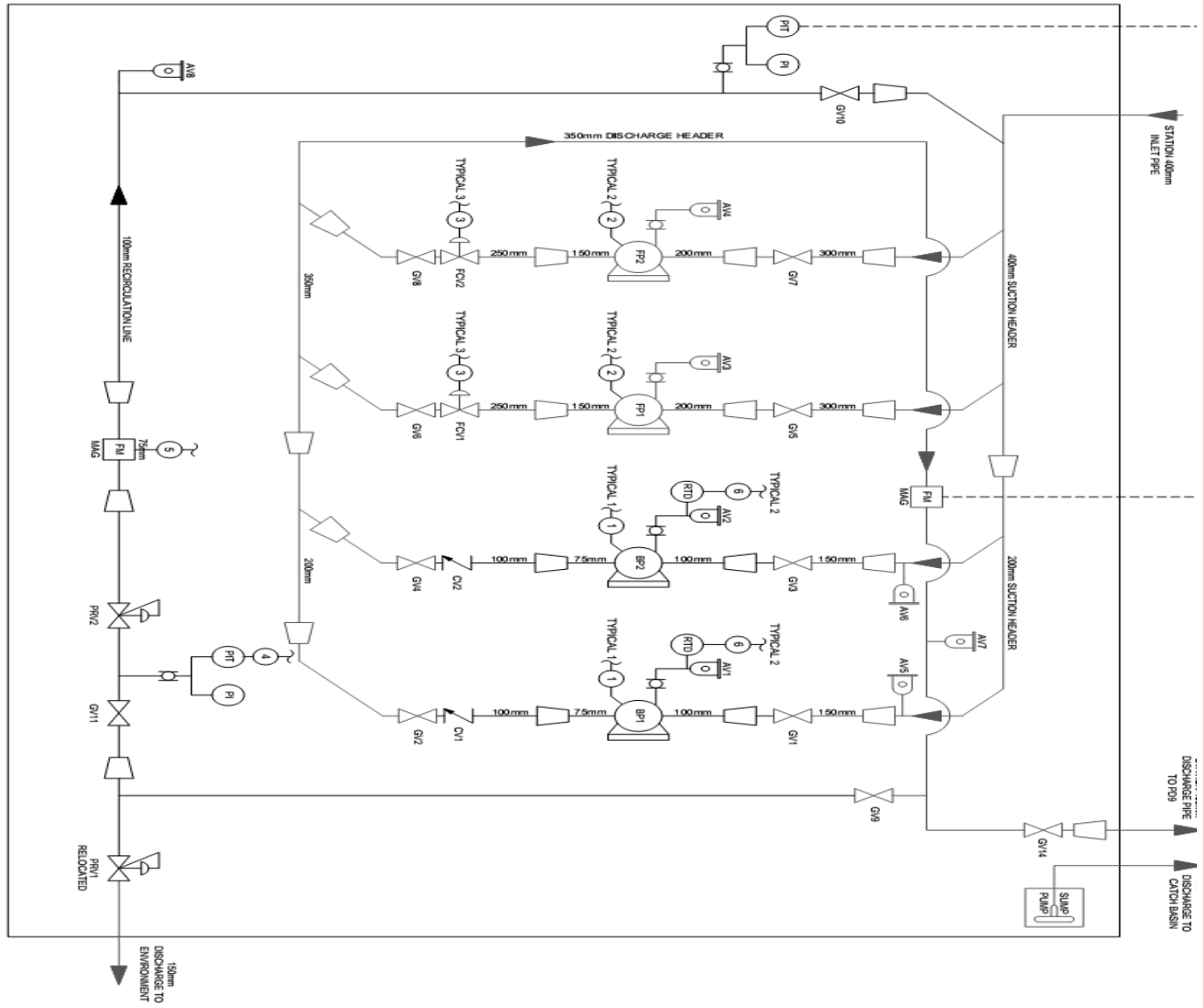
Process flow diagrams typically do not include:

- Pipe classes or piping line numbers
- Process control instrumentation (sensors and final elements)
- Minor bypass lines
- Isolation and shutoff valves
- Relief and safety valves
- Maintenance vents and drains
- Flanges

