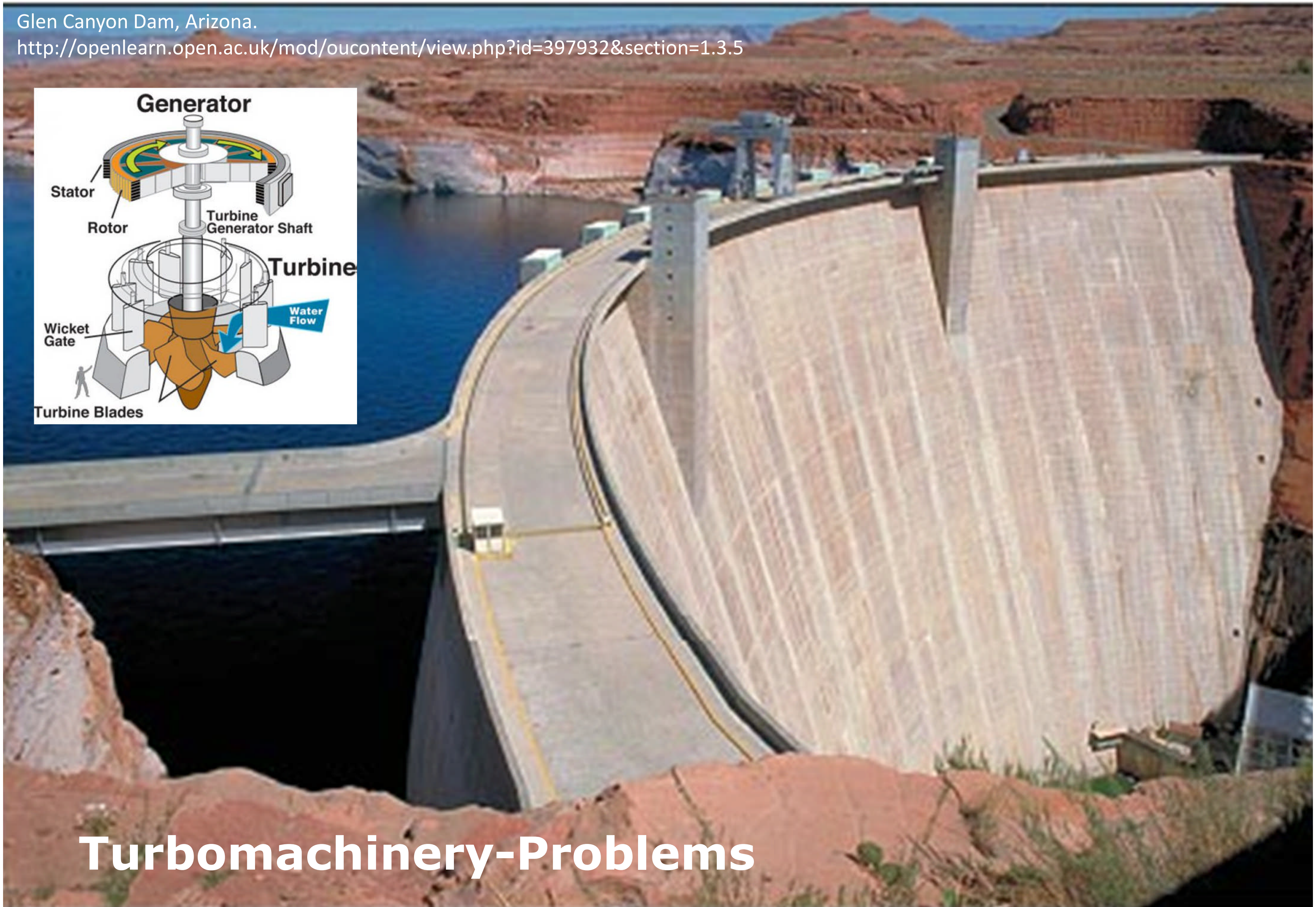
Glen Canyon Dam, Arizona.
http://openlearn.open.ac.uk/mod/oucontent/view.php?id=397932&section=1.3.5



Turbomachinery-Problems

Worked example 15

An 8" pump of the type described by the performance curves of Figure 6 is required to pump water at 0.025m^3/s. What is the efficiency and pump power for this operation point? What differential pressure does the pump generate?

