# TEST 3

MY SOLUTIONS

Oladuwa A. Odunlan & Spencer W. Reed

# TEST 3

(1)

## PURPOSE

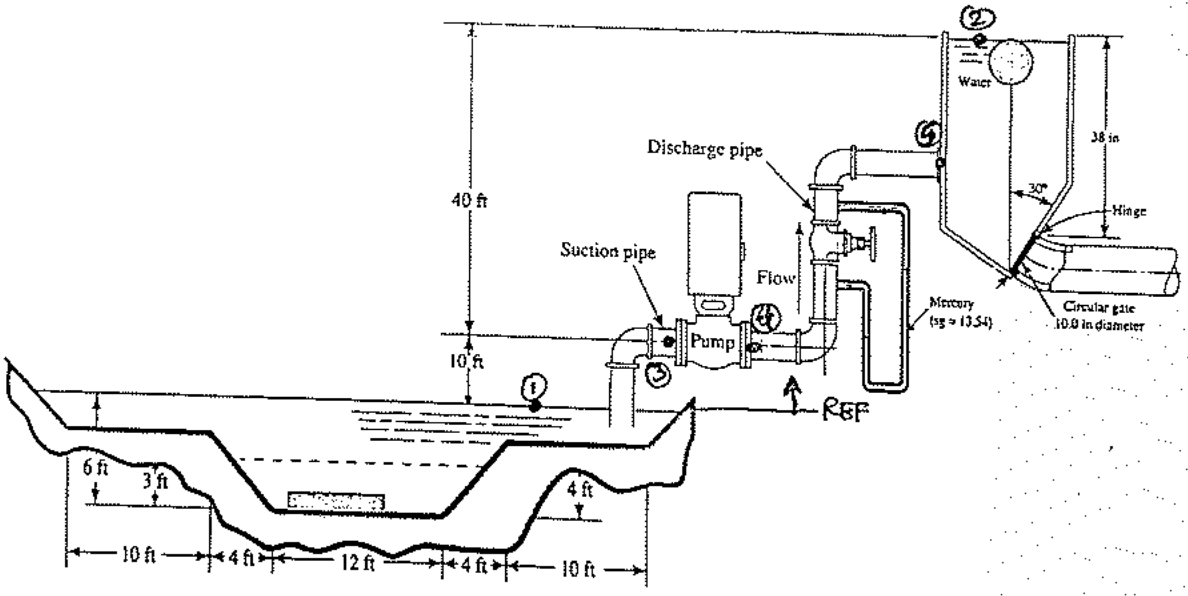
Redesign a pumped system to deliver water from a lower open channel to an elevated open channel. The redesign includes:

(a) The new pump power required to pump the adjusted flow rate of at least 30% more of the original flow rate of 3.387 $ft^3/s$ and determine the appropriate commercial steel pipe required for the increased flow rate.

(b) Compute the total horizontal and vertical forces acting on the entire discharge pipe length including fittings, when supported.

(c) Pre-select a pump that might satisfy the requirements and specify the overall characteristics of that pump

## DRAWINGS & DIAGRAMS




## SOURCES

Mott, R., Untener, J. A., "Applied Fluid Mechanics," 8th Edition, Pearson Education Inc. (2023)

## DESIGN CONSIDERATIONS

- Constant properties
- Incompressible fluid
- Isothermal conditions

(2)

- Steady state
- Newtonian fluid
- Use of gate valve } assumptions
- Use of 90° elbows

MATERIALS

- Water at 60°F
- Steel pipe

DATA & VARIABLES

$L_{discharge} = 2500\,ft$
$L_{suction} = 11\,ft$
$Q_{pump} = 3.387 + (0.5 \times 3.387) = 5.081\,ft^3/s$
$\eta_{pump} = 0.6$
$g = 32.2\,ft/s^2$
$A_{pipe} = 0.3477\,ft^2$ (from 2nd test)
$D_{pipe} = 0.6651\,ft$ (from 2nd test)
$\varepsilon = 1.5 \times 10^{-4}\,ft$

$\nu = 1.21 \times 10^{-5}\,ft^2/s$
$\gamma = 62.4\,lb/ft^3$
Initial $Q_{pump} = 3.387\,ft^3/s$
Initial velocity $= 9.753\,ft/s$

PROCEDURE & CALCULATIONS

2)(i) Now, I will need to calculate the pump head to include all minor losses using the Bernoulli's equation from point (1) to (2). We have,

$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_{L_{1-2}}$$

Assuming $V_1 = V_2$ and $P_1 = P_2 = 0$ since both channels are opened to the atmosphere. We get,

$$h_A = (Z_2 - Z_1) + h_{L_{1-2}} \quad (1) \qquad \text{where } Z_2 - Z_1 = 50\,ft$$

To determine the total energy loss, we computed the one due to pipe, and the minor losses due to elbows, valve, entrance (bottom open channel), and exit (top open channel), per test instructions.

$$h_{L_{1-2}} = h_{L_{ent}} + h_{L_{suct}} + 3h_{L_{elb}} + h_{L_{val}} + h_{L_{disch}} + h_{L_{exit}} \quad (2)$$

The velocity can be determined using the flow rate eqn,

$$V = Q/A = (5.081\,ft^3/s / 0.3472\,ft^2) \Rightarrow V = 14.634\,ft/s$$

$h_{L_{entrance}} = \frac{KV^2}{2g}$ where $K = 0.78$ for an inward-projecting pipe. Page 231, Fig 10.14.

$= \frac{(0.78)(14.634\,ft/s)^2}{2 \times 32.2\,ft/s^2} = \boxed{2.594\,ft} \Rightarrow$ a(i) $\frac{0.78 \times (9.755)^2}{2 \times 32.2} = 1.153\,ft$

$h_{L_{exit}} = \frac{KV^2}{2g}$ where $K = 1.0$ from the Textbook Page 227, Fig. 10.4.

$= \frac{1.0(14.634\,ft/s)^2}{2 \times 32.2\,ft/s^2} = \boxed{3.325\,ft} \Rightarrow$ a(i) $\frac{1.0 \times (9.755)^2}{2(32.2)} = 1.478\,ft$

$h_{L_{v}} = \frac{KV^2}{2g}$ where $K = 8f_T$ for a fully open gate valve and $f_T = 0.014$ for a 8" Sch. 40 pipe.

