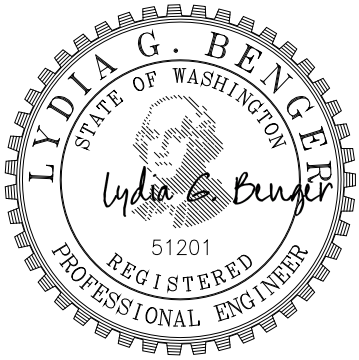
NEW RIVER CLASS FERRY

Piping System and Mechanical Calculations

Prepared for: NCDOT • Raleigh, North Carolina

Ref: 16101-200-505-1 Rev. - August 3, 2017



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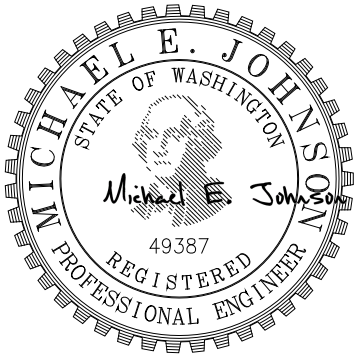

8/7/2017

Elliott Bay Design Group
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REVISIONS

REV	DESCRIPTION	DATE	APPROVED
-	Initial issue	08/2/17	LGB 51201 MEJ 49387

GENERAL NOTES

1. P.E. stamp applies to the EBDG engineered sections of this report as shown in the following table:

Professional Engineer	**Applicable Appendices**
Lydia Benger	Appendices B,D,G,H,I,J,K, and L
Michael Johnson	Appendices A,C, E and F

TABLE OF CONTENTS

1 PURPOSE

This report documents the calculations used to devleop of the machinery and piping systems for the NEW RIVER CLASS FERRY, a design for the North Carolina Department of Transportation. The subject vessel is a 183 foot 7 inch long by 46 foot wide by 11 foot deep passenger and vehicle ferry intended for service within the Outer Banks of North Carolina, and the associated rivers.

The calculations relating to each specific system are presented in separate appendices. Each appendix provides the following information:

- Description of the system
- Calculation procedures
- Given and assumed parameters
- Formulas and software used
- Calculation results
- References used in preparing the calculations

2 REGULATORY FRAMEWORK

The NEW RIVER CLASS FERRY will be inspected by the US Coast Guard under the provisions of 46 CFR Subchapter H. Piping and mechanical system designs shall comply with the applicable regulations.

Appendix A

Shaft Arrangement, Dwg. 16101-200-243-1

1 DESCRIPTION

This appendix documents the shafting calculations used to determine minimum shaft diameters for the shafting arrangement.

2 PROCEDURE

Calculations were performed in accordance with [1].

3 REGULATORY FRAMEWORK

The NEW RIVER CLASS FERRY will be USCG inspected under the provisions of 46 CFR Subchapter H.

4 GIVEN AND ASSUMED PARAMETERS

- Maximum propeller input speed is 670 RPM [2]
- Chosen reduction gear ratio is 2.5:1
- Main engines are rated 600 HP at 1800 RPM [3]
- Full power will be delivered to propeller at 1675 RPM or higher

5 FORMULAS

(not used)

6 CALCULATIONS

6.1 Line shaft between reduction gear and cycloidal propeller

The minimum calculated shaft diameter is 3.74in. The chosen line shaft diameter is 4.5 inches to maintain commonality with similar vessels in the NCDOT fleet.

6.2 Line shafts between engine and reduction gear

The minimum calculated shaft diameter is 2.77 in. A 3-inch nominal shaft diameter was chosen pending final equipment selections and detail design.

7 REFERENCES

[1] American Bureau of Shipping, *Rules for Building and Classing Steel Vessels Under 90 Meters (295 feet) in Length 2017,* Houston, Texas, 2016.

[2] L. Erdman (2017, Apr. 7), *16101: NC Ferry VSP's,* lee.erdman@voith.com, 4/7/2017.

[3] Caterpillar, "C18 Performance Data [EM0268]," 3/8/17.

LINE SHAFT BETWEEN REDUCTION GEAR AND PROPELLER

APPROACH

Calculation of required shaft diameter according to ABS Rules for Building and Classing Steel Vessels Under 90 m, for line shaft between reduction gear and cycloidal propeller

ASSUMPTIONS

1 Shafting is ABS Grade 2, mininmum
2 Engine is rated for 600 HP @ 1800 RPM, max power delivered to propller at 1675 RPM or higher
3 98.5% Gear efficiency assumed

INPUTS

Unit System used in this calculation: US

Solid Shaft Inputs

	1675	RPM	Engine Speed	Ref 2
	600	HP	Engine power at rated speed	Ref 2
	2.5		Reduction Gear Ratio	
	0.985		Reduction Gear Efficiency	
H =	591	HP	Shaft power at rated speed	
R =	670.0	RPM	Rated speed	
K =	1.100		Shaft design factor from 4-3-1/Table 1or 4-3-1/Table 2	Ref 1
U =	60000	psi	Minimum specified ultimate tensile strength	Ref 1, 4-3-1/7.3
c_1 =	3.695		(coefficient for vessel over 150' in length)	Ref 1, 4-3-1/7.1
c_2 =	23180		(imperial units coefficient)	

CALCULATION OF SOLID SHAFT DIAMETER Ref 1, 4-3-1/7.1

The minimum diameter of propulsion shafting is to be determined by the following equation:

$$D = 100 \cdot K \cdot \sqrt[3]{\frac{H}{R} \cdot \frac{c_1}{U + c_2}}$$

H =	591.0	HP
K =	1.100	
R =	670.00	RPM
U =	60000	psi
c_1 =	3.695	
c_2 =	23180	

D = 3.74 in = 94.90 mm

NOTES

Chosen shaft diameter = 4.5in OD

REFERENCES

1) *ABS Rules for Building and Classing Steel Vessels Under 90m (295ft) 2017*
2) *CAT C18 Performance Data, EM0268*

LINE SHAFTS BETWEEN ENGINE AND REDUCTION GEAR

APPROACH

Calculation of required shaft diameter according to ABS Rules for Building and Classing Steel Vessels Under 90 m, for line shaft between engine and reduction gear.

ASSUMPTIONS

1 Shafting is ABS Grade 2, minimum
2 Engine is rated for 600 HP @ 1800 RPM, max power delivered to propller at 1675 RPM or higher

INPUTS

Unit System used in this calculation: US

Solid Shaft Inputs

	1675	RPM	Engine Speed	Ref 2
	600	HP	Engine power at rated speed	Ref 2
	1		Reduction Gear Ratio (no reduction)	
	1		Reduction Gear Efficiency (no reduction)	
H =	600	HP	Shaft power at rated speed	
R =	1675.0	RPM	Rated speed	

K =	1.100		Shaft design factor from 4-3-1/Table 1or 4-3-1/Table 2	Ref 1
U =	60000	psi	Minimum specified ultimate tensile strength	Ref 1, 4-3-1/7.1
c_1 =	3.695		(coefficient for vessel over 150' in length)	Ref 1, 4-3-1/7.1
c_2 =	23180		(imperial units coefficient)	

CALCULATION OF SOLID SHAFT DIAMETER Ref 1, 4-3-1/7.1

The minimum diameter of propulsion shafting is to be determined by the following equation:

$$D = 100 \cdot K \cdot \sqrt[3]{\frac{H}{R} \cdot \frac{c_1}{U + c_2}}$$

H =	600.0	HP
K =	1.100	
R =	1675.00	RPM
U =	60000	psi
c_1 =	3.695	
c_2 =	23180	

D = 2.77 in = 70.28 mm

NOTES

Chosen shaft diamger = 3in

REFERENCES

1) *ABS Rules for Building and Classing Steel Vessels Under 90m (295ft) 2017*
2) *CAT C18 Performance Data, EM0268*

Appendix B

Cooling System, Dwg. 16101-200-256-1

1 DESCRIPTION

This appendix documents the first principles calculations used in designing the cooling system. These calculations are used to identify steady state frictional losses throughout the piping system and to validate system design.

2 PROCEDURE

Calculations are presented in the following sequence:

- Pipe size calculations
- Main engine cooling system pressure calculations
- Generator engine cooling system pressure calculations

Frictional losses through the piping system are calculated by constructing a model using PIPE-FLO Professional software utilizing the Darcy Weisbach method.

3 GIVEN AND ASSUMED PARAMETERS

- The cooling system is to be constructed of Schedule 40 carbon steel pipe.
- Pressure drop through each cooler is assumed to be constant across the coolant flow range available from each engine. From [1], [2], and [3], the pressure drop through each of the various keel coolers are as follows:

Cooler	Pressure Drop
Main Engine JW	3.5 psi at 78 gpm
Main Engine SCAC	2.5 psi at 97 gpm
Generator JW	2.5 psi at 86 gpm
Generator SCAC	2.5 psi at 40 gpm

- Each main engine is supplied with an engine mounted, full flow, gear oil cooler which contributes an additional 5 psi drop to the main engine after cooler circuit.
- The fluid in the system is assumed to be a fresh water glycol mixture with a viscosity of 0.9199 cp and a density of 64.75 lbs/cu ft.
- Piping system lengths, routing, fittings, etc. are estimated based on [4] and [5].
- References [6], [7], [8] and [9] provide pump data used to construct the engine cooling models.

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Pipe Size Calculations

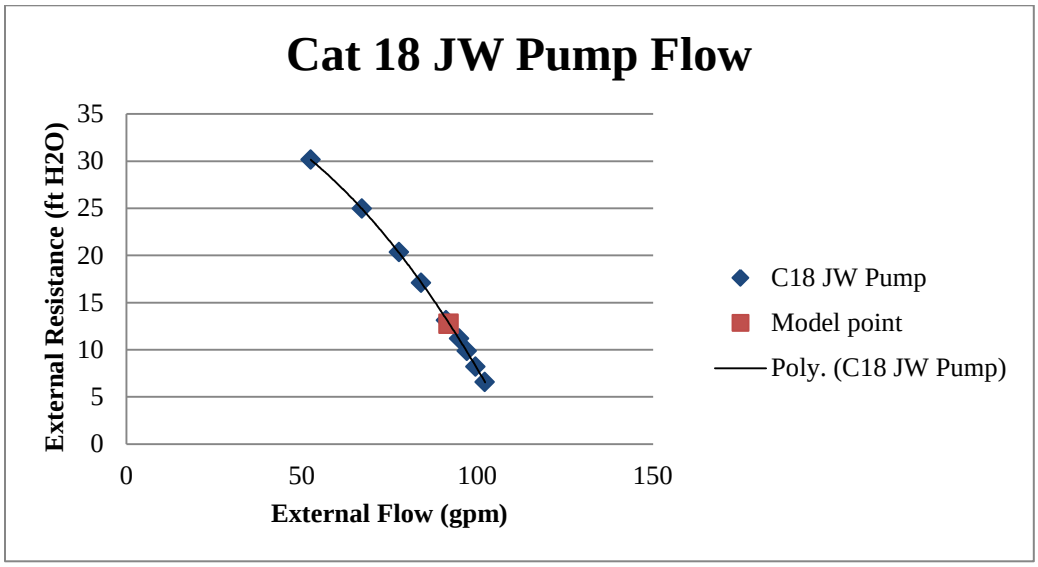
Pipe sizes are based on the nominal velocity limits found in Marine Engineering, Chapter 20, Table 3, [10]. The following table shows the flow rates of cooling water occurring in the system, and the resulting pipe sizes.

Pipe Segment	Flow Rate gpm	Pipe Size (NPS)	ID in	Design Velocity (ft/s) Nominal	Limit	V ft/s
Main Engine JW Circuit	102	2 1/2" SCH 40	2.47	7.86	15.00	6.65
Main Engine SCAC Circuit	104	2 1/2" SCH 40	2.47	7.86	15.00	6.78
Generator JW Circuit	75	2" SCH 40	2.07	7.19	15.00	6.96
Generator SCAC Circuit	44	2" SCH 40	2.07	7.19	15.00	4.09

5.2 Main Engine Cooling System Pressure Calculations

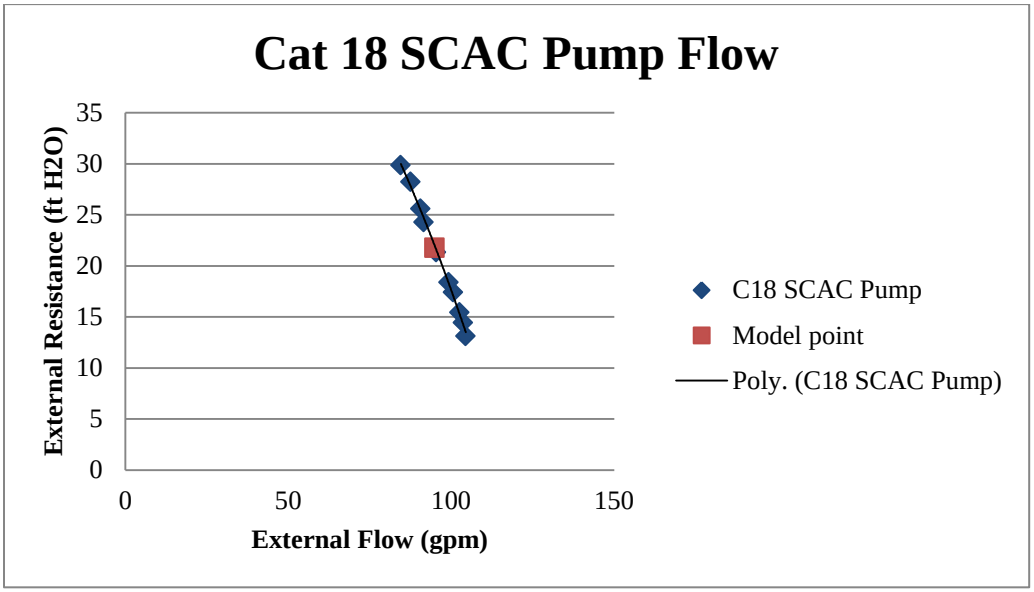
As shown in the attached pipeflo model of the off-engine jacket water circuit piping for the main engine, the calculated pressure drop is 12.7 feet H2O resulting in a flow rate of 91.8 gpm. As shown in Figure 5-1, this is comfortably within the operating range of the pump.

Figure 5-1: Main Engine Jacket Water Circuit



As shown in the attached pipeflo model of the off-engine aftercooler circuit piping for the main engine, the calculated pressure drop is 21.8 feet H2O resulting in a flow rate of 94.9 gpm. As shown in Figure 5-2, this is comfortably within the operating range of the pump.

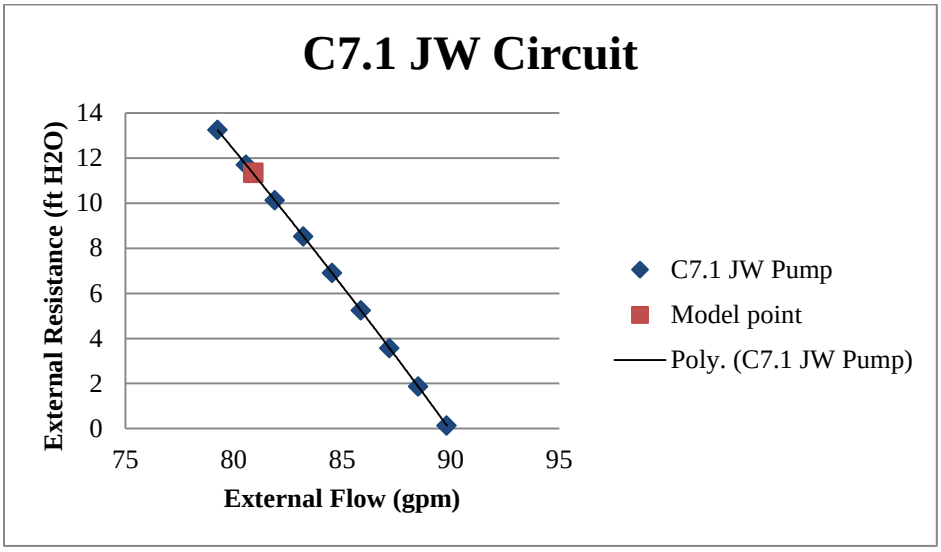
Figure 5-2: Main Engine After Cooler Circuit



5.3 Generator Engine Cooling System Pressure Calculations

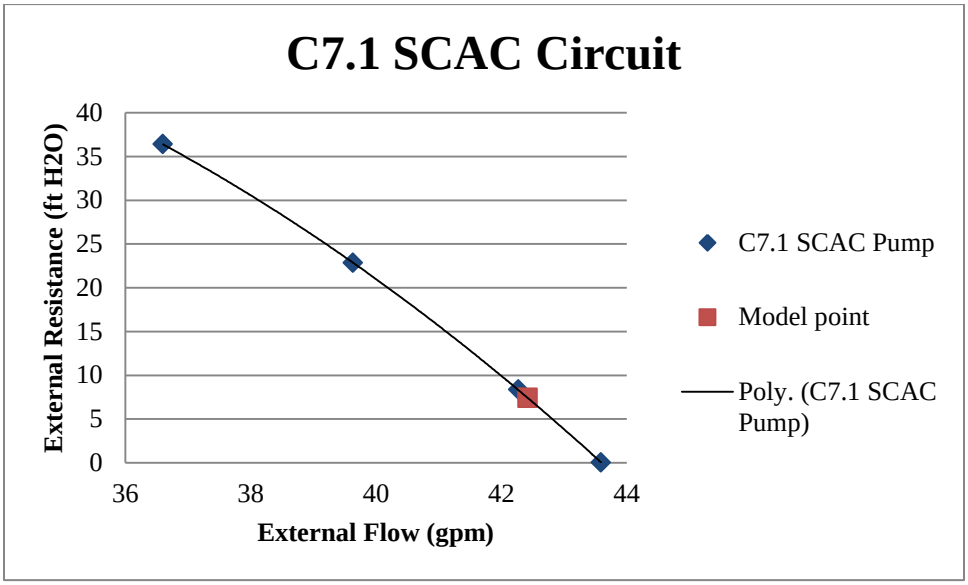
As shown in the attached pipeflo model of the off-engine jacket water circuit piping for the generator engine, the calculated pressure drop is 11.3 ft H2O psi resulting in a flow rate of 80.9 gpm. As shown in Figure 5-3, this is comfortably within the operating range of the pump.

Figure 5-3: Generator Jacket Water Circuit



As shown in the attached pipeflo model of the off-engine aftercooler circuit piping for the generator engine, the calculated pressure drop is 7.4 ft H2O resulting in a flow rate of 42.4 gpm. As shown in Figure 5-4, this is comfortably within the operating range of the pump.

Figure 5-4: Generator After Cooler Circuit



6 REFERENCES

[1] Fernstrum, Elliott Bay Passenger Ferry Quote#JFQ030917-2, 3/9/17.

[2] Fernstrum, Elliott Bay Passenger Ferry Quote#JFQ071217-1, 7/12/17.

[3] J. Friendshuh, "Email: RE: RWF QUOTE JFQ071217-1 16101 Passenger Ferry Gen Set," joef@fernstrum.com, 7/14/17.

[4] Elliott Bay Design Group, "NCDOT New River Class Ferry: Profiles and Arrangements," 16101-200-101-1, Seattle, WA.

[5] Elliott Bay Design Group, "NCDOT New River Class Ferry: Cooling System Schematic," 16101-200-256-1, Seattle, WA.

[6] Caterpillar, "C18 Marine IMO II & EPA Tier III SCAC engine Jacket Water Pump data EM0326," 3/8/17.

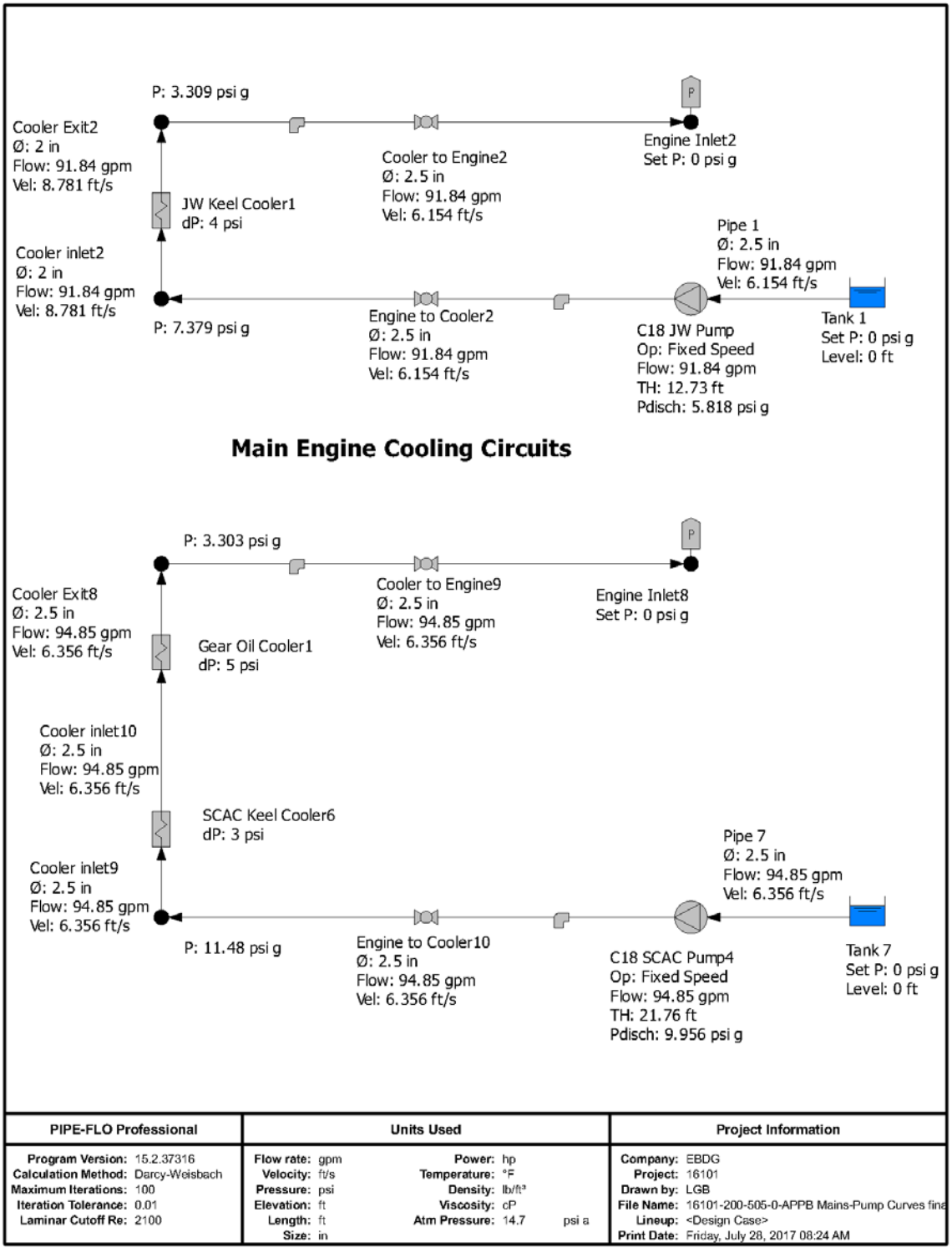
[7] Caterpillar, "C18 Marine IMO II EPA Tier III SCAC Engine SCAC pump Data EM0328," 3/8/17.

[8] Caterpillar, "C7.1 Maine Genset Data Jacket Water Pump Performance EM5101," 7/10/17.

[9] Caterpillar, "C7.1 Marine Genset Data Auxiliary Pump Performance Data EM5100," 1/11/2017.

[10] R. L. Harrington, Marine Engineering, Jersey City, NJ: SNAME, 1992.

MAIN ENGINE COOLING PIPE-FLO MODEL



List Report

File Name: 16101-200-505-0-APPB Mains-Pump Curves final.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Percent Tolerance: 0.01
Allowable Deviation: 1 %

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 08:26 AM
Atmospheric Pressure: 14.7 psi a

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria		Design Limits: Velocity	Design Limits: Pressure	Design Limits: Reynolds Number
Sch 40 Steel	Steel A53-B36.10	1.800E-03 in	0.0	Min:	ft/s	psi g	
standard	Schedule:40	140		Max:	ft/s	psi g	

Fluid Zones

Fluid Zone Name / Table Name	Temperature / Pressure	Fluid State / Relative Molecular Mass	Density / Viscosity	Vapor Pressure / Critical Pressure	Specific Heat Capacity (cp) / Specific Heat Ratio (k)
50% ethlyene glycol	120 °F	Liquid	65.98 lb/ft³	1.284 psi a	--
50% Dowtherm SR-1	0 psi g	27.24	1.653 cP	691.3 psi a	--

Centrifugal Pumps

Pump Name	Test Speed / Operating Speed	Suction Elevation / Suction Pressure	Discharge Elevation / Discharge Pressure	Total Head / dP	Flow Rate / Power	Efficiency / BEP Efficiency	NPSHa / NPSHr	Design NPSH Margin Ratio
C18 JW Pump	1946 rpm	5 ft	5 ft	12.73 ft	91.84 gpm	--	29.24 ft	--
Fixed Speed	1946 rpm	-0.01439 psi g	5.818 psi g	5.832 psi	--	--- %	--	
C18 SCAC Pump4	2160 rpm	5 ft	5 ft	21.76 ft	94.85 gpm	--	29.24 ft	--
Fixed Speed	2160 rpm	-0.01529 psi g	9.956 psi g	9.971 psi	--	--- %	--	

C18 JW Pump — Company: CAT C18 JW Pump; Curve: Manual Pump; Type: ; Size: Diameter: 2.5 in; POR: from -- to --

C18 SCAC Pump4 — Company: CAT C18 SCAC Pump; Curve: Manual Pump; Type: ; Size: Diameter: 2.5 in; POR: from -- to --

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Device / Inlet Elevation / Outlet Device / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number / Pipe Friction Factor	Inlet Total Pressure / Inlet Static Pressure / Inlet Energy Grade / Inlet Hydraulic Grade	Total dP / Total Head Loss	Outlet Total Pressure / Outlet Static Pressure / Outlet Energy Grade / Outlet Hydraulic Grade	V&F Friction Factor / V&F Resistance K / V&F dP / V&F Head Loss
Cooler Exit2	2 in	JW Keel Cooler1	91.84 gpm	3.344 psi g	0.03502 psi	3.309 psi g	0.01899
Sch 40 Steel	2.067 in	0 ft	8.781 ft/s	2.795 psi g		2.76 psi g	0.00
50% ethlyene glycol	0.5 ft	Node 6	89848	7.298 ft	0.07643 ft	7.221 ft	0 psi
		0 ft	0.02198	6.099 ft		6.023 ft	0 ft
Cooler Exit8	2.5 in	Gear Oil Cooler1	94.85 gpm	3.318 psi g	0.01529 psi	3.303 psi g	0.01821
Sch 40 Steel	2.469 in	0 ft	6.356 ft/s	3.031 psi g		3.016 psi g	0.00
50% ethlyene glycol	0.5 ft	Node 18	77688	7.242 ft	0.03336 ft	7.209 ft	0 psi
		0 ft	0.02186	6.615 ft		6.581 ft	0 ft
Cooler inlet10	2.5 in	SCAC Keel Cooler6	94.85 gpm	8.471 psi g	0.1529 psi	8.318 psi g	0.01821
Sch 40 Steel	2.469 in	0 ft	6.356 ft/s	8.184 psi g		8.031 psi g	0.00
50% ethlyene glycol	5 ft	Gear Oil Cooler1	77688	18.49 ft	0.3336 ft	18.15 ft	0 psi
		0 ft	0.02186	17.86 ft		17.53 ft	0 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Cooler inlet2 Sch 40 Steel 50% ethlyene glycol	2 in 2.067 in 0.5 ft	Node 7 0 ft JW Keel Cooler1 0 ft	91.84 gpm 8.781 ft/s 89848 0.02198	7.379 psi g 6.83 psi g 16.1 ft 14.91 ft	0.03502 psi 0.07643 ft	7.344 psi g 6.795 psi g 16.03 ft 14.83 ft	0.01899 0.00 0 psi 0 ft
Cooler inlet9 Sch 40 Steel 50% ethlyene glycol	2.5 in 2.469 in 0.25 ft	Node 19 0 ft SCAC Keel Cooler6 0 ft	94.85 gpm 6.356 ft/s 77688 0.02186	11.48 psi g 11.19 psi g 25.05 ft 24.42 ft	7.643E-03 psi 0.01668 ft	11.47 psi g 11.18 psi g 25.04 ft 24.41 ft	0.01821 0.00 0 psi 0 ft
Cooler to Engine2 Sch 40 Steel 50% ethlyene glycol	2.5 in 2.469 in 25 ft	Node 6 0 ft Engine Inlet2 5 ft	91.84 gpm 6.154 ft/s 75219 0.02196	3.309 psi g 3.039 psi g 7.221 ft 6.633 ft	3.309 psi 2.221 ft	0 psi g -0.2697 psi g 5 ft 4.411 ft	0.01821 1.11 0.2983 psi 0.6509 ft
Cooler to Engine9 Sch 40 Steel 50% ethlyene glycol	2.5 in 2.469 in 23 ft	Node 18 0 ft Engine Inlet8 5 ft	94.85 gpm 6.356 ft/s 77688 0.02186	3.303 psi g 3.016 psi g 7.209 ft 6.581 ft	3.303 psi 2.209 ft	0 psi g -0.2877 psi g 5 ft 4.372 ft	0.01821 1.07 0.309 psi 0.6745 ft
Engine to Cooler10 Sch 40 Steel 50% ethlyene glycol	2.5 in 2.469 in 15 ft	C18 SCAC Pump4 5 ft Node 19 0 ft	94.85 gpm 6.356 ft/s 77688 0.02186	9.956 psi g 9.668 psi g 26.73 ft 26.1 ft	-1.523 psi 1.675 ft	11.48 psi g 11.19 psi g 25.05 ft 24.42 ft	0.01821 1.07 0.309 psi 0.6745 ft
Engine to Cooler2 Sch 40 Steel 50% ethlyene glycol	2.5 in 2.469 in 15 ft	C18 JW Pump 5 ft Node 7 0 ft	91.84 gpm 6.154 ft/s 75219 0.02196	5.818 psi g 5.548 psi g 17.7 ft 17.11 ft	-1.561 psi 1.594 ft	7.379 psi g 7.109 psi g 16.1 ft 15.52 ft	0.01821 1.11 0.2985 psi 0.6515 ft
Pipe 1 Sch 40 Steel 50% ethlyene glycol	2.5 in 2.469 in 0.5 ft	Tank 1 5 ft C18 JW Pump 5 ft	91.84 gpm 6.154 ft/s 75219 0.02196	0 psi g -0.2697 psi g 5 ft 4.411 ft	0.01439 psi 0.0314 ft	-0.01439 psi g -0.2841 psi g 4.969 ft 4.38 ft	0.01821 0.00 0 psi 0 ft
Pipe 7 Sch 40 Steel 50% ethlyene glycol	2.5 in 2.469 in 0.5 ft	Tank 7 5 ft C18 SCAC Pump4 5 ft	94.85 gpm 6.356 ft/s 77688 0.02186	0 psi g -0.2877 psi g 5 ft 4.372 ft	0.01529 psi 0.03336 ft	-0.01529 psi g -0.303 psi g 4.967 ft 4.339 ft	0.01821 0.00 0 psi 0 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
Tank 1 50% ethlyene glycol	5 ft 0 ft	0 psi g 0 psi g	5 ft	Pipe 1	0 ft	91.84 gpm	0 psi g
Tank 7 50% ethlyene glycol	5 ft 0 ft	0 psi g 0 psi g	5 ft	Pipe 7	0 ft	94.85 gpm	0 psi g

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Gear Oil Cooler1	0 ft 8.318 psi g	0 ft 3.318 psi g	5 psi 10.91 ft	94.85 gpm
JW Keel Cooler1	0 ft 7.344 psi g	0 ft 3.344 psi g	4 psi 8.73 ft	91.84 gpm
SCAC Keel Cooler6	0 ft 11.47 psi g	0 ft 8.471 psi g	3 psi 6.547 ft	94.85 gpm

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 18	0 ft	3.303 psi g	6.581 ft
Node 19	0 ft	11.48 psi g	24.42 ft
Node 6	0 ft	3.309 psi g	6.328 ft
Node 7	0 ft	7.379 psi g	15.21 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Engine Inlet2	5 ft	0 psi g	4.411 ft	91.84 gpm
Engine Inlet8	5 ft	0 psi g	4.372 ft	94.85 gpm

Bill of Materials Report

File Name: 16101-200-505-0-APPB Mains-Pump Curves final.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.2.37316
Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 08:25 AM

Centrifugal Pumps

Centrifugal Pump Name Operation				
C18 JW Pump Fixed Speed	**Company:** CAT C18 JW Pump **Type:** **Size:** **Curve:** Manual Pump	**Test Speed:** 1946 rpm **Impeller Diameter:** 2.5 in **POR: from** -- **to** --		
C18 SCAC Pump4 Fixed Speed	**Company:** CAT C18 SCAC Pump **Type:** **Size:** **Curve:** Manual Pump	**Test Speed:** 2160 rpm **Impeller Diameter:** 2.5 in **POR: from** -- **to** --		

Tanks

Tank Name
Tank 1
Tank 7

Fixed dP Devices

Fixed dP Device Name	Fixed dP
Gear Oil Cooler1	5 psi
JW Keel Cooler1	4 psi
SCAC Keel Cooler6	3 psi

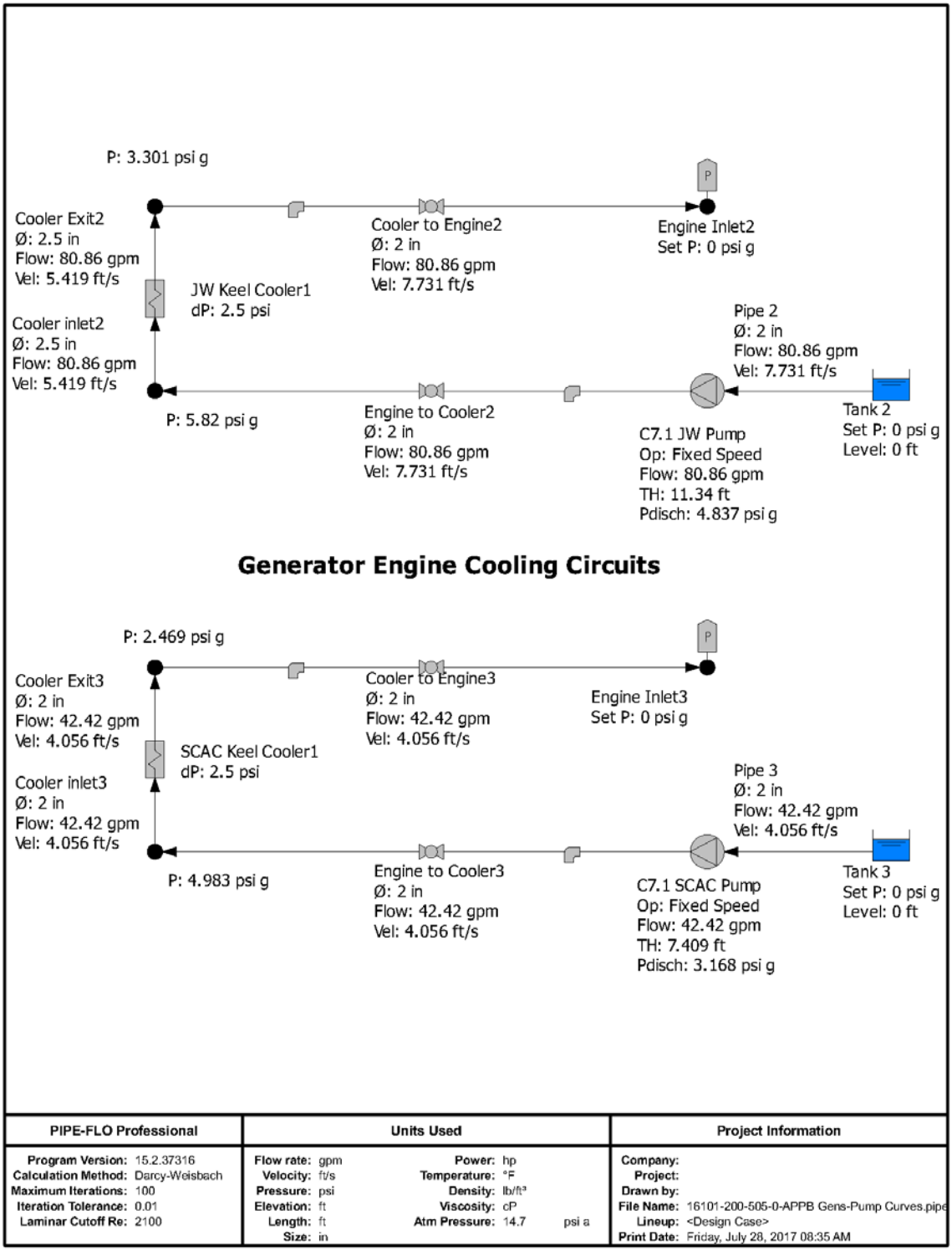
Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Cooler Exit2	Sch 40 Steel	2 in	0.5 ft	
Cooler Exit8	Sch 40 Steel	2.5 in	0.5 ft	
Cooler inlet10	Sch 40 Steel	2.5 in	5 ft	
Cooler inlet2	Sch 40 Steel	2 in	0.5 ft	
Cooler inlet9	Sch 40 Steel	2.5 in	0.25 ft	
Cooler to Engine2	Sch 40 Steel	2.5 in	25 ft	1 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Enlargement (2.5 in x 2 in - 3 in)
Cooler to Engine9	Sch 40 Steel	2.5 in	23 ft	1 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°)
Engine to Cooler10	Sch 40 Steel	2.5 in	15 ft	1 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°)
Engine to Cooler2	Sch 40 Steel	2.5 in	15 ft	1 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Contraction (2.5 in x 2 in - 3 in)
Pipe 1	Sch 40 Steel	2.5 in	0.5 ft	
Pipe 7	Sch 40 Steel	2.5 in	0.5 ft	

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Sch 40 Steel	Steel A53-B36.10 Schedule: 40	2 in	1.00 ft	
Sch 40 Steel	Steel A53-B36.10 Schedule: 40	2.5 in	84.75 ft	4 x Ball 16 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Contraction (2.5 in x 2 in - 3 in) 1 x Reducer - Enlargement (2.5 in x 2 in - 3 in)

GENERATOR ENGINE COOLING PIPE-FLO MODEL



PIPE-FLO Professional		Units Used				Project Information	
Program Version:	15.2.37316	Flow rate:	gpm	Power:	hp	Company:	
Calculation Method:	Darcy-Weisbach	Velocity:	ft/s	Temperature:	°F	Project:	
Maximum Iterations:	100	Pressure:	psi	Density:	lb/ft³	Drawn by:	
Iteration Tolerance:	0.01	Elevation:	ft	Viscosity:	cP	File Name:	16101-200-505-0-APPB Gens-Pump Curves.pipe
Laminar Cutoff Re:	2100	Length:	ft	Atm Pressure:	14.7 psi a	Lineup:	<Design Case>
		Size:	in			Print Date:	Friday, July 28, 2017 08:35 AM

List Report

File Name: 16101-200-505-0-APPB Gens-Pump Curves.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Percent Tolerance: 0.01
Allowable Deviation: 1 %

Company:
Project:
by:
Date: Friday, July 28, 2017 08:36 AM
Atmospheric Pressure: 14.7 psi a

