DOUBLE-ENDED AZIMUTH DRIVE FERRY

Piping System and Mechanical Calculations

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REVISIONS

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-	Initial issue	08/10/18	MEJ 49387

GENERAL NOTES

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1 PURPOSE

This report documents the calculations used to devleop of the machinery and piping systems for the DOUBLE-ENDED AZIMUTH DRIVE FERRY, a design for the North Carolina Department of Transportation. The subject vessel is a 183 foot 7 inch long by 46 foot 10 inch wide by 10 foot 6 inch deep passenger and vehicle ferry intended for service within the Outer Banks of North Carolina, and 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 DOUBLE-ENDED AZIMUTH DRIVE 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

Cooling System, Dwg. 18026-200-256-1

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
- Seawater cooling system pressure calculations
- Sea Chest Sizing
- Freshwater Cooling System 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 seawater cooling systems will be constructed of Class 200 copper nickel pipe.
- Maximum summer water temperature is assumed to be 86°F.
- System elevations were estimated from [1] and all elevations are in reference to the vessel's baseline:

Table 3-1: Elevations

Elevation Point	Elevation
Waterline	4.5 feet
Sea Chest	2.5 feet
Main Engine Sea Water Pump	3.5 feet

- Piping system lengths, routing, fittings, etc. are estimated based on [1] and [2].

3.1 Generator Cooling System

- Each main generator is supplied with an engine mounted sea water pump.
- Each main generator is supplied with engine mounted coolers for jacket water and separate circuit aftercooler.
- The system is designed for sea water supply to two generators, and the auxiliary seawater system, and ballast system with one sea chest closed. Under normal operation, both sea chests are intended to be open.
- 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

- Reference [3] provides pump data used to construct the engine cooling models.

3.2 Auxiliary Seawater Cooling System

- Auxiliary sweater cooling demands, estimated from preliminary vendor data, are as follows:

Table 3-2: Auxiliary Seawater Demands

Item	Flow Rate	Pressure Drop
Machinery HVAC Chillers [4]	9 gpm x 4 = 36 gpm	10 psi
Freshwater Cooling Heat Exchanger [5]	30 gpm x 1 = 30 gpm	5.6 psi
Propulsion Drive Heat Exchanger	15 gpm x 2 = 30 gpm	10 psi

- Flowrate and pressure drop for propulsion drive heat exchangers estimated. Flowrate based on 34kW estimated heat rejection [6] and a seawater temperature rise of 10°F or less. A 10 psi pressure drop through the heat exchanger was assumed.

- 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

- Freshwater cooling heat exchangers are sized so that each can handle the full heat rejection of all four motors, allowing one heat exchanger to be out of service while vessel is operating.

- Seawater cooling branches are balanced with Hays Measurflo valves, which have a minimum operating pressure of 2 PSI.

3.3 Freshwater Cooling System

- The freshwater cooling system will be constructed with SCH 10S stainless steel pipe.

- The fluid medium is a 30% ethylene glycol solution with the following properties:

Specific weight	64.04 lb/cu ft
Viscosity	1.301 cP
Temperature	100.4 °F
Vapor pressure	0.8264 psia

- Freshwater flowrate requirements are based on four (4) Ramme SW500_S_250_1241_B liquid cooled electric motors integrated provided with Schottel SCD 200 STP 150 thrusters. [7]

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, [8]. The following table shows the flow rates of cooling water occurring in the system, and the resulting pipe sizes.

Pipe Segment	Flow Rate	Pipe Size	Schedule	d, ID	Design Velocity			V
					Nominal		Limit	
	gpm	(NPS)		in	ft/s		ft/s	ft/s
FW Single Motor	13.2	1	SCH 10S	1.097	5.0 √d	5.24	20	4.48
FW Cooling Supply	26.4	1 1/4	SCH 10S	1.442	5.0 √d	6.00	20	5.19
FW Cooling Return	26.4	1 1/4	SCH 10S	1.442	5.0 √d	6.00	20	5.19
FW Cooling Pump main	52.8	2	SCH 10S	2.157	5.0 √d	7.34	20	4.64
FW Cooling pump suction	52.8	2	SCH 10S	2.157	3.0 √d	4.41	15	4.64
ME SW Suction (1 engine)	80	2	CL 200	2.209	3.0 √d	4.46	12	6.70
ME SW Discharge (1 engine)	80	2	CL 200	2.209	5.0 √d	7.43	12	6.70
ME SW Discharge (3 engines)	240	4	CL 200	4.282	5.0 √d	10.35	12	5.35
SW Chiller (single)	9	3/4	CL 200	0.920	5.0 √d	4.80	12	4.34
SW Chiller Header (4 chillers)	36	1 1/2	CL 200	1.756	5.0 √d	6.63	12	4.77
SW Prop Drive HEX	30	1 1/2	CL 200	1.756	5.0 √d	6.63	12	3.97
SW Thuster Drive HEX	30	1 1/2	CL 200	1.756	5.0 √d	6.63	12	3.97
SW HEX Supply	30	1 1/2	CL 200	1.756	5.0 √d	6.63	12	3.97
Aux SW Pump Disch	96	2	CL 200	2.209	5.0 √d	7.43	12	8.04
Aux SW Pump Suction	96	2 1/2	CL 200	2.709	3.0 √d	4.94	12	5.34
1 SW Suction (2ME + AUX)	336	5	CL 200	5.312	3.0 √d	6.91	12	4.86
2 SW Suctions (2ME + AUX + Ballast	536	5	CL 200	5.312	3.0 √d	6.91	12	7.76

5.2 Generator Cooling System Pressure Calculations

As shown in the attached pipeflo model of the seawater cooling piping, the calculated pressure drop of 27.7 feet H2O result in a flow rate of 74.2 gpm for the given pump.

5.3 Auxiliary Seawater Cooling System Pressure Calculations

As shown in the attached pipeflo model of the required pump capacity and head for the auxiliary seawater cooling system is 45.2 feet H2O at a flow rate of 96 gpm.

5.4 Freshwater Cooling System Pressure Calculations

As shown in the attached pipeflo model of the required pump capacity and head for the freshwater seawater cooling system is 71.4 feet H2O at a flow rate of 51.9 gpm.

6 REFERENCES

[1] Elliott Bay Design Group, "NCDOT Double-Ended Azimuth Drive Ferry: Profiles and Arrangements," 18026-200-101-1, Seattle, WA.

[2] Elliott Bay Design Group, "NCDOT Double-Ended Azimuth Drive Ferry: Cooling System Schematic," 18026-200-256-1, Seattle, WA.

[3] CAT, C18 Auxiliary Pump Performance, Ref. EM 0327, June 21, 2018.

[4] S. Brigham (2018, July 25), *RE: 18026 HVAC System for Switchboard Room,* email: Available e-mail: sab@flagshipmarine.com, 7/25/18.

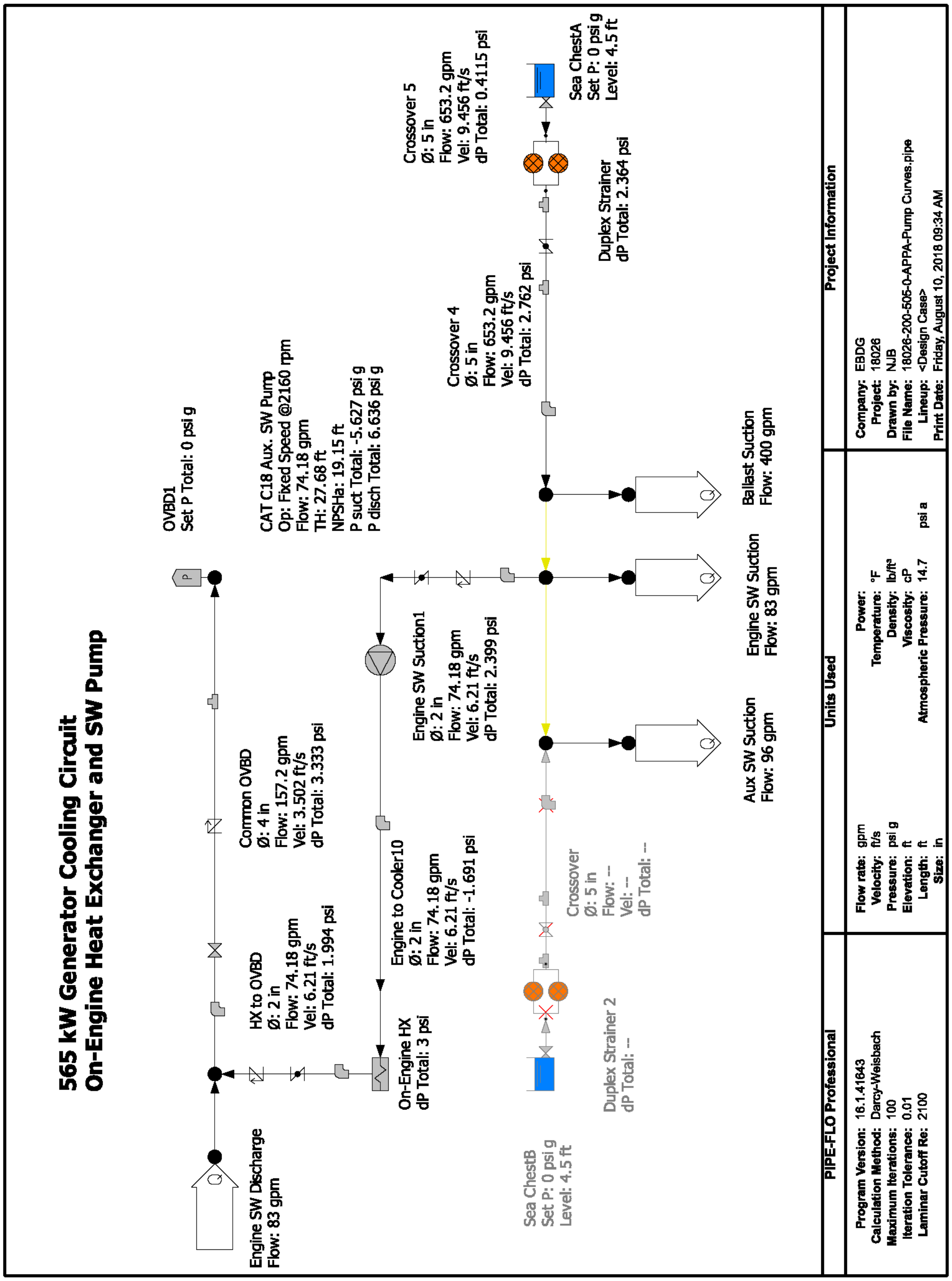
[5] Alfa Laval (MSI / Kevin Oakley), "Plate Heat Exchanger TL3-PFG," EBDG-NDOT Ferry TL3-PFG Propulsion Motor Cooling HX.pdf, Seattle, WA, 07/24/18.

[6] F. Gonzalez (2018, Jun. 29), *RE: 18026 Z-Drive ferry switchboard room arrangement / questions,* email: felixgonzalez@epdltd.com, 06/29/18.

[7] Ramme Electric Machines GMBH, "Techniche Datanblatt/Technical Data sheet SW500_S_250_1241_B," Osterweick, Germany, 07/24/18.

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

GENERATOR COOLING PIPE-FLO MODEL



List Report

File Name:	18026-200-505-0-APPA-Pump Curves.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	<Design Case>	**Laminar Cutoff Re:**	2100	**Project:**	18026
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	NJB
Version:	16.1.41643	**Percent Tolerance:**	0.01	**Date:**	Friday, August 10, 2018 09:34 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
Cu-Ni 90-10 CL200	Copper Nickel MIL-T-16420K	6E-05 in	0.0	Min:	ft/s	psi g	
standard	Schedule:Class 200	150		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)
Seawater 85F	85 °F	Liquid	63.8 lb/ft³	0.5846 psi a	–
Seawater 3.5% Salinity	0 psi g	29	0.871 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
CAT C18 Aux. SW Pump	2160 rpm	5.5 ft	5.5 ft	27.68 ft	74.18 gpm	–	19.15 ft	–
Fixed Speed @2160 rpm	2160 rpm	-5.627 psi g	6.636 psi g	12.26 psi	–	– %	–	

Company: CAT
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
Common OVBD	4 in	Engine SW Suction2	157.2 gpm	3.333 psi g	3.333 psi	0 psi g	0.01607
Cu-Ni 90-10 CL200	4.282 in	1.75 ft	3.502 ft/s	3.248 psi g		-0.08443 psi g	3.34
Seawater 85F	15 ft	OVBD1	136200	9.273 ft	0.7729 ft	8.5 ft	0.2822 psi
		8.5 ft	0.01697	9.082 ft		8.309 ft	0.6369 ft
Crossover	5 in	Duplex Strainer 2	–	–	–	–	–
Cu-Ni 90-10 CL200	5.312 in	1.75 ft	–	–		–	3.18
Seawater 85F	20 ft	Node 1	–	–	–	–	–
		2.5 ft	–	–		–	–
Crossover 2	5 in	Node 1	96 gpm	-3.229 psi g	2.949E-03 psi	-3.232 psi g	0.01533
Cu-Ni 90-10 CL200	5.312 in	2.5 ft	1.39 ft/s	-3.242 psi g		-3.245 psi g	0.00
Seawater 85F	5 ft	5" Duplex Strainer 1	67055	-4.788 ft	6.656E-03 ft	-4.795 ft	0 psi
		2.5 ft	0.01963	-4.818 ft		-4.825 ft	0 ft
Messages: Reversed flow							
Crossover 3	5 in	5" Duplex Strainer 1	253.2 gpm	-3.212 psi g	0.01683 psi	-3.229 psi g	0.01533
Cu-Ni 90-10 CL200	5.312 in	2.5 ft	3.665 ft/s	-3.304 psi g		-3.321 psi g	0.00
Seawater 85F	5 ft	5" Duplex Strainer 2	176845	-4.75 ft	0.03798 ft	-4.788 ft	0 psi
		2.5 ft	0.01611	-4.959 ft		-4.997 ft	0 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
Crossover 4 Cu-Ni 90-10 CL200 Seawater 85F	5 in 5.312 in 25 ft	Duplex Strainer 1.75 ft 5" Duplex Strainer 2 2.5 ft	653.2 gpm 9.456 ft/s 456241 0.01353	-0.4497 psi g -1.065 psi g 0.735 ft -0.6546 ft	2.762 psi 5.485 ft	-3.212 psi g -3.828 psi g -4.75 ft -6.139 ft	0.01533 3.18 1.959 psi 4.423 ft
Crossover 5 Cu-Ni 90-10 CL200 Seawater 85F	5 in 5.312 in 1.5 ft	Sea ChestA 2.5 ft Duplex Strainer 2.5 ft	653.2 gpm 9.456 ft/s 456241 0.01353	1.994 psi g 1.378 psi g 7 ft 5.61 ft	0.4115 psi 0.9289 ft	1.582 psi g 0.9665 psi g 6.071 ft 4.681 ft	0.01533 0.62 0.3833 psi 0.8652 ft
Engine SW Suction1 Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 12 ft	5" Duplex Strainer 1 2.5 ft CAT C18 Aux. SW Pump 5.5 ft	74.18 gpm 6.21 ft/s 124602 0.01736	-3.229 psi g -3.494 psi g -4.788 ft -5.387 ft	2.399 psi 2.415 ft	-5.627 psi g -5.893 psi g -7.202 ft -7.802 ft	0.01869 2.90 0.7693 psi 1.736 ft
Engine to Cooler10 Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 6 ft	CAT C18 Aux. SW Pump 5.5 ft On-Engine HX 0 ft	74.18 gpm 6.21 ft/s 124602 0.01736	6.636 psi g 6.37 psi g 20.48 ft 19.88 ft	-1.691 psi 1.683 ft	8.327 psi g 8.061 psi g 18.8 ft 18.2 ft	0.01869 2.24 0.5956 psi 1.344 ft
HX to OVBD Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 12 ft	On-Engine HX 0 ft Engine SW Suction2 1.75 ft	74.18 gpm 6.21 ft/s 124602 0.01736	5.327 psi g 5.061 psi g 12.02 ft 11.42 ft	1.994 psi 2.751 ft	3.333 psi g 3.067 psi g 9.273 ft 8.674 ft	0.01869 3.46 0.9182 psi 2.073 ft
Pipe 1 Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 12 ft	5" Duplex Strainer 1 2.5 ft Engine SW Suction 1.75 ft	83 gpm 6.948 ft/s 139412 0.01698	-3.229 psi g -3.561 psi g -4.788 ft -5.538 ft	0.03563 psi 0.8304 ft	-3.264 psi g -3.597 psi g -5.618 ft -6.369 ft	0.01869 0.00 0 psi 0 ft
Pipe 2 Cu-Ni 90-10 CL200 Seawater 85F	4 in 4.282 in 12 ft	5" Duplex Strainer 2 2.5 ft Ballast Suction 1.75 ft	400 gpm 8.912 ft/s 346602 0.01424	-3.212 psi g -3.759 psi g -4.75 ft -5.984 ft	-0.07051 psi 0.5909 ft	-3.141 psi g -3.688 psi g -5.341 ft -6.575 ft	0.01607 0.00 0 psi 0 ft
Pipe 3 Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 12 ft	Engine SW Discharge 1.75 ft Engine SW Suction2 1.75 ft	83 gpm 6.948 ft/s 139412 0.01698	3.701 psi g 3.368 psi g 10.1 ft 9.353 ft	0.3679 psi 0.8304 ft	3.333 psi g 3 psi g 9.273 ft 8.523 ft	0.01869 0.00 0 psi 0 ft
Pipe 4 Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 12 ft	Node 1 2.5 ft Aux SW Suction 1.75 ft	96 gpm 8.037 ft/s 161248 0.01651	-3.232 psi g -3.676 psi g -4.795 ft -5.798 ft	0.1463 psi 1.08 ft	-3.378 psi g -3.823 psi g -5.875 ft -6.879 ft	0.01869 0.00 0 psi 0 ft
Sea Chest Crossover3 Cu-Ni 90-10 CL200 Seawater 85F	5 in 5.312 in 1.5 ft	Sea ChestB 2.5 ft Duplex Strainer 2 2.5 ft	– – – –	– – – –	– –	– – – –	– 0.62 – –

Tanks

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

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Sea ChestA	2.5 ft	0 psi g	7 ft				
Seawater 85F	4.5 ft	1.994 psi g	-653.2 gpm				
Unspecified	–	–					
				Crossover 5	0 ft	653.2 gpm	1.994 psi g
Sea ChestB	2.5 ft	0 psi g	–				
Seawater 85F	4.5 ft	–	–				
Unspecified	–	–					
				Sea Chest Crossover3	0 ft	–	1.994 psi g

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
On-Engine HX	0 ft 8.327 psi g	0 ft 5.327 psi g	3 psi 6.772 ft	74.18 gpm

Curve dP Devices

Curve dP Device Name Description	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Duplex Strainer Miller Lehman Duplex 6"	2.5 ft 1.582 psi g	1.75 ft -0.4497 psi g	2.364 psi 5.336 ft	653.2 gpm
Duplex Strainer 2 Miler Leaman Duplex 6"	2.5 ft –	1.75 ft –	– –	–

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
5" Duplex Strainer 1	2.5 ft	-3.229 psi g	-5.185 ft
5" Duplex Strainer 2	2.5 ft	-3.212 psi g	-5.694 ft
Engine SW Suction2	1.75 ft	3.333 psi g	8.759 ft
Node 1	2.5 ft	-3.232 psi g	-5.311 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
OVBD1	8.5 ft	0 psi g	8.309 ft	157.2 gpm

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Aux SW Suction	1.75 ft	-3.378 psi g	-6.879 ft	96 gpm	Flow out
Ballast Suction	1.75 ft	-3.141 psi g	-6.575 ft	400 gpm	Flow out
Engine SW Discharge	1.75 ft	3.701 psi g	9.353 ft	83 gpm	Flow in
Engine SW Suction	1.75 ft	-3.264 psi g	-6.369 ft	83 gpm	Flow out

Bill of Materials Report

File Name:	18026-200-505-0-APPA-Pump Curves.pipe	**Company:**	EBDG
Lineup:	<Design Case>	**Project:**	18026
Program Name:	PIPE-FLO Professional	**by:**	NJB
Version:	16.1.41643	**Date:**	Friday, August 10, 2018 09:35 AM

Centrifugal Pumps

Centrifugal Pump Name / Operation				
CAT C18 Aux. SW Pump Fixed Speed @2160 rpm	**Company:** CAT **Type:** **Size:** **Curve:** Manual Pump	**Test Speed:** 2160 rpm **Impeller Diameter:** 2 in **POR: from** -- **to** --		

Tanks

Tank Name
Sea ChestA
Sea ChestB

Fixed dP Devices

Fixed dP Device Name	Fixed dP
On-Engine HX	3 psi

Curve dP Devices

Curve dP Device Name	Curve Description
Duplex Strainer	Miller Lehman Duplex 6"
Duplex Strainer 2	Miler Leaman Duplex 6"

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Common OVBD	Cu-Ni 90-10 CL200	4 in	15 ft	1 x Swing Check - Vertical 1 x Gate - Knife 1 x Tee - Flow Thru Branch 3 x Elbow - Standard 90°
Crossover	Cu-Ni 90-10 CL200	5 in	20 ft	1 x Entrance - Sharp Edged 1 x Butterfly 1 x Elbow - Standard 90° 2 x Tee - Flow Thru Run 1 x Tee - Flow Thru Branch
Crossover 2	Cu-Ni 90-10 CL200	5 in	5 ft	
Crossover 3	Cu-Ni 90-10 CL200	5 in	5 ft	
Crossover 4	Cu-Ni 90-10 CL200	5 in	25 ft	1 x Entrance - Sharp Edged 1 x Butterfly 1 x Elbow - Standard 90° 2 x Tee - Flow Thru Run 1 x Tee - Flow Thru Branch
Crossover 5	Cu-Ni 90-10 CL200	5 in	1.5 ft	1 x Entrance - Sharp Edged 1 x Gate - Wedge Disc
Engine SW Suction1	Cu-Ni 90-10 CL200	2 in	12 ft	1 x Swing Check - Vertical 2 x Elbow - Standard 90° 1 x Butterfly
Engine to Cooler10	Cu-Ni 90-10 CL200	2 in	6 ft	6 x Elbow - Short radius, r/d 1 (90°)
HX to OVBD	Cu-Ni 90-10 CL200	2 in	12 ft	1 x Butterfly 3 x Elbow - Standard 90° 1 x Swing Check - Vertical
Pipe 1	Cu-Ni 90-10 CL200	2 in	12 ft	
Pipe 2	Cu-Ni 90-10 CL200	4 in	12 ft	
Pipe 3	Cu-Ni 90-10 CL200	2 in	12 ft	
Pipe 4	Cu-Ni 90-10 CL200	2 in	12 ft	
Sea Chest Crossover3	Cu-Ni 90-10 CL200	5 in	1.5 ft	1 x Entrance - Sharp Edged 1 x Gate - Wedge Disc

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Cu-Ni 90-10 CL200	Copper Nickel MIL-T-16420K Schedule: Class 200	2 in	66.00 ft	2 x Butterfly 6 x Elbow - Short radius, r/d 1 (90°) 5 x Elbow - Standard 90° 2 x Swing Check - Vertical

Pipeline Material Summary				
Specification	**Material**	**Size**	**Total Length**	**Valves & Fittings**
Cu-Ni 90-10 CL200	Copper Nickel MIL-T-16420K Schedule: Class 200	4 in	27.00 ft	3 x Elbow - Standard 90° 1 x Gate - Knife 1 x Swing Check - Vertical 1 x Tee - Flow Thru Branch
Cu-Ni 90-10 CL200	Copper Nickel MIL-T-16420K Schedule: Class 200	5 in	58.00 ft	2 x Butterfly 2 x Elbow - Standard 90° 4 x Entrance - Sharp Edged 2 x Gate - Wedge Disc 2 x Tee - Flow Thru Branch 4 x Tee - Flow Thru Run