$= \frac{(8)(0.014)(14.634\,ft/s)^2}{2 \times 32.2\,ft/s^2} = \boxed{0.372\,ft} \Rightarrow$ a(i) $\frac{8(0.014)(9.755)^2}{2 \times 32.2} = 0.165\,ft$

$3h_{L_{elbow}} = 3K_{elb}\frac{V^2}{2g}$ where $K = 30f_T$ for a 90° standard elbow and $f_T = 0.014$ for a 8" Sch. 40 pipe.

$= \frac{3(30)(0.014)(14.634\,ft/s)^2}{2 \times 32.2\,ft/s^2} = \boxed{4.190\,ft} \Rightarrow$ a(i) $\frac{3 \times 30 \times 0.014 \times (9.755)^2}{2 \times 32.2} = 1.862\,ft$

$h_{L_{pipe}} = f\frac{L}{D}\frac{V^2}{2g}$

$R_e = \frac{VD}{\nu} = \frac{(14.634\,ft/s)(0.6651\,ft)}{1.21 \times 10^{-5}\,ft^2/s} = 804386$ or $8.04 \times 10^5$

From test 2, $R_e = 5.36 \times 10^5$ and $f = 0.01566$

$D/\varepsilon = \frac{0.6651\,ft}{1.5 \times 10^{-4}\,ft} = 4434$

From Moody chart: $f \cong 0.01523$

So,

$h_{L_{suction}} = \frac{(0.01523)(11\,ft)(14.634\,ft/s)^2}{(0.6651\,ft)(2 \times 32.2\,ft/s^2)} = 10.838\,ft$

$h_{L_{disch}} = \frac{(0.01523)(2500\,ft)(14.634\,ft/s)^2}{(0.6651\,ft)(2 \times 32.2\,ft/s^2)} = 190.368\,ft$

From test 2,

$h_{L_{suct}} = 0.383\,ft$ and

$h_{L_{disch}} = 26.979\,ft$

Substitute known values into eqn (2),

$h_{L_{1-2}} = 2.594\,ft + 0.838\,ft + 4.190\,ft + 0.372\,ft + 190.368\,ft + 3.325\,ft$

$h_{L_{1-2}} = 201.687\,ft$

a(i) $h_{L_{1-2}} = (1.153 + 1.478 + 0.165 + 1.862 + 0.383 + 26.979)\,ft$

$h_{L_{1-2}} = 92.02\,ft$

(4)

Substituting $h_{L_{1-2}}$ into eqn (1),

$$h_A = 50\,ft + 201.687\,ft$$

$$\boxed{h_A = 251.687\,ft}$$

Now, the new pump power

$$P = \frac{\gamma Q h_A}{\eta} = \frac{(62.4\,lb/ft^3)(5.081\,ft^3/s)(251.687\,ft)}{0.6}$$

$$P = 132997.45\,lb\cdot ft/s$$

Using the conversion factor, the required new pump power (in HP) is

$$\boxed{\therefore\ P = 241.81\,HP}$$

(ii) $h_A = 50\,ft + 92.02\,ft$

$$\boxed{h_A = 142.02\,ft}$$

(ii) $P = \dfrac{(62.4)(3.387)(142.02)}{0.6}$

$$P = 50026.316\,ft/s$$

$$\boxed{P = 90.96\,HP}$$

To determine the appropriate commercial steel pipe to accomplish the increase flow rate using the same pump power (from (a-i)) and increasing the pipe size, we have,

$$P = \frac{\gamma Q h_A}{\eta} \Rightarrow \frac{P\eta}{\gamma Q} = h_A \Rightarrow \frac{P\eta}{\gamma Q} = (z_2 - \cancel{z_1}^{\,0}) + h_{L_{1-2}} \Rightarrow$$

$$\frac{P\eta}{\gamma Q} - z_2 = h_{L_{ent}} + h_{L_{suct}} + 3h_{L_{elb}} + h_{L_{valve}} + h_{L_{disch.}} + h_{L_{exit}}$$

$$\frac{P\eta}{\gamma Q} - z_2 = K_{ent}\frac{V^2}{2g} + f\frac{L_{s}}{D}\frac{V^2}{2g} + 3K_{elb}\frac{V^2}{2g} + K_{valve}\frac{V^2}{2g} + f\frac{L_{disch}}{D}\frac{V^2}{2g} + K_{exit}\frac{V^2}{2g}$$

$$\frac{P\eta}{\gamma Q} - z_2 = \left[K_{ent} + f\frac{L_{suct}}{D} + 3K_{elb} + K_{valve} + f\frac{L_{disch.}}{D} + K_{exit}\right]\frac{V^2}{2g}$$

$$Q = VA = \frac{V\pi D^2}{4} \Rightarrow V = \frac{4Q}{\pi D^2} \Rightarrow V^2 = \frac{16Q^2}{\pi^2 D^4}$$

Substituting $V^2$,

$$\underbrace{\underbrace{\frac{P\eta}{\gamma Q} - z_2}_{LHS} = \underbrace{\left[K_{ent} + f\frac{L_{suct}}{D} + 3K_{elb} + K_{valve} + f\frac{L_{disch.}}{D} + K_{exit}\right]}_{RHS1}\underbrace{\frac{8Q^2}{g\pi^2 D^4}}_{RHS2}}_{RHS}$$

$K_{ent} = 0.78$, $K_{elb} = 30f_T$, $K_{valve} = 8f_T$, $K_{exit} = 1.0$, and $P = 50026.3\,lb\cdot ft/s$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{R_e^{0.9}}\right)\right]^2} \quad \text{and} \quad f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)}\right)\right]^2}$$

