Section 1

An Introduction to Centrifugal Pumps
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WHAT IS PROGRAMMED LEARNING?

1. In programmed learning, information is broken down into small steps called **frames**. Each frame asks you to make some kind of written answer.

   A blank space indicates you are to write in a simple one word _______________________

2. After you have filled in the blank, compare your answer with the answers on page. Do not look at the answer until you have filled in the_________________________.

3. The frame may ask for something you already know.
   For example:
   In winter, antifreeze is added to the ___________ in a car's radiator.

4. The frame may ask you to interpret a statement.
   For example:
   Alcohol lowers the freezing point of water. To keep water from freezing in cold weather, may be _______________ added to the water.

5. The frame may ask you to circle the best answer out of two given to you. For example:
   Alcohol (can/cannot) be used in a car radiator as an antifreeze.

6. The frame may ask you to interpret a drawing.
   For example:
   
   ![Diagram of Closed and Open Thermostats]

   Circulation of water through the car's radiator is controlled by the_____________________.

7. All programs, whether they are about cars, chemistry, or literature are designed to help you learn.
   In a program, what you ________________ is most important.

8. The program is also designed so you can go through it at your own speed; not at the author's speed.
   I should do this program as fast as (they think/I think).

9. A program is not a test. A test tries to find out what you have already learned.
   A test doesn't try to ______________ you any new material.

10. Usually, you must finish a test in the amount of time given by (yourself/the tester).

11. Although a program may look like a test, a program is not a _______________

Now go on to Page 2 and begin.
SECTION 1

AN INTRODUCTION TO CENTRIFUGAL PUMPS

Exhibits 1, 2, and 3 are placed in the center of the book so that they may be removed easily for reference. Please remove the m now so that you will have them available when needed.

1. The force of gravity causes a liquid to flow from one elevation to a (higher/lower) elevation.
2. Potential energy is stored energy. Liquid at higher pressure has more potential energy than liquids at lower pressure. Thus, liquid flows from pressure areas to ______________ pressure areas.
3. Liquid at higher elevations has (more/less) potential energy than liquid at lower elevations.
4. In the drawings below, indicate the direction of flow with arrows.
5. Within a system, liquids flow because there is a pressure difference in the system.

There (is/is not) a pressure difference in this system.

Since both tanks have the same pressure, the liquid (flows/does not flow).

6. Look at this system.
7. A pump is a machine that adds ___________ to a liquid.
8. A pump moves a liquid by mechanical means.

By installing a pump in the piping between tank A and tank B, liquid can be moved from a ___________ elevation to a ______________ elevation.
9. Look at the drawing.

This pump is moving liquid from a ______________ pressure area to a ______________ pressure area.

10. Pumps are also used to move more liquid in a given amount of time.

11. In moving a liquid from a lower elevation to a higher elevation, the pump adds energy to the liquid at low elevation to provide the ______________ needed to lift it to the higher elevation.

12. Pumps are used to:

   move liquids from __________ elevations to __________ elevations;
   move liquids from __________ pressure areas to areas of __________ pressure;
   increase the __________ rate of a liquid.

13. Pumping adds energy to a liquid. The energy of a liquid may be _________ by pumping it.

14. Centrifugal force is the force of spinning.

When an object such as a liquid in a bucket is spun around in a circle, it pushes (outward from/inward toward) the center of the circle.

15. One way to increase the energy of a liquid is to whirl the liquid around in circles.

When a liquid is spun around like in a clothes washer, it pushes (inward to the center/outward from the center) of the circle.

16. This outward force is called __________ force.
17. This is how a centrifugal pump works. Liquid first comes in at the center.

   It is then forced ______________ from the center.

18. Pressure at the pump outlet is greater than pressure at the inlet.

   Liquid leaving the pump has (more/less) energy than liquid entering the pump.

19. The pump part that spins the liquid is called the impeller.

   Liquid flows through the pump inlet and into the ____________(center) of the impeller.

20. The impeller whirls the liquid around in a circle.

   The liquid is forced from the center to the _______________ of the impeller.

21. The faster the impeller turns, the _______________ the liquid moves.

22. The impeller is made up of guide vanes. The liquid’s path is directed by these ________.

23. Centrifugal force pushes the liquid outward from the eye.

   It enters the _______________ when it leaves the outer edge of the impeller.

24. When the liquid enters the casing, its speed (increases/ decreases).

25. Look at the impeller in this pump illustration.

   As the speed of the liquid decreases, its pressure__________________.

26. As centrifugal force moves the liquid away from the eye, a low-pressure area is formed (in the eye/ at the rim).

27. The low-pressure area in the eye causes liquid to flow into the _______________.

28. In the centrifugal pump, liquid is moved by centrifugal force from a ______________ pressure area at the eye to a _______________ pressure area at the pump’s discharge.

29. The impeller.

   Energy is added to the liquid as it moves through the rotating vanes of the _______________.

30. The rotating _______________ of the impeller move the liquid in a circular path.

31. The impeller is housed in the _______________.

32. Liquid enters the pump through the pump inlet, or suction.

   It comes into the center of the impeller through the impeller _______________.

33. When the liquid has moved to the outer rim of the impeller, it enters the casing and moves from the impeller to the _______________ nozzle.
34. As the liquid leaves the impeller, its velocity decreases.
   Velocity is partially converted to pressure in the casing.
   The liquid's velocity decreases, and part of this velocity shows up as an increase in ____________.

35. The impeller is rotated by an outside power source (pump driver, or prime mover) connected to the pump ____________.

36. The rotating shaft ____________ the impeller.

37. The parts of the pump fit together closely.
   A pump is apt to leak where the shaft passes into the pump ____________.

38. Find the boxing pack.
   Where the shaft passes into the casing, packing provides a seal to reduce ____________.

39. The packing box may be filled with a flexible packing material.
   This packing material presses around the ____________.

40. A mechanical seal may be used instead of flexible ____________.

41. Where the packing rubs against the shaft, the shaft may ____________ excessively.

42. In most centrifugal pump, part of the shaft is protected by a removable sleeve.
   Find the shaft sleeve.
   The shaft sleeve can be ____________ more easily and less expensively than the whole shaft.

43. Liquid leaks from the high-pressure area (discharge) back into the suction area.
   Find the wear rings.
   The space between the eye (suction section) and the casing (discharge section) is fitted with ____________ ____________.

44. The casing wear ring is stationary, and the impeller wear ring rotates with the ____________.

45. The close fit between the stationary wear ring and the rotating wear ring (increases/decreases) the amount of high-pressure liquid leaking back into the inlet stream.

46. Some leakage is necessary for lubrication.
   Liquid leaking between the wear rings acts as a lubricant and coolant, and keeps the rings from ____________-against each other.

47. Worn wear rings are removed and replaced more easily and less ____________ than a casing or an impeller.

48. As the rings become worn, clearance between them (increases/decreases), and more liquid flows from the discharge back into the suction.

49. The wear rings are lubricated and cooled by the ____________ being pumped.

50. Without proper lubrication, the wear rings can come into ____________ with each other, get hot, and seize.

51. For this reason, a centrifugal pump is never started unless it is filled with ____________.

HOW PUMPS ARE RATED

52. Pumps are rated partly according to their pumping characteristics.
   For example, a certain pump delivers 100 gallons per minute (GPM).
   This pump has a rated capacity of ____________ GPM.

53. Capacity is usually a factor in ____________ a pump.

54. Suction and discharge pressure also affect the rating of a pump.
   For example, a pump produces a discharge pressure of 30 PSIG.
   It has a rated discharge pressure of ____________ psiG.

55. Pumps are rated according to the things you need to know to operate the pump efficiently.
   Ratings help you select the ____________ pump for your operation.

56. For example, you need to pump out a huge tank quickly.
   If all other conditions are equal, a pump with a capacity of (100 GPM/500 GPM) is preferred.

Capacity

57. The capacity of a pump is the amount of liquid that the pump moves in a given length of time.
   Capacity is usually measured in gallons per minute, abbreviated ____________.
58. Gallons, pounds, and cubic feet are measures of (amount/time).

59. Minutes, hours, and days are measures of ____________.

60. Check the measurements that are measures of both amount and time.
   _______gallons per minute
   _______pound per square inch
   _______cubic feet
   _______barrels per day

61. Pump capacity can be changed by changing the speed of the impeller (RPM, or revolutions per minute).
   Increasing pump speed also (increases/decreases) pump capacity.

62. The pump and its prime mover usually run best within a range of specific speeds.
   To increase the pump speed, you must also increase the speed of the ____________.