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria		Design Limits: Velocity	Design Limits: Pressure	Reynolds Number
Sch 40 Steel	Steel A53-B36.10	1.800E-03 in	0.0	Min:	ft/s	psi g	
standard	Schedule:40	140		Max:	ft/s	psi g	

Fluid Zones

Fluid Zone Name / Table Name	Temperature / Pressure	Fluid State / Relative Molecular Mass	Density / Viscosity	Vapor Pressure / Critical Pressure	Specific Heat Capacity (cp) / Specific Heat Ratio (k)
Fresh Water	120 °F	Liquid	61.7 lb/ft³	1.695 psi a	1.014 BTU/lb°F
Water	0 psi g	18	0.5543 cP	3199 psi a	--

Centrifugal Pumps

Pump Name	Test Speed / Operating Speed	Suction Elevation / Suction Pressure	Discharge Elevation / Discharge Pressure	Total Head / dP	Flow Rate / Power	Efficiency / BEP Efficiency	NPSHa / NPSHr	Design NPSH Margin Ratio
C7.1 JW Pump	3600 rpm	5 ft	5 ft	11.34 ft	80.86 gpm	--	30.29 ft	--
Fixed Speed	3600 rpm	-0.02356 psi g	4.837 psi g	4.86 psi	--	--- %	--	

Company: CAT C7.1 JW
Curve: Manual Pump
Type:
Size:
Diameter: 2 in
POR: from -- to --

Pump Name	Test Speed / Operating Speed	Suction Elevation / Suction Pressure	Discharge Elevation / Discharge Pressure	Total Head / dP	Flow Rate / Power	Efficiency / BEP Efficiency	NPSHa / NPSHr	Design NPSH Margin Ratio
C7.1 SCAC Pump	1800 rpm	5 ft	5 ft	7.409 ft	42.42 gpm	--	30.33 ft	--
Fixed Speed	1800 rpm	-6.812E-03 psi g	3.168 psi g	3.175 psi	--	--- %	--	

Company: CAT C7.1 SCAC
Curve: Manual Pump
Type:
Size:
Diameter: 2 in
POR: from -- to --

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Device / Inlet Elevation / Outlet Device / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number / Pipe Friction Factor	Inlet Total Pressure / Inlet Static Pressure / Inlet Energy Grade / Inlet Hydraulic Grade	Total dP / Total Head Loss	Outlet Total Pressure / Outlet Static Pressure / Outlet Energy Grade / Outlet Hydraulic Grade	V&F Friction Factor / V&F Resistance K / V&F dP / V&F Head Loss
Cooler Exit2	2.5 in	JW Keel Cooler1	80.86 gpm	3.311 psi g	9.516E-03 psi	3.301 psi g	0.01821
Sch 40 Steel	2.469 in	0 ft	5.419 ft/s	3.115 psi g		3.106 psi g	0.00
Fresh Water	0.5 ft	Node 6	184664	7.727 ft	0.02221 ft	7.705 ft	0 psi
		0 ft	0.02003	7.271 ft		7.249 ft	0 ft
Cooler Exit3	2 in	SCAC Keel Cooler1	42.42 gpm	2.476 psi g	6.812E-03 psi	2.469 psi g	0.01899
Sch 40 Steel	2.067 in	0 ft	4.056 ft/s	2.367 psi g		2.36 psi g	0.00
Fresh Water	0.5 ft	Node 8	115722	5.779 ft	0.0159 ft	5.763 ft	0 psi
		0 ft	0.02142	5.524 ft		5.508 ft	0 ft
Cooler inlet2	2.5 in	Node 7	80.86 gpm	5.82 psi g	9.516E-03 psi	5.811 psi g	0.01821
Sch 40 Steel	2.469 in	0 ft	5.419 ft/s	5.625 psi g		5.615 psi g	0.00
Fresh Water	0.5 ft	JW Keel Cooler1	184664	13.58 ft	0.02221 ft	13.56 ft	0 psi
		0 ft	0.02003	13.13 ft		13.11 ft	0 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Cooler inlet3 Sch 40 Steel Fresh Water	2 in 2.067 in 0.5 ft	Node 9 0 ft SCAC Keel Cooler1 0 ft	42.42 gpm 4.056 ft/s 115722 0.02142	4.983 psi g 4.874 psi g 11.63 ft 11.37 ft	6.812E-03 psi 0.0159 ft	4.976 psi g 4.867 psi g 11.61 ft 11.36 ft	0.01899 0.00 0 psi 0 ft
Cooler to Engine2 Sch 40 Steel Fresh Water	2 in 2.067 in 15 ft	Node 6 0 ft Engine Inlet2 5 ft	80.86 gpm 7.731 ft/s 220579 0.02039	3.301 psi g 2.903 psi g 7.705 ft 6.776 ft	3.301 psi 2.705 ft	0 psi g -0.398 psi g 5 ft 4.071 ft	0.01899 1.14 0.4523 psi 1.056 ft
Cooler to Engine3 Sch 40 Steel Fresh Water	2 in 2.067 in 15 ft	Node 8 0 ft Engine Inlet3 5 ft	42.42 gpm 4.056 ft/s 115722 0.02142	2.469 psi g 2.36 psi g 5.763 ft 5.508 ft	2.469 psi 0.7634 ft	0 psi g -0.1095 psi g 5 ft 4.744 ft	0.01899 1.12 0.1227 psi 0.2865 ft
Engine to Cooler2 Sch 40 Steel Fresh Water	2 in 2.067 in 15 ft	C7.1 JW Pump 5 ft Node 7 0 ft	80.86 gpm 7.731 ft/s 220579 0.02039	4.837 psi g 4.439 psi g 16.29 ft 15.36 ft	-0.9835 psi 2.705 ft	5.82 psi g 5.422 psi g 13.58 ft 12.66 ft	0.01899 1.14 0.4521 psi 1.055 ft
Engine to Cooler3 Sch 40 Steel Fresh Water	2 in 2.067 in 15 ft	C7.1 SCAC Pump 5 ft Node 9 0 ft	42.42 gpm 4.056 ft/s 115722 0.02142	3.168 psi g 3.058 psi g 12.39 ft 12.14 ft	-1.815 psi 0.7634 ft	4.983 psi g 4.874 psi g 11.63 ft 11.37 ft	0.01899 1.12 0.1227 psi 0.2865 ft
Pipe 2 Sch 40 Steel Fresh Water	2 in 2.067 in 0.5 ft	Tank 2 5 ft C7.1 JW Pump 5 ft	80.86 gpm 7.731 ft/s 220579 0.02039	0 psi g -0.398 psi g 5 ft 4.071 ft	0.02356 psi 0.05498 ft	-0.02356 psi g -0.4216 psi g 4.945 ft 4.016 ft	0.01899 0.00 0 psi 0 ft
Pipe 3 Sch 40 Steel Fresh Water	2 in 2.067 in 0.5 ft	Tank 3 5 ft C7.1 SCAC Pump 5 ft	42.42 gpm 4.056 ft/s 115722 0.02142	0 psi g -0.1095 psi g 5 ft 4.744 ft	6.812E-03 psi 0.0159 ft	-6.812E-03 psi g -0.1164 psi g 4.984 ft 4.728 ft	0.01899 0.00 0 psi 0 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
Tank 2 Fresh Water	5 ft 0 ft	0 psi g 0 psi g	5 ft	Pipe 2	0 ft	80.86 gpm	0 psi g
Tank 3 Fresh Water	5 ft 0 ft	0 psi g 0 psi g	5 ft	Pipe 3	0 ft	42.42 gpm	0 psi g

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
JW Keel Cooler1	0 ft 5.811 psi g	0 ft 3.311 psi g	2.5 psi 5.835 ft	80.86 gpm
SCAC Keel Cooler1	0 ft 4.976 psi g	0 ft 2.476 psi g	2.5 psi 5.835 ft	42.42 gpm

PIPE-FLO Professional Version: 15.2.37316 List Report Friday, July 28, 2017 08:36 AM Page 2

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 6	0 ft	3.301 psi g	7.012 ft
Node 7	0 ft	5.82 psi g	12.89 ft
Node 8	0 ft	2.469 psi g	5.508 ft
Node 9	0 ft	4.983 psi g	11.37 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Engine Inlet2	5 ft	0 psi g	4.071 ft	80.86 gpm
Engine Inlet3	5 ft	0 psi g	4.744 ft	42.42 gpm

Bill of Materials Report

File Name: 16101-200-505-0-APPB Gens-Pump Curves.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.2.37316
Company:
Project:
by:
Date: Friday, July 28, 2017 08:36 AM

Centrifugal Pumps

Centrifugal Pump Name Operation		
C7.1 JW Pump Fixed Speed	**Company:** CAT C7.1 JW **Type:** **Size:** **Curve:** Manual Pump	**Test Speed:** 3600 rpm **Impeller Diameter:** 2 in **POR: from** -- **to** --
C7.1 SCAC Pump Fixed Speed	**Company:** CAT C7.1 SCAC **Type:** **Size:** **Curve:** Manual Pump	**Test Speed:** 1800 rpm **Impeller Diameter:** 2 in **POR: from** -- **to** --

Tanks

Tank Name
Tank 2
Tank 3

Fixed dP Devices

Fixed dP Device Name	Fixed dP
JW Keel Cooler1	2.5 psi
SCAC Keel Cooler1	2.5 psi

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Cooler Exit2	Sch 40 Steel	2.5 in	0.5 ft	
Cooler Exit3	Sch 40 Steel	2 in	0.5 ft	
Cooler inlet2	Sch 40 Steel	2.5 in	0.5 ft	
Cooler inlet3	Sch 40 Steel	2 in	0.5 ft	
Cooler to Engine2	Sch 40 Steel	2 in	15 ft	1 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Contraction (2 in x 2.5 in - 3 in)
Cooler to Engine3	Sch 40 Steel	2 in	15 ft	1 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°)
Engine to Cooler2	Sch 40 Steel	2 in	15 ft	1 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Enlargement (2 in x 2.5 in - 3 in)
Engine to Cooler3	Sch 40 Steel	2 in	15 ft	1 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 2	Sch 40 Steel	2 in	0.5 ft	
Pipe 3	Sch 40 Steel	2 in	0.5 ft	

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Sch 40 Steel	Steel A53-B36.10 Schedule: 40	2 in	62.00 ft	4 x Ball 16 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Contraction (2 in x 2.5 in - 3 in) 1 x Reducer - Enlargement (2 in x 2.5 in - 3 in)
Sch 40 Steel	Steel A53-B36.10 Schedule: 40	2.5 in	1.00 ft	

Appendix C

Exhaust System, Dwg. 16101-200-259-1

1 DESCRIPTION

This appendix documents the calculations used in designing the diesel engine exhaust systems. These calculations estimate frictional losses through the exhaust piping to verify that system backpressure is below the engine manufacturers' published requirements.

2 PROCEDURE

Calculations are presented in the following sequence:

- Main engine exhaust piping ΔP calculations
- Generator exhaust piping ΔP calculations
- Emergency generator exhaust piping ΔP calculations

Frictional losses through the piping system are calculated by constructing a model using PIPE-FLO Professional software utilizing the Darcy-Weisbach method.

3 GIVEN AND ASSUMED PARAMETERS

- Main engine exhaust gas characteristics are taken from [1] [2] as follows:

Caterpillar C18, 600 hp at 1800 RPM	
Exhaust Gas Flow Rate at Stack	3,066 ft^3/min
Exhaust Gas Temperature at Stack	703.0 °F
Maximum Allowable Backpressure	27 inches H_2O

- Generator exhaust gas characteristics are taken from [3] [4] as follows:

Caterpillar C7.1, 150 ekW at 1800 RPM	
Exhaust Gas Flow Rate at Stack	1,042 ft^3/min
Exhaust Gas Temperature at Stack	712.9 °F
Maximum Allowable Backpressure	60 inches H_2O

- Emergency generator exhaust gas characteristics are taken from [5] as follows:

Caterpillar C4.4 ACERT, 66 ekW at 1800 RPM	
Exhaust Gas Flow Rate at Stack	8.5 kg/min
Exhaust Gas Temperature at Stack	759 °F
Maximum Allowable Backpressure	60 inches H_2O

- For the purpose of calculating piping friction losses, exhaust gas pressure is assumed to be standard atmospheric pressure, 14.7 PSIA, plus half the maximum allowable backpressure value listed for the system analyzed.
- In calculating frictional losses through pipe, exhaust gas is assumed to have the same density and dynamic viscosity as air at assumed system pressure and stack temperature noted above for the system analyzed.
- System pipe lengths, routing and fittings are estimated based on the routing shown in [6].
- Selected main engine silencer is an 8 inch Harco VRSA-8 with estimated backpressure of 7.9 in H_20. Backpressure estimated with vendor provided calculation tool [7].
- Selected generator silencer is a 5 inch Harco VRSA-5 with estimated backpressure of 5.9 in H_20. Backpressure estimated with vendor provided calculation tool [7].
- Selected emergency generator silencer is a 4 inch Harco VRS-4 SISO with estimated backpressure of 9.7 in H_20. Backpressure estimated with vendor provided calculation tool [7]. In conjunction with the side-inlet, side-outlet silencer, the selected emergency generator spark arrestor is a Harco 5AA. Backpressure of spark arrestor estimated at 18 inH20 based on testing agency guidelines [8].

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Main Engine Exhaust Piping ΔP Calculation

As shown in the attached PIPE-FLO results, the estimated main engine exhaust piping backpressure is approximately 16.2 in H_2O, 60% of the stated vendor design value.

5.2 Generator Exhaust Piping ΔP Calculation

As shown in the attached PIPE-FLO results, the estimated generator exhaust piping backpressure is approximately 16.5 in H_2O, 28% of the stated vendor maximum.

5.3 Emergency Generator Exhaust Piping ΔP Calculation

Exhaust gas volumetric flow rate is first determined using the given mass flow rate from the engine technical data [5].

Exhaust gas temperature at stack	404° C (759° F)
Assumed exhaust gas pressure at stack	14.7 psia
Air density at stack temp. and press.	0.519 kg/m^3
Given mass flow rate	8.5 kg/min
Volumetric flow rate	16.38 m^3/min **(578 ft^3/min)**

As shown in the attached PIPE-FLO results, the estimated emergency generator exhaust piping backpressure is approximately 14 in H_2O, 23% of the stated vendor maximum.

6 REFERENCES

[1] Caterpillar, "EM0268; C18 600HP at 1800 rpm Systems Data," March 8, 2017.

[2] Caterpillar, EM0268; C18 600HP at 1800 rpm Performance Data, March 8, 2017.

[3] Caterpillar, "EM5070; C7.1 150ekW at 1800 rpm Performance Data," July 10, 2017.

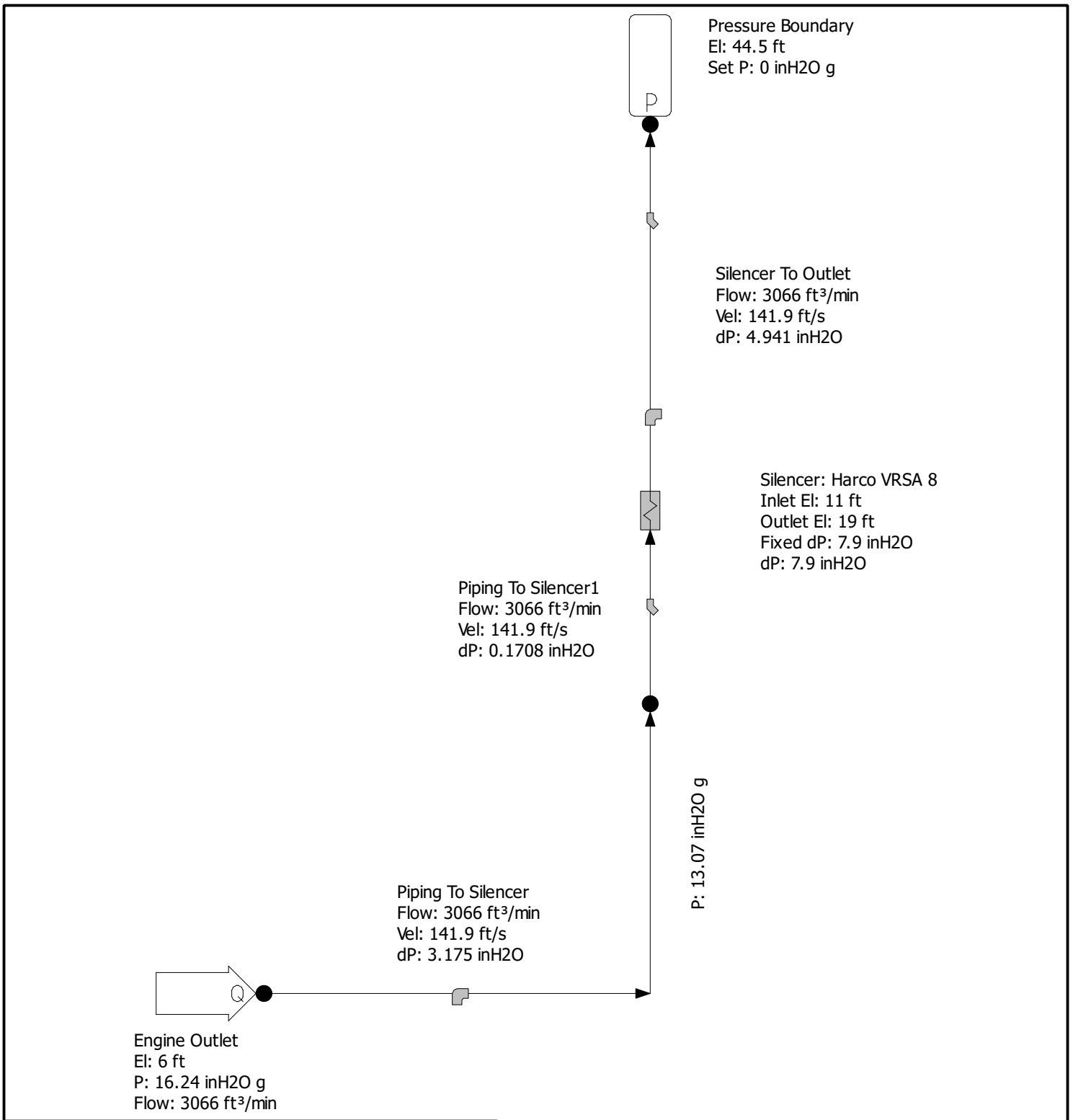
[4] Caterpillar, "EM5070; C7.1 150ekW at 1800 rpm Systems Data," July 10, 2017.

[5] Caterpillar, "LEHM0240-00; C4.4 ACERT Marine Generator Set Package Specifications," 2016.

[6] Elliott Bay Design Group, "Exhaust Arrangement; 16101-200-259-1," Rev -, Seattle, WA, 7/28/17.

[7] Harco Manufacturing, "Silencer Back Pressure Calculator," [Online]. Available: http://harcomfg.com/. [Accessed July 2017].

[8] USFS, "Spark Arrester Guide," 2017.



Project Information

Company: Elliott Bay Design Group
Project: 16101: Main Engine Exhaust
Drawn by: NJB
File Name: 16101-200-259-1 ME Exhaust Piping Calculations.pipe
Lineup: <Design Case>
Print Date: Friday, July 28, 2017 11:42 AM

PIPE-FLO Professional

Program Version: 15.1.36149
Calculation Method: Darcy-Weisbach
Maximum Iterations: 100
Iteration Tolerance: 0.01
Laminar Cutoff Re: 2100

Units Used

Flow rate: ft³/min
Velocity: ft/s
Pressure: psi g
Elevation: ft
Length: ft
Size: in
Power:
Temperature: °F
Density: lb/ft³
Viscosity: cP
Atmospheric Pressure: 406.8 inH2O a

List Report

File Name: 16101-200-259-1 ME Exhaust Piping Calculations.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 15.1.36149

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 406.8 inH2O a

Company: Elliott Bay Design Group
Project: 16101: Main Engine Exhaust
by: NJB
Date: Friday, July 28, 2017 11:43 AM

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria	Design Limits: Velocity	Pressure	Reynolds Number
Steel, Sch 10 standard	Steel A53-B36.10 Schedule:10	1.800E-03 in 140	0.0	to ft/s	to psi g	to
Steel, Sch 20 standard	Steel A53-B36.10 Schedule:20	1.800E-03 in 140	0.0	to ft/s	to psi g	to
Steel, Sch 40 standard	Steel A53-B36.10 Schedule:40	1.800E-03 in 140	0.0	to ft/s	to psi g	to

Fluid Zones

Fluid Zone Name / Table Name	Temperature	Pressure	Fluid State	Density / Viscosity	Vapor Pressure / Critical Pressure	Specific Heat Ratio (k) / Relative Molecular Mass
Engine Exhaust (Air at 703F)	703 °F	13.42 inH2C	Gas	0.03522 lb/ft³	6.005E+06 inH2O a	1.373
Air				0.03181 cP	15151 inH2O a	28.96

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Elevation / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number	Total Head Loss / V&F Head Loss	Inlet Pressure / Outlet Pressure	Total dP / V&F dP	Pipe Friction Factor / V&F Friction Factor / V&F Resistance K
Silencer To Outlet	8 in	19 ft	3066 ft³/min	704.4 ft	4.941 inH2O g	4.941 inH2C	0.0178
Steel, Sch 20	8.125 in	44.5 ft	141.9 ft/s	465.8 ft	0 inH2O g	3.153 inH2C	0.01402
Engine Exhaust (Air at 703F)	29 ft		158328				1.49
	Inlet Device: Silencer: Harco VRSA 8		**Outlet Device:** Pressure Boundary				
Piping To Silencer	8 in	6 ft	3066 ft³/min	464 ft	16.24 inH2O g	3.175 inH2C	0.0178
Steel, Sch 20	8.125 in	11 ft	141.9 ft/s	184.3 ft	13.07 inH2O g	1.248 inH2C	0.01402
Engine Exhaust (Air at 703F)	34 ft		158328				0.59
	Inlet Device: Engine Outlet		**Outlet Device:** Node 1				
Piping To Silencer1	8 in	11 ft	3066 ft³/min	25.23 ft	13.07 inH2O g	0.1708 inH2C	0.0178
Steel, Sch 20	8.125 in	11 ft	141.9 ft/s	8.776 ft	12.9 inH2O g	0.05941 inH2C	0.01402
Engine Exhaust (Air at 703F)	2 ft		158328				0.03
	Inlet Device: Node 1		**Outlet Device:** Silencer: Harco VRSA 8				

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation / Inlet Pressure	Outlet Elevation / Outlet Pressure	dP / Head Loss	Flow Rate
Silencer: Harco VRSA 8	11 ft 12.9 inH2O g	19 ft 4.941 inH2O g	7.9 inH2O 1167 ft	3066 ft³/min

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	11 ft	13.07 inH2O g	1628 ft

Pressure Boundaries					
Pressure Boundary Name	**Elevation**	**Pressure**	**Hydraulic Grade**	**Flow Rate**	
Pressure Boundary	44.5 ft	0 inH2O g	-268.5 ft	3066 ft³/min	
Flow Demands					
Flow Demand Name	**Elevation**	**Pressure**	**Hydraulic Grade**	**Flow Rate**	**Flow Direction**
Engine Outlet	6 ft	16.24 inH2O g	2092 ft		Flow in

Bill of Materials Report

File Name: 16101-200-259-1 ME Exhaust Piping Calculations.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.1.36149

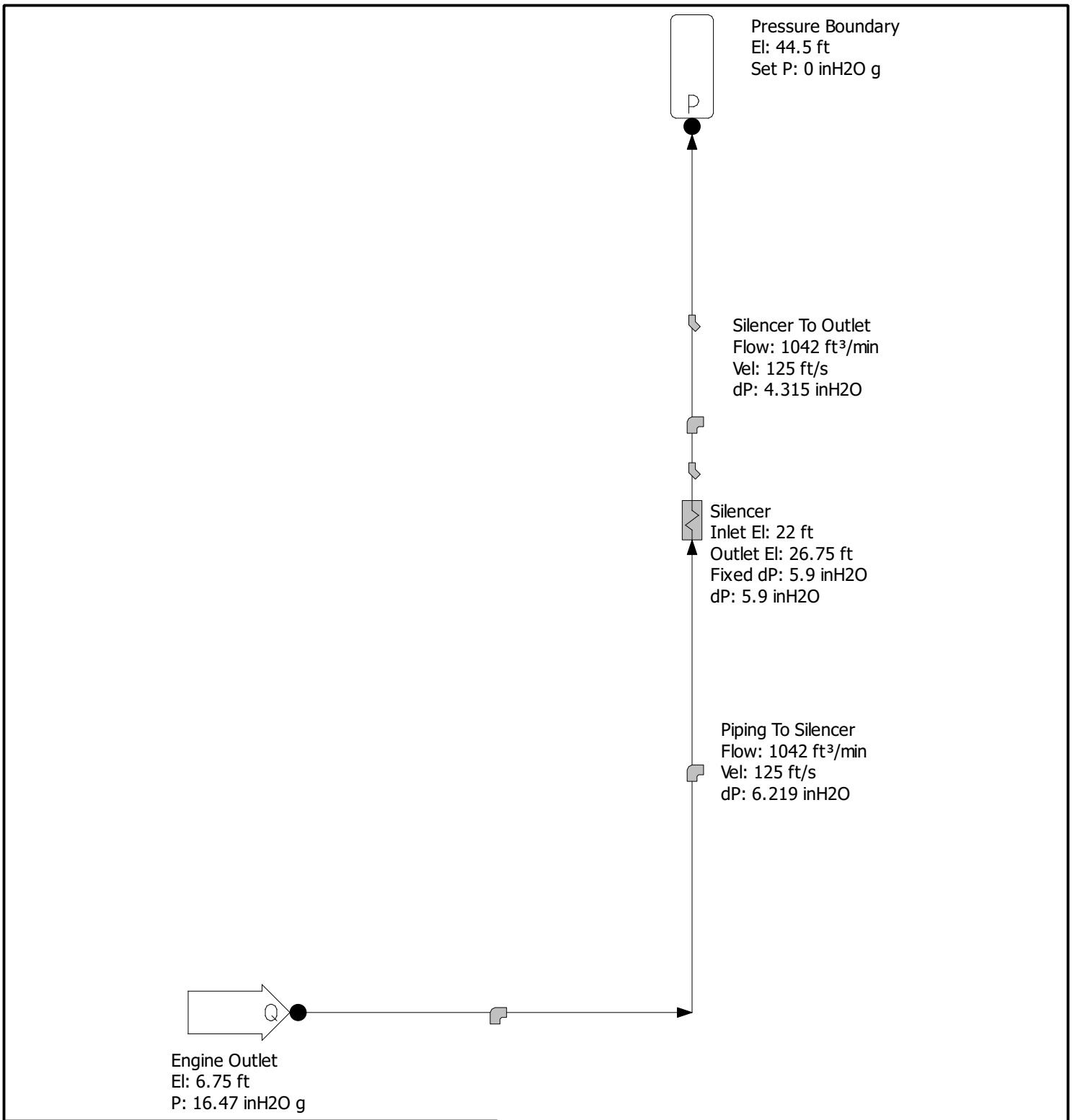
Company: Elliott Bay Design Group
Project: 16101: Main Engine Exhaust
by: NJB
Date: Friday, July 28, 2017 11:43 AM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Silencer To Outlet	Steel, Sch 20	8 in	29 ft	1 x Exit - Projecting 2 x Elbow - Long radius, r/d 1.5 (45°) 1 x Mitre Bend @ 45°
Piping To Silencer	Steel, Sch 20	8 in	34 ft	3 x Elbow - Long radius, r/d 1.5 (90°)
Piping To Silencer1	Steel, Sch 20	8 in	2 ft	1 x Mitre Bend @ 0°

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Steel, Sch 20	Steel A53-B36.10 Schedule: 20	8 in	65.00 ft	2 x Elbow - Long radius, r/d 1.5 (45°) 3 x Elbow - Long radius, r/d 1.5 (90°) 1 x Exit - Projecting 1 x Mitre Bend @ 0° 1 x Mitre Bend @ 45°



Project Information

Company:	Elliott Bay Design Group
Project:	16101: SSDG Exhaust
Drawn by:	NJB
File Name:	16101-200-259-1 SSGENERATOR Exhaust Piping Calculations.pipe
Lineup:	<Design Case>
Print Date:	Friday, July 28, 2017 11:45 AM

PIPE-FLO Professional

Program Version:	15.1.36149
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used

Flow rate:	ft³/min	**Power:**	
Velocity:	ft/s	**Temperature:**	°F
Pressure:	psi g	**Density:**	lb/ft³
Elevation:		**Viscosity:**	cP
Length:	ft	**Atmospheric Pressure:**	406.8 inH2O a
Size:	in		

List Report

File Name: 16101-200-259-1 SSGENERATOR Exhaust Piping Calcul
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 15.1.36149

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 406.8 inH2O a

Company: Elliott Bay Design Group
Project: 16101: SSDG Exhaust
by: NJB
Date: Friday, July 28, 2017 11:47 AM

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria	Design Limits: Velocity	Pressure	Reynolds Number
Steel, Sch 10 standard	Steel A53-B36.10 Schedule:10	1.800E-03 in 140	0.0	to ft/s	to psi g	to
Steel, Sch 20 standard	Steel A53-B36.10 Schedule:20	1.800E-03 in 140	0.0	to ft/s	to psi g	to
Steel, Sch 40 standard	Steel A53-B36.10 Schedule:40	1.800E-03 in 140	0.0	to ft/s	to psi g	to

Fluid Zones

Fluid Zone Name / Table Name	Temperature	Pressure	Fluid State	Density / Viscosity	Vapor Pressure / Critical Pressure	Specific Heat Ratio (k) / Relative Molecular Mass
Engine Exhaust (Air at 713F)	713 °F	14.97 inH2C	Gas	0.03505 lb/ft³	6.202E+06 inH2O a	1.372
Air				0.03199 cP	15151 inH2O a	28.96

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Elevation / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number	Total Head Loss / V&F Head Loss	Inlet Pressure / Outlet Pressure	Total dP / V&F dP	Pipe Friction Factor / V&F Friction Factor / V&F Resistance K
Piping To Silencer	5 in	6.75 ft	1042 ft³/min	907.9 ft	16.47 inH2O g	6.219 inH2C	0.02018
Steel, Sch 40	5.047 in	22 ft	125 ft/s	278.5 ft	10.25 inH2O g	1.877 inH2C	0.0155
Engine Exhaust (Air at 713F)	54 ft		85730				1.15
	Inlet Device: Engine Outlet		**Outlet Device:** Silencer				
Silencer To Outlet	5 in	26.75 ft	1042 ft³/min	622.7 ft	4.315 inH2O g	4.315 inH2C	0.02018
Steel, Sch 40	5.047 in	44.5 ft	125 ft/s	389.6 ft	0 inH2O g	2.625 inH2C	0.0155
Engine Exhaust (Air at 713F)	20 ft		85730				1.60
	Inlet Device: Silencer		**Outlet Device:** Pressure Boundary				

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation / Inlet Pressure	Outlet Elevation / Outlet Pressure	dP / Head Loss	Flow Rate
Silencer	22 ft 10.25 inH2O g	26.75 ft 4.315 inH2O g	5.9 inH2O 875.8 ft	1042 ft³/min

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary	44.5 ft	0 inH2O g	-198.3 ft	1042 ft³/min

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Engine Outlet	6.75 ft	16.47 inH2O g	2208 ft		Flow in

Bill of Materials Report

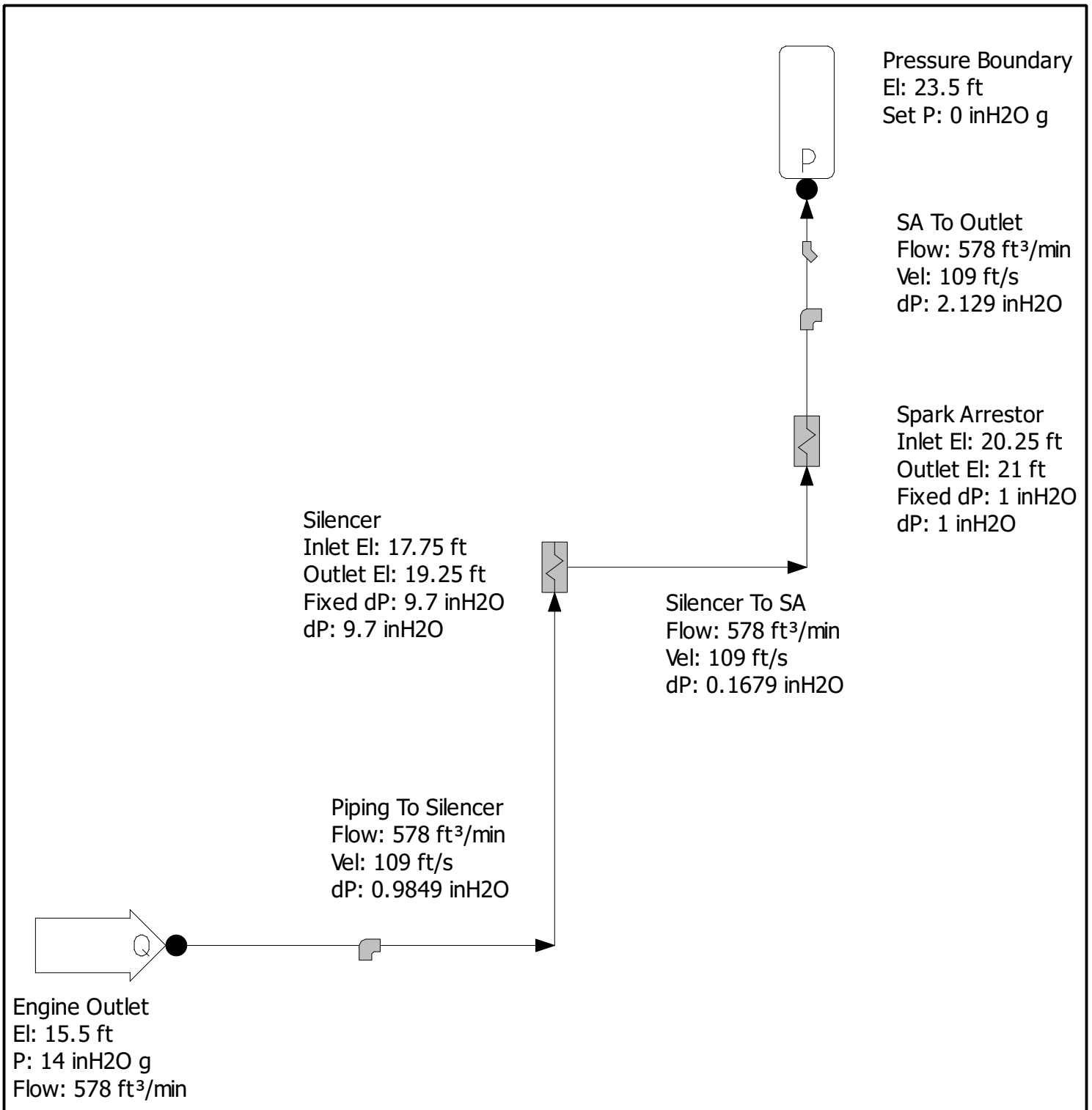
File Name: 16101-200-259-1 SSGENERATOR Exhaust Piping Calculations.pip
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.1.36149
Company: Elliott Bay Design Group
Project: 16101: SSDG Exhaust
by: NJB
Date: Friday, July 28, 2017 11:45 AM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Piping To Silencer	Steel, Sch 40	5 in	54 ft	3 x Elbow - Long radius, r/d 1.5 (90°) 2 x Elbow - Standard 45°
Silencer To Outlet	Steel, Sch 40	5 in	20 ft	2 x Mitre Bend @ 15° 1 x Elbow - Standard 45° 1 x Exit - Projecting 1 x Mitre Bend @ 45°

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Steel, Sch 40	Steel A53-B36.10 Schedule: 40	5 in	74.00 ft	3 x Elbow - Long radius, r/d 1.5 (90°) 3 x Elbow - Standard 45° 1 x Exit - Projecting 2 x Mitre Bend @ 15° 1 x Mitre Bend @ 45°



Project Information	
Company:	Elliott Bay Design Group
Project:	16101: EGEN Exhaust
Drawn by:	NJB
File Name:	16101-200-259-1 EGENERATOR Exhaust Piping Calculations.pipe
Lineup:	<Design Case>
Print Date:	Wednesday, August 02, 2017 10:29 AM

PIPE-FLO Professional	
Program Version:	15.1.36149
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used			
Flow rate:	ft³/min	**Power:**	
Velocity:	ft/s	**Temperature:**	°F
Pressure:	psi g	**Density:**	lb/ft³
Elevation:		**Viscosity:**	cP
Length:	ft	**Atmospheric Pressure:**	406.8 inH2O a
Size:	in		

List Report

File Name: 16101-200-259-1 EGENERATOR Exhaust Piping Calculat
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 15.1.36149

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 406.8 inH2O a

Company: Elliott Bay Design Group
Project: 16101: EGEN Exhaust
by: NJB
Date: Wednesday, August 02, 2017 10:29 AM

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria	Design Limits: Velocity	Pressure	Reynolds Number
Steel, Sch 10 standard	Steel A53-B36.10 Schedule:10	1.800E-03 in 140	0.0	to ft/s	to psi g	to
Steel, Sch 20 standard	Steel A53-B36.10 Schedule:20	1.800E-03 in 140	0.0	to ft/s	to psi g	to
Steel, Sch 40 standard	Steel A53-B36.10 Schedule:40	1.800E-03 in 140	0.0	to ft/s	to psi g	to

Fluid Zones

Fluid Zone Name / Table Name	Temperature	Pressure	Fluid State	Density / Viscosity	Vapor Pressure / Critical Pressure	Specific Heat Ratio (k) / Relative Molecular Mass
Engine Exhaust (Air at 713F)	713 °F	14.97 inH2C	Gas	0.03505 lb/ft³	6.202E+06 inH2O a	1.372
Air				0.03199 cP	15151 inH2O a	28.96

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Elevation / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number	Total Head Loss / V&F Head Loss	Inlet Pressure / Outlet Pressure	Total dP / V&F dP	Pipe Friction Factor / V&F Friction Factor / V&F Resistance K
Piping To Silencer	4 in	15.5 ft	578 ft³/min	143.9 ft	14 inH2O g	0.9849 inH2C	0.02174
Steel, Sch 40	4.026 in	17.75 ft	109 ft/s	84.16 ft	13.01 inH2O g	0.5669 inH2C	0.01629
Engine Exhaust (Air at 713F)	5 ft		59614				0.46
	Inlet Device: Engine Outlet		**Outlet Device:** Silencer				
Silencer To SA	4 in	19.25 ft	578 ft³/min	23.92 ft	3.302 inH2O g	0.1679 inH2C	0.02174
Steel, Sch 40	4.026 in	20.25 ft	109 ft/s	0 ft	3.134 inH2O g	0 inH2C	0.01629
Engine Exhaust (Air at 713F)	2 ft		59614				0.00
	Inlet Device: Silencer		**Outlet Device:** Spark Arrestor				
SA To Outlet	4 in	21 ft	578 ft³/min	313.6 ft	2.129 inH2O g	2.129 inH2C	0.02174
Steel, Sch 40	4.026 in	23.5 ft	109 ft/s	277.7 ft	0 inH2O g	1.871 inH2C	0.01629
Engine Exhaust (Air at 713F)	3 ft		59614				1.50
	Inlet Device: Spark Arrestor		**Outlet Device:** Pressure Boundary				

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation / Inlet Pressure	Outlet Elevation / Outlet Pressure	dP / Head Loss	Flow Rate
Silencer	17.75 ft 13.01 inH2O g	19.25 ft 3.302 inH2O g	9.7 inH2O 1440 ft	578 ft³/min
Spark Arrestor	20.25 ft 3.134 inH2O g	21 ft 2.129 inH2O g	1 inH2O 148.4 ft	578 ft³/min

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary	23.5 ft	0 inH2O g	-161 ft	578 ft³/min

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Engine Outlet	15.5 ft	14 inH2O g	1909 ft		Flow in

Bill of Materials Report

File Name: 16101-200-259-1 EGENERATOR Exhaust Piping Calculations.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.1.36149
Company: Elliott Bay Design Group
Project: 16101: EGEN Exhaust
by: NJB
Date: Wednesday, August 02, 2017 10:29 AM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Piping To Silencer	Steel, Sch 40	4 in	5 ft	2 x Elbow - Long radius, r/d 1.5 (90°)
Silencer To SA	Steel, Sch 40	4 in	2 ft	
SA To Outlet	Steel, Sch 40	4 in	3 ft	1 x Elbow - Standard 45° 1 x Exit - Projecting 1 x Mitre Bend @ 45°

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Steel, Sch 40	Steel A53-B36.10 Schedule: 40	4 in	10.00 ft	2 x Elbow - Long radius, r/d 1.5 (90°) 1 x Elbow - Standard 45° 1 x Exit - Projecting 1 x Mitre Bend @ 45°

Appendix D

Fuel Oil System, Dwg. 16101-200-261-1

1 DESCRIPTION

This appendix documents the first principles calculations used in designing the fuel oil system. These calculations are used to identify steady state frictional losses throughout the piping system and to validate system design.