$$\%\ diff = \frac{LHS - RHS}{LHS} \times 100$$

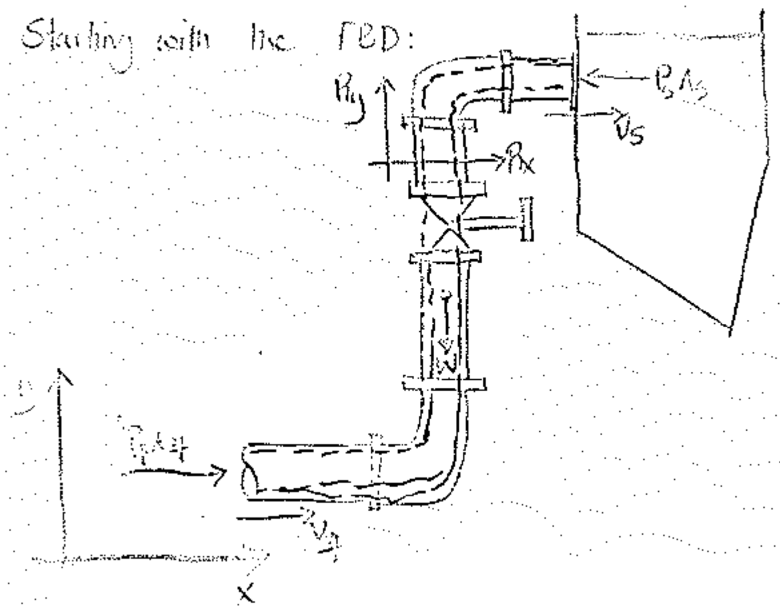
⑤

From the Excel iteration, the minimum diameter is,

$$\boxed{D = 0.8988\ ft = 10.7856\ in}$$

From Table F1, we picked an 10" Schedule 40 pipe. The inside diameter is 10.020 in (0.8350 ft) and the flow area is $0.5479\ ft^2$.

b) Starting with the FBD:




Where $R_x$ & $R_y$ represent the reaction forces of the pipe against the fluid.

Applying the force equation, we have,

$$\sum \vec{F} = \rho Q(\vec{V}_2 - \vec{V}_1).$$

In the x-direction,

$$\sum F_x = \rho Q(V_{2x} - V_{1x})$$

Since the pipe diameter and the flow rate are the same, velocities are equal.

$$\sum F_x = \rho Q(\cancel{\vec{V}_{2x}} - \cancel{\vec{V}_{1x}}) \Rightarrow \sum F_x = \rho Q(0) \Rightarrow \sum F_x = 0.$$

From the FBD,

$$P_4A_4 + R_x - P_5A_5 = 0 \Rightarrow R_x = P_5A_5 - P_4A_4 \quad \text{where } A_5 = A_4 \text{ (same pipe diameter)}$$

$$\Rightarrow R_x = (P_5 - P_4)A$$

To calculate $P_4$, we applied Bernoulli's equation for point 1 to 4. We have,

$$h_A + \cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + \cancel{Z_1}^{0} = \frac{P_4}{\gamma} + \frac{V_4^2}{2g} + Z_4 + h_{L1\text{-}4}$$

where $P_1 = 0$ (gage), $V_1 = 0$, $Z_1 = 0$, $Z_4 = 10$, and $h_{L1\text{-}4} = h_{Lent.} + h_{el} + h_{Lsuct}$

$$\Rightarrow P_4 = \gamma\left(h_A - \frac{V_4^2}{2g} - Z_4 - h_{Lent.} - h_{Lelb} - h_{Lsuct}\right)$$

$$= 62.4\ lb/ft^3\left[142.022\ ft - \frac{(9.755\ ft/s)^2}{2\times 32.2\ ft/s^2} - 10\ ft - 1.153\ ft - \frac{1.871\ ft}{3} - 0.383\ ft\right] = 8011.2\ lb/ft^2$$

$$\boxed{P_4 = 55.63\ psi}$$

To determine $P_5$, we applied Bernoulli's equation from point 1-5. We have,

$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_5}{\gamma} + \frac{V_5^2}{2g} + z_5 + h_{L_{1-5}}$$

where $P_1 = 0$, $V_1 = 0$, $z_1 = 0$, assuming $z_5$ is 30ft from point 1, and $h_{L_{1-5}} = h_{L_{ent}} + h_{L_{suct}} + 3h_{L_{elb}} + h_{L_{val}} + h_{L_{disch}} + h_{L_{exit}}$

$$\Rightarrow P_5 = \gamma\left[h_A - \frac{V_5^2}{2g} - z_5 - h_{L_{ent}} - h_{L_{suct}} - 3h_{L_{elb}} - h_{L_{val}} - h_{L_{disch}} - h_{L_{exit}}\right]$$

$$P_5 = 62.4\,lb/ft^3\left[142.022\,ft - \frac{(9.755\,ft/s)^2}{2\times 32.2\,ft/s^2} - 30ft - 92.022\,ft\right]$$ ($h_{L_{1-5}}$ calculated from part a-i)

$$P_5 = 1155.8\,lb/ft^2$$

$$\boxed{\therefore P_5 = 8.03\,psi}$$

Substituting known factors into the $R_x$ eqn,

$$R_x = (1155.8\,lb/ft^2 - 8011.7\,lb/ft^2)\,0.3472\,ft^2$$

$$R_x = -2380.2\,lb$$

$$\boxed{\therefore R_x = 2380.2\,lb \longleftarrow}$$

In the y-direction,

$$\Sigma F_y = \rho Q(V_{2y} - V_{1y}).$$ $V_{2y} = V_{1y} = 0$ since there are velocities in the y-direction.

$$\Sigma F_y = \rho Q(0) \Rightarrow \Sigma F_y = 0$$

We have,

$$R_y - W = 0 \Rightarrow R_y = W \quad \text{where } W = \gamma V = \gamma A L$$ ($L$ = length of discharge pipe)

$$R_y = 62.4\,lb/ft^3 \times 0.3472\,ft^2 \times 2500\,ft$$

$$\boxed{\therefore R_y = 54163.2\,lb}$$

Summary

To deliver water from the lower open channel to the higher open channel, at a rate of 3.557 ft³/s, we will need a pump of 90.96HP with a pump head loss of 142.02ft which include minor losses due to the elbows, valve, entrance, and exit losses. This shows an increase in the pump power and pump head loss previously calculated when the minor losses due to all fittings, entrance, and exit loss were not considered. With an increased flow rate of 5.081 ft³/s, there is an increase in pipe diameter which is 0.7983ft to accommodate for the increase in flow rate. This resulted in a larger pump of 241.21HP as well as an increase in the pump head loss, 251.607ft. In both cases, we assumed its efficiency is 60%. The pipe diameter for the system of pump power 90.96HP should be 10" Schedule 40 pipe.

For our civil engineers, we determined the values of $R_x$ and $R_y$ while also considering the weight of

the pipe. Since the vertical force is considerably larger than the horizontal force, which is also acting in the opposite direction, more support is needed in the horizontal planes.
Finally, we pre-selected a 60Hz, radial-type kinetic pump with an estimated speed of 3,365.05 RPM, a pump suction and discharge size of 6in, respectively, and maximum impeller size of 7.5inches.
The approximate impeller diameter is 7.21in, approx. power and efficiency of 67BHP and 78%, respectively. The pump size is determined to be 84.5in X 30in, weighing 930lbs. The radial-type kinetic pump was selected because it is cheaper, in terms of upfront and maintenance costs, compact in size, and can handle different flow rates and pressures.

