40.19 A make up pump that cycles on and off intermittently as required has a service factor of 1.25 and provides a water horsepower of $15hp$. The pump efficiency is 84%. The pump is driven by an electric motor with an efficiency of 93%. What is the smallest motor that could be used?

A. $10hp$

B. $15hp$

C. $20hp$

D. $25hp$

The service factor allows a pump to be run harder than its brake horsepower rating provided the pump is not used continuously, therefore the service factor is applicable for the intermittent use case. The water horsepower, *whp*, and pump efficiency can be used to determine the required of the motor, before accounting for the service factor:

$$bhp = \frac{whp}{\eta_p} = \frac{15hp}{.84} = 17.9hp$$

Divide by the service factor to specify the required motor bhp for intermittent use:

$$bhp_{SF} = \frac{17.9hp}{1.25} = 14.3hp$$

Note the motor efficiency is additional information and not required for the solution. Motors are sized based on *bhp only*, therefore it is not appropriate to consider electrical losses in the motor unless the question relates to required electrical power. A $15hp$ motor is sufficient.

Answer B

40.20 A boiler feed pump circulates $30gpm$ against $30ft$ of head. A booster pump in series is rated for $5ft$ of head at $30gpm$. What is the combined total discharge head for this arrangement?

A. $5ft$

B. $25ft$

C. $30ft$

D. $35ft$

Pumps in series must operate with the same volume flow rate. However, the pressure developed i.e. discharge head for series operation is additive. Substitute and solve:

$$\Delta h_{total} = \Delta h_{booster} + \Delta h_{boiler\,feed} = 5ft + 30ft = 35ft$$

Answer D

40.21 A viscous liquid with a specific gravity of 1.1 is pumped with a volume flow rate of $100gpm$. The suction pressure measured at the inlet of the pump is $5psi$ of vacuum. The discharge pressure measured $3ft$ above the pump outlet is $10psig$. The diameter of the piping reduces from $4in$ on the suction side to $2in$ on the discharge side. The pump has a mechanical efficiency of 80%. What is the input power to the pump?

A. $3/4hp$

B. $1hp$

C. $1 1/4hp$

D. $1 1/2hp$

A useful and common form of the Bernoulli Equation can be applied for pumping applications such as this. A term is added to the original Bernoulli Equation, h_A, to reflect the head pressure added by the pump. Isolate h_A and collect like terms.

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_f + h_A$$

$$h_A = \frac{P_2 - P_1}{\gamma} + \frac{v_2^2 - v_1^2}{2g} + z_2 - z_1 + h_f$$

First consider the difference in static pressure. The suction pressure measured at the pump inlet is $5psi$ of vacuum. A vacuum pressure is implied to be gauge pressure as it is not possible to pull a vacuum more than atmospheric pressure. The discharge pressure is $10psig$. Ignore the 3ft elevation for the time being; this will be accounted for when analyzing the Δz term. Note the specific weight of the viscous liquid is 1.1 times the specific weight of water. See specific gravity, sg, in the reference handbook. Convert square inches to square feet to ultimately obtain units of ft (of viscous liquid).

$$\frac{P_2 - P_1}{\gamma} = \frac{(10psi - (-5psi))\left(\frac{144in^2}{1ft^2}\right)}{\left(62.4\frac{lb_f}{ft^3}\right)(1.1)} = 31.47ft$$

Although the velocity term is often ignored, in this case the discharge piping diameter is reduced with respect to the suction side piping; therefore the velocity will increase for a given volume flow rate. To be safe, include the velocity term in the solution. Use the steel pipe friction tables to obtain the actual diameter and velocity where possible.

$$D_1 = 4in\,(nominal)$$

$$Q_1 = 100gpm$$

$$v_1 = 2.52\frac{ft}{s}$$