63. Increasing pump capacity by increasing pump the RPM (is/is not) always practical.

64. In a centrifugal pump, the liquid moves outward from the ____________ of the impeller toward the rim of the impeller.

65. Liquid travels from the inlet into the eye of the impeller.
   The liquid is forced to move in a circular path by the rotating ____________ of the impeller.

66. Centrifugal force propels the liquid (inward/outward) through the rotating vanes.

67. Because the impeller is rotating, the liquid in the impeller is also ____________.

68. Circumference is the distance around a circle.

69. Look at the drawing.

[Diagram]

IMPELLER

The circumference of impeller ________ is less than the circumference of impeller ________.

70. Because the shafts of both impellers rotate at the same speed, they both travel the same number of revolutions in a given length of time.
   But, liquid traveling around the outer edge of impeller B travels (farther/the same distance).

71. The distance traveled around a circular path in a given length of time is the tangential velocity.
   Any point on the rim of impeller has the greater tangential velocity.

72. As a drop of liquid moves outward from the eye, the circular path it travels continually in size.

73. Because the size of the circular path continually increases, the tangential velocity as the liquid moves outward from the eye.

74. Thus, the larger the diameter of the impeller, the __________ the final tangential velocity for a given RPM.

75. After the high-velocity liquid leaves the rim of the impeller, it enters the casing where its velocity decreases.
   A large part of the velocity is converted to ________.

76. Increasing the tangential velocity increases the pressure at the pump’s discharge.
   Without changing impellers, tangential velocity is increased by (increasing/decreasing) pump speed.

77. Without changing pump speed, liquid can be pumped to higher elevations or higher pressures by ________ the size of the impeller.

78. Pump capacity can be increased by increasing pump ________, or by using a larger ________.
Pressure and Head

79. Pressure is the force acting on a unit of area (usually one square inch).
   When force is measured in pounds, pressure may be stated as ______________ per square inch (PSI).

80. Head is the height of a liquid.

81. The pressure exerted by a head of liquid does not depend on the diameter of the container.

83. This pressure (includes/does not include) the pressure of the atmosphere on the liquid.

84. Atmospheric pressure is ___________ PSIA (pounds per square inch absolute).

85. An instrument that measures atmospheric pressure as well as tank pressure is measuring absolute pressure. This is written as pounds per square inch absolute.
   psiA is an abbreviation for pounds per square inch ______________.

86. A pressure gage records only __________ pressure.

87. Since a gage reads atmospheric pressure as 0, it is measuring gauge pressure.
   psiG is an abbreviation for pounds per square inch ______________.

88. psiA is always a (larger/smaller) number than psiG.

89. Pressure in this tank is 43 psiG.
   Atmospheric pressure is 14.7 psiA.

90. Absolute pressure in the tank is (more/less) than 43 psiA.

91. 43 PSIG and 57.7 psiA are (the same amount/different amounts) of pressure.

92. psiA = psiG + ______________.

93. psiG = psiA - ______________.

94. A gage reads 30 psiG. The absolute pressure in the tank is ___________ psiA.
95. A 10-foot head of water makes a pressure gauge read 4.33 psiG.

A 100-foot head of water makes the gauge read _____ PSIG.

96. By dividing 43.3 ÷ 100 or 4.33 ÷ 10 we can see that, for each foot of water, 0.433 psiG is exerted.

A 1-foot head of water exerts ______________ psiG.

97. A 15-foot head of water exerts 6.49 psiG (15 x 0.433).

We can find out how much pressure a column of water exerts by multiplying the ______________ of the water by 0.433.

98. Because oil weighs less than water, a 10-foot head of oil exerts (more/less) pressure than a 10-foot head of water.

99. A 100-foot head of crude oil and 100-foot head of water produce (the same pressure/different pressures).

100. The specific gravity of a substance is the weight of the substance divided by the weight of the same volume of water. The specific gravity of water is 1.

A liquid with a specific gravity of less than 1 weighs (more/less) than the same volume of water.

101. A 1-foot head of water exerts 0.433 psiG.

A 1-foot head of liquid with a specific gravity of 0.5 exerts ______________ psiG.

102. Water and a liquid with a specific gravity of 0.5 have the same height.

But the liquid with the 0.5 specific gravity exerts _____________ as much pressure as the water does.

Now look at Exhibit 2.

103. Exhibit 2 is a chart for converting head to pressure, or pressure to _____________.

104. To read the chart, you must know the _____________ of the liquid being pumped.

105. Suppose the head of a liquid is 200 feet and the specific gravity is 0.5

Using a straightedge, find the line between 0.5 on the specific gravity scale and 200 feet on the head scale.

The pressure exerted by this liquid is about __________ psiG.

106. Head can be changed to pressure; pressure can also be changed to head.

By reading a gauge at the bottom of a closed tank, you can tell the _____________of the liquid in the tank (if you know what the liquid is).

107. Compare these two tanks of liquid.

There is a greater head of liquid in (tank A/tank B).

108. Look at the pressure gauges to find which of these tanks has the greater head of liquid.

With the same liquid in each tank, (tank A/tank B) has the greater head.
109. These tanks contain liquids of the same specific gravity (SG).

![Image of two tanks with gages A and B]

The pressure reading would be higher on (gage A/ gage B).

110. Head = \text{pressure} \div (\text{SG} \times 0.433) \\
Pressure = \text{head} \times \text{SG} \times 0.433 \\
Head may be expressed in terms of \underline{_______}, and pressure may be expressed in terms of \underline{_______}.

111. Pressure = 30 psiG \\
SG = 0.5 \\
Head = 30 \div (0.5 \times 0.433) = 30 \div 0.216 = \approx 138 \text{ feet} \\
For this liquid to exert 30 psiG, the column must be about \underline{_______} feet high.

112. Head = 10 feet \\
SG = 0.5 \\
Pressure = 10 \times 0.5 \times 0.433 = 5 \times 0.433 = 2.16 psiG \\
This liquid exerts (twice as much/half as much) pressure as the same head of water does.

113. \textit{Suction head} is the sum of the pressure changed to head, plus the velocity changed to head, at the inlet to the pump. \\
\textit{Discharge head} is the sum of the pressure changed to head, plus the velocity changed to head, at the \underline{_______} of the pump.

114. Velocity head is normally very small and is not used in pumping calculations. \\
Suction head, then, is the \underline{_______} at the suction, changed to head.

115. Discharge head is the pressure at the discharge, changed to \underline{__________}.

116. Gages record the pressure at the pump suction and at the pump discharge.

![Diagram of a pump with suction and discharge pressures]

The height of water in the suction tank exerts pressure, which is recorded on the \((P_s/P_d)\) gauge.

117. Since the height of water is higher on the discharge side, the \((P_s/P_d)\) gauge records the higher pressure.

118. The pump adds pressure to the liquid as it passes through the pump. \\
The discharge pressure is actually the suction pressure plus the \underline{_______} that the pump adds.

119. Even without a pump in the line, the liquid rises until it is equal on both sides.

![Diagram of a liquid rising without a pump]

Without pumping, the liquid rises to point \underline{_______}.

120. To move the liquid from point 2 to point 3, a \underline{_______} may be used.

121. The pump provides the \underline{__________} needed to move the liquid above point 2.
122. The pump raises the liquid from the level of the suction tank into the discharge tank.

123. The total head is the discharge head (minus/plus) the suction head.

124. This pump is lifting water.

125. Total head can be estimated by measuring the height of liquid in the suction and discharge tanks and (adding/subtracting) these heads.

126. Or, total head can be calculated by reading the pressures at the pump suction and discharge and converting these pressure measurements to ________________ measurements.

127. This drawing shows a suction-lift system.

128. The distance the liquid must be lifted to the pump is called the suction ______________.

129. The pump must supply enough energy to raise the liquid a distance equal to the suction lift plus the discharge head.

130. The pressure acting on the surface of a liquid is transmitted throughout the liquid.
131. This pressure is 10 psiG. The gauge at the pump suction reads ___________psiG.

Of the 15 psiG on the suction gauge, 10 psiG is due to pressure acting on the surface of the liquid.

132. The remaining 5 psiG is due to the __________ of the liquid in the tank.

133. Look at the drawing.

134. For liquid to flow into the pump, there must be some pressure at the pump suction.

The pump (works/cannot work) if absolute suction pressure is 0 psiA.