2 PROCEDURE

Calculations are presented in the following sequence:

- Pipe size calculations
- Engine fuel pump supply pressure calculations
- Engine fuel pump return pressure

Frictional losses through the piping system are calculated by constructing a model using PIPE-FLO Professional software utilizing the Darcy Weisbach method.

3 GIVEN AND ASSUMED PARAMETERS

- The fuel oil system is to be constructed of Schedule 40 carbon steel pipe.
- Maximum fuel flow rate to each main engine is 3.34 gpm, from [1].
- Maximum fuel flow rate to each generator is 1.1 gpm, from [2].
- The main engines and generators have the following fuel system design constraints [1], [2]:

Table 5-1: Fuel System Design Constraints

Parameter	Maximum
Allowable supply line restriction to main engine	4.37 psi
Allowable return line restriction from main engine	3.93 psi
Allowable supply line restriction to generator engine	1.47 psi
Allowable return line restriction from generator engine	1.47 psi

- Piping system lengths, routing, fittings, etc. are estimated based on the Profiles and Arrangements, and Fuel Oil Diagram [3] [4].
- Each main engine fuel supply utilizes a Racor 751000MAXM duplex fuel filter with a pressure drop of 3.5 psi at a flowrate of 6.0 gpm, from [5].
- Each generator engine fuel supply utilizes a Racor 1000MAM fuel filter with a pressure drop of 0.5 psi at a flowrate of 3.0 gpm, from [5]
- The system is normally arranged such that an engine and generator pair consumes fuel from the nearest tank. The model assumes a worst case wherein both main engines and one generator are utilizing one tank.

- Tank and engine elevations were estimated from [3] and all elevations are in reference to the vessel's baseline:

Table 5-2: Elevations

Elevation Point	Elevation
Fuel tank low fuel level	3.5 feet
Fuel tank high fuel level	7.5 feet
Main Engine fuel inlet	3.75 feet
Main Engine fuel outlet	5.8 feet
Generator fuel inlet	4.25 feet
Generator fuel outlet	4.25 feet

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Pipe Size Calculations

Pipe sizes are based on the nominal velocity limits found in Marine Engineering, Chapter 20, Table 3, [6]. The following table shows the flow rates of fuel occurring in the system, and the resulting pipe sizes.

Table 5-3: Fuel Oil System Pipe Sizes and Velocities

Pipe Segment	Flow Rate gpm	Pipe/Tube Size (NPS)	ID in	Design Velocity (ft/s) Nominal	Limit	V ft/s
Fill Rate	50	2" Sch 80	1.940	6.96	12.00	5.29
Supply Main (1 me, 1 gen)	4.44	2" Sch 40	2.070	2.88	7.00	0.41
Return main (1 me, 1 gen)	4.44	2" Sch 40	2.070	7.19	12.00	0.41
Main Engine - Supply	3.34	3/4" Sch 40	0.820	1.81	7.00	1.97
Generator - Supply	1.10	3/4" Sch 40	0.820	1.81	7.00	0.65
Main Engine - Return	3.34	3/4" Sch 40	0.820	4.53	12.00	1.97
Generator - Return	1.10	1" Sch 40	1.050	5.12	12.00	0.40

5.2 Engine Fuel Suction Pressure Calculations

The attached system model confirms that the piping systems are compatible with the main engines' fuel supply allowable line restriction requirements. As listed above, the maximum fuel line restriction is 4.37 psi. The attached model shows the calculated pressure loss to be 2.5 psi.

The attached system model confirms that the piping systems are compatible with the generator engines' fuel supply allowable line restriction requirements. As listed above, the maximum fuel line restriction is 1.47 psi. The attached model shows the calculated pressure loss to be 0.6 psi.

5.3 Engine Fuel Return Pressure Calculations

The attached model of the fuel system's return piping confirms that the backpressure at the main engines does not exceed the listed maximum value of 3.93psi. The return line restriction at the main engines was found to be 1.163 psi.

The generators fuel return line restriction is calculated to be 1.35 psi which is below the stated maximum of 1.47 psi. Note, however, that this assumes the generator is installed on a foundation that is approximately 16" above the engine room grating. This is also considering the scenario wherein both main engines are returning to the same tank. Particular attention should be paid toward generator selection and installation with respect to fuel oil return during detail design.

6 REFERENCES

[1] Caterpillar, "C18 Systems Data," EM0270, 12/19/2016.

[2] Northern Lights, "ISM Toyota Mitsubishi Marine Genset Specs; Model M944T3," Feb 2016.

[3] Elliott Bay Design Group, "NCDOT Pedestrian Ferry: Profiles and Arrangements," 16109-003-101-1, Seattle, WA.

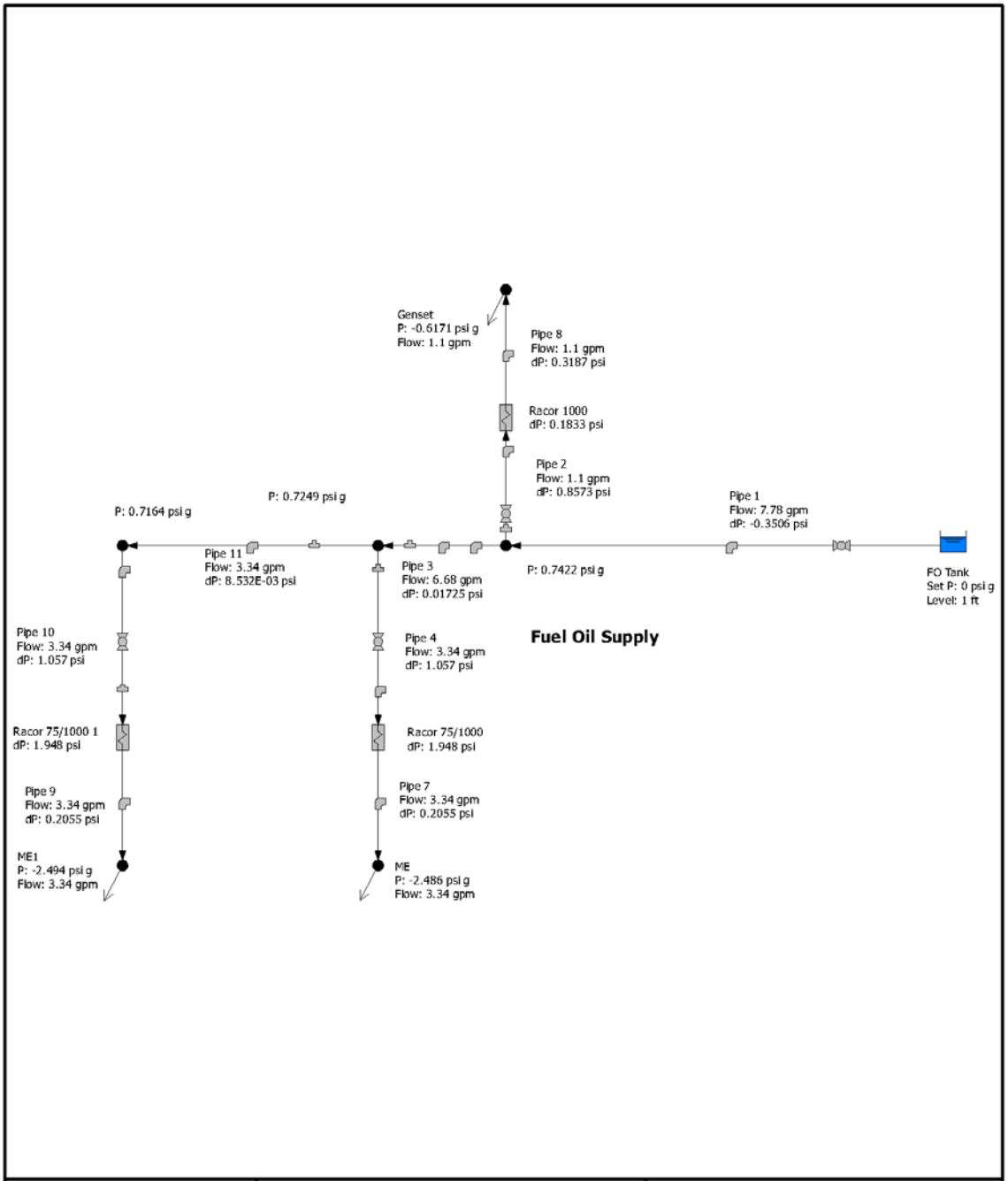
[4] Elliott Bay Design Group, "NCDOT Pedestrian Ferry: Fuel Oil Diagram," 16109-003-261-1, Seattle, WA.

[5] Parker Racor, "Racor Products Catolog: Marine Fuel Filtration Products: 79/1000MAV".

[6] Parker Racor, "Racor Products Catolog:Marine Fuel Filtration Products: 1000MA".

[7] R. L. Harrington, Marine Engineering, Jersey City, NJ: SNAME, 1992.

FUEL OIL SUPPLY PIPE-FLO MODEL



PIPE-FLO Professional		Units Used				Project Information	
Program Version:	15.2.37316	Flow rate:	gpm	Power:	hp	Company:	EBDG
Calculation Method:	Darcy-Weisbach	Velocity:	ft/s	Temperature:	°F	Project:	16101
Maximum Iterations:	100	Pressure:	psi	Density:	lb/ft³	Drawn by:	LGB
Iteration Tolerance:	0.01	Elevation:	ft	Viscosity:	cP	File Name:	16101-200-261 Supply.pipe
Laminar Cutoff Re:	2100	Length:	ft	Atm Pressure:	14.7 psi a	Lineup:	<Design Case>
		Size:	in			Print Date:	Friday, July 28, 2017 08:46 AM

List Report

File Name: 16101-200-261 Supply.pipe	**Calculation Method:** Darcy-Weisbach	**Company:** EBDG	
Lineup: <Design Case>	**Laminar Cutoff Re:** 2100	**Project:** 16101	
Progam Name: PIPE-FLO Professional	**Max Iterations:** 100	**by:** LGB	
Version: 15.2.37316	**Percent Tolerance:** 0.01	**Date:** Friday, July 28, 2017 08:47 AM	
	Allowable Deviation: 1 %	**Atmospheric Pressure:** 14.7 psi a	

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits: Velocity	Design Limits: Pressure	Design Limits: Reynolds Number
ASTM A53 Sch 40 standard	Steel A53-B36.10 Schedule:40	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Fuel 3 Fuel 3 Max	50 °F 0 psi g	Liquid 1	56.38 lb/ft³ 10.19 cP	0.2171 psi a 3199 psi a	-- --

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1 ASTM A53 Sch 40 Fuel 3	2 in 2.067 in 30 ft	FO Tank 2.5 ft Node 1 1.5 ft	7.78 gpm 0.7439 ft/s 1055 0.06068	0.3915 psi g 0.3882 psi g 3.5 ft 3.491 ft	-0.3506 psi 0.1044 ft	0.7422 psi g 0.7388 psi g 3.396 ft 3.387 ft	0.01899 1.58 5.307E-03 psi 0.01355 ft
Pipe 10 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	Node 6 1.5 ft Racor 75/1000 1 3.5 ft	3.34 gpm 2.009 ft/s 1136 0.05634	0.7164 psi g 0.6918 psi g 3.33 ft 3.267 ft	1.057 psi 0.6993 ft	-0.3404 psi g -0.365 psi g 2.63 ft 2.568 ft	0.02398 2.94 0.07219 psi 0.1844 ft
Pipe 11 ASTM A53 Sch 40 Fuel 3	2 in 2.067 in 15 ft	Node 5 1.5 ft Node 6 1.5 ft	3.34 gpm 0.3193 ft/s 452.8 0.1413	0.7249 psi g 0.7243 psi g 3.352 ft 3.35 ft	8.532E-03 psi 0.02179 ft	0.7164 psi g 0.7157 psi g 3.33 ft 3.328 ft	0.01899 1.44 8.955E-04 psi 2.287E-03 ft
Pipe 2 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	Node 1 1.5 ft Racor 1000 3.5 ft	1.1 gpm 0.6618 ft/s 374.1 0.1711	0.7422 psi g 0.7395 psi g 3.396 ft 3.389 ft	0.8573 psi 0.1896 ft	-0.1151 psi g -0.1178 psi g 3.206 ft 3.199 ft	0.02398 2.94 7.830E-03 psi 0.02 ft
Pipe 3 ASTM A53 Sch 40 Fuel 3	2 in 2.067 in 10 ft	Node 1 1.5 ft Node 5 1.5 ft	6.68 gpm 0.6387 ft/s 905.7 0.07067	0.7422 psi g 0.7397 psi g 3.396 ft 3.389 ft	0.01725 psi 0.04406 ft	0.7249 psi g 0.7224 psi g 3.352 ft 3.345 ft	0.01899 2.85 7.070E-03 psi 0.01806 ft
Pipe 4 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	Node 5 1.5 ft Racor 75/1000 3.5 ft	3.34 gpm 2.009 ft/s 1136 0.05634	0.7249 psi g 0.7003 psi g 3.352 ft 3.289 ft	1.057 psi 0.6993 ft	-0.3319 psi g -0.3565 psi g 2.652 ft 2.589 ft	0.02398 2.94 0.07219 psi 0.1844 ft
Pipe 7 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 3 ft	Racor 75/1000 3.5 ft ME 3.75 ft	3.34 gpm 2.009 ft/s 1136 0.05634	-2.28 psi g -2.305 psi g -2.324 ft -2.387 ft	0.2055 psi 0.2748 ft	-2.486 psi g -2.51 psi g -2.599 ft -2.662 ft	0.02398 1.92 0.04713 psi 0.1204 ft

PIPE-FLO Professional **Version: 15.2.37316** **List Report** **Friday, July 28, 2017 08:47 AM** **Page 1**

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 8 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 3 ft	Racor 1000 3.5 ft Genset 4.25 ft	1.1 gpm 0.6618 ft/s 374.1 0.1711	-0.2984 psi g -0.3011 psi g 2.738 ft 2.731 ft	0.3187 psi 0.06393 ft	-0.6171 psi g -0.6198 psi g 2.674 ft 2.667 ft	0.02398 1.92 5.112E-03 psi 0.01306 ft
Pipe 9 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 3 ft	Racor 75/1000 1 3.5 ft ME1 3.75 ft	3.34 gpm 2.009 ft/s 1136 0.05634	-2.289 psi g -2.313 psi g -2.346 ft -2.409 ft	0.2055 psi 0.2748 ft	-2.494 psi g -2.519 psi g -2.621 ft -2.684 ft	0.02398 1.92 0.04713 psi 0.1204 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
FO Tank Fuel 3	2.5 ft 1 ft	0 psi g 0.3915 psi g	3.5 ft	Pipe 1	0 ft	7.78 gpm	0.3915 psi g

Curve dP Devices

Curve dP Device Name Description	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Racor 1000 Racor 1000	3.5 ft -0.1151 psi g	3.5 ft -0.2984 psi g	0.1833 psi 0.4683 ft	1.1 gpm
Racor 75/1000 Racor 75/1000	3.5 ft -0.3319 psi g	3.5 ft -2.28 psi g	1.948 psi 4.976 ft	3.34 gpm
Racor 75/1000 1 Racor 75/1000	3.5 ft -0.3404 psi g	3.5 ft -2.289 psi g	1.948 psi 4.976 ft	3.34 gpm

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	1.5 ft	0.7422 psi g	3.388 ft
Node 5	1.5 ft	0.7249 psi g	3.328 ft
Node 6	1.5 ft	0.7164 psi g	3.298 ft

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Genset	4.25 ft	-0.6171 psi g	2.667 ft	1.1 gpm	Flow out
ME	3.75 ft	-2.486 psi g	-2.662 ft	3.34 gpm	Flow out
ME1	3.75 ft	-2.494 psi g	-2.684 ft	3.34 gpm	Flow out

Bill of Materials Report

File Name: 16101-200-261 Supply.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 08:46 AM

Tanks

Tank Name
FO Tank

Curve dP Devices

Curve dP Device Name	Curve Description
Racor 1000	Racor 1000
Racor 75/1000	Racor 75/1000
Racor 75/1000 1	Racor 75/1000

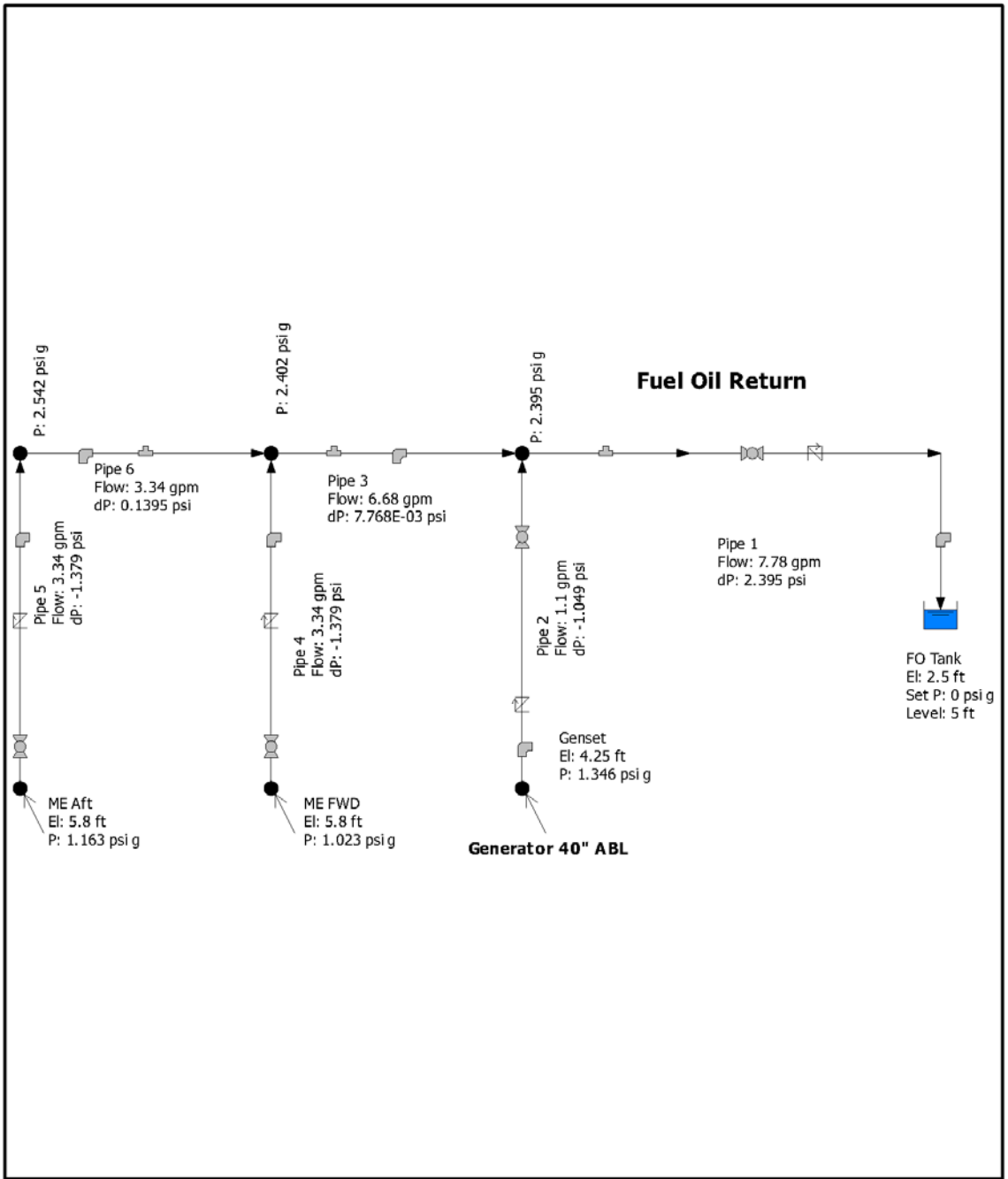
Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	ASTM A53 Sch 40	2 in	30 ft	4 x Pipe Bend - r/d 1 (90°) 1 x Ball
Pipe 10	ASTM A53 Sch 40	0.75 in	10 ft	1 x Ball 1 x Reducer - Contraction (0.75 in x 2 in - 0 in) 1 x Tee - Flow Thru Branch 3 x Pipe Bend - r/d 1.5 (90°)
Pipe 11	ASTM A53 Sch 40	2 in	15 ft	4 x Pipe Bend - r/d 1.5 (90°) 1 x Tee - Flow Thru Run
Pipe 2	ASTM A53 Sch 40	0.75 in	10 ft	1 x Reducer - Contraction (0.75 in x 2 in - 0 in) 1 x Ball 3 x Pipe Bend - r/d 1.5 (90°) 1 x Tee - Flow Thru Branch
Pipe 3	ASTM A53 Sch 40	2 in	10 ft	2 x Pipe Bend - r/d 1 (90°) 3 x Elbow - Standard 90° 1 x Tee - Flow Thru Run
Pipe 4	ASTM A53 Sch 40	0.75 in	10 ft	1 x Ball 1 x Reducer - Contraction (0.75 in x 2 in - 0 in) 3 x Pipe Bend - r/d 1.5 (90°) 1 x Tee - Flow Thru Branch
Pipe 7	ASTM A53 Sch 40	0.75 in	3 ft	4 x Pipe Bend - r/d 1 (90°)
Pipe 8	ASTM A53 Sch 40	0.75 in	3 ft	4 x Pipe Bend - r/d 1 (90°)
Pipe 9	ASTM A53 Sch 40	0.75 in	3 ft	4 x Pipe Bend - r/d 1 (90°)

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
ASTM A53 Sch 40	Steel A53-B36.10 Schedule: 40	0.75 in	39.00 ft	3 x Ball 12 x Pipe Bend - r/d 1 (90°) 9 x Pipe Bend - r/d 1.5 (90°) 3 x Reducer - Contraction (0.75 in x 2 in - 0 in) 3 x Tee - Flow Thru Branch
ASTM A53 Sch 40	Steel A53-B36.10 Schedule: 40	2 in	55.00 ft	1 x Ball 3 x Elbow - Standard 90° 6 x Pipe Bend - r/d 1 (90°) 4 x Pipe Bend - r/d 1.5 (90°) 2 x Tee - Flow Thru Run

FUEL OIL RETURN PIPE-FLO MODEL



PIPE-FLO Professional		Units Used				Project Information	
Program Version:	15.2.37316	Flow rate:	gpm	Power:	hp	Company:	EBDG
Calculation Method:	Darcy-Weisbach	Velocity:	ft/s	Temperature:	°F	Project:	16101
Maximum Iterations:	100	Pressure:	psi	Density:	lb/ft³	Drawn by:	LGB
Iteration Tolerance:	0.01	Elevation:	ft	Viscosity:	cP	File Name:	16101-200-261 Return.pipe
Laminar Cutoff Re:	2100	Length:	ft	Atm Pressure:	14.7 psi a	Lineup:	<Design Case>
		Size:	in			Print Date:	Friday, July 28, 2017 08:58 AM

List Report

File Name: 16101-200-261 Return.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Percent Tolerance: 0.01
Allowable Deviation: 1 %

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 08:59 AM
Atmospheric Pressure: 14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits: Velocity	Design Limits: Pressure	Design Limits: Reynolds Number
ASTM A 53 Sch 40 standard	Steel A53-B36.10 Schedule:40	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	
ASTM-A-269 0.065 Wall standard	SSteel ASTM-A-269 Schedule:.065	6E-05 in 100	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Fuel 3 Fuel 3 Max	50 °F 0 psi g	Liquid 1	56.38 lb/ft³ 10.19 cP	0.2171 psi a 3199 psi a	-- --

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1 ASTM A 53 Sch 40 Fuel 3	2 in 2.067 in 30 ft	Node 1 1.5 ft FO Tank 7.5 ft	7.78 gpm 0.7439 ft/s 1055 0.06068	2.395 psi g 2.391 psi g 7.616 ft 7.608 ft	2.395 psi 0.1162 ft	0 psi g -3.367E-03 psi g 7.5 ft 7.491 ft	0.01899 2.94 9.910E-03 psi 0.02531 ft
Pipe 2 ASTM A 53 Sch 40 Fuel 3	1 in 1.049 in 10 ft	Genset 4.25 ft Node 1 1.5 ft	1.1 gpm 0.4083 ft/s 293.9 0.2178	1.346 psi g 1.345 psi g 7.688 ft 7.685 ft	-1.049 psi 0.07141 ft	2.395 psi g 2.394 psi g 7.616 ft 7.614 ft	0.02249 2.64 2.681E-03 psi 6.848E-03 ft
Pipe 3 ASTM A 53 Sch 40 Fuel 3	2 in 2.067 in 3 ft	Node 2 1.5 ft Node 1 1.5 ft	6.68 gpm 0.6387 ft/s 905.7 0.07067	2.402 psi g 2.4 psi g 7.636 ft 7.63 ft	7.768E-03 psi 0.01984 ft	2.395 psi g 2.392 psi g 7.616 ft 7.61 ft	0.01899 1.90 4.713E-03 psi 0.01204 ft
Pipe 4 ASTM A 53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	ME FWD 5.8 ft Node 2 1.5 ft	3.34 gpm 2.009 ft/s 1136 0.05634	1.023 psi g 0.9987 psi g 8.414 ft 8.351 ft	-1.379 psi 0.7776 ft	2.402 psi g 2.378 psi g 7.636 ft 7.573 ft	0.02398 4.19 0.1028 psi 0.2627 ft
Pipe 5 ASTM A 53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	ME Aft 5.8 ft Node 3 1.5 ft	3.34 gpm 2.009 ft/s 1136 0.05634	1.163 psi g 1.138 psi g 8.77 ft 8.707 ft	-1.379 psi 0.7776 ft	2.542 psi g 2.517 psi g 7.992 ft 7.93 ft	0.02398 4.19 0.1028 psi 0.2627 ft
Pipe 6 ASTM A 53 Sch 40 Fuel 3	1 in 1.049 in 15 ft	Node 3 1.5 ft Node 2 1.5 ft	3.34 gpm 1.24 ft/s 892.3 0.07173	2.542 psi g 2.533 psi g 7.992 ft 7.969 ft	0.1395 psi 0.3564 ft	2.402 psi g 2.393 psi g 7.636 ft 7.612 ft	0.02249 2.61 0.02441 psi 0.06234 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
FO Tank Fuel 3	2.5 ft 5 ft	0 psi g 1.958 psi g	7.5 ft				
				Pipe 1	5 ft	7.78 gpm	0 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	1.5 ft	2.395 psi g	7.61 ft
Node 2	1.5 ft	2.402 psi g	7.605 ft
Node 3	1.5 ft	2.542 psi g	7.949 ft

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Genset	4.25 ft	1.346 psi g	7.685 ft	1.1 gpm	Flow in
ME Aft	5.8 ft	1.163 psi g	8.707 ft	3.34 gpm	Flow in
ME FWD	5.8 ft	1.023 psi g	8.351 ft	3.34 gpm	Flow in

Bill of Materials Report

File Name: 16101-200-261 Return.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 08:58 AM

Tanks

Tank Name
FO Tank

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	ASTM A 53 Sch 40	2 in	30 ft	1 x Swing Check - Vertical 1 x Tee - Flow Thru Branch 3 x Pipe Bend - r/d 1.5 (90°) 1 x Ball
Pipe 2	ASTM A 53 Sch 40	1 in	10 ft	1 x Reducer - Contraction (1 in x 2 in - 1.5 in) 1 x Swing Check - Vertical 1 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 3	ASTM A 53 Sch 40	2 in	3 ft	2 x Pipe Bend - r/d 1 (90°) 1 x Tee - Flow Thru Branch
Pipe 4	ASTM A 53 Sch 40	0.75 in	10 ft	1 x Swing Check - Angled 1 x Reducer - Enlargement (0.75 in x 2 in - 3 in) 4 x Pipe Bend - r/d 1.5 (90°) 1 x Ball
Pipe 5	ASTM A 53 Sch 40	0.75 in	10 ft	1 x Swing Check - Angled 1 x Reducer - Enlargement (0.75 in x 2 in - 3 in) 4 x Pipe Bend - r/d 1.5 (90°) 1 x Ball
Pipe 6	ASTM A 53 Sch 40	1 in	15 ft	1 x Tee - Flow Thru Branch 4 x Elbow - Long radius, r/d 1.5 (90°)

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
ASTM A 53 Sch 40	Steel A53-B36.10 Schedule: 40	0.75 in	20.00 ft	2 x Ball 8 x Pipe Bend - r/d 1.5 (90°) 2 x Reducer - Enlargement (0.75 in x 2 in - 3 in) 2 x Swing Check - Angled
ASTM A 53 Sch 40	Steel A53-B36.10 Schedule: 40	1 in	25.00 ft	1 x Ball 8 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Contraction (1 in x 2 in - 1.5 in) 1 x Swing Check - Vertical 1 x Tee - Flow Thru Branch
ASTM A 53 Sch 40	Steel A53-B36.10 Schedule: 40	2 in	33.00 ft	1 x Ball 2 x Pipe Bend - r/d 1 (90°) 3 x Pipe Bend - r/d 1.5 (90°) 1 x Swing Check - Vertical 2 x Tee - Flow Thru Branch

Appendix E

Machinery Ventilation System, Dwg. 16101-200-513-1

1 DESCRIPTION

This appendix documents the calculations used in designing the machinery ventilation system. The required ventilation rate was calculated for each machinery or void space in the hold, and ducting calculations performed to determine required fan performance. Louver sizes for the emergency generator room are also determined.

2 PROCEDURE

Calculations are presented in the following sequence:

1) Space Airflow Calculation — Flow rates are calculated based on advised air changes per hour based upon space type or airflow per occupant [1]. For spaces containing diesel engines or oil fired machinery, airflow is based upon equipment combustion air intake and heat dissipation.

2) Duct/Trunk Size Calculation — Duct and trunk sizes are calculated based on nominal velocity limits given in [2]. These calculations are developed in conjunction with a preliminary duct layout in which flows through branches are determined.

3) Fan Pressure Calculation — Fan total and static pressures are calculated based on the frictional losses through the ducting established in the preceding step.

3 REGULATORY FRAMEWORK

The NEW RIVER CLASS ferries will be inspected by the US Coast Guard under the provisions of 46 CFR Subchapter H.

4 GIVEN AND ASSUMED PARAMETERS

- A maximum outdoor air temperature of 95°F is assumed for hold ventilation calculations. The maximum expected dry bulb temperature over a 20-year period is 95.2 °F. Per ASHRAE climatic data [3], the 0.4% outdoor air design temperature is 88.1 °F, which represents a temperature that is exceeded fewer than 40 hours per year.

- The machinery and void hold spaces will be fitted with flow-through ventilation systems utilizing 100% outdoor air.

- Compartment volumes are estimated based on the arrangement shown in [4]

- The following main propulsion engine parameters at 100% MCR are used in the calculations [5].

Parameter	Value
Combustion Air Intake	1,375 cfm
Engine Heat Rejection to Engine Room	1,534 btu/min

- The following diesel generator parameters at 100% MCR are used in the calculations for the ship service generators [6].

Parameter	Value
Combustion Air Intake	511 cfm
Generator Engine Heat Rejection	538 btu/min

- SSDG alternator heat rejection is estimated using 8% of rated generator capacity at full power or 683 btu/min

- The following parameters from [7] are used to size louvers for the emergency generator:

Parameter	Value
Max allowable duct restriction	0.5 in H_2O
Total Radiator Airflow, unrestricted	10171 cfm
Total Radiator Airflow, 0.5 inH2O restriction	9841 cfm

- The following oil cooler parameters at full capacity are used in the calculations for the cycloidal propellers [8].

Parameter	Value
Oil Cooler Rejection to Thruster Room	569 btu/min

- Engine Room ventilation calculation assumes:
  - Maximum temperature rise of 22.5 °F
  - Two main engines and one ship service generator operating at full power.

- Heat radiated from hot exhaust piping is estimated using data from [9], which assumes 1 3/4 inches to 2 3/4 inches of insulation and a 610°F temperature difference between exhaust and ambient.

- Lighting heat loads are not considered for these calculations, as lighting is intended to be high efficiency LEDs with minimal contribution to the heat load.

5 CONCLUSIONS

5.1 Engine Room

A minimum ventilation supply rate of 12,320 cfm and ventilation exhaust rate of 10,100 cfm are required to provide cooling and combustion air in the engine room.

Two supply fans, each providing 6,300 cfm, will supply air to the engine room via a pair of ventilation supply plenums on the main deck. Air will exhaust through the exhaust uptake to the

01 deck. The calculated total pressure loss is 2.02 inches H_2O. The corresponding static pressure for a 24-inch supply fan is 1.8 inches H_2O.

5.2 Voids

A minimum ventilation rate of 800 cfm is required to maintain six air changes per hour in each void.

One supply fan, providing 1,000 cfm, will supply air to each void via a ventilation supply plenum on the main deck. Air will exhaust through the exhaust plenums on the main deck. The calculated total pressure is 1.33 inches H_2O. The corresponding static pressure for a 12-inch supply fan is 1.24 inches H_2O.

5.3 Thruster Rooms

A minimum ventilation rate of 900 cfm is required to provide cooling and maintain six air changes per hour in each thruster room.

One supply fan, providing 1,000 cfm, will supply air to each thruster room via a ventilation supply plenum on the main deck. Air will exhaust through the exhaust plenums on the main deck. The calculated total pressure is 1.21 inches H_2O. The corresponding static pressure for a 12-inch supply fan is 1.12 inches H_2O.

5.4 Emergency Generator Room

Louvers 39 inches wide by 60 inches tall were selected to keep the emergency generator room restriction below 0.5 inches H_2O.

REFERENCES

[1] The Society of Naval Architects and Marine Engineers, "Technical and Research Bulletin 4-16: Calculations for Merchant Ship Heating, Ventilation and Air Conditioning Design," New York, NY, 08/1980.

[2] R. L. Harrington, Marine Engineering, Jersey City, NJ: SNAME, 1992.

[3] ASHRAE, Climatic Design Condtions Hattaras Billy Mitchel AP, NC, USA, ASHRAE, 2009.

[4] Elliott Bay Design Group, "New River Class Ferry: Profiles and Deck Arrangements," 16101-200-101-1, Rev -, Seattle, WA, 2017.

[5] Caterpillar, "EM0268; C18 600HP at 1800 rpm Performance Data," March 8, 2017.

[6] Caterpillar, "EM5070; C7.1 150ekW at 1800 rpm Performance Data," July 10, 2017.

[7] Caterpillar, LEHM02040-00 C4.4 ACERT Marine Generator Set Package, 2016.

[8] Rexroth Bosch Group, "Oil/Air Coolers Types KOL and KOLP, 10kW".

[9] International Organization for Standardization, "ISO 8861: Shipbuilding - Engine-room ventilation in diesel-engined ships - Design requirements and basis of calculations," 1988.

Engine Room Ventilation

Approach

The minimum required airflow to the Engine Room is calculated based on i) airflow necessary to dissipate heat given off by running equipment, and ii) minimum airflow of 6 air change per hour into the space.