# Part C

We use a kinetic pump because they are cheaper, smaller and you cant control the flow.

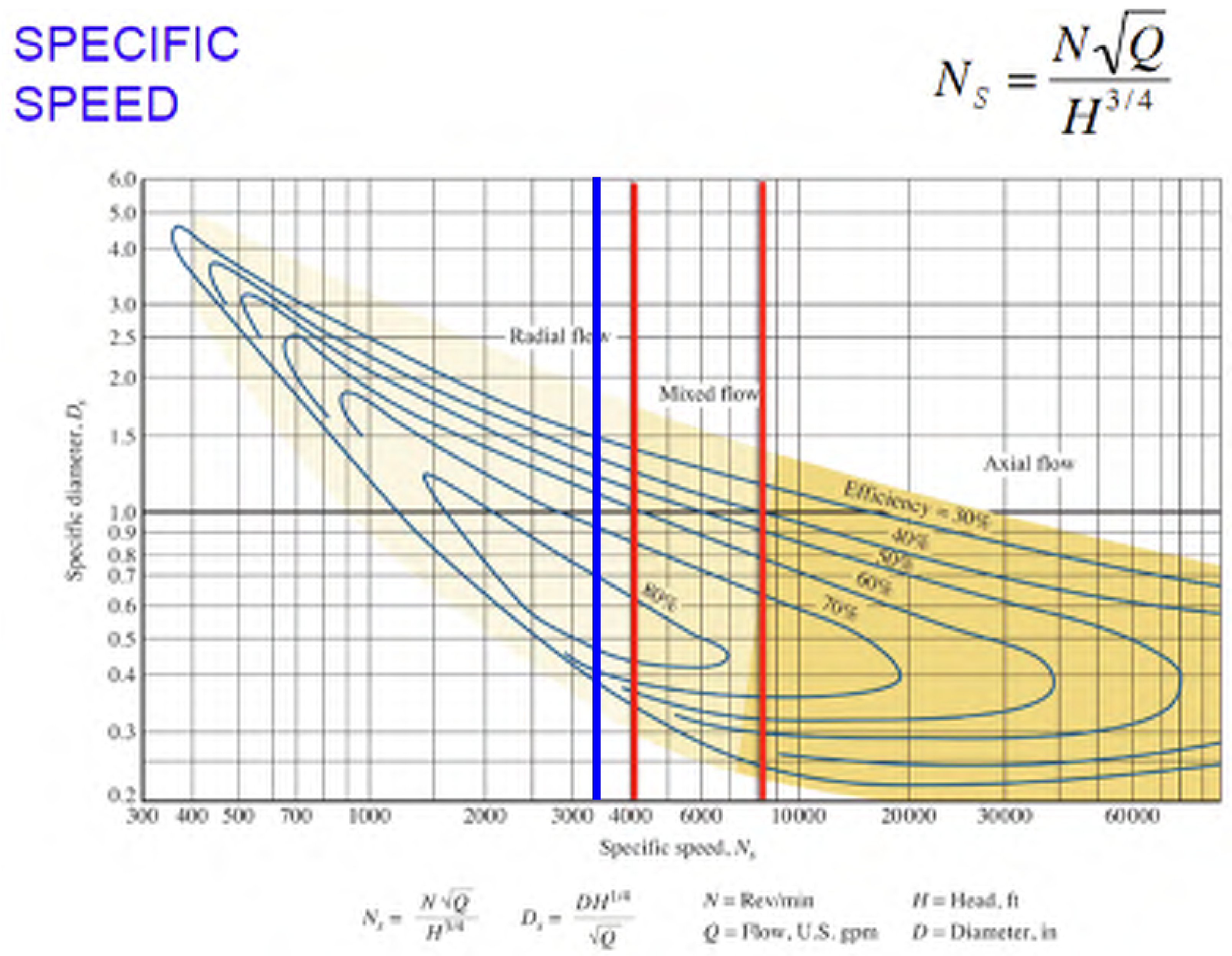
Ns = (N*sqrt(Q)) / H^3/4
    = (3550*sqrt(1520.76)) / (142.022^3/4)
    = 3,365.05

i) Pump Suction = 6 inches
   Discharge Size = 6 inches
   Max Imeller Size = 7.5 inches