135. In a suction-lift system, suction pressure is provided by (the head of liquid/atmospheric pressure).

136. If there is no atmospheric pressure, then there (can/ cannot) be a suction lift.

Vapor Pressure

137. Sometimes, when the absolute suction pressure is not high enough, liquids vaporize or evaporate at the pump suction.

To understand why this happens we must understand what makes liquids ___________.

138. Heat is a form of energy (thermal energy).

Heating a liquid (increases/decreases) its energy.

139. When ice is heated sufficiently, the added energy melts the ice, and the solid ice becomes ____________.

140. If even more heat is added to this water, the liquid water becomes steam, which is a ____________.

141. When the liquid absorbs so much heat that vapors can escape from the liquid surface, the liquid evaporates.

Evaporation occurs when ____________ escapes from the surface of a liquid.

142. Vapors need energy to escape the liquid.

This energy comes from the ____________ in the liquid.

143. Liquids and gases also exert a pressure on everything they touch.

144. In a liquid, the vapors exert a pressure before they escape.

Vapor pressure is the pressure of the vapor that is trapped (above/in) the liquid.
145. Vapor pressure causes the liquid to vaporize, or evaporate.
   The higher the vapor pressure, the (more/less) rapidly the liquid vaporizes.

146. The vapor pressure of a liquid is measured by finding the pressure that the liquid's vapor exerts in a closed container.
   At room temperature, gasoline has a higher vapor pressure than water.
   Therefore, the _________ will evaporate before the __________-will.

147. Heating a liquid (increases/decreases) its vapor pressure.

148. At higher temperatures, the same liquid – for example, water – has a (higher/lower) vapor pressure.

149. At the same temperature, different liquids have (the same/different) vapor pressures.

150. The higher the vapor pressure of a liquid, the (more/less) heat it needs to vaporize.
   There is also a pressure that is exerted on a liquid’s surface by the gases and vapors above the liquid.

151. The pressure on a liquid tends to (cause/prevent) the escape of vapors from the liquid.

152. To keep the liquid at the pump from vaporizing, the absolute suction pressure must be (higher/lower) than the vapor pressure of the liquid at that temperature.

153. If the suction head of a pump is 8 feet, and the vapor pressure of the liquid (changed to equivalent head) is 9 feet, liquid (vaporizes/does not vaporize).

---

Net Positive Suction Head (NPSH)

154. Net positive suction head (NPSH) is the absolute suction head minus the vapor pressure head.
   If suction head is 50 feet and vapor pressure head is 35 feet, NPSH is ______________ feet.

155. Or, NPSHₐ (available) is the absolute pressure at the pump suction, changed to head, (plus/minus) the vapor pressure of the liquid being pumped, changed to ____________

156. NPSHₑ (required) is the minimum head needed at the suction to get the liquid into the impeller without ________________.

157. If NPSHₐ is the same as NPSHₑ, the pump may lose suction.
   If the NPSHₐ available falls below the NPSHₑ, the pump (operates/does not operate) properly.

158. NPSHₐ available must be (more/less) than NPSHₑ.

159. NPSH = (Absolute pressure at pump suction) – (vapor pressure at pump temp) ÷ (SG. x 0.433)
   SG (Specific gravity) = 1.0
   Vapor pressure = 15 psiG
   Suction pressure = 5 psiG
   Absolute suction pressure = 5 + 14.7 = 19.7 psiG
   NPSHₐ = (19.7 – 15) ÷ (1 x 0.433) = about 10.8 feet
   If the NPSHₑ required is 8 feet, the pump (operates/does not operate) properly.

160. NPSHₐ = 7.8 feet
    NPSHₑ = 15 feet
   The pump (operates/does not operate) properly.

Friction

161. Liquid is flowing through this line.
   Pressure must be greater at (A/B).
162. During flow, pressure is being converted to velocity.
   
   As velocity increases during flow, pressure (increases/decreases).
   
   The pressure difference between A and B is called the pressure drop.
   
163. To increase the flow rate, _________ the pressure drop.
   
164. Fluid flowing through a pipe creates friction.
   
   Friction is a (driving force/resisting force) for fluid flow.
   
165. For fluid to flow, the driving force must be (greater/less) than the resisting force.
   
166. Or, the pressure drop must be greater than the amount of ____________.
   
167. As flow rate increases, friction increases.
   
   To overcome this friction, a _________ pressure drop is needed.
   
168. The more resistance the pipe offers to flow, the greater the pressure drop needed to move the liquid.
   
A small pipe offers (more/less) resistance than a larger pipe.
   
169. The pressure drop needed is greater in the (large/small) pipe.
   
170. When the flow rate of liquid into a pump is increased, friction increases.
   
   Increasing the flow rate __________ the available suction pressure.
   
171. A smaller pipe is used on the suction of pump B.
   
   Resistance to flow is greater in pump (A/B).
   
172. The available suction pressure is lower at (A/B).
   
173. This means that NPSH_A may be too (high/low) for the pump to operate properly.
   
174. With increased resistance to flow at the pump suction, liquid may ______________.
   
175. As the flow rate of the liquid increases, the suction pressure decreases, because the friction increases with fluid velocity.
   
   Some pressure is lost in overcoming __________
   
176. A increase in flow rate increases friction and decreases suction pressure.
   
   The NPSH_A (increases/decreases).
   
177. Look at the drawing.
   
   The gauge above the liquid reads ______ psiG.
   
178. The height of the liquid is ____________ feet.
179. Pressure due to the liquid level is:

\[ \text{Pressure} = 0.433 \times 10 \times 0.5 = 2.16 \text{ PSIG.} \]

The gauge at the pump suction should read 30 + 2.16, or ______ psiG.

180. The gauge at the pump suction actually reads 31.16 psiG.

The gauge records a lower pressure because some pressure has been used to overcome _____________.

181. If there is no NPSH\textsubscript{a}, liquid ________ at the eye.

182. \textbf{NPSH} = (Absolute suction pressure – vapor pressure at pump temperature) \div (0.433 \times SG)

Or, when the absolute suction pressure increases, the NPSH\textsubscript{a} ________;
when the suction head increases, the NPSH\textsubscript{a} available ________;
when the suction head decreases, the NPSH\textsubscript{a} ____________.

183. \textbf{Total head} = discharge head – suction head

Or, when the suction head increases, the total head ____________;
when the discharge head increases, the total head ________________.

\textbf{Horsepower}

184. A centrifugal pump is operated by coupling its to the shaft of an outside power source (prime mover, or driver).

185. Brake horsepower (Bhp) is a unit used for measuring \textit{rate of work}.

The Bhp horsepower necessary to overcome friction and other losses and to move the liquid is provided by the ________________.

186. The amount of useful work that a pump delivers is the difference between the pressure the liquid has as it enters the pump and the pressure it has as it ____________ the pump.

187. Part of the Bhp input into the pump is used to overcome friction and other losses; part goes to increase the pressure of the liquid being pumped.

The Bhp applied directly to the liquid is called fluid ________________.

188. The Bhp input is always (more/less) than the fluid horsepower, or horsepower output.

The overall efficiency of a pump is the percentage of the Bhp input that is transferred to the liquid leaving the pump.

189. A pump that operates at 100 Bhp input and 75 fluid Bhp has an overall ____________ of 75%.

190. The overall efficiency of a pump is found by dividing the Bhp output of the pump by the Bhp input, or

\[ \text{Bhp output} \div \text{Bhp input} \]

If the Bhp input is 5 and the fluid Bhp is 4, then the efficiency of the pump is ________%.

191. If two pumps have the same capacity, a low-efficiency pump requires (more/less) horsepower than a high-efficiency pump to move the same amount of liquid at the same pressure and rate of flow.

192. The volumetric efficiency of a pump is a measure of its internal leakage.

The main source of internal leakage is the liquid flowing back between the wear rings from the discharge into the __________ of the pump.

193. Volumetric efficiency is found by dividing the amount of liquid pumped by the amount of liquid pumped plus internal leakage:

\[ \text{amount pumped} \div (\text{amount pumped} + \text{internal leakage}) \]

In a pump discharging 45 US GPM, 5 US GPM leaks between the wear rings. The volumetric efficiency is __________%.

194. As the wear rings become worn, the volumetric efficiency decreases and the overall efficiency ____________.

\textbf{Performance Curves}

For Questions numbers 195 through 221 look at Exhibit 3, which shows a sample set of performance curves for a centrifugal pump.

195. In the exhibit there are four curves which show the relationship of capacity to:

______________ head;

________________;

________________; and

________________.

\[ \]
196. The graph in the exhibit is set up so that capacity is read at the bottom.
Efficiency, horsepower, and total head are read at the (left side/ right side) of the graph.