D1 T5 K10

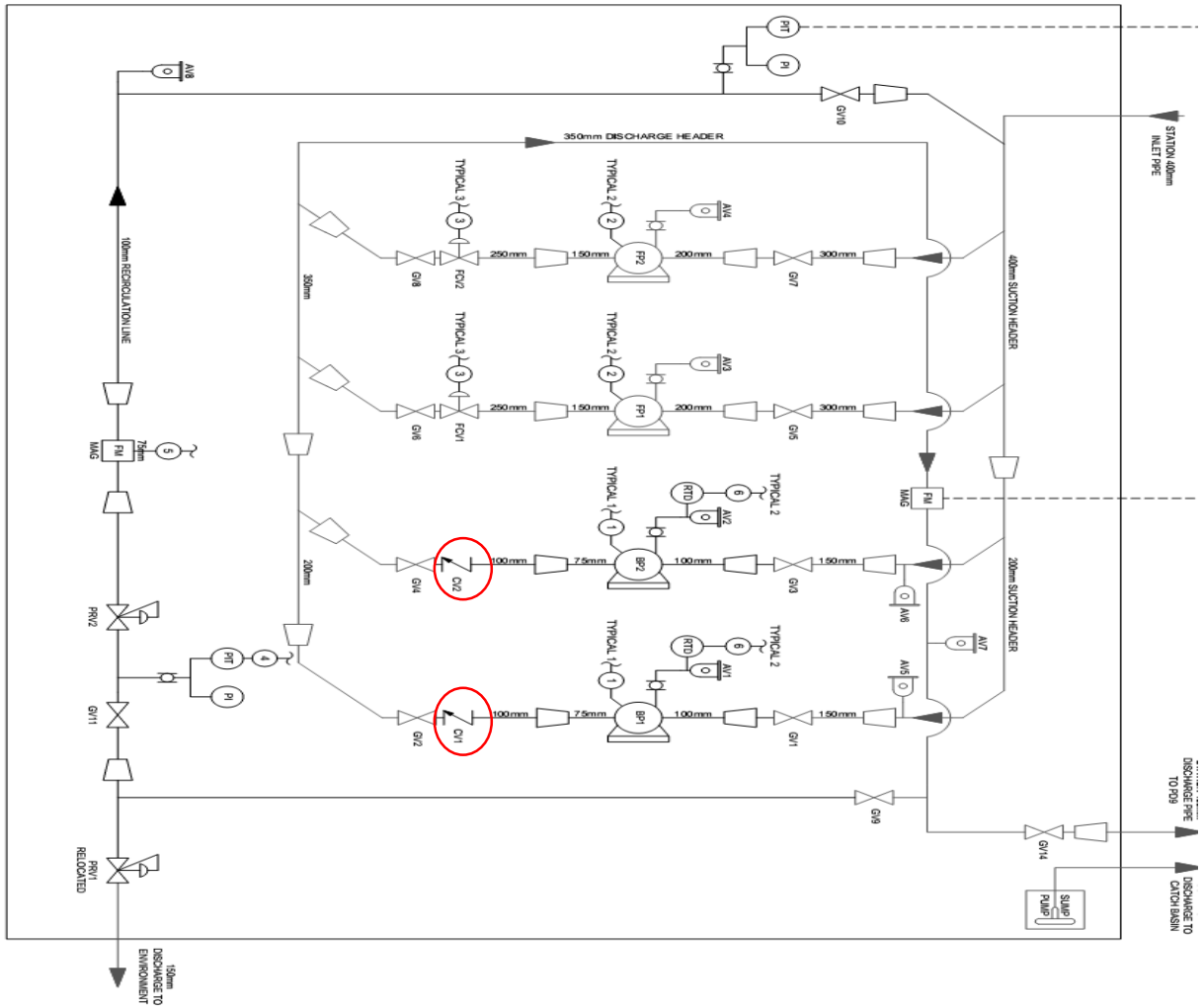
61. Per the diagram, how many pump discharge check valves are present?

a. 1
b. 2
c. 3
d. 4



61. Answer
b. 2

Two check valves are present on the discharge side of the pumps (CV1 & CV2) on pumps BP1 & BP2. The other pumps (FP1 & FP2) have flow control valves.