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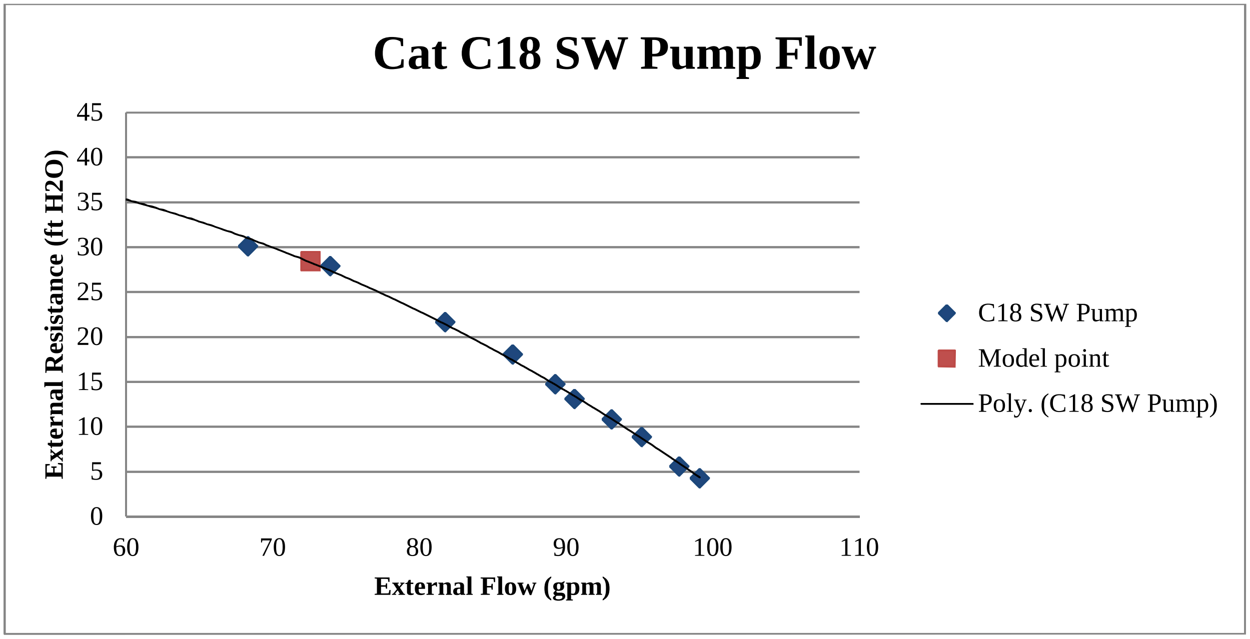
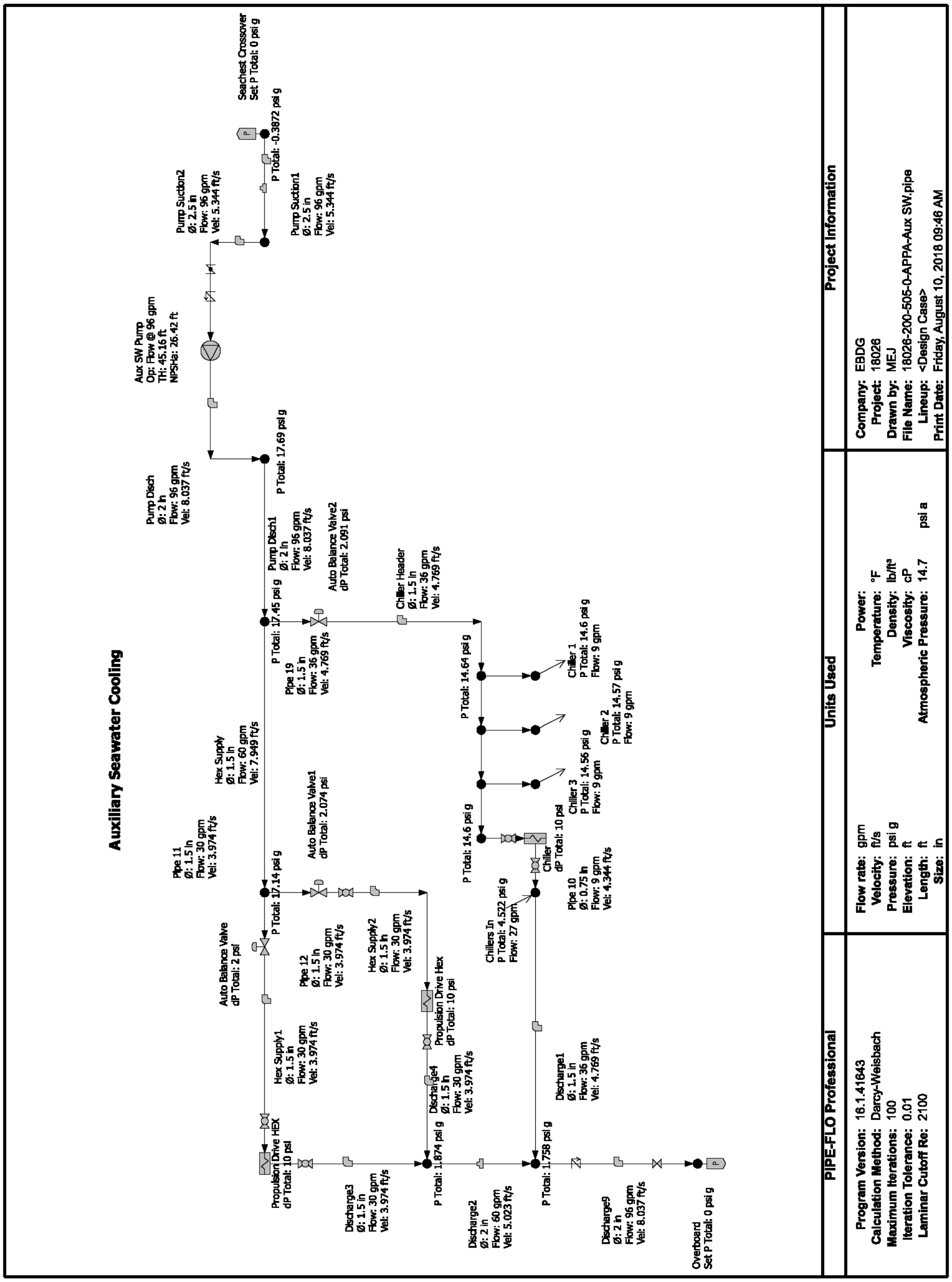
MAIN ENGINE SEA WATER PUMP CURVE



AUXILIARY SEA WATER SYSTEM PIPE-FLO MODEL



List Report

File Name:	18026-200-505-0-APPA-Aux SW.pipe	Calculation Method:	Darcy-Weisbach	Company:	EBDG
Lineup:	<Design Case>	Laminar Cutoff Re:	2100	Project:	18026
Progam Name:	PIPE-FLO Professional	Max Iterations:	100	by:	MEJ
Version:	16.1.41643	Percent Tolerance:	0.01	Date:	Friday, August 10, 2018 09:47 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	 Pressure	 Reynolds Number
Cu-Ni 90-10 CL200 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 85F Seawater 3.5% Salinity	85 °F 0 psi g	Liquid 29	63.8 lb/ft³ 0.871 cP	0.5846 psi a 3199 psi a	– –

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Aux SW Pump	5.5 ft -2.408 psi g	5.5 ft 17.6 psi g	45.16 ft 20.01 psi	96 gpm	26.42 ft

Messages: Calculated results based on minimum or zero dP at Most Hydraulically Remote Loop.

Sizing Control Valves

Sizing Valve Name Operational Mode and Set Point	Flow Coefficient	Elevation	Inlet Pressure Outlet Pressure	dP Head Loss	Flow Rate	Allowable dP min Allowable dP max
Auto Balance Valve FCV @ 30 gpm	21.45 Cv	2.5 ft	17.13 psi g 15.13 psi g	2 psi 4.514 ft	30 gpm	2 –
Messages: This device controls the flow rate in the Most Hydraulically Remote Loop.						
Auto Balance Valve1 FCV @ 30 gpm	21.07 Cv	2.5 ft	17.13 psi g 15.06 psi g	2.074 psi 4.682 ft	30 gpm	2 psi 80 psi
Auto Balance Valve2 FCV @ 36 gpm	25.18 Cv	2.5 ft	17.44 psi g 15.35 psi g	2.091 psi 4.721 ft	36 gpm	2 –

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
Chiller Header Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 10 ft	Auto Balance Valve2 2.5 ft Node 8 3.25 ft	36 gpm 4.769 ft/s 76067 0.01922	15.35 psi g 15.19 psi g 37.15 ft 36.79 ft	0.7111 psi 0.8552 ft	14.64 psi g 14.48 psi g 36.29 ft 35.94 ft	0.01975 1.11 0.1732 psi 0.391 ft
Chiller Header1 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 2 ft	Node 7 3.25 ft Node 6 3.25 ft	18 gpm 2.385 ft/s 38033 0.02233	14.61 psi g 14.57 psi g 36.24 ft 36.15 ft	0.01195 psi 0.02697 ft	14.6 psi g 14.56 psi g 36.21 ft 36.12 ft	0.01975 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
Chiller Header2 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 2 ft	Node 8 3.25 ft Node 7 3.25 ft	27 gpm 3.577 ft/s 57050 0.02042	14.64 psi g 14.55 psi g 36.29 ft 36.09 ft	0.02459 psi 0.05549 ft	14.61 psi g 14.53 psi g 36.24 ft 36.04 ft	0.01975 0.00 0 psi 0 ft
Chiller Header3 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 2 ft	Node 6 3.25 ft Node 1 3.25 ft	9 gpm 1.192 ft/s 19017 0.02628	14.6 psi g 14.59 psi g 36.21 ft 36.19 ft	3.515E-03 psi 7.934E-03 ft	14.6 psi g 14.59 psi g 36.2 ft 36.18 ft	0.01975 0.00 0 psi 0 ft
Discharge1 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 15 ft	Chillers In 3.25 ft Node 4 8.5 ft	36 gpm 4.769 ft/s 76067 0.01922	4.522 psi g 4.365 psi g 13.46 ft 13.1 ft	2.764 psi 0.9895 ft	1.758 psi g 1.601 psi g 12.47 ft 12.11 ft	0.01975 0.83 0.1299 psi 0.2933 ft
Discharge2 Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 3 ft	Node 3 8.5 ft Node 4 8.5 ft	60 gpm 5.023 ft/s 100780 0.01811	1.874 psi g 1.7 psi g 12.73 ft 12.34 ft	0.1162 psi 0.2623 ft	1.758 psi g 1.584 psi g 12.47 ft 12.08 ft	0.01869 0.37 0.06494 psi 0.1466 ft
Discharge3 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 15 ft	Propulsion Drive HEX 6 ft Node 3 8.5 ft	30 gpm 3.974 ft/s 63389 0.01997	3.313 psi g 3.205 psi g 13.48 ft 13.23 ft	1.439 psi 0.7493 ft	1.874 psi g 1.765 psi g 12.73 ft 12.48 ft	0.01975 1.01 0.1094 psi 0.2469 ft
Discharge4 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 10 ft	Propulsion Drive Hex 6 ft Node 3 8.5 ft	30 gpm 3.974 ft/s 63389 0.01997	3.239 psi g 3.13 psi g 13.31 ft 13.07 ft	1.365 psi 0.5818 ft	1.874 psi g 1.765 psi g 12.73 ft 12.48 ft	0.01975 1.01 0.1094 psi 0.2469 ft
Discharge9 Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 15 ft	Node 4 8.5 ft Overboard 8.5 ft	96 gpm 8.037 ft/s 161248 0.01651	1.758 psi g 1.313 psi g 12.47 ft 11.46 ft	1.758 psi 3.968 ft	0 psi g -0.4447 psi g 8.5 ft 7.496 ft	0.01869 2.61 1.159 psi 2.617 ft
Hex Supply Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 6 ft	Node 2 2.5 ft Node 5 2.5 ft	60 gpm 7.949 ft/s 126778 0.01734	17.45 psi g 17.02 psi g 41.89 ft 40.91 ft	0.3093 psi 0.6981 ft	17.14 psi g 16.71 psi g 41.19 ft 40.21 ft	0.01975 0.00 0 psi 0 ft
Hex Supply1 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 10 ft	Auto Balance Valve 2.5 ft Propulsion Drive HEX 3 ft	30 gpm 3.974 ft/s 63389 0.01997	15.13 psi g 15.03 psi g 36.66 ft 36.42 ft	0.4915 psi 0.6094 ft	14.64 psi g 14.53 psi g 36.05 ft 35.81 ft	0.01975 1.12 0.1216 psi 0.2745 ft
Hex Supply2 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 10 ft	Auto Balance Valve1 2.5 ft Propulsion Drive Hex 3 ft	30 gpm 3.974 ft/s 63389 0.01997	15.06 psi g 14.95 psi g 36.49 ft 36.25 ft	0.4915 psi 0.6094 ft	14.57 psi g 14.46 psi g 35.88 ft 35.64 ft	0.01975 1.12 0.1216 psi 0.2745 ft
Pipe 10 Cu-Ni 90-10 CL200 Seawater 85F	0.75 in 0.92 in 0.5 ft	Chiller 3.25 ft Chillers In 3.25 ft	9 gpm 4.344 ft/s 36297 0.02266	4.55 psi g 4.42 psi g 13.52 ft 13.23 ft	0.02827 psi 0.06381 ft	4.522 psi g 4.392 psi g 13.46 ft 13.16 ft	0.02328 0.07 9.074E-03 psi 0.02048 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 11 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 0.5 ft	Node 5 2.5 ft Auto Balance Valve 2.5 ft	30 gpm 3.974 ft/s 63389 0.01997	17.14 psi g 17.03 psi g 41.19 ft 40.95 ft	7.419E-03 psi 0.01675 ft	17.13 psi g 17.03 psi g 41.18 ft 40.93 ft	0.01975 0.00 0 psi 0 ft
Pipe 12 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 0.5 ft	Node 5 2.5 ft Auto Balance Valve1 2.5 ft	30 gpm 3.974 ft/s 63389 0.01997	17.14 psi g 17.03 psi g 41.19 ft 40.95 ft	7.419E-03 psi 0.01675 ft	17.13 psi g 17.03 psi g 41.18 ft 40.93 ft	0.01975 0.00 0 psi 0 ft
Pipe 15 Cu-Ni 90-10 CL200 Seawater 85F	0.75 in 0.92 in 1 ft	Node 1 3.25 ft Chiller 3.25 ft	9 gpm 4.344 ft/s 36297 0.02266	14.6 psi g 14.47 psi g 36.2 ft 35.91 ft	0.04747 psi 0.1071 ft	14.55 psi g 14.42 psi g 36.09 ft 35.8 ft	0.02328 0.07 9.074E-03 psi 0.02048 ft
Pipe 16 Cu-Ni 90-10 CL200 Seawater 85F	0.75 in 0.92 in 1 ft	Node 6 3.25 ft Chiller 3 3.25 ft	9 gpm 4.344 ft/s 36297 0.02266	14.6 psi g 14.47 psi g 36.21 ft 35.91 ft	0.03839 psi 0.08666 ft	14.56 psi g 14.43 psi g 36.12 ft 35.83 ft	0.02328 0.00 0 psi 0 ft
Pipe 17 Cu-Ni 90-10 CL200 Seawater 85F	0.75 in 0.92 in 1 ft	Node 7 3.25 ft Chiller 2 3.25 ft	9 gpm 4.344 ft/s 36297 0.02266	14.61 psi g 14.48 psi g 36.24 ft 35.94 ft	0.03839 psi 0.08666 ft	14.57 psi g 14.44 psi g 36.15 ft 35.86 ft	0.02328 0.00 0 psi 0 ft
Pipe 18 Cu-Ni 90-10 CL200 Seawater 85F	0.75 in 0.92 in 1 ft	Node 8 3.25 ft Chiller 1 3.25 ft	9 gpm 4.344 ft/s 36297 0.02266	14.64 psi g 14.51 psi g 36.29 ft 36 ft	0.03839 psi 0.08666 ft	14.6 psi g 14.47 psi g 36.2 ft 35.91 ft	0.02328 0.00 0 psi 0 ft
Pipe 19 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 0.5 ft	Node 2 2.5 ft Auto Balance Valve2 2.5 ft	36 gpm 4.769 ft/s 76067 0.01922	17.45 psi g 17.29 psi g 41.89 ft 41.54 ft	0.01028 psi 0.02321 ft	17.44 psi g 17.28 psi g 41.87 ft 41.51 ft	0.01975 0.00 0 psi 0 ft
Pump Disch Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 6 ft	Aux SW Pump 5.5 ft On-Engine HX 2.5 ft	96 gpm 8.037 ft/s 161248 0.01651	17.6 psi g 17.15 psi g 45.22 ft 44.22 ft	-0.09237 psi 2.792 ft	17.69 psi g 17.25 psi g 42.43 ft 41.43 ft	0.01869 2.24 0.9974 psi 2.251 ft
Pump Disch1 Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 6 ft	On-Engine HX 2.5 ft Node 2 2.5 ft	96 gpm 8.037 ft/s 161248 0.01651	17.69 psi g 17.25 psi g 42.43 ft 41.43 ft	0.2393 psi 0.5401 ft	17.45 psi g 17.01 psi g 41.89 ft 40.89 ft	0.01869 0.00 0 psi 0 ft
Pump Suction1 Cu-Ni 90-10 CL200 Seawater 85F	2.5 in 2.709 in 2 ft	Seachest Crossover 2.5 ft Pressure Boundary 1 2.5 ft	96 gpm 5.344 ft/s 131486 0.01714	0 psi g -0.1966 psi g 2.5 ft 2.056 ft	0.3872 psi 0.8739 ft	-0.3872 psi g -0.5838 psi g 1.626 ft 1.182 ft	0.01782 1.82 0.3573 psi 0.8065 ft
Pump Suction2 Cu-Ni 90-10 CL200 Seawater 85F	2.5 in 2.709 in 5 ft	Pressure Boundary 1 2.5 ft Aux SW Pump 5.5 ft	96 gpm 5.344 ft/s 131486 0.01714	-0.3872 psi g -0.5838 psi g 1.626 ft 1.182 ft	2.021 psi 1.562 ft	-2.408 psi g -2.605 psi g 0.06384 ft -0.3799 ft	0.01782 3.14 0.6175 psi 1.394 ft

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Chiller	3.25 ft 14.55 psi g	3.25 ft 4.55 psi g	10 psi 22.57 ft	9 gpm
Propulsion Drive HEX	3 ft 14.64 psi g	6 ft 3.313 psi g	10 psi 22.57 ft	30 gpm
Propulsion Drive Hex	3 ft 14.57 psi g	6 ft 3.239 psi g	10 psi 22.57 ft	30 gpm

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	3.25 ft	14.6 psi g	36.04 ft
Node 2	2.5 ft	17.45 psi g	41.11 ft
Node 3	8.5 ft	1.874 psi g	12.44 ft
Node 4	8.5 ft	1.758 psi g	11.88 ft
Node 5	2.5 ft	17.14 psi g	40.7 ft
Node 6	3.25 ft	14.6 psi g	36.07 ft
Node 7	3.25 ft	14.61 psi g	36.04 ft
Node 8	3.25 ft	14.64 psi g	36.01 ft
On-Engine HX	2.5 ft	17.69 psi g	41.43 ft
Pressure Boundary 1	2.5 ft	-0.3872 psi g	1.182 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Overboard	8.5 ft	0 psi g	7.496 ft	96 gpm
Seachest Crossover	2.5 ft	0 psi g	2.056 ft	96 gpm

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Chiller 1	3.25 ft	14.6 psi g	35.91 ft	9 gpm	Flow out
Chiller 2	3.25 ft	14.57 psi g	35.86 ft	9 gpm	Flow out
Chiller 3	3.25 ft	14.56 psi g	35.83 ft	9 gpm	Flow out
Chillers In	3.25 ft	4.522 psi g	13.13 ft	27 gpm	Flow in

Bill of Materials Report

File Name:	18026-200-505-0-APPA-Aux SW.pipe	**Company:**	EBDG
Lineup:	<Design Case>	**Project:**	18026
Program Name:	PIPE-FLO Professional	**by:**	MEJ
Version:	16.1.41643	**Date:**	Friday, August 10, 2018 09:47 AM

Sizing Pumps

Sizing Pump Name / Operation	Design Point Flow Rate	Design Point Total Head
Aux SW Pump Flow @ 96 gpm	96 gpm	45.16 ft

Sizing Valves

Sizing Valve Name	Operation	Flow	dP	Sizing Flow Coefficient
Auto Balance Valve	FCV @ 30 gpm	30 gpm	2 psi	21.45 Cv
Auto Balance Valve1	FCV @ 30 gpm	30 gpm	2.074 psi	21.07 Cv
Auto Balance Valve2	FCV @ 36 gpm	36 gpm	2.091 psi	25.18 Cv

Fixed dP Devices

Fixed dP Device Name	Fixed dP
Chiller	10 psi
Propulsion Drive HEX	10 psi
Propulsion Drive Hex	10 psi

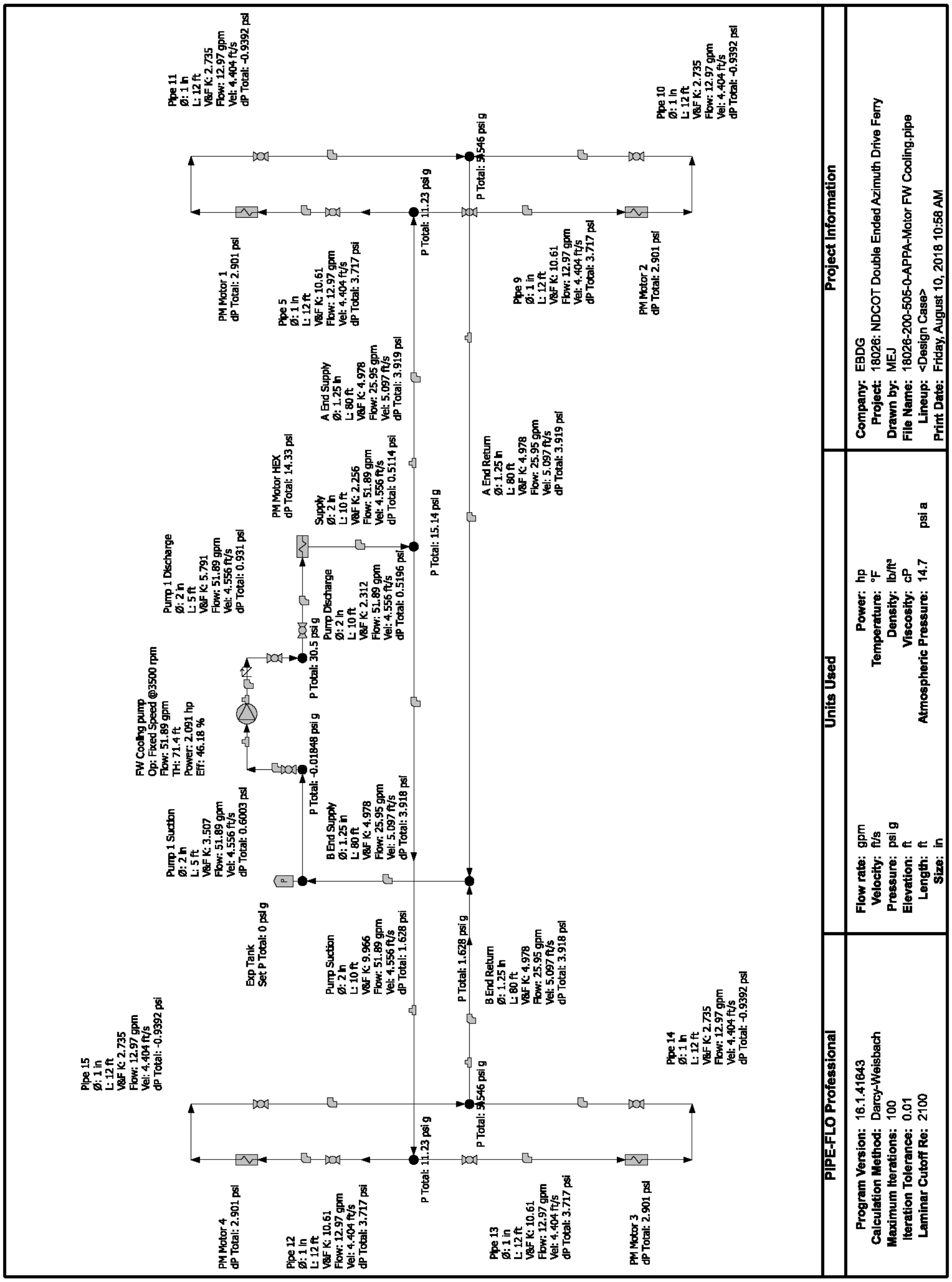
Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Chiller Header	Cu-Ni 90-10 CL200	1.5 in	10 ft	4 x Elbow - Long radius, r/d 1.5 (90°)
Chiller Header1	Cu-Ni 90-10 CL200	1.5 in	2 ft	
Chiller Header2	Cu-Ni 90-10 CL200	1.5 in	2 ft	
Chiller Header3	Cu-Ni 90-10 CL200	1.5 in	2 ft	
Discharge1	Cu-Ni 90-10 CL200	1.5 in	15 ft	3 x Elbow - Long radius, r/d 1.5 (90°)
Discharge2	Cu-Ni 90-10 CL200	2 in	3 ft	1 x Tee - Flow Thru Run
Discharge3	Cu-Ni 90-10 CL200	1.5 in	15 ft	3 x Elbow - Long radius, r/d 1.5 (90°) 1 x Ball 1 x Reducer - Enlargement (1.5 in x 1.25 in - 0 in)
Discharge4	Cu-Ni 90-10 CL200	1.5 in	10 ft	3 x Elbow - Long radius, r/d 1.5 (90°) 1 x Ball 1 x Reducer - Enlargement (1.5 in x 1.25 in - 0 in)
Discharge9	Cu-Ni 90-10 CL200	2 in	15 ft	2 x Pipe Bend - r/d 1.5 (90°) 1 x Swing Check - Vertical 1 x Gate - Wedge Disc 1 x Exit - Projecting
Hex Supply	Cu-Ni 90-10 CL200	1.5 in	6 ft	
Hex Supply1	Cu-Ni 90-10 CL200	1.5 in	10 ft	1 x Reducer - Contraction (1.5 in x 1.25 in - 0 in) 3 x Elbow - Long radius, r/d 1.5 (90°) 1 x Ball
Hex Supply2	Cu-Ni 90-10 CL200	1.5 in	10 ft	3 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Contraction (1.5 in x 1.25 in - 0 in) 1 x Ball
Pipe 10	Cu-Ni 90-10 CL200	0.75 in	0.5 ft	1 x Ball
Pipe 11	Cu-Ni 90-10 CL200	1.5 in	0.5 ft	
Pipe 12	Cu-Ni 90-10 CL200	1.5 in	0.5 ft	
Pipe 15	Cu-Ni 90-10 CL200	0.75 in	1 ft	1 x Ball
Pipe 16	Cu-Ni 90-10 CL200	0.75 in	1 ft	
Pipe 17	Cu-Ni 90-10 CL200	0.75 in	1 ft	
Pipe 18	Cu-Ni 90-10 CL200	0.75 in	1 ft	
Pipe 19	Cu-Ni 90-10 CL200	1.5 in	0.5 ft	
Pump Disch	Cu-Ni 90-10 CL200	2 in	6 ft	6 x Elbow - Short radius, r/d 1 (90°)
Pump Disch1	Cu-Ni 90-10 CL200	2 in	6 ft	
Pump Suction1	Cu-Ni 90-10 CL200	2.5 in	2 ft	1 x Tee - Flow Thru Branch 3 x Elbow - Long radius, r/d 1.5 (90°)