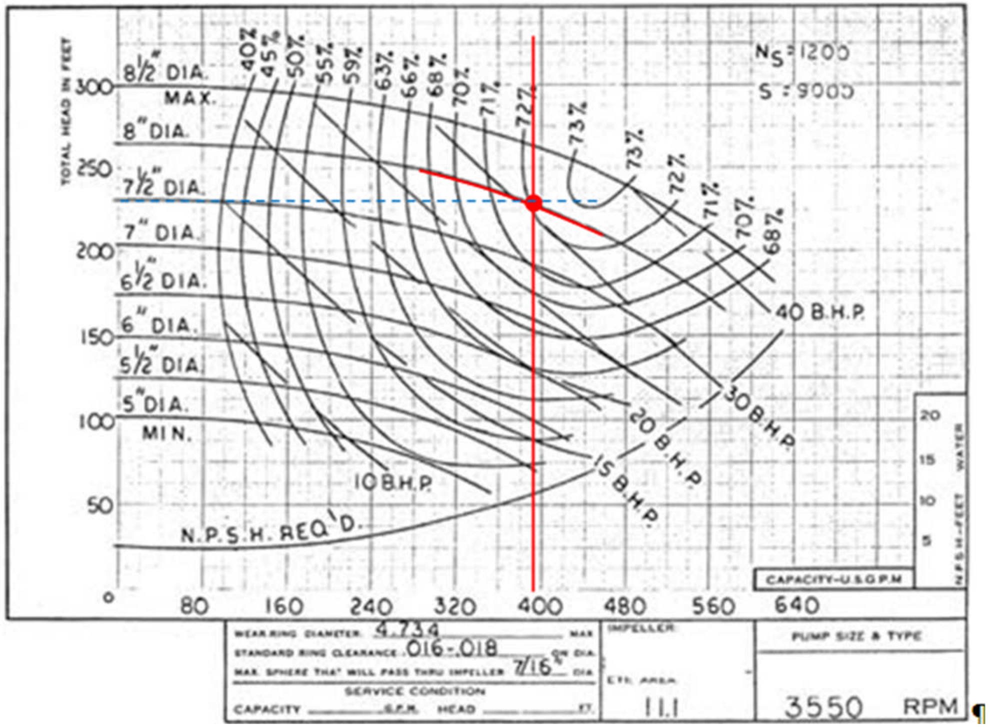
Answer: 72.1%, 23.1 kW, 673 kPa

1 US gpm = 3.79 lpm
1 litre = 10^{-3} m^3
1 foot = 12 "
1" = 25.4×10^{-3} m

Solution to Worked Example 15

- Convert flowrate to US gpm:
- 1 US gpm = 3.79 lpm=3.79x10^{-3} m^3 per minute

$$\frac{0.025}{3.79 \times 10^{-3}} \times 60 = 396US\ gpm$$



Solution to Worked Example 15

- Read off bhp and efficiency:
- Efficiency ~ 72.1%
- Pump power ~ 31 bhp
- Convert to SI units: 1hp = 746W approx

$$31 \times 746 = 23.1kW$$

- From graph, head generated ~225 ft.
- Convert to differential pressure:

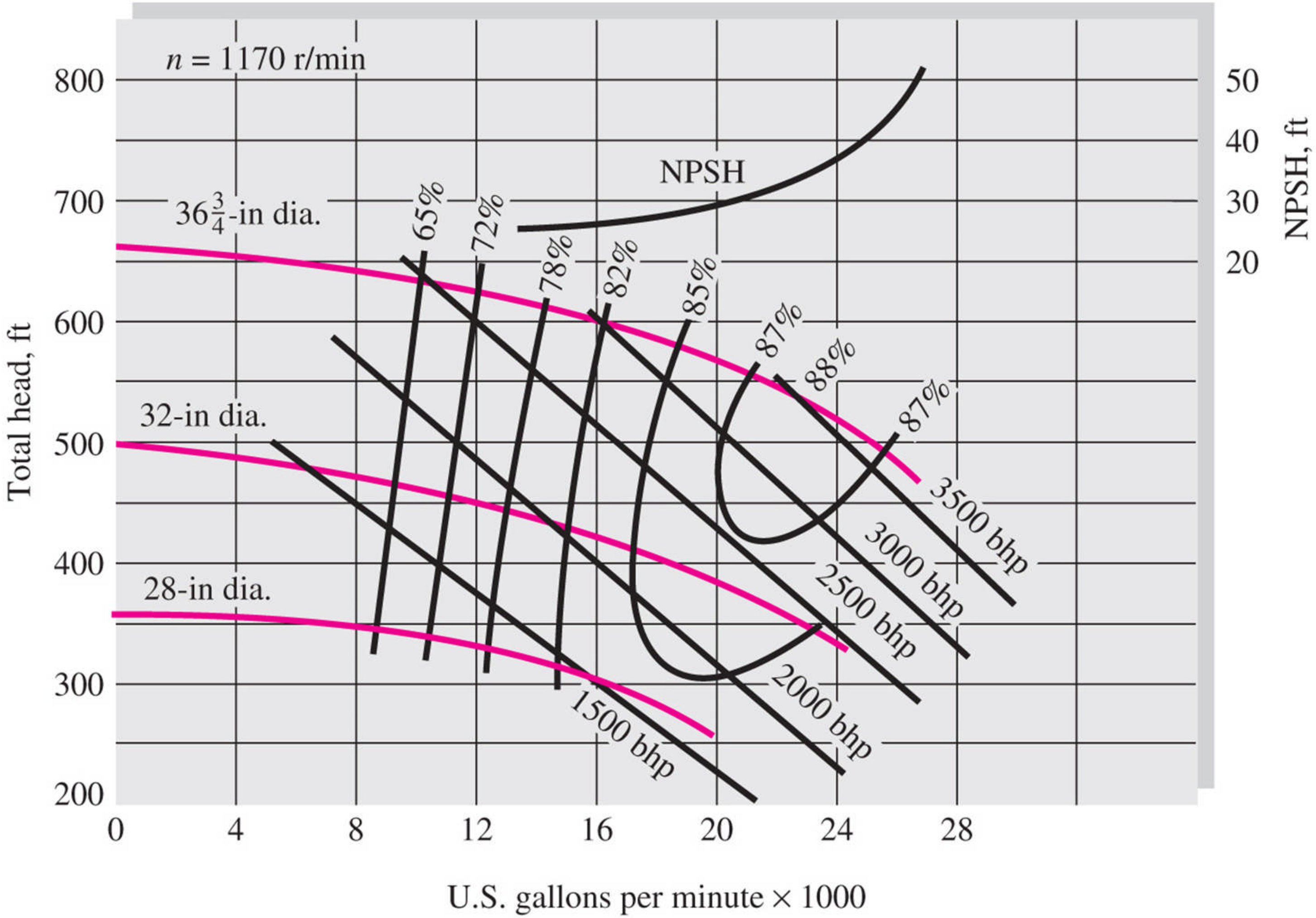
$$\Delta p = \rho g h$$
$$= 1000 \times 9.81$$
$$\times (225 \times 12 \times 25.4 \times 10^{-3}) = 673kPa$$

Worked example 16

The performance data for a 32” pump is given below. The pump is to pump 24,000 US gpm of water from a reservoir where the pressure at the surface is 1.01 bar. If the head loss due to friction from reservoir to pump inlet is 6 ft, how far below the reservoir surface should the pump inlet be placed to avoid cavitation for water at 15.5°C, density 1000 kg/m^3 and p_v= 1.8kPa.