197. NPSH$_r$ is read at the ________________ side.

198. Find the line on the graph for 200 US GPM.
This line crosses the NPSH$_r$ curve at about ______ on the NPSH$_r$ scale.

199. If the pump is pumping 200 US GPM, the minimum NPSH$_r$ for this pump is about _______________feet.

200. Find where the 200 US GPM line crosses the efficiency curve.
From the efficiency scale on the left, you can read that this pump pumps 200 US GPM at about ______% efficiency.

201. The 200 US GPM line and the BHp curve show that the horsepower required for this pump at 200 US GPM is about ________________.

202. Look at the efficiency curve.
Maximum efficiency on this curve is about ______%.

203. At maximum efficiency, this pump is pumping ________ US GPM.

204. Find the other performance values at 400 US GPM.
The BHp required is about ________________.
The total head is about ______________feet.
NPSH$_r$ is _______________ feet.

205. This pump is more efficient when it is pumping (200/300) US GPM.

206. These pump performance curves were made up for a pump moving water with 1.0 SG.
For more viscous (thicker) liquids like oil, which resist flow more than water does, the curves should be
adjusted for (higher/lower) values

207. All centrifugal pumps come with a set of performance curves.
These curves can be used to find the NPSH$_r$, total _________, efficiency, and ___________ for each pump at different capacities.

208. The performance curves can also show some general principles of centrifugal pump performance.
For example, look at the relationship between the total head curve and the capacity line.
When the total head decreases, the pump capacity ________, except at very low capacity.

209. Suppose the discharge valve of a pump is pinched down and the discharge head increases.
The total head increases, and the capacity ________

210. As the level in the tank falls, the suction head decreases.
The total head increases, and the rate of flow __________

211. Look at the NPSH$_r$ curve and the capacity line.
As the pumping rate increases, the NPSH$_r$ ________________.

212. Suppose the pump is operating at a point where the NPSH$_a$ and NPSH$_r$ are about equal and you try to increase the flow rate.
The pump will lose.____________________.

213. Look at the efficiency curve.
The efficiency of a pump is relatively __________at high and low flow rates.

214. For every pump, there is a capacity where the pump operation is most _______________ and therefore most economical.

215. Look at the BHp curve.
As the flow rate increases, the BHp required ________________.

216. Other factors affecting the performance of a centrifugal pump are not shown on the chart.
For example, a viscous (thick) liquid resists flow and is (easier/harder) to pump.

217. If the liquid being pumped becomes more viscous (for a given total head), the pump capacity is less.
The BHp required to a pump a viscous liquid is ________________.

218. Impellers of different sizes can be installed in a pump.
An impeller of ______________diameter can pump to a higher head.
219. To pump at a higher rate to a higher head requires more horsepower.

When the size of the impeller is changed, neither the suction casing nor the size of the impeller eye is changed. As the rate increases, the NPSH$_r$ __________

220. The speed of turbine-driven pumps can be controlled. Increasing the speed has the same effect as installing an impeller of larger diameter in a motor-driven pump.

Decreasing speed has the effect of installing an impeller of _______________ diameter in a motor-driven pump.

221. If the specific gravity of a material being pumped changes, the horsepower required changes.

The capacity and head characteristics of a pump do not change when the ___________ of the material being pumped changes, but the horsepower required does change.
Section 2

*Design and Construction Of Centrifugal Pumps*
SECTION 2

DESIGN AND CONSTRUCTION OF
CENTRIFUGAL PUMPS

PUMP TYPES

1. Pumps are classified according to impeller design and the number of impellers.
   A multistage pump has more than ______________ impeller.

2. A two-stage pump has ____________________ impellers.

3. A two-stage pump has the same effect as joining ___________________ single-stage pump in series.

4. The first pump discharges into the ______________ pump.

5. A multistage pump has two or more impellers mounted on one ________________.
   The head at the discharge of the second impeller is greater than the head at the discharge of the first.

6. The greater the number of impellers, the (higher/lower) the final discharge head is.

7. Since liquids are nearly incompressible, all the impellers in the pump are designed for about the same capacity.
   The impellers of a multistage pump are all about the _______________ size.

8. Pumps are also classified as single-suction or double-suction.
   In a single-suction pump, liquid enters from (one side/both sides) of the impeller.

9. In a double-suction pump, liquid enters through (one side/both sides) of the impeller.

10. Since liquid enters at both sides of the impeller, a double-suction pump is used for (high/low) capacity operations.

11. Double-suction pumps have lower NPSH requirements.
    When the NPSH available is low, a _______________-suction pump is probably better suited for the pumping job.

12. Impellers may be open, partially open, or enclosed.

13. On an open impeller, the sides of the vanes (are/are not) covered.

14. More liquid leaves the rim of the (open/partially open/enclosed) impeller.

15. Flow at least controlled in the ________ impeller.

16. The ________________ impeller is the least likely to be-come clogged.

Propeller Pumps

17. A propeller pump works very much like an impeller pump.

   Instead of an impeller, the _______________ whips the liquid passing through it to high speed.
18. In this way the propeller adds __________ to the liquid.

19. There are differences between impellers and propellers.

For example, liquid leaves the (propeller/impeller) in the same direction as it entered.

20. Liquid leaves the (impeller/propeller) at right angles to the way it entered.

21. Liquid enters the impeller only through the eye in the (impeller /propeller) pump.

22. In the propeller pump, liquid enters the pump (through the eye/through the blades)

23. The area through which liquid enters the pump is smaller in the (impeller/propeller) pump.

24. Therefore, the __________ pump can handle larger capacities.

25. The best features of the impeller pump and the propeller pump are combined in the turbine pump.

The turbine pump is a mixture of the pump an the __________ pump.

26. The flow of liquid through a turbine pump is

_________ like the flow through a centrifugal pump.

_________ like the flow through a propeller pump.

_________ halfway between the flow through a centrifugal and the flow through a propeller pump.

27. The turbine pump, like a propeller or an impeller pump, can be single or multistage.

The multistage pump is used when you need a higher discharge (capacity/head).
28. Name the following pump designs.

A. ____________________

B. ________________

C. ____________________

D. ________________

E ____________________

Which of these pumps are not centrifugal pumps?(A/B/C/D/E)

Vertical and Horizontal Pumps

30. This pump must move liquid up out of a water well, or pit, or any other source of liquid.

There (is/is no) suction head available.

There (is/is no) suction head available.

31. The pressure needed to move liquid into the pump suction must come from ________________ pressure.

32. If the well is deep, atmospheric pressure (can/cannot) push the liquid all the way up into the pump suction.

33. One way to increase the NPSH available is to (increase/ decrease) the distance liquid has to move up to get to the pump suction.

34. Here the pump has been placed in the well liquid.

This gives the pump (more/less) NPSH available.
35. Since the well is deep and narrow, the pump must be put in it (horizontally/vertically).

36. To provide better NPSH, the pump is installed (horizontally/vertically) and (above/below) the level of the liquid.

Because of the large amount of discharge head needed to lift liquid from a well, the turbine vertical pump is generally (single-/multi-) stage.

**Pumps Operating in Series or in Parallel**

37. When the discharge of one pump is fed into the suction of another pump, the two pumps operate in *series*.

38. When the pumps are connected in series, the second pump takes liquid from the first and increases the discharge head.

Installing pumps in series increases the discharge ____________ of the system.

39. The second pump cannot discharge more liquid than it receives from the first.

Thus, pumps in series (should/should not) have about the same capacities.

40. Pumps that discharge into the same line are operating in *parallel*.

Pumps (A/B) are operating in parallel.

41. Operating pumps in parallel __________ the capacity of the system.

42. With pumps operating in parallel, the total amount discharged equals the amount discharged from the first pump __________ the amount discharged from the second.

43. Since liquid discharged from the first pump does not enter the second, the discharge head produced by the two together is (greater than/the same as) the head produced by each one separately.

44. Pumps operated in parallel should have about the __________ total head characteristics.

45. Pumps are operated in parallel to increase ________.

46. Pumps are operated in series to increase ________________.

47. Two pumps with similar capacity and head characteristics at a given speed may be connected in either ________________ or ________________.

48. To increase capacity, connect pumps in ________________.

49. To increase head, connect pumps in ________________.

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Regulating Pump Discharge

50. The amount of liquid discharged from a Pump can be changed in a variety of ways.

A ____________ on the discharge can be open or closed.