ii) Approximate Impeller Diameter = 7.21 inches

iii) Approximate Power and Efficiency = 69 BHP and 78% efficiency

iv) Pump Size - 84.5 inches x 30 inches
    Pump Weight = 930 lbs

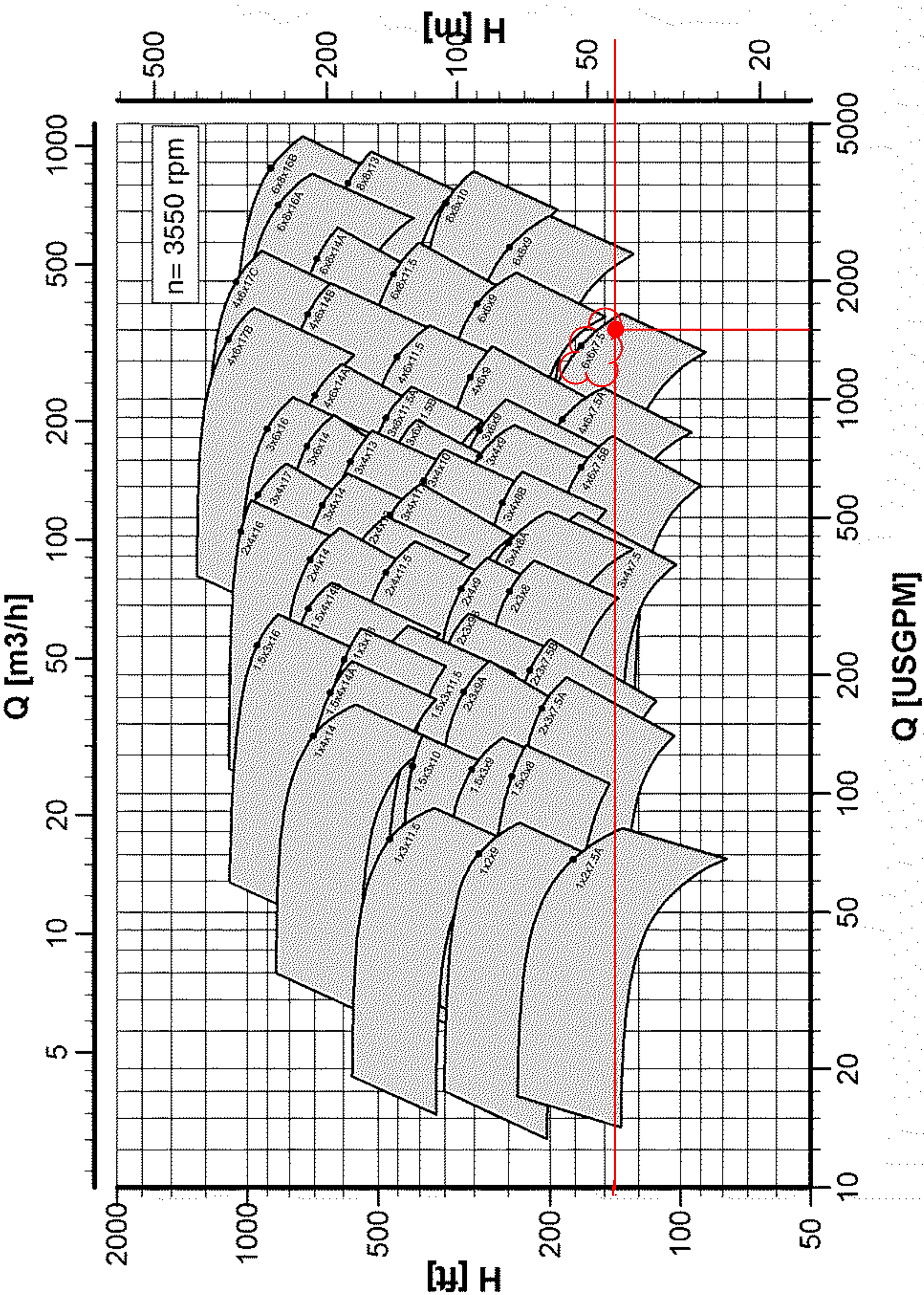


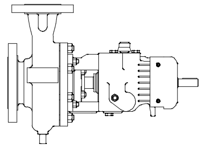
# SULZER

**CURVES - TYPE OHH**

**Range of Performances - 60 Hertz 3550 rpm**

| Series **2.00** | Page |
| --- | --- |
| CURVES | 60hz |
| 12 February 2002 | **E0D** |



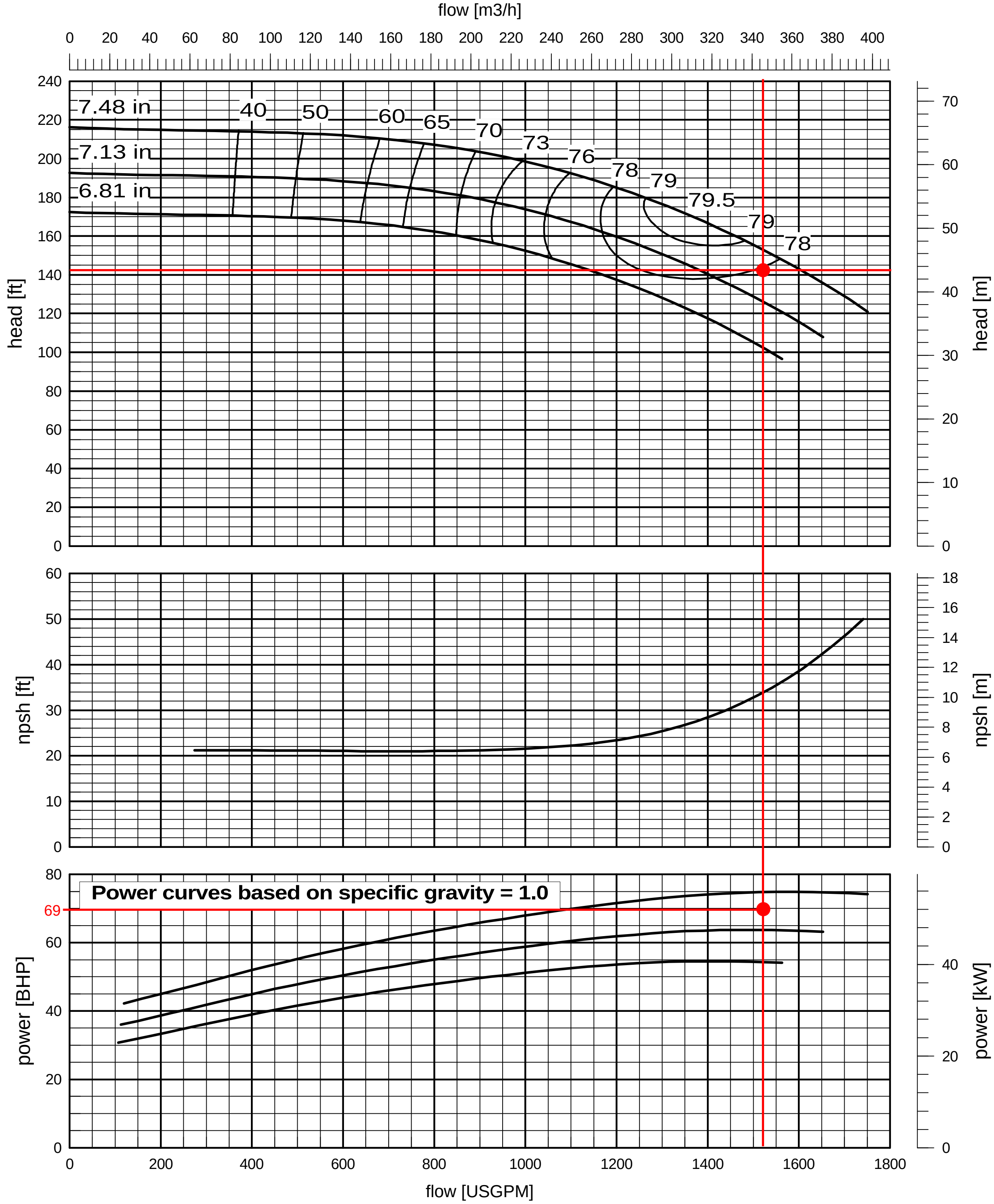


# 6 x 6 x 7.5 -1 OHH

**SULZER**

**Series 2.00 / 60Hz E009**

| | | | | |
|---|---|---|---|---|
| **Curve No** | **OHH 46-1-1-02** | **NSS** | **10970 (212)** | Speed |
| **Efficiency Basis** | **API Std. clearances** | **NS** | **2790 (54)** | **3550** |
| **Max Solid** | **.31 in (8 mm)** | **Rotation** | **CCW viewed from coupling** | rpm |