62. Piping isometrics show _____

a. expected operation for all conditions including startup, shutdown, normal, and maximum
b. design flow rates, piping diameters, valves, and sensors
c. pipe lengths, design flow rates, elevations, fittings, and valves
d. pipe lengths, pipe diameters, elevations, fittings, and valves

62. Answer
d. pipe lengths, pipe diameters, elevations, fittings, and valves

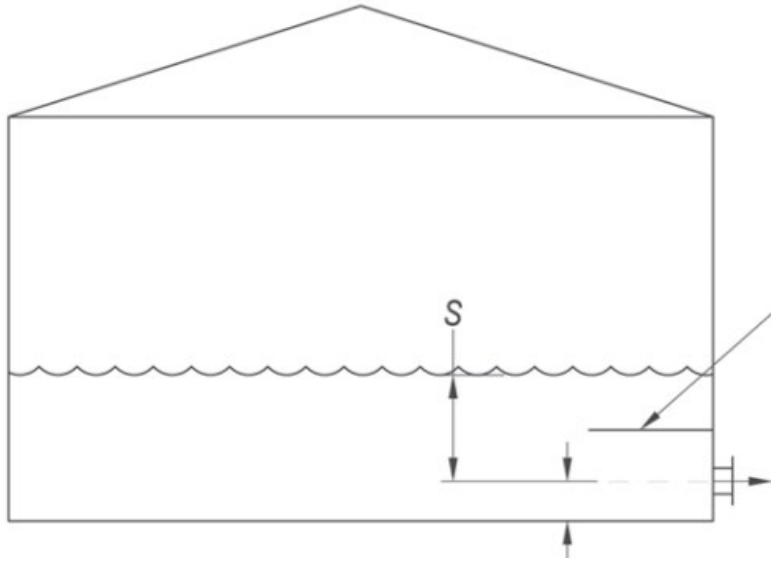
Isometric drawings provide a realistic view of the piping from three sides. Location and direction are provided on the drawing to properly orient equipment and piping in the process. By reviewing the isometric drawing, the assessment professional can determine the actual length of process piping, size of the piping, fittings, and elevation of the piping and the process components. This is very important when developing piping system models to accurately determine process values, such as pressure at specific locations or flow through specific sections of the system. Additionally it is important to review isometric drawings when identifying where to take measurements such as flow rates to ensure flowmeters can be installed properly and that the desired process flow is being measured.

63. Submergence is increased by:

a. increasing the liquid level above the source (suction to pump) tank outlet.
b. increasing the source vessel's (suction to pump) height above the pump suction nozzle.
c. shortening the pump suction pipe length.
d. using a slower speed pump to provide the same flow.

63. Answer
a. increasing the liquid level above the source (suction to pump) tank outlet.

Submergence is the height liquid level over the suction bell or pipe inlet. In this question it is referend to the pipe inlet that is exiting the suction tank. A minimum submergence is needed to limit vortices drawing air into the suction line and to provide minimum NPSHA. The only option in the question that that increased the level above the tank outlet, is option a. The other options would improve the suction pressure or NPSHA, but none would increase submergence.



64. A centrifugal pump draws flow from an open tank and discharges to a second (receiver) open tank located at an elevation 25 feet above the first tank. The pump operates on a variable frequency drive to maintain the level in the suction side tank, the total head of the system can be reduced by:

a. increasing the liquid level in the source tank
b. moving the pump closer to the receiving tank
c. increasing the liquid level in the receiving tank
d. Raising the speed of the pump

64. Answer
a. Increasing the liquid level in the source tank

Reducing the total head requires reducing the static or friction head within the system. Think about it from the perspective of the pump. Of the options given, moving the pump within system closer to the receiving tank will not change the total head requirements, increasing the receiver tank level will increase the total head, raising the pump speed will increase the flow rate and the total head through additional friction head, but raising the source level will increase the suction head seen by the pump and thus reduce the total head.