Pipelines				
Pipeline	**Specification**	**Size**	**Length**	**Valves and Fittings**
Pump Suction2	Cu-Ni 90-10 CL200	2.5 in	5 ft	1 x Swing Check - Vertical 2 x Elbow - Standard 90° 1 x Butterfly 1 x Reducer - Contraction (2.5 in x 2 in - 0 in)

Pipeline Material Summary				
Specification	**Material**	**Size**	**Total Length**	**Valves & Fittings**
Cu-Ni 90-10 CL200	Copper Nickel MIL-T-16420K Schedule: Class 200	0.75 in	4.50 ft	2 x Ball
Cu-Ni 90-10 CL200	Copper Nickel MIL-T-16420K Schedule: Class 200	1.5 in	83.50 ft	4 x Ball 19 x Elbow - Long radius, r/d 1.5 (90°) 2 x Reducer - Contraction (1.5 in x 1.25 in - 0 in) 2 x Reducer - Enlargement (1.5 in x 1.25 in - 0 in)
Cu-Ni 90-10 CL200	Copper Nickel MIL-T-16420K Schedule: Class 200	2 in	30.00 ft	6 x Elbow - Short radius, r/d 1 (90°) 1 x Exit - Projecting 1 x Gate - Wedge Disc 2 x Pipe Bend - r/d 1.5 (90°) 1 x Swing Check - Vertical 1 x Tee - Flow Thru Run
Cu-Ni 90-10 CL200	Copper Nickel MIL-T-16420K Schedule: Class 200	2.5 in	7.00 ft	1 x Butterfly 3 x Elbow - Long radius, r/d 1.5 (90°) 2 x Elbow - Standard 90° 1 x Reducer - Contraction (2.5 in x 2 in - 0 in) 1 x Swing Check - Vertical 1 x Tee - Flow Thru Branch

FRESHWATER COOLING SYSTEM PIPE-FLO MODEL



List Report

File Name: 18026-200-505-0-APPA-Motor FW Cooling.pipe	**Calculation Method:** Darcy-Weisbach	**Company:** EBDG	
Lineup: <Design Case>	**Laminar Cutoff Re:** 2100	**Project:** 18026: NDCOT Double Ended Azimuth Drive Ferry	
Progam Name: PIPE-FLO Professional	**Max Iterations:** 100	**by:** MEJ	
Version: 16.1.41643	**Percent Tolerance:** 0.01	**Date:** Friday, August 10, 2018 10:58 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
Sch 10 Stainless standard	Stainless A53-B36.19 Schedule:10S	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)
30% Ethylene Glycol 30% Dowtherm SR-1	100.4 °F 10 psi g	Liquid 22.61	64.65 lb/ft³ 1.301 cP	0.8264 psi a 1575 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
FW Cooling pump Fixed Speed @3500 rpm	3500 rpm 3500 rpm	0 ft -0.6187 psi g	0 ft 31.44 psi g	71.4 ft 32.05 psi	51.89 gpm 2.091 hp	46.18 % 47 %	29.52 ft 10 ft	–

Company: Ampco Pumps   Size: 1.5x1.25SS
Curve: Catalog Pump   Diameter: 4.75 in
Type: Z-SERIES   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
A End Return Sch 10 Stainless 30% Ethylene Glycol	1.25 in 1.442 in 80 ft	Node 5 0 ft Pressure Boundary 2 0 ft	25.95 gpm 5.097 ft/s 45301 0.025	5.546 psi g 5.365 psi g 12.35 ft 11.95 ft	3.919 psi 8.729 ft	1.628 psi g 1.447 psi g 3.626 ft 3.223 ft	0.02074 4.98 0.9022 psi 2.01 ft
A End Supply Sch 10 Stainless 30% Ethylene Glycol	1.25 in 1.442 in 80 ft	PM Motor HEX1 0 ft Node 2 0 ft	25.95 gpm 5.097 ft/s 45301 0.025	15.14 psi g 14.96 psi g 33.73 ft 33.33 ft	3.919 psi 8.729 ft	11.23 psi g 11.04 psi g 25 ft 24.6 ft	0.02074 4.98 0.9022 psi 2.01 ft
B End Return Sch 10 Stainless 30% Ethylene Glycol	1.25 in 1.442 in 80 ft	Node 7 0 ft Pressure Boundary 2 0 ft	25.95 gpm 5.097 ft/s 45301 0.025	5.546 psi g 5.365 psi g 12.35 ft 11.95 ft	3.918 psi 8.728 ft	1.628 psi g 1.447 psi g 3.626 ft 3.223 ft	0.02074 4.98 0.9022 psi 2.01 ft
B End Supply Sch 10 Stainless 30% Ethylene Glycol	1.25 in 1.442 in 80 ft	PM Motor HEX1 0 ft Node 6 0 ft	25.95 gpm 5.097 ft/s 45301 0.025	15.14 psi g 14.96 psi g 33.73 ft 33.33 ft	3.918 psi 8.728 ft	11.23 psi g 11.04 psi g 25 ft 24.6 ft	0.02074 4.98 0.9022 psi 2.01 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 10 Sch 10 Stainless 30% Ethylene Glycol	1 in 1.097 in 12 ft	PM Motor 2 4 ft Node 5 0 ft	12.97 gpm 4.404 ft/s 29774 0.02739	4.607 psi g 4.472 psi g 14.26 ft 13.96 ft	-0.9392 psi 1.908 ft	5.546 psi g 5.411 psi g 12.35 ft 12.05 ft	0.02224 2.73 0.37 psi 0.8242 ft
Pipe 11 Sch 10 Stainless 30% Ethylene Glycol	1 in 1.097 in 12 ft	PM Motor 1 4 ft Node 5 0 ft	12.97 gpm 4.404 ft/s 29774 0.02739	4.607 psi g 4.472 psi g 14.26 ft 13.96 ft	-0.9392 psi 1.908 ft	5.546 psi g 5.411 psi g 12.35 ft 12.05 ft	0.02224 2.73 0.37 psi 0.8242 ft
Pipe 12 Sch 10 Stainless 30% Ethylene Glycol	1 in 1.097 in 12 ft	Node 6 0 ft PM Motor 4 4 ft	12.97 gpm 4.404 ft/s 29774 0.02739	11.23 psi g 11.09 psi g 25 ft 24.7 ft	3.717 psi 4.28 ft	7.508 psi g 7.373 psi g 20.72 ft 20.42 ft	0.02224 10.61 1.435 psi 3.196 ft
Pipe 13 Sch 10 Stainless 30% Ethylene Glycol	1 in 1.097 in 12 ft	Node 6 0 ft PM Motor 3 4 ft	12.97 gpm 4.404 ft/s 29774 0.02739	11.23 psi g 11.09 psi g 25 ft 24.7 ft	3.717 psi 4.28 ft	7.508 psi g 7.373 psi g 20.72 ft 20.42 ft	0.02224 10.61 1.435 psi 3.196 ft
Pipe 14 Sch 10 Stainless 30% Ethylene Glycol	1 in 1.097 in 12 ft	PM Motor 3 4 ft Node 7 0 ft	12.97 gpm 4.404 ft/s 29774 0.02739	4.607 psi g 4.472 psi g 14.26 ft 13.96 ft	-0.9392 psi 1.908 ft	5.546 psi g 5.411 psi g 12.35 ft 12.05 ft	0.02224 2.73 0.37 psi 0.8242 ft
Pipe 15 Sch 10 Stainless 30% Ethylene Glycol	1 in 1.097 in 12 ft	PM Motor 4 4 ft Node 7 0 ft	12.97 gpm 4.404 ft/s 29774 0.02739	4.607 psi g 4.472 psi g 14.26 ft 13.96 ft	-0.9392 psi 1.908 ft	5.546 psi g 5.411 psi g 12.35 ft 12.05 ft	0.02224 2.73 0.37 psi 0.8242 ft
Pipe 17 Sch 10 Stainless 30% Ethylene Glycol	2 in 2.157 in 1 ft	Exp Tank 0 ft Flow Demand 1 0 ft	51.89 gpm 4.556 ft/s 60570 0.02293	0 psi g -0.1448 psi g 0 ft -0.3226 ft	0.01848 psi 0.04115 ft	-0.01848 psi g -0.1633 psi g -0.04115 ft -0.3637 ft	0.0188 0.00 0 psi 0 ft
Pipe 5 Sch 10 Stainless 30% Ethylene Glycol	1 in 1.097 in 12 ft	Node 2 0 ft PM Motor 1 4 ft	12.97 gpm 4.404 ft/s 29774 0.02739	11.23 psi g 11.09 psi g 25 ft 24.7 ft	3.717 psi 4.28 ft	7.508 psi g 7.373 psi g 20.72 ft 20.42 ft	0.02224 10.61 1.435 psi 3.196 ft
Pipe 9 Sch 10 Stainless 30% Ethylene Glycol	1 in 1.097 in 12 ft	Node 2 0 ft PM Motor 2 4 ft	12.97 gpm 4.404 ft/s 29774 0.02739	11.23 psi g 11.09 psi g 25 ft 24.7 ft	3.717 psi 4.28 ft	7.508 psi g 7.373 psi g 20.72 ft 20.42 ft	0.02224 10.61 1.435 psi 3.196 ft
Pump 1 Discharge Sch 10 Stainless 30% Ethylene Glycol	2 in 2.157 in 5 ft	FW Cooling pump 0 ft Node 1 0 ft	51.89 gpm 4.556 ft/s 60570 0.02293	31.44 psi g 31.29 psi g 70.02 ft 69.7 ft	0.931 psi 2.074 ft	30.5 psi g 30.36 psi g 67.95 ft 67.63 ft	0.0188 5.79 0.8386 psi 1.868 ft
Pump 1 Suction Sch 10 Stainless 30% Ethylene Glycol	2 in 2.157 in 5 ft	Flow Demand 1 0 ft FW Cooling pump 0 ft	51.89 gpm 4.556 ft/s 60570 0.02293	-0.01848 psi g -0.1633 psi g -0.04115 ft -0.3637 ft	0.6003 psi 1.337 ft	-0.6187 psi g -0.7635 psi g -1.378 ft -1.701 ft	0.0188 3.51 0.5079 psi 1.131 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
Pump Discharge Sch 10 Stainless 30% Ethylene Glycol	2 in 2.157 in 10 ft	Node 1 0 ft PM Motor HEX 0 ft	51.89 gpm 4.556 ft/s 60570 0.02293	30.5 psi g 30.36 psi g 67.95 ft 67.63 ft	0.5196 psi 1.157 ft	29.98 psi g 29.84 psi g 66.79 ft 66.47 ft	0.0188 2.31 0.3348 psi 0.7459 ft
Pump Suction Sch 10 Stainless 30% Ethylene Glycol	2 in 2.157 in 10 ft	Pressure Boundary 2 0 ft Exp Tank 0 ft	51.89 gpm 4.556 ft/s 60570 0.02293	1.628 psi g 1.483 psi g 3.626 ft 3.304 ft	1.628 psi 3.626 ft	0 psi g -0.1448 psi g 0 ft -0.3226 ft	0.0188 9.97 1.443 psi 3.215 ft
Supply Sch 10 Stainless 30% Ethylene Glycol	2 in 2.157 in 10 ft	PM Motor HEX 0 ft PM Motor HEX1 0 ft	51.89 gpm 4.556 ft/s 60570 0.02293	15.65 psi g 15.51 psi g 34.87 ft 34.55 ft	0.5114 psi 1.139 ft	15.14 psi g 15 psi g 33.73 ft 33.41 ft	0.0188 2.26 0.3267 psi 0.7277 ft

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
PM Motor 1	4 ft 7.508 psi g	4 ft 4.607 psi g	2.901 psi 6.461 ft	12.97 gpm
PM Motor 2	4 ft 7.508 psi g	4 ft 4.607 psi g	2.901 psi 6.461 ft	12.97 gpm
PM Motor 3	4 ft 7.508 psi g	4 ft 4.607 psi g	2.901 psi 6.461 ft	12.97 gpm
PM Motor 4	4 ft 7.508 psi g	4 ft 4.607 psi g	2.901 psi 6.461 ft	12.97 gpm
PM Motor HEX	0 ft 29.98 psi g	0 ft 15.65 psi g	14.33 psi 31.92 ft	51.89 gpm

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Flow Demand 1	0 ft	-0.01848 psi g	-0.3637 ft
Node 1	0 ft	30.5 psi g	67.63 ft
Node 2	0 ft	11.23 psi g	24.67 ft
Node 5	0 ft	5.546 psi g	12.02 ft
Node 6	0 ft	11.23 psi g	24.67 ft
Node 7	0 ft	5.546 psi g	12.02 ft
PM Motor HEX1	0 ft	15.14 psi g	33.36 ft
Pressure Boundary 2	0 ft	1.628 psi g	3.25 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Exp Tank	0 ft	0 psi g	-0.3226 ft	51.89 gpm

PIPE-FLO Professional Version: 16.1.41643 List Report Friday, August 10, 2018 10:58 AM Page 3

Bill of Materials Report

File Name: 18026-200-505-0-APPA-Motor FW Cooling.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 16.1.41643
Company: EBDG
Project: 18026: NDCOT Double Ended Azimuth Drive Ferry
by: MEJ
Date: Friday, August 10, 2018 10:58 AM

Centrifugal Pumps

Centrifugal Pump Name / Operation				
FW Cooling pump Fixed Speed @3500 rpm	**Company:** Ampco Pumps **Type:** Z-SERIES **Size:** 1.5x1.25SS **Curve:** Catalog Pump	**Test Speed:** 3500 rpm **Impeller Diameter:** 4.75 in **POR: from** --	**to** --	

Fixed dP Devices

Fixed dP Device Name	Fixed dP
PM Motor 1	2.901 psi
PM Motor 2	2.901 psi
PM Motor 3	2.901 psi
PM Motor 4	2.901 psi
PM Motor HEX	14.33 psi

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
A End Return	Sch 10 Stainless	1.25 in	80 ft	6 x Elbow - Standard 90° 1 x Tee - Flow Thru Branch
A End Supply	Sch 10 Stainless	1.25 in	80 ft	6 x Elbow - Standard 90° 1 x Tee - Flow Thru Branch
B End Return	Sch 10 Stainless	1.25 in	80 ft	6 x Elbow - Standard 90° 1 x Tee - Flow Thru Branch
B End Supply	Sch 10 Stainless	1.25 in	80 ft	6 x Elbow - Standard 90° 1 x Tee - Flow Thru Branch
Pipe 10	Sch 10 Stainless	1 in	12 ft	4 x Elbow - Standard 90° 1 x Ball
Pipe 11	Sch 10 Stainless	1 in	12 ft	4 x Elbow - Standard 90° 1 x Ball
Pipe 12	Sch 10 Stainless	1 in	12 ft	4 x Elbow - Standard 90° 1 x Ball 1 x 3-way ball valve
Pipe 13	Sch 10 Stainless	1 in	12 ft	4 x Elbow - Standard 90° 1 x Ball 1 x 3-way ball valve
Pipe 14	Sch 10 Stainless	1 in	12 ft	4 x Elbow - Standard 90° 1 x Ball
Pipe 15	Sch 10 Stainless	1 in	12 ft	4 x Elbow - Standard 90° 1 x Ball
Pipe 17	Sch 10 Stainless	2 in	1 ft	
Pipe 5	Sch 10 Stainless	1 in	12 ft	4 x Elbow - Standard 90° 1 x Ball 1 x 3-way ball valve
Pipe 9	Sch 10 Stainless	1 in	12 ft	4 x Elbow - Standard 90° 1 x Ball 1 x 3-way ball valve
Pump 1 Discharge	Sch 10 Stainless	2 in	5 ft	4 x Elbow - Standard 90° 1 x Ball 1 x Tee - Flow Thru Branch 1 x Swing Check - Angled 1 x Reducer - Enlargement (2 in x 1.25 in - 3 in)
Pump 1 Suction	Sch 10 Stainless	2 in	5 ft	4 x Elbow - Standard 90° 1 x Tee - Flow Thru Branch 1 x Ball 1 x Reducer - Contraction (2 in x 1.5 in - 3 in)
Pump Discharge	Sch 10 Stainless	2 in	10 ft	4 x Elbow - Standard 90° 1 x Ball
Pump Suction	Sch 10 Stainless	2 in	10 ft	4 x Elbow - Standard 90° 1 x Air Separator

Pipelines				
Pipeline	**Specification**	**Size**	**Length**	**Valves and Fittings**
Supply	Sch 10 Stainless	2 in	10 ft	4 x Elbow - Standard 90°

Pipeline Material Summary				
Specification	**Material**	**Size**	**Total Length**	**Valves & Fittings**
Sch 10 Stainless	Stainless A53-B36.19 Schedule: 10S	1 in	96.00 ft	4 x 3-way ball valve 8 x Ball 32 x Elbow - Standard 90°
Sch 10 Stainless	Stainless A53-B36.19 Schedule: 10S	1.25 in	320.00 ft	24 x Elbow - Standard 90° 4 x Tee - Flow Thru Branch
Sch 10 Stainless	Stainless A53-B36.19 Schedule: 10S	2 in	41.00 ft	1 x Air Separator 3 x Ball 20 x Elbow - Standard 90° 1 x Reducer - Contraction (2 in x 1.5 in - 3 in) 1 x Reducer - Enlargement (2 in x 1.25 in - 3 in) 1 x Swing Check - Angled 2 x Tee - Flow Thru Branch

SEA CHEST SIZING

SEA CHEST AREA CHECKS

APPROACH

Calculation of required sea chest cross sectional area per ABS Rules for Building and Classing Steel Vessels, 2018.

ASSUMPTIONS

1) Sea Chest suctions include: 4" sch 80 for Fire Main, 6" sch 80 for SW Cooling
2)
3)

INPUTS Ref 1, 4-6-2/9.13.5

Units Used: US

A_p =	37.56	in2	Total area of pipes taking suction from sea chest
$\%_{fa}$ =	50%		Strainer percent free (clear) area
R_{min}=	1.5		ABS Required strainer clear area to suction area
R=	3		Chosen clear area ratio, not less than R_{min}.

CALCULATION OF SEA CHEST CROSS SECTIONAL AREA

$A_{sc} = A_p * R / \%_{fa}$ Sea chest cross sectional area

A_{sc} = **225.38** in2 Sea chest cross sectional area

$D_{sc} = 2*(A/\pi)^{0.5}$

D_{sc} = **16.94** in Minimum diameter for pipe sea chest

$L_{sc} = A^{0.5}$

L_{sc} = ***15.01*** in Minimum edge length of square sea chest

NOTES

1) Selecting 20" XS pipe for Engine Room Sea Chest => 19" ID

REFERENCES

1) *ABS Rules for Building and Classing Steel Vessels, 2018*
2) *ABS Rules for Building and Classing Steel Vessels under 90 Meters, 2018*

Appendix B

Exhaust System, Dwg. 18026-200-259-1

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 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 Generator exhaust gas characteristics are taken from [1] [2] as follows:

Caterpillar C18, 565 kW at 1800 RPM	
Exhaust Gas Flow Rate at Stack	3,623 ft^3/min
Exhaust Gas Temperature at Stack	709.7 °F
Maximum Allowable Backpressure	40 inches H_2O

- Emergency generator exhaust gas characteristics are taken from [3] 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 [4].
- Selected main generator silencer is a 10 inch Harco 2458VRSA10 with estimated backpressure of 4.5 in H_20. Backpressure estimated with vendor provided calculation tool [5].
- Selected emergency generator silencer is a 4 inch Harco VRS-4 SISO with estimated backpressure of 9.8 in H_20. Backpressure estimated with vendor provided calculation tool [5]. 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 1 inH20 based on vendor guidance.

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Main generator Exhaust Piping ΔP Calculation

As shown in the attached PIPE-FLO results, the estimated main engine exhaust piping backpressure is approximately 29.4 in H_2O, 74% of the stated vendor maximum design value.

5.2 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 [3].

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 13.6 in H_2O, 23% of the stated vendor maximum.

6 VENDOR DATA

The following vendor provided data was used in the calculations

6.1 CAT C18 Generator rated 565 kW at 1,800 RPM

From [2]:

General Performance Data Top

GENSET POWER WITHOUT FAN	PERCENT LOAD	ENGINE POWER	BRAKE MEAN EFF PRES (BMEP)	BRAKE SPEC FUEL CONSUMPTN (BSFC)	VOL FUEL CONSUMPTN (VFC)	INLET MFLD PRES	INLET MFLD TEMP	EXH MFLD TEMP	EXH MFLD PRES	ENGINE OUTLET TEMP
EKW	%	BHP	PSI	LB/BHP-HR	GAL/HR	IN-HG	DEG F	DEG F	IN-HG	DEG F
621.5	110	884	351	0.347	43.8	81.4	149.0	1,208.6	80.2	734.6
565.0	100	803	320	0.350	40.1	77.1	146.5	1,159.8	74.9	709.7
508.5	90	723	287	0.351	36.2	71.6	143.7	1,107.4	68.5	680.7
452.0	80	642	255	0.356	32.7	66.3	140.9	1,063.4	62.4	657.1
423.8	75	602	239	0.349	30.0	59.7	138.1	1,026.3	55.3	638.6
395.5	70	562	224	0.341	27.4	53.4	135.5	993.2	48.7	622.6
339.0	60	482	192	0.348	24.0	46.0	133.0	959.9	41.7	608.9
282.5	50	402	160	0.364	20.9	39.8	131.3	932.0	36.2	599.0
226.0	40	322	128	0.376	17.3	30.9	129.3	891.0	28.6	583.2
169.5	30	241	96	0.395	13.6	21.8	127.2	831.6	21.2	555.8
141.2	25	201	80	0.412	11.8	17.8	125.4	789.9	18.1	535.6
113.0	20	161	64	0.436	10.0	14.0	123.0	736.5	15.2	508.9
56.5	10	80.4	32	0.542	6.2	6.9	116.7	574.4	9.9	421.2

GENSET POWER WITHOUT FAN	PERCENT LOAD	ENGINE POWER	COMPRESSOR OUTLET PRES	COMPRESSOR OUTLET TEMP	WET INLET AIR VOL FLOW RATE	ENGINE OUTLET WET EXH GAS VOL FLOW RATE	WET INLET AIR MASS FLOW RATE	WET EXH GAS MASS FLOW RATE	WET EXH VOL FLOW RATE (32 DEG F AND 29.98 IN HG)	DRY EXH VOL FLOW RATE (32 DEG F AND 29.98 IN HG)
EKW	%	BHP	IN-HG	DEG F	CFM	CFM	LB/HR	LB/HR	FT3/MIN	FT3/MIN
621.5	110	884	87	448.5	1,702.6	3,804.1	7,515.5	7,821.9	1,566.1	1,424.4
565.0	100	803	82	430.3	1,654.0	3,622.7	7,277.7	7,558.6	1,523.2	1,391.0
508.5	90	723	77	408.2	1,590.5	3,419.7	6,974.2	7,227.7	1,474.4	1,352.0
452.0	80	642	71	386.7	1,523.5	3,225.0	6,658.8	6,887.7	1,419.9	1,307.0
423.8	75	602	64	362.1	1,428.3	2,997.1	6,220.5	6,430.2	1,341.8	1,237.4
395.5	70	562	57	338.6	1,335.8	2,781.9	5,794.9	5,986.7	1,263.8	1,167.5
339.0	60	482	50	311.6	1,230.7	2,551.3	5,312.9	5,480.7	1,174.0	1,086.2
282.5	50	402	43	288.3	1,137.6	2,351.3	4,895.0	5,041.2	1,092.0	1,013.7
226.0	40	322	34	252.2	999.5	2,053.9	4,284.1	4,405.2	968.3	901.8
169.5	30	241	24	212.0	854.2	1,725.1	3,646.6	3,742.1	835.3	781.0
141.2	25	201	20	192.8	790.3	1,565.4	3,368.2	3,451.2	773.3	725.5
113.0	20	161	16	173.8	729.8	1,402.4	3,106.0	3,176.2	711.9	670.7
56.5	10	80.4	9	136.2	615.6	1,049.4	2,614.4	2,658.1	585.8	558.0

From [1]:

EXHAUST SYSTEM		
THE INSTALLED SYSTEM MUST COMPLY WITH THE SYSTEM LIMITS BELOW FOR ALL EMISSIONS CERTIFIED ENGINES TO ASSURE REGULATORY COMPLIANCE.		
MAXIMUM ALLOWABLE SYSTEM BACK PRESSURE	40	IN-H20
MANIFOLD TYPE	WET	
MAXIMUM ALLOWABLE STATIC WEIGHT ON EXHAUST CONNECTION	5.5	LB

