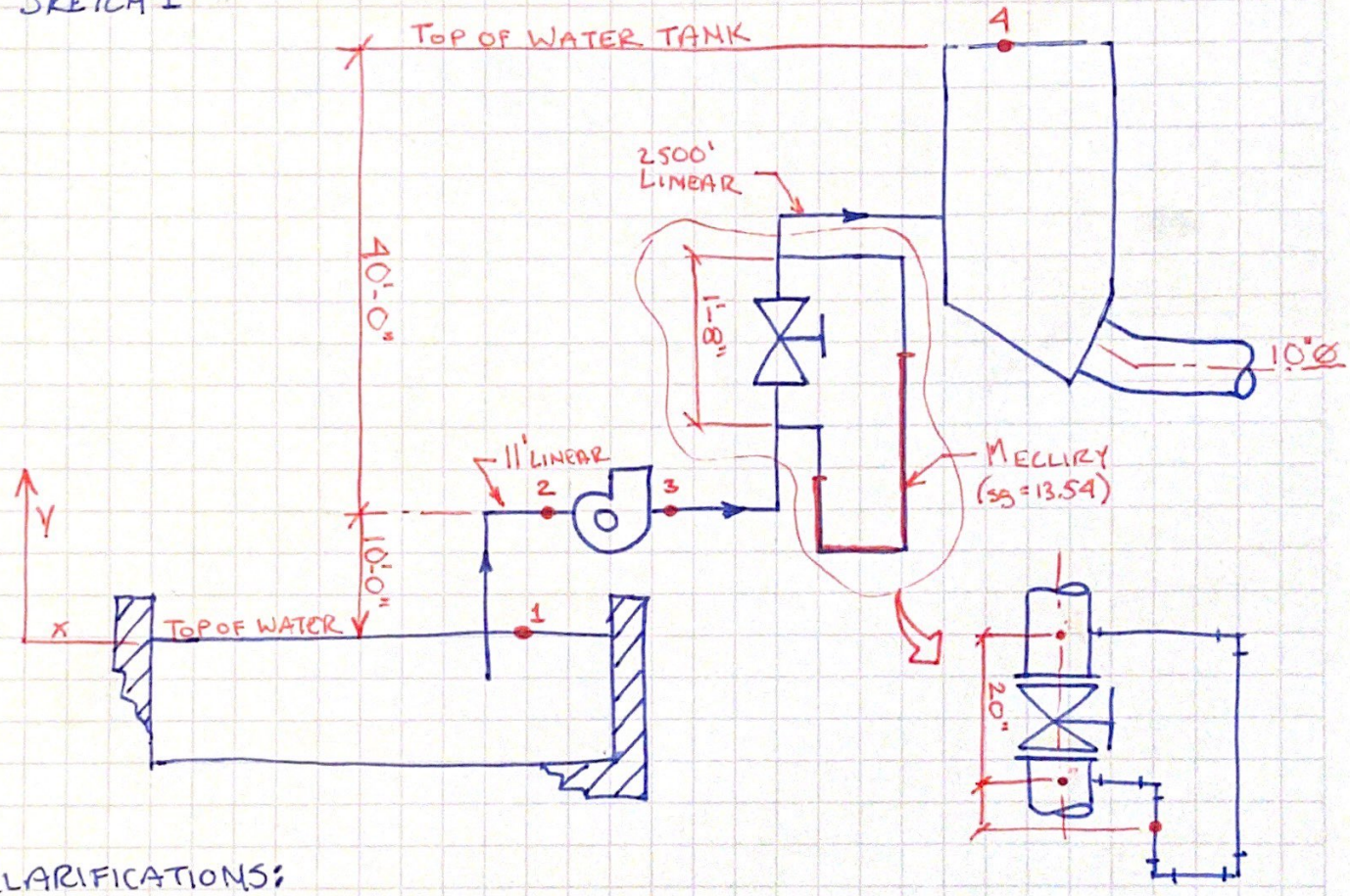
CUSTOMER: TEST 1 DATE: 2-17-21 PROJECT NO. 330

TITLE: BY: CRO REFERENCE NO.