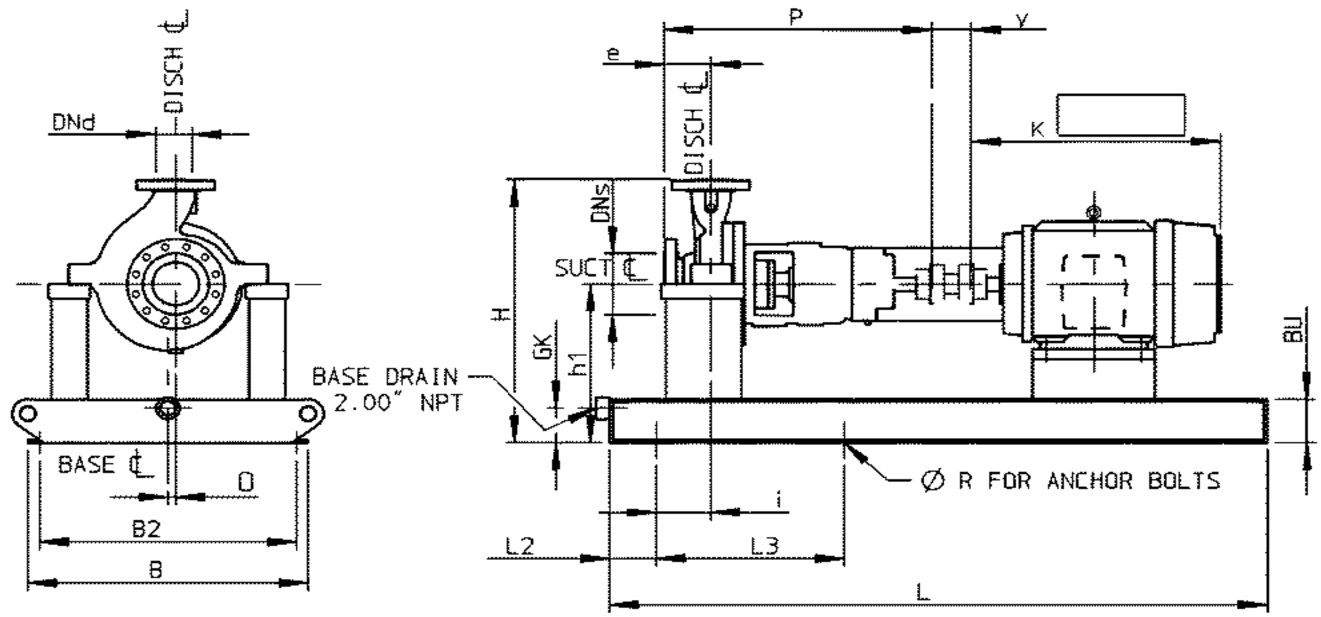



| **Rated Conditions** | | |
|---|---|---|
| Project | Item | |
| H = | Q = | P = |
| Calculated Efficiency = | | $NPSH_{3\%}$ = |
| | | **Issued: MSC / 05.13.2002** |

# SULZER

## DIMENSIONAL DATA - TYPE OHH

**General Arrangement Dimensions – End Suction – US Customary Units**




**Certified by :**________________________
**Date:** _______________ Certified for Nozzle & Anchor Bolt locations only when signed above
Ref No. : ________________________________
Project Name : ____________________________
Project Item No.: __________________________

HH -- Number of Base Hold Down Holes each side, equally spaced.
L3 -- Distance between holes.
GH -- # of Grout Holes

| API No. | Base wt lbs | B | B2 | BU | L | L2 | L3 | R | GK | HH | GH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.5** | 800 | 30 | 27 | 6 | 72.5 | 6 | 30.25 | 1 | 4.75 | 3 | 4 |
| **2.0** | 930 | 30 | 27 | 6 | 84.5 | 6 | 24.16 | 1 | 4.75 | 4 | 4 |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

Dimension K is derived from NEMA standards or motor supplier catalogue. The rotation is counterclockwise – H.I. looking from Drive End.
All dimensions are in nominal inches and for guidance only. Certified Drawings will be issued for actual construction.
**When Available** 'TS" frame should be used to minimize coupling size, there is no price difference on drivers. **WP-XXX**