Harco 2458VRSA10 backpressure calculated using [5]:

CALCULATION OF BACK PRESSURE OF SILENCER

Item #	Silencer Model	Name of Model	Item #	Silencer Model	Name of Model
1	SFH	Super Critical Grade	10	RFH	Residential Grade
2	LPRS	Super Critical Grade	11	RSL	Residential Grade
3	SCSC	Super Critical Grade	12	IRTS	Residential Grade
4	VCS	Super Critical Grade	13	SASR	Residential Grade S.A.
5	VRS	Critical Grade	14	RSL	Residential Grade S.A.
6	CFHI	Critical Grade	15	VRSA	Critical Grade S. A.
7	CSCS	Critical grade	16	VCSA	Super Critical Grade S. A.
8	CFH	Critical grade	17	M	Industrial Grade
9	HCY	Critical Grade	18	EXT	Extreme grade

Choose Silencer model	VRSA	***MODEL***
Introduce Exhaust CFM	3623	
Introduce Diameter of Outlet (in)	10	
Introduce Temp. (F)	709.7	
Introduce Max. BP of Engine	40	
Inlet/Outlet Configuration		
(FOR TUBULAR SILENCERS ONLY)	END IN-END OUT	

Introduce Lbs/Hr	
or Kg/s	
Introduce Temp. (C)	
Introduce BP of Piping & Elbows	

$$ACFM = \frac{ExhaustTemp. + 460}{2275} x \frac{Lbs}{Hr}$$

$$TempF = 9x\frac{C}{5} + 32$$

$$1\frac{Lbs}{Hr} = 7936.56x1\frac{Kg}{Second}$$

Calculate Outlet Flow Area

$$Flow\,Area\,(ft)^2 = \frac{\pi x(0.08333xdiameter)^2}{4} = 0.7854xd^2x0.0069444 = 0.005454xd^2$$

Outlet Flow Area	0.545
Temp (F)	709.7
CFM	3623

Calculate Velocity ft/min (V) 0

6643

OK

Calculate Back Pressure (in H2O)

$$P = cx\frac{V^2}{4005^2}x\frac{530}{(T+460)} =$$

4.5

OK

Note: Exhaust Velocity should not exceed 9000 ft/min on all Critical and Super Critical applications and velocity should not exceed 12000 ft/min for the rest of the applications

6.2 CAT C4.4 Generator rated 66 kW at 1,800 RPM

From [3]:

EXHAUST SYSTEM

Exhaust Gas Data

Exhaust gas flow (total)	10.4 kg/min (105ekW), 9.5kg/min (90 ekW), 8.5kg/min (66 ekW), 7.5kg/min (51 ekW)
Exhaust stack temperature	431° (105 ekW), 419°C (90 ekW), 404°C (66 ekW), 395°C (51 ekW)
Exhaust stack temperature	808°F (105 ekW), 786°F (90 ekW), 7593°F (66 ekW), 743°F (51 ekW)
Engine exhaust connection	63 mm (2.5 in) ID, 6 x 9 mm (0.35 in) holes on 88.9 mm (3.5 in) PCD
Max. allowable system backpressure	15 kPa (60 in H_2O)

Harco 1236 VRS4SI-SO backpressure calculated using [5]:

CALCULATION OF BACK PRESSURE OF SILENCER

Item #	Silencer Model	Name of Model	Item #	Silencer Model	Name of Model
1	SFH	Super Critical Grade	10	RFH	Residential Grade
2	LPRS	Super Critical Grade	11	RSL	Residential Grade
3	SCSC	Super Critical Grade	12	IRTS	Residential Grade
4	VCS	Super Critical Grade	13	SASR	Residential Grade S.A.
5	VRS	Critical Grade	14	RSL	Residential Grade S.A.
6	CFHI	Critical Grade	15	VRSA	Critical Grade S. A.
7	CSCS	Critical grade	16	VCSA	Super Critical Grade S. A.
8	CFH	Critical grade	17	M	Industrial Grade
9	HCY	Critical Grade	18	EXT	Extreme grade

Choose Silencer model	VCS	***MODEL***		
Introduce Exhaust CFM	578			
Introduce Diameter of Outlet (in)	4		*Introduce Lbs/Hr*	
Introduce Temp. (F)	759		*or Kg/s*	0.1417
Introduce Max. BP of Engine	60		*Introduce Temp. (C)*	404
Inlet/Outlet Configuration			*Introduce BP of Piping & Elbows*	
(FOR TUBULAR SILENCERS ONLY)	SIDE IN-SIDE OUT			

$$ACFM = \frac{ExhaustTemp. + 460}{2275} x \frac{Lbs}{Hr}$$

$$TempF = 9x\frac{C}{5} + 32$$

$$1\frac{Lbs}{Hr} = 7936.56x1\frac{Kg}{Second}$$

Calculate Outlet Flow Area

$$Flow\ Area\ (ft)^2 = \frac{\pi x (0.08333xdiameter)^2}{4} = 0.7854xd^2x0.0069444 = 0.005454xd^2$$

Outlet Flow Area	0.087
Temp (F)	759
CFM	578

Calculate Velocity ft/min (V) 5

6624

OK

Calculate Back Pressure (in H2O)

$$P = cx\frac{V^2}{4005^2} x \frac{530}{(T+460)} =$$

9.8

OK

Note: Exhaust Velocity should not exceed 9000 ft/min on all Critical and Super Critical applications and velocity should not exceed 12000 ft/min for the rest of the applications

7 REFERENCES

[1] Caterpillar, "EM4133; C18 565 ekW at 1800 rpm Systems Data," May 24, 2018.

[2] Caterpillar, EM4133; C18 565 ekW at 1800 rpm Performance Data, May 24, 2018.

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

[4] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Exhaust Arrangement; 18026-200-259-1," Seattle, WA.

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

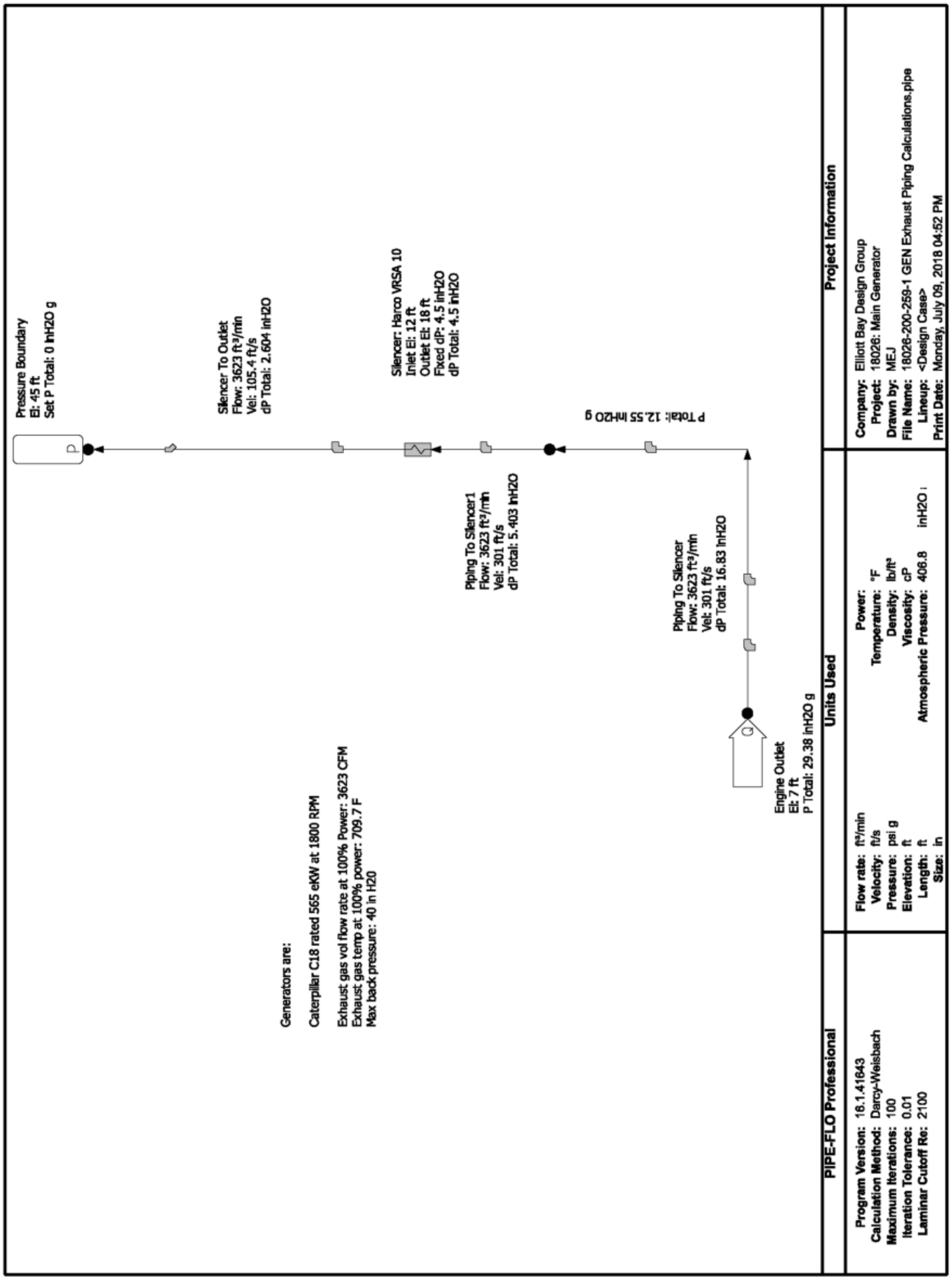
[6] USFS, "Spark Arrester Guide," 2017.

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

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

[9] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Profiles and Arrangements," 18026-200-101-1, Seattle, WA.

MAIN GENERATOR EXHAUST MODEL



List Report

File Name: 18026-200-259-1 GEN Exhaust Piping Calculations.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 16.1.41643

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

Company: Elliott Bay Design Group
Project: 18026: Main Generator
by: MEJ
Date: Monday, July 09, 2018 04:53 PM
Atmospheric Pressure: 406.8 inH2O 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, Sch 10 standard	Steel A53-B36.10 Schedule:10	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	
Steel, Sch 20 standard	Steel A53-B36.10 Schedule:20	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	
Steel, 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)
Engine Exhaust (Air at 709.7F) Air	709.7 °F 20.01 inH2O g	Gas 28.96	0.03557 lb/ft³ 0.03193 cP	6.137E+06 inH2O a 15151 inH2O a	0.2527 BTU/lb°F 1.372

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
Piping To Silencer Steel, Sch 40 Engine Exhaust (Air at 709.7F)	6 in 6.065 in 27.66 ft	Engine Outlet 7 ft Node 1 11 ft	3623 ft³/min 301 ft/s 252176 0.01725	29.38 inH2O g 19.76 inH2O g 4305 ft 2897 ft	16.83 inH2O 2458 ft	12.55 inH2O g 2.924 inH2O g 1846 ft 438.6 ft	0.0149 0.80 7.72 inH2O 1129 ft
Piping To Silencer1 Steel, Sch 40 Engine Exhaust (Air at 709.7F)	6 in 6.065 in 2 ft	Node 1 11 ft Silencer: Harco VRSA 10 12 ft	3623 ft³/min 301 ft/s 252176 0.01725	12.55 inH2O g 2.924 inH2O g 1846 ft 438.6 ft	5.403 inH2O 789.3 ft	7.145 inH2O g -2.479 inH2O g 1057 ft -350.6 ft	0.0149 0.49 4.739 inH2O 693.2 ft
Silencer To Outlet Steel, Sch 20 Engine Exhaust (Air at 709.7F)	10 in 10.25 in 28.25 ft	Silencer: Harco VRSA 10 18 ft Pressure Boundary 45 ft	3623 ft³/min 105.4 ft/s 149214 0.01769	2.604 inH2O g 1.424 inH2O g 398.9 ft 226.3 ft	2.604 inH2O 353.9 ft	0 inH2O g -1.18 inH2O g 45 ft -127.6 ft	0.01337 1.47 1.729 inH2O 252.9 ft

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Silencer: Harco VRSA 10	12 ft 7.145 inH2O g	18 ft 2.604 inH2O g	4.5 inH2O 658.2 ft	3623 ft³/min

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	11 ft	12.55 inH2O g	438.6 ft

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Pressure Boundaries				
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary	45 ft	0 inH2O g	-127.6 ft	3623 ft³/min

Flow Demands					
Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Engine Outlet	7 ft	29.38 inH2O g	2897 ft	3623 ft³/min	Flow in

Bill of Materials Report

File Name: 18026-200-259-1 GEN Exhaust Piping Calculations.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 16.1.41643
Company: Elliott Bay Design Group
Project: 18026: Main Generator
by: MEJ
Date: Monday, July 09, 2018 04:53 PM

Fixed dP Devices

Fixed dP Device Name	Fixed dP
Silencer: Harco VRSA 10	4.5 InH2O

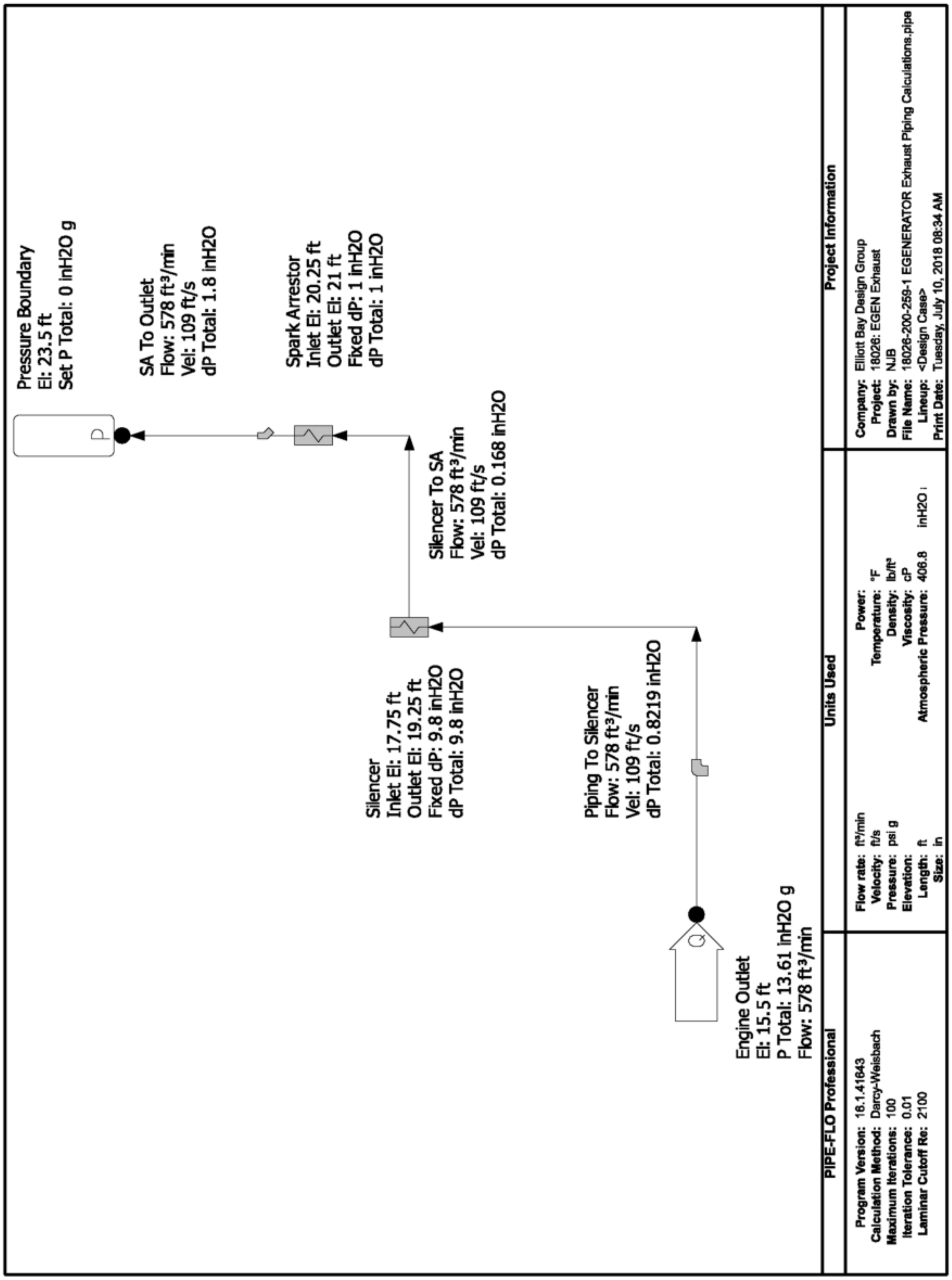
Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Piping To Silencer	Steel, Sch 40	6 in	27.66 ft	1 x Elbow - Short radius, r/d 1 (90°) 1 x Elbow - Long radius, r/d 1.5 (90°) 2 x Elbow - Long radius, r/d 1.5 (45°)
Piping To Silencer1	Steel, Sch 40	6 in	2 ft	1 x Elbow - Long radius, r/d 1.5 (90°) 1 x Reducer - Enlargement (6 in x 10 in - 7 in)
Silencer To Outlet	Steel, Sch 20	10 in	28.25 ft	1 x Exit - Projecting 2 x Elbow - Long radius, r/d 1.5 (45°) 1 x Mitre Bend @ 45°

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Steel, Sch 20	Steel A53-B36.10 Schedule: 20	10 in	28.25 ft	2 x Elbow - Long radius, r/d 1.5 (45°) 1 x Exit - Projecting 1 x Mitre Bend @ 45°
Steel, Sch 40	Steel A53-B36.10 Schedule: 40	6 in	29.66 ft	2 x Elbow - Long radius, r/d 1.5 (45°) 2 x Elbow - Long radius, r/d 1.5 (90°) 1 x Elbow - Short radius, r/d 1 (90°) 1 x Reducer - Enlargement (6 in x 10 in - 7 in)

EMERGENCY GENERATOR EXHAUST MODEL



List Report

File Name:	18026-200-259-1 EGENERATOR Exhaust Piping Calculat	**Calculation Method:**	Darcy-Weisbach	**Company:**	Elliott Bay Design Group
Lineup:	<Design Case>	**Laminar Cutoff Re:**	2100	**Project:**	18026: EGEN Exhaust
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	NJB
Version:	16.1.41643	**Percent Tolerance:**	0.01	**Date:**	Monday, July 09, 2018 04:51 PM
		Allowable Deviation:	1 %	**Atmospheric Pressure:**	406.8 inH2O 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, Sch 10 standard	Steel A53-B36.10 Schedule:10	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	
Steel, Sch 20 standard	Steel A53-B36.10 Schedule:20	1.800E-03 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	
Steel, 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)
Engine Exhaust (Air at 713F) Air	759 °F 29.98 inH2O g	Gas 28.96	0.03492 lb/ft³ 0.03279 cP	7.181E+06 inH2O a 15151 inH2O a	0.2543 BTU/lb°F 1.369

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
Piping To Silencer Steel, Sch 40 Engine Exhaust (Air at 713F)	4 in 4.026 in 5 ft	Engine Outlet 15.5 ft Silencer 17.75 ft	– – – –	– – – –	– –	– – – –	– 0.33 – –
SA To Outlet Steel, Sch 40 Engine Exhaust (Air at 713F)	4 in 4.026 in 3 ft	Spark Arrestor 21 ft Pressure Boundary 23.5 ft	– – – –	– – – –	– –	– – – –	– 1.24 – –
Silencer To SA Steel, Sch 40 Engine Exhaust (Air at 713F)	4 in 4.026 in 2 ft	Silencer 19.25 ft Spark Arrestor 20.25 ft	– – – –	– – – –	– –	– – – –	– 0.00 – –

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Silencer	17.75 ft –	19.25 ft –	– –	–
Spark Arrestor	20.25 ft –	21 ft –	– –	–

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Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary	23.5 ft	0 inH2O g	–	–

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Engine Outlet	15.5 ft	–	–	–	Flow in

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Bill of Materials Report

File Name:	18026-200-259-1 EGENERATOR Exhaust Piping Calculations.pipe	**Company:**	Elliott Bay Design Group
Lineup:	<Design Case>	**Project:**	18026: EGEN Exhaust
Program Name:	PIPE-FLO Professional	**by:**	NJB
Version:	16.1.41643	**Date:**	Monday, July 09, 2018 04:50 PM

Fixed dP Devices

Fixed dP Device Name	Fixed dP
Silencer	9.8 inH2O
Spark Arrestor	1 inH2O

Pipelines

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

Pipeline Material Summary

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

Appendix C

Fuel Oil Piping System, Dwg. 18026-200-261-1

1 DESCRIPTION

This appendix documents the 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 generator is 200.2 g/hr = 3.34 gpm, from [1].
- The generators have the following fuel system design constraints [1]:

Table 1: Fuel System Design Constraints

Parameter	Maximum
Allowable supply line restriction to generator	8.9 in Hg = 4.37 psi
Allowable return line restriction from generator	8.0 in Hg = 3.93 psi

- Piping system lengths, routing, fittings, etc. are estimated based on the Profiles and Arrangements, and Fuel Oil Diagram [2] [3].
- Each generator 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 [4].
- The system is normally arranged such that one generator consumes fuel from the nearest tank. The model assumes a worst case wherein two generators are utilizing one tank.
- Tank and engine elevations were estimated from [2] and all elevations are in reference to the vessel's baseline:

Table 2: Elevations

Elevation Point	Elevation
Fuel tank low fuel level	4.5 feet
Fuel tank high fuel level	7.75 feet
Main Engine fuel inlet	5.0 feet

Elevation Point	Elevation
Main Engine fuel outlet	7.5 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, [5]. The following table shows the flow rates of fuel occurring in the system, and the resulting pipe sizes.

Table 3: Fuel Oil System Pipe Sizes and Velocities

Pipe Segment	Flow Rate	Pipe Size	Schedule	d, ID	Design Velocity			V
					Nominal		Limit	
	gpm	(NPS)		in	ft/s		ft/s	ft/s
Fill Rate	**50**	**2**	**SCH 80**	1.939	2.0 √d	2.78	15	5.43
Supply Main (2 Generators)	**6.68**	**2**	**SCH 40**	2.067	5.0 √d	7.19	20	0.64
Return Main (2 Generators)	**6.68**	**2**	**SCH 40**	2.067	5.0 √d	7.19	20	0.64
Generator Supply	**3.34**	**3/4**	**SCH 40**	0.824	5.0 √d	4.54	20	2.01
Generator Return	**3.34**	**3/4**	**SCH 40**	0.824	1.0 √d	0.91	4	2.01

5.2 Engine Fuel Suction Pressure Calculations

The attached system model confirms that the piping systems are compatible with the generator's 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 2.6 psi.

5.3 Engine Fuel Return Pressure Calculations

The attached model of the fuel system's return piping confirms that the backpressure at the generators does not exceed the listed maximum value of 3.93psi. The return line restriction at the generator was found to be 0.77 psi.

6 VENDOR DATA

6.1 CAT c18 Generator Rated 565 kW at 1,800 RPM

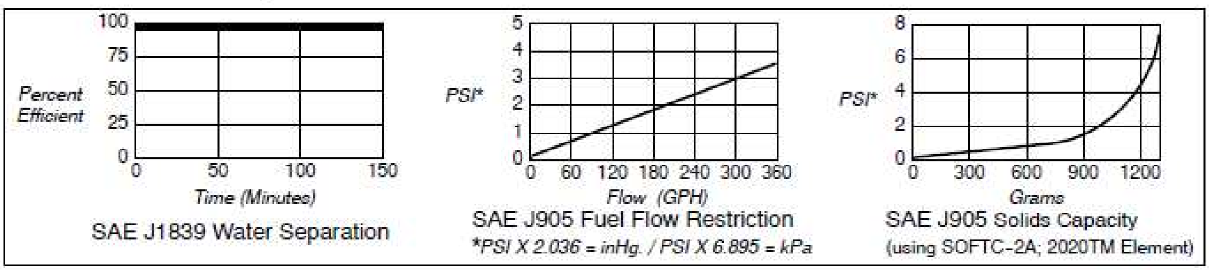
From [1]:

FUEL SYSTEM		
MAXIMUM FUEL FLOW FROM TRANSFER PUMP TO ENGINE	200.2	G/HR
MAXIMUM ALLOWABLE FUEL SUPPLY LINE RESTRICTION	8.9	IN-HG
MAXIMUM ALLOWABLE FUEL TEMPERATURE AT TRANSFER PUMP INLET	126	DEG F
MAXIMUM ALLOWABLE FUEL RETURN LINE RESTRICTION	8.0	IN-HG
NORMAL FUEL PRESSURE IN A CLEAN SYSTEM	109.1	PSI
FUEL SYSTEM TYPE	MEUI	
MAXIMUM TRANSFER PUMP PRIMING LIFT WITHOUT PRIMING PUMP	9.8	FT
MAXIMUM HEAT REJECTION TO FUEL	165	BTU/MIN
MAXIMUM HEAD PRESSURE AT FUEL TRANSFER PUMP INLET	22	PSI

6.2 Racor 751000 MAXM

From [4]:

Performance Graphs *-These results are from controlled laboratory tests. Field results may vary by application.*



7 REFERENCES

[1] Caterpillar, "C18 565 kW at 1800 RPM Systems Data," EM4133, May 24, 2018.