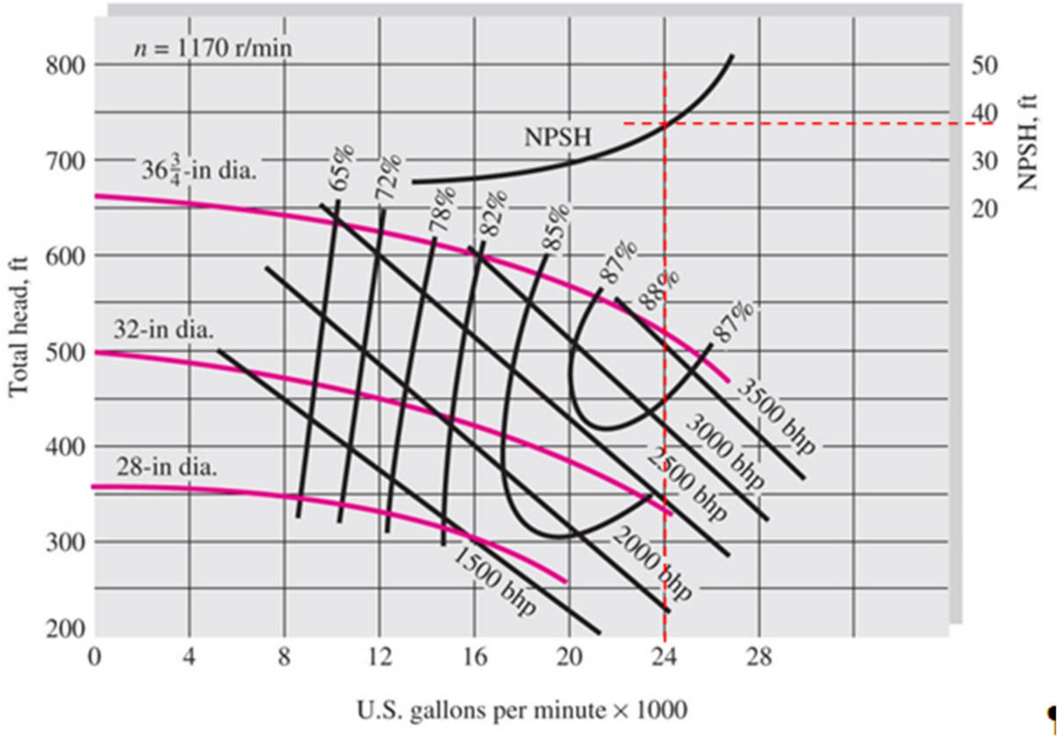
Answer: 3.3m minimum

Worked Example 16



Solution to Worked Example 16

- From the graph, at 24,000 US gpm the NPSH required is 38 ft.

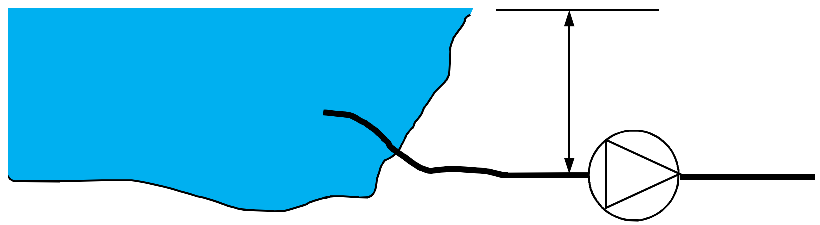


- Convert to metres:

$$38 \times 12 \times 25.4 \times 10^{-3} = 11.58m$$

Solution to Worked Example 16

- Apply EBE between reservoir surface and pump inlet:



$$\frac{p_a}{\rho g} + z = \frac{p_i}{\rho g} + \frac{v_i^2}{2g} + H_f$$

- From Eq 6, for no cavitation we need $$NPSH \le \frac{p_i}{\rho g} + \frac{v_i^2}{2g} - \frac{p_v}{\rho g}$$

- Combine to give: $$NPSH \le \frac{p_a}{\rho g} + z - H_f - \frac{p_v}{\rho g}$$