65. For a low horsepower and low cost commodity pump with no external support systems that is installed in a non-critical system with redundancy, what type of maintenance strategy would likely result in the lowest life cycle cost

a. Run to failure (Reactive)
b. Predictive
c. Continuous monitoring
d. Preventative, during scheduled outages

65. Answer
a. Run to failure

Reference ANSI/HI 9.6.5

Table 9.6.5.1.3 — Asset reliability management strategies

Reactive	Preventive	Predictive
• Small parts	• Wear	• Random failure
• Noncritical	• Consumable	• Critical
• Redundant	• Failure well understood	• Incorrect maintenance
• Failure unlikely		

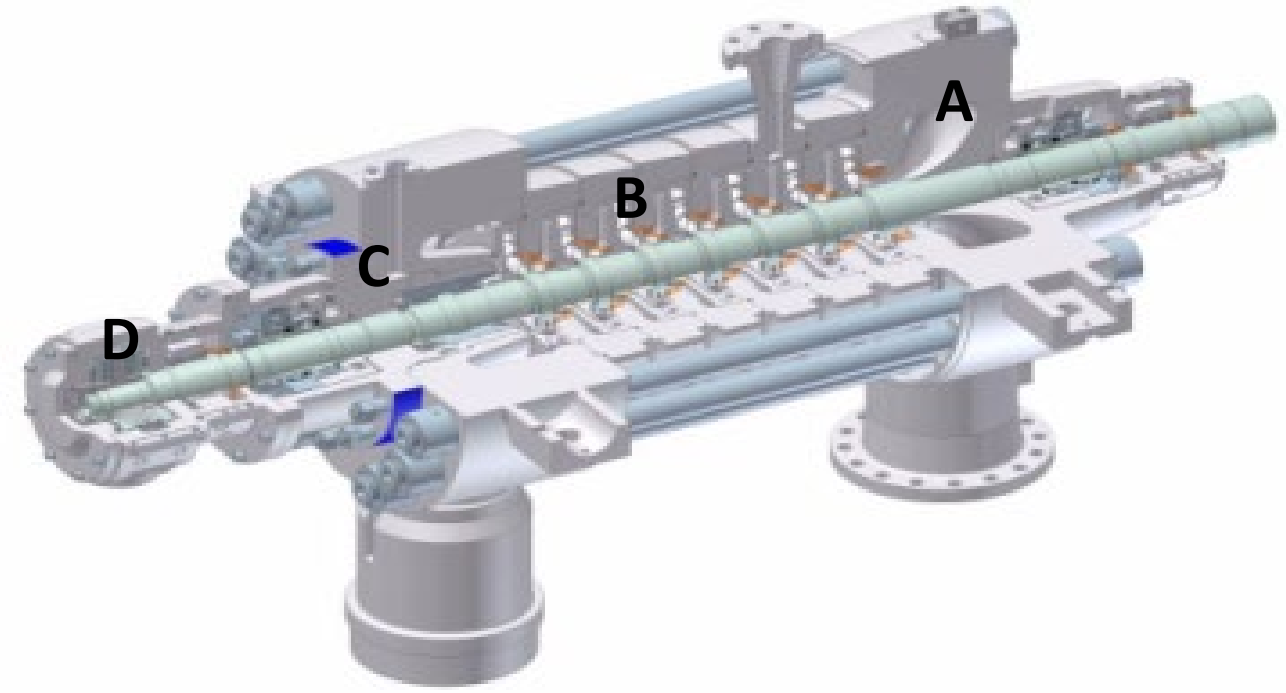
The maintenance strategy applied to an pump should consider its design and requirements for periodic maintenance recommended by the manufacturer, any ancillary systems (i.e. oil bath vs. oil mist), the criticality of the service, if there is any safety concerns, redundancy, availability of replacement parts or units, and the cost to maintain versus replace the equipment.

In this question, it is stated that the equipment is low cost, has redundancy, has not external systems, and it is in a non-critical system. For these reason it is likely that doing predictive or preventative maintenance would cost more than replacing the pump if it fails unexpectedly; therefore, run to failure is the best maintenance strategy.

The last option of doing preventative maintenance during outages is a good consideration, and if there is periodic maintenance that is recommended by the manufacturer this would be appropriate. If this was a facility that had scheduled outages to do maintenance; they would likely want to focus their attention on critical systems and not non-critical systems.

66. In the multistage pump shown, what labeled position has the highest shaft torque?

a. Before the first stage impelle
b. At the shaft midpoint
c. Following the final stage
d. At the thrust bearing



66. Answer
a. Before the first stage impeller

The torque requirement increases with every impeller that is added. In this example point A is between first stage impeller and coupling, and there are seven impeller stages to the left of point A. Each impeller stage to the left of point A adds to the torque required at point A, which must be handled by the coupling and driver. For this reason the shaft will be the thickest at point A and possibly be thinner toward the thrust bearing end (point D).