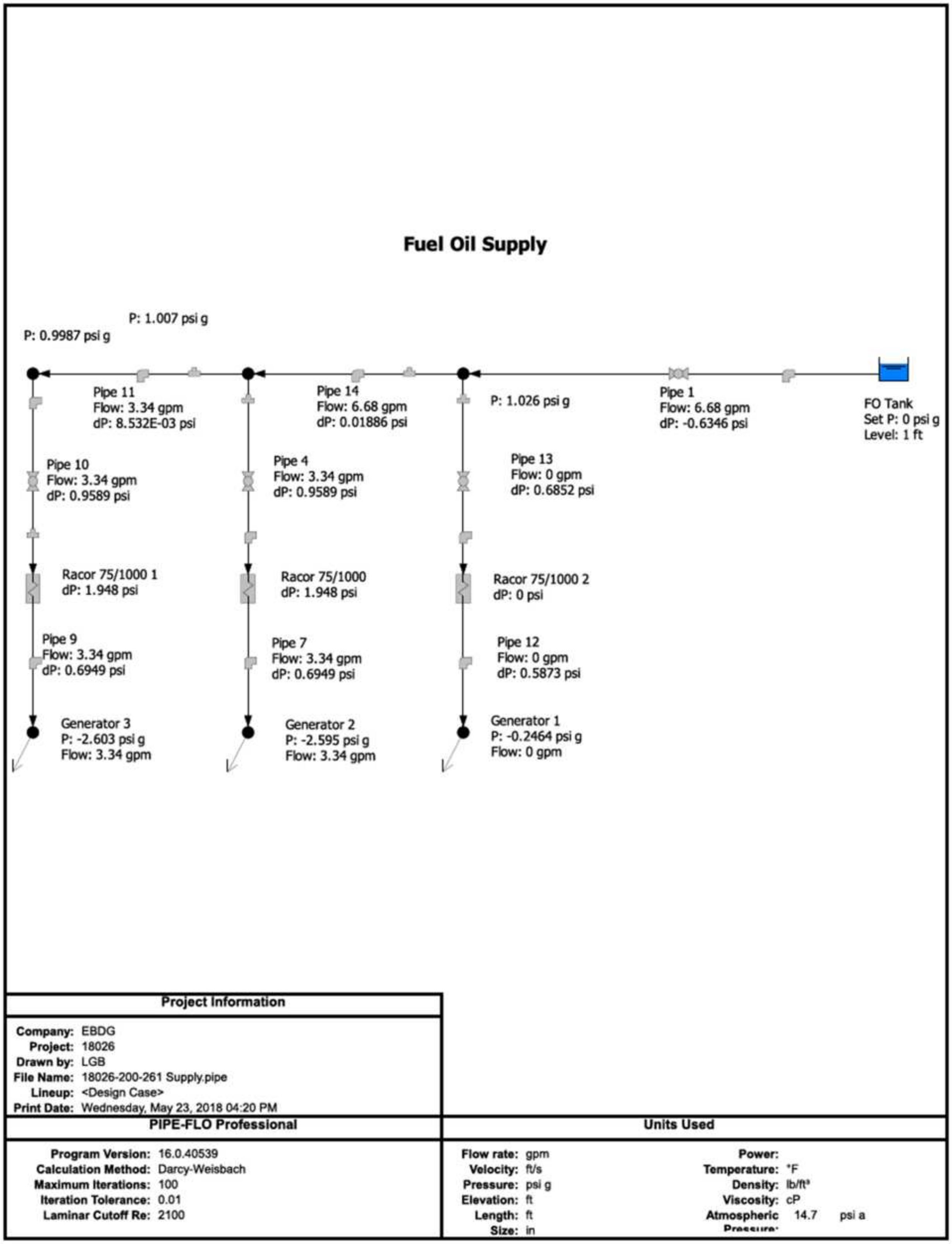
[2] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Profiles and Arrangements," 18026-200-101-1, Seattle, WA.

[3] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Fuel Oil Diagram," 18026-200-261-1, Seattle, WA.

[4] Parker Hannifin Corp, "Racor Products: Parts, Service and Technical Information (Marine Turbine Series)".

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

FUEL OIL SUPPLY PIPE-FLO MODEL



List Report

File Name:	18026-200-261 Supply.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	<Design Case>	**Laminar Cutoff Re:**	2100	**Project:**	18026
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	LGB
Version:	16.0.40539	**Iteration Tolerance:**	0.01	**Date:**	Wednesday, May 23, 2018 04:20 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
ASTM A53 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
Fuel 3 Fuel 3 Max	50 °F	0 psi g	Liquid	56.38 lb/ft³ 10.19 cP	0.2171 psi a 3199 psi a	-- 1

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
Pipe 1 ASTM A53 Sch 40 Fuel 3	2 in 2.067 in 40 ft	3.5 ft 1.75 ft	6.68 gpm 0.6387 ft/s 905.7	0.1292 ft 0.0252 ft	0.3915 psi g 1.026 psi g	-0.6346 psi 9.866E-03 psi	0.07067 0.01899 3.98
	Inlet Device: FO Tank		**Outlet Device:** Node 1				
Pipe 9 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 3 ft	3.5 ft 5 ft	3.34 gpm 2.009 ft/s 1136	0.2748 ft 0.1204 ft	-1.909 psi g -2.603 psi g	0.6949 psi 0.04713 psi	0.05634 0.02398 1.92
	Inlet Device: Racor 75/1000 1		**Outlet Device:** Generator 3				
Pipe 10 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	1.75 ft 3.5 ft	3.34 gpm 2.009 ft/s 1136	0.6993 ft 0.1844 ft	0.9987 psi g 0.03976 psi g	0.9589 psi 0.07219 psi	0.05634 0.02398 2.94
	Inlet Device: Node 6		**Outlet Device:** Racor 75/1000 1				
Pipe 7 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 3 ft	3.5 ft 5 ft	3.34 gpm 2.009 ft/s 1136	0.2748 ft 0.1204 ft	-1.9 psi g -2.595 psi g	0.6949 psi 0.04713 psi	0.05634 0.02398 1.92
	Inlet Device: Racor 75/1000		**Outlet Device:** Generator 2				
Pipe 4 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	1.75 ft 3.5 ft	3.34 gpm 2.009 ft/s 1136	0.6993 ft 0.1844 ft	1.007 psi g 0.04829 psi g	0.9589 psi 0.07219 psi	0.05634 0.02398 2.94
	Inlet Device: Node 5		**Outlet Device:** Racor 75/1000				
Pipe 11 ASTM A53 Sch 40 Fuel 3	2 in 2.067 in 15 ft	1.75 ft 1.75 ft	3.34 gpm 0.3193 ft/s 452.8	0.02179 ft 2.287E-03 ft	1.007 psi g 0.9987 psi g	8.532E-03 psi 8.955E-04 psi	0.1413 0.01899 1.44
	Inlet Device: Node 5		**Outlet Device:** Node 6				
Pipe 12 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 3 ft	3.5 ft 5 ft	0 gpm 0 ft/s 0	0 ft 0 ft	0.3409 psi g -0.2464 psi g	0.5873 psi 0 psi	-- 0.02398 1.92
	Inlet Device: Racor 75/1000 2		**Outlet Device:** Generator 1				

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
Pipe 13 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	1.75 ft 3.5 ft	0 gpm 0 ft/s 0	0 ft 0 ft	1.026 psi g 0.3409 psi g	0.6852 psi 0 psi	-- 0.02398 2.94
	Inlet Device: Node 1		**Outlet Device:** Racor 75/1000 2				
Pipe 14 ASTM A53 Sch 40 Fuel 3	2 in 2.067 in 15 ft	1.75 ft 1.75 ft	6.68 gpm 0.6387 ft/s 905.7	0.04816 ft 9.149E-03 ft	1.026 psi g 1.007 psi g	0.01886 psi 3.582E-03 psi	0.07067 0.01899 1.44
	Inlet Device: Node 1		**Outlet Device:** Node 5				

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	3.5 ft 1 ft	0 psi g 0.3915 psi g	4.5 ft				
				Pipe 1	0 ft	6.68 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 75/1000 1 Racor 75/1000	3.5 ft 0.03976 psi g	3.5 ft -1.909 psi g	1.948 psi 4.976 ft	3.34 gpm
Racor 75/1000 Racor 75/1000	3.5 ft 0.04829 psi g	3.5 ft -1.9 psi g	1.948 psi 4.976 ft	3.34 gpm
Racor 75/1000 2 Racor 75/1000	3.5 ft 0.3409 psi g	3.5 ft 0.3409 psi g	0 psi 0 ft	0 gpm

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	1.75 ft	1.026 psi g	4.367 ft
Node 5	1.75 ft	1.007 psi g	4.299 ft
Node 6	1.75 ft	0.9987 psi g	4.269 ft

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Generator 3	5 ft	-2.603 psi g	-1.712 ft		Flow out
Generator 2	5 ft	-2.595 psi g	-1.691 ft		Flow out
Generator 1	5 ft	-0.2464 psi g	4.371 ft		Flow out

Bill of Materials Report

File Name: 18026-200-261 Supply.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 16.0.40539

Company: EBDG
Project: 18026
by: LGB
Date: Wednesday, May 23, 2018 04:20 PM

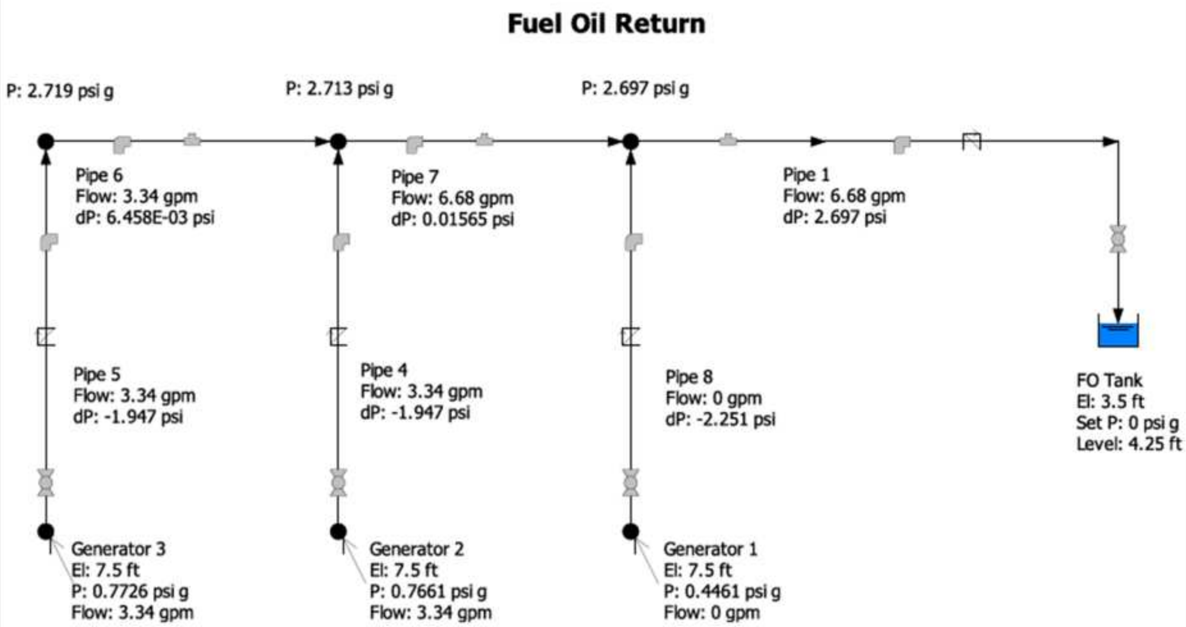
Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	ASTM A53 Sch 40	2 in	40 ft	1 x Ball 6 x Elbow - Standard 90° 1 x Entrance - Sharp Edged
Pipe 9	ASTM A53 Sch 40	0.75 in	3 ft	4 x Pipe Bend - r/d 1 (90°)
Pipe 10	ASTM A53 Sch 40	0.75 in	10 ft	1 x Ball 1 x Reducer - Contraction (0.75 in x 2 in 1 x Tee - Flow Thru Branch 3 x Pipe Bend - r/d 1.5 (90°)
Pipe 7	ASTM A53 Sch 40	0.75 in	3 ft	4 x Pipe Bend - r/d 1 (90°)
Pipe 4	ASTM A53 Sch 40	0.75 in	10 ft	1 x Ball 1 x Reducer - Contraction (0.75 in x 2 in 3 x Pipe Bend - r/d 1.5 (90°) 1 x Tee - Flow Thru Branch
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 12	ASTM A53 Sch 40	0.75 in	3 ft	4 x Pipe Bend - r/d 1 (90°)
Pipe 13	ASTM A53 Sch 40	0.75 in	10 ft	1 x Ball 1 x Reducer - Contraction (0.75 in x 2 in 3 x Pipe Bend - r/d 1.5 (90°) 1 x Tee - Flow Thru Branch
Pipe 14	ASTM A53 Sch 40	2 in	15 ft	4 x Pipe Bend - r/d 1.5 (90°) 1 x Tee - Flow Thru Run

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	70.00 ft	1 x Ball 6 x Elbow - Standard 90° 1 x Entrance - Sharp Edged 8 x Pipe Bend - r/d 1.5 (90°) 2 x Tee - Flow Thru Run

FUEL OIL RETURN PIPE-FLO MODEL



Project Information

Company:	EBDG
Project:	18026
Drawn by:	NJB
File Name:	18026-200-261 Return.pipe
Lineup:	<Design Case>
Print Date:	Wednesday, May 23, 2018 04:19 PM

PIPE-FLO Professional

Program Version:	16.0.40539
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used

Flow rate:	gpm	Power:	
Velocity:	ft/s	Temperature:	°F
Pressure:	psi g	Density:	lb/ft³
Elevation:	ft	Viscosity:	cP
Length:	ft	Atmospheric Pressure:	14.7 psi a
Size:	in		

List Report

File Name:	18026-200-261 Return.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	<Design Case>	**Laminar Cutoff Re:**	2100	**Project:**	18026
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	NJB
Version:	16.0.40539	**Iteration Tolerance:**	0.01	**Date:**	Wednesday, May 23, 2018 04:19 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
ASTM-A-269 0.065 Wall standard	SSteel ASTM-A-269 Schedule:.065	6E-05 in 100	0.0	to ft/s	to psi g	to
ASTM A 53 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
Fuel 3 Fuel 3 Max	50 °F	0 psi g	Liquid	56.38 lb/ft³ 10.19 cP	0.2171 psi a 3199 psi a	-- 1

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
Pipe 1 ASTM A 53 Sch 40 Fuel 3	2 in 2.067 in 40 ft	1.75 ft 8.5 ft	6.68 gpm 0.6387 ft/s 905.7	0.1393 ft 0.03527 ft	2.697 psi g 0 psi g	2.697 psi 0.01381 psi	0.07067 0.01899 5.56
Inlet Device: Node 1			**Outlet Device:** FO Tank				
Pipe 4 ASTM A 53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	7.5 ft 1.75 ft	3.34 gpm 2.009 ft/s 1136	0.7776 ft 0.2627 ft	0.7661 psi g 2.713 psi g	-1.947 psi 0.1028 psi	0.05634 0.02398 4.19
Inlet Device: Generator 2			**Outlet Device:** Node 2				
Pipe 5 ASTM A 53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	7.5 ft 1.75 ft	3.34 gpm 2.009 ft/s 1136	0.7776 ft 0.2627 ft	0.7726 psi g 2.719 psi g	-1.947 psi 0.1028 psi	0.05634 0.02398 4.19
Inlet Device: Generator 3			**Outlet Device:** Node 3				
Pipe 6 ASTM A 53 Sch 40 Fuel 3	2 in 2.067 in 10 ft	1.75 ft 1.75 ft	3.34 gpm 0.3193 ft/s 452.8	0.01649 ft 3.491E-03 ft	2.719 psi g 2.713 psi g	6.458E-03 psi 1.367E-03 psi	0.1413 0.01899 2.20
Inlet Device: Node 3			**Outlet Device:** Node 2				
Pipe 7 ASTM A 53 Sch 40 Fuel 3	2 in 2.067 in 10 ft	1.75 ft 1.75 ft	6.68 gpm 0.6387 ft/s 905.7	0.03997 ft 0.01396 ft	2.713 psi g 2.697 psi g	0.01565 psi 5.467E-03 psi	0.07067 0.01899 2.20
Inlet Device: Node 2			**Outlet Device:** Node 1				
Pipe 8 ASTM A 53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft	7.5 ft 1.75 ft	0 gpm 0 ft/s 0	0 ft 0 ft	0.4461 psi g 2.697 psi g	-2.251 psi 0 psi	-- 0.02398 4.19
Inlet Device: Generator 1			**Outlet Device:** Node 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
FO Tank Fuel 3	3.5 ft 4.25 ft	0 psi g 1.664 psi g	7.75 ft				
				Pipe 1	5 ft	6.68 gpm	0 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	1.75 ft	2.697 psi g	8.635 ft
Node 2	1.75 ft	2.713 psi g	8.656 ft
Node 3	1.75 ft	2.719 psi g	8.664 ft

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
Generator 3	7.5 ft	0.7726 psi g	9.411 ft		Flow in
Generator 2	7.5 ft	0.7661 psi g	9.394 ft		Flow in
Generator 1	7.5 ft	0.4461 psi g	8.639 ft		Flow in

Bill of Materials Report

File Name: 18026-200-261 Return.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 16.0.40539

Company: EBDG
Project: 18026
by: NJB
Date: Wednesday, May 23, 2018 04:19 PM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	ASTM A 53 Sch 40	2 in	40 ft	1 x Swing Check - Vertical 1 x Tee - Flow Thru Branch 1 x Ball 6 x Elbow - Standard 90°
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 ir 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 ir 4 x Pipe Bend - r/d 1.5 (90°) 1 x Ball
Pipe 6	ASTM A 53 Sch 40	2 in	10 ft	1 x Tee - Flow Thru Branch 4 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 7	ASTM A 53 Sch 40	2 in	10 ft	1 x Tee - Flow Thru Branch 4 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 8	ASTM A 53 Sch 40	0.75 in	10 ft	1 x Swing Check - Angled 1 x Reducer - Enlargement (0.75 in x 2 ir 4 x Pipe Bend - r/d 1.5 (90°) 1 x Ball

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
ASTM A 53 Sch 40	Steel A53-B36.10 Schedule: 40	0.75 in	30.00 ft	3 x Ball 12 x Pipe Bend - r/d 1.5 (90°) 3 x Reducer - Enlargement (0.75 in x 2 in - 3 in) 3 x Swing Check - Angled
ASTM A 53 Sch 40	Steel A53-B36.10 Schedule: 40	2 in	60.00 ft	1 x Ball 8 x Elbow - Long radius, r/d 1.5 (90°) 6 x Elbow - Standard 90° 1 x Swing Check - Vertical 3 x Tee - Flow Thru Branch

Appendix D

Machinery Ventilation, Dwg. 18026-200-513-1

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, electrical equipment, 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.
4) Pipe size Calculations	Frictional losses through the chilled water piping system pump head and power requirements are calculated by constructing a model using PIPE-FLO Professional software utilizing the Darcy Weisbach method.

3 REGULATORY FRAMEWORK

The DOUBLE-ENDED AZIMUTH DRIVE FERRY 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 on average.

- The Engine Room, Voids, and Thruster Rooms 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 ship service generator parameters at 100% MCR are used in the calculations [5].

Parameter	Value
Combustion Air Intake	1,654 cfm
Engine Heat Rejection to Air	1709 btu/min
Generator Heat Dissipated	30.4 kW (1,730 btu/min)
Generator Air Flow	66 m3/min (2,331 cfm)

- 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

- Engine Room ventilation calculation assumes:
  - Maximum temperature rise of 25 °F
  - Two ship service generators 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.
- Thruster Room ventilation calculation assumes:
  - Maximum space temperature of 104°F (40°C)
  - Estimated heat rejection of 4.6 kW per thruster with 30% margin added.
- The Switchboard Room will be fitted with a dedicated air conditioning system, which maintains the Switchboard Room at 95°F at the outdoor air conditions given above, with the propulsion plant operating at full power. This machinery space HVAC system will also serve the EOS. The EOS will be maintained at 74°F.
- The Switchboard Room HVAC System is a chilled water system, consisting of three fan coil units, two serving the switchboard room, and one serving the EOS. Vendor estimated total demand flow is 30 GPM. [8] The fan coils are served by four equally sized seawater cooled chiller sized so that the Switchboard room can be cooled with one chiller out of operation.
- Chilled water piping will be Type K copper pipe.

5 CONCLUSIONS

5.1 Engine Room

A minimum ventilation supply rate of 17,900cfm and ventilation exhaust rate of 15,400 cfm are required to provide cooling and combustion air in the engine room.

Four supply fans, each providing 4,500 cfm, will supply air to the engine room separate ventilation supply plenums on the main deck. Air will exhaust through the exhaust uptake to the 01 deck. The calculated total pressure loss is 2.45 inches H_2O. The corresponding static pressure for a 15-inch supply fan is 1.7 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 1.30 inches H_2O. The corresponding static pressure for a 12-inch supply fan is 1.21 inches H_2O.

5.3 Thruster Rooms

A minimum ventilation rate of 2000 cfm is required to provide cooling air in each thruster room.

One supply fan, providing 2,000 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 1.3 inches H_2O. The corresponding static pressure for a 12-inch supply fan is 1.15 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.

5.5 Switchboard Room

With the anticipated propulsion electrical equipment, the switchboard room requires 94,980 BTUH of cooling. The switchboard room will be fitted with two equally sized fan coils, each rated at 48,000 BTUH. As calculated in Appendix E, the EOS requires 25,600 BTUH of cooling. A 36,000 BTUH fan coil is required for the EOS. Chilled water will be supplied by four chillers, each rated at 36,000 BTUH.

The estimated head for each chilled water pump is 94 ft TDH at 30gpm. See the attached PIPE-FLO model for additional details.

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, "Double-Ended Azimuth Drive Ferry: Profiles and Deck Arrangements," 18026-200-101-1, Rev -, Seattle, WA, 2018.

[5] Caterpillar, "EM4133; C18 565kW at 1800 rpm Performance Data," May 24, 2018.