DESCRIPTION: CKD: REV:

SKETCH 1



CLARIFICATIONS:

- TOPO CONTOURS OF LOWER OPEN CHANNEL IS NEGLIGBLE.
- THE 10" PIPE DOES NOT OPEN
- NO DIMENSIONS ON UPPER VESSEL ARE NECESSARY.
  ~~- OR, WE DO NEED TO DETERMINE WHERE THE BOTTOM OF UPPER VESSEL IS LOCATED IN REFERENCE TO POINT 1 (NOT POSSIBLE W/ OUT MORE INFO)~~
- ~~"OPEN PIPE" BUT CLOSED NOZZLE ("CIRCULAR GATE")~~

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(a) PURPOSE:
- DETERMINE THE REQUIRED PUMP POWER hp.
- CREATE EXCEL CALCULATOR TO AUTOPOPULATE SOLUTIONS.
- SELECT PIPE DIAMETER FROM TABLE F1. SELECT DIAMETER SUCH THAT FLUID FLOW VELOCITY IN PIPE IS CLOSE TO 3 m/s => 9.84251969 ft/s
* SEE SKETCH ON PAGE 1
- COMPANY REQUIRES 3.387 ft^3/s FROM LOWER TO UPPER

SOURCES: MOTT & UNTENER. APPLIED FLUID MECHANICS. 7th EDITION. PEARSON 2015

DESIGN CONSIDERATIONS:
- ASSUMED THE FOLLOWING W/ GIVEN DATA:
1. INCOMPRESSIBLE FLUIDS
2. STEADY STATE
3. ISOTHERMAL W/ T = 60°F
4. 3.387 ft^3/s DELIVERED
5. OPEN CHANNEL FLOW
6. WATER & MERCURY DO NOT MIX

VARIABLES: $\gamma_w = 62.4$ $\eta_w = 2.35 \times 10^{-5}$ $\nu_w = 1.21 \times 10^{-5}$ CHANGED TO 9.7552 ft/s w/ 8" Ø SCH40

$e_M = 60\%$ SUCTION: 11ft DISCHARGE: 2500ft

$K_p = 5.3$ P_{ATM}: 14.7 psia $V = 3$ m/s = 9.8425 ft/s (TABLE 10.4)

$Q = 3.387\ ft^3/s$ 8"Ø SCH 40 f_T = .014 (TABLE 10.5) 90° ELL $L_e/D = 30$

$SS_{HG} = 13.54$ MANOMETER TAPS: 20in APART

MATERIALS: WATER, SCH 40 STEEL PIPE, MERCURY

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PROCEDURE & CALCULATION

- REFERENCE POINTS NEED PLACED FIRST.
- USE BERNOULLI'S EQUATION W/ ENERGY LOSSES & PUMP HEAD.

$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_{L12}$$

- FIND LOSSES (FRICTION) DUE TO PIPE, FITTINGS, VALVE
- I AM ASSUMING NO LOSSES DUE TO MANOMETER BRANCHES
- PUMP POWER w/ 60% EFFICIENCY

$$P = \frac{\gamma Q h_A}{(.6)}$$

- FIND PIPE AREA => DETERMINES SIZE

$Q = VA \Rightarrow$

$3.387 \frac{ft^3}{s} = 9.8425 \frac{ft}{s} A$

$A = .3442 ft^2$

FLOW AREA = $.3472 ft^3$ 8"Ø

$3.387 \frac{ft^3}{s} = .3472 ft^3 V$

$9.7552 ft/s$

SOLVE FOR PRESSURE AT POINT 2

$$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} - h_{L12} = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g}$$

$$\frac{P_2}{\gamma} = (Z_1 - Z_2) - \frac{V_2^2}{2g} - h_{L12}$$

$$\frac{P_2}{62.4} = -10ft - \frac{(9.8425)^2}{2(32.2)} - h_{L12}$$

NEED TO SOLVE FOR h_{L12}

→ INDUSTRY STANDARD IS 90 LONG RADIUS OR 90 SHORT RADIUS
LR ELL = 1.5R
SR ELL = 1R
(I WILL USE BOOK'S "STANDARD RADIUS")