Space and Equipment Loads

Main Engines

Main Engine Heat Rejection, qe =	1,534.00	*btu/min*	*Cat C18 600 BHP @ 1800 rpm*
Main engine Air Consumption, Qe =	1,375.00	*cfm*	
Number of Engines Operating, Ne =	2.00		
Engine Heat Rejection =	3,068.00	btu/min	

Generators

Generator Total Heat Rejection, qe =	1,221.00	*btu/min*	*CAT C7.1 150 ekW @ 1800 rpm*
Generator Engine Air Consumption, Qe =	511.00	*cfm*	
Number of Engines Operating, Ne =	1.00		
Engine Heat Rejection =	1,221.00	btu/min	

Exhaust Piping

Piping Diameter =	8.00	in	
Piping Length =	103.00	ft	
Heat Emmission Factor =	0.20	kW/m	ISO 8861, Figure 3
	3.47	btu/min/ft	
Estimated Exhaust Heat Rejection =	357.39	btu/min	

Main Deck Solar Load

Deck Temperature (Ts) =	145.00	°F	
Inside Temperature (Ti) =	117.50	°F	
Area =	2,216.00	ft^2	
Heat Transfer Coefficient (U) =	0.12	$btuh/ft^2°F$	
Heat Gain (q) =	121.88	btu/min	q=U x A * (Ts -Ti)/60

Side Shell

Temperature (T0) =	95.00	°F	
Inside Temperature (Ti) =	117.50	°F	
Area =	359.00	ft^2	
Heat Transfer Coefficient (U) =	1.34	$btuh/ft^2°F$	
Heat Gain (q) =	-180.26	btu/min	q=U x A * (To -Ti)/60

Side Shell

Temperature (To) =	95.00	°F	
Inside Temperature (Ti) =	117.50	°F	
Area =	205.00	ft^2	
Heat Transfer Coefficient (U) =	1.34	$btuh/ft^2°F$	
Heat Gain (q) =	-102.94	btu/min	q=U x A * (To -Ti)/60

Wetted Shell

Water Temperature (Tw) =	86.00	°F	
Inside Temperature (Ti) =	117.50	°F	
Area =	2,303.00	ft^2	
Heat Transfer Coefficient (U) =	0.80	$btuh/ft^2°F$	
Heat Gain (q) =	-968.47	btu/min	q=U x A * (Tw -Ti)/60

Total Heat Load =	3,516.61	btu/min

Inlet Air Conditions			
Summer Air In Temperature (TIN) =	95.00	*°F*	
Humidity Ratio	0.022	*lb/lb dry air*	
Air In Enthalpy (hIN) =	46.78	*Btu / lb*	*[5], Ch. 1, Eqn 32*
Air In Specific Volume (rIN) =	14.47	*ft³ / lb dry air*	*[5], Ch. 1, Eqn 28*
Exhaust Air Conditions			
Max Temperature (TOUT) =	117.50	*°F*	
Air Out Enthalpy (hOUT) =	52.40	*Btu / lb*	*[5], Ch. 1, Eqn 32*
Air out Specific Volume (rOUT) =	15.06	*ft³ / lb dry air*	*[5], Ch. 1, Eqn 28*
Other Givens			
Volume of Space (V) =	22,500	*ft³*	*[2]*
Minutes per air change (MA) =	10.00	*min*	*6 ACH*
Calculated Airflow based on Total Heat Load and Air Consumption			
Total Heat Rejection (Qe) =	3,517	*Btu / min*	
D Enthalpy (Dh) =	5.62	*Btu / lb*	*Dh= hOUT - hIN*
Required CFM (Heat Load) =	9,060	*cfm*	*CFM = (Qe / Dh x rIN)*
consumption air (Qc)=	3,261	*cfm*	
cooling + combustion air =	12,321	*cfm*	
Calculated Airflow based on minimum air exchanges:			
Volume of Space (V) =	22,500	*ft³*	
Air exchanges / min (AC)=	10	*min/AC*	
Required CFM(Air Exchange) =	2,250	*cfm*	*CFM = V/MA*
Calculated Exhaust Airflow			
inlet air (V)=	12,321	*cfm*	*(maximum of required airflows)*
inlet air specific volume (rIN)=	14.47	*ft3/lb*	
exhaust air specific volume (rOUT)=	15.06	*ft3/lb*	
expansion =	4.06%		
consumption air (Qc)=	2,750	*cfm*	
exhaust air =	10,071	*cfm*	*CFM = V / rIN * rOUT - Qc*
Results			
Total intake air=	12,300	*cfm*	*(based on heat load and air consumption)*
total exhaust air =	**10,100**	*cfm*	

Engine Room Total Pressure Calculation

Input Variables

Supply Air Temperature (T_{IN}) =	88	°F
Humidity Ratio	0.0217	lb/lb dry air
Air In Specific Volume (r_{IN}) =	14.29	ft³ / lb dry air
Supply air specific weight	0.070	lb/cu ft
Supply air viscosity	3.89E-07	lb-s/sq ft²
Supply air density	0.0022	slugs/cu ft
Max Temperature (T_{OUT}) =	115.0	°F
Air out Specific Volume (r_{OUT}) =	14.99	ft³ / lb dry air
Exhaust air specific weight	0.067	lb/cu ft
Exhaust air viscosity	4.02E-07	lb-s/sq ft²
Exhaust air density	0.0021	slugs/cu ft
Supply air flow rate	12600	cfm
Exhaust air flow rate	10400	ft/min

Description	height (in)	width (in)	w/h	eqiv dia (in)	hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Run A														
Inlet Demister (two in parallel), 0.4" H20	18	25	1.39	22.49	20.93	3.13		1	3150	1008	1.64E+05	0.018	6.900	30.24
Inlet to Structural Trunk- 90 deg sharp	9	72	8.00	24.11	16.00	4.50		1	6300	1400	1.74E+05	0.018	1.300	10.99
Structrual Trunk, Net Area	12.00	72.00	0.17	-	20.57	6.00	9	1	6300	1050	1.67E+05	0.018	0.094	0.45
Add' 1 HL for misc losses in trunk	12.00	72.00	0.17	-	20.57	6.00	9	1	6300	1050	1.67E+05	0.018	1.000	4.76
Deck cutout, outlet to plenum	12	64	5.33	27.24	20.21	5.33		1	6300	1181	1.85E+05	0.018	1.500	9.03
Abrupt contraction - Plenum to Duct			-	-	24.00	3.14		1	6300	2005	3.73E+05	0.016	0.500	8.67
Fire Damper	24	24	1.00	25.53	24.00	3.14		1	6300	2005	3.73E+05	0.016	0.520	9.02
Fan			-	-	24.00	3.14		1	6300	2005	3.73E+05	0.016	0.000	0.00
Ducting			-	-	24.00	3.14	4	1	6300	2005	3.73E+05	0.016	0.033	0.56
Rect to Round Transition, 12" long	20	24	1.20	23.28	21.82	3.33		1	6300	1890	3.20E+05	0.017	0.060	0.92
Divide Flow, Equal Areas	10	24	2.40	16.10	14.12	1.67		1	3550	2130	2.33E+05	0.018	0.100	1.96
Ducting	10	24	2.40	16.10	14.12	1.67	2	1	3550	2130	2.33E+05	0.018	0.031	0.60
60 degree Direct take-off	8	8	1.00	8.51	8.00	0.44		1	750	1688	1.05E+05	0.021	1.500	18.42
Ducting	8	8	1.00	8.51	8.00	0.44	8	1	750	1688	1.05E+05	0.021	0.255	3.14
Elbow	8	8	1.00	8.51	8.00	0.44		1	750	1688	1.05E+05	0.021	0.300	3.68
Outlet, abrupt discharge w/ screen	8	8	1.00	8.51	8.00	0.44	1	1	750	1688	1.05E+05	0.021	1.600	19.65
													Segment total pressure	*122.10*

Description	height (in)	width (in)	h/w		hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Exhaust Vent														
Deck Cutout to Trunk (two in parallel)	32.00	62.00	0.52		42.21	13.78		1	5200	377	1.14E+05	0.018	0.750	0.46
Structrual Trunk	58.00	58.00	1.00	-	58.00	23.36	10	1	10400	445	1.85E+05	0.017	0.034	0.03
Add' 1 HL for misc losses in trunk	58.00	58.00	1.00	-	58.00	23.36	10	1	10400	445	1.85E+05	0.017	1.000	0.85
Deck penetration	44	64	1.45	56.20	52.15	19.56		1	10400	532	2.15E+05	0.016	0.200	0.24
Structrual Trunk, Net Area (less exhaust)	49.50	49.50	1.00	-	49.50	17.02	10	1	10400	611	2.17E+05	0.016	0.040	0.06
Add' 1 HL for misc losses in trunk	49.50	49.50	1.00	-	49.50	17.02	10	1	10400	611	2.17E+05	0.016	1.000	1.61
Fire Damper	78	60	1.30	72.61	67.83	25.09		1	10400	414	2.18E+05	0.016	0.520	0.39
Exhaust Louver with insect screen	78	60	1.30	-	67.83	19.50		1	10400	533	2.59E+05	0.016	3.600	4.42
													Segment total pressure	*8.07*

	FT	in H2O
supply air total pressure	**122.10**	**1.643**
exhaust air total pressure	**8.07**	**0.109**
Total	**130.17**	**1.752**
15% design margin	**149.69**	**2.015**

Supply Fan Static Pressure	
Fan Dia (in)	24.00
Fan area (ft2)	3.14
flowrate (cfm)	6300
velocity (fpm)	2005
fan velocity pressure	0.2229
Static Pressure for fan selection (in H20)	**1.792**

Void Ventilation

Approach

The minimum required airflow to the Engine Room is calculated based on i) airflow necessary to dissipate heat given off by running equipment, and ii) minimum airflow of 6 air change per hour into the space.

Space and Equipment Loads

Main Deck Solar Load

Deck Temperature (Ts) =	145.00	°F	
Inside Temperature (Ti) =	115.00	°F	
Area =	901.00	ft^2	
Heat Transfer Coefficient (U) =	0.12	$btuh/ft^2°F$	
Heat Gain (q) =	54.06	btu/min	q=U x A * (Ts -Ti)/60

Side Shell

Temperature (T0) =	95.00	°F	
Inside Temperature (Ti) =	115.00	°F	
Area =	138.00	ft^2	
Heat Transfer Coefficient (U) =	1.39	$btuh/ft^2°F$	
Heat Gain (q) =	-63.94	btu/min	q=U x A * (To -Ti)/60

Side Shell

Temperature (To) =	95.00	°F	
Inside Temperature (Ti) =	115.00	°F	
Area =	292.00	ft^2	
Heat Transfer Coefficient (U) =	1.34	$btuh/ft^2°F$	
Heat Gain (q) =	-130.33	btu/min	q=U x A * (To -Ti)/60

Wetted Shell

Water Temperature (Tw) =	86.00	°F	
Inside Temperature (Ti) =	115.00	°F	
Area =	975.00	ft^2	
Heat Transfer Coefficient (U) =	0.80	$btuh/ft^2°F$	
Heat Gain (q) =	-377.47	btu/min	q=U x A * (Tw -Ti)/60

Total Heat Load = -517.68 btu/min

Inlet Air Conditions			
Summer Air In Temperature (TIN) =	95.00	*°F*	
Humidity Ratio	0.022	*lb/lb dry air*	
Air In Enthalpy (hIN) =	46.78	*Btu / lb*	*[5], Ch. 1, Eqn 32*
Air In Specific Volume (rIN) =	14.47	*ft³ / lb dry air*	*[5], Ch. 1, Eqn 28*
Exhaust Air Conditions			
Max Temperature (TOUT) =	115.00	*°F*	
Air Out Enthalpy (hOUT) =	51.77	*Btu / lb*	*[5], Ch. 1, Eqn 32*
Air out Specific Volume (rOUT) =	14.99	*ft³ / lb dry air*	*[5], Ch. 1, Eqn 28*
Other Givens			
Volume of Space (V) =	8,054	*ft³*	*[2]*
Minutes per air change (MA) =	10.00	*min*	*6 ACH*
Calculated Airflow based on Total Heat Load			
Total Heat Rejection (Qe) =	(518)	*Btu / min*	
D Enthalpy (Dh) =	4.99	*Btu / lb*	*Dh= hOUT - hIN*
Required CFM (Heat Load) =	(1,500)	*cfm*	*CFM = (Qe / Dh x rIN)*
consumption air (Qc)=	-	*cfm*	
cooling + combustion air =	(1,500)	*cfm*	
Calculated Airflow based on minimum air exchanges:			
Volume of Space (V) =	8,054	*ft³*	
Air exchanges / min (AC)=	10	*min/AC*	
Required CFM(Air Exchange) =	805	*cfm*	*CFM = V/MA*
Calculated Exhaust Airflow			
inlet air (V)=	805	*cfm*	*(maximum of required airflows)*
inlet air specific volume (rIN)=	14.47	*ft3/lb*	
exhaust air specific volume (rOUT)=	14.99	*ft3/lb*	
expansion =	3.61%		
consumption air (Qc)=	-	*cfm*	
exhaust air =	834	*cfm*	*CFM = V / rIN * rOUT - Qc*
Results			
Total intake air=	800	*cfm*	*(minimum airflow)*
total exhaust air =	**834**	*cfm*	

Void Total Pressure Calculation

Input Variables

Supply Air Temperature (T_{IN}) =	88	°F
Humidity Ratio	0.0217	lb/lb dry air
Air In Specific Volume (r_{IN}) =	14.29	ft³ / lb dry air
Supply air specific weight	0.070	lb/cu ft
Supply air viscosity	3.89E-07	lb-s/sq ft²
Supply air density	0.0022	slugs/cu ft
Max Temperature (T_{OUT}) =	115.0	°F
Air out Specific Volume (r_{OUT}) =	14.99	ft³ / lb dry air
Exhaust air specific weight	0.067	lb/cu ft
Exhaust air viscosity	4.02E-07	lb-s/sq ft²
Exhaust air density	0.0021	slugs/cu ft
Supply air flow rate	1000	cfm
Exhaust air flow rate	1000	cfm

Description	height (in)	width (in)	w/h	eqiv dia (in)	hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Supply Ducting														
Inlet Demister	12	12	1.00	12.76	12.00	1.00		1	1000	1000	9.30E+04	0.021	8.600	37.09
Inlet to Structural Trunk- 90 deg sharp	15	24	1.60	20.05	18.46	2.50		1	1000	400	5.72E+04	0.022	1.300	0.90
Structrual Trunk, Net Area	15	24	0.63	-	18.46	2.50	3	1	1000	400	5.29E+04	0.022	0.043	0.03
Add' 1 HL for misc losses in trunk	15	24	0.63	-	18.46	2.50		1	1000	400	5.29E+04	0.022	1.000	0.69
Abrupt contraction - trunk to pipe			-	-	12.00	0.79		1	1000	1273	1.18E+05	0.020	0.600	4.20
Elbow r/d = 1			-	-	12.00	0.79		2	1000	1273	1.18E+05	0.020	0.300	4.20
Fan			-	-	12.00	0.79		1	1000	1273	1.18E+05	0.020	0.000	0.00
Ducting					12.00	0.79	17	1	1000	1273	1.18E+05	0.020	0.339	2.37
Tee, straight branch 12x10					10.00	0.55		2	500	917	7.11E+04	0.022	2.090	15.15
Ducting				10.00	10.00	0.55	9	1	500	917	7.11E+04	0.022	0.236	0.86
Balancing Damper, Butterfly			-	-	10.00	0.55		1	500	917	7.11E+04	0.022	0.190	0.69
Terminal w/ Screen (wire mesh)			-	-	10.00	0.55		1	500	917	7.11E+04	0.022	1.600	5.80
													Segment total pressure	71.97

Description	height (in)	width (in)	h/w		hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Exhaust Vent														
Deck Cutout to Structural Trunk	10	20	0.50		13.33	1.39		1	1000	720	6.88E+04	0.021	0.900	2.01
Structrual Trunk, Net Area	14	24	0.58	-	17.68	2.33	10	1	1000	429	5.43E+04	0.022	0.149	0.12
Add' 1 HL for misc losses in trunk	14	24	0.58	-	17.68	2.33	10	1	1000	429	5.43E+04	0.022	1.000	0.79
Exhaust Louver with insect screen	18	16	1.13	-	16.94	1.20		1	1000	833	1.01E+05	0.020	3.600	10.78
													Segment total pressure	*13.71*

	FT	in H2O
supply air total pressure	**71.97**	**0.969**
exhaust air total pressure	**13.71**	**0.184**
Total	**85.67**	**1.153**
15% design margin	**98.52**	**1.326**

Supply Fan Static Pressure	
Fan Dia (in)	12.00
Fan area (ft2)	0.79
flowrate (cfm)	1000
velocity (fpm)	1273
fan velocity pressure	0.0898
Static Pressure for fan selection (in H20)	**1.2361**

Thruster Room Ventilation

Approach

The minimum required airflow to the Engine Room is calculated based on i) airflow necessary to dissipate heat given off by running equipment, and ii) minimum airflow of 6 air change per hour into the space.

Space and Equipment Loads

Cycloidal Propeller

Heat Rejection, qe =	569.00	*btu/min*	*Oil Cooler 10kW*

Main Deck Solar Load

Deck Temperature (Ts) =	145.00	°F	
Inside Temperature (Ti) =	115.00	°F	
Area =	760.00	ft^2	
Heat Transfer Coefficient (U) =	0.12	$btuh/ft^2°F$	
Heat Gain (q) =	45.60	btu/min	q=U x A * (Ts -Ti)/60

Side Shell and Ballast Tanks

Temperature (T0) =	95.00	°F	
Inside Temperature (Ti) =	115.00	°F	
Area =	240.00	ft^2	
Heat Transfer Coefficient (U) =	1.39	$btuh/ft^2°F$	
Heat Gain (q) =	-111.20	btu/min	q=U x A * (To -Ti)/60

Side Shell

Temperature (To) =	95.00	°F	
Inside Temperature (Ti) =	115.00	°F	
Area =	240.00	ft^2	
Heat Transfer Coefficient (U) =	1.34	$btuh/ft^2°F$	
Heat Gain (q) =	-107.12	btu/min	q=U x A * (To -Ti)/60

Wetted Shell

Water Temperature (Tw) =	86.00	°F	
Inside Temperature (Ti) =	115.00	°F	
Area =	760.00	ft^2	
Heat Transfer Coefficient (U) =	0.80	$btuh/ft^2°F$	
Heat Gain (q) =	-294.23	btu/min	q=U x A * (Tw -Ti)/60

Total Heat Load =	102.05	btu/min

Inlet Air Conditions			
Summer Air In Temperature (TIN) =	95.00	*°F*	
Humidity Ratio	0.022	*lb/lb dry air*	
Air In Enthalpy (hIN) =	46.78	*Btu / lb*	*[5], Ch. 1, Eqn 32*
Air In Specific Volume (rIN) =	14.47	*ft³ / lb dry air*	*[5], Ch. 1, Eqn 28*
Exhaust Air Conditions			
Max Temperature (TOUT) =	115.00	*°F*	
Air Out Enthalpy (hOUT) =	51.77	*Btu / lb*	*[5], Ch. 1, Eqn 32*
Air out Specific Volume (rOUT) =	14.99	*ft³ / lb dry air*	*[5], Ch. 1, Eqn 28*
Other Givens			
Volume of Space (V) =	8,517	*ft³*	*[2]*
Minutes per air change (MA) =	10.00	*min*	*6 ACH*
Calculated Airflow based on Total Heat Load and Air Consumption			
Total Heat Rejection (Qe) =	102	*Btu / min*	
D Enthalpy (Dh) =	4.99	*Btu / lb*	*Dh= hOUT - hIN*
Required CFM (Heat Load) =	296	*cfm*	*CFM = (Qe / Dh x rIN)*
consumption air (Qc)=	-	*cfm*	
cooling + combustion air =	296	*cfm*	*(50% combustion air from cooling air)*
Calculated Airflow based on minimum air exchanges:			
Volume of Space (V) =	8,517	*ft³*	
Air exchanges / min (AC)=	10	*min/AC*	
Required CFM(Air Exchange) =	852	*cfm*	*CFM = V/MA*
Calculated Exhaust Airflow			
inlet air (V)=	852	*cfm*	*(maximum of required airflows)*
inlet air specific volume (rIN)=	14.47	*ft3/lb*	
exhaust air specific volume (rOUT)=	14.99	*ft3/lb*	
expansion =	3.61%		
consumption air (Qc)=	-	*cfm*	
exhaust air =	882	*cfm*	*CFM = V / rIN * rOUT - Qc*
Results			
Total intake air=	900	*cfm*	*(minimum airflow)*
total exhaust air =	**900**	*cfm*	

Thruster Room Total Pressure Calculation

Input Variables

Supply Air Temperature (T_{IN}) =	88	°F
Humidity Ratio	0.0217	lb/lb dry air
Air In Specific Volume (r_{IN}) =	14.29	ft³ / lb dry air
Supply air specific weight	0.070	lb/cu ft
Supply air viscosity	3.89E-07	lb-s/sq ft²
Supply air density	0.0022	slugs/cu ft
Max Temperature (T_{OUT}) =	115.0	°F
Air out Specific Volume (r_{OUT}) =	14.99	ft³ / lb dry air
Exhaust air specific weight	0.067	lb/cu ft
Exhaust air viscosity	4.02E-07	lb-s/sq ft²
Exhaust air density	0.0021	slugs/cu ft
Supply air flow rate	1000	cfm
Exhaust air flow rate	1000	cfm

Description	height (in)	width (in)	w/h	eqiv dia (in)	hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Supply Ducting														
Inlet Demister	12	12	1.00	12.76	12.00	1.00		1	1000	1000	9.30E+04	0.021	8.600	37.09
Inlet to Structural Trunk- 90 deg sharp	15	24	1.60	20.05	18.46	2.50		1	1000	400	5.72E+04	0.022	1.300	0.90
Structrual Trunk	15	24	0.63	-	18.46	2.50	3	1	1000	400	5.29E+04	0.022	0.043	0.03
Add' 1 HL for misc losses in trunk	15	24	0.63	-	18.46	2.50		1	1000	400	5.29E+04	0.022	1.000	0.69
Abrupt contraction - trunk to pipe			-	-	12.00	0.79		1	1000	1273	1.18E+05	0.020	0.600	4.20
Elbow r/d = 1			-	-	12.00	0.79		2	1000	1273	1.18E+05	0.020	0.300	4.20
Fan			-	-	12.00	0.79		1	1000	1273	1.18E+05	0.020	0.000	0.00
Ducting					12.00	0.79	6	1	1000	1273	1.18E+05	0.020	0.119	0.84
Tee, run, 12x8					12.00	0.79		2	750	955	8.88E+04	0.021	0.200	1.57
Ducting				10.00	12.00	0.79	10	1	750	955	8.88E+04	0.021	0.207	0.82
Tee, branch 12x8					8.00	0.35		2	250	716	4.44E+04	0.024	2.090	9.25
Ducting				8.00	8.00	0.35	10	1	250	716	4.44E+04	0.024	0.361	0.80
Balancing Damper, Butterfly			-	-	8.00	0.35		1	250	716	4.44E+04	0.024	0.190	0.42
Terminal w/ Screen (wire mesh)			-	-	8.00	0.35		1	250	716	4.44E+04	0.024	1.600	3.54
													Segment total pressure	64.33

Description	height (in)	width (in)	h/w		hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Exhaust Vent														
Deck Cutout to Structural Trunk	10	20	0.50		13.33	1.39		1	1000	720	6.88E+04	0.021	0.900	2.01
Structrual Trunk, Net Area	14	24	0.58	-	17.68	2.33	10	1	1000	429	5.43E+04	0.022	0.149	0.12
Add' 1 HL for misc losses in trunk	14	24	0.58	-	17.68	2.33	10	1	1000	429	5.43E+04	0.022	1.000	0.79
Exhaust Louver with insect screen	18	16	1.13	-	16.94	1.20		1	1000	833	1.01E+05	0.020	3.600	10.78
													Segment total pressure	*13.71*

	FT	in H2O
supply air total pressure	**64.33**	**0.866**
exhaust air total pressure	**13.71**	**0.184**
Total	**78.04**	**1.050**
15% design margin	**89.75**	**1.208**

Supply Fan Static Pressure	
Fan Dia (in)	12.00
Fan area (ft2)	0.79
flowrate (cfm)	1000
velocity (fpm)	1273
fan velocity pressure	0.0898
Static Pressure for fan selection (in H20)	**1.1180**

Emergency Generator Room Total Pressure Calculation

Input Variables

Supply Air Temperature (T_{IN}) =	88	°F
Humidity Ratio	0.0217	lb/lb dry air
Air In Specific Volume (r_{IN}) =	14.29	ft³ / lb dry air
Supply air specific weight	0.070	lb/cu ft
Supply air viscosity	3.89E-07	lb-s/sq ft²
Supply air density	0.0022	slugs/cu ft
Max Temperature (T_{OUT}) =	115.0	°F
Air out Specific Volume (r_{OUT}) =	14.99	ft³ / lb dry air
Exhaust air specific weight	0.067	lb/cu ft
Exhaust air viscosity	4.02E-07	lb-s/sq ft²
Exhaust air density	0.0021	slugs/cu ft
Supply air flow rate	9841	cfm
Exhaust air flow rate	9841	cfm

Description	height (in)	width (in)	h/w		hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Egen Room Inlet														
Inlet louver with insect screen	60	39	1.54	-	47.27	9.75		1	9841	1009	3.42E+05	0.015	3.600	15.82
Fire Damper	60	39	1.54	-	47.27	16.25		1	9841	606	2.22E+05	0.016	0.520	0.82
													Segment total pressure	*15.82*

Description	height (in)	width (in)	w/h	eqiv dia (in)	hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Radiator Outlet														
Exhaust louver, duct connected	60	39	0.65	51.16	47.27	9.75		1	9841	1009	3.42E+05	0.015	3.100	13.62
Fire Damper	60	39	0.65	51.16	47.27	16.25		1	9841	606	2.05E+05	0.016	0.520	0.82
Fan			-	-	30.00	4.91		1	9841	2005	4.31E+05	0.016	0.000	0.00
Ducting	60	39	0.65	51.16	47.27	12.19	2	1	9841	807	2.73E+05	0.016	0.008	0.02
													Segment total pressure	14.47

	FT	in H2O
supply air total pressure	**15.82**	**0.213**
exhaust air total pressure	**14.47**	**0.195**
Total	**30.29**	**0.408**
15% design margin	**34.83**	**0.469**

Appendix F

Accomodations HVAC

1 DESCRIPTION

This appendix presents calculations performed to estimate heating, ventilation, and air conditioning requirements for the NEW RIVER CLASS FERRY design. The resulting heating and cooling loads were used to estimate electrical requirements for the vessel.

2 PROCEDURE

Heating and cooling load calculations were performed using the procedures outlined in [1], modified as follows:

- Passenger Lounge ventilation rate calculated using requirements from [2].
- Low-e glass is specified for the Crew Lounge and Passenger lounge. Glass solar factors (GSF) for these spaces were modified for geographic location and use of low-e coated glass using the RLF method from [3].

3 REGULATORY FRAMEWORK

The NEW RIVER CLASS ferries will be US Coast Guard under the provisions of 46 CFR Subchapter H.

4 GIVEN AND ASSUMED PARAMETERS

- The Pilothouse, Crew Lounge, Passenger Lounge, and EOS will be air-conditioned using air-cooled split heat pump units.
- The Pilothouse, Crew Lounge, Passenger Lounge, and EOS will utilize split heat pumps as primary heat, with electric strip heaters for backup.
- The hold spaces of existing vessels are not heated, except for the Engine Room. The Engine Room will be fitted with two (2) five-kilowatt unit heaters per NCDOT request.
- Single pane windows are assumed for the Pilothouse. Low-e coated dual pane insulating glass is assumed for exterior windows in the Crew Lounge and Passenger Lounge. Dual pane A-60 windows are assumed in the EOS.
- Bulkhead insulation in air-conditioned or heated passenger and crew spaces is assumed to have a maximum overall heat transfer coefficient of U = 0.12 BTU/hr/ft^2/°F. This corresponds to 3 inches of fiberglass insulation plus 1" stiffener wrap on unlined decks or bulkhead or 2" of fiberglass insulation plus 1" stiffener wrap on decks with furred sheet metal linings, Table 18, Type 92 or Table 17 Type 55 in [4] respectively.
- The following environmental conditions, taken from [5] and [6] were used to determine the HVAC loads:

Environmental Condition	Summer	Winter
Outside Air Dry Bulb Temperature (°F)	95	27
Outside Air Relative Humidity (%)	75	-
Sea Water Temperature (°F)	86	32
Air Conditioned Spaces Temperature (°F)	74	70

Environmental Condition	Summer	Winter
Air Conditioned Spaces Humidity (%)	55	-

- Space areas estimated from [7].

5 CONCLUSIONS

Calculations are presented below. Heating and cooling loads for each space are estimated as follows:

Space	Winter Heat Load	Summer Heat Load (BTUH)		
	Qw (BTUH)	Sensible, Qs	Latent, Ql	Total, Qt
Pilothouse	12,605	24,874	2,312	27,186
Crew Lounge	7,936	20,966	4,520	25,486
Passenger Lounge	29,562	44,444	16,000	60,444
EOS	14,170	22,388	3,200	25,588

REFERENCES

[1] The Society of Naval Architects and Marine Engineers, "Technical and Research Bulletin 4-16: Calculations for Merchant Ship Heating, Ventilation and Air Conditioning Design," New York, NY, 12/2015.

[2] ASHRAE, ASHRAE Standard 62.1-2016 Ventilation for Acceptable Indoor Air Quality, Atlanta, GA: ASHRAE, 2016.

[3] AHSRAE, 2009 ASHRAE Handbook: Fundamentals, Atlanta, GA, 2009.

[4] The Society of Naval Architects and Marine Engineers, Technical and Research Bulletin 4-7: Thermal Insulation Report, New York, NY, 1963.

[5] AHSRAE, *ASHRAE Handbook - Fundamentals, Hatteras Billy Mitchell AP, NC, USA WMO#723139,* 2009.

[6] NOAA, "Station HCGN7 - USCG Station Hatteras, NC - Climatic Summary Plots for Sea Temperature," 24 Nov 2015. [Online]. Available: http://www.ndbc.noaa.gov/view_climplot.php?station=hcgn7&meas=st.

[7] EBDG - NC, PLLC, "New River Class Ferry: Profiles and Deck Arrangements," 16101-200-101-1, Rev -, Seattle, WA, 2017.

GLASS SOLAR FACTOR FOR LOW-E WINDOWS

Calculation of fenestration load
using RLF method from ASHRAE Fundamentals, Ch 17

CF_{fen}= U(Δt-0.46*DR) + PXI x SGHC x IAC X FF_s

q_{fen}= A x CF_{fen}

Given/Assumed

1) Glass u value taken from SNAME T&R 4-16
2) Cooling design temperature, To =95F, Ti = 74
3) DR from ASHRAE data for Hatteras Billy Mitchell AP
4) Latitude is 35.2 degrees, using Peak Irradiance from ASHRAE Fundamentals, Table 10, 35 degrees
5) Assume no interior shading, IAC = 1
6) Assume no exterior shading (no shading modifications to PXI)
7) SHGC assumes use of Low-e coated window glass with a SHGC of less than .47
8) FF_s taken from ASHRAE Fundamentas Table 13, single family detached column (see descriptions on page 17.1)
9) Worst combination of PXI and FF_s, West Facing, used for calculation

U=	0.60	BTU/h-SF-°F	fenestration NFRC heating U-factor
Δt=	21	°F	cooling design temperautre difference
DR=	12	°F	cooling daily range
PXI=	237	btu/h-SF	peak exterior irradiance
SHGC=	0.47		rated or estimated solar heat gain coefficient
IAC=	1		interior shading attenuation coefficient
FF_s=	0.56		fenstration solar load factor
Cf_{fen}=	71.67	BTUH/sf	fenestration cooling load

Use Cf_{fen}= 75 BTUH/sf

ROOM LOAD CALCULATIONS

Pilothouse (SB)														
				Deck Area:	144 ft^2					Volume:	1152 ft^3			
Space No:				Height:	8 ft									
Lighting Load Calculation														
Description						Area (ft2)		LC, (Btu/hr/ft^2)			qs (btuh)		qt (btuh)	
Lighting						144		7			1,008		1,008	
										Lighting Totals:	1,008		1,008	
Equipment Load Calculation														
Description				qs (btuh)	ql (btuh)		Qty			Use Factor	q_s (btuh)	q_l (btuh)	q_t (btuh)	
Coffee Maker (commercial)				6,500	2,000		1			0.5	3,250	1,000	4,250	
Electronics				7,000			1			1	7,000		7,000	
										Equipment Totals:	10250	1000	11250	
Personnel Load Calculation														
Description	Gender	Type		q_s (btuh)	q_l (btuh)				Count		q_s (btuh)	q_l (btuh)	q_t (btuh)	
SEATED AT REST	male	1-P1		240	160				1		240	160	400	
SEATED AT REST	mixed	1-P2		210	140				0					
										Personnel Totals:	240	160	400	
Ventilation Requirements														
Type	Description			Rate	Unit		Qty				OA (cfm)		EX (cfm)	
By Occupancy	Low Occupancy			15	cfm/person		1	people			15			
Rate of Change	AC, Pilot House			1	ach		1152	ft^3			19			
Sanitary Fixtures				50	cfm/fixture		0	fixture						
											20			
			Heating Outside Air Temp			27 °F				Cooling Outside Air Temp		95 °F		
			Heating Inside Air Temp			70 °F				Cooling Design Temp:		74 °F		

Heating and Cooling Load Calculation					**Heating**				**Cooling Season**					
Description	Load Key	Insul Type		Area (ft^2)	T (°F)	ΔT	U or GSF	q_w (btuh)	T (°F)	ΔT	U or GSF	q_s (btuh)	q_l (btuh)	q_t (btuh)
Pilot House Top	Over	C-2		243.0	27	43	0.120	1,254	95	21	0.120	612		612
Crew Lounge	Belw	C-2		144.0	70	0	0.120		74	0	0.120			
Exterior - Weather (Solar)	Fwd	C-2		0.0	27	43	0.120		95	21	0.120			
Exterior - Weather	Fwd	C-2		46.0	27	43	0.120	237	95	21	0.120	116		116
Exterior - Windows (Solar)	Fwd	001-H1	☼↔	0.0	27	43	1.130		125	51	160			
Exterior - Windows (Shaded)	Fwd	001-H2	W↔I	22.0	27	43	1.130	1,069	95	21	160	3,520		3,520
Exterior - Windows (Shaded)	Aft	001-H2	W↔I	22.0	27	43	1.130	1,069	95	21	1.130	522		522
Exterior - Weather	Aft	C-2		46.0	27	43	0.120	237	95	21	0.120	116		116
Exterior - Weather (Solar)	Port	C-2		56.9	27	43	0.120	294	125	51	0.120	348		348
Exterior - Weather	Port	C-2		101.1	27	43	0.120	522	95	21	0.120	255		255
Exterior - Windows (Solar)	Port	001-H1	☼↔	30.1	27	43	1.130	1,463	125	51	160	4,816		4,816
Exterior - Windows (Shaded)	Port	001-H2	W↔I	39.9	27	43	1.130	1,939	95	21	1.130	947		947
Exterior - Weather (Shaded)	Stbd	C-2		180.0	27	43	0.120	929	95	21	0.120	454		454
Exterior - Windows (Shaded)	Stbd	001-H2	W↔I	52.0	27	43	1.130	2,527	95	21	1.130	1,234		1,234
LIGHTS	Lght											1,008		1,008
EQUIPMENT	Eqpt											10,250	1,000	11,250
PERSONNEL	Pers											240	160	400
Ventilation	OA				27	43		1,066	95	21		437	1,152	1,589
						Space Totals:		12,605			Totals:	24,874	2,312	27,186

*** This calculation sheet assumes sun on port side only (single boundary)**

Crew Lounge

Deck Area: 240 ft^2 Volume: 1920 ft^3

Space No: Height: 8 ft

Lighting Load Calculation

Description	Area (ft2)	LC, (Btu/hr/ft^2)	qs (btuh)		qt (btuh)
Lighting	240	7	1,680		1,680
Lighting Totals:			1,680		1,680

Equipment Load Calculation

Description	qs (btuh)	ql (btuh)		Qty	Use Factor	q_s (btuh)	q_l (btuh)	q_t (btuh)
Coffee Maker (commercial)	6,500	2,000		1	0.5	3,250	1,000	4,250
Electronics	6,000			1	1	6,000		6,000
Microwave	3,000			1	0.3	900		900
Refrigerator	1,670			1	1	1,670		1,670
Equipment Totals:						**11820**	**1000**	**12820**

Personnel Load Calculation

Description	Gender	Type	q_s (btuh)	q_l (btuh)		Count	q_s (btuh)	q_l (btuh)	q_t (btuh)
SEATED AT REST	male	1-P1	240	160		4	960	640	1,600
SEATED AT REST	mixed	1-P2	210	140		0			
Personnel Totals:							**960**	**640**	**1600**

Ventilation Requirements

Type	Description	Rate	Unit	Qty	OA (cfm)		
By Occupancy	High Occupancy	12	cfm/person	4 people	48		
Sanitary Fixtures		50	cfm/fixture	1 fixture	50		
				Chosen:	**50**		

Heating Outside Air Temp 27 °F — Cooling Outside Air Temp 95 °F

Heating Inside Air Temp 70 °F — Cooling Design Temp: 74 °F

Heating and Cooling Load Calculation

					Heating				**Cooling Season**					
Description	Load Key	Insul Type		Area (ft^2)	T (°F)	ΔT	U or GSF	q_w (btuh)	T (°F)	ΔT	U or GSF	q_s (btuh)	q_l (btuh)	q_t (btuh)
Exterior - Weather (Solar)	Over	C-2		64.0	27	43	0.120	330	130	56	0.120	430		430
Pilot House	Over	C-2		144.0	70	0	0.120		74	0	0.120			
Passenger Lounge	Belw	C-2		24.0	70	0	0.120		74	0	0.120			
Engine Room	Belw	C-2		72.0	45	25	0.120	216	115	41	0.120	354		354
Exterior - Weather	Belw	C-2		144.0	27	43	0.120	743	95	21	0.120	363		363
Exterior - Weather (Solar)	Fwd	C-2		81.0	27	43	0.120	418	115	41	0.120	399		399
Exterior - Windows (Solar)	Fwd	002-H1	☼↔	9.0	27	43	0.610	236	115	41	75.000	675		675
Exterior - Windows (Shaded)	Aft	002-H2	W↔I	6.0	27	43	0.610	157	95	21	0.610	77		77
Exterior - Weather	Aft	C-2		84.0	27	43	0.120	433	95	21	0.120	212		212
Exterior - Weather (Solar)	Port	C-2		195.0	27	43	0.120	1,006	115	41	0.120	959		959
Exterior - Windows (Solar)	Port	002-H1	☼↔	15.0	27	43	0.610	393	115	41	75.000	1,125		1,125
Exterior - Weather	Stbd	C-2		128.0	27	43	0.120	660	95	21	0.120	323		323
Uptakes	Stbd	C-2		70.0	27	43	0.120	361	115	41	0.120	344		344
Exterior - Windows (Shaded)	Stbd	002-H2	W↔I	12.0	27	43	0.610	315	95	21	0.610	154		154
LIGHTS	Lght											1,680		1,680
EQUIPMENT	Eqpt											11,820	1,000	12,820
PERSONNEL	Pers											960	640	1,600
Ventilation	OA				27	43		2,666	95	21		1,092	2,880	3,972
Space Totals:								7,936			Totals:	20,966	4,520	25,486

*** This calculation sheet assumes sun on forward and port sides**

Passenger Lounge	Deck Area: 640 ft^2	Volume: 5120 ft^3
Space No:	Height: 8 ft	

Lighting Load Calculation

Description	Area (ft2)	LC, (Btu/hr/ft$^{2)}$	qs (btuh)		qt (btuh)
Lighting	640	7	4,480		4,480
		Lighting Totals:	4,480		4,480

Equipment Load Calculation

Description					Qty	Use Factor	q_s (btuh)	q_l (btuh)	q_t (btuh)
						Equipment Totals:	**0**	**0**	**0**

Personnel Load Calculation

Description						Count	q_s (btuh)	q_l (btuh)	q_t (btuh)
SEATED AT REST	male	1-P1	240	160		0			
SEATED AT REST	mixed	1-P2	210	140		32	6,720	4,480	11,200
						Personnel Totals:	**6720**	**4480**	**11200**

Ventilation Requirements

Type	Description	Rate	Unit	Qty	OA (cfm)		
per ASHRAE 62.1	People OA Rate	5	cfm/person	32	160		
	Area OA Rate	0.06	cfm/cf	640	38		
	Sum				198		
				Chosen:	**200**		

	Heating Outside Air Temp 27 °F	Cooling Outside Air Temp	95 °F
	Heating Inside Air Temp 70 °F	Cooling Design Temp:	74 °F

Heating and Cooling Load Calculation					**Heating**				**Cooling Season**					
Description	Load Key	Insul Type		Area (ft^2)	T (°F)	ΔT	U or GSF	q_w (btuh)	T (°F)	ΔT	U or GSF	q_s (btuh)	q_l (btuh)	q_t (btuh)
Exterior - Weather	Over	C-2		640.0	27	43	0.120	3,302	95	21	0.120	1,613		1,613
Crew Lounge	Over	C-2		96.0	70	0	0.120		74	0	0.120			
EOS	Belw	C-2		210.0	70	0	0.120		74	0	0.120			
Engine Room	Belw	C-2		317.0	45	25	0.120	951	115	41	0.120	1,560		1,560
Voids	Belw	C-2		209.0	27	43	0.120	1,078	115	41	0.120	1,028		1,028
Exterior - Weather	Fwd	C-2		84.0	27	43	0.120	433	95	21	0.120	212		212
Exterior - Windows (Shaded)	Fwd	002-H2	W↔I	6.0	27	43	0.610	157	95	21	0.610	77		77
Exterior - Weather	Aft	C-2		84.0	27	43	0.120	433	95	21	0.120	212		212
Exterior - Windows (Shaded)	Aft	002-H2	W↔I	6.0	27	43	0.610	157	95	21	0.610	77		77
Exterior - Weather	Port	C-2		423.0	27	43	0.120	2,183	95	21	0.120	1,066		1,066
Engine Room	Port	C-2		180.0	27	43	0.120	929	115	41	0.120	886		886
EOS	Port	C-2		162.0	70	0	0.120		74	0	0.120			
Exterior - Windows (Shaded)	Port	002-H2	W↔I	0.0	27	43	0.610		95	21	0.610			
Exterior - Weather (Solar)	Stbd	C-2		506.0	27	43	0.120	2,611	125	51	0.120	3,097		3,097
Exterior - Windows (Solar)	Stbd	002-H2	W↔I	254.0	27	43	0.610	6,662	125	51	75.000	19,050		19,050
LIGHTS	Lght											4,480		4,480
EQUIPMENT	Eqpt													
PERSONNEL	Pers											6,720	4,480	11,200
Ventilation	OA				27	43		10,664	95	21		4,368	11,520	15,888
							Space Totals:	29,562			Totals:	44,444	16,000	60,444

*** This calculation sheet assumes sun on starboard side only**

EOS	Deck Area: 360 ft^2	Volume: 2880 ft^3
Space No:	Height: 8 ft	

Lighting Load Calculation

Description	Area (ft2)	LC, (Btu/hr/ft$^{2)}$	qs (btuh)		qt (btuh)
Lighting	360	7	2,520		2,520
		Lighting Totals:	2,520		2,520

Equipment Load Calculation

Description	qs (btuh)	ql (btuh)		Qty	Use Factor	q_s (btuh)	q_l (btuh)	q_t (btuh)
Switchboard / Electronics	10,000			1	1	10,000		10,000
					Equipment Totals:	**10000**	**0**	**10000**

Personnel Load Calculation

Description	Gender	Type	q_s (btuh)	q_l (btuh)		Count	q_s (btuh)	q_l (btuh)	q_t (btuh)
SEATED AT REST	male	1-P1	240	160		2	480	320	800
SEATED AT REST	mixed	1-P2	210	140		0			
						Personnel Totals:	**480**	**320**	**800**

Ventilation Requirements

Type	Description	Rate	Unit	Qty	OA (cfm)		
By Occupancy	Low Occupancy	15	cfm/person	2 people	30		
Rate of Change		1	ach	2880 ft^3	48		
Sanitary Fixtures		50	cfm/fixture	0 fixture			
				Chosen:	**50**		

	Heating Outside Air Temp 27 °F	Cooling Outside Air Temp	95 °F
	Heating Inside Air Temp 70 °F	Cooling Design Temp:	74 °F

Heating and Cooling Load Calculation					**Heating**				**Cooling Season**					
Description	Load Key	Insul Type		Area (ft^2)	T (°F)	ΔT	U or GSF	q_w (btuh)	T (°F)	ΔT	U or GSF	q_s (btuh)	q_l (btuh)	q_t (btuh)
Exterior - Weather	Over	C-2		96.0	27	43	0.120	495	95	21	0.120	242		242
Passenger Lounge	Over	C-2		264.0	70	0	0.120		74	0	0.120			
EOS Floor	Belw	0-D4	I↓I	360.0	32	38	0.695	9,508	86	12	0.801	3,460		3,460
Engine Room	Fwd	C-2		123.0	55	15	0.120	221	115	41	0.120	605		605
Engine Room - Windows	Fwd	002-H2	W↔I	24.0	55	15	0.610	220	115	41	0.610	600		600
Void	Aft	C-2		147.0	55	15	0.120	265	115	41	0.120	723		723
Engine Room	Port	C-2		210.0	55	15	0.120	378	115	41	0.120	1,033		1,033
Engine Room - Windows	Port	002-H2	W↔I	30.0	55	15	0.610	275	115	41	0.610	750		750
Exterior - Weather (solar)	Stbd	C-2		144.0	27	43	0.120	743	125	51	0.120	881		881
LIGHTS	Lght											2,520		2,520
EQUIPMENT	Eqpt											10,000		10,000
PERSONNEL	Pers											480	320	800
Ventilation	OA				27	43		2,666	95	21		1,092	2,880	3,972
							Space Totals:	14,770			Totals:	22,388	3,200	25,588

*** This calculation sheet assumes sun on starboard side only**

Appendix G

Fire Main System, Dwg. 16101-200-521-1

1 DESCRIPTION

This appendix documents the calculations used in designing the fire main piping system. These calculations establish pump capacity in accordance with regulatory requirements and minimum pipe sizes based upon nominal velocity limits. Estimated losses through the system piping are calculated to establish the total dynamic head (TDH) and net positive suction head (NPSH) requirements for the fire pumps.