51. By partially closing the valve, more ____________ is needed to get liquid out of the pump.

52. Partially closing the valve (increases/decreases) the discharge volume.

53. Here is another way to regulate the discharge volume.

A ____________ line is connected to the discharge line.

54. An open ____________ is the bypass line allows liquid to flow through the bypass line as well as through the discharge line.

55. When this valve is opened, some of the liquid from the ____________ flows into the bypass.

56. Then it flows back to the pump’s ________________.

57. This means that (more/less) liquid is actually discharged form the pump into the discharge line.

58. Being able to adjust the pump discharge is important when the pump may be moved and used for a ________________ operation.

MECHANICAL DETAILS

Packing Box

59. The rotating shaft of a centrifugal pump extends out through the casing so that the impeller may be coupled to the ________________.

59. The drawing shows a typical packing box.

60. The packing is formed around the ____________ to minimize leakage of liquid from the pump.

61. The packing box surrounds the shaft where it enters the ________________. 
62. Normally, the packing is formed into rings which conform to the shape of the ________________.

63. Packing must be a low-friction material which is non-abrasive. Abrasive material damages the ________________.

64. To minimize leakage along the shaft, the packing is ________________ against the shaft.

65. If the shaft is permitted to rub directly against the packing, the section of shaft in the packing box ________________.

66. To keep from replacing the whole shaft due to packing wear, a ________________ is used to cover the section of shaft inside the packing box.

67. Packing must be a material that is not attacked and weakened by the liquid being pumped.

   Packing which is weakened by the liquid permits some of the liquid being pumped to ________________ to the atmosphere.

68. Packing is chosen for the ________________ being pumped and its temperature.

69. A packing gland at the (inner/outer) end of the packing box holds the packing in place.

   The pressure necessary to compress the ________________ against the shaft sleeve and control leakage is supplied by the packing gland nuts.

70. A small amount of leakage between the packing and the shaft is necessary for ________________.

71. The amount of ________________ is usually determined by company practices.

72. The packing gland holds the ________________ in place and controls the amount of ________________.

73. If the nut is tightened too much, the rubbing surfaces may not be sufficiently ________________, and there may be excessive wear on the ________________ and the ________________.

74. Since insufficient lubrication may cause overheating, packing gland nuts must be ________________ to allow the amount of leakage specified by company practices.

75. Look at the drawing.

   The lantern ring is a metal cage about the size of a packing ring that fits around the ________________ sleeve inside the packing box.

76. The lantern ring provides a space between the packing rings near the center of the packing box which can be supplied with lubricating or seal ________________.

77. The lantern-ring arrangement shown differs from ring packing in the way it is ________________.

78. The lubricating fluid can be liquid from the pump or liquid from outside the pump.

   When a corrosive or erosive liquid is being pumped, lantern-ring lubrication from (another source/the pump) is used.

79. Lubricating fluid is pumped into the packing box under pressure higher than the pressure inside the casing.

   This pressure keeps the liquid in the pump from entering the ________________.

80. Lantern-ring packing is also used in a pump operating at less than atmospheric pressure. When the pump operates under vacuum, air may be pulled into it during operation.

   To keep air out, the pressure of the sealing-lubricating fluid must be (above/below) the pressure of the atmosphere.
81. In a pump operating under vacuum, the lubricating liquid is usually the liquid being pumped, if that liquid is non-corrosive.

   It is pumped into the packing box at a pressure above _____________________ pressure.

82. Pump A is pumping a light oil. Pump B is pumping acid.

   (Pump A/Pump B) is fitted with a lantern ring.

83. Liquid leaking from the pump is a hazard, especially if it vaporizes at a low temperature. Leakage can also be expensive.

   Therefore, pump packing should be ____________ frequently to make sure it is operating properly.

**Mechanical Seals**

84. Mechanical seals may be used in the packing box. A mechanical seal has two antifriction surfaces. One element is held stationary by the seal flange.

   The other element rotates with the ___________________.

85. The stationary seal ring is usually made of ___________________.

86. The rotating seal ring is faced with special metal where it comes in contact with the ___________________ seal ring.

87. The spring holder is held in place on the shaft by a set screw.

   The compression ring and the rotating seal ring are free to move along the ____________.

88. The springs push against the compression ring and compress the flexible O-ring against the shaft and the rotating seal members to prevent at this point.

89. The O-ring is made of rubber or some other flexible material, depending on the liquid being pumped. It makes a tight ____________ between the rotating elements and the shaft.

90. Heat is generated between the stationary and rotating faces.

   Oil is circulated in the packing box to cool and ________________ the seal.

91. The lubricant also helps to keep corrosive or ________________ material out of the seal.

92. A single seal has one set of sealing faces. This seal has two sets of sealing faces.

It is a ___________________ seal.
Impeller Thrust

93. During operation, pressure in the discharge portion of the casing is greater than the pressure in the suction portion.

94. The discharge pressure acting on the right side of the impeller exerts a force to the left.

The suction pressure and the discharge pressure acting on the left side of the impeller exerts a force to the ____________.

95. Since the suction pressure is less than the discharge pressure, the total force acting to the left is _______ than the force acting to the right.

96. This imbalance of forces creates thrust along the shaft.

To overcome this thrust and hold the ____________ in its proper position, a thrust bearing is used.

97. Both sides of the impeller maintain close clearance with the casing.

98. A collar at the back of the impeller has the same inside dimension as the suction eye.

Wear rings between the collar and the casing minimize _______________ into the collar.

99. Any leakage into the collar flows back into the suction through a hole in the impeller.

This hole equalizes pressure between the left and right sides of the ________________.

100. Since the ________________ on both sides of the impeller is about equal, there is almost no thrust.

101. In multistage pumps, several methods can be used to minimize thrust.

Some pumps are constructed so that some of the impellers face one way on the shaft and the others face the other way. One set of impellers offsets the _______________of the others.

Balancing Drum

102. When all impellers are installed in the same direction on the shaft, thrust may be reduced with a balancing drum.

The thrust created by each impeller acts to the left/right.
103. The total impeller thrust is the sum of the thrust of all the impellers.

The pressure acting on the left side of the balancing drum is the pump __________ pressure.

104. The space on the right side of the balancing drum is open to the suction.

This space is at ________________ pressure.

105. The pressure difference across the balancing drum creates a force acting to the right.

The drum is sized so that this force balances the impeller ________________-

106. The small clearance between the balancing drum and the casing minimizes leakage from the discharge back to the suction.

As wear increases, this clearance increases, and the volumetric efficiency of the pump ________________.

ALIGNMENT AND VIBRATION

107. The pump and prime mover are joined by couplings.

The pump and ________________ must be properly aligned.

108. If the pump is handling hot liquid, then the pump should be heated to near operating ______________ to check alignment.

109. Improper alignment of the pump and prime mover puts a strain on the shaft and may wear or break the shaft or couplings.

Improper alignment may also cause bearings and seals to ________________ excessively or fail.

110. Improper alignment may also damage wear rings, and permit the impeller to ________________ against other parts.

111. Any improperly balanced rotating assembly may cause excessive vibration.

Misalignment of pump and prime mover or partially blocked impellers may also cause ________________.

112. Cavitation in the impeller is the continual forming and collapsing of vapor bubbles in the liquid.

Cavitation may cause the pump to ________________.

113. Sometimes vibration can be heard, or detected by ________________ the pump.

114. Many pumps are equipped with gauges and meters which ________________ vibration.

115. Excessive vibration is a sign that something is wrong with the pump. If unusual noise or vibration occurs, the pump must be ________________ as soon as possible.

LUBRICATION

Wear Rings

116. Wear rings simplify maintenance by protecting the casing and the ________________

117. Wear rings are lubricated only by the ________________ being pumped.

118. Wear rings are not properly lubricated if the liquid in the pump vaporizes or if the pump runs ________________.

The Packing Box

119. Packing must always be lubricated. Normally, ring packing is lubricated by the ________________ being pumped.

The lantern ring and packing are lubricated by an oil pumped to the ring, especially if the pump is handling ________________ or erosive liquid.

121. Some packing boxes are lubricated by grease cups instead of ________________.

Bearings and Couplings

122. The pump shaft must rotate with the least friction possible.

Resistance to the rotation of the shaft must be as ________________ as possible.

123. The impeller must be kept in position while it rotates. It must be free to rotate, but not to ________________ in other directions.
124. Besides rotating, the shaft may tend to move in two other ways.

In most pumps, more of the area of the impeller is exposed to discharge pressure than to suction pressure.

This unbalanced pressure causes a __________ to be exerted in an axial direction.