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

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

ENGINE ROOM

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

Generators

Generator Engine Heat Rejection, qe =	1,709.00	*btu/min*	*CAT C18 565 ekW @ 1800 rpm*
Generator Heat Rejection, qa =	1,730.00		
Generator Engine Air Consumption, Qe =	1,654.00	*cfm*	
Number of Generators Operating, Ne =	2.00		
Generator Heat Rejection =	6,878.00	btu/min	

Exhaust Piping

Piping Diameter =	6.00	in	
Piping Length =	80.00	ft	
Heat Emmission Factor =	0.30	kW/m	
	5.40	btu/min/ft	
Estimated Exhaust Heat Rejection =	432.00	btu/min	

Main Deck Solar Load

Deck Temperature (Ts) =	145.00	°F	
Inside Temperature (Ti) =	117.50	°F	
Area =	2,038.00	ft^2	
Heat Transfer Coefficient (U) =	0.12	$btuh/ft^2 °F$	
Heat Gain (q) =	112.09	btu/min	q=U x A * (Ts -Ti)/60

Side Shell (port)

Temperature (T0) =	95.00	°F	
Inside Temperature (Ti) =	117.50	°F	
Area =	300.00	ft^2	
Heat Transfer Coefficient (U) =	1.32	$btuh/ft^2 °F$	
Heat Gain (q) =	-148.50	btu/min	q=U x A * (To -Ti)/60

Side Shell (stbd)

Temperature (To) =	95.00	°F	
Inside Temperature (Ti) =	117.50	°F	
Area =	230.00	ft^2	
Heat Transfer Coefficient (U) =	1.32	$btuh/ft^2 °F$	
Heat Gain (q) =	-113.85	btu/min	q=U x A * (To -Ti)/60

Wetted Shell

Water Temperature (Tw) =	86.00	°F	
Inside Temperature (Ti) =	117.50	°F	
Area =	2,087.00	ft^2	
Heat Transfer Coefficient (U) =	0.80	$btuh/ft^2 °F$	
Heat Gain (q) =	-877.64	btu/min	q=U x A * (Tw -Ti)/60
Total Heat Load =	6,282.10	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) =	120.00	*°F*	
Air Out Enthalpy (hOUT) =	53.02	*Btu / lb*	*[5], Ch. 1, Eqn 32*
Air out Specific Volume (rOUT) =	15.12	*ft³ / lb dry air*	*[5], Ch. 1, Eqn 28*
Other Givens			
Volume of Space (V) =	20,184	*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) =	6,282	*Btu / min*	
D Enthalpy (Dh) =	6.24	*Btu / lb*	*Dh= hOUT - hIN*
Required CFM (Heat Load) =	14,566	*cfm*	*CFM = (Qe / Dh x rIN)*
consumption air (Qc)=	3,308	*cfm*	
cooling + combustion air =	17,874	*cfm*	
Calculated Airflow based on minimum air exchanges:			
Volume of Space (V) =	20,184	*ft³*	
Air exchanges / min (AC)=	10	*min/AC*	
Required CFM(Air Exchange) =	2,018	*cfm*	*CFM = V/MA*
Calculated Exhaust Airflow			
inlet air (V)=	17,874	*cfm*	*(maximum of required airflows)*
inlet air specific volume (rIN)=	14.47	*ft3/lb*	
exhaust air specific volume (rOUT)=	15.12	*ft3/lb*	
expansion =	4.51%		
consumption air (Qc)=	3,308	*cfm*	
exhaust air =	15,372	*cfm*	*CFM = V / rIN * rOUT - Qc*
Results			
Total intake air=	17,900	*cfm*	*(based on heat load and air consumption)*
total exhaust air =	**15,400**	*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 ft^2
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 ft^2
Exhaust air density	0.0021	slugs/cu ft
Supply air flow rate	18000	cfm
Exhaust air flow rate	15500	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)
Supply Ducting														
Inlet Demister, 0.5" H20	15	36	2.40	24.15	21.18	3.75		1	4500	1200	1.97E+05	0.018	5.900	36.65
Inlet to Structural Trunk- 90 deg sharp	9	48	5.33	20.43	15.16	3.00		1	4500	1500	1.76E+05	0.018	1.150	11.16
Structrual Trunk, Net Area	15.00	48.00	0.31	-	22.86	5.00	6	1	4500	900	1.59E+05	0.018	0.057	0.20
Add' 1 HL for misc losses in trunk	15.00	48.00	0.31	-	22.86	5.00		1	4500	900	1.59E+05	0.018	1.000	3.49
Deck cutout, outlet to plenum	12	40	3.33	22.33	18.46	3.33		1	4500	1350	1.93E+05	0.018	1.250	9.83
Fire Damper	18	18	1.00	19.15	18.00	1.77		1	4500	2546	3.55E+05	0.017	0.520	14.54
Fan			-	-	15.00	1.23		1	4500	3667	4.26E+05	0.017	0.000	0.00
Abrupt contraction - Plenum to Duct			-	-	15.00	1.23		1	4500	3667	4.26E+05	0.017	0.400	23.20
Ducting			-	-	15.00	1.23	1	1	4500	3667	4.26E+05	0.017	0.017	1.00
Gradual Expansion			-	-	21.00	2.41		1	4500	1871	3.05E+05	0.017	0.100	1.51
Ducting			-	-	21.00	2.41	3	1	4500	1871	3.05E+05	0.017	0.029	0.44
Miter Elbow	12	18	1.50	15.55	14.40	1.50		1	2250	1500	1.67E+05	0.019	1.150	11.16
Outlet Louver	12	18	1.50	15.55	14.40	1.50	1	1	2250	1500	1.67E+05	0.019	3.000	29.11
													Segment total pressure	*142.29*

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 less exhaust)	62.00	32.00	1.94		42.21	11.64		1	7750	666	2.01E+05	0.017	0.750	1.43
Structrual Trunk, (net area less exhaust)	68.00	92.00	0.74	-	78.20	33.77	10	1	15500	459	2.57E+05	0.016	0.024	0.02
Add' 1 HL for misc losses in trunk	68.00	92.00	0.74	-	78.20	33.77		1	15500	459	2.57E+05	0.016	1.000	0.91
Deck penetration	36	84	2.33	57.23	50.40	17.43		1	15500	889	3.47E+05	0.015	0.200	0.68
Structrual Trunk, Net Area (less exhaust)	44.00	88.00	0.50	-	58.67	20.45	10	1	15500	758	3.19E+05	0.015	0.031	0.08
Add' 1 HL for misc losses in trunk	44.00	88.00	0.50	-	58.67	20.45		1	15500	758	3.19E+05	0.015	1.000	2.48
Fire Damper	78	60	1.30	72.61	67.83	25.09		1	15500	618	3.25E+05	0.015	0.520	0.86
Exhaust Louver with insect screen	78	60	1.30	-	67.83	19.50		1	15500	795	3.86E+05	0.015	3.600	9.81
													Segment total pressure	*16.27*

	FT	in H2O
supply air total pressure	**142.29**	**1.915**
exhaust air total pressure	**16.27**	**0.219**
Total	**158.56**	**2.134**
15% design margin	**182.34**	**2.454**

Supply Fan Static Pressure	
Fan Dia (in)	15.00
Fan area (ft2)	1.23
flowrate (cfm)	4500
velocity (fpm)	3667
fan velocity pressure	0.7452
Static Pressure for fan selection (in H20)	**1.709**

SWITCHBOARD ROOM

Switchboard Room

Space No: SWBD	Deck Area:	615 ft^2	Volume:	6018 ft^3
	Height:	11 ft		

Lighting Load Calculation

Description	Area (ft2)	LC, (Btu/hr/ft^2)	qs (btuh)		qt (btuh)
Lighting	615	7	4,305		4,305
		Lighting Totals:	4,305		4,305

Equipment Load Calculation

Description	qs (btuh)	ql (btuh)		Qty	Use Factor	q_s (btuh)	q_l (btuh)	q_t (btuh)
Propulsion Switchboard (2.55 kW)	8,709			1	1	8,709		8,709
VFD Drive Cabinets (6.2 kW ea)	21,260			4	1	85,038		85,038
					Equipment Totals:	93747	0	93747

Personnel Load Calculation

Description		Type	q_s (btuh)	q_l (btuh)		Count	q_s (btuh)	q_l (btuh)	q_t (btuh)
						Personnel Totals:	0	0	0

Ventilation Requirements

Type	Description	Rate	Unit	Qty		OA (cfm)		EX (cfm)
ASHRAE	Low Occupancy	5	cfm/person	0	people			
		0.06	cfm/sf	615		37		
						37		

Heating Outside Air Temp	27 °F	Cooling Outside Air Temp	95 °F
Heating Inside Air Temp	45 °F	Cooling Design Temp:	95 °F

Heating and Cooling Load Calculation

Description	Load Key	Insul Type		Area (ft^2)	Heating T (°F)	ΔT	U or GSF	q_w (btuh)	Cooling Season T (°F)	ΔT	U or GSF	q_s (btuh)	q_l (btuh)	q_t (btuh)
Car Deck	Over	C-2		615.0	27	18	0.120	1,328	130	35	0.120	2,583		2,583
Wetted Shell	Belw	0-D3	S↓I	637.0	37	8	1.295	6,599	86	-9	1.198	-6,868		-6,868
Engine Room	Fwd	C-2		316.0	45	0	0.120		115	20	0.120	758		758
Port shell above WL	Port	C-2		98.0	27	18	0.120	212	115	20	0.120	235		235
Void	Aft	C-2		430.0	70	-25	0.120	-1,290	110	15	0.120	774		774
Stbd shell above WL	Stbd	C-2		50.0	27	18	0.120	108	95	0	0.120			
EOS	Stbd	C-2		220.0	70	-25	0.120	-660	74	-21	0.120	-554		-554
LIGHTS	Lght											4,305		4,305
EQUIPMENT	Eqpt											93,747		93,747
PERSONNEL	Pers													
							Space Totals:	6,297			Totals:	94,980	0	94,980

Switchboard Room Supply Fan Total Pressure Calculation

Input Variables

Supply Air Temperature (T_{IN}) =	95	°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	3.93E-07	lb-s/sq ft^2
Supply air density	0.0022	slugs/cu ft
Max Temperature (T_{OUT}) =	95.0	°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	3.93E-07	lb-s/sq ft^2
Exhaust air density	0.0021	slugs/cu ft
Supply air flow rate	50	cfm
Exhaust air flow rate	50	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)
Switchboard Room Supply														
Inlet gooseneck with vent head			-	-	4.00	0.09		1	50	573	1.68E+04	0.030	1.400	1.98
Ducting			-	-	4.00	0.09	12	1	50	573	1.76E+04	0.030	1.072	1.52
fire damper					4.00	0.09		1	50	573	1.68E+04	0.030	0.520	0.74
elbow, r/d = 1.5			-	-	4.00	0.09		2	50	573	1.76E+04	0.030	0.300	0.85
fan			-	-	4.00	0.09		1	50	573	1.76E+04	0.030	0.000	0.00
outlet with screen			-	-	4.00	0.09		1	50	573	1.76E+04	0.030	1.600	2.27
													Segment total pressure	*7.35*

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)
Switchboard Room Exhauxt														
Inlet					4.00	0.09		1	50	573	1.68E+04	0.030	1.400	1.98
ducting					4.00	0.09	5	1	50	573	1.76E+04	0.030	0.447	0.63
Balancing Damper, Butterfly			-	-	4.00	0.09		1	50	573	1.68E+04	0.030	0.190	0.27
Fire Damper					4.00	0.09		1	50	573	1.68E+04	0.030	0.520	0.74
elbow, r/d = 1.5			-	-	4.00	0.09		1	50	573	1.76E+04	0.030	0.300	0.42
Inlet gooseneck with vent head			-	-	4.00	0.09		1	50	573	1.68E+04	0.030	2.400	3.40
													Segment total pressure	7.44

	FT	in H2O
supply air total pressure	**7.35**	**0.099**
exhaust air total pressure	**7.44**	**0.100**
Total	**14.79**	**0.199**
15% design margin:	**17.01**	**0.229**

Switchboard Room AHU Ducting

Input Variables

Supply Air Temperature (T_{IN}) =	95	°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	3.93E-07	lb-s/sq ft^2
Supply air density	0.0022	slugs/cu ft
Max Temperature (T_{OUT}) =	95.0	°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	3.93E-07	lb-s/sq ft^2
Exhaust air density	0.0021	slugs/cu ft
Supply air flow rate	2150	cfm
Exhaust air flow rate	2150	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 from Unit														
HVAC Unit Discharge	12.00	13.28	1.11	13.42	12.61	1.11		1	2150	1943	1.88E+05	0.019	0.000	0.00
Ducting	12.00	13.28	1.11	13.42	12.61	1.11	1	1	2150	1943	1.88E+05	0.019	0.018	0.29
Size Change	8.00	22.00	2.75	13.69	11.73	1.22		1	2150	1759	1.58E+05	0.019	0.100	1.33
Ducting	8	22	2.75	13.69	11.73	1.22	12	1	2150	1759	1.58E+05	0.019	0.236	3.16
Elbows	8	22	2.75	13.69	11.73	1.22	2	1	2150	1759	1.58E+05	0.019	0.300	4.00
Outlet, abrupt discharge w/ screen	8	22	2.75	13.69	11.73	1.22	1	1	2150	1759	1.58E+05	0.019	1.800	24.02
													Segment total pressure	32.81

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)
Return Ducting														
Entrance to plenum, with screen	24.00	26.0	0.92	-	24.96	4.33		1	2150	496	9.50E+04	0.019	1.000	1.06
Fitler (0.2" H20 allowance)	24.00	26.0	0.92	-	24.96	2.60		1	2150	827	1.51E+05	0.018	4.000	11.80
													Segment total pressure	*12.86*

	FT	in H2O
supply air total pressure	**32.81**	**0.442**
inlet air total pressure	**12.86**	**0.173**
Total	**45.67**	**0.615**
15% design margin	**52.52**	**0.707**

Supply Fan Static Pressure	
Fan Dia (in)	-
Fan area (ft2)	1.11
flowrate (cfm)	2150
velocity (fpm)	1943
fan velocity pressure	0.2092
Static Pressure for fan selection (in H20)	**0.50**

VOIDS

Void Ventilation

Approach

The minimum required airflow to the Void 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 ft^2
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 ft^2
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	2	1	1000	1273	1.18E+05	0.020	0.040	0.28
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	10	1	500	917	7.11E+04	0.022	0.262	0.95
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	69.97

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	**69.97**	**0.942**
exhaust air total pressure	**13.71**	**0.184**
Total	**83.68**	**1.126**
15% design margin	**96.23**	**1.295**

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)	**1.2052**

THRUSTER ROOMS

Thruster Room Ventilation

Approach

The minimum required airflow to the Thruster 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

Motors and Thrusters

Heat Rejection, qe =	882.25	btu/min	*(4.7 kW per thruster +30% margin = 15.5k*

Main Deck Solar Load

Deck Temperature (Ts) =	145.00	°F	
Inside Temperature (Ti) =	113.00	°F	
Area =	766.00	ft^2	
Heat Transfer Coefficient (U) =	0.12	$btuh/ft^2°F$	
Heat Gain (q) =	49.02	btu/min	q=U x A * (Ts -Ti)/60

Side Shell and Ballast Tanks

Temperature (T0) =	95.00	°F	
Inside Temperature (Ti) =	113.00	°F	
Area =	280.00	ft^2	
Heat Transfer Coefficient (U) =	1.39	$btuh/ft^2°F$	
Heat Gain (q) =	-116.76	btu/min	q=U x A * (To -Ti)/60

Side Shell

Temperature (To) =	95.00	°F	
Inside Temperature (Ti) =	113.00	°F	
Area =	280.00	ft^2	
Heat Transfer Coefficient (U) =	1.34	$btuh/ft^2°F$	
Heat Gain (q) =	-112.48	btu/min	q=U x A * (To -Ti)/60

Wetted Shell

Water Temperature (Tw) =	86.00	°F	
Inside Temperature (Ti) =	113.00	°F	
Area =	1,084.00	ft^2	
Heat Transfer Coefficient (U) =	0.80	$btuh/ft^2°F$	
Heat Gain (q) =	-390.73	btu/min	q=U x A * (Tw -Ti)/60

Total Heat Load =	311.31	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) =	104.00	*°F*	
Air Out Enthalpy (hOUT) =	49.03	*Btu / lb*	*[5], Ch. 1, Eqn 32*
Air out Specific Volume (rOUT) =	14.71	*ft³ / lb dry air*	*[5], Ch. 1, Eqn 28*

Other Givens			
Volume of Space (V) =	9,312	*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) =	311	*Btu / min*	
D Enthalpy (Dh) =	2.25	*Btu / lb*	*Dh= hOUT - hIN*
Required CFM (Heat Load) =	2,005	*cfm*	*CFM = (Qe / Dh x rIN)*
consumption air (Qc)=	-	*cfm*	
cooling + combustion air =	2,005	*cfm*	*(50% combustion air from cooling air)*

Calculated Airflow based on minimum air exchanges:			
Volume of Space (V) =	9,312	*ft³*	
Air exchanges / min (AC)=	10	*min/AC*	
Required CFM(Air Exchange) =	931	*cfm*	*CFM = V/MA*

Calculated Exhaust Airflow			
inlet air (V)=	2,005	*cfm*	*(maximum of required airflows)*
inlet air specific volume (rIN)=	14.47	*ft3/lb*	
exhaust air specific volume (rOUT)=	14.71	*ft3/lb*	
expansion =	1.62%		
consumption air (Qc)=	-	*cfm*	
exhaust air =	2,038	*cfm*	*CFM = V / rIN * rOUT - Qc*

Results			
Total intake air=	2,000	*cfm*	*(based on heat load and air consumption)*
total exhaust air =	**2,000**	*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 ft^2
Supply air density	0.0022	slugs/cu ft
Max Temperature (T_{OUT}) =	104.0	°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	3.89E-07	lb-s/sq ft^2
Exhaust air density	0.0021	slugs/cu ft
Supply air flow rate	2000	cfm
Exhaust air flow rate	2000	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, 0.5" H2O	15	20	1.33	18.38	17.14	2.08		1	2000	960	1.28E+05	0.019	9.300	36.97
Inlet to Structural Trunk- 90 deg sharp	9	48	5.33	20.43	15.16	3.00		1	2000	667	7.83E+04	0.021	1.150	2.20
Structrual Trunk, net area	15	48	0.31	-	22.86	5.00	6	1	2000	400	6.75E+04	0.021	0.065	0.05
Add' 1 HL for misc losses in trunk	15	48	0.31	-	22.86	5.00		1	2000	400	6.75E+04	0.021	1.000	0.69
Deck cutout, outlet to plenum	12	40	3.33	22.33	18.46	3.33		1	2000	600	8.59E+04	0.020	1.250	1.94
Inlet , plenum to ducting	15	15	1.00	15.00	15.00	1.23		1	2000	1630	1.90E+05	0.018	0.500	5.73
Fan			-	15.00	15.00	1.23		1	2000	1630	1.90E+05	0.018	0.000	0.00
Ducting				15.00	15.00	1.23	10	1	2000	1630	1.90E+05	0.018	0.146	1.67
Elbow, 45deg, r/d=1				15.00	15.00	1.23		1	2000	1630	1.90E+05	0.018	0.300	3.44
Subtotal, supply:														**52.69**
Branch A														
Div tee, straight branch, run			-	14.00	14.00	1.07		1	1500	1403	1.52E+05	0.019	0.140	1.19
Elbow, 45deg, r/d=1				14.00	15.00	1.23		1	1500	1222	1.42E+05	0.019	0.300	1.93
Ducting			-	14.00	14.00	1.07	5	1	1500	1403	1.52E+05	0.019	0.081	0.69
Balancing Damper, Butterfly			-	14.00	14.00	1.07		1	1500	1403	1.52E+05	0.019	0.190	1.61
Terminal with screen			-	14.00	14.00	1.07		1	1500	1403	1.52E+05	0.019	1.600	13.59
Subtotal, Branch A:														**19.01**
Branch B														
Div tee, straight branch, branch			-	10.00	10.00	0.55	8	1	500	917	7.11E+04	0.022	3.720	13.48
Ducting			-	10.00	10.00	0.55	3	1	500	917	7.11E+04	0.022	0.079	0.29
Balancing Damper, Butterfly			-	10.00	10.00	0.55		1	500	917	7.11E+04	0.022	0.190	0.69
Terminal with screen			-	10.00	10.00	0.55		1	500	917	7.11E+04	0.022	1.600	5.80
Subtotal, Branch B:														**20.26**
												Segment total pressure		72.95

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, equiv. area	23	27	0.85		24.84	4.31		1	2000	464	8.51E+04	0.020	1.250	1.16
Structrual Trunk, Net Area	23	43	0.53	-	29.97	6.87	6	1	2000	291	6.45E+04	0.021	0.050	0.02
Add' 1 HL for misc losses in trunk	23	43	0.53	-	29.97	6.87	6	1	2000	291	6.45E+04	0.021	1.000	0.37
Exhaust Louver with insect screen	15	26	0.58	-	19.02	2.71		1	2000	738	1.04E+05	0.019	3.900	9.17
												Segment total pressure		*10.72*

	FT	in H2O
supply air total pressure	**72.95**	**0.982**
exhaust air total pressure	**10.72**	**0.144**
Total	**83.66**	**1.126**
15% design margin	**96.21**	**1.295**

Supply Fan Static Pressure	
Fan Dia (in)	15.00
Fan area (ft2)	1.23
flowrate (cfm)	2000
velocity (fpm)	1630
fan velocity pressure	0.1472
Static Pressure for fan selection (in H20)	**1.1477**

EMERGENCY GENERATOR ROOM

Emergency Generator Room Total Pressure Calculation

Input Variables

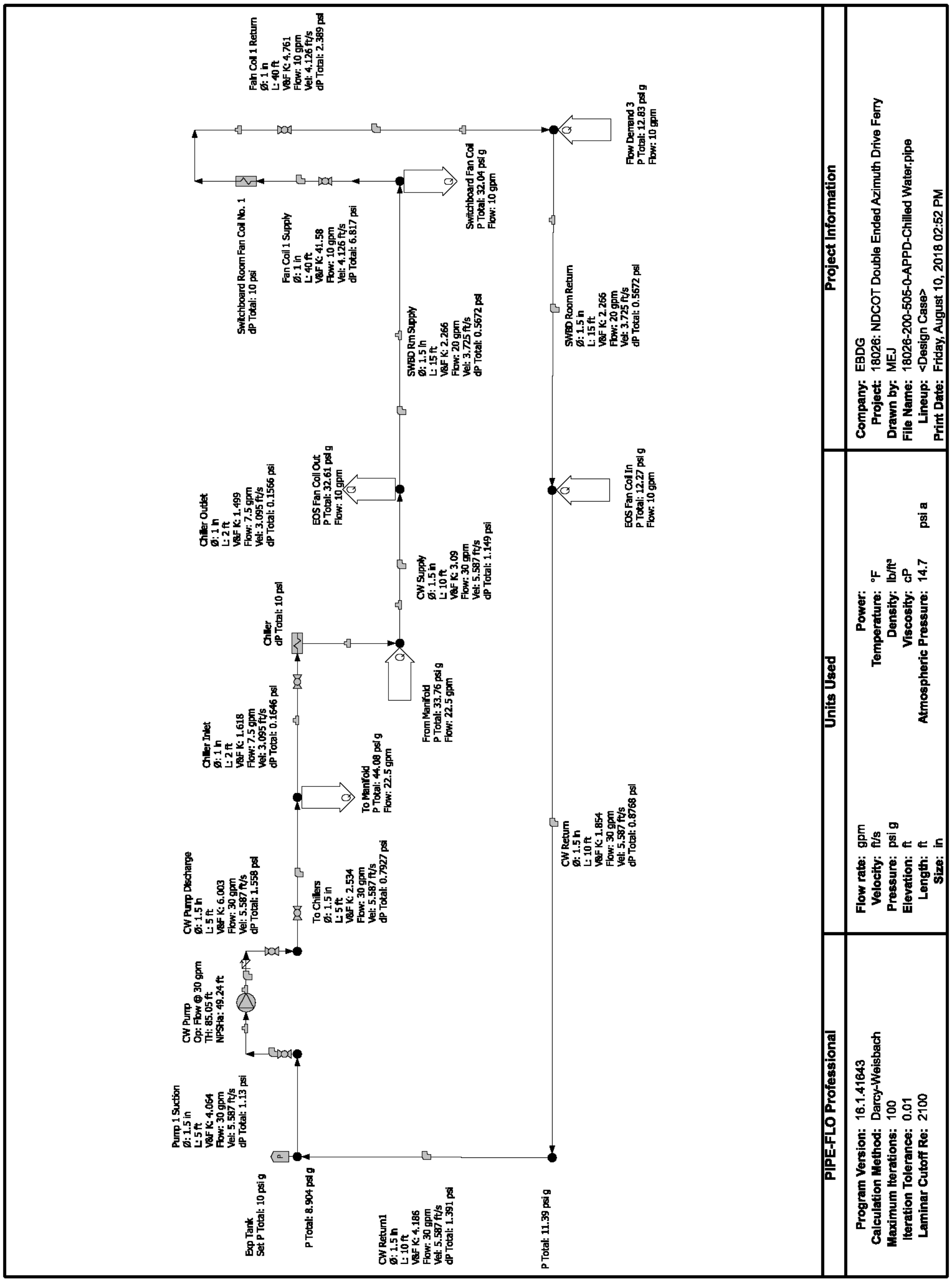
Supply Air Temperature (T_{IN}) =	88	°F
Humidity Ratio	0.0217	lb/lb dry air
Air In Specific Volume (r_{IN}) =	14.29	ft³ / lb dry air
Supply air specific weight	0.070	lb/cu ft
Supply air viscosity	3.89E-07	lb-s/sq ft^2
Supply air density	0.0022	slugs/cu ft
Max Temperature (T_{OUT}) =	115.0	°F
Air out 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 ft^2
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**

CHILLED WATER PIPING



List Report

File Name: 18026-200-505-0-APPD-Chilled Water.pipe	**Calculation Method:** Darcy-Weisbach	**Company:** EBDG	
Lineup: <Design Case>	**Laminar Cutoff Re:** 2100	**Project:** 18026: NDCOT Double Ended Azimuth Drive Ferry	
Progam Name: PIPE-FLO Professional	**Max Iterations:** 100	**by:** MEJ	
Version: 16.1.41643	**Percent Tolerance:** 0.01	**Date:** Friday, August 10, 2018 02:52 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
Type K Copper Pipe standard	Copper Tube H23 Schedule:K	6E-05 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)
30% Ethylene Glycol 30% Dowtherm SR-1	38 °F 10 psi g	Liquid 22.61	65.45 lb/ft³ 3.475 cP	0.09051 psi a 1575 psi a	– –