| **PUMP** | **PUMP** | **DNs** | **DNd** | **O** | **B** | **e** | **P** | **h1** | **i** | **H** | **y** | **BASE REFERENCE** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SIZE** | **wt lbs** | | | | | **in** | | | | | | **(Electric Driver - NEMA Frame)** |
| **1x2x7.5-1** | 311 | 2 | 1 | 0 | 30 | 4.92 | 31.06 | 18 | **5.63** | 27.06 | 5 | 1.5 (143T-286T) (284TS-286TS) |
| **2x3x7.5A-1** | 332 | 3 | 2 | 0 | 30 | 4.92 | 31.18 | 18 | **5.38** | 27.06 | 5 | 2.0 (324T-405T) (324TS-405TS) |
| **2x3x7.5B-1** | 331 | 3 | 2 | 0 | 30 | 4.92 | 31.18 | 18 | **5.38** | 27.06 | 5 | |
| **3x4x7.5-1** | 352 | 4 | 3 | 0 | 30 | 4.92 | 31.26 | 18 | **5.36** | 27.06 | 5 | |
| **4x6x7.5B-1** | 398 | 6 | 4 | 0 | 30 | 5.51 | 32.20 | 18 | **5** | 28.04 | 5 | |
| **4x6x7.5A-1** | 399 | 6 | 4 | 0 | 30 | 5.51 | 32.20 | 18 | **5** | 28.04 | 5 | |
| **6x6x7.5-1** | 522 | 6 | 6 | 1 | 30 | 8.07 | 35.67 | 18 | **5.63** | 30.60 | 7 | 2.0 (284T-365T) (284TS-365TS) |
| **1.5x3x8-1** | 335 | 3 | 1.5 | 0 | 30 | 5.51 | 32.01 | 18 | **5.65** | 27.06 | 5 | 1.5 (143T-286T) (284TS-286TS) |
| **2x3x8-1** | 336 | 3 | 2 | 0 | 30 | 5.91 | 32.56 | 18 | **5.63** | 27.06 | 5 | 2.0 (324T-405T) (324TS-405TS) |
| **3x4x8A-1** | 360 | 4 | 3 | 0 | 30 | 6.30 | 32.83 | 18 | **5.38** | 27.45 | 5 | |
| **3x4x8B-1** | 370 | 4 | 3 | 0 | 30 | 6.30 | 33.03 | 18 | **5.63** | 27.45 | 5 | |
| **3x4x8B-2** | 370 | 4 | 3 | 0 | 30 | 6.30 | 33.03 | 18 | **5.63** | 27.45 | 5 | |
| **1x2x9-1** | 320 | 2 | 1 | 0 | 30 | 5.51 | 31.65 | 18 | **5.63** | 27.06 | 5 | |
| **1.5x3x9-1** | 334 | 3 | 1.5 | 0 | 30 | 5.51 | 31.69 | 18 | **5.63** | 27.06 | 5 | |
| **2x3x9A-1** | 338 | 3 | 2 | 0 | 30 | 5.51 | 31.73 | 18 | **5.5** | 27.45 | 5 | |
| **2x3x9B-1** | 334 | 3 | 2 | 0 | 30 | 5.51 | 31.81 | 18 | **5.63** | 27.45 | 5 | |
| **2x4x9-1** | 360 | 4 | 2 | 0 | 30 | 5.51 | 31.77 | 18 | **5.38** | 28.04 | 5 | |
| **3x4x9-1** | 374 | 4 | 3 | 0 | 30 | 5.51 | 31.85 | 20 | **7.38** | 30.43 | 5 | |
| **3x4x9-2** | 374 | 4 | 3 | 0 | 30 | 5.51 | 31.85 | 20 | **7.38** | 30.43 | 5 | |
| **3x6x9-1** | 406 | 6 | 3 | 0.5 | 30 | 5.91 | 32.32 | 20 | **7.25** | 31.02 | 5 | |
| **3x6x9-2** | 406 | 6 | 3 | 0.5 | 30 | 5.91 | 32.32 | 20 | **7.25** | 31.02 | 5 | |

## Analysis

This test proves that when all losses are accounted for the pumps HP must be higher resulting in a larger pump. We saw this when pump HP was recalculated from test 2 and adding in the minor losses before figuring the pump HP for this test and keeping the same pipe size from test 2. Proving that a larger pipe is needed through iteration to accommodate the new flow rate and pump size we showed that a 10-inch pipe was best suited.

Using moments and pressures in the system we were able to provide civil engineers with the forces in the system so they could determine how to stabilize it. Our force in the X direction was found to 2380 lbs and in the Y direction it was 54163 lbs.

When selecting pumps kinetic pumps are typically the best in most cases. They are cheaper, smaller and you can decide what flow you want with valves. When selecting a pump the information we gather led to the selection of a 6x6x7.5 pump. It has a 6-inch inlet and outlet and has a max size impeller of 7.5 inches. The impeller diameter we figured was a 7.3 inch impeller. The power required is 69 HP and the efficiency is 78% which is above our 60% needs. The total size and weight of the pump is 84.5 inches by 30 inches with a weight of 930 pounds.

| | | | | |
|---|---|---|---|---|
| **Pipe Info** | | | | |
| Ldisch | 2500 | ft | | |
| Lsuct | 11 | ft | | |
| $\varepsilon$ | 1.50E-04 | ft | | |
| z2 | 50 | ft | | |
| z1 | 0 | ft | | |
| z3=z4 | 10 | ft | | |

SELECTING -> 8 in Schedule 40 Steel Pipe from 2nd test (Appendix K)

| | | |
|---|---|---|
| D | 0.6651 | ft |
| A | 0.3472 | $ft^2$ |

| | | |
|---|---|---|
| **Pump Info** | | |
| Initial Q | 3.387 | $ft^3/s$ |
| $\eta$ | 0.6 | |
| **Fluid Info** | | |
| $\nu$ | 1.21E-05 | $ft^2/s$ |
| $\gamma$ | 62.4 | $lb/ft^3$ |
| **General Info** | | |
| g | 32.2 | $ft/s^2$ |

**ENERGY LOSSES**

| | | |
|---|---|---|
| v | 9.755 | ft/s |
| Re | 5.36E+05 | |
| D/$\varepsilon$ | 4.43E+03 | |
| f | 0.01566 | |
| $f_T$ | 0.014 | |
| $K_{entrance}$ | 0.78 | |
| $K_{exit}$ | 1.00 | |
| $K_{valve}$ | 0.11 | |
| $K_{elbow}$ | 0.42 | |

| | | |
|---|---|---|
| h_entrance | 1.153 | ft |
| h_exit | 1.478 | ft |
| h_valve | 0.166 | ft |
| h_elbow | 1.871 | ft |
| h_suction= | 0.383 | ft |
| h_discharge= | 86.972 | ft |
| h_1-2= | 92.022 | ft |

| | | | | | |
|---|---|---|---|---|---|
| | PUMP HEAD | hA= | 142.022 | ft | |
| a-i | PUMP POWER | P= | 50026.99 | lb x ft/s | <---- with minor losses |
| | | **P=** | **91.0** | **HP** | |

**Pipe Info**

| | | |
|---|---|---|
| Ldisch | 2500 | ft |
| Lsuct | 11 | ft |
| ε | 1.50E-04 | ft |
| z2 | 50 | ft |
| z1 | 0 | ft |
| z3=z4 | 10 | ft |

SELECTING -> 8 in Schedule 40 Steel Pipe from 2nd test (Appendix K)

| | | |
|---|---|---|
| D | 0.6651 | ft |
| A | 0.3472 | $ft^2$ |

**Pump Info**

| | | |
|---|---|---|
| Initial Q | 3.387 | $ft^3/s$ |
| increased Q | 5.081 | $ft^3/s$ |
| η | 0.6 | |