125. Movement can also occur if the pump has a long, un-supported shaft, or if the impeller is out of balance.

This is (axial/radial) movement.

126. Both radial and axial movement must be ______________ if the impeller is to remain in position.

127. Bearing support the shaft and allow it to rotate with very little friction.

Bearings also control __________ and __________ movement of the shaft.

128. The bearing lubricant provides a fluid film between the rotating shaft and the bearing.

This fluid film prevents the shaft and its stationary supports from __________ against each other.

129. A radial (journal) bearing on which the shaft rests controls ______________ movements.

130. A thrust bearing limits end-to-end movement of the shaft.

A thrust bearing limits the amount of (axial/radial) movement.

131. Some pumps use ball bearings to control both radial and thrust movement.

The shaft of this pump is supported by both __________ and ball bearings.

132. Ball bearings are lubricated so that there is almost no __________ between the ball and any of the other parts it touches.

133. The ball bearings __________ - freely as the shaft rotates.

134. Ball bearings may be grease-or oil-lubricated.

Where the load on the bearing is great and considerable heat is generated, oil is used as the lubricant because it also __________ the shaft and bearing.

135. Grease-packed bearings can be over greased.

Over greasing causes the bearing to __________.

136. Slinger rings are also used to move lubricating oil from the reservoir to the bearing.

A slinger ring fixed to the shaft and rotating with it throws oil from the reservoir on the __________.
137. Large pumps use heavy-duty sleeve bearings instead of ball bearings.

A sleeve bearing has (more/less) surface area than a ball bearing does.

138. A sleeve bearing can support a very __________.

139. Sleeve bearings control (radial/axial) movement.

140. The bearing is made of low-friction metal (babbit) and is lubricated by a film of ____________.

141. The oil is supplied to the bearing under pressure through grooves on the bearing surface.

   The high-pressure oil insures that the shaft (can/cannot) squeeze the film of oil out of the bearing under heavy load.

142. The shaft rotates on a film of ____________, and there is no direct contact between the shaft and bearing.

143. Oil can be supplied to a sleeve bearing either by an oil ring or under pressure by a lube-oil pump.

144. The ring rotating on the ____________ picks up oil from the reservoir and carries it up to the bearing.

145. In a pressurized oil system, oil is pumped to each ________________.

146. Lube-oil pumps are used when the load on the bearings is great.

   Where possible, the pressure lube-oil system should be working before the pump is started so that there is an oil film between the shaft and the ________________.

147. Pumps with a large axial load use a babbitt-faced (anti-friction) thrust bearing.

   The thrust collar rotates as part of the ____________.

148. The stationary thrust shoes restrict axial movement of the shaft.

   The shoes are pivoted to absorb minor variations in the rotation of the thrust ________________.

149. Oil may be pumped to the bearing, or the bearing may run in oil to maintain a lubrication ________________ between the surfaces.

150. The temperature of the lubricating oil must be maintained within the operating range.

   If the temperature rises too high, bearings may ________________ and fail.

151. Many pump couplings are lubricated with heavy oil or grease.

   Before the pump is started and during operation, the couplings should be checked for lubrication and ________________.
152. The operating manual or the supervisor specifies the ___________ and amount of oil to be used for lubricating the coupling.

153. Oil must be free of dirt and water.
   Water breaks down the film between the shaft and bearing, and _______________ is abrasive.

**PUMP COOLING**

154. Pumps performing heavy-duty service and pumps moving hot liquids may be water-jacketed.
   Pump parts subjected to ____________ temperatures are surrounded with water jackets.

155. Water is circulated to cool the lubricating oil, packing, and other parts where ____________ temperatures may develop.

156. Friction between the shaft and packing creates heat.
   Sometimes the heat generated in the packing box area is too great to be carried away by the or the lubricant.

157. To keep the shaft and packing from overheating, they are fitted with ________________.

158. Look at the drawing.

The cooling water circulates in the ______________ surrounding the packing box.

159. When the bearing lubricant must be cooled, the bearing and reservoirs may be surrounded with ______________.

160. Where the heat generated is too great to be carried away by water-jacketed reservoirs, the lube oil is pumped through a shell-and-tube cooler and then to the ________________.

161. If not much heat is generated by the pump, heat is lost directly to the _______________ through the reservoir housing.

162. High temperature pumps usually have water-jacketed bases (pedestals).
   The more heat the pump has to handle, the more thoroughly it is ________________.
Section 3

Operation
SECTION 3
OPERATION

STARTUP

1. Pump-lubricating mechanisms must be checked to assure that they will deliver a ___________ supply of clean and dry lubricant all the time that the pump is in service.

2. If bearings take grease instead of oil, grease fittings must be routinely greased and grease cups must be filled.
   Do not __________________ the bearings.

3. The temperature of pumping equipment may be increased either by the liquid being pumped or by friction.
   Parts of the pump which cannot tolerate increased temperatures are provided with __________ systems.

4. If the pump is handling hot liquid, the packing box is usually _______________ to prevent the packing from deteriorating.

5. Surfaces of mechanical seals are cooled.
   If the surfaces get too hot, wear and deterioration (increases/decreases).

6. Bearing housings may be cooled to maintain proper clearance.
   If a bearing overheats, it may expand and freeze to the ____________.

7. Pump pedestals may be cooled to maintain alignment between the pump and the ____________.

8. Before starting the pump, the complete ___________ and ___________ systems should be checked and in good working order.

9. Cooling _____________ must be circulating through all water-cooling systems.

10. A pump that is to handle hot liquid should be warmed before it is started to prevent damage from unequal expansion of parts.
    Unequal expansion may permit contact between the stationary and ______________ parts.

11. The pump should be warmed gradually by slowly circulating hot _____________ through the pump.

12. A spare pump in hot service is usually kept warm be using a small circulating line from the ______________ of the operating pump.

13. Steam tracer lines may be run alongside lines to and from the pump to keep liquid within the proper viscosity range so that it flows freely.
    Steam tracer lines should be operating (before/after) the pump is started.

14. After the prime mover has been checked for proper lubrication and is ready to operate, if the pump shaft is accessible, it should be turned by hand to see that it is free to ________________.

15. When a newly installed or reconditioned prime mover is returned to service, the direction of its shaft rotation should be checked before it is ________________ to the pump.

16. All valves that control the flow of liquid into and out of the pump should be set according to instructions
    If the valves are not set properly, the wrong liquid may be pumped, or liquid may be pumped into the ______________ place.

17. When practical, the pump is started with the discharge valve closed or almost closed.
    Closing the discharge valve (increases/decreases) the pumping rate.

18. Horsepower requirements _______________ as rate decreases, and the prime mover is less likely to overload.

19. At low rates the pump is less likely to lose ________________.

20. If the suction valve is closed, no liquid can enter the pump.
    The pump is started with the suction valve (open/closed).

21. When practical, a centrifugal pump is started with the discharge valve ________________; the suction valve is always ________________.

22. A spare pump with an automatic startup device must be set with both the suction and the discharge valves ________________.

23. Centrifugal pumps should never run dry, because they overheat.
    Before startup, pumps are primed by filling the casing with ________________.
24. Liquid is brought into the pump by venting the casing.
   If the liquid being pumped is dangerous, venting should be done to (an open/a closed) system.

25. Care must be taken to make sure that the suction line to the pump remains full of ____________________.

26. Vapor rises from the liquid, and vapor pockets are apt to form at (high/low) points in the suction system.

27. Unless vapor pockets in the suction line are vented off, they can work themselves into the pump and cause the pump to lose ________________.

28. The suction line is usually provided with vent valves at high points in the line through which ________________ may be vented.

29. With the prime mover functioning properly, the pump is ready to start if:
   all bleeders, vents, and drains are ________;
   the ____________ and ____________ systems are checked;
   the ____________ tracer lines are turned on;
   the discharge and suction ____________ are properly set;
   the pump is ____________________.

30. When all systems have been checked and the pump has been primed, the pump is ready to operate.
   Then the ____________________ is started.

31. When the pump is up to speed, the ____________ valve is slowly opened.

32. If the discharge pressure remains normal and steady, then the pump has taken ________________ and is operating as it should.

33. If the pump operates for any length of time with the discharge valve closed, it may overheat.
   Then liquid may ________________, and the pump loses suction.

34. If the discharge pressure does not rise, or if it rises and then drops again, the pump has probably lost its ________________.

35. If the pump has lost its prime, the pump must be shut down and then ________________.

36. The pump should be checked for leaks in casing packing box flanges and bleeders. The packing box gland should be checked that ________________ is sufficient for packing lubrication, but not excessive.