2 PROCEDURE

Calculations are presented in the following sequence:

- Fire main pipe nominal velocity calculations
- Fire pump TDH and NPSH calculations

Minimum fire pump capacity, pressure, and nozzle size is based upon the requirements found in 46 CFR Subchapter H, [1].

Frictional losses through the piping system are calculated by constructing a model using PIPE-FLO Professional software utilizing the Darcy Weisbach method.

3 GIVEN AND ASSUMED PARAMETERS

- Fire main system is to be constructed of Class 200 copper nickel pipe.
- Piping system lengths, routing, fittings, etc. are estimated based on the Profiles and Arrangements, and Fire Main System Schematic [2] [3].
- In accordance with [1], the required pressure at the two most remote fire hydrants is 50 psi and the required nozzle orifice size is 5/8".
- The theoretical discharge from a 5/8" orifice at 50 psi is assumed to be 82 gpm, or 164 gpm for two nozzles.
- To maintain fleet commonality, the client prefers the fire pump be a Goulds 3796 2x2-10, 3550 rpm, 8.5 inch impeller.
- The following elevations above baseline are assumed for the system calculation

Waterline	4.5 ft
Pump inlet/outlet	2.5 ft
01 Deck Stations	24 ft

- The fluid medium is seawater with the following properties:

Specific weight	64.04 lb/cu ft
Viscosity	1.206 cP
Temperature	60 °F
Vapor pressure	0.2513 psia

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Pipe Size Calculations

Pipe sizes are based on the nominal velocity limits found in Marine Engineering, Chapter 20, Table 3, [4]. The following table shows the flow rates of fuel occurring in the system, and the resulting pipe sizes.

Table 5-1: Nominal Pipe Velocity

Pipe Segment	Flow Rate gpm	Pipe Size (NPS)	ID in	Design Velocity (ft/s) Nominal	Limit	V ft/s
Firemain Suction	164	3" CL 200 CUNI	3.310	5.46	12.00	5.96
Firemain Discharge	164	3" CL 200 CUNI	3.310	9.10	12.00	5.96
Firemain Branch (1 hydrant)	82	1-1/2" CL 200 CUNI	1.756	6.63	12.00	10.58
Firemain Branch (2 hydrants)	164	2" CL 200 CUNI	2.209	7.43	12.00	13.37
Firemain Overboard	164	3" CL 200 CUNI	3.310	9.10	12.00	5.96

Note that the velocity limit of 12 feet per second is exceeded in a 2" line with a 164 gpm flowrate, and it is likely this limit will be exceeded in some cases with the client's preferred fire pump. This is acceptable; however, as the fire system is infrequently used and minimal pipe wear is anticipated over the life of the vessel.

5.2 Fire Pump TDH and NPSHa Calculation

From the enclosed system model, the minimum fire main pump operating point is 165 gpm at a total dynamic head of 182 feet H2O while discharging from the two most remote fire stations with a pitot pressure of 50 psig. The system provides NPSH of 31.5 feet H2O. The client's preferred pump is also modeled. This pump will provide a 192 gpm at 237 feet H2O while discharging from the two most remote fire stations; this exceeds the minimum regulatory requirements.

6 REFERENCES

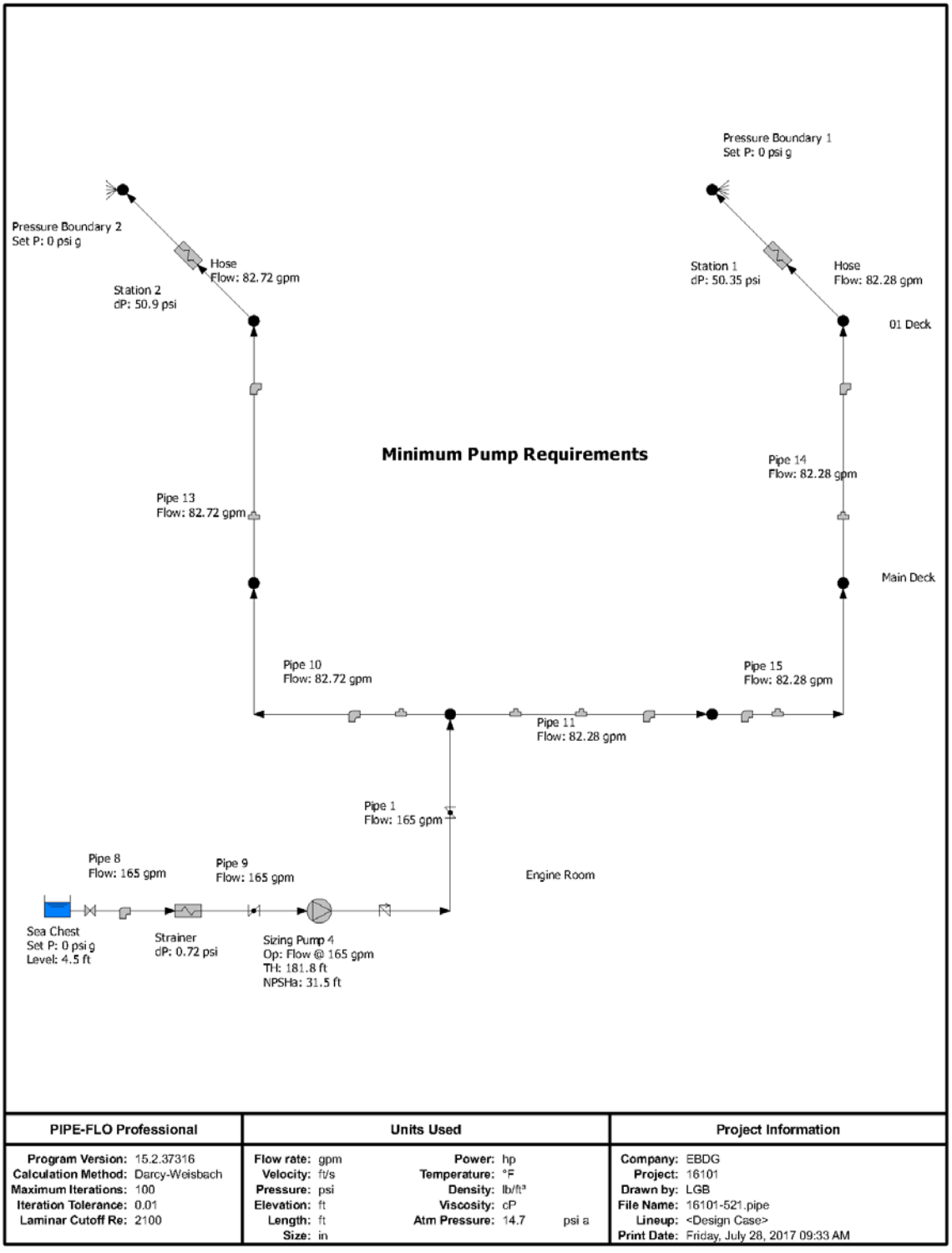
[1] USCG, "46 CFR, Chapter I, Subchapter H, Part 76 Fire Protection Equipment," 7/21/2017.

[2] Elliott Bay Design Group, "NCDOT New River Class Ferry: Profiles and Arrangements," 16101-200-101-1, Seattle, WA.

[3] Elliott Bay Design Group, "NCDOT New River Class Ferry: Fire Main System Schematic," 16101-200-521-1, Seattle, WA.

[4] R. L. Harrington, Marine Engineering, Jersey City, NJ: SNAME, 1992.

FIRE MAIN PIPE-FLO MODEL



PIPE-FLO Professional		Units Used				Project Information	
Program Version:	15.2.37316	Flow rate:	gpm	Power:	hp	Company:	EBDG
Calculation Method:	Darcy-Weisbach	Velocity:	ft/s	Temperature:	°F	Project:	16101
Maximum Iterations:	100	Pressure:	psi	Density:	lb/ft³	Drawn by:	LGB
Iteration Tolerance:	0.01	Elevation:	ft	Viscosity:	cP	File Name:	16101-521.pipe
Laminar Cutoff Re:	2100	Length:	ft	Atm Pressure:	14.7 psi a	Lineup:	<Design Case>
		Size:	in			Print Date:	Friday, July 28, 2017 09:33 AM

List Report

File Name: 16101-521.pipe	**Calculation Method:** Darcy-Weisbach	**Company:** EBDG	
Lineup: <Design Case>	**Laminar Cutoff Re:** 2100	**Project:** 16101	
Progam Name: PIPE-FLO Professional	**Max Iterations:** 100	**by:** LGB	
Version: 15.2.37316	**Percent Tolerance:** 0.01	**Date:** Friday, July 28, 2017 09:15 AM	
	Allowable Deviation: 1 %	**Atmospheric Pressure:** 14.7 psi a	

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits Velocity	 Pressure	 Reynolds Number
CuNi Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Seawater Seawater 3.5% Salinity	60 °F 0 psi g	Liquid 29	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 4	2.5 ft -0.4351 psi g	2.5 ft 80.41 psi g	181.8 ft 80.84 psi	165 gpm	31.5 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Hose CuNi Class 200 Seawater	1.5 in 1.756 in 150 ft	Node 1 24 ft Station 1 24 ft	82.28 gpm 10.9 ft/s 126044 0.01736	64.97 psi g 64.15 psi g 170.1 ft 168.2 ft	14.61 psi 32.86 ft	50.36 psi g 49.53 psi g 137.2 ft 135.4 ft	0.01975 0.00 0 psi 0 ft
Hose CuNi Class 200 Seawater	1.5 in 1.756 in 150 ft	Node 3 24 ft Station 2 24 ft	82.72 gpm 10.96 ft/s 126707 0.01734	65.65 psi g 64.82 psi g 171.6 ft 169.7 ft	14.75 psi 33.17 ft	50.9 psi g 50.07 psi g 138.4 ft 136.6 ft	0.01975 0.00 0 psi 0 ft
Pipe 1 CuNi Class 200 Seawater	3 in 3.31 in 10 ft	Sizing Pump 4 2.5 ft Node 2 11 ft	165 gpm 6.152 ft/s 134088 0.01705	80.41 psi g 80.14 psi g 183.3 ft 182.7 ft	4.587 psi 1.815 ft	75.82 psi g 75.56 psi g 181.5 ft 180.9 ft	0.01702 2.47 0.6455 psi 1.451 ft
Pipe 10 CuNi Class 200 Seawater	2 in 2.209 in 20 ft	Node 2 11 ft Node 6 14 ft	82.72 gpm 6.925 ft/s 100723 0.01811	75.82 psi g 75.49 psi g 181.5 ft 180.7 ft	2.71 psi 3.093 ft	73.11 psi g 72.78 psi g 178.4 ft 177.6 ft	0.01869 2.18 0.7237 psi 1.627 ft
Pipe 11 CuNi Class 200 Seawater	3 in 3.31 in 65 ft	Node 2 11 ft Node 9 11 ft	82.28 gpm 3.068 ft/s 66868 0.01967	75.82 psi g 75.75 psi g 181.5 ft 181.3 ft	0.4522 psi 1.017 ft	75.37 psi g 75.3 psi g 180.5 ft 180.3 ft	0.01702 2.31 0.1506 psi 0.3385 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 13 CuNi Class 200 Seawater	1.5 in 1.756 in 20 ft	Node 6 14 ft Node 3 24 ft	82.72 gpm 10.96 ft/s 126707 0.01734	73.11 psi g 72.28 psi g 178.4 ft 176.5 ft	7.458 psi 6.77 ft	65.65 psi g 64.82 psi g 171.6 ft 169.7 ft	0.01975 1.26 1.044 psi 2.347 ft
Pipe 14 CuNi Class 200 Seawater	1.5 in 1.756 in 20 ft	Node 8 14 ft Node 1 24 ft	82.28 gpm 10.9 ft/s 126044 0.01736	72.16 psi g 71.34 psi g 176.3 ft 174.4 ft	7.193 psi 6.173 ft	64.97 psi g 64.15 psi g 170.1 ft 168.2 ft	0.01975 0.97 0.7969 psi 1.792 ft
Pipe 15 CuNi Class 200 Seawater	2 in 2.209 in 40 ft	Node 9 11 ft Node 8 14 ft	82.28 gpm 6.888 ft/s 100196 0.01813	75.37 psi g 75.04 psi g 180.5 ft 179.7 ft	3.204 psi 4.204 ft	72.16 psi g 71.83 psi g 176.3 ft 175.5 ft	0.01869 1.76 0.5779 psi 1.3 ft
Pipe 4 CuNi Class 200 Seawater	1.5 in 1.756 in 0.01 ft	Station 1 24 ft Pressure Boundary 1 24 ft	82.28 gpm 10.9 ft/s 126044 0.01736	9.742E-04 psi g -0.8203 psi g 24 ft 22.16 ft	9.742E-04 psi 2.191E-03 ft	0 psi g -0.8212 psi g 24 ft 22.15 ft	0.01975 0.00 0 psi 0 ft
Pipe 7 CuNi Class 200 Seawater	1.5 in 1.756 in 0.01 ft	Station 2 24 ft Pressure Boundary 2 24 ft	82.72 gpm 10.96 ft/s 126707 0.01734	9.835E-04 psi g -0.8289 psi g 24 ft 22.14 ft	9.835E-04 psi 2.211E-03 ft	0 psi g -0.8299 psi g 24 ft 22.13 ft	0.01975 0.00 0 psi 0 ft
Pipe 8 CuNi Class 200 Seawater	3 in 3.31 in 5 ft	Sea Chest 0 ft Strainer 2.5 ft	165 gpm 6.152 ft/s 134088 0.01705	2.001 psi g 1.74 psi g 4.5 ft 3.912 ft	1.484 psi 0.8362 ft	0.5176 psi g 0.256 psi g 3.664 ft 3.076 ft	0.01702 1.11 0.291 psi 0.6544 ft
Pipe 9 CuNi Class 200 Seawater	3 in 3.31 in 2 ft	Strainer 2.5 ft Sizing Pump 4 2.5 ft	165 gpm 6.152 ft/s 134088 0.01705	-0.2024 psi g -0.464 psi g 2.045 ft 1.457 ft	0.2327 psi 0.5231 ft	-0.4351 psi g -0.6967 psi g 1.522 ft 0.9335 ft	0.01702 0.77 0.2003 psi 0.4504 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
Sea Chest	0 ft 4.5 ft	0 psi g 2.001 psi g	4.5 ft	Pipe 8	0 ft	165 gpm	2.001 psi g

Curve dP Devices

Curve dP Device Name Description	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Station 1 5/8" Nozzle	24 ft 50.36 psi g	24 ft 9.742E-04 psi g	50.35 psi 113.2 ft	82.28 gpm
Station 2 5/8" Nozzle	24 ft 50.9 psi g	24 ft 9.835E-04 psi g	50.9 psi 114.4 ft	82.72 gpm
Strainer Eaton Model 72 3"	2.5 ft 0.5176 psi g	2.5 ft -0.2024 psi g	0.72 psi 1.619 ft	165 gpm

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	24 ft	64.97 psi g	168.2 ft
Node 2	11 ft	75.82 psi g	181 ft
Node 3	24 ft	65.65 psi g	169.7 ft
Node 6	14 ft	73.11 psi g	177.1 ft
Node 8	14 ft	72.16 psi g	175 ft
Node 9	11 ft	75.37 psi g	180 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	24 ft	0 psi g	22.15 ft	82.28 gpm
Pressure Boundary 2	24 ft	0 psi g	22.13 ft	82.72 gpm

Bill of Materials Report

File Name: 16101-521.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 09:15 AM

Sizing Pumps

Sizing Pump Name Operation	Design Point Flow Rate	 Total Head
Sizing Pump 4 Flow @ 165 gpm	165 gpm	181.8 ft

Tanks

Tank Name
Sea Chest

Curve dP Devices

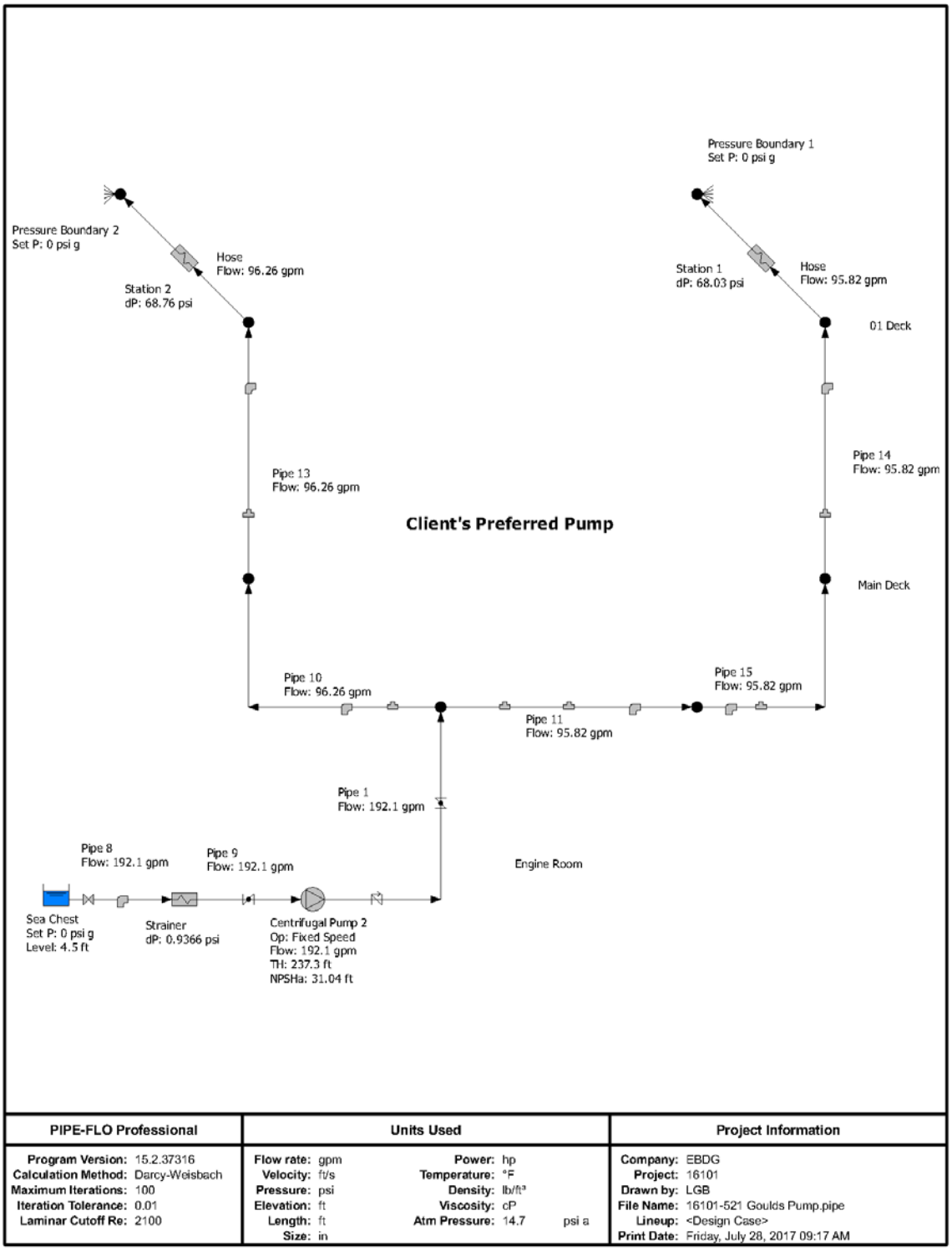
Curve dP Device Name	Curve Description
Station 1	5/8" Nozzle
Station 2	5/8" Nozzle
Strainer	Eaton Model 72 3"

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Hose	CuNi Class 200	1.5 in	150 ft	
Hose	CuNi Class 200	1.5 in	150 ft	
Pipe 1	CuNi Class 200	3 in	10 ft	1 x Butterfly 1 x Swing Check - Angled
Pipe 10	CuNi Class 200	2 in	20 ft	3 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Contraction (2 in x 3 in - 0 in) 1 x Tee - Flow Thru Branch
Pipe 11	CuNi Class 200	3 in	65 ft	1 x Tee - Flow Thru Branch 1 x Tee - Flow Thru Run 4 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 13	CuNi Class 200	1.5 in	20 ft	1 x Reducer - Contraction (1.5 in x 2 in - 2 in) 1 x Tee - Flow Thru Run 3 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 14	CuNi Class 200	1.5 in	20 ft	1 x Reducer - Contraction (1.5 in x 2 in - 3 in) 1 x Tee - Flow Thru Run 2 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 15	CuNi Class 200	2 in	40 ft	1 x Tee - Flow Thru Run 1 x Reducer - Contraction (2 in x 3 in - 3 in) 5 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 4	CuNi Class 200	1.5 in	0.01 ft	
Pipe 7	CuNi Class 200	1.5 in	0.01 ft	
Pipe 8	CuNi Class 200	3 in	5 ft	2 x Elbow - Long radius, r/d 1.5 (90°) 1 x Gate - Wedge Disc 1 x Entrance - Sharp Edged
Pipe 9	CuNi Class 200	3 in	2 ft	1 x Butterfly

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
CuNi Class 200	Copper Nickel MIL-T-16420K Schedule: Class 200	1.5 in	340.02 ft	5 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Contraction (1.5 in x 2 in - 2 in) 1 x Reducer - Contraction (1.5 in x 2 in - 3 in) 2 x Tee - Flow Thru Run
CuNi Class 200	Copper Nickel MIL-T-16420K Schedule: Class 200	2 in	60.00 ft	8 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Contraction (2 in x 3 in - 0 in) 1 x Reducer - Contraction (2 in x 3 in - 3 in) 1 x Tee - Flow Thru Branch 1 x Tee - Flow Thru Run
CuNi Class 200	Copper Nickel MIL-T-16420K Schedule: Class 200	3 in	82.00 ft	2 x Butterfly 6 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Sharp Edged 1 x Gate - Wedge Disc 1 x Swing Check - Angled 1 x Tee - Flow Thru Branch 1 x Tee - Flow Thru Run



PIPE-FLO Professional		Units Used				Project Information	
Program Version:	15.2.37316	Flow rate:	gpm	Power:	hp	Company:	EBDG
Calculation Method:	Darcy-Weisbach	Velocity:	ft/s	Temperature:	°F	Project:	16101
Maximum Iterations:	100	Pressure:	psi	Density:	lb/ft³	Drawn by:	LGB
Iteration Tolerance:	0.01	Elevation:	ft	Viscosity:	cP	File Name:	16101-521 Goulds Pump.pipe
Laminar Cutoff Re:	2100	Length:	ft	Atm Pressure:	14.7 psi a	Lineup:	<Design Case>
		Size:	in			Print Date:	Friday, July 28, 2017 09:17 AM

Appendix H

Sanitary Drains System, Dwg. 16101-200-528-1

1 DESCRIPTION

This appendix documents the first principles calculations used in selecting the zero discharge pump for the sanitary drains system. These calculations are used to establish minimum pipe sizes based upon nominal velocity limits and to identify steady state frictional losses to establish the total dynamic head (TDH) and net positive suction head (NPSH) requirements for the zero discharge pumps.

2 PROCEDURE

Calculations are presented in the following sequence:

- Pipe size calculations
- Zero discharge pump TDH and NPSH calculations

Frictional losses through the piping system are calculated by constructing a model using PIPE-FLO Professional software utilizing the Darcy Weisbach method.

3 GIVEN AND ASSUMED PARAMETERS

- The zero discharge system is to be constructed of Schedule 80 CPVC pipe.
- Piping system lengths, routing, fittings, etc. are estimated based on the Profiles and Arrangements, and Sanitary Drains Schematic, [1] [2].
- A pressure of 10 psig is assumed at the zero discharge connection on the Main Deck.
- The zero discharge tanks are 2 feet above baseline, the pump suction and discharge are 2.5 feet above baseline, and the zero discharge connection on the Main Deck is assumed to be 11 feet above baseline, [1].
- The fluid used for all calculations is fresh water with the following properties:

Temperature:	60 degrees F
Specific Weight:	62.37 lb/cuft
Dynamic viscosity:	1.105 cP
Vapor Pressure:	0.2564 psia

- A single pump shall be capable of emptying the two 500 gallon tanks in 10 minutes or less, so the minimum flowrate is 100 gpm.
- To maintain fleet commonality the client prefers an MP Pumps Flomax 10 2x2, 3450 rpm with a 5.5 inch impeller for the zero discharge pump.

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Pipe Size Calculations

Pipe sizes are based on the nominal velocity limits found in Marine Engineering, Chapter 20, Table 3, [3]. The following table shows the flow rates of zero discharge effluent occurring in the system, and the resulting pipe sizes.

Table 5-1: Zero Discharge System Pipe Sizes and Velocities

Pipe Segment	Flow Rate	Pipe Size	ID	Design Velocity (ft/s)		V
	gpm	(NPS)	in	Nominal	Limit	ft/s
Pump suction	100	2" SCH 80	1.94	4.18	15.00	10.57
Pump discharge	100	2" SCH 80	1.94	6.96	15.00	10.57

While the expected velocities exceed the nominal velocities , the expected velocities are still well below the maxium limit.

5.2 Zero Discharge Pump TDH and NPSH Calculation

From the enclosed system model, the zero discharge pump shall be sized for 105 gpm at 75 feet H2O TDH. The system has 30.5 NPSH available. The system model considers the client's preferred pump; this operating point is on the pump curve of the client's preferred pump.

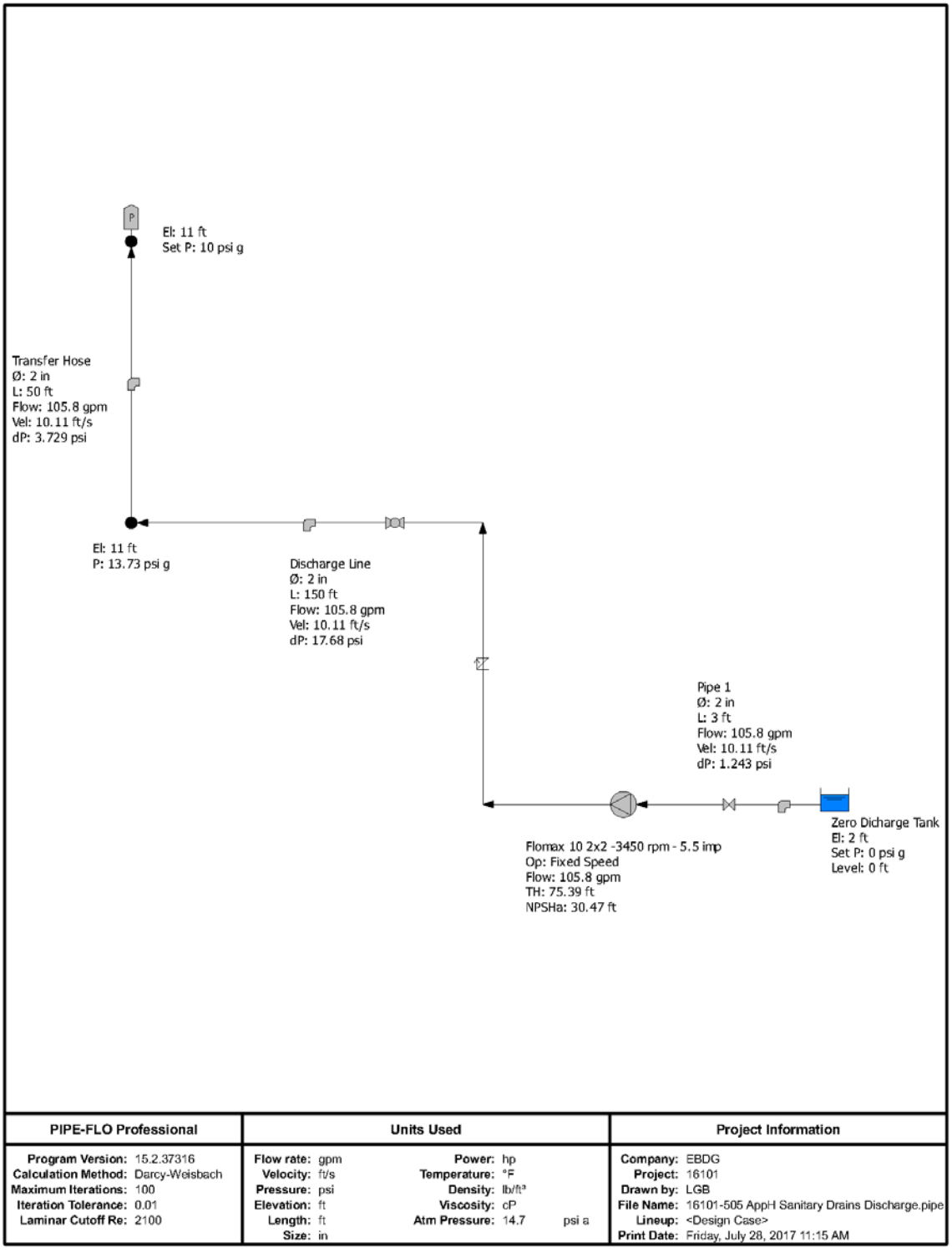
6 REFERENCES

[1] Elliott Bay Design Group, "NCDOT New River Class Ferry: Profiles and Arrangements," 16101-200-101-1, Seattle, WA.

[2] Elliott Bay Design Group, "NCDOT New River Class Ferry: Sanitary Drains Schematic," 16101-200-528-1, Seattle, WA.

[3] R. L. Harrington, Marine Engineering, Jersey City, NJ: SNAME, 1992.

ZERO DISCHARGE PIPE-FLO MODEL



PIPE-FLO Professional		Units Used			Project Information	
Program Version:	15.2.37316	Flow rate:	gpm	Power: hp	Company:	EBDG
Calculation Method:	Darcy-Weisbach	Velocity:	ft/s	Temperature: °F	Project:	16101
Maximum Iterations:	100	Pressure:	psi	Density: lb/ft³	Drawn by:	LGB
Iteration Tolerance:	0.01	Elevation:	ft	Viscosity: cP	File Name:	16101-505 AppH Sanitary Drains Discharge.pipe
Laminar Cutoff Re:	2100	Length:	ft	Atm Pressure: 14.7 psi a	Lineup:	<Design Case>
		Size:	in		Print Date:	Friday, July 28, 2017 11:15 AM

List Report

File Name: 16101-505 AppH Sanitary Drains Discharge.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Percent Tolerance: 0.01
Allowable Deviation: 1 %

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 11:16 AM
Atmospheric Pressure: 14.7 psi a

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria		Design Limits Velocity	Design Limits Pressure	Reynolds Number
Carbon Steel SCH 80	Steel A53-B36.10	1.800E-03 in	0.0	Min:	ft/s	psi g	
standard	Schedule:80	140		Max:	ft/s	psi g	
Plastic Pipe	PVC PIPE D1785	6E-05 in	0.0	Min:	ft/s	psi g	
standard	Schedule:40	140		Max:	ft/s	psi g	

Fluid Zones

Fluid Zone Name / Table Name	Temperature / Pressure	Fluid State / Relative Molecular Mass	Density / Viscosity	Vapor Pressure / Critical Pressure	Specific Heat Capacity (cp) / Specific Heat Ratio (k)
Water	60 °F	Liquid	62.37 lb/ft³	0.2564 psi a	--
Water	0 psi g	18	1.105 cP	3199 psi a	--

Centrifugal Pumps

Pump Name	Test Speed / Operating Speed	Suction Elevation / Suction Pressure	Discharge Elevation / Discharge Pressure	Total Head / dP	Flow Rate / Power	Efficiency / BEP Efficiency	NPSHa / NPSHr	Design NPSH Margin Ratio
Flomax 10 2x2 -3450 rpm - 5.5 imp	3450 rpm	2.5 ft	2.5 ft	75.39 ft	105.8 gpm	--	30.47 ft	--
Fixed Speed	3450 rpm	-1.243 psi g	31.41 psi g	32.65 psi	--	--- %	6.922 ft	

Company: Flomax
Curve: Manual Pump
Type:

Size: 10 2x2
Diameter: 5.5 in
POR: from -- to --

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Device / Inlet Elevation / Outlet Device / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number / Pipe Friction Factor	Inlet Total Pressure / Inlet Static Pressure / Inlet Energy Grade / Inlet Hydraulic Grade	Total dP / Total Head Loss	Outlet Total Pressure / Outlet Static Pressure / Outlet Energy Grade / Outlet Hydraulic Grade	V&F Friction Factor / V&F Resistance K / V&F dP / V&F Head Loss
Discharge Line	2 in	lomax 10 2x2 -3450 rpm - 5.5 im	105.8 gpm	31.41 psi g	17.68 psi	13.73 psi g	0.01899
Plastic Pipe	2.067 in	2.5 ft	10.11 ft/s	30.72 psi g		13.04 psi g	5.68
Water	150 ft	Pressure Boundary	146322	75.02 ft	32.32 ft	42.7 ft	3.908 psi
		11 ft	0.01683	73.43 ft		41.11 ft	9.024 ft
Pipe 1	2 in	Zero Dicharge Tank	105.8 gpm	0 psi g	1.243 psi	-1.243 psi g	0.01899
Plastic Pipe	2.067 in	2 ft	10.11 ft/s	-0.6883 psi g		-1.931 psi g	1.20
Water	3 ft	lomax 10 2x2 -3450 rpm - 5.5 im	146322	2 ft	2.369 ft	-0.3694 ft	0.8245 psi
		2.5 ft	0.01683	0.4108 ft		-1.959 ft	1.903 ft
Transfer Hose	2 in	Pressure Boundary	105.8 gpm	13.73 psi g	3.729 psi	10 psi g	0.01899
Plastic Pipe	2.067 in	11 ft	10.11 ft/s	13.04 psi g		9.312 psi g	0.53
Water	50 ft	Pressure Boundary 1	146322	42.7 ft	8.61 ft	34.09 ft	0.366 psi
		11 ft	0.01683	41.11 ft		32.5 ft	0.845 ft

Tanks

Tank Name / Fluid Zone	Bottom Elevation / Liquid Level	Surface Pressure / Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration

PIPE-FLO Professional Version: 15.2.37316 List Report Friday, July 28, 2017 11:16 AM Page 1

Zero Dicharge Tank	2 ft	0 psi g	2 ft			
Water	0 ft	0 psi g				
			Pipe 1	0 ft	105.8 gpm	0 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Pressure Boundary	11 ft	13.73 psi g	41.11 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	11 ft	10 psi g	32.5 ft	105.8 gpm

Bill of Materials Report

File Name: 16101-505 AppH Sanitary Drains Discharge.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 11:16 AM

Centrifugal Pumps

Centrifugal Pump Name Operation			
Flomax 10 2x2 -3450 rpm - 5.5 imp Fixed Speed	**Company:** Flomax **Type:** **Size:** 10 2x2 **Curve:** Manual Pump	**Test Speed:** 3450 rpm **Impeller Diameter:** 5.5 in **POR: from** -- **to** --	

Tanks

Tank Name
Zero Dicharge Tank

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Discharge Line	Plastic Pipe	2 in	150 ft	8 x Elbow - Standard 90° 1 x Swing Check - Vertical 3 x Ball
Pipe 1	Plastic Pipe	2 in	3 ft	1 x Gate - Knife 1 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Inward
Transfer Hose	Plastic Pipe	2 in	50 ft	2 x Pipe Bend - r/d 4 (90°)

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Plastic Pipe	PVC PIPE D1785 Schedule: 40	2 in	203.00 ft	3 x Ball 1 x Elbow - Long radius, r/d 1.5 (90°) 8 x Elbow - Standard 90° 1 x Entrance - Inward 1 x Gate - Knife 2 x Pipe Bend - r/d 4 (90°) 1 x Swing Check - Vertical

Appendix I

Bilge System, Dwg. 16101-200-529-1

1 DESCRIPTION

This appendix documents the calculations used in designing the bilge piping system. These calculations establish minimum bilge pipe sizes and required pump capacity in accordance with regulatory requirements. Estimated losses through the bilge system are calculated to establish the total dynamic head (TDH) and net positive suction head (NPSH) requirements for the bilge pump.