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
CW Pump	0 ft 7.774 psi g	0 ft 46.43 psi g	85.05 ft 38.66 psi	30 gpm	49.24 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
CW Pump Discharge Type K Copper Pipe 30% Ethylene Glycol	1.5 in 1.481 in 5 ft	CW Pump 0 ft Node 1 0 ft	30 gpm 5.587 ft/s 19325 0.02619	46.43 psi g 46.21 psi g 102.2 ft 101.7 ft	1.558 psi 3.427 ft	44.87 psi g 44.65 psi g 98.72 ft 98.24 ft	0.0206 6.00 1.324 psi 2.912 ft
CW Return Type K Copper Pipe 30% Ethylene Glycol	1.5 in 1.481 in 10 ft	EOS Fan Coil In 0 ft Pressure Boundary 2 0 ft	30 gpm 5.587 ft/s 19325 0.02619	12.27 psi g 12.05 psi g 26.99 ft 26.51 ft	0.8768 psi 1.929 ft	11.39 psi g 11.17 psi g 25.06 ft 24.58 ft	0.0206 1.85 0.4089 psi 0.8995 ft
CW Return1 Type K Copper Pipe 30% Ethylene Glycol	1.5 in 1.481 in 10 ft	Pressure Boundary 2 0 ft Exp Tank 0 ft	30 gpm 5.587 ft/s 19325 0.02619	11.39 psi g 11.17 psi g 25.06 ft 24.58 ft	1.391 psi 3.06 ft	10 psi g 9.779 psi g 22 ft 21.52 ft	0.0206 4.19 0.923 psi 2.031 ft
CW Supply Type K Copper Pipe 30% Ethylene Glycol	1.5 in 1.481 in 10 ft	From Manifold 0 ft EOS Fan Coil Out 0 ft	30 gpm 5.587 ft/s 19325 0.02619	33.76 psi g 33.54 psi g 74.27 ft 73.79 ft	1.149 psi 2.529 ft	32.61 psi g 32.39 psi g 71.74 ft 71.26 ft	0.0206 3.09 0.6814 psi 1.499 ft
Chiller Inlet Type K Copper Pipe 30% Ethylene Glycol	1 in 0.995 in 2 ft	To Manifold 0 ft Chiller 0 ft	7.5 gpm 3.095 ft/s 7191 0.03384	44.08 psi g 44.01 psi g 96.98 ft 96.83 ft	0.1646 psi 0.3622 ft	43.91 psi g 43.85 psi g 96.62 ft 96.47 ft	0.02281 1.62 0.1094 psi 0.2407 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
Chiller Outlet Type K Copper Pipe 30% Ethylene Glycol	1 in 0.995 in 2 ft	Chiller 0 ft From Manifold 0 ft	7.5 gpm 3.095 ft/s 7191 0.03384	33.91 psi g 33.85 psi g 74.62 ft 74.47 ft	0.1566 psi 0.3446 ft	33.76 psi g 33.69 psi g 74.27 ft 74.12 ft	0.02281 1.50 0.1014 psi 0.2231 ft
Fain Coil 1 Return Type K Copper Pipe 30% Ethylene Glycol	1 in 0.995 in 40 ft	witchboard Room Fan Coil No. 0 ft Flow Demand 3 0 ft	10 gpm 4.126 ft/s 9588 0.03132	15.22 psi g 15.1 psi g 33.5 ft 33.23 ft	2.389 psi 5.257 ft	12.83 psi g 12.71 psi g 28.24 ft 27.97 ft	0.02281 4.76 0.5725 psi 1.26 ft
Fan Coil 1 Supply Type K Copper Pipe 30% Ethylene Glycol	1 in 0.995 in 40 ft	Switchboard Fan Coil 0 ft witchboard Room Fan Coil No. 0 ft	10 gpm 4.126 ft/s 9588 0.03132	32.04 psi g 31.92 psi g 70.5 ft 70.23 ft	6.817 psi 15 ft	25.22 psi g 25.1 psi g 55.5 ft 55.23 ft	0.02281 41.58 5 psi 11 ft
Pipe 17 Type K Copper Pipe 30% Ethylene Glycol	1.5 in 1.481 in 1 ft	Exp Tank 0 ft Node 0 ft	30 gpm 5.587 ft/s 19325 0.02619	10 psi g 9.779 psi g 22 ft 21.52 ft	1.096 psi 2.412 ft	8.904 psi g 8.683 psi g 19.59 ft 19.1 ft	0.0206 4.76 1.05 psi 2.309 ft
Pump 1 Suction Type K Copper Pipe 30% Ethylene Glycol	1.5 in 1.481 in 5 ft	Node 0 ft CW Pump 0 ft	30 gpm 5.587 ft/s 19325 0.02619	8.904 psi g 8.683 psi g 19.59 ft 19.1 ft	1.13 psi 2.486 ft	7.774 psi g 7.553 psi g 17.1 ft 16.62 ft	0.0206 4.06 0.8961 psi 1.972 ft
SWBD Rm Supply Type K Copper Pipe 30% Ethylene Glycol	1.5 in 1.481 in 15 ft	EOS Fan Coil Out 0 ft Switchboard Fan Coil 0 ft	20 gpm 3.725 ft/s 12884 0.02898	32.61 psi g 32.51 psi g 71.74 ft 71.53 ft	0.5672 psi 1.248 ft	32.04 psi g 31.94 psi g 70.5 ft 70.28 ft	0.0206 2.27 0.2221 psi 0.4886 ft
SWBD Room Return Type K Copper Pipe 30% Ethylene Glycol	1.5 in 1.481 in 15 ft	Flow Demand 3 0 ft EOS Fan Coil In 0 ft	20 gpm 3.725 ft/s 12884 0.02898	12.83 psi g 12.74 psi g 28.24 ft 28.02 ft	0.5672 psi 1.248 ft	12.27 psi g 12.17 psi g 26.99 ft 26.77 ft	0.0206 2.27 0.2221 psi 0.4886 ft
To Chillers Type K Copper Pipe 30% Ethylene Glycol	1.5 in 1.481 in 5 ft	Node 1 0 ft To Manifold 0 ft	30 gpm 5.587 ft/s 19325 0.02619	44.87 psi g 44.65 psi g 98.72 ft 98.24 ft	0.7927 psi 1.744 ft	44.08 psi g 43.86 psi g 96.98 ft 96.5 ft	0.0206 2.53 0.5588 psi 1.229 ft

Fixed dP Devices

Fixed dP Device Name	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Chiller	0 ft 43.91 psi g	0 ft 33.91 psi g	10 psi 22 ft	7.5 gpm
Switchboard Room Fan Coil No. 1	0 ft 25.22 psi g	0 ft 15.22 psi g	10 psi 22 ft	10 gpm

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node	0 ft	8.904 psi g	19.1 ft
Node 1	0 ft	44.87 psi g	98.24 ft

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Pressure Boundary 2	0 ft	11.39 psi g	24.58 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Exp Tank	0 ft	10 psi g	21.52 ft	30 gpm

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
EOS Fan Coil In	0 ft	12.27 psi g	26.64 ft	10 gpm	Flow in
EOS Fan Coil Out	0 ft	32.61 psi g	71.39 ft	10 gpm	Flow out
Flow Demand 3	0 ft	12.83 psi g	28 ft	10 gpm	Flow in
From Manifold	0 ft	33.76 psi g	73.96 ft	22.5 gpm	Flow in
Switchboard Fan Coil	0 ft	32.04 psi g	70.26 ft	10 gpm	Flow out
To Manifold	0 ft	44.08 psi g	96.66 ft	22.5 gpm	Flow out

Bill of Materials Report

File Name: 18026-200-505-0-APPD-Chilled Water.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 16.1.41643
Company: EBDG
Project: 18026: NDCOT Double Ended Azimuth Drive Ferry
by: MEJ
Date: Friday, August 10, 2018 02:53 PM

Sizing Pumps

Sizing Pump Name / Operation	Design Point Flow Rate	Design Point Total Head
CW Pump Flow @ 30 gpm	30 gpm	85.05 ft

Fixed dP Devices

Fixed dP Device Name	Fixed dP
Chiller	10 psi
Switchboard Room Fan Coil No. 1	10 psi

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
CW Pump Discharge	Type K Copper Pipe	1.5 in	5 ft	4 x Elbow - Standard 90° 1 x Ball 1 x Tee - Flow Thru Branch 1 x Swing Check - Angled 1 x Reducer - Enlargement (1.5 in x 1.25 in - 0 in)
CW Return	Type K Copper Pipe	1.5 in	10 ft	3 x Elbow - Standard 90°
CW Return1	Type K Copper Pipe	1.5 in	10 ft	4 x Elbow - Standard 90° 1 x Air Separator
CW Supply	Type K Copper Pipe	1.5 in	10 ft	3 x Elbow - Standard 90° 3 x Tee - Flow Thru Run
Chiller Inlet	Type K Copper Pipe	1 in	2 ft	1 x Tee - Flow Thru Branch 1 x Reducer - Contraction (1 in x 1.25 in - 0 in) 1 x Ball
Chiller Outlet	Type K Copper Pipe	1 in	2 ft	1 x Tee - Flow Thru Branch 1 x Reducer - Enlargement (1 in x 1.25 in - 0 in)
Fain Coil 1 Return	Type K Copper Pipe	1 in	40 ft	4 x Elbow - Standard 90° 1 x Ball 1 x Tee - Flow Thru Run 1 x Tee - Flow Thru Branch 1 x Reducer - Enlargement (1 in x 1.25 in - 0 in)
Fan Coil 1 Supply	Type K Copper Pipe	1 in	40 ft	4 x Elbow - Standard 90° 1 x Ball 1 x 3-way ball valve 1 x 4 PSI allowance for auto flow control valve 5 1 x Reducer - Contraction (1 in x 1.25 in - 0 in)
Pipe 17	Type K Copper Pipe	1.5 in	1 ft	1 x 1 PSI Allowance for Suction Strainer
Pump 1 Suction	Type K Copper Pipe	1.5 in	5 ft	4 x Elbow - Standard 90° 1 x Tee - Flow Thru Branch 1 x Ball 1 x Reducer - Contraction (1.5 in x 1.25 in - 0 in)
SWBD Rm Supply	Type K Copper Pipe	1.5 in	15 ft	1 x Tee - Flow Thru Run 3 x Elbow - Standard 90°
SWBD Room Return	Type K Copper Pipe	1.5 in	15 ft	3 x Elbow - Standard 90° 1 x Tee - Flow Thru Run
To Chillers	Type K Copper Pipe	1.5 in	5 ft	4 x Elbow - Standard 90° 1 x Ball

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Type K Copper Pipe	Copper Tube H23 Schedule: K	1 in	84.00 ft	1 x 3-way ball valve 1 x 4 PSI allowance for auto flow control valve 3 x Ball 8 x Elbow - Standard 90° 2 x Reducer - Contraction (1 in x 1.25 in - 0 in) 2 x Reducer - Enlargement (1 in x 1.25 in - 0 in) 3 x Tee - Flow Thru Branch 1 x Tee - Flow Thru Run

Pipeline Material Summary				
Specification	**Material**	**Size**	**Total Length**	**Valves & Fittings**
Type K Copper Pipe	Copper Tube H23 Schedule: K	1.5 in	76.00 ft	1 x 1 PSI Allowance for Suction Strainer 1 x Air Separator 3 x Ball 28 x Elbow - Standard 90° 1 x Reducer - Contraction (1.5 in x 1.25 in - 0 in) 1 x Reducer - Enlargement (1.5 in x 1.25 in - 0 in) 1 x Swing Check - Angled 2 x Tee - Flow Thru Branch 5 x Tee - Flow Thru Run

Appendix E

Accomodations HVAC

1 DESCRIPTION

This appendix presents calculations performed to estimate heating, ventilation, and air conditioning requirements for the DOUBLE-ENDED AZIMUTH DRIVE 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 DOUBLE-ENDED AZIMUTH DRIVE ferries will be US Coast Guard under the provisions of 46 CFR Subchapter H.

4 GIVEN AND ASSUMED PARAMETERS

- The Pilothouse, Crew Lounge, and Passenger Lounge will be air-conditioned using air-cooled split heat pump units.
- The Pilothouse, Crew Lounge, and Passenger Lounge will utilize split heat pumps as primary heat, with electric strip heaters for backup
- The EOS will be air conditioned using a chilled water fan coil as part of the machinery space HVAC system. A heater in the EOS fan coil will provide heat for the space.
- 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. A third 5 kilowatt heater will be installed in the Switchboard Room.
- 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
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, "Double-Ended Azimuth Drive Ferry: Profiles and Deck Arrangements," 18026-200-101-1, Seattle, WA, 2018.

GLASS SOLAR FACTOR FOR LOW-E WINDOWS

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

$CF_{fen}= U(\Delta t\text{-}0.46{*}DR) + PXI \times SGHC \times IAC \; X \; FF_s$

$q_{fen}= A \times CF_{fen}$

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	ft²	Volume:	1152	ft³
Space No:		Height:	8	ft			

Lighting Load Calculation

Description	Area (ft2)	LC, (Btu/hr/ft²)	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	ft³	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

Description	Load Key	Insul Type		Area (ft²)	Heating T (°F)	ΔT	U or GSF	q_w (btuh)	Cooling Season 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

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

Description	Load Key	Insul Type		Area (ft^2)	Heating T (°F)	Heating ΔT	Heating U or GSF	q_w (btuh)	Cooling Season T (°F)	Cooling ΔT	Cooling 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

Description	Load Key	Insul Type		Area (ft^2)	Heating T (°F)	ΔT	U or GSF	q_w (btuh)	Cooling Season 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

Description	Load Key	Insul Type		Area (ft^2)	Heating T (°F)	ΔT	U or GSF	q_w (btuh)	Cooling Season 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 F

Fire Main System, Dwg. 18026-200-521-1

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	4.25 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	Pipe Size	Schedule	d, ID	Design Velocity			V
					Nominal		Limit	
	gpm	(NPS)		in	ft/s		ft/s	ft/s
Firemain Suction	**164**	**3**	**CL 200**	3.310	3.0 √d	5.46	15	6.11
Firemain Discharge	**164**	**3**	**CL 200**	3.310	5.0 √d	9.10	15	6.11
Firemain Branch (1 hydrant)	**82**	**1 1/2**	**CL 200**	1.756	5.0 √d	6.63	15	10.86
Firemain Branch (2 hydrants)	**164**	**2**	**CL 200**	2.209	5.0 √d	7.43	15	13.73
Firemain Overboard	**164**	**3**	**CL 200**	3.310	5.0 √d	9.10	15	6.11

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

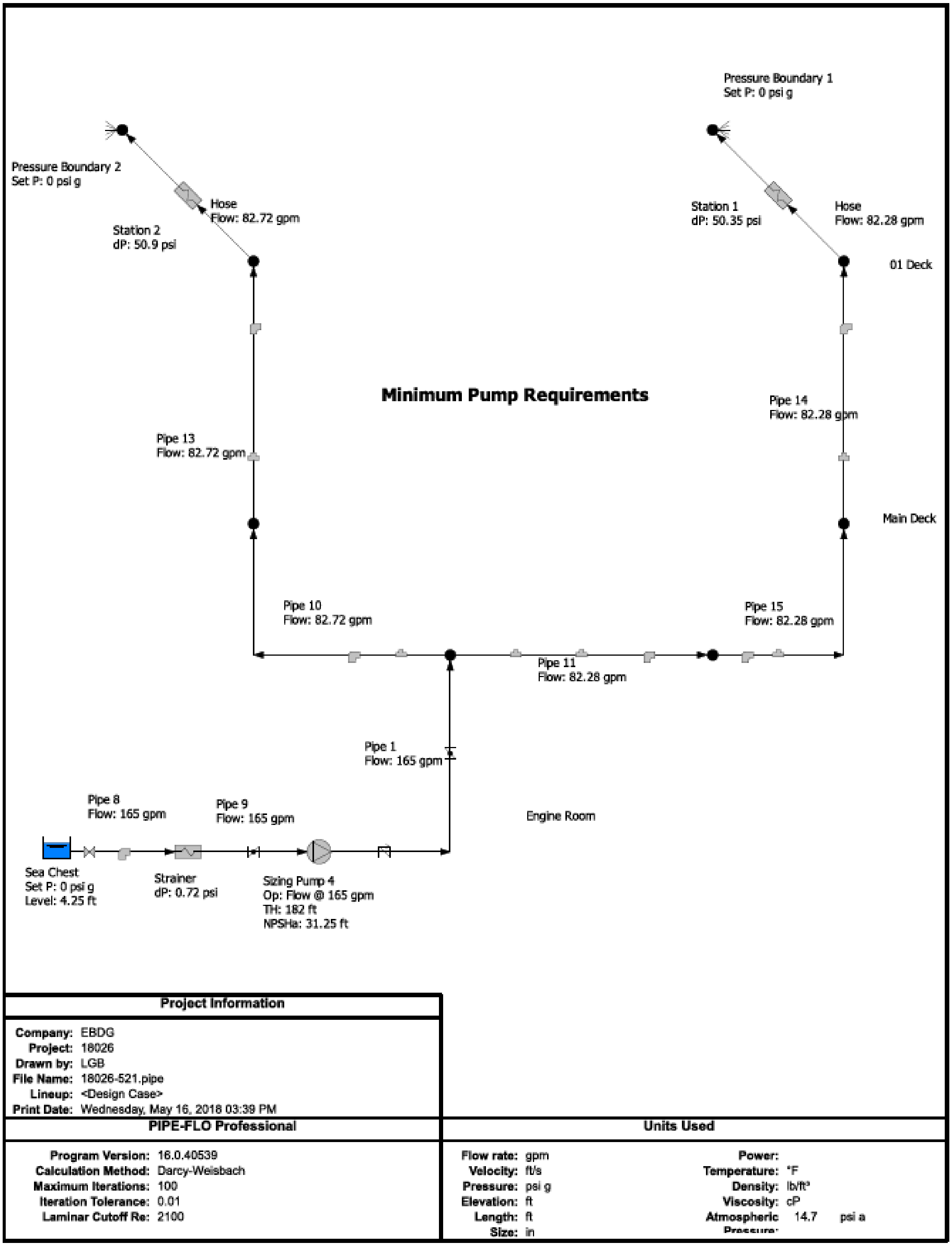
[1] USCG, "46 CFR, Chapter I, Subchapter H, Part 76 Fire Protection Equipment," 5/16/2018.

[2] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Profiles and Arrangements," 18026-200-101-1, Seattle, WA.

[3] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Fire Main System Schematic," 18026-200-521-1, Seattle, WA.

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

FIRE MAIN PIPE-FLO MODEL



List Report

File Name: 18026-521.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: LGB
Date: Wednesday, May 16, 2018 03:41 PM

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
CuNi Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	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
Seawater Seawater 3.5% Salinity	60 °F	0 psi g	Liquid	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- 29

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 4	2.5 ft -0.5463 psi g	2.5 ft 80.41 psi g	182 ft 80.95 psi		31.25 ft

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
Pipe 1 CuNi Class 200 Seawater	3 in 3.31 in 10 ft	2.5 ft 11 ft	165 gpm 6.152 ft/s 134088	1.815 ft 1.451 ft	80.41 psi g 75.82 psi g	4.587 psi 0.6455 psi	0.01705 0.01702 2.47
Inlet Device: Sizing Pump 4			**Outlet Device:** Node 2				
Hose CuNi Class 200 Seawater	1.5 in 1.756 in 150 ft	24 ft 24 ft	82.28 gpm 10.9 ft/s 126044	32.86 ft 0 ft	64.97 psi g 50.36 psi g	14.61 psi 0 psi	0.01736 0.01975 0.00
Inlet Device: Node 1			**Outlet Device:** Station 1				
Pipe 4 CuNi Class 200 Seawater	1.5 in 1.756 in 0.01 ft	24 ft 24 ft	82.28 gpm 10.9 ft/s 126044	2.191E-03 ft 0 ft	9.742E-04 psi g 0 psi g	9.742E-04 psi 0 psi	0.01736 0.01975 0.00
Inlet Device: Station 1			**Outlet Device:** Pressure Boundary 1				
Hose CuNi Class 200 Seawater	1.5 in 1.756 in 150 ft	24 ft 24 ft	82.72 gpm 10.96 ft/s 126707	33.17 ft 0 ft	65.65 psi g 50.9 psi g	14.75 psi 0 psi	0.01734 0.01975 0.00
Inlet Device: Node 3			**Outlet Device:** Station 2				
Pipe 7 CuNi Class 200 Seawater	1.5 in 1.756 in 0.01 ft	24 ft 24 ft	82.72 gpm 10.96 ft/s 126707	2.211E-03 ft 0 ft	9.835E-04 psi g 0 psi g	9.835E-04 psi 0 psi	0.01734 0.01975 0.00
Inlet Device: Station 2			**Outlet Device:** Pressure Boundary 2				
Pipe 8 CuNi Class 200 Seawater	3 in 3.31 in 5 ft	0 ft 2.5 ft	165 gpm 6.152 ft/s 134088	0.8362 ft 0.6544 ft	1.89 psi g 0.4064 psi g	1.484 psi 0.291 psi	0.01705 0.01702 1.11
Inlet Device: Sea Chest			**Outlet Device:** Strainer				

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
Pipe 9 CuNi Class 200 Seawater	3 in 3.31 in 2 ft	2.5 ft 2.5 ft	165 gpm 6.152 ft/s 134088	0.5231 ft 0.4504 ft	-0.3136 psi g -0.5463 psi g	0.2327 psi 0.2003 psi	0.01705 0.01702 0.77
Inlet Device: Strainer			**Outlet Device:** Sizing Pump 4				
Pipe 14 CuNi Class 200 Seawater	1.5 in 1.756 in 20 ft	14 ft 24 ft	82.28 gpm 10.9 ft/s 126044	6.173 ft 1.792 ft	72.16 psi g 64.97 psi g	7.193 psi 0.7969 psi	0.01736 0.01975 0.97
Inlet Device: Node 8			**Outlet Device:** Node 1				
Pipe 13 CuNi Class 200 Seawater	1.5 in 1.756 in 20 ft	14 ft 24 ft	82.72 gpm 10.96 ft/s 126707	6.77 ft 2.347 ft	73.11 psi g 65.65 psi g	7.458 psi 1.044 psi	0.01734 0.01975 1.26
Inlet Device: Node 6			**Outlet Device:** Node 3				
Pipe 11 CuNi Class 200 Seawater	3 in 3.31 in 65 ft	11 ft 11 ft	82.28 gpm 3.068 ft/s 66868	1.017 ft 0.3385 ft	75.82 psi g 75.37 psi g	0.4522 psi 0.1506 psi	0.01967 0.01702 2.31
Inlet Device: Node 2			**Outlet Device:** Node 9				
Pipe 15 CuNi Class 200 Seawater	2 in 2.209 in 40 ft	11 ft 14 ft	82.28 gpm 6.888 ft/s 100196	4.204 ft 1.3 ft	75.37 psi g 72.16 psi g	3.204 psi 0.5779 psi	0.01813 0.01869 1.76
Inlet Device: Node 9			**Outlet Device:** Node 8				
Pipe 10 CuNi Class 200 Seawater	2 in 2.209 in 20 ft	11 ft 14 ft	82.72 gpm 6.925 ft/s 100723	3.093 ft 1.627 ft	75.82 psi g 73.11 psi g	2.71 psi 0.7237 psi	0.01811 0.01869 2.18
Inlet Device: Node 2			**Outlet Device:** Node 6				

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 Seawater	0 ft 4.25 ft	0 psi g 1.89 psi g	4.25 ft				
				Pipe 8	0 ft	165 gpm	1.89 psi g

Curve dP Devices

Curve dP Device Name Description	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
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 0.4064 psi g	2.5 ft -0.3136 psi g	0.72 psi 1.619 ft	165 gpm
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

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 2	11 ft	75.82 psi g	181 ft
Node 1	24 ft	64.97 psi g	168.2 ft

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
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: 18026-521.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 16.0.40539

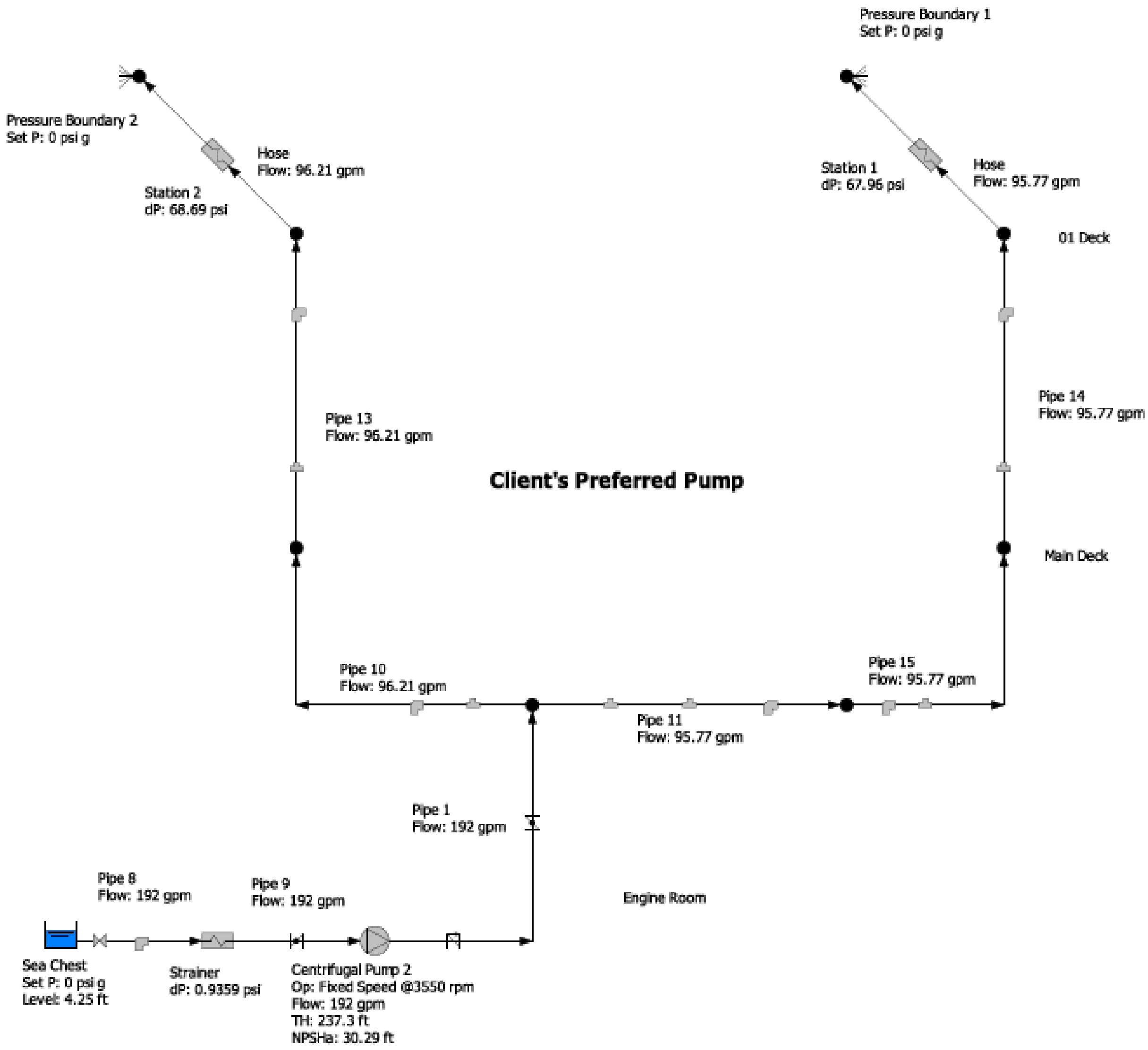
Company: EBDG
Project: 18026
by: LGB
Date: Wednesday, May 16, 2018 03:40 PM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	CuNi Class 200	3 in	10 ft	1 x Butterfly 1 x Swing Check - Angled
Hose	CuNi Class 200	1.5 in	150 ft	
Pipe 4	CuNi Class 200	1.5 in	0.01 ft	
Hose	CuNi Class 200	1.5 in	150 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
Pipe 14	CuNi Class 200	1.5 in	20 ft	1 x Reducer - Contraction (1.5 in x 2 in - 1 x Tee - Flow Thru Run 2 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 - 1 x Tee - Flow Thru Run 3 x Elbow - Long radius, r/d 1.5 (90°)
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 15	CuNi Class 200	2 in	40 ft	1 x Tee - Flow Thru Run 1 x Reducer - Contraction (2 in x 3 in - 3 5 x Elbow - Long radius, r/d 1.5 (90°)
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 1 x Tee - Flow Thru Branch

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



Project Information

Company: EBDG
Project: 18026
Drawn by: LGB
File Name: 18026-521 Goulds Pump.pipe
Lineup: <Design Case>
Print Date: Wednesday, May 16, 2018 03:41 PM

PIPE-FLO Professional

Program Version: 16.0.40539
Calculation Method: Darcy-Weisbach
Maximum Iterations: 100
Iteration Tolerance: 0.01
Laminar Cutoff Re: 2100

Units Used

Flow rate:	gpm	**Power:**	hp
Velocity:	ft/s	**Temperature:**	°F
Pressure:	psi g	**Density:**	lb/ft³
Elevation:	ft	**Viscosity:**	cP
Length:	ft	**Atmospheric Pressure:**	14.7 psi a
Size:	in		

Appendix G

Sanitary Drain System, Dwg. 18026-200-528-1

1 DESCRIPTION

This appendix documents the 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	Schedule	d, ID	Design Velocity			V
					Nominal		Limit	
	gpm	(NPS)		in	ft/s		ft/s	ft/s
Pump Suction	**100**	**2**	**SCH 80**	1.939	3.0 √d	4.18	15	10.86
Pump Discharge	**100**	**2**	**SCH 80**	1.939	5.0 √d	6.96	15	10.86

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.