37. The temperature of the packing and bearings should be checked by using a thermometer.
   Poor lubrication, poor cooling or mechanical trouble may be indicated by ________________ temperature.

38. The shaft flexible coupling should be checked to ensure it is not leaking ________________ lubricant.

39. Periodic checking should assure that operation stays smooth and continuous.
   If unusual noises develop, the ________________ should be determined.

40. It may be necessary to correct pumping conditions.
   If the trouble is mechanical, the pump should be ________________.

SHUTDOWN

41. If the pump is to be taken out of service, then it must be properly shut down.
   The driver is shut down and locked out to be sure that it is not ________________ again by accident.

42. If the pump is equipped with a remote emergency shut-down device, you may try this device now to see if it ________________.

43. The suction and discharge valves are closed and all liquid is ________________ from the pump to a safe location.

44. The lubricating and cooling systems are shut down.
   If freezing is likely, then water must be drained from the ________________ system.

45. If the pump drains completely, the suction and discharge valves are tightly ________________.

46. Steam ________________ lines are left on or turned off depending on the operating situation.

47. If the pump is to be worked on in place, ________________ must be installed in the lines in accordance with company practices.
48. If the pump is to be taken to the shop for repairs, it is purged or flushed out, disconnected from the base, and ____________ are installed on the process lines.

49. Hazardous vapors or liquids are purged from the pump with an inert material.

The pump is purged with steam or washed with ____________.

50. If a pump is going to be set as an operating spare, the cooling and flushing systems are left operating, and the suction and discharge valves may be left open in the line.

The pump is ready to ____________.

51. Usually, a check valve in the discharge line prevents liquid in the line from backing up through the spare ____________.

52. During shutdown the check valve should close automatically.

If liquid should lead back through the spare, then the pumping system loses ____________.

**COMMON PUMP PROBLEMS**

**Gradual Loss of Pump Capacity**

53. Foreign material in the impeller causes the pump to lose capacity. Foreign material in the impeller may also cause imbalance and damage the pump.

If the liquid is apt to contain ____________ material, strainers or screens are used.

54. A pump in a new installation or where extensive work has been done upstream should be protected by a screen installed in the (suction/discharge) line.

55. The screens may be removed when no more blocking material comes through the suction line.

Normally, screens are not necessary with ____________ liquid.

56. Pump capacity decreases if the prime mover, such as a turbine, (loses/gains) speed.

If the balancing drum is worn, a pump may lose capacity.

57. Too much liquid circulates back into the suction of the pump when the clearance between the drum and the casing ____________.

58. Pumps lose capacity when worn wear rings allow liquid in the discharge section to flow back into the ____________ of the impeller.

59. Thus, liquid that should be leaving the pump with the discharge is returned to the ____________.

60. If the tips of the impeller vanes become worn, the pump moves (more/less) liquid.

61. If there is blockage in the discharge line, the total head ____________ and the rate decreases.

62. Look at the graph.

![Graph of Total Head vs. Capacity (Pumping Rate US GPM)](image_url)

63. As total head increases, the rate (increases/decreases).

The head increases to overcome the additional frictional resistance, and the rate decreases.

Increasing head and decreasing rate indicates that the ____________ Line may be partially blocked.

64. Rate may decrease because of a partially plugged strainer in the ____________ line.

65. Common causes of reduced capacity are:

- worn wear rings allowing liquid to ____________ from the discharge to the suction;
- increasing total head due to an increase in discharge pressure or a decrease in suction pressure;
- foreign material in the ____________;
- pump turbine losing ____________;
- worn balancing system or worn ____________ vanes;
- plugged strainer in suction.
Reconditioned Pump Returned to Service-Capacity Still Below Normal

66. Some obstruction may still remain in the ______________ or discharge lines.

67. If an electric motor has been improperly wired, the impeller may be ______________ in the wrong direction.

68. Unless the prime mover (steam turbine) has also been checked and repaired, it may be still delivering insufficient ______________.

Pump Functions Properly at Low Rates—Loses Suction at High Rates

69. The NPSHₐ (available) decreases when the suction line is plugged.

If NPSHₐ is too low, the pump (can/cannot) handle at high rates.

70. One common obstruction in the suction line is a partially plugged suction ______________.

71. If the eye of the impeller is partially blocked, the NPSHᵣ (required) of the pump (increases/decreases).

72. If the suction temperature increases or lighter material is being pumped, the vapor pressure ______________ and the NPSHₐ decreases, for any given rate.

73. Normally, a prime mover is chosen to handle a specific liquid.

If a different liquid is pumped, the prime mover may be ______________.

74. If an electric motor keeps kicking off, it is usually over-loaded.

If a turbine does not get up to speed, it may also be ______________.

75. When the amount of work required to pump the liquid is (greater/less) than the work output of the driver, a motor continually kicks off, or a turbine does not get up to speed.

76. If the prime mover is not designed to handle the required capacity, this problem may be corrected by ______________ the rate of the pump.

Pump Continually Loses Suction

77. Liquids of higher specific gravity are heavier than liquids of lower specific gravity.

If a liquid of high specific gravity is substituted for one of lower specific gravity, the prime mover may be ______________.

78. The viscosity of a liquid may also cause the prime mover to overload.

A liquid of higher viscosity is (harder/easier) to pump.

79. Overloading may be corrected by increasing the size of the ______________ or by decreasing the ______________ of the pump.

80. Capacity may be decreased by changing the impeller to a ______________ diameter or by slowing the ______________.

81. If packing fits too tightly against the shaft, friction (increases/decreases) and may cause the prime mover to overload.

82. Loosening the packing ______________ may reduce the friction.

83. If the casing is warped, the impeller may not rotate freely.

This restriction on the impeller may ______________ the prime mover.

84. A damaged impeller or warped casing must be repaired or ______________.

Motor Kicks Off, Engine Lags, or Turbine Will Not Get Up to Speed

85. A pump that continually loses suction may be improperly primed and may have a ______________ pocket in the suction line.

86. An air leak in the suction system of a pump operating under vacuum may cause the pump to lose its ______________.

87. The seal line to the packing box of a pump operating under vacuum may be blocked; and ______________ may enter the pump through the packing.

88. If a lantern ring is out of place in a pump operating at vacuum, it may prevent sealing liquid from entering the packing box.

If air enters the pump ______________, the pump will probably lose its prime.

89. If the pump is operating very close to the NPSH limit, the pump may intermittently lose its ______________.

If suction strainers are partially plugged, the NPSH available is (higher/lower) than normal.
Cavitation

91. Cavitation is the formation and collapse of vapor bubbles in the _________________.

92. Cavitation occurs when the pump is operating near the minimum NPSH\textsubscript{a}.
   
   When cavitation occurs, some of the liquid flashes to _________________.

93. If this happens in the suction section or at the eye of the impeller, the vapor bubbles are carried into the _________________.

94. As the pressure _________________, the vapor bubbles collapse in the vanes, and the liquid rushes in with such force that it knocks off little particles of the metal vanes.
   
   This causes pitting and erosion of the _________________.

95. The violent collapse of the vapor bubbles causes a crackling noise in the pump, which is a good indication of _________________.

96. To correct cavitation, the NPSH available must be _________________ or the pumping rate must be _________________.

97. The NPSH available may be increased by decreasing the rate of the pump.
   
   By throttling (partly closing) the discharge valve, the rate may be _________________.

98. NPSH available may also be increased by increasing the level of liquid on the (suction/discharge) side of the pump.

99. Decreasing the pumping rate may restore operation to a range where sufficient NPSH is available at the pump suction.
   
   If the crackling noise stops, the adjustment (has/has not) corrected the cavitation.

100. To correct cavitation:

    _________________ NPSH\textsubscript{a} or _________________ rate, which decreases NPSH\textsubscript{r}.

101. Cavitation is an operating problem.

    Cavitation becomes a mechanical problem if the pump is _________________ by the effects of cavitation.

FEATURES OF THE CENTRIFUGAL PUMP

102. Since the impeller of a pump rotates smoothly, the flow of liquid from the pump is (smooth/pulsed).

103. If the discharge of a positive displacement pump is blocked off, excess pressure may build up in the casing (depending on the type and size of the prime mover).

   The flow of liquid can be stopped in a centrifugal pump without building up excessive _________________ in the casing, because the impeller can still move freely.

104. Thus, the prime mover (is/is not) overloaded.

105. Even though pressure does not build up excessively, energy is imparted to the liquid remaining in the pump.

   This energy is used up as friction.