8"Ø SCH40 => $f_T = .014$

90° ELL $L_e/D = 30 \Rightarrow K = (L_e/D) f_T = 30(.014) = .42$

$$h_L = K \cdot \frac{v^2}{2g} \Rightarrow .42 \cdot \frac{(9.7522)^2}{2(32.2)} = .62 ft$$

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USING DARCY EQUATION TO FIND h_L

$f_T = .014$ (10.5)

$D = .6651$ ft. pg 500

$$h_L = .014 \cdot \frac{11\text{ft}}{.6651\text{ft}} \cdot \frac{9.7552\text{ft/s}^2}{2(32.2)}$$

$* h_L = .342$ ft

BACK TO SOLVING $P_1 - P_2$

$$\frac{P_2}{62.4} = -10\text{ft} - \frac{(9.7552)^2}{2(32.2)} - .342\text{ ft} - .62\text{ft}$$

$$P_2 = -776.237 \text{ lb/ft}^2 \times \frac{1\text{ psi}}{144 \text{ lb/ft}^2} = -5.39 \text{ psi}$$

$P_2 = -5.39$ psi

SOLVING $P_3 - P_4$, BERNOULLI

$$\frac{P_3}{\gamma} + z_3 + \frac{v_3^2}{2g} - h_{L3-4} = \frac{P_4}{\gamma} + z_4 + \frac{v_4^2}{2g}$$

$$\frac{P_3}{\gamma} = (z_4 - z_3) - \frac{v_3^2}{2g} + h_{L3-4}$$

$$\frac{P_3}{62.4} = -40\text{ft} - \frac{(9.7552)^2}{2(32.2)} + h_{L3-4}$$

SOLVE FOR LOSSES $P_3 - P_4$

8"Ø SCH 40 $\Rightarrow f_T = .014$

90° ELL $L_e/D = 30 \Rightarrow K = (L_e/D) f_T = 30(.014) = .42(2) \Rightarrow .84 . \frac{(9.7522^2)}{2(32.)} = 1.24$ ft

VALVE $K = 5.3 \Rightarrow 5.3 . \frac{(9.7522^2)}{2(32.)} = 7.827$ ft.

USING DARCY EQUATION TO FIND h_L 8"Ø

$$.014 . \frac{2500}{.6651} . \frac{(9.7522^2)}{2(32.2)} = 77.714\text{ft}$$

TOTAL $h_{L3-4} = 1.24 + 7.827 + 77.714 = 86.781$ ft

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CONTINUE SOLVING P3-P4

$$\frac{P_3}{62.4} = -40ft - \frac{(9.7522^2)}{2(32.2)} + 86.781ft$$

$$P_3 = 2826.983 \times \frac{1psi}{144\,lb/ft^2} = 19.63\,psi$$

$$P_3 = 19.63psi$$

SOLVE FOR REQUIRED PUMP POWER hp 1hp = 550 lb ft/s

- THE REQUIRED POWER IS FOUND BY ADDING UP CHANGE IN ELEVATION P1 - P4 AND ADDING THE SUM OF THE LOSSES

$$h_A = h_{L3-4} + h_{L1-2} + z_4 - z_1$$

$$h_A = 86.781ft + 1.04ft + (50-0)ft$$

$$h_A = 137.821ft$$

$$P = \frac{\gamma Q h_A}{em} \qquad \frac{62.4(3.387ft^3/s)(137.821ft)}{.6} \times \frac{1hp}{550lbft/s}$$

$$\boxed{P = 88.3\,hp}$$

SUMMARY THE PUMP WILL REQUIRE 88.3hp FOR GIVEN FLOW RATE 3.387ft³/s

ANALYSIS THE PRESSURE DID NOT NEED CALCULATED TO SOLVE FOR HEAD LOSS TO PUMP.

ALL LOSSES ARE A FUNCTION OF VELOCITY.