**Fluid Info**

| | | |
|---|---|---|
| ν | 1.21E-05 | $ft^2/s$ |
| γ | 62.4 | $lb/ft^3$ |

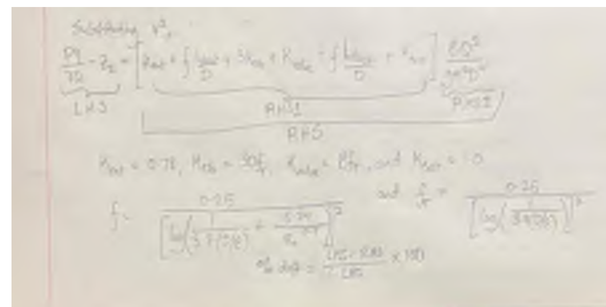
**General Info**

| | | |
|---|---|---|
| g | 32.2 | $ft/s^2$ |

**ENERGY LOSSES**

| | | |
|---|---|---|
| v | 14.633 | ft/s |
| Re | 8.04E+05 | |
| D/ε | 4.43E+03 | |
| f | 0.01523 | |
| $f_T$ | 0.014 | |
| $K_{entrance}$ | 0.78 | |
| $K_{exit}$ | 1.00 | |
| $K_{valve}$ | 0.11 | |
| $K_{elbow}$ | 0.42 | |

| | | |
|---|---|---|
| h_entrance | 2.593 | ft |
| h_exit | 3.325 | ft |
| h_valve | 0.374 | ft |
| h_elbow | 4.211 | ft |
| h_suction= | 0.837 | ft |
| h_discharge= | 190.310 | ft |
| h_1-2= | 201.650 | ft |




PUMP HEAD hA= 251.650 ft LHS= 44.681 ft

a-i PUMP POWER P= 50026.99 lb x ft/s <---- with minor losses

**P= 91.0 HP**

a-ii P= 132964.93 lb x ft/s <---- increased flow rate ai

**P= 241.8 HP**

| Iteration | D (ft) | V (ft/s) | Re | D/ε | f | fT | RHS1 | RHS2 | RHS | %diff |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 6.4687 | 5.35E+05 | 6.67E+03 | 0.0149 | 0.0130 | 40.5185 | 0.649751 | 26.32694 | 41.08% |
| 2 | 0.5 | 25.8748 | 1.07E+06 | 3.33E+03 | 0.0157 | 0.0149 | 82.1512 | 10.396024 | 854.04629 | -1811.41% |
| 3 | 1.2 | 4.4921 | 4.46E+05 | 8.00E+03 | 0.0149 | 0.0125 | 34.2622 | 0.313345 | 10.73587 | 75.97% |
| 4 | 1.05 | 5.8673 | 5.09E+05 | 7.00E+03 | 0.0149 | 0.0128 | 38.7101 | 0.534552 | 20.69254 | 53.69% |
| 5 | 1 | 6.4687 | 5.35E+05 | 6.67E+03 | 0.0149 | 0.0130 | 40.5185 | 0.649751 | 26.32694 | 41.08% |
| 6 | 0.9 | 7.9860 | 5.94E+05 | 6.00E+03 | 0.0150 | 0.0132 | 44.8037 | 0.990324 | 44.37013 | 0.70% |
| 7 | 0.899 | 8.0038 | 5.95E+05 | 5.99E+03 | 0.0150 | 0.0132 | 44.8518 | 0.994738 | 44.61581 | 0.15% |
| 8 | 0.8989 | 8.0056 | 5.95E+05 | 5.99E+03 | 0.0150 | 0.0132 | 44.8567 | 0.995180 | 44.64047 | 0.09% |
| **9** | **0.8988** | **8.0074** | **5.95E+05** | **5.99E+03** | **0.0150** | **0.0132** | **44.8615** | **0.995623** | **44.66514** | **0.04%** |
| 10 | 0.89881 | 8.0072 | 5.95E+05 | 5.99E+03 | 0.0150 | 0.0132 | 44.861 | 0.995579 | 44.66267 | 0.04% |

Min. Diameter

0.8988 ft 10.7856 in

a-iii SELECTING --> 10 in Schedule 40 Steel pipe

10.7856 in

| | | |
|---|---|---|
| **D** | **0.835** | **ft** |
| **A** | **0.5479** | **$ft^2$** |

| | | |
|---|---|---|
| **Pipe Info** | | |
| Ldisch | 2500 | ft |
| Lsuct | 11 | ft |
| $\varepsilon$ | 1.50E-04 | ft |
| z2 | 50 | ft |
| z1 | 0 | ft |
| z3=z4 | 10 | ft |
| z5 | 30 | ft |

SELECTING -> 8 in Schedule 40 Steel Pipe from 2nd test (Appendix K)

| | | |
|---|---|---|
| D | 0.6651 | ft |
| A | 0.3472 | $ft^2$ |

| | | |
|---|---|---|
| **Pump Info** | | |
| Initial Q | 3.387 | $ft^3/s$ |
| $\eta$ | 0.6 | |
| **Fluid Info** | | |
| $\nu$ | 1.21E-05 | $ft^2/s$ |
| $\gamma$ | 62.4 | $lb/ft^3$ |
| **General Info** | | |
| g | 32.2 | $ft/s^2$ |

**ENERGY LOSSES**

| | | |
|---|---|---|
| v | 9.755 | ft/s |
| Re | 5.36E+05 | |
| D/$\varepsilon$ | 4.43E+03 | |
| f | 0.01566 | |
| $f_T$ | 0.014 | |
| $K_{entrance}$ | 0.78 | |
| $K_{exit}$ | 1.00 | |
| $K_{valve}$ | 0.11 | |
| $K_{elbow}$ | 0.42 | |

| | | |
|---|---|---|
| h_entrance | 1.153 | ft |
| h_exit | 1.478 | ft |
| h_valve | 0.166 | ft |
| h_elbow | 1.871 | ft |
| h_suction= | 0.383 | ft |
| h_discharge= | 86.972 | ft |
| h_1-2= | 92.022 | ft |

PUMP HEAD hA= 142.022 ft

PRESSURE AT OUTLET

| | | |
|---|---|---|
| p4 | 8011.250 | lb/ft2 |
| p4 | 55.634 | psi |

PRESSURE AT THE ELEVATED OPEN CHANNEL INLET

| | | |
|---|---|---|
| p5 | 1155.795 | lb/ft2 |
| p5 | 8.026 | psi |

REACTION AT X-AXIS

| | | |
|---|---|---|
| Rx | -2380.214 | lb |

REACTION AT Y-AXIS

| | | |
|---|---|---|
| Ry | 54163.200 | lb |