- H_f is 6 feet, convert to metres:

$$6 \times 12 \times 25.4 \times 10^{-3} = 1.83\ m$$

Solution to Worked Example 16

- So

$$NPSH \leq \frac{p_a}{\rho g} + z - H_f - \frac{p_v}{\rho g}$$

$$11.58 \leq \frac{1.01 \times 10^5}{\rho g} + z - 1.83 - \frac{1.8 \times 10^3}{\rho g}$$

- Therefore need $z \geq 3.3m$

Worked example 17

A pump from the family of Figure 8 has a diameter of 21” and operates at 1500 rpm. Estimate the discharge and differential pressure for this pump when operating at BEP (best efficiency point) for water with density 1000 kg/m^3. What is the input power required for this pump

Answer: 0.45m^3/s, 835 kPa, 423 kW

Solution to Worked Example 17

- Identify the BEP on the graph
- Reading from the graph, at BEP:

$$C_{Q^*} \approx 0.118$$

$$\eta \approx 0.87$$

$$C_{H^*} \approx 4.7$$

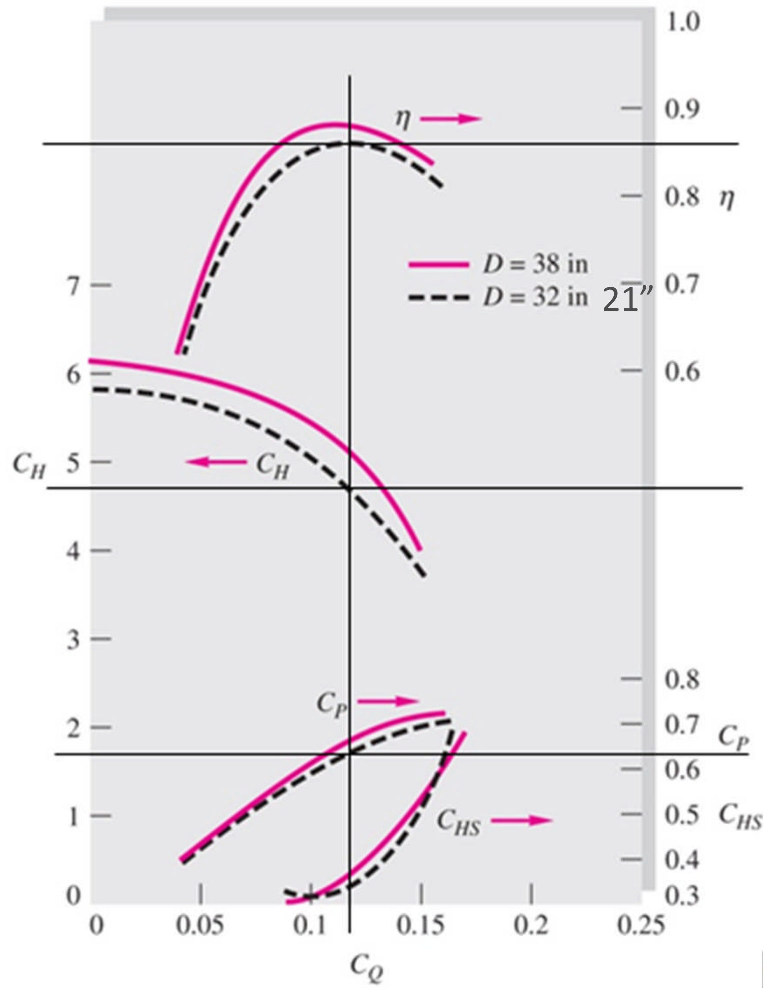
$$C_{P^*} \approx 0.63$$

- Find Q from Capacity coefficient

$$\text{Capacity coefficient } C_Q = \frac{Q}{nD^3}$$

- D=21”=0.533m, n=1500rpm=25 rps

$$\therefore Q^* = 0.118 \times 25 \times 0.533^3 = 0.45 m^3/s$$



Solution to Worked Example 17

- Find pump head from head coefficient

$$\text{Head coefficient } C_H = \frac{gH}{n^2D^2}$$

$$\therefore \quad H^* = (4.7 \times 25^2 \times 0.533^2)/9.8 = 85.1 \text{ m}$$

- Neglecting the difference between pump inlet and outlet elevations:

$$\Delta p = \rho g H = 1000 \times 9.81 \times 85.1 = 835 \text{ kPa}$$

- Find pump input power from power coefficient:

$$\text{Power coefficient } C_P = \frac{P}{\rho n^3 D^5}$$

$$\therefore P^* = 0.63 \times 1000 \times 25^3 \times 0.533^5 = 423kW$$

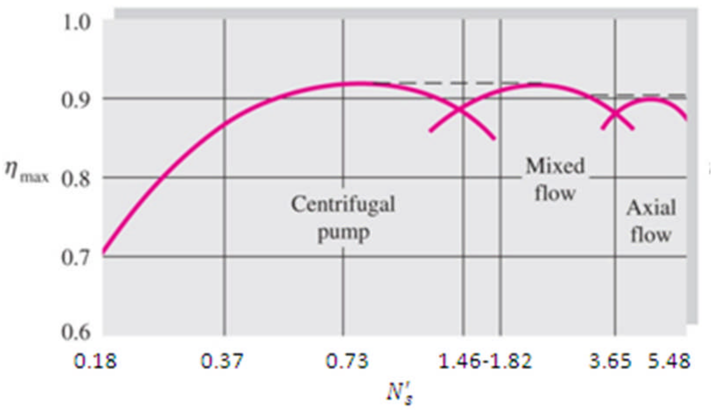
Worked example 18

If a pump has the following values at BEP (best-efficiency point):
$C_H^* = 0.163$ and $C_Q^* = 0.0325$
what is the non-dimensional specific speed? What rotary pump type does this correspond to?

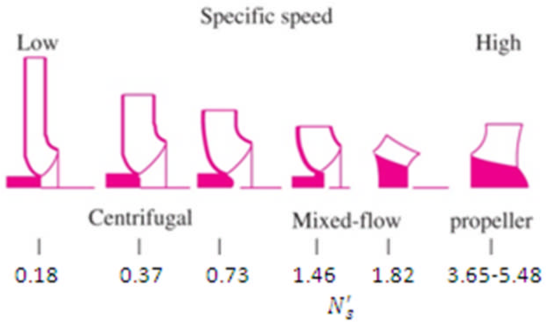
Ans: 0.703, centrifugal (radial)

Solution to worked example 18

$$N_s' = \frac{C_{Q^*}^{0.5}}{C_{H^*}^{0.75}} = \frac{0.0325^{0.5}}{0.163^{0.75}} = 0.703$$



(a)



Centrifugal pump

A centrifugal pump delivers 550 gal/min of water at 20°C w
horsepower is 22 and the efficiency is 71%. (a) Estimate the head ris
pressure rise in psi. (b) Also estimate the head rise and horsepower if inste
is 550 gal/min of gasoline at 20°C.

Solution: (a) For water at 20°C, take $\rho \approx 998\ \text{kg/m}^3 \approx 1.94\ \text{slug/ft}^3$. The po

$$\bigstar\quad \text{Power} = 22(550) = 12100\ \frac{\text{ft}\cdot\text{lbf}}{\text{s}} = \frac{\rho g Q H}{\eta} = \frac{(62.4)\left(\frac{550}{449}\ \frac{\text{ft}^3}{\text{s}}\right)}{0.71}$$

or $\quad H \approx \mathbf{112\ ft}$ *Ans.* (a)

Pressure rise $\Delta p = \rho g H = (62.4)(112) = 7011\ \text{psf} \div 144 \approx \mathbf{49\ psi}$

(b) For gasoline at 20°C, take $\rho \approx 680\ \text{kg/m}^3 \approx 1.32\ \text{slug/ft}^3$. If visco
number) is not important, the operating conditions (flow rate, impeller size
exactly the same and hence the head is the same and the power scales with

$$H \approx \mathbf{112\ ft}\ (\text{of } \textit{gasoline});\quad \text{Power} = P_{water}\frac{\rho_{gasoline}}{} = 22\left(\frac{680}{998}\right) \approx \mathbf{15\ hp}$$

[redacted] A pump delivers 1500 L/min of water at 20°C against a pressure rise of 270 kPa. Kinetic and potential energy changes are negligible. If the driving motor supplies 9 kW, what is the overall efficiency?