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(b) PURPOSE: - TO FIND VALVE PERFORMANCE, USE PRESSURE DIFFERENTIAL METER. ENERGY LOSSES IN VALVE CAN BE FOUND BY COMPUTING

$$\frac{\Delta p}{\gamma} = K\frac{V^2}{2g}$$

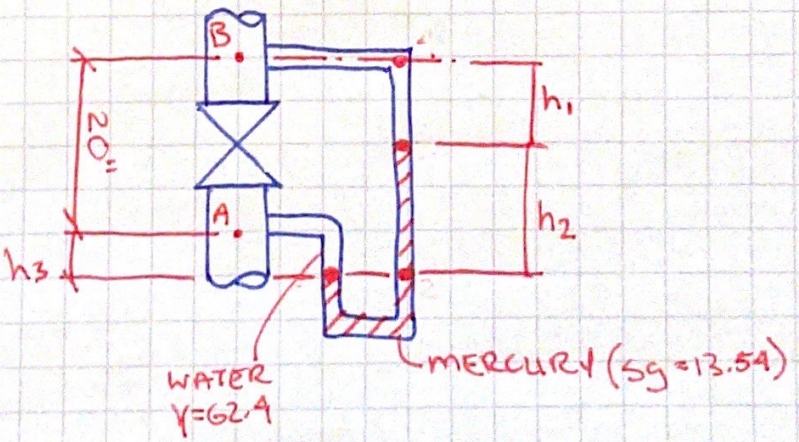
- CREATE EXCEL CALCULATOR
* SEE SKETCH ON PAGE 1. SEE REFERENCE DATA, VARIABLES, DESIGN CONSIDERATIONS & MATERIAL ON PAGE 2

PROCEDURE: - NEW REF. POINTS WILL BE CREATED FOR LOCAL CALCULATION (REFERED TO AS "h")

* - HOW CAM I CALCULATE WITHOUT AMOTHER ↓ h DIMENSION PROVIDED?
* - IT IS EXPOSED TO AN ATMOSPHERIC PRESSURE AT POINT 2 ON UPPER VESSEL
- USE INCREMENT OF PRESSURE

$$\Delta p = \gamma * h$$

SKETCH 2



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CALCULATIONS:

$$20" + h_3 = h_1 + h_2$$

$$P_A + \gamma_w h_3$$

$$P_A + \gamma_w h_3 - \gamma_{HG} h_2$$

$$P_A + \gamma_w h_3 - \gamma_{HG} h_2 - \gamma_w (20" + h_3) = P_B$$

SPECIFIC WEIGHT OF WATER & MERCURY

$$\gamma_{HG} = 13.54(62.4) = 844.896$$

$$P_B - P_A = \gamma_w h_3 - \gamma_{HG} h_2 - \gamma_w (20" + h_3)$$

$$= 62.4 h_3 - 844.896 h_2 - 62.4(20") - 62.4 h_3$$

$$P_B - P_A = -844.896 h_2 - 1248" \quad (104')$$

GIVEN: $\frac{\Delta P}{\gamma} = K \frac{V^2}{2g} \Rightarrow \Delta P = 5.3 \cdot 62.4 \cdot \frac{9.7522^2}{2(32.2)}$

$$\Delta p = 488.4 \frac{lb}{ft^2}$$

$$\therefore \quad 488.4 \frac{lb}{ft^2} = -844.896 h_2 - 1248 in \cdot \frac{1 ft}{12 in}$$

$$h_2 = -.701 ft \cdot \frac{12 in}{1 ft}$$

$$\boxed{h_2 = -8.41 in}$$

$$h_2 = \frac{\Delta p + \gamma_w \left(\frac{20"}{12}\right)}{-\gamma_{HG}}$$

CUSTOMER: TEST 1 DATE: 2-26-21 PROJECT NO. 330

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DESCRIPTION: CKD: REV:

SUMMARY: THE MANOMETER IS DIFLECTING FROM STATIC REST - 8.41 IN, OR -8.41 IN. IN RESPECT TO FLOW AND Z COORDINATE

ANALYSIS: LARGER PRESSURES ACROSS PA WILL FORCE h_2 TO INCREASE IN MAGNITUDE.