2 PROCEDURE

Calculations are presented in the following sequence:

- Bilge pipe size and pump capacity calculations
- Bilge pipe nominal velocity calculations
- Bilge pump TDH and NPSH calculation

Bilge pipe size and capacity are based on the regulatory requirements found in [1].

Frictional losses through the piping system are calculated by constructing a model using PIPE-FLO Professional software utilizing the Darcy Weisbach method.

3 GIVEN AND ASSUMED PARAMETERS

- Bilge system is to be constructed of Schedule 80 carbon steel pipe.
- Piping system lengths, routing, fittings, etc. are estimated based on the Profiles and Arrangements, and Bilge and Ballast System Schematic [2] [3].
- The fluid medium is seawater with the following properties:

Specific weight	64.04 lb/cu ft
Viscosity	1.206 cP
Temperature	60 °F
Vapor pressure	0.2513 psia

- The following elevations above baseline are assumed for the system calculation

Overboard Discharge	9.5 ft
Pump inlet/outlet	2.5 ft
Lazarette Bilge Suction	4.0 ft
Thruster Bilge Suction	3.0 ft
Void Bilge Suction	1.0 ft
Engine Room Bilge Suction	0.0 ft

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Bilge Pipe Size and Pump Capacity Calculation

From the attached spreadsheet, the minimum internal bilge main diameter is 3.02 inches ± 0.25 inches. 3 inch schedule 80 steel pipe has an inside diameter of 2.9 inches, and is minimum acceptable size for the bilge main. The minimum bilge piping diameter for the hull compartments ranges from 2.0 inches to 2.45 inches. The acceptable minimum NPS pipe size ranges from 2 inches to 2.5 inches schedule 80 steel pipe.

The minimum bilge pump capacity to maintain a nominal velocity of 400 feet per minute in the bilge main is 149 gpm.

5.2 Bilge Pipe Nominal Velocity Calculation

Pipe sizes are checked against the nominal velocity limits found in Marine Engineering, Chapter 20, Table 3, [4]. The following table shows the flow rates of bilge water occurring in the system.

Table 5-1: Nominal Pipe Velocity

Pipe Segment	Flow Rate	Pipe Size	ID	Design Velocity (ft/s)		V
	gpm	(NPS)	in	Nominal	Limit	ft/s
Bilge Main	149	3" Schedule 80 Steel	2.900	5.11	15.00	7.05
Engine Room Bilge Branch	149	2.5" Schedule 80 Steel	2.320	4.57	15.00	11.01
All other Bilge Branches	149	2" Schedule 80 Steel	1.940	4.18	15.00	15.75
Overboard Discharge	149	3" Schedule 80 Steel	2.900	8.51	15.00	7.05

Note that it is necessary to throttle the pump discharge when pumping individual compartments beyond the void, so the velocity in those smaller lines is not likely to exceed the 15 feet per second limit.

5.3 Bilge Pump TDH and NPSH Calculation

From the enclosed system model, the bilge pump is required to produce about 40 feet H2O TDH at the required flowrate of 149 gpm. Calculated NPSH available for the bilge system ranges from about 6 feet to 12 feet in the void and engine room, respectively.

Note that it is necessary to throttle the pump discharge when pumping an individual compartment beyond the void to prevent pump cavitation.

6 REFERENCES

[1] USCG, "46 CFR, Chapter I, Subchapter F, 56.50-50," 7/21/2017.

[2] Elliott Bay Design Group, "NCDOT New River Class Ferry: Profiles and Arrangements," 16101-200-101-1, Seattle, WA.

[3] Elliott Bay Design Group, "NCDOT New River Class Ferry: Bilge and Ballast System

Schematic," 16101-200-529-1, Seattle, WA.

[4] R. L. Harrington, Marine Engineering, Jersey City, NJ: SNAME, 1992.

BILGE PIPE SIZING AND PUMP CAPACITY

BILGE SYSTEM SIZING CALCULATIONS

APPROACH

Size bilge pipes and bilge pumps per the requirements of 46CFR Subchapter F, 56.50-50.

ASSUMPTIONS

1. Unit System used in this calculation: US.
2. Bilge piping is schedule 80.

CALCULATION OF PIPE SIZE FOR SUCTION TO EACH MAIN BILGE PUMP 46CFR 56.50-50(d)(1)

L =	180.5	ft	length on load waterline
B =	46	ft	breadth
D =	10.5	ft	molded depth to bulkhead deck
Gross Tons =	400		gross tons
d_{MIN} =	2.50	in	minimum internal diameter of suction pipe 46CFR 56.50-50(d)(3)

$$d = 1 + \sqrt{\frac{L \times (B + D)}{2500}}$$

d = 3.02 in **required internal diameter of suction pipe**

use: 3" sch 80 pipe w/ an id = 2.9 in

CALCULATION OF PIPE SIZE FOR SUCTION OF EACH BRANCH 46CFR 56.50-50(d)(2)

c =	see table	ft	compartment length
B =	46	ft	breadth
D =	10.5	ft	molded depth to bulkhead deck
d_{MIN} =	2	in	minimum internal diameter of branch suction pipe
d_{MAX} =	4	in	maximum internal diameter of branch suction pipe
d =	see table	in	required internal diameter of branch suction pipe
id =	see table	in	actual diameter of branch suction pipe

$$d = 1 + \sqrt{\frac{c \times (B + D)}{1500}}$$

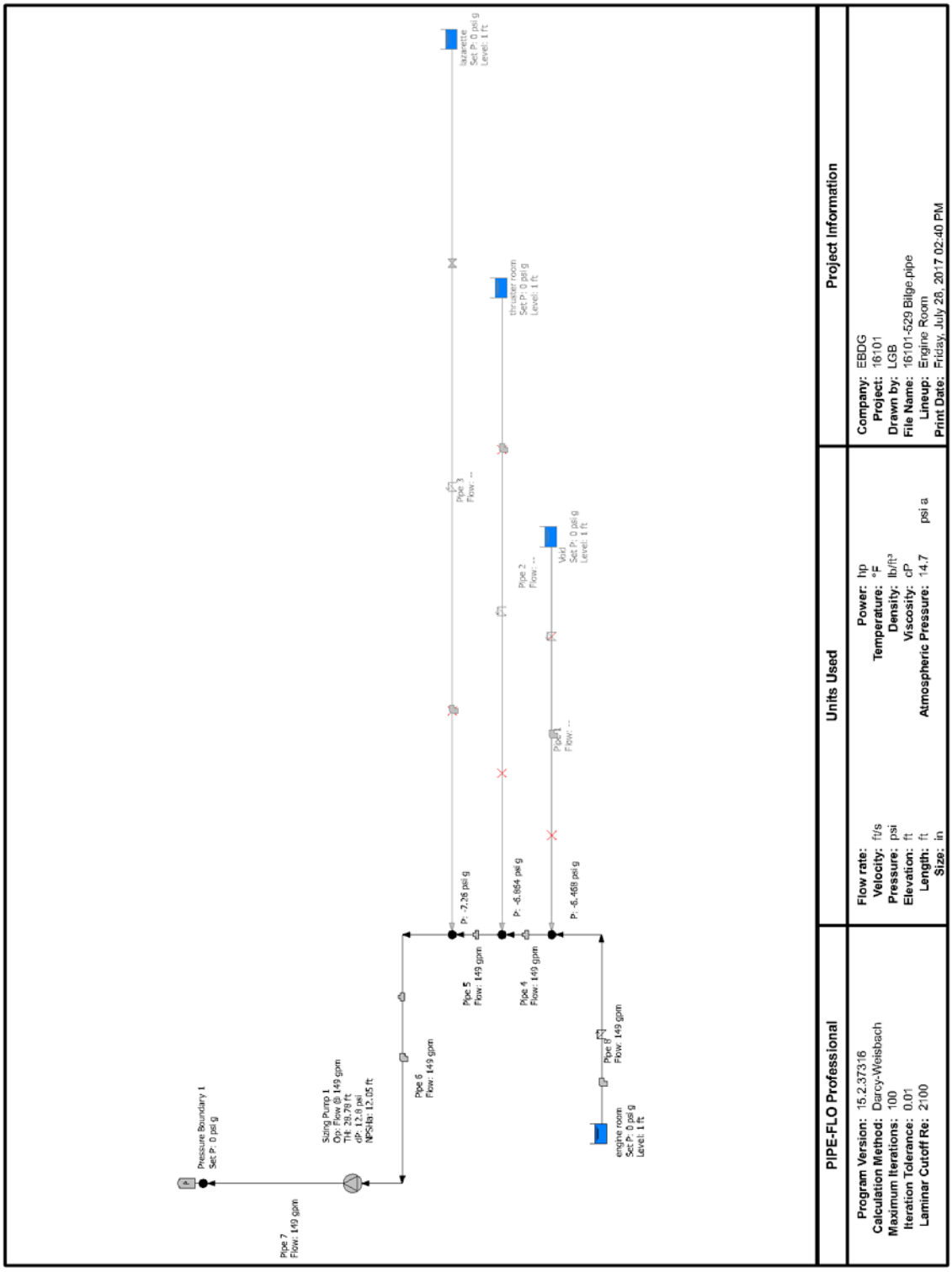
Compartment	c (ft)	**d (in)**	pipe selected	id (in)	PASS
Lazarette A	11.8	**2.000**	2" sch 80 pipe	1.939	**PASS**
Thruster Room A	32	**2.098**	2" sch 80 pipe	1.939	**PASS**
Void A	20	**2.000**	2" sch 80 pipe	1.939	**PASS**
Eninge Room	56	**2.452**	2½" sch 80 pipe	2.323	**PASS**
Void B	20	**2.000**	2" sch 80 pipe	1.939	**PASS**
Thruster Room B	32	**2.098**	2" sch 80 pipe	1.939	**PASS**
Lazarette B	11.8	**2.000**	2" sch 80 pipe	1.939	**PASS**

CALCULATION OF PUMP CAPACITY 46CFR 56.50-55(c)

d =	3.02	in	required diameter of main bilge suction
a =	7.16	in²	required cross sectional area of main bilge suction
v =	400	ft / min	required pump suction velocity

V = 149 gpm **required pump capacity**

BILGE SYSTEM PIPE-FLO MODEL



List Report

File Name:	16101-529 Bilge.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	Engine Room	**Laminar Cutoff Re:**	2100	**Project:**	16101
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	LGB
Version:	15.2.37316	**Percent Tolerance:**	0.01	**Date:**	Friday, July 28, 2017 02:44 PM
		Allowable Deviation:	1 %	**Atmospheric Pressure:**	14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits Velocity	Design Limits Pressure	Design Limits Reynolds Number
Steel A53 sch 80 standard	Steel A53-B36.10 Schedule:80	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Sea Water Seawater 3.5% Salinity	60 °F 0 psi g	Liquid 29	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -9.084 psi g	2.5 ft 3.715 psi g	28.78 ft 12.8 psi	149 gpm	12.05 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1	2 in	Void	--	--	--	--	--
Steel A53 sch 80	1.939 in	1 ft	--	--		--	4.50
Sea Water	3 ft	Node 1	--	--	--	--	--
		2.5 ft	--	--		--	--
Pipe 2	2 in	thruster room	--	--	--	--	--
Steel A53 sch 80	1.939 in	3 ft	--	--		--	4.78
Sea Water	30 ft	Node 2	--	--	--	--	--
		2.5 ft	--	--		--	--
Pipe 3	2 in	lazarette	--	--	--	--	--
Steel A53 sch 80	1.939 in	4 ft	--	--		--	5.47
Sea Water	62 ft	Node 3	--	--	--	--	--
		2.5 ft	--	--		--	--
Pipe 4	3 in	Node 1	149 gpm	-6.468 psi g	0.396 psi	-6.864 psi g	0.01754
Steel A53 sch 80	2.9 in	2.5 ft	7.237 ft/s	-6.83 psi g		-7.226 psi g	1.05
Sea Water	0.5 ft	Node 2	138204	-12.04 ft	0.8905 ft	-12.93 ft	0.381 psi
		2.5 ft	0.02008	-12.86 ft		-13.75 ft	0.8567 ft
Pipe 5	3 in	Node 2	149 gpm	-6.864 psi g	0.396 psi	-7.26 psi g	0.01754
Steel A53 sch 80	2.9 in	2.5 ft	7.237 ft/s	-7.226 psi g		-7.622 psi g	1.05
Sea Water	0.5 ft	Node 3	138204	-12.93 ft	0.8905 ft	-13.83 ft	0.381 psi
		2.5 ft	0.02008	-13.75 ft		-14.64 ft	0.8567 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 6 Steel A53 sch 80 Sea Water	3 in 2.9 in 45 ft	Node 3 2.5 ft Sizing Pump 1 2.5 ft	149 gpm 7.237 ft/s 138204 0.02008	-7.26 psi g -7.622 psi g -13.83 ft -14.64 ft	1.823 psi 4.1 ft	-9.084 psi g -9.446 psi g -17.92 ft -18.74 ft	0.01754 1.30 0.4699 psi 1.057 ft
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 20 ft	Sizing Pump 1 2.5 ft Pressure Boundary 1 9.5 ft	149 gpm 7.237 ft/s 138204 0.02008	3.715 psi g 3.353 psi g 10.85 ft 10.04 ft	3.715 psi 1.352 ft	0 psi g -0.362 psi g 9.5 ft 8.686 ft	0.01754 0.00 0 psi 0 ft
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft	engine room 0 ft Node 1 2.5 ft	149 gpm 11.28 ft/s 172532 0.02033	0.4447 psi g -0.4345 psi g 1 ft -0.9771 ft	6.913 psi 13.04 ft	-6.468 psi g -7.348 psi g -12.04 ft -14.02 ft	0.01847 4.50 3.954 psi 8.892 ft

Tanks

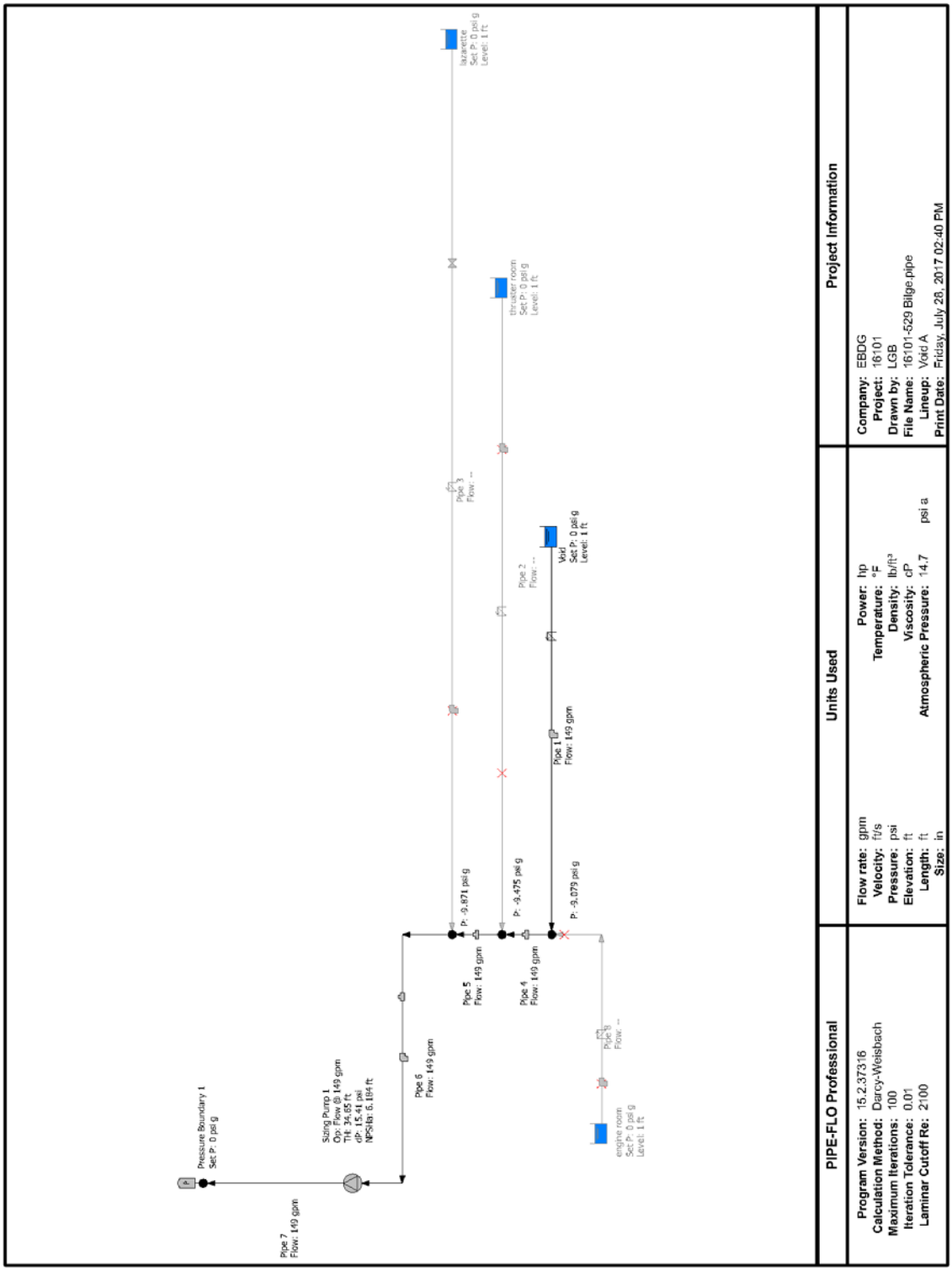
Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
Void	1 ft 1 ft	0 psi g --	--	Pipe 1	0 ft	--	0.4447 psi g
engine room	0 ft 1 ft	0 psi g 0.4447 psi g	1 ft	Pipe 8	0 ft	149 gpm	0.4447 psi g
lazarette Sea Water	4 ft 1 ft	0 psi g --	--	Pipe 3	0 ft	--	0.4447 psi g
thruster room Sea Water	3 ft 1 ft	0 psi g --	--	Pipe 2	0 ft	--	0.4447 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	2.5 ft	-6.468 psi g	-13.44 ft
Node 2	2.5 ft	-6.864 psi g	-13.75 ft
Node 3	2.5 ft	-7.26 psi g	-14.64 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psi g	8.686 ft	149 gpm



List Report

File Name: 16101-529 Bilge.pipe
Lineup: Void A
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Percent Tolerance: 0.01
Allowable Deviation: 1 %

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 02:46 PM
Atmospheric Pressure: 14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits: Velocity	Design Limits: Pressure	Design Limits: Reynolds Number
Steel A53 sch 80 standard	Steel A53-B36.10 Schedule:80	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Sea Water Seawater 3.5% Salinity	60 °F 0 psi g	Liquid 29	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -11.69 psi g	2.5 ft 3.715 psi g	34.65 ft 15.41 psi	149 gpm	6.184 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1 Steel A53 sch 80 Sea Water	2 in 1.939 in 3 ft	Void 1 ft Node 1 2.5 ft	149 gpm 16.19 ft/s 206700 0.02071	0.4447 psi g -1.367 psi g 2 ft -2.073 ft	9.524 psi 19.91 ft	-9.079 psi g -10.89 psi g -17.91 ft -21.99 ft	0.01928 4.50 8.16 psi 18.35 ft
Pipe 2 Steel A53 sch 80 Sea Water	2 in 1.939 in 30 ft	thruster room 3 ft Node 2 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 4.78 -- --
Pipe 3 Steel A53 sch 80 Sea Water	2 in 1.939 in 62 ft	lazarette 4 ft Node 3 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 5.47 -- --
Pipe 4 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	Node 1 2.5 ft Node 2 2.5 ft	149 gpm 7.237 ft/s 138204 0.02008	-9.079 psi g -9.441 psi g -17.91 ft -18.73 ft	0.396 psi 0.8905 ft	-9.475 psi g -9.837 psi g -18.8 ft -19.62 ft	0.01754 1.05 0.381 psi 0.8567 ft
Pipe 5 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	Node 2 2.5 ft Node 3 2.5 ft	149 gpm 7.237 ft/s 138204 0.02008	-9.475 psi g -9.837 psi g -18.8 ft -19.62 ft	0.396 psi 0.8905 ft	-9.871 psi g -10.23 psi g -19.7 ft -20.51 ft	0.01754 1.05 0.381 psi 0.8567 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 6 Steel A53 sch 80 Sea Water	3 in 2.9 in 45 ft	Node 3 2.5 ft Sizing Pump 1 2.5 ft	149 gpm 7.237 ft/s 138204 0.02008	-9.871 psi g -10.23 psi g -19.7 ft -20.51 ft	1.823 psi 4.1 ft	-11.69 psi g -12.06 psi g -23.79 ft -24.61 ft	0.01754 1.30 0.4699 psi 1.057 ft
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 20 ft	Sizing Pump 1 2.5 ft Pressure Boundary 1 9.5 ft	149 gpm 7.237 ft/s 138204 0.02008	3.715 psi g 3.353 psi g 10.85 ft 10.04 ft	3.715 psi 1.352 ft	0 psi g -0.362 psi g 9.5 ft 8.686 ft	0.01754 0.00 0 psi 0 ft
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft	engine room 0 ft Node 1 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 4.50 -- --

Tanks

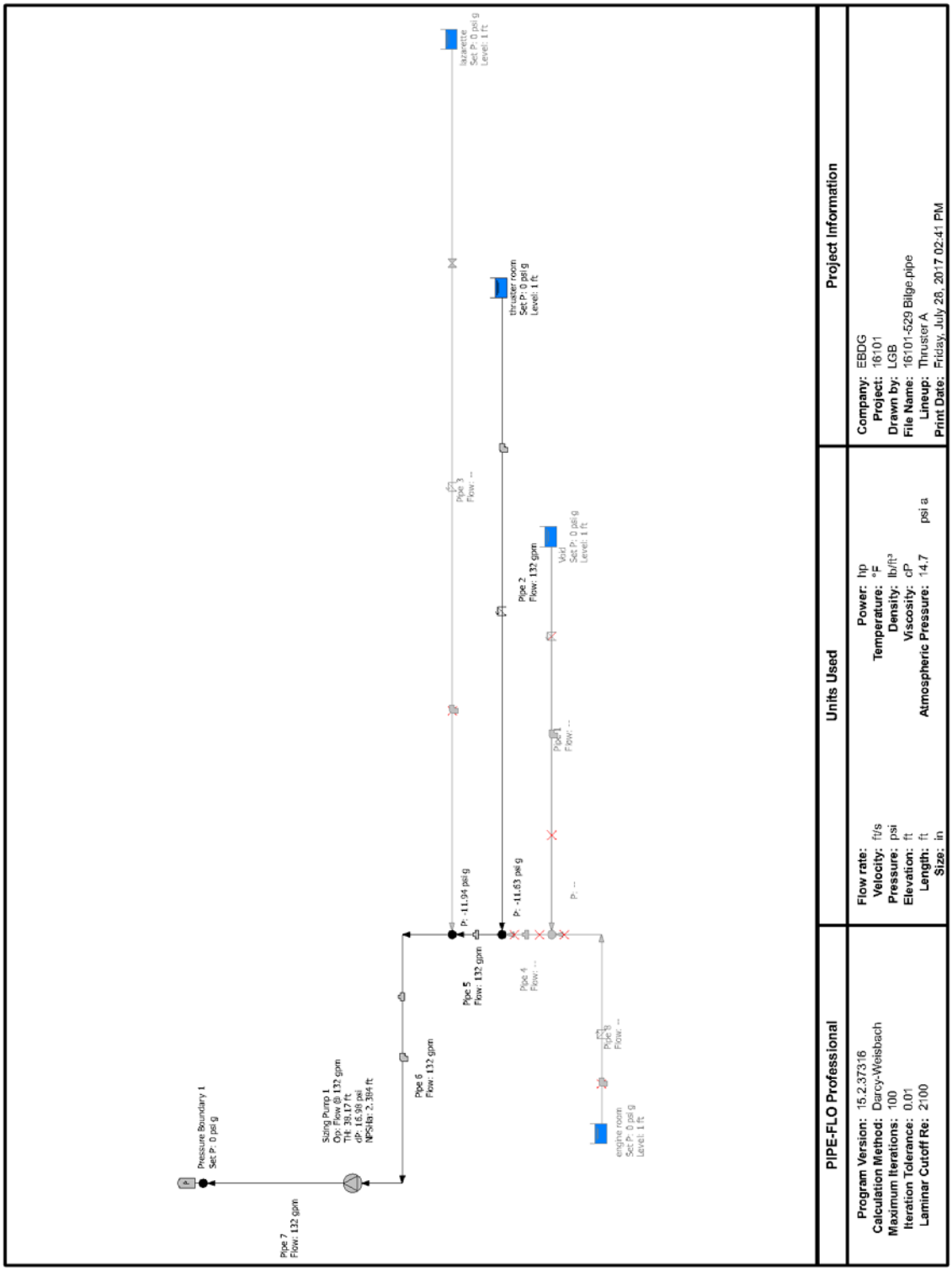
Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
Void	1 ft 1 ft	0 psi g 0.4447 psi g	2 ft	Pipe 1	0 ft	149 gpm	0.4447 psi g
engine room	0 ft 1 ft	0 psi g --	--	Pipe 8	0 ft	--	0.4447 psi g
lazarette Sea Water	4 ft 1 ft	0 psi g --	--	Pipe 3	0 ft	--	0.4447 psi g
thruster room Sea Water	3 ft 1 ft	0 psi g --	--	Pipe 2	0 ft	--	0.4447 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	2.5 ft	-9.079 psi g	-20.36 ft
Node 2	2.5 ft	-9.475 psi g	-19.62 ft
Node 3	2.5 ft	-9.871 psi g	-20.51 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psi g	8.686 ft	149 gpm



List Report

File Name:	16101-529 Bilge.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	Thruster A	**Laminar Cutoff Re:**	2100	**Project:**	16101
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	LGB
Version:	15.2.37316	**Percent Tolerance:**	0.01	**Date:**	Friday, July 28, 2017 02:47 PM
		Allowable Deviation:	1 %	**Atmospheric Pressure:**	14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits Velocity	Design Limits Pressure	Reynolds Number
Steel A53 sch 80 standard	Steel A53-B36.10 Schedule:80	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Sea Water Seawater 3.5% Salinity	60 °F 0 psi g	Liquid 29	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -13.38 psi g	2.5 ft 3.591 psi g	38.17 ft 16.98 psi	132 gpm	2.384 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1 Steel A53 sch 80 Sea Water	2 in 1.939 in 3 ft	Void 1 ft Node 1 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 4.50 -- --
Pipe 2 Steel A53 sch 80 Sea Water	2 in 1.939 in 30 ft	thruster room 3 ft Node 2 2.5 ft	132 gpm 14.34 ft/s 183117 0.02087	0.4447 psi g -0.9769 psi g 4 ft 0.8035 ft	12.07 psi 27.65 ft	-11.63 psi g -13.05 psi g -23.65 ft -26.84 ft	0.01928 4.78 6.788 psi 15.26 ft
Pipe 3 Steel A53 sch 80 Sea Water	2 in 1.939 in 62 ft	lazarette 4 ft Node 3 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 5.47 -- --
Pipe 4 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	Node 1 2.5 ft Node 2 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.05 -- --
Pipe 5 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	Node 2 2.5 ft Node 3 2.5 ft	132 gpm 6.412 ft/s 122436 0.02033	-11.63 psi g -11.91 psi g -23.65 ft -24.29 ft	0.311 psi 0.6992 ft	-11.94 psi g -12.22 psi g -24.35 ft -24.99 ft	0.01754 1.05 0.299 psi 0.6723 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 6 Steel A53 sch 80 Sea Water	3 in 2.9 in 45 ft	Node 3 2.5 ft Sizing Pump 1 2.5 ft	132 gpm 6.412 ft/s 122436 0.02033	-11.94 psi g -12.22 psi g -24.35 ft -24.99 ft	1.444 psi 3.248 ft	-13.38 psi g -13.67 psi g -27.6 ft -28.23 ft	0.01754 1.30 0.3688 psi 0.8292 ft
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 20 ft	Sizing Pump 1 2.5 ft Pressure Boundary 1 9.5 ft	132 gpm 6.412 ft/s 122436 0.02033	3.591 psi g 3.307 psi g 10.57 ft 9.936 ft	3.591 psi 1.075 ft	0 psi g -0.2841 psi g 9.5 ft 8.861 ft	0.01754 0.00 0 psi 0 ft
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft	engine room 0 ft Node 1 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 4.50 -- --

Tanks

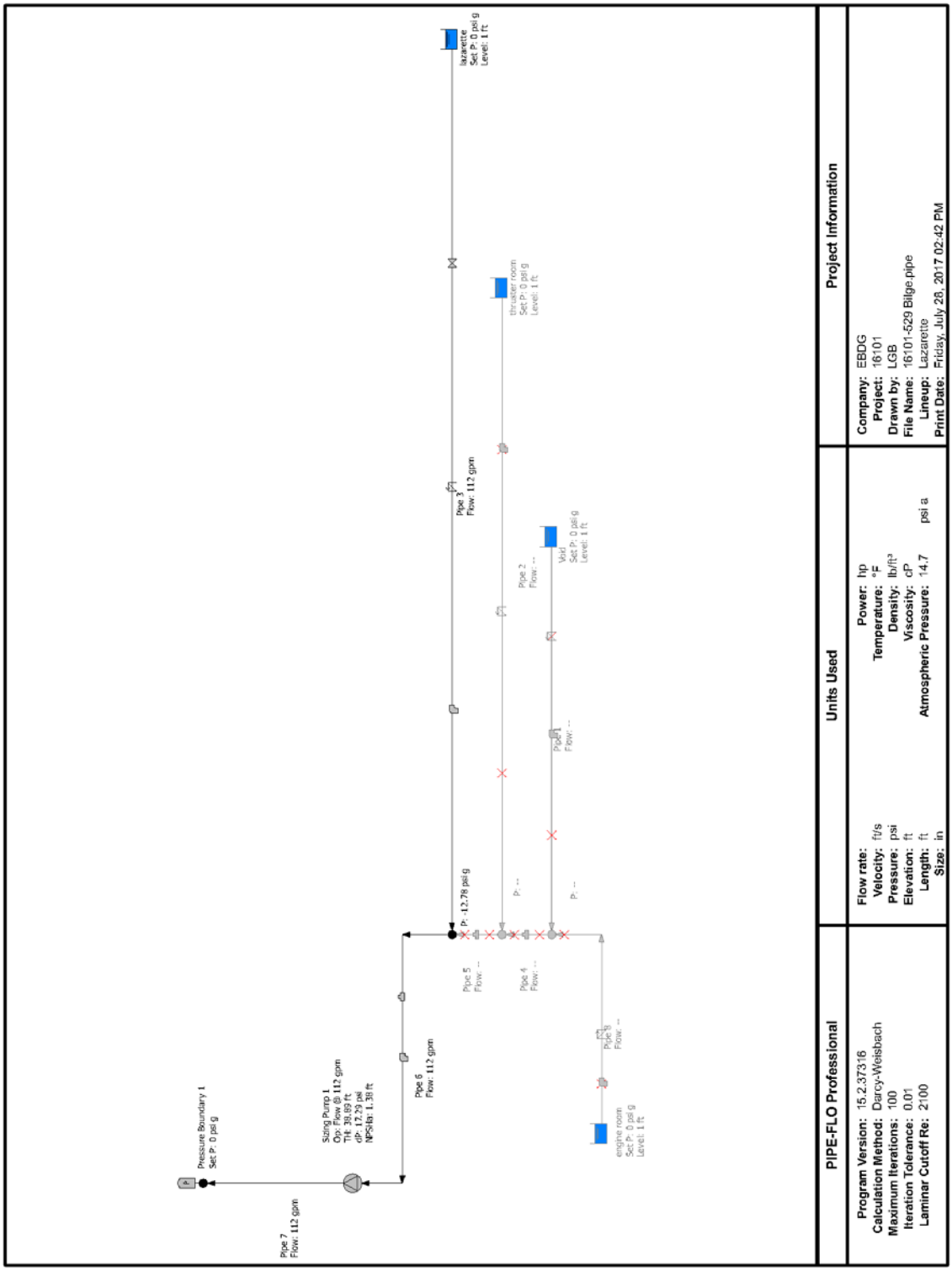
Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
Void	1 ft 1 ft	0 psi g --	--	Pipe 1	0 ft	--	0.4447 psi g
engine room	0 ft 1 ft	0 psi g --	--	Pipe 8	0 ft	--	0.4447 psi g
lazarette Sea Water	4 ft 1 ft	0 psi g --	--	Pipe 3	0 ft	--	0.4447 psi g
thruster room Sea Water	3 ft 1 ft	0 psi g 0.4447 psi g	4 ft	Pipe 2	0 ft	132 gpm	0.4447 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	2.5 ft	--	--
Node 2	2.5 ft	-11.63 psi g	-25.57 ft
Node 3	2.5 ft	-11.94 psi g	-24.99 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psi g	8.861 ft	132 gpm



List Report

File Name: 16101-529 Bilge.pipe
Lineup: Lazarette
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Percent Tolerance: 0.01
Allowable Deviation: 1 %

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 02:47 PM
Atmospheric Pressure: 14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits Velocity	Design Limits Pressure	Reynolds Number
Steel A53 sch 80 standard	Steel A53-B36.10 Schedule:80	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Sea Water Seawater 3.5% Salinity	60 °F 0 psi g	Liquid 29	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -13.83 psi g	2.5 ft 3.464 psi g	38.89 ft 17.29 psi	112 gpm	1.38 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1 Steel A53 sch 80 Sea Water	2 in 1.939 in 3 ft	Void 1 ft Node 1 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 4.50 -- --
Pipe 2 Steel A53 sch 80 Sea Water	2 in 1.939 in 30 ft	thruster room 3 ft Node 2 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 4.78 -- --
Pipe 3 Steel A53 sch 80 Sea Water	2 in 1.939 in 62 ft	lazarette 4 ft Node 3 2.5 ft	112 gpm 12.17 ft/s 155372 0.02111	0.4447 psi g -0.5787 psi g 5 ft 2.699 ft	13.22 psi 31.23 ft	-12.78 psi g -13.8 psi g -26.23 ft -28.53 ft	0.01928 5.47 5.598 psi 12.59 ft
Pipe 4 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	Node 1 2.5 ft Node 2 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.05 -- --
Pipe 5 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	Node 2 2.5 ft Node 3 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.05 -- --

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 6 Steel A53 sch 80 Sea Water	3 in 2.9 in 45 ft	Node 3 2.5 ft Sizing Pump 1 2.5 ft	112 gpm 5.44 ft/s 103885 0.02071	-12.78 psi g -12.98 psi g -26.23 ft -26.69 ft	1.054 psi 2.371 ft	-13.83 psi g -14.04 psi g -28.6 ft -29.06 ft	0.01754 1.30 0.2655 psi 0.597 ft
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 20 ft	Sizing Pump 1 2.5 ft Pressure Boundary 1 9.5 ft	112 gpm 5.44 ft/s 103885 0.02071	3.464 psi g 3.259 psi g 10.29 ft 9.828 ft	3.464 psi 0.7884 ft	0 psi g -0.2045 psi g 9.5 ft 9.04 ft	0.01754 0.00 0 psi 0 ft
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft	engine room 0 ft Node 1 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 4.50 -- --

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
Void	1 ft 1 ft	0 psi g --	--	Pipe 1	0 ft	--	0.4447 psi g
engine room	0 ft 1 ft	0 psi g --	--	Pipe 8	0 ft	--	0.4447 psi g
lazarette Sea Water	4 ft 1 ft	0 psi g 0.4447 psi g	5 ft	Pipe 3	0 ft	112 gpm	0.4447 psi g
thruster room Sea Water	3 ft 1 ft	0 psi g --	--	Pipe 2	0 ft	--	0.4447 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	2.5 ft	--	--
Node 2	2.5 ft	--	--
Node 3	2.5 ft	-12.78 psi g	-27.61 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psi g	9.04 ft	112 gpm

Bill of Materials Report

File Name: 16101-529 Bilge.pipe
Lineup: Engine Room
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 02:43 PM

Sizing Pumps

Sizing Pump Name Operation	Design Point Flow Rate	 Total Head
Sizing Pump 1 Flow @ 149 gpm	149 gpm	28.78 ft

Tanks

Tank Name
Void
engine room
lazarette
thruster room

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	Steel A53 sch 80	2 in	3 ft	2 x Elbow - Long radius, r/d 1.5 (90°) 1 x Stop Check - Angled 1 x Reducer - Enlargement (2 in x 3 in - 3.5 in)
Pipe 2	Steel A53 sch 80	2 in	30 ft	1 x Stop Check - Angled 3 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Enlargement (2 in x 3 in - 3.5 in)
Pipe 3	Steel A53 sch 80	2 in	62 ft	1 x Stop Check - Angled 1 x Gate - Wedge Disc 5 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Enlargement (2 in x 3 in - 3.5 in)
Pipe 4	Steel A53 sch 80	3 in	0.5 ft	1 x Tee - Flow Thru Branch
Pipe 5	Steel A53 sch 80	3 in	0.5 ft	1 x Tee - Flow Thru Branch
Pipe 6	Steel A53 sch 80	3 in	45 ft	1 x Elbow - Long radius, r/d 1.5 (90°) 3 1 x Tee - Flow Thru Branch
Pipe 7	Steel A53 sch 80	3 in	20 ft	
Pipe 8	Steel A53 sch 80	2.5 in	20 ft	1 x Stop Check - Angled 3 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Enlargement (2.5 in x 3 in - 3.5 in)

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Steel A53 sch 80	Steel A53-B36.10 Schedule: 80	2 in	95.00 ft	10 x Elbow - Long radius, r/d 1.5 (90°) 1 x Gate - Wedge Disc 3 x Reducer - Enlargement (2 in x 3 in - 3.5 in) 3 x Stop Check - Angled
Steel A53 sch 80	Steel A53-B36.10 Schedule: 80	2.5 in	20.00 ft	3 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Enlargement (2.5 in x 3 in - 3.5 in) 1 x Stop Check - Angled
Steel A53 sch 80	Steel A53-B36.10 Schedule: 80	3 in	66.00 ft	1 x Elbow - Long radius, r/d 1.5 (90°) 3 x Tee - Flow Thru Branch

Appendix J

Ballast System, Dwg. 16101-200-529-1

1 DESCRIPTION

This appendix documents the calculations used in designing the ballast piping system. These calculations establish ballast pipe sizes and required pump capacity based upon a desired ballast loading and unloading rate. Estimated losses through the ballast system are calculated to establish the total dynamic head (TDH) and net positive suction head (NPSH) requirements for the bilge pump.