Solution: With pressure rise given, we don't need density. Compute "water" power:

$$P_{water} = \rho g Q H = Q\,\Delta p = \left(\frac{1.5}{60}\ \frac{\text{m}^3}{\text{s}}\right)\left(270\ \frac{\text{kN}}{\text{m}^2}\right) = 6.75\ \text{kW}, \quad \therefore\ \eta = \frac{6.75}{9.0} = \mathbf{75\%} \quad \textit{Ans.}$$

[redacted] A pump delivers gasoline at 20°C and 12 m^3/h. At the inlet, $p_1 = 100$ kPa, $z_1 = 1$ m, and $V_1 = 2$ m/s. At the exit $p_2 = 500$ kPa, $z_2 = 4$ m, and $V_2 = 3$ m/s. How much power is required if the motor efficiency is 75%?

Solution: For gasoline, take $\rho g \approx 680(9.81) = 6671\ \text{N/m}^3$. Compute head and power:

$$H = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 - \frac{p_1}{\rho g} - \frac{V_1^2}{2g} - z_1 = \frac{500000}{6671} + \frac{(3)^2}{2(9.81)} + 4 - \frac{100000}{6671} - \frac{(2)^2}{2(9.81)} - 1,$$

$$\text{or:}\quad H \approx 63.2\ \text{m}, \quad \text{Power} = \frac{\rho g Q H}{\eta} = \frac{6671\left(\frac{12}{3600}\right)(63.2)}{0.75} \approx \mathbf{1870\ W} \quad \textit{Ans.}$$

In a test of the pump in the figure, the data are: p_1 = 100 mmHg (vacuum), p_2 = 500 mmHg (gage), D_1 = 12 cm, and D_2 = 5 cm. The flow rate is 180 gal/min of light oil (SG = 0.91). Estimate (a) the head developed; and (b) the input power at 75% efficiency.

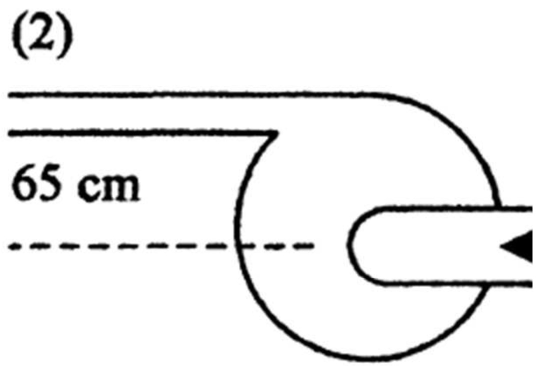


Fig. P11.12

Solution: Convert 100 mmHg = 13332 Pa, 500 mmHg = 66661 Pa, 0.01136 m^3/s. Compute $V_1 = Q/A_1 = 0.01136/[(\pi/4)(0.12)^2] = 1.00$ m/s. Al 5.79 m/s. Calculate $\gamma_{oil} = 0.91(9790) = 8909$ N/m^3. Then the head is

$$H = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 - \frac{p_1}{\gamma} - \frac{V_1^2}{2g} - z_1$$

$$= \frac{66661}{8909} + \frac{(5.79)^2}{2(9.81)} + 0.65 - \frac{-13332}{8909} - \frac{(1.00)^2}{2(9.81)} - 0, \quad \text{or:} \quad \mathbf{H = 11.3\ m}$$

$$Power = \frac{\gamma QH}{\eta} = \frac{8909(0.01136)(11.3)}{0.75} = \mathbf{1520\ W} \quad Ans.\ (b)$$