   The fluid in the blocked pump (may/may not) overheat.

106. Since at low flow rates or no flow, the liquid tends to _________________, it is not recommended that centrifugal pumps be operated below 10\% of rated capacity.

107. Where low rates are of concern, a discharge-to-suction bypass and a cooler may be provided.

   This assures that sufficient _________________ is circulating through the pump at all times.

108. Centrifugal pumps are simple in construction and relatively (inexpensive/expensive) to build.
Appendix I

Introduction to Centrifugal Pumps Test Answers

Programmed Learning
Page 1
1. answer
2. blank
3. water, or liquid
4. alcohol, or antifreeze
5. can
6. thermostat
7. learn
8. I think
9. teach
10. the tester
11. test

Section 1
Page 1
1. lower
2. higher
3. more

Section 1
Page 2
5. is
6. does not flow
7. pressure, or energy
8. lower; higher

Section 1
Page 3
9. lower
10. higher
11. energy, or pressure
12. lower; higher
13. increased
14. outward from
15. outward from the center
16. centrifugal
17. outward
18. more
19. eye
20. outside, or periphery
21. faster
22. vanes
23. casing, or housing
24. decreases
25. increases
26. in the eye
27. eye
28. low
29. impeller
30. vanes
31. casing
32. eye
33. discharge
34. pressure
35. shaft
36. turns, or rotates
37. casing
38. leakage
39. shaft
40. packing
41. wear
42. replaced
43. wear rings
44. impeller
45. decreases
46. rubbing
47. expensively
48. increases
49. liquid
50. contact
51. liquid
52. 100
53. rating
54. 30
55. best, or right, or proper
56. 500 GPM
57. GPM
58. amount
59. time
60. gallons per minute
Introduction to Centrifugal Pumps Test Answers

109. gauge A
110. pressure head
111. 138
112. half as much
113. discharge, or outlet pressure
114. pressure
115. head
116. Ps
117. Pd
118. pressure
119. 2
120. pump
121. energy, or pressure

Section 1
Page 9
122. total
123. minus
124. 23
125. subtracting head
126. lifted
127. lift
128. total
129. surface

Section 1
Page 10
130. 15
131. height, or head pressure
132. cannot work
133. atmospheric pressure
134. cannot evaporate, or vaporize
135. increases
136. water, or liquid vapor
137. heat vapor
138. more
139. in

Section 1
Page 11
140. more gasoline water
141. increases
142. higher
143. different
144. less
145. prevent
146. higher
147. vaporizes
148. 15
Appendix I

Introduction to Centrifugal Pumps Test Answers

24 propeller
25 Propeller
impeller
26 halfway between

Section 2

Page 20
28 single-suction
B. double-suction
C. multistage
D. propeller pump
E. turbine pump
30 D and E is no
31 atmospheric
32 cannot
33 decrease
34 more

Section 2

Page 21
35 vertically
36 vertically; below
multi-
37 A
38 head
39 should
40 B
41 increases
42 plus, or +
43 the same as
44 same
45 capacity
46 head
47 parallel; series
48 parallel
49 series

Section 2

Page 22
50 valve
51 pressure
52 decreases
53 bypass
54 valve
55 discharge
56 suction
57 less
58 different
59 prime mover, or driver
60 shaft
61 casing, or housing

Section 2

Page 23
62 shaft
63 shaft
64 pressed, or tightened
65 wears
66 sleeve
67 escape, or leak
68 liquid
69 outer
packing
70 lubrication
71 leakage
72 packing
leakage
73 lubricated
shaft, or sleeve
packing
74 adjusted
75 shaft
76 oil
77 lubricated
78 another source
79 packing box
80 above
81 atmospheric
82 Pump B
83 checked
84 shaft
85 carbon
86 stationary
87 shaft
88 leakage
89 seal
90 lubricate
91 erosive
92 double
93 left
94 right
95 greater
96 impeller
97 discharge
98 leakage
99 impeller
100 pressure
101 thrust
102 left
103 discharge
104 suction
105 thrust
106 decreases
107 prime mover, or driver
108 temperature
109 wear
110 rub
111 vibration
112 vibrate
113 feeling
114 detect
115 shut down
116 impeller
117 liquid
118 dry
119 liquid
120 corrosive
121 oil
122 small
123 move
124 force
125 radial
126 controlled, or minimized
127 axial; radial
128 rubbing
129 radial
130 axial
131 thrust
132 wear, or friction
133 turn
134 cools
135 overheat
136 bearing
137 more
138 heavy, or large
139 radial
140 oil
141 cannot
142 oil
143 reservoir
144 shaft
145 bearing
146 bearing
147 shaft
148 collar
149 oil
150 overheating
151 leakage
152 grade
153 dirt
154 high
155 high
156 air
157 water jackets
158 water jacket
159 water-jackets
160 bearings
161 air, or atmosphere

[ 3 ]
Appendix I

Introduction to Centrifugal Pumps Test Answers

Section 3

Page 34

162 water-jacketed

Section 3

Page 33

48 blinds, or blanks, or plugs
49 water
50 start, or operate
51 pump
52 capacity
53 foreign
54 suction
55 clear, or clean
56 loses
57 increases
58 eye
59 suction
60 less
61 increases
62 decreases
63 discharge
64 suction
65 leak
   impeller
   speed
   impeller

Section 3

Page 35

66 suction
67 turning
68 power, or speed
69 cannot
70 strainer
71 increases
72 increases
73 overloaded
74 overloaded
75 greater
76 decreasing
77 overload
78 harder
79 prime mover
   capacity
80 smaller; pump, or prime
   mover
81 increases
82 gland, or nut
83 overload
84 replaced
85 vapor
86 prime
87 air
88 suction
89 prime, or suction
90 lower

Section 3

Page 36

91 liquid
92 vapor
93 impeller
EXHIBIT 3 TYPICAL CENTRIFUGAL PUMP PERFORMANCE CURVE

- **Efficiency**
- **Head**
- **NPSHr**
- **Bhp**

**Graphs:**
- **Head (ft)** vs. **Flow (US gpm)**
- **Efficiency (%)** vs. **Flow (US gpm)**
- **NPSHr (ft)** vs. **Flow (US gpm)**
- **Power (Bhp)** vs. **Flow (US gpm)**
**An introduction to Centrifugal Pumps**

Help Sheet: These are the answers in number/alphabetical order. Any number or word or phase may be used for an answer multiple times throughout test.

<table>
<thead>
<tr>
<th>Answer</th>
<th>Definition</th>
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<td>blinds, or blanks, or plugs</td>
</tr>
<tr>
<td>2</td>
<td>both sides</td>
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<td>Brake horsepower</td>
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<td>6.4</td>
<td>bypass</td>
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<td>10</td>
<td>C. multistage</td>
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<td>14</td>
<td>can</td>
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<td>cannot</td>
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<td>cannot work</td>
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<td>23</td>
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<td>collar</td>
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<td>105</td>
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<td>0.5 x 0.433, or about .216</td>
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<tr>
<td>43 + 14.7, or 57.7</td>
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<td>GPM</td>
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<td>a closed</td>
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<td>amount</td>
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<td>B</td>
<td>does not include</td>
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<td>barrels per day</td>
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An introduction to Centrifugal Pumps

Help Sheet: These are the answers in number/alphabetical order. Any number or word or phrase may be used for an answer multiple times throughout test.

is
is not
larger
leak
leakage
leaking
learn
leaves
left
less
lift
lifted
liquid
liquid
loses
low
lower
lower;
lower; higher
lubricate
lubricated
lubricating
lubricating; cooling
lubrication
may
minus
more
move
moving
multi-
NPSH
oil
one
one side
open
operates
outer
outside, or periphery
outward
outward from
outward from the center
over grease
overheat
overload
overloaded
packing
packing box
parallel
parallel; series
Pd
plus, or +
pounds
described power, or speed
pressed, or tightened
pressure
pressure, or energy
prevent
prime
prime mover
prime mover, or driver
prime, or suction
primed
Propeller
propeller
Ps
pump
pump, or prime mover
Pump B
radial
rating
replaced
re-primed, or primed
reservoir
resisting force
right
Right side
rings
rotate
rotating
rub
rubbing
same
seal
second
series
shaft
shaft, or sleeve
should
shut down
single-suction
sleeve
small
smaller
smaller; pump, or prime mover
smooth
specific gravity
speed
speed, or RPM; impeller
start, or operate
started
stationary
steam
strainer
subtracting