2 PROCEDURE

Calculations are presented in the following sequence:

- Ballast pipe nominal velocity calculations
- Ballast pump TDH and NPSH calculation

Frictional losses through the piping system are calculated by constructing a model using PIPE-FLO Professional software utilizing the Darcy Weisbach method.

3 GIVEN AND ASSUMED PARAMETERS

- Ballast system is to be constructed of copper nickel class 200.
- Piping system lengths, routing, fittings, etc. are estimated based on the Profiles and Arrangements, and Bilge and Ballast System Schematic [2] [3].
- The fluid medium is seawater with the following properties:

Specific weight	64.00 lb/cu ft
Dynamic viscosity	2.51E-5 lb-s/sq ft
Temperature	60 °F
Vapor pressure	0.26 psia

- The following elevations above baseline are assumed for the system calculation

Waterline	4.5 ft
Overboard Discharge	9.5 ft
Pump inlet/outlet	2.5 ft
Tank Suction/Discharge	2.0 ft

- Desired ballast loading rate is 400 gpm split between two pumps. To calculate the worst case loading condition, the ballast tanks are approaching full capacity.
- Desired ballast unloading rate is 400 gpm split between two pumps. To calculate the worst case unloading condition, the ballast tanks are approaching empty.
- Desired ballast trimming rate is 200 gpm with one pump. To calculate the worst case trimming condition, the source tank is approaching empty and the destination tank is approaching full capacity.

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Ballast Pipe Size and Nominal Velocity Calculation

Pipe sizes are based on the nominal velocity limits found in Marine Engineering, Chapter 20, Table 3, [3]. The following table shows the flow rates of sea water occurring in the system, and the resulting pipe sizes.

Table 5-1: Nominal Pipe Velocity

Pipe Segment	Flow Rate	Pipe Size	ID	Design Velocity (ft/s)		V
	gpm	(NPS)	in	Nominal	Limit	ft/s
Ballast Pump Suction (1 pump)	200	4" CL 200 CUNI	4.282	6.21	12.00	4.34
Ballast Pump Discharge (1 pump)	200	4" CL 200 CUNI	4.282	10.35	12.00	4.34
Ballast Loading (1 tank)	100	3" CL 200 CUNI	3.310	9.10	12.00	3.63
Ballast Unloading (1 tank)	100	3" CL 200 CUNI	3.310	5.46	12.00	3.63
Ballast Main Suction (2 pumps)	400	4" CL 200 CUNI	4.282	6.21	12.00	8.68
Ballast Main Discharge (2 pumps)	400	4" CL 200 CUNI	4.282	10.35	12.00	8.68

5.2 Ballast Pump TDH and NPSH Calculations

Three different conditions are considered in the attached system model.

- Loading ballast water with 2 pumps in operation
- Unloading ballast water with 2 pumps in operation
- Trimming ballast water with 1 pump in operation

For loading ballast water, the enclosed system model predicts that each ballast pump is required to produce 13.4 feet H2O TDH at the required flowrate of 200 gpm. Calculated NPSH available for each ballast pump in this condition is approximately 32 feet H2O.

For unloading ballast water, the enclosed system model predicts that each ballast pump is required to produce 17 feet H2O TDH at the required flowrate of 200 gpm. Calculated NPSH available for each ballast pump in this condition is approximately 28 feet H2O.

For trimming ballast water from one end to the other, the enclosed system model predicts that the ballast pump is required to produce 17.3 feet H2O TDH at the required flowrate of 200 gpm. Calculated NPSH available for the ballast pump in this condition is approximately 28 feet H2O.

The Ballast pumps are selected for 200 gpm at 20 feet H2O TDH.

6 REFERENCES

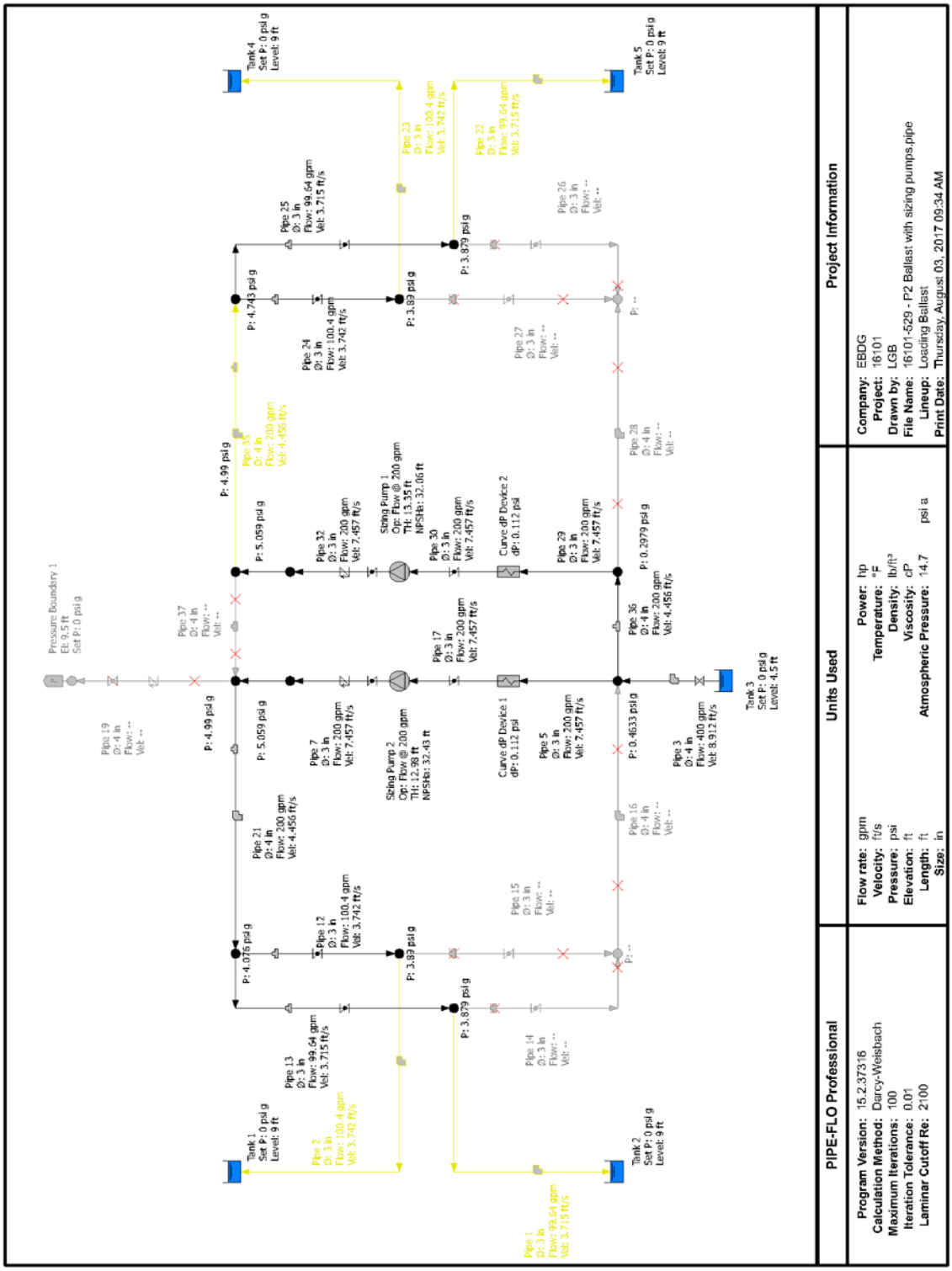
[1] USCG, "46 CFR, Chapter I, Subchapter F, 56.50-50," 7/21/2017.

[2] Elliott Bay Design Group, "NCDOT New River Class Ferry: Profiles and Arrangements," 16101-200-101-1, Seattle, WA.

[3] Elliott Bay Design Group, "NCDOT New River Class Ferry: Bilge and Ballast System Schematic," 16101-200-529-1, Seattle, WA.

[4] R. L. Harrington, Marine Engineering, Jersey City, NJ: SNAME, 1992.

BALLAST SYSTEM PIPE-FLO MODEL



List Report

File Name: 16101-529 - P2 Ballast with sizing pumps.pipe
Lineup: Loading Ballast
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Percent Tolerance: 0.01
Allowable Deviation: 1 %

Company: EBDG
Project: 16101
by: LGB
Date: Thursday, August 03, 2017 09:34 AM
Atmospheric Pressure: 14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits Velocity	 Pressure	 Reynolds Number
Copper Nickel Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Sea Water Seawater 3.5% Salinity	60 °F 0 psi g	Liquid 29	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -0.1885 psi g	2.5 ft 5.749 psi g	13.35 ft 5.937 psi	200 gpm	32.06 ft
Sizing Pump 2	2.5 ft -0.02309 psi g	2.5 ft 5.749 psi g	12.98 ft 5.772 psi	200 gpm	32.43 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	Tank 2 2 ft Node 1 4 ft	99.64 gpm 3.715 ft/s 80970 0.01889	3.879 psi g 3.784 psi g 12.72 ft 12.51 ft	-0.1234 psi 1.723 ft	4.003 psi g 3.907 psi g 11 ft 10.79 ft	0.01702 2.21 0.2108 psi 0.4739 ft
Messages: Reversed flow							
Pipe 12 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Node 7 4 ft Node 2 4 ft	100.4 gpm 3.742 ft/s 81561 0.01887	4.076 psi g 3.979 psi g 13.16 ft 12.95 ft	0.1862 psi 0.4186 ft	3.89 psi g 3.793 psi g 12.75 ft 12.53 ft	0.01702 1.79 0.1729 psi 0.3889 ft
Pipe 13 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Node 7 4 ft Node 1 4 ft	99.64 gpm 3.715 ft/s 80970 0.01889	4.076 psi g 3.98 psi g 13.16 ft 12.95 ft	0.1966 psi 0.442 ft	3.879 psi g 3.784 psi g 12.72 ft 12.51 ft	0.01702 1.79 0.1704 psi 0.3832 ft
Pipe 14 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Node 1 4 ft Node 8 4 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 15 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Node 2 4 ft Node 8 4 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --
Pipe 16 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Node 8 4 ft Node 4 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.45 -- --
Pipe 17 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Curve dP Device 1 2.5 ft Sizing Pump 2 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	0.317 psi g -0.06732 psi g 3.213 ft 2.349 ft	0.3401 psi 0.7647 ft	-0.02309 psi g -0.4074 psi g 2.448 ft 1.584 ft	0.01702 0.77 0.2943 psi 0.6618 ft
Pipe 19 Copper Nickel Class 200 Sea Water	4 in 4.282 in 15 ft	Node 5 2.5 ft Pressure Boundary 1 9.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 2.53 -- --
Pipe 2 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	Tank 1 2 ft Node 2 4 ft	100.4 gpm 3.742 ft/s 81561 0.01887	3.89 psi g 3.793 psi g 12.75 ft 12.53 ft	-0.113 psi 1.746 ft	4.003 psi g 3.906 psi g 11 ft 10.78 ft	0.01702 2.21 0.2138 psi 0.4808 ft
Messages: Reversed flow							
Pipe 20 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Valve 5 2.5 ft Node 5 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	5.059 psi g 4.674 psi g 13.87 ft 13.01 ft	0.06864 psi 0.1543 ft	4.99 psi g 4.606 psi g 13.72 ft 12.86 ft	0.01702 0.00 0 psi 0 ft
Pipe 21 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Node 5 2.5 ft Node 7 4 ft	200 gpm 4.456 ft/s 125637 0.01725	4.99 psi g 4.853 psi g 13.72 ft 13.41 ft	0.9142 psi 0.5556 ft	4.076 psi g 3.939 psi g 13.16 ft 12.86 ft	0.01607 1.41 0.194 psi 0.4363 ft
Pipe 22 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	Tank 5 2 ft Node 9 4 ft	99.64 gpm 3.715 ft/s 80970 0.01889	3.879 psi g 3.784 psi g 12.72 ft 12.51 ft	-0.1234 psi 1.723 ft	4.003 psi g 3.907 psi g 11 ft 10.79 ft	0.01702 2.21 0.2108 psi 0.4739 ft
Messages: Reversed flow							
Pipe 23 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	Tank 4 2 ft Node 10 4 ft	100.4 gpm 3.742 ft/s 81561 0.01887	3.89 psi g 3.793 psi g 12.75 ft 12.53 ft	-0.113 psi 1.746 ft	4.003 psi g 3.906 psi g 11 ft 10.78 ft	0.01702 2.21 0.2138 psi 0.4808 ft
Messages: Reversed flow							
Pipe 24 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Sizing Valve 8 2.5 ft Node 10 4 ft	100.4 gpm 3.742 ft/s 81561 0.01887	4.743 psi g 4.646 psi g 13.16 ft 12.95 ft	0.8533 psi 0.4186 ft	3.89 psi g 3.793 psi g 12.75 ft 12.53 ft	0.01702 1.79 0.1729 psi 0.3889 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 25 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Sizing Valve 8 2.5 ft Node 9 4 ft	99.64 gpm 3.715 ft/s 80970 0.01889	4.743 psi g 4.648 psi g 13.16 ft 12.95 ft	0.8637 psi 0.442 ft	3.879 psi g 3.784 psi g 12.72 ft 12.51 ft	0.01702 1.79 0.1704 psi 0.3832 ft
Pipe 26 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Node 9 4 ft Node 11 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --
Pipe 27 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Node 10 4 ft Node 11 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --
Pipe 28 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Node 15 2.5 ft Node 11 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.45 -- --
Pipe 29 Copper Nickel Class 200 Sea Water	3 in 3.31 in 1.5 ft	Node 15 2.5 ft Curve dP Device 2 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	0.2979 psi g -0.08645 psi g 3.17 ft 2.306 ft	0.03432 psi 0.07717 ft	0.2636 psi g -0.1208 psi g 3.093 ft 2.228 ft	0.01702 0.00 0 psi 0 ft
Pipe 3 Copper Nickel Class 200 Sea Water	4 in 4.282 in 10 ft	Tank 3 0 ft Node 4 2.5 ft	400 gpm 8.912 ft/s 251273 0.01509	2.001 psi g 1.452 psi g 4.5 ft 3.266 ft	1.538 psi 0.9582 ft	0.4633 psi g -0.08556 psi g 3.542 ft 2.308 ft	0.01607 0.35 0.194 psi 0.4363 ft
Pipe 30 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Curve dP Device 2 2.5 ft Sizing Pump 1 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	0.1516 psi g -0.2328 psi g 2.841 ft 1.977 ft	0.3401 psi 0.7647 ft	-0.1885 psi g -0.5729 psi g 2.076 ft 1.212 ft	0.01702 0.77 0.2943 psi 0.6618 ft
Pipe 32 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Pump 1 2.5 ft Sizing Valve 7 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	5.749 psi g 5.364 psi g 15.43 ft 14.56 ft	0.69 psi 1.551 ft	5.059 psi g 4.674 psi g 13.87 ft 13.01 ft	0.01702 1.62 0.6213 psi 1.397 ft
Pipe 33 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Valve 7 2.5 ft Node 16 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	5.059 psi g 4.674 psi g 13.87 ft 13.01 ft	0.06864 psi 0.1543 ft	4.99 psi g 4.606 psi g 13.72 ft 12.86 ft	0.01702 0.00 0 psi 0 ft
Pipe 35 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Sizing Valve 8 2.5 ft Node 16 2.5 ft	200 gpm 4.456 ft/s 125637 0.01725	4.99 psi g 4.853 psi g 13.72 ft 13.41 ft	0.2471 psi 0.5556 ft	4.743 psi g 4.606 psi g 13.16 ft 12.86 ft	0.01607 1.41 0.194 psi 0.4363 ft
Messages: Reversed flow							
Pipe 36 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	Node 4 2.5 ft Node 15 2.5 ft	200 gpm 4.456 ft/s 125637 0.01725	0.4633 psi g 0.3261 psi g 3.542 ft 3.233 ft	0.1654 psi 0.372 ft	0.2979 psi g 0.1607 psi g 3.17 ft 2.861 ft	0.01607 0.96 0.1323 psi 0.2974 ft

PIPE-FLO Professional **Version: 15.2.37316** **List Report** **Thursday, August 03, 2017 09:34 AM** **Page 3**

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 37 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	Node 16 2.5 ft Node 5 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.96 -- --
Pipe 5 Copper Nickel Class 200 Sea Water	3 in 3.31 in 1.5 ft	Node 4 2.5 ft Curve dP Device 1 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	0.4633 psi g 0.079 psi g 3.542 ft 2.678 ft	0.03432 psi 0.07717 ft	0.429 psi g 0.04468 psi g 3.465 ft 2.6 ft	0.01702 0.00 0 psi 0 ft
Pipe 7 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Pump 2 2.5 ft Sizing Valve 5 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	5.749 psi g 5.364 psi g 15.43 ft 14.56 ft	0.69 psi 1.551 ft	5.059 psi g 4.674 psi g 13.87 ft 13.01 ft	0.01702 1.62 0.6213 psi 1.397 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
Tank 1	2 ft 9 ft	0 psi g 4.003 psi g	11 ft	Pipe 2	0 ft	100.4 gpm	4.003 psi g
Tank 2	2 ft 9 ft	0 psi g 4.003 psi g	11 ft	Pipe 1	0 ft	99.64 gpm	4.003 psi g
Tank 3	0 ft 4.5 ft	0 psi g 2.001 psi g	4.5 ft	Pipe 3	0 ft	400 gpm	2.001 psi g
Tank 4	2 ft 9 ft	0 psi g 4.003 psi g	11 ft	Pipe 23	0 ft	100.4 gpm	4.003 psi g
Tank 5	2 ft 9 ft	0 psi g 4.003 psi g	11 ft	Pipe 22	0 ft	99.64 gpm	4.003 psi g

Curve dP Devices

Curve dP Device Name Description	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Curve dP Device 1 Eaton model 72	2.5 ft 0.429 psi g	2.5 ft 0.317 psi g	0.112 psi 0.2518 ft	200 gpm
Curve dP Device 2 Eaton model 72	2.5 ft 0.2636 psi g	2.5 ft 0.1516 psi g	0.112 psi 0.2518 ft	200 gpm

Nodes

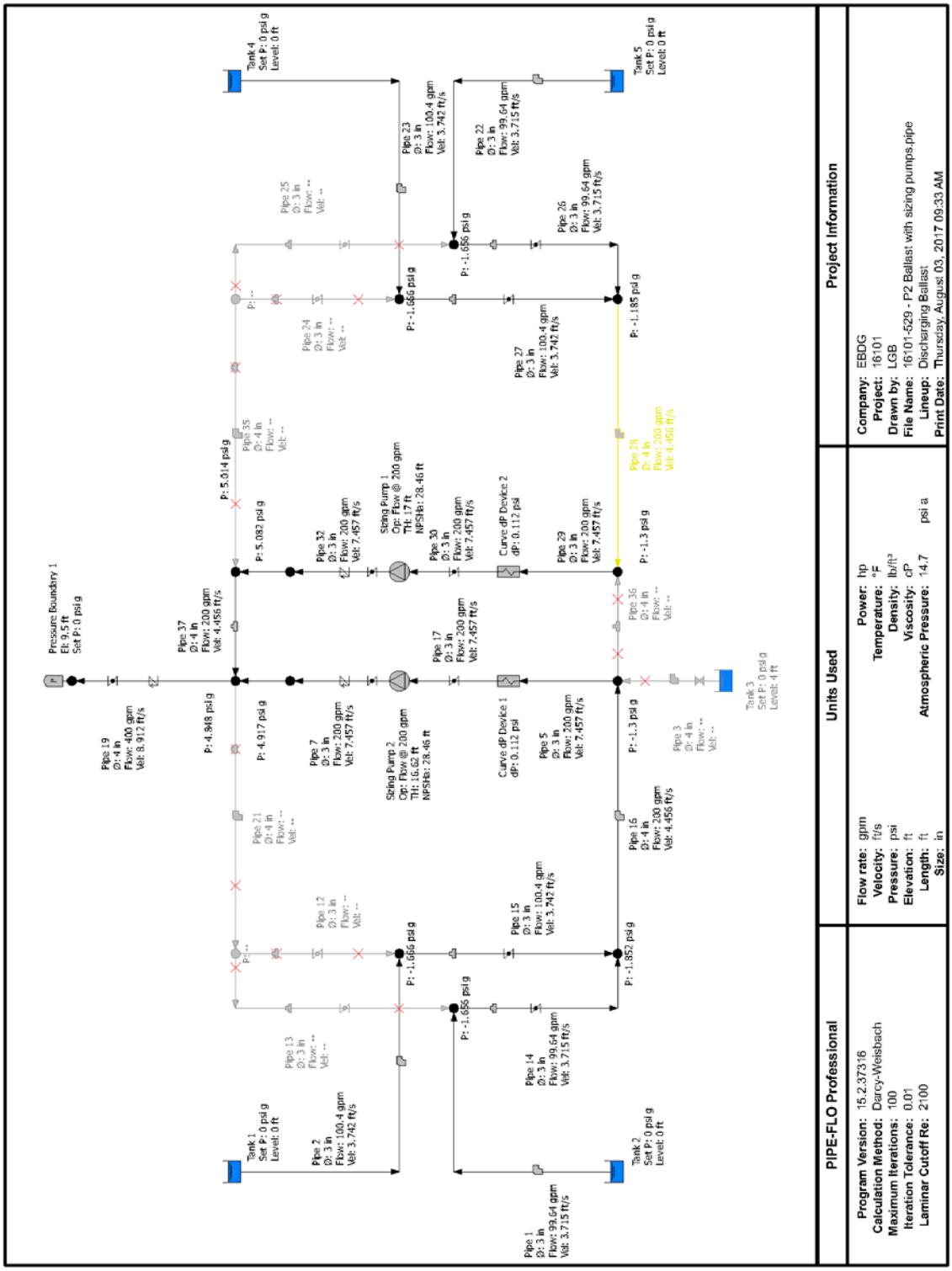
Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	4 ft	3.879 psi g	12.51 ft
Node 10	4 ft	3.89 psi g	12.53 ft
Node 11	2.5 ft	--	--

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 15	2.5 ft	0.2979 psi g	2.583 ft
Node 16	2.5 ft	4.99 psi g	13.13 ft
Node 2	4 ft	3.89 psi g	12.53 ft
Node 4	2.5 ft	0.4633 psi g	2.739 ft
Node 5	2.5 ft	4.99 psi g	13.13 ft
Node 7	4 ft	4.076 psi g	12.92 ft
Node 8	4 ft	--	--
Node 9	4 ft	3.879 psi g	12.51 ft
Sizing Valve 5	2.5 ft	5.059 psi g	13.01 ft
Sizing Valve 7	2.5 ft	5.059 psi g	13.01 ft
Sizing Valve 8	2.5 ft	4.743 psi g	12.92 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psi g	--	--



List Report

File Name: 16101-529 - P2 Ballast with sizing pumps.pipe
Lineup: Discharging Ballast
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Percent Tolerance: 0.01
Allowable Deviation: 1 %

Company: EBDG
Project: 16101
by: LGB
Date: Thursday, August 03, 2017 09:33 AM
Atmospheric Pressure: 14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits Velocity	Design Limits Pressure	Reynolds Number
Copper Nickel Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Sea Water Seawater 3.5% Salinity	60 °F 0 psi g	Liquid 29	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -1.786 psi g	2.5 ft 5.772 psi g	17 ft 7.558 psi	200 gpm	28.46 ft
Sizing Pump 2	2.5 ft -1.786 psi g	2.5 ft 5.607 psi g	16.62 ft 7.393 psi	200 gpm	28.46 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	Tank 2 2 ft Node 1 4 ft	99.64 gpm 3.715 ft/s 80970 0.01889	0 psi g -0.09538 psi g 2 ft 1.786 ft	1.656 psi 1.723 ft	-1.656 psi g -1.751 psi g 0.2774 ft 0.06294 ft	0.01702 2.21 0.2108 psi 0.4739 ft
Pipe 12 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Node 7 4 ft Node 2 4 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --
Pipe 13 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Node 7 4 ft Node 1 4 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --
Pipe 14 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Node 1 4 ft Node 8 4 ft	99.64 gpm 3.715 ft/s 80970 0.01889	-1.656 psi g -1.751 psi g 0.2774 ft 0.06294 ft	0.1966 psi 0.442 ft	-1.852 psi g -1.948 psi g -0.1646 ft -0.3791 ft	0.01702 1.79 0.1704 psi 0.3832 ft
Pipe 15 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Node 2 4 ft Node 8 4 ft	100.4 gpm 3.742 ft/s 81561 0.01887	-1.666 psi g -1.763 psi g 0.2541 ft 0.03646 ft	0.1862 psi 0.4186 ft	-1.852 psi g -1.949 psi g -0.1646 ft -0.3822 ft	0.01702 1.79 0.1729 psi 0.3889 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 16	4 in	Node 8	200 gpm	-1.852 psi g	-0.5523 psi	-1.3 psi g	0.01607
Copper Nickel Class 200	4.282 in	4 ft	4.456 ft/s	-1.989 psi g		-1.437 psi g	0.45
Sea Water	8 ft	Node 4	125637	-0.1646 ft	0.2581 ft	-0.4227 ft	0.06173 psi
		2.5 ft	0.01725	-0.4731 ft		-0.7313 ft	0.1388 ft
Pipe 17	3 in	Curve dP Device 1	200 gpm	-1.446 psi g	0.3401 psi	-1.786 psi g	0.01702
Copper Nickel Class 200	3.31 in	2.5 ft	7.457 ft/s	-1.83 psi g		-2.171 psi g	0.77
Sea Water	2 ft	Sizing Pump 2	162530	-0.7517 ft	0.7647 ft	-1.516 ft	0.2943 psi
		2.5 ft	0.01642	-1.616 ft		-2.381 ft	0.6618 ft
Pipe 19	4 in	Node 5	400 gpm	4.848 psi g	4.848 psi	0 psi g	0.01607
Copper Nickel Class 200	4.282 in	2.5 ft	8.912 ft/s	4.299 psi g		-0.5489 psi g	2.53
Sea Water	15 ft	Pressure Boundary 1	251273	13.4 ft	3.901 ft	9.5 ft	1.387 psi
		9.5 ft	0.01509	12.17 ft		8.266 ft	3.118 ft
Pipe 2	3 in	Tank 1	100.4 gpm	0 psi g	1.666 psi	-1.666 psi g	0.01702
Copper Nickel Class 200	3.31 in	2 ft	3.742 ft/s	-0.09678 psi g		-1.763 psi g	2.21
Sea Water	85 ft	Node 2	81561	2 ft	1.746 ft	0.2541 ft	0.2138 psi
		4 ft	0.01887	1.782 ft		0.03646 ft	0.4808 ft
Pipe 20	3 in	Sizing Valve 5	200 gpm	4.917 psi g	0.06864 psi	4.848 psi g	0.01702
Copper Nickel Class 200	3.31 in	2.5 ft	7.457 ft/s	4.532 psi g		4.464 psi g	0.00
Sea Water	3 ft	Node 5	162530	13.56 ft	0.1543 ft	13.4 ft	0 psi
		2.5 ft	0.01642	12.69 ft		12.54 ft	0 ft
Pipe 21	4 in	Node 5	--	--	--	--	--
Copper Nickel Class 200	4.282 in	2.5 ft	--	--		--	1.41
Sea Water	8 ft	Node 7	--	--	--	--	--
		4 ft	--	--		--	--
Pipe 22	3 in	Tank 5	99.64 gpm	0 psi g	1.656 psi	-1.656 psi g	0.01702
Copper Nickel Class 200	3.31 in	2 ft	3.715 ft/s	-0.09538 psi g		-1.751 psi g	2.21
Sea Water	85 ft	Node 9	80970	2 ft	1.723 ft	0.2774 ft	0.2108 psi
		4 ft	0.01889	1.786 ft		0.06294 ft	0.4739 ft
Pipe 23	3 in	Tank 4	100.4 gpm	0 psi g	1.666 psi	-1.666 psi g	0.01702
Copper Nickel Class 200	3.31 in	2 ft	3.742 ft/s	-0.09678 psi g		-1.763 psi g	2.21
Sea Water	85 ft	Node 10	81561	2 ft	1.746 ft	0.2541 ft	0.2138 psi
		4 ft	0.01887	1.782 ft		0.03646 ft	0.4808 ft
Pipe 24	3 in	Sizing Valve 8	--	--	--	--	--
Copper Nickel Class 200	3.31 in	2.5 ft	--	--		--	1.79
Sea Water	2 ft	Node 10	--	--	--	--	--
		4 ft	--	--		--	--
Pipe 25	3 in	Sizing Valve 8	--	--	--	--	--
Copper Nickel Class 200	3.31 in	2.5 ft	--	--		--	1.79
Sea Water	4 ft	Node 9	--	--	--	--	--
		4 ft	--	--		--	--
Pipe 26	3 in	Node 9	99.64 gpm	-1.656 psi g	-0.4705 psi	-1.185 psi g	0.01702
Copper Nickel Class 200	3.31 in	4 ft	3.715 ft/s	-1.751 psi g		-1.28 psi g	1.79
Sea Water	4 ft	Node 11	80970	0.2774 ft	0.442 ft	-0.1646 ft	0.1704 psi
		2.5 ft	0.01889	0.06294 ft		-0.3791 ft	0.3832 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 27 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Node 10 4 ft Node 11 2.5 ft	100.4 gpm 3.742 ft/s 81561 0.01887	-1.666 psi g -1.763 psi g 0.2541 ft 0.03646 ft	-0.4809 psi 0.4186 ft	-1.185 psi g -1.282 psi g -0.1646 ft -0.3822 ft	0.01702 1.79 0.1729 psi 0.3889 ft
Pipe 28 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Node 15 2.5 ft Node 11 2.5 ft	200 gpm 4.456 ft/s 125637 0.01725	-1.185 psi g -1.322 psi g -0.1646 ft -0.4731 ft	0.1148 psi 0.2581 ft	-1.3 psi g -1.437 psi g -0.4227 ft -0.7313 ft	0.01607 0.45 0.06173 psi 0.1388 ft
Messages: Reversed flow							
Pipe 29 Copper Nickel Class 200 Sea Water	3 in 3.31 in 1.5 ft	Node 15 2.5 ft Curve dP Device 2 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	-1.3 psi g -1.684 psi g -0.4227 ft -1.287 ft	0.03432 psi 0.07717 ft	-1.334 psi g -1.718 psi g -0.4999 ft -1.364 ft	0.01702 0.00 0 psi 0 ft
Pipe 3 Copper Nickel Class 200 Sea Water	4 in 4.282 in 10 ft	Tank 3 0 ft Node 4 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.35 -- --
Pipe 30 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Curve dP Device 2 2.5 ft Sizing Pump 1 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	-1.446 psi g -1.83 psi g -0.7517 ft -1.616 ft	0.3401 psi 0.7647 ft	-1.786 psi g -2.171 psi g -1.516 ft -2.381 ft	0.01702 0.77 0.2943 psi 0.6618 ft
Pipe 32 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Pump 1 2.5 ft Sizing Valve 7 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	5.772 psi g 5.388 psi g 15.48 ft 14.61 ft	0.69 psi 1.551 ft	5.082 psi g 4.698 psi g 13.93 ft 13.06 ft	0.01702 1.62 0.6213 psi 1.397 ft
Pipe 33 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Valve 7 2.5 ft Node 16 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	5.082 psi g 4.698 psi g 13.93 ft 13.06 ft	0.06864 psi 0.1543 ft	5.014 psi g 4.629 psi g 13.77 ft 12.91 ft	0.01702 0.00 0 psi 0 ft
Pipe 35 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Sizing Valve 8 2.5 ft Node 16 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.41 -- --
Pipe 36 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	Node 4 2.5 ft Node 15 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.96 -- --
Pipe 37 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	Node 16 2.5 ft Node 5 2.5 ft	200 gpm 4.456 ft/s 125637 0.01725	5.014 psi g 4.876 psi g 13.77 ft 13.46 ft	0.1654 psi 0.372 ft	4.848 psi g 4.711 psi g 13.4 ft 13.09 ft	0.01607 0.96 0.1323 psi 0.2974 ft
Pipe 5 Copper Nickel Class 200 Sea Water	3 in 3.31 in 1.5 ft	Node 4 2.5 ft Curve dP Device 1 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	-1.3 psi g -1.684 psi g -0.4227 ft -1.287 ft	0.03432 psi 0.07717 ft	-1.334 psi g -1.718 psi g -0.4999 ft -1.364 ft	0.01702 0.00 0 psi 0 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 7 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Pump 2 2.5 ft Sizing Valve 5 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	5.607 psi g 5.222 psi g 15.11 ft 14.24 ft	0.69 psi 1.551 ft	4.917 psi g 4.532 psi g 13.56 ft 12.69 ft	0.01702 1.62 0.6213 psi 1.397 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
Tank 1	2 ft 0 ft	0 psi g 0 psi g	2 ft	Pipe 2	0 ft	100.4 gpm	0 psi g
Tank 2	2 ft 0 ft	0 psi g 0 psi g	2 ft	Pipe 1	0 ft	99.64 gpm	0 psi g
Tank 3	0 ft 4 ft	0 psi g --	--	Pipe 3	0 ft	--	1.779 psi g
Tank 4	2 ft 0 ft	0 psi g 0 psi g	2 ft	Pipe 23	0 ft	100.4 gpm	0 psi g
Tank 5	2 ft 0 ft	0 psi g 0 psi g	2 ft	Pipe 22	0 ft	99.64 gpm	0 psi g

Curve dP Devices

Curve dP Device Name Description	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Curve dP Device 1 Eaton model 72	2.5 ft -1.334 psi g	2.5 ft -1.446 psi g	0.112 psi 0.2518 ft	200 gpm
Curve dP Device 2 Eaton model 72	2.5 ft -1.334 psi g	2.5 ft -1.446 psi g	0.112 psi 0.2518 ft	200 gpm

Nodes

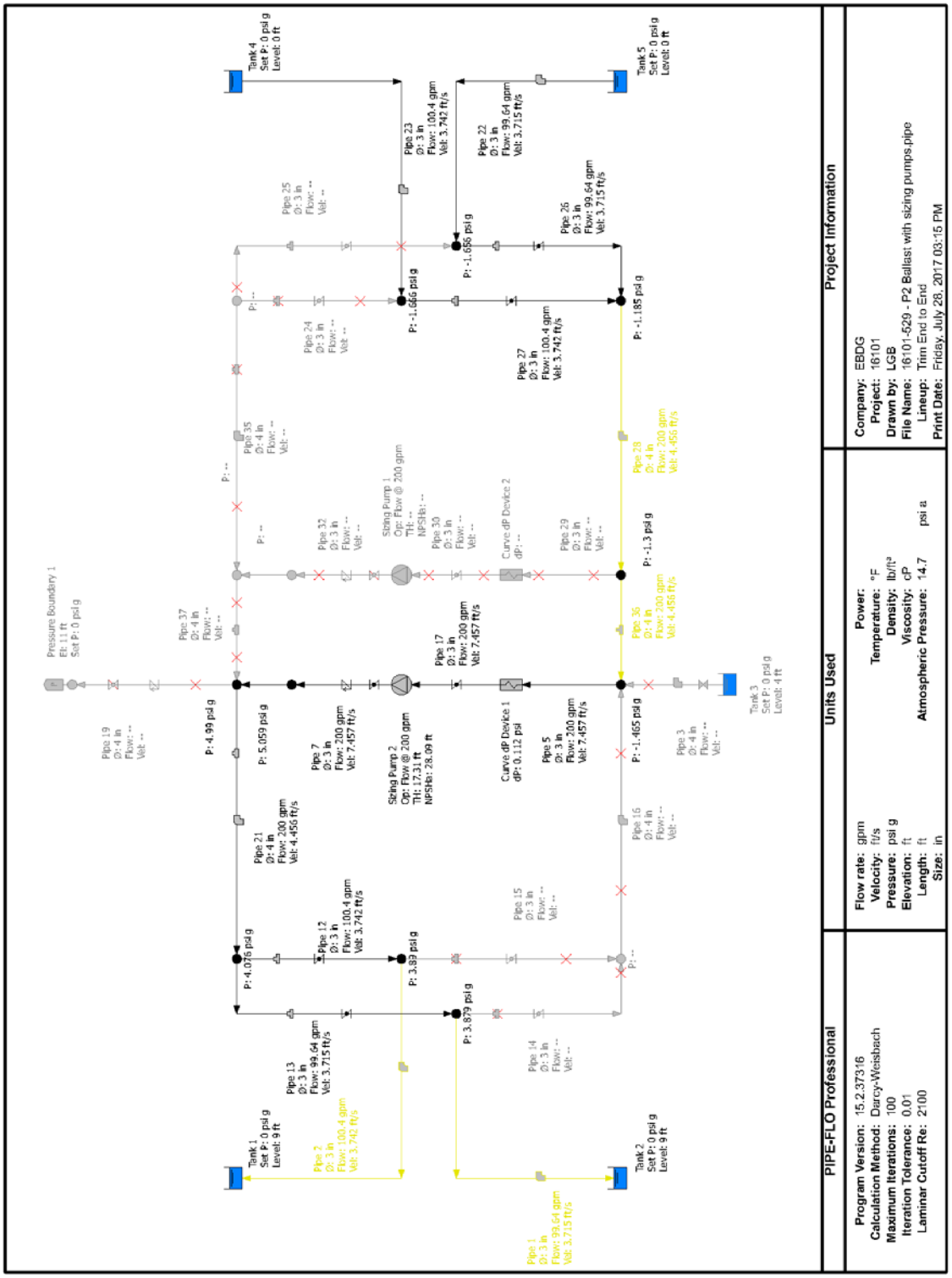
Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	4 ft	-1.656 psi g	0.06294 ft
Node 10	4 ft	-1.666 psi g	0.03646 ft
Node 11	2.5 ft	-1.185 psi g	-0.4115 ft
Node 15	2.5 ft	-1.3 psi g	-1.009 ft
Node 16	2.5 ft	5.014 psi g	13.19 ft
Node 2	4 ft	-1.666 psi g	0.03646 ft
Node 4	2.5 ft	-1.3 psi g	-1.009 ft
Node 5	2.5 ft	4.848 psi g	12.6 ft
Node 7	4 ft	--	--

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 8	4 ft	-1.852 psi g	-0.4115 ft
Node 9	4 ft	-1.656 psi g	0.06294 ft
Sizing Valve 5	2.5 ft	4.917 psi g	12.69 ft
Sizing Valve 7	2.5 ft	5.082 psi g	13.06 ft
Sizing Valve 8	2.5 ft	--	--

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psi g	8.266 ft	400 gpm



List Report

File Name:	16101-529 - P2 Ballast with sizing pumps.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	Trim End to End	**Laminar Cutoff Re:**	2100	**Project:**	16101
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	LGB
Version:	15.2.37316	**Percent Tolerance:**	0.01	**Date:**	Friday, July 28, 2017 03:15 PM
		Allowable Deviation:	1 %	**Atmospheric Pressure:**	14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits: Velocity	Design Limits: Pressure	Reynolds Number
Copper Nickel Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Sea Water Seawater 3.5% Salinity	60 °F 0 psi g	Liquid 29	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft --	2.5 ft --	-- --	--	--
Sizing Pump 2	2.5 ft -1.952 psi g	2.5 ft 5.749 psi g	17.31 ft 7.7 psi	200 gpm	28.09 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	Tank 2 2 ft Node 1 4 ft	99.64 gpm 3.715 ft/s 80970 0.01889	3.879 psi g 3.784 psi g 12.72 ft 12.51 ft	-0.1234 psi 1.723 ft	4.003 psi g 3.907 psi g 11 ft 10.79 ft	0.01702 2.21 0.2108 psi 0.4739 ft
Messages: Reversed flow							
Pipe 12 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Node 7 4 ft Node 2 4 ft	100.4 gpm 3.742 ft/s 81561 0.01887	4.076 psi g 3.979 psi g 13.16 ft 12.95 ft	0.1862 psi 0.4186 ft	3.89 psi g 3.793 psi g 12.75 ft 12.53 ft	0.01702 1.79 0.1729 psi 0.3889 ft
Pipe 13 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Node 7 4 ft Node 1 4 ft	99.64 gpm 3.715 ft/s 80970 0.01889	4.076 psi g 3.98 psi g 13.16 ft 12.95 ft	0.1966 psi 0.442 ft	3.879 psi g 3.784 psi g 12.72 ft 12.51 ft	0.01702 1.79 0.1704 psi 0.3832 ft
Pipe 14 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Node 1 4 ft Node 8 4 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 15 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Node 2 4 ft Node 8 4 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --
Pipe 16 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Node 8 4 ft Node 4 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.45 -- --
Pipe 17 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Curve dP Device 1 2.5 ft Sizing Pump 2 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	-1.612 psi g -1.996 psi g -1.124 ft -1.988 ft	0.3401 psi 0.7647 ft	-1.952 psi g -2.336 psi g -1.888 ft -2.753 ft	0.01702 0.77 0.2943 psi 0.6618 ft
Pipe 19 Copper Nickel Class 200 Sea Water	4 in 4.282 in 15 ft	Node 5 2.5 ft Pressure Boundary 1 11 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 2.53 -- --
Pipe 2 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	Tank 1 2 ft Node 2 4 ft	100.4 gpm 3.742 ft/s 81561 0.01887	3.89 psi g 3.793 psi g 12.75 ft 12.53 ft	-0.113 psi 1.746 ft	4.003 psi g 3.906 psi g 11 ft 10.78 ft	0.01702 2.21 0.2138 psi 0.4808 ft
Messages: Reversed flow							
Pipe 20 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Valve 5 2.5 ft Node 5 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	5.059 psi g 4.674 psi g 13.87 ft 13.01 ft	0.06864 psi 0.1543 ft	4.99 psi g 4.606 psi g 13.72 ft 12.86 ft	0.01702 0.00 0 psi 0 ft
Pipe 21 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Node 5 2.5 ft Node 7 4 ft	200 gpm 4.456 ft/s 125637 0.01725	4.99 psi g 4.853 psi g 13.72 ft 13.41 ft	0.9142 psi 0.5556 ft	4.076 psi g 3.939 psi g 13.16 ft 12.86 ft	0.01607 1.41 0.194 psi 0.4363 ft
Pipe 22 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	Tank 5 2 ft Node 9 4 ft	99.64 gpm 3.715 ft/s 80970 0.01889	0 psi g -0.09538 psi g 2 ft 1.786 ft	1.656 psi 1.723 ft	-1.656 psi g -1.751 psi g 0.2774 ft 0.06294 ft	0.01702 2.21 0.2108 psi 0.4739 ft
Pipe 23 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	Tank 4 2 ft Node 10 4 ft	100.4 gpm 3.742 ft/s 81561 0.01887	0 psi g -0.09678 psi g 2 ft 1.782 ft	1.666 psi 1.746 ft	-1.666 psi g -1.763 psi g 0.2541 ft 0.03646 ft	0.01702 2.21 0.2138 psi 0.4808 ft
Pipe 24 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Sizing Valve 8 2.5 ft Node 10 4 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --
Pipe 25 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Sizing Valve 8 2.5 ft Node 9 4 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.79 -- --

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 26 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	Node 9 4 ft Node 11 2.5 ft	99.64 gpm 3.715 ft/s 80970 0.01889	-1.656 psi g -1.751 psi g 0.2774 ft 0.06294 ft	-0.4705 psi 0.442 ft	-1.185 psi g -1.28 psi g -0.1646 ft -0.3791 ft	0.01702 1.79 0.1704 psi 0.3832 ft
Pipe 27 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Node 10 4 ft Node 11 2.5 ft	100.4 gpm 3.742 ft/s 81561 0.01887	-1.666 psi g -1.763 psi g 0.2541 ft 0.03646 ft	-0.4809 psi 0.4186 ft	-1.185 psi g -1.282 psi g -0.1646 ft -0.3822 ft	0.01702 1.79 0.1729 psi 0.3889 ft
Pipe 28 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Node 15 2.5 ft Node 11 2.5 ft	200 gpm 4.456 ft/s 125637 0.01725	-1.185 psi g -1.322 psi g -0.1646 ft -0.4731 ft	0.1148 psi 0.2581 ft	-1.3 psi g -1.437 psi g -0.4227 ft -0.7313 ft	0.01607 0.45 0.06173 psi 0.1388 ft
Messages: Reversed flow							
Pipe 29 Copper Nickel Class 200 Sea Water	3 in 3.31 in 1.5 ft	Node 15 2.5 ft Curve dP Device 2 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.00 -- --
Pipe 3 Copper Nickel Class 200 Sea Water	4 in 4.282 in 10 ft	Tank 3 0 ft Node 4 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.35 -- --
Pipe 30 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	Curve dP Device 2 2.5 ft Sizing Pump 1 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.77 -- --
Pipe 32 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Pump 1 2.5 ft Sizing Valve 7 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.62 -- --
Pipe 33 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Valve 7 2.5 ft Node 16 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.00 -- --
Pipe 35 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	Sizing Valve 8 2.5 ft Node 16 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 1.41 -- --
Pipe 36 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	Node 4 2.5 ft Node 15 2.5 ft	200 gpm 4.456 ft/s 125637 0.01725	-1.3 psi g -1.437 psi g -0.4227 ft -0.7313 ft	0.1654 psi 0.372 ft	-1.465 psi g -1.603 psi g -0.7947 ft -1.103 ft	0.01607 0.96 0.1323 psi 0.2974 ft
Messages: Reversed flow							

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 37 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	Node 16 2.5 ft Node 5 2.5 ft	-- -- -- --	-- -- -- --	-- --	-- -- -- --	-- 0.96 -- --
Pipe 5 Copper Nickel Class 200 Sea Water	3 in 3.31 in 1.5 ft	Node 4 2.5 ft Curve dP Device 1 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	-1.465 psi g -1.85 psi g -0.7947 ft -1.659 ft	0.03432 psi 0.07717 ft	-1.5 psi g -1.884 psi g -0.8719 ft -1.736 ft	0.01702 0.00 0 psi 0 ft
Pipe 7 Copper Nickel Class 200 Sea Water	3 in 3.31 in 3 ft	Sizing Pump 2 2.5 ft Sizing Valve 5 2.5 ft	200 gpm 7.457 ft/s 162530 0.01642	5.749 psi g 5.364 psi g 15.43 ft 14.56 ft	0.69 psi 1.551 ft	5.059 psi g 4.674 psi g 13.87 ft 13.01 ft	0.01702 1.62 0.6213 psi 1.397 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
Tank 1	2 ft 9 ft	0 psi g 4.003 psi g	11 ft	Pipe 2	0 ft	100.4 gpm	4.003 psi g
Tank 2	2 ft 9 ft	0 psi g 4.003 psi g	11 ft	Pipe 1	0 ft	99.64 gpm	4.003 psi g
Tank 3	0 ft 4 ft	0 psi g --	--	Pipe 3	0 ft	--	1.779 psi g
Tank 4	2 ft 0 ft	0 psi g 0 psi g	2 ft	Pipe 23	0 ft	100.4 gpm	0 psi g
Tank 5	2 ft 0 ft	0 psi g 0 psi g	2 ft	Pipe 22	0 ft	99.64 gpm	0 psi g

Curve dP Devices

Curve dP Device Name Description	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Curve dP Device 1 Eaton model 72	2.5 ft -1.5 psi g	2.5 ft -1.612 psi g	0.112 psi 0.2518 ft	200 gpm
Curve dP Device 2 Eaton model 72	2.5 ft --	2.5 ft --	-- --	--

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	4 ft	3.879 psi g	12.51 ft
Node 10	4 ft	-1.666 psi g	0.03646 ft
Node 11	2.5 ft	-1.185 psi g	-0.4115 ft

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 15	2.5 ft	-1.3 psi g	-0.7313 ft
Node 16	2.5 ft	--	--
Node 2	4 ft	3.89 psi g	12.53 ft
Node 4	2.5 ft	-1.465 psi g	-1.381 ft
Node 5	2.5 ft	4.99 psi g	13.13 ft
Node 7	4 ft	4.076 psi g	12.92 ft
Node 8	4 ft	--	--
Node 9	4 ft	-1.656 psi g	0.06294 ft
Sizing Valve 5	2.5 ft	5.059 psi g	13.01 ft
Sizing Valve 7	2.5 ft	--	--
Sizing Valve 8	2.5 ft	--	--

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	11 ft	0 psi g	--	--

Bill of Materials Report

File Name: 16101-529 - P2 Ballast with sizing pumps.pipe
Lineup: Discharging Ballast
Program Name: PIPE-FLO Professional
Version: 15.2.37316
Company: EBDG
Project: 16101
by: LGB
Date: Thursday, August 03, 2017 09:41 AM

Sizing Pumps

Sizing Pump Name Operation	Design Point Flow Rate	 Total Head
Sizing Pump 1 Flow @ 200 gpm	200 gpm	17 ft
Sizing Pump 2 Flow @ 200 gpm	200 gpm	16.62 ft

Tanks

Tank Name
Tank 1
Tank 2
Tank 3
Tank 4
Tank 5

Curve dP Devices

Curve dP Device Name	Curve Description
Curve dP Device 1	Eaton model 72
Curve dP Device 2	Eaton model 72

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	Copper Nickel Class 200	3 in	85 ft	6 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Inward
Pipe 12	Copper Nickel Class 200	3 in	2 ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 13	Copper Nickel Class 200	3 in	4 ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 14	Copper Nickel Class 200	3 in	4 ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 15	Copper Nickel Class 200	3 in	2 ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 16	Copper Nickel Class 200	4 in	8 ft	2 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 17	Copper Nickel Class 200	3 in	2 ft	1 x Butterfly
Pipe 19	Copper Nickel Class 200	4 in	15 ft	1 x Swing Check - Vertical 1 x Exit - Rounded 1 x Butterfly
Pipe 2	Copper Nickel Class 200	3 in	85 ft	6 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Inward
Pipe 20	Copper Nickel Class 200	3 in	3 ft	
Pipe 21	Copper Nickel Class 200	4 in	8 ft	2 x Elbow - Long radius, r/d 1.5 (90°) 1 x Tee - Flow Thru Branch
Pipe 22	Copper Nickel Class 200	3 in	85 ft	6 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Inward
Pipe 23	Copper Nickel Class 200	3 in	85 ft	6 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Inward
Pipe 24	Copper Nickel Class 200	3 in	2 ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 25	Copper Nickel Class 200	3 in	4 ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 26	Copper Nickel Class 200	3 in	4 ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 27	Copper Nickel Class 200	3 in	2 ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 28	Copper Nickel Class 200	4 in	8 ft	2 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 29	Copper Nickel Class 200	3 in	1.5 ft	

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 3	Copper Nickel Class 200	4 in	10 ft	1 x Elbow - Long radius, r/d 1.5 (90°) 3 1 x Gate - Wedge Disc
Pipe 30	Copper Nickel Class 200	3 in	2 ft	1 x Butterfly
Pipe 32	Copper Nickel Class 200	3 in	3 ft	1 x Swing Check - Vertical 1 x Butterfly
Pipe 33	Copper Nickel Class 200	3 in	3 ft	
Pipe 35	Copper Nickel Class 200	4 in	8 ft	2 x Elbow - Long radius, r/d 1.5 (90°) 1 x Tee - Flow Thru Branch
Pipe 36	Copper Nickel Class 200	4 in	5 ft	1 x Tee - Flow Thru Branch
Pipe 37	Copper Nickel Class 200	4 in	5 ft	1 x Tee - Flow Thru Branch
Pipe 5	Copper Nickel Class 200	3 in	1.5 ft	
Pipe 7	Copper Nickel Class 200	3 in	3 ft	1 x Swing Check - Vertical 1 x Butterfly

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Copper Nickel Class 200	Copper Nickel MIL-T-16420K Schedule: Class 200	3 in	383.00 ft	12 x Butterfly 24 x Elbow - Long radius, r/d 1.5 (90°) 4 x Entrance - Inward 2 x Swing Check - Vertical 8 x Tee - Flow Thru Branch
Copper Nickel Class 200	Copper Nickel MIL-T-16420K Schedule: Class 200	4 in	67.00 ft	1 x Butterfly 9 x Elbow - Long radius, r/d 1.5 (90°) 1 x Exit - Rounded 1 x Gate - Wedge Disc 1 x Swing Check - Vertical 4 x Tee - Flow Thru Branch

Appendix K

Lube Oil and Waste Oil System, Dwg. 16101-200-529-2

1 DESCRIPTION

This appendix documents the first principles calculations used in designing the lube oil and waste oil system. These calculations are used to identify steady state frictional losses and to verify compliance with manufacturer-stated performance limits.

2 PROCEDURE

Calculations are presented in the following sequence:

- Pipe size calculations
- Frictional loss and pump ΔP calculations

Frictional losses through the piping system are calculated by constructing a model using PIPE-FLO Professional software utilizing the Darcy Weisbach method.

3 GIVEN AND ASSUMED PARAMETERS

- The Waste Oil system is to be constructed of Schedule 80 carbon steel pipe.
- Piping system lengths, routing, fittings, etc. are estimated based on the Profiles and Arrangements, and Lube Oil and Waste Oil Schematic [1] [2].
- A pressure of 10 psig is assumed at the waste oil discharge on the Main Deck.
- The waste oil tank is 2 feet above baseline, the pump suction and discharge are 4 feet above baseline, and the waste oil discharge on the Main Deck is assumed to be 12 feet above baseline, [1].
- The fluid used for all calculations is SAE 30 Lube Oil with the following properties:

Temperature:	50 degrees F
Specific Weight:	55.99 lb/cuft
Dynamic viscosity:	479.4 cP
Vapor Pressure:	0.2173 psia

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Pipe Size Calculations

Pipe sizes are based on the nominal velocity limits found in Marine Engineering, Chapter 20, Table 3, [3]. The following table shows the flow rates of lube oil occurring in the system, and the resulting pipe sizes.

Table 5-1: Waste Oil System Pipe Sizes and Velocities

Pipe Segment	Flow Rate	Pipe Size	ID	Design Velocity (ft/s)		V
	gpm	(NPS)	in	Nominal	Limit	ft/s
Pump suction	16	1 1/2" SCH 80	1.50	1.22	4.00	2.83
Pump discharge	16	1 1/2" SCH 80	1.50	2.45	6.00	2.83

5.2 Frictional Loss and Pump ΔP Calculation

From the enclosed system model, the waste oil pump must provide at a minimum 20 psig when operating at a flow rate of 16 gpm.

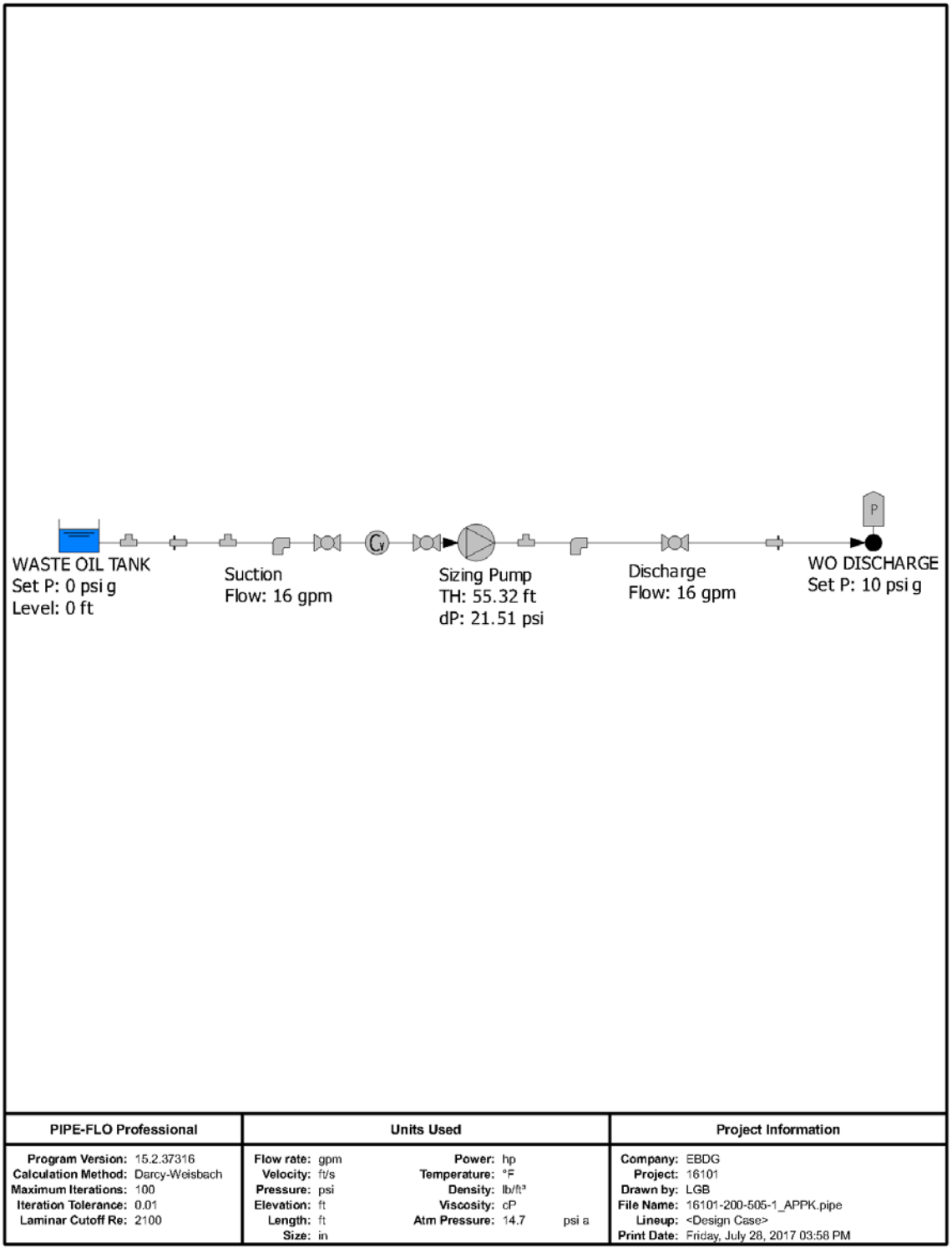
6 REFERENCES

[1] Elliott Bay Design Group, "NCDOT New River Class Ferry: Profiles and Arrangements," 16101-200-101-1, Seattle, WA.

[2] Elliott Bay Design Group, "NCDOT New River Class Ferry: Lube Oil and Waste Oil Piping Schematic," 16101-200-529-2, Seattle, WA.

[3] R. L. Harrington, Marine Engineering, Jersey City, NJ: SNAME, 1992.

WASTE OIL SYSTEM PIPE-FLO MODEL



PIPE-FLO Professional		Units Used				Project Information	
Program Version:	15.2.37316	Flow rate:	gpm	Power:	hp	Company:	EBDG
Calculation Method:	Darcy-Weisbach	Velocity:	ft/s	Temperature:	°F	Project:	16101
Maximum Iterations:	100	Pressure:	psi	Density:	lb/ft³	Drawn by:	LGB
Iteration Tolerance:	0.01	Elevation:	ft	Viscosity:	cP	File Name:	16101-200-505-1_APPK.pipe
Laminar Cutoff Re:	2100	Length:	ft	Atm Pressure:	14.7 psi a	Lineup:	<Design Case>
		Size:	in			Print Date:	Friday, July 28, 2017 03:58 PM

List Report

File Name:	16101-200-505-1_APPK.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	<Design Case>	**Laminar Cutoff Re:**	2100	**Project:**	16101
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	LGB
Version:	15.2.37316	**Percent Tolerance:**	0.01	**Date:**	Friday, July 28, 2017 03:59 PM
		Allowable Deviation:	1 %	**Atmospheric Pressure:**	14.7 psi a

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria		Design Limits: Velocity	Design Limits: Pressure	Design Limits: Reynolds Number
Steel A53-B36.10	Steel A53-B36.10	1.800E-03 in	0.0	Min:	ft/s	psi g	
standard	Schedule:80	140		Max:	ft/s	psi g	

Fluid Zones

Fluid Zone Name / Table Name	Temperature / Pressure	Fluid State / Relative Molecular Mass	Density / Viscosity	Vapor Pressure / Critical Pressure	Specific Heat Capacity (cp) / Specific Heat Ratio (k)
SAE 30 Lube Oil	50 °F	Liquid	55.99 lb/ft³	0.2173 psi a	--
SAE 30 Lube	40 psi g	1	479.4 cP	3199 psi a	--

Sizing Pumps

Pump Name	Suction Elevation / Suction Pressure	Discharge Elevation / Discharge Pressure	Total Head / dP	Flow Rate	NPSHa
Sizing Pump	4 ft	4 ft	55.32 ft	16 gpm	25.66 ft
	-4.501 psi g	17.01 psi g	21.51 psi		

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Device / Inlet Elevation / Outlet Device / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number / Pipe Friction Factor	Inlet Total Pressure / Inlet Static Pressure / Inlet Energy Grade / Inlet Hydraulic Grade	Total dP / Total Head Loss	Outlet Total Pressure / Outlet Static Pressure / Outlet Energy Grade / Outlet Hydraulic Grade	V&F Friction Factor / V&F Resistance K / V&F dP / V&F Head Loss
Discharge	1.5 in	Sizing Pump	16 gpm	17.01 psi g	7.011 psi	10 psi g	0.02054
Steel A53-B36.10	1.5 in	4 ft	2.905 ft/s	16.96 psi g		9.949 psi g	2.99
SAE 30 Lube Oil	10 ft	WO DISCHARGE	63.12	47.75 ft	11.03 ft	36.72 ft	0.1526 psi
		11 ft	1.014	47.61 ft		36.59 ft	0.3924 ft
Suction	1.5 in	WASTE OIL TANK	16 gpm	0 psi g	4.501 psi	-4.501 psi g	0.02054
Steel A53-B36.10	1.5 in	2 ft	2.905 ft/s	-0.05099 psi g		-4.552 psi g	8.13
SAE 30 Lube Oil	8 ft	Sizing Pump	63.12	2 ft	9.576 ft	-7.576 ft	0.4146 psi
		4 ft	1.014	1.869 ft		-7.707 ft	1.066 ft

Tanks

Tank Name / Fluid Zone	Bottom Elevation / Liquid Level	Surface Pressure / Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
WASTE OIL TANK	2 ft	0 psi g	2 ft				
SAE 30 Lube Oil	0 ft	0 psi g					
				Suction	0 ft	16 gpm	0 psi g

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
WO DISCHARGE	11 ft	10 psi g	36.59 ft	16 gpm

Bill of Materials Report

File Name: 16101-200-505-1_APPK.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16101
by: LGB
Date: Friday, July 28, 2017 04:00 PM

Sizing Pumps

Sizing Pump Name / Operation	Design Point Flow Rate	Design Point Total Head
Sizing Pump Flow @ 16 gpm	16 gpm	55.32 ft

Tanks

Tank Name
WASTE OIL TANK

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Discharge	Steel A53-B36.10	1.5 in	10 ft	3 x Ball 2 x Elbow - Long radius, r/d 1.5 (90°) 1 x Exit - Projecting 1 x Tee - Flow Thru Branch
Suction	Steel A53-B36.10	1.5 in	8 ft	2 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Inward 1 x Strainer 1 x Tee - Flow Thru Run 1 x Tee - Flow Thru Branch 1 x Ball 1 x Ball

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Steel A53-B36.10	Steel A53-B36.10 Schedule: 80	1.5 in	18.00 ft	5 x Ball 4 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Inward 1 x Exit - Projecting 1 x Strainer 2 x Tee - Flow Thru Branch 1 x Tee - Flow Thru Run

Appendix L

Potable and Sanitary Water System, Dwg. 16101-200-533-1

1 DESCRIPTION

This appendix documents the calculations used in designing the potable water system. These calculations were used to determine flow demand and pipe sizes for the potable water piping and to size the potable water pressure tank and pump.

2 PROCEDURE

Calculations are presented in the following sequence:

- Demand water supply calculation
- Potable water tank sizing calculation
- Potable water pump requirements

System sizing is based on the guidance found in Appendix A of [1] and estimated usage factors.

Water system pressure tank is sized in accordance with [2] .

3 GIVEN AND ASSUMED PARAMETERS

- The potable water system is Steel Schedule 40 at the tank connection and Copper Seamless Hard Drawn Type K beyond the tank shut off valve. These calculations assume
- The system is supplied with two pumps. One pump will pressurize the system in normal operation and the second pump will be on standby. Pump will cycle on at 40 psig and off at 60 psig.
- Water closets flush using 1.28 gallons per flush, low-volume, flush-o-meter valves.
- Fixture count, system pipe lengths, routing and fittings are estimated based on the Profiles and Deck Arrangements [3] and Potable and Sanitary Water Piping Schematic [4].
- The highest potable and sanitary water outlet is on the bridge deck at the window washing system, 38 feet ABL.
- The pump inlet and outlet elevation is 2.5 feet.
- Required residual pressure at the highest outlet is 15 psi.
- The water tank is assumed to have 5 feet of water.
- Friction losses from the outlet of the pump to the highest outlet of the system are assumed to be 20 psi.

4 FORMULAS

The following formulas, taken from [2], are used to estimate the size of the potable water pressure tank:

$$\text{Eq 1: Supplemental Drawdown (gal)} = (\text{Peak demand (gpm)} - \text{pump capacity(gpm)}) \times \textit{Peak Demand Time}\ (min)$$

$$\text{Eq 2: Total Pressure Tank Volume} = \frac{\textit{Minimum Drawdown} + \textit{Supplemental Drawdown}}{\textit{Acceptance Factor}}$$

$$\text{Eq 3: Acceptance Factor} = 1 - \frac{P1\ (\textit{tank precharge}) + 14.7}{P2\ (\textit{cutout}) + 14.7}$$

5 CALCULATIONS

5.1 Demand Water Supply Calculations

Table 5-1: Water Supply

Level	Item	Qty	Water Supply Fixture Units, Table A-2	Item Totals	Flow Rate (gpm)	Usage Factor	Total Flow
Bridge Deck	Window Wash**	1	1	1	1.5	0.5	0.8
	Hose Bib*	2	2.5	3.5	2.5	0.1	0.5
	Total, Main Deck:			**4.5**			**1.3**
01 Deck	Service Sink	1	1.5	1.5	2.5	0.1	0.3
	Lavatory	1	1	1	1.5	1	1.5
	Hose Bib	1	1	1	2.5	0.1	0.3
	Head	1	5	5	1.5	1	1.5
	Total, 01Deck:			**8.5**			**3.5**
Main Deck	Service Sink	1	1.5	1.5	2.5	0.1	0.3
	Lavatory	2	1	2	1.5	1	3.0
	Hose Bib	2	1	2	1.5	1	3.0
	Head	2	5	10	1.5	1	3.0
	Total, Main Deck:			**15.5**			**9.3**
Hold	Hose Bib	3	1	3	2.5	0.1	0.8
	Total, Hold			**3**			**0.8**
Total WSFU for Vessel			31.5				14.8
Supply demand, from [1], Ch A-3, line 1			**40**	**GPM**			
Excluding water closets, from [1], Ch A-3, Line 2			**20**	**GPM**			
* First hose bib is 2.5 WSFU, additional are 1.0							
**Window wash WSFU is estimated as similar to a sink							

Demand flow from Chart A-3, Line 1 is 40 gpm, from [1]. However, varying the usage factors to simulate different system loads results in instantaneous demands ranging from 8 to 16 gpm. A pump sized for flows in this range with a maximum head of 50 psi coupled with a suitable pressure tank to prevent pump cycling will suffice.

5.2 Pressure Tank Sizing Calculation

Per [2], Table IV.1.2, the minimum draw-down for an 8 gpm pump is 8 gallons. The minimum pressure tank volume is calculated as follows:

Table 5-2: Pressure Tank Sizing

	Item	Qty		Note / Reference
(1)	Pump Capacity	8	gpm	
(2)	Minimum Drawdown	8	gallons	
(4)	Peak Demand Estimation	16	gpm	
(5)	Peak Demand Time	0.08	minutes	
(6)	P1 pressure tank precharge	40	psi	
(7)	P2 cutout pressure	60	psi	
(9)	Supplemental Drawdown	0.64	gallons	Eq. 1: [(4) - (1)] * (5)
(10)	Total Required Drawdown	8.64	gallons	Eq. 2: (2) + (9)
(11)	Acceptance Factor	0.27		Eq. 3: 1 - [[(6) + 14.7]/[(7) + 14.7]]
(12)	Total Calculated Tank Size	32	gallons	Eq. 4 (10) / (11)

5.3 Friction Loss

In order to determine the pump head requirements, the piping system between the potable water supply tank and potable water pressure tank are modeled using Pipe-Flo Professional 15 utilizing the Darcy-Weisbach friction loss method.

The pressure tank is set to 50 psi to represent 15 psi at the highest potable water outlet and 20 psi friction losses in the piping.

Based upon the attached model, at a flow rate of 16 gpm the velocity in the water suction line is 3.0 ft/sec, head loss is 1.5 ft, and the pump total head requirement is 113.5 ft.

The potable water pump will operate between 40 and 60 psi against a pressure tank, and should be selected with a shutoff head exceeding 60 psi and an NPSHr well below the NPSHa of the system for the flow rate at 40 psi. System NPSHa at various flow rates are as follows:

Table 5-3: System NPSHa

Flow Rate, (gpm)	System NPSHa, ft	Velocity, ft/s
4	38.23	1.05
8	37.94	2.11
12	37.49	3.16
16	36.86	4.22
20	36.08	5.27

6 REFERENCES

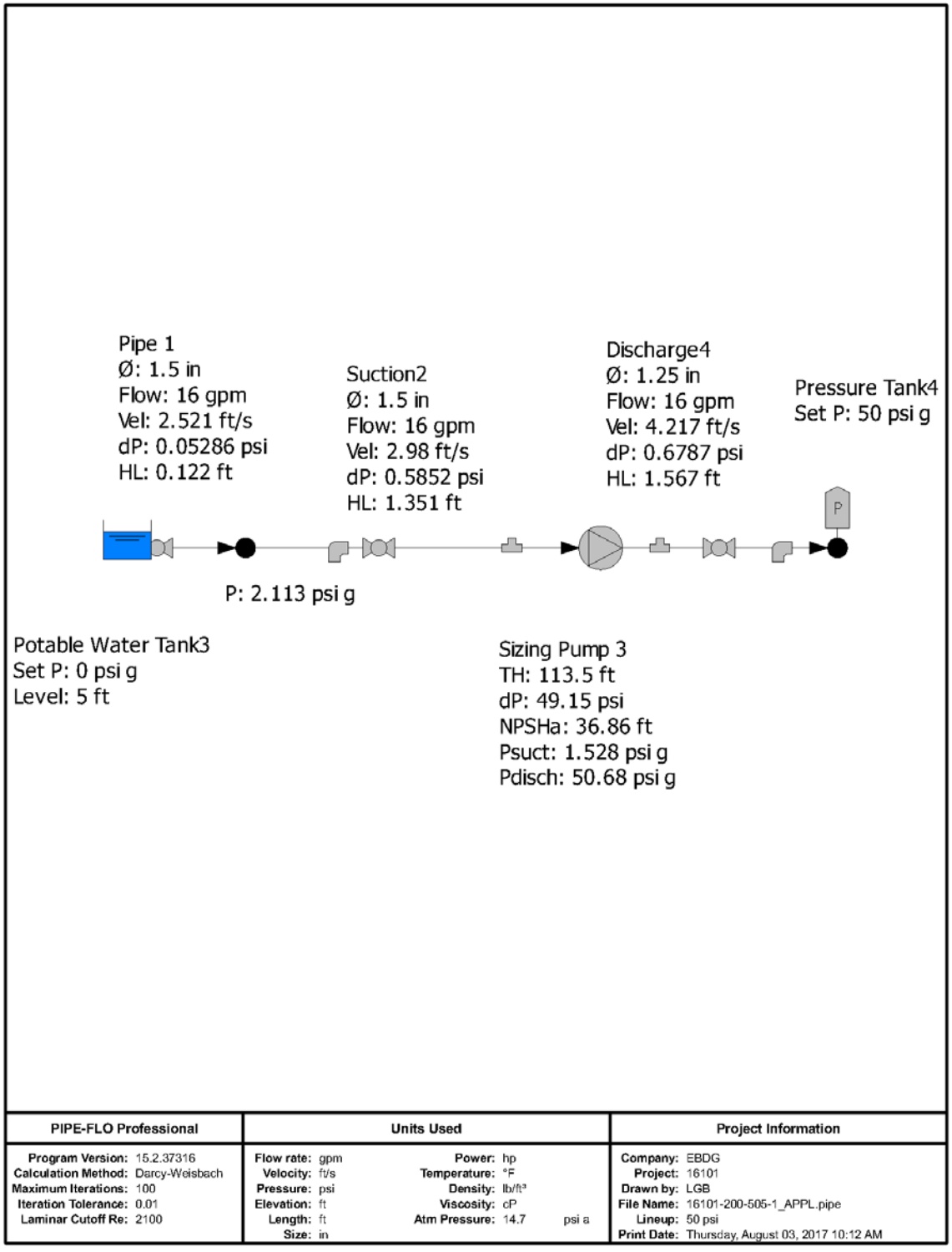
[1] IAPMO/ANSI UPC 1 - 2009: Uniform Plumbing Code, Ontario, CA: International Association of Plumbing and Mechanical Officials, 04/2009.

[2] Water Systems Council, Wellcare Information For You About Sizing a Pressure Tank, Washington, DC.

[3] EBDG, "16101-200-101-1 Profiles and Deck Arrangements," 7/28/17.

[4] EBDG, "16101-200-533-1 Potable and Sanitary Water Piping Schematic," 7/21/17.

Potable and Sanitary Water Pipe-Flo Model



PIPE-FLO Professional		Units Used				Project Information	
Program Version:	15.2.37316	Flow rate:	gpm	Power:	hp	Company:	EBDG
Calculation Method:	Darcy-Weisbach	Velocity:	ft/s	Temperature:	°F	Project:	16101
Maximum Iterations:	100	Pressure:	psi	Density:	lb/ft³	Drawn by:	LGB
Iteration Tolerance:	0.01	Elevation:	ft	Viscosity:	cP	File Name:	16101-200-505-1_APPL.pipe
Laminar Cutoff Re:	2100	Length:	ft	Atm Pressure:	14.7 psi a	Lineup:	50 psi
		Size:	in			Print Date:	Thursday, August 03, 2017 10:12 AM

List Report

File Name:	16101-200-505-1_APPL.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	50 psi	**Laminar Cutoff Re:**	2100	**Project:**	16101
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	LGB
Version:	15.2.37316	**Percent Tolerance:**	0.01	**Date:**	Thursday, August 03, 2017 10:12 AM
		Allowable Deviation:	1 %	**Atmospheric Pressure:**	14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits Velocity	Design Limits Pressure	Reynolds Number
Copper Tube, K - Discharge standard	Copper Tube H23 Schedule:K	6E-05 in 140	8.0 ft/s	**Min:** **Max:**	ft/s ft/s	15 psi g 80 psi g	
Copper Tube, K - Suction standard	Copper Tube H23 Schedule:K	6E-05 in 140	4.0 ft/s	**Min:** **Max:**	ft/s ft/s	psi g psi g	
Steel ASTM A53 standard	Steel A53-B36.10 Schedule:40	1.800E-03 in 140	0.0	**Min:** **Max:**	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Potable Water Water	60 °F 60 psi g	Liquid 18	62.37 lb/ft³ 1.105 cP	0.2564 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 3	2.5 ft 1.528 psi g	2.5 ft 50.68 psi g	113.5 ft 49.15 psi	16 gpm	36.86 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Discharge4 Copper Tube, K - Discharge Potable Water	1.25 in 1.245 in 5 ft	Sizing Pump 3 2.5 ft Pressure Tank4 2.5 ft	16 gpm 4.217 ft/s 36750 0.02255	50.68 psi g 50.56 psi g 119.5 ft 119.2 ft	0.6787 psi 1.567 ft	50 psi g 49.88 psi g 117.9 ft 117.7 ft	0.02152 4.58 0.5487 psi 1.267 ft
Pipe 1 Steel ASTM A53 Potable Water	1.5 in 1.61 in 2 ft	Potable Water Tank3 2.5 ft Sizing Pump 5 2.5 ft	16 gpm 2.521 ft/s 28419 0.02647	2.166 psi g 2.123 psi g 7.5 ft 7.401 ft	0.05286 psi 0.122 ft	2.113 psi g 2.07 psi g 7.378 ft 7.279 ft	0.02018 0.84 0.03597 psi 0.08305 ft
Suction2 Copper Tube, K - Suction Potable Water	1.5 in 1.481 in 20 ft	Sizing Pump 5 2.5 ft Sizing Pump 3 2.5 ft	16 gpm 2.98 ft/s 30894 0.02343	2.113 psi g 2.053 psi g 7.378 ft 7.24 ft	0.5852 psi 1.351 ft	1.528 psi g 1.468 psi g 6.027 ft 5.889 ft	0.0206 5.99 0.3582 psi 0.827 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
Potable Water Tank3 Potable Water	2.5 ft 5 ft	0 psi g 2.166 psi g	7.5 ft				

PIPE-FLO Professional **Version: 15.2.37316** **List Report** **Thursday, August 03, 2017 10:12 AM** **Page 1**

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
Potable Water Tank3 Potable Water	2.5 ft 5 ft	0 psi g 2.166 psi g	7.5 ft				
				Pipe 1	0 ft	16 gpm	2.166 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Sizing Pump 5	2.5 ft	2.113 psi g	7.26 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Tank4	2.5 ft	50 psi g	117.7 ft	16 gpm

Bill of Materials Report

File Name: 16101-200-505-1_APPL.pipe
Lineup: 50 psi
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16101
by: LGB
Date: Thursday, August 03, 2017 10:12 AM

Sizing Pumps

Sizing Pump Name Operation	Design Point Flow Rate	 Total Head
Sizing Pump 3 Flow @ 16 gpm	16 gpm	113.5 ft

Tanks

Tank Name
Potable Water Tank3

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Discharge4	Copper Tube, K - Discharge	1.25 in	5 ft	1 x Ball 2 x Tee - Flow Thru Branch 3 x Elbow - Standard 90°
Pipe 1	Steel ASTM A53	1.5 in	2 ft	1 x Entrance - Inward 1 x Ball
Suction2	Copper Tube, K - Suction	1.5 in	20 ft	1 x Entrance - Inward 6 x Elbow - Standard 90° 1 x Tee - Flow Thru Branch 1 x Strainer 2 x Ball

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Copper Tube, K - Discharge	Copper Tube H23 Schedule: K	1.25 in	5.00 ft	1 x Ball 3 x Elbow - Standard 90° 2 x Tee - Flow Thru Branch
Copper Tube, K - Suction	Copper Tube H23 Schedule: K	1.5 in	20.00 ft	2 x Ball 6 x Elbow - Standard 90° 1 x Entrance - Inward 1 x Strainer 1 x Tee - Flow Thru Branch
Steel ASTM A53	Steel A53-B36.10 Schedule: 40	1.5 in	2.00 ft	1 x Ball 1 x Entrance - Inward