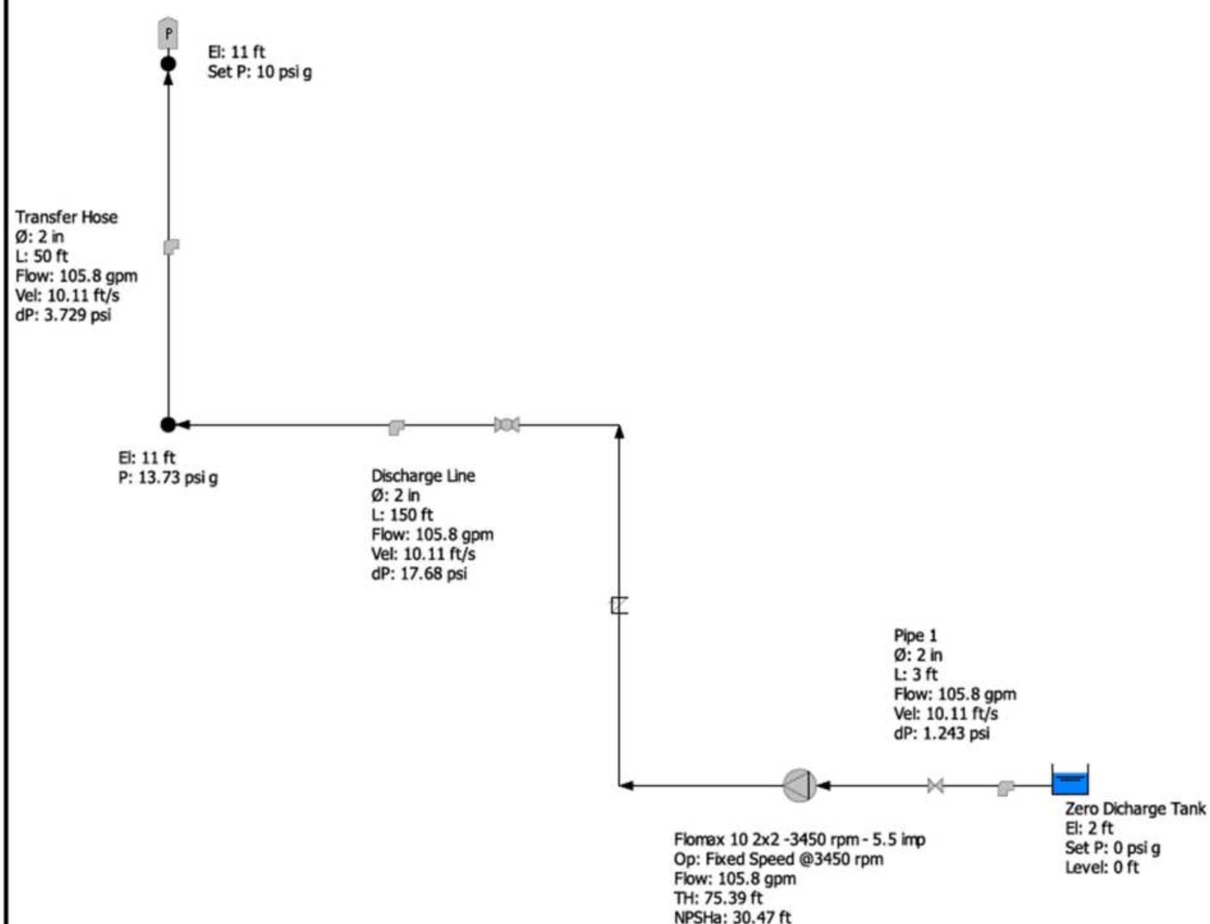
6 REFERENCES

[1] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Profiles and Arrangements," 18026-200-101-1, Seattle, WA.

[2] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Sanitary Drains Schematic," 18026-200-528-1, Seattle, WA.

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

ZERO DISCHARGE PIPE-FLO MODEL



Project Information	
Company:	EBDG
Project:	18026
Drawn by:	NJB
File Name:	18026-505 AppH Sanitary Drains Discharge.pipe
Lineup:	<Design Case>
Print Date:	Wednesday, May 23, 2018 04:39 PM

PIPE-FLO Professional	
Program Version:	16.0.40539
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used			
Flow rate:	gpm	Power:	
Velocity:	ft/s	Temperature:	°F
Pressure:	psi g	Density:	lb/ft³
Elevation:	ft	Viscosity:	cP
Length:	ft	Atmospheric Pressure:	14.7 psi a
Size:	in		

List Report

File Name: 18026-505 AppH Sanitary Drains Discharge.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Wednesday, May 23, 2018 04:40 PM

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
Carbon Steel SCH 80 standard	Steel A53-B36.10 Schedule:80	1.800E-03 in 140	0.0	to ft/s	to psi g	to
Plastic Pipe standard	PVC PIPE D1785 Schedule:40	6E-05 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
Water Water	60 °F	0 psi g	Liquid	62.37 lb/ft³ 1.105 cP	0.2564 psi a 3199 psi a	-- 18

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 Fixed Speed @3450 rpm	3450 rpm 3450 rpm	2.5 ft -1.243 psi g	2.5 ft 31.41 psi g	75.39 ft 32.65 psi	105.8 gpm --	-- -- %	30.47 ft 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 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
Discharge Line Plastic Pipe Water	2 in 2.067 in 150 ft	2.5 ft 11 ft	105.8 gpm 10.11 ft/s 146322	32.32 ft 9.024 ft	31.41 psi g 13.73 psi g	17.68 psi 3.908 psi	0.01683 0.01899 5.68
	Inlet Device: Flomax 10 2x2 -3450 rpm - 5.5 imp		**Outlet Device:** Pressure Boundary				
Pipe 1 Plastic Pipe Water	2 in 2.067 in 3 ft	2 ft 2.5 ft	105.8 gpm 10.11 ft/s 146322	2.369 ft 1.903 ft	0 psi g -1.243 psi g	1.243 psi 0.8245 psi	0.01683 0.01899 1.20
	Inlet Device: Zero Dicharge Tank		**Outlet Device:** Flomax 10 2x2 -3450 rpm - 5.5 imp				
Transfer Hose Plastic Pipe Water	2 in 2.067 in 50 ft	11 ft 11 ft	105.8 gpm 10.11 ft/s 146322	8.61 ft 0.845 ft	13.73 psi g 10 psi g	3.729 psi 0.366 psi	0.01683 0.01899 0.53
	Inlet Device: Pressure Boundary		**Outlet Device:** Pressure Boundary 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
Zero Dicharge Tank Water	2 ft 0 ft	0 psi g 0 psi g	2 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
Zero Dicharge Tank Water	2 ft 0 ft	0 psi g 0 psi g	2 ft				
				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: 18026-505 AppH Sanitary Drains Discharge.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 16.0.40539

Company: EBDG
Project: 18026
by: NJB
Date: Wednesday, May 23, 2018 04:40 PM

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 H

Bilge System, Dwg. 18026-200-529-1

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	Schedule	d, ID	Design Velocity			V
					Nominal		Limit	
	gpm	(NPS)		in	ft/s		ft/s	ft/s
Bilge Main	**149**	**3**	**SCH 80**	2.900	3.0 √d	5.11	15	7.24
Engine Room Bilge Branch	**149**	**2 1/2**	**SCH 80**	2.323	3.0 √d	4.57	15	11.28
All Other Bilge Branches	**125**	**2**	**SCH 80**	1.939	3.0 √d	4.18	15	13.58
Overboard Discharge	**149**	**3**	**SCH 80**	2.900	5.0 √d	8.51	15	7.24

Note that it is necessary to throttle the pump discharge when pumping individual compartments beyond the engine room.

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 148 gpm. Calculated NPSH available for the bilge system ranges from about 6 feet to 12 feet in the SWBD room and engine room, respectively.

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

6 REFERENCES

[1] USCG, "46 CFR, Chapter I, Subchapter F, 56.50-50," 5/16/18.

[2] Elliott Bay Design Group, "NCDOT Z-Drive Ferry: Profiles and Arrangements," 18026-200-101-1, Seattle, WA.

[3] Elliott Bay Design Group, "NCDOT Z-Drive Ferry: Bilge and Ballast System Schematic,"

18026-200-529-1, 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 =	178.03	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 = 3.01 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

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

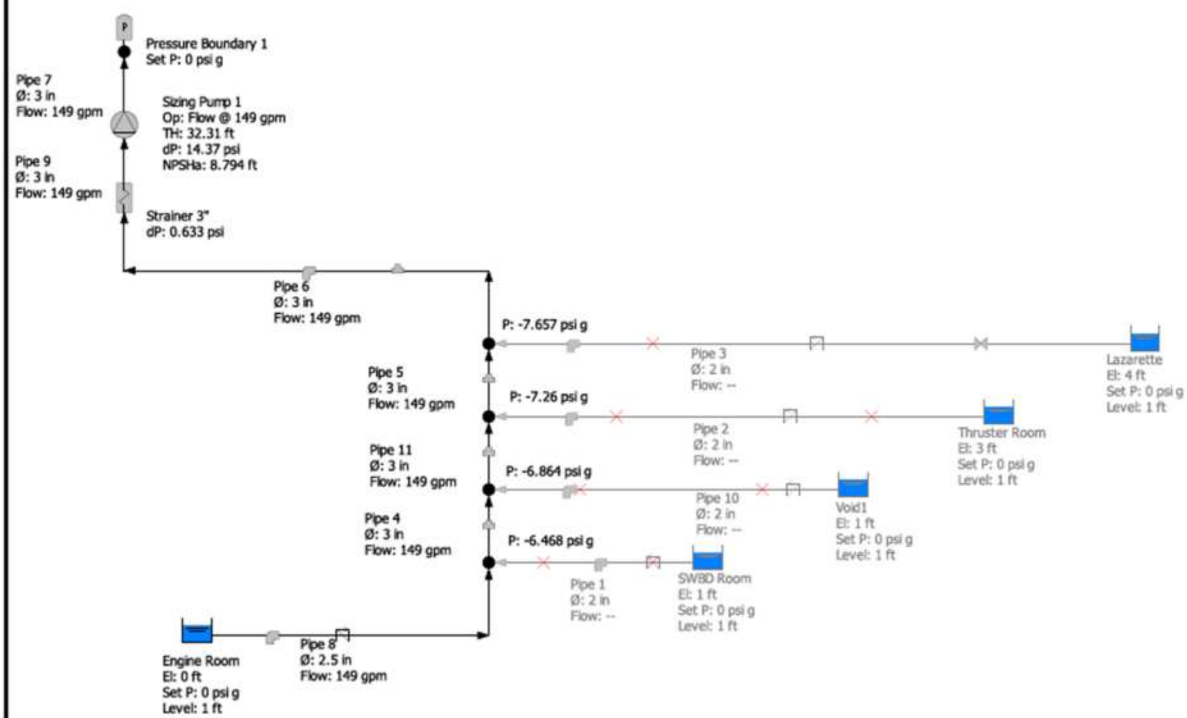
Compartment	c (ft)	**d (in)**	pipe selected	id (in)	PASS
Lazarette A	11.8	**2.000**	2" sch 80 pipe	1.939	**PASS**
Thruster Room A	32	**2.098**	2" sch 80 pipe	1.939	**PASS**
Void A	16	**2.000**	2" sch 80 pipe	1.939	**PASS**
Engine Room	48	**2.345**	2½" sch 80 pipe	2.323	**PASS**
SWBD Room	16	**2.000**	2" sch 80 pipe	1.939	**PASS**
Void B	16	**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 =	3.01	in	required diameter of main bilge suction
a =	7.10	in^2	required cross sectional area of main bilge suction
v =	400	ft / min	required pump suction velocity

V = 148 gpm **required pump capacity**

BILGE SYSTEM PIPE-FLO MODEL



Project Information	
Company:	EBDG
Project:	18026
Drawn by:	NJB
File Name:	18026-529 Bilge.pipe
Lineup:	Engine Room
Print Date:	Thursday, May 17, 2018 10:37 AM

PIPE-FLO Professional	
Program Version:	16.0.40539
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used			
Flow rate:		**Power:**	
Velocity:	ft/s	**Temperature:**	°F
Pressure:	psi g	**Density:**	lb/ft³
Elevation:	ft	**Viscosity:**	cP
Length:	ft	**Atmospheric Pressure:**	14.7 psi a
Size:	in		

List Report

File Name:	18026-529 Bilge.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	Engine Room	**Laminar Cutoff Re:**	2100	**Project:**	18026
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	NJB
Version:	16.0.40539	**Iteration Tolerance:**	0.01	**Date:**	Thursday, May 17, 2018 10:38 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
Steel A53 sch 80 standard	Steel A53-B36.10 Schedule:80	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
Sea Water Seawater 3.5% Salinity	60 °F	0 psi g	Liquid	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- 29

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -10.53 psi g	2.5 ft 3.835 psi g	32.31 ft 14.37 psi		8.794 ft

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
Pipe 1 Steel A53 sch 80 Sea Water	2 in 1.939 in 6 ft	1 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -6.468 psi g	-- --	-- -- 4.50
	Inlet Device: SWBD Room		**Outlet Device:** Node 1				
Pipe 2 Steel A53 sch 80 Sea Water	2 in 1.939 in 40 ft	3 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -7.26 psi g	-- --	-- -- 4.78
	Inlet Device: Thruster Room		**Outlet Device:** Node 2				
Pipe 3 Steel A53 sch 80 Sea Water	2 in 1.939 in 72 ft	4 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -7.657 psi g	-- --	-- -- 5.47
	Inlet Device: Lazarette		**Outlet Device:** Node 3				
Pipe 5 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	149 gpm 7.237 ft/s 138204	0.8905 ft 0.8567 ft	-7.26 psi g -7.657 psi g	0.396 psi 0.381 psi	0.02008 0.01754 1.05
	Inlet Device: Node 2		**Outlet Device:** Node 3				
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 24 ft	2.5 ft 9.5 ft	149 gpm 7.237 ft/s 138204	1.623 ft 0 ft	3.835 psi g 0 psi g	3.835 psi 0 psi	0.02008 0.01754 0.00
	Inlet Device: Sizing Pump 1		**Outlet Device:** Pressure Boundary 1				
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft	0 ft 2.5 ft	149 gpm 11.28 ft/s 172532	13.04 ft 8.892 ft	0.4447 psi g -6.468 psi g	6.913 psi 3.954 psi	0.02033 0.01847 4.50
	Inlet Device: Engine Room		**Outlet Device:** Node 1				

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
Pipe 6 Steel A53 sch 80 Sea Water	3 in 2.9 in 56 ft	2.5 ft 2.5 ft	149 gpm 7.237 ft/s 138204	4.843 ft 1.057 ft	-7.657 psi g -9.811 psi g	2.154 psi 0.4699 psi	0.02008 0.01754 1.30
Inlet Device: Node 3			**Outlet Device:** Strainer 3"				
Pipe 9 Steel A53 sch 80 Sea Water	3 in 2.9 in 3 ft	2.5 ft 2.5 ft	149 gpm 7.237 ft/s 138204	0.2029 ft 0 ft	-10.44 psi g -10.53 psi g	0.09022 psi 0 psi	0.02008 0.01754 0.00
Inlet Device: Strainer 3"			**Outlet Device:** Sizing Pump 1				
Pipe 4 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	149 gpm 7.237 ft/s 138204	0.8905 ft 0.8567 ft	-6.468 psi g -6.864 psi g	0.396 psi 0.381 psi	0.02008 0.01754 1.05
Inlet Device: Node 1			**Outlet Device:** Node 6				
Pipe 11 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	149 gpm 7.237 ft/s 138204	0.8905 ft 0.8567 ft	-6.864 psi g -7.26 psi g	0.396 psi 0.381 psi	0.02008 0.01754 1.05
Inlet Device: Node 6			**Outlet Device:** Node 2				
Pipe 10 Steel A53 sch 80 Sea Water	2 in 1.939 in 21 ft	1 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -6.864 psi g	-- --	-- -- 4.50
Inlet Device: Void1			**Outlet Device:** Node 6				

Tanks

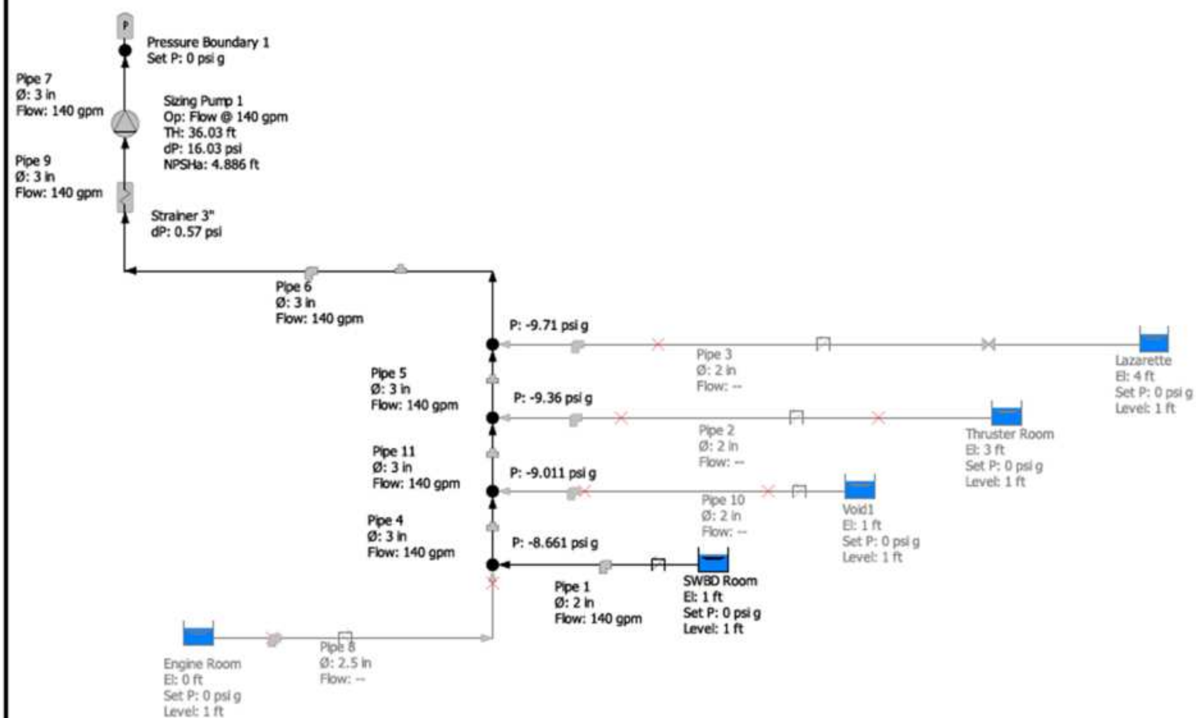
Tank Name / Fluid Zone	Bottom Elevation / Liquid Level	Surface Pressure / Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
Lazarette Sea Water	4 ft 1 ft	0 psi g --	--	Pipe 3	0 ft	--	0.4447 psi g
Thruster Room Sea Water	3 ft 1 ft	0 psi g --	--	Pipe 2	0 ft	--	0.4447 psi g
SWBD Room Sea Water	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
Void1 Sea Water	1 ft 1 ft	0 psi g --	--	Pipe 10	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	-7.26 psi g	-14.64 ft
Node 3	2.5 ft	-7.657 psi g	-15.53 ft
Node 6	2.5 ft	-6.864 psi g	-13.75 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



Project Information	
Company:	EBDG
Project:	18026
Drawn by:	NJB
File Name:	18026-529 Bilge.pipe
Lineup:	SWBD Room
Print Date:	Thursday, May 17, 2018 10:37 AM

PIPE-FLO Professional	
Program Version:	16.0.40539
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used			
Flow rate:	gpm	Power:	
Velocity:	ft/s	Temperature:	°F
Pressure:	psi g	Density:	lb/ft³
Elevation:	ft	Viscosity:	cP
Length:	ft	Atmospheric Pressure:	14.7 psi a
Size:	in		

List Report

File Name: 18026-529 Bilge.pipe
Lineup: SWBD Room
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Thursday, May 17, 2018 10:39 AM

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	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
Sea Water Seawater 3.5% Salinity	60 °F	0 psi g	Liquid	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- 29

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -12.27 psi g	2.5 ft 3.754 psi g	36.03 ft 16.03 psi		4.886 ft

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
Pipe 1 Steel A53 sch 80 Sea Water	2 in 1.939 in 6 ft	1 ft 2.5 ft	140 gpm 15.21 ft/s 194215	18.97 ft 16.2 ft	0.4447 psi g -8.661 psi g	9.106 psi 7.204 psi	0.02079 0.01928 4.50
Inlet Device: SWBD Room			**Outlet Device:** Node 1				
Pipe 2 Steel A53 sch 80 Sea Water	2 in 1.939 in 40 ft	3 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -9.36 psi g	-- --	-- -- 4.78
Inlet Device: Thruster Room			**Outlet Device:** Node 2				
Pipe 3 Steel A53 sch 80 Sea Water	2 in 1.939 in 72 ft	4 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -9.71 psi g	-- --	-- -- 5.47
Inlet Device: Lazarette			**Outlet Device:** Node 3				
Pipe 5 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	140 gpm 6.8 ft/s 129856	0.7863 ft 0.7563 ft	-9.36 psi g -9.71 psi g	0.3497 psi 0.3364 psi	0.02021 0.01754 1.05
Inlet Device: Node 2			**Outlet Device:** Node 3				
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 24 ft	2.5 ft 9.5 ft	140 gpm 6.8 ft/s 129856	1.442 ft 0 ft	3.754 psi g 0 psi g	3.754 psi 0 psi	0.02021 0.01754 0.00
Inlet Device: Sizing Pump 1			**Outlet Device:** Pressure Boundary 1				
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft	0 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -8.661 psi g	-- --	-- -- 4.50
Inlet Device: Engine Room			**Outlet Device:** Node 1				

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
Pipe 6 Steel A53 sch 80 Sea Water	3 in 2.9 in 56 ft	2.5 ft 2.5 ft	140 gpm 6.8 ft/s 129856	4.297 ft 0.9328 ft	-9.71 psi g -11.62 psi g	1.911 psi 0.4148 psi	0.02021 0.01754 1.30
Inlet Device: Node 3			Outlet Device: Strainer 3"				
Pipe 9 Steel A53 sch 80 Sea Water	3 in 2.9 in 3 ft	2.5 ft 2.5 ft	140 gpm 6.8 ft/s 129856	0.1803 ft 0 ft	-12.19 psi g -12.27 psi g	0.08017 psi 0 psi	0.02021 0.01754 0.00
Inlet Device: Strainer 3"			Outlet Device: Sizing Pump 1				
Pipe 4 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	140 gpm 6.8 ft/s 129856	0.7863 ft 0.7563 ft	-8.661 psi g -9.011 psi g	0.3497 psi 0.3364 psi	0.02021 0.01754 1.05
Inlet Device: Node 1			Outlet Device: Node 6				
Pipe 11 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	140 gpm 6.8 ft/s 129856	0.7863 ft 0.7563 ft	-9.011 psi g -9.36 psi g	0.3497 psi 0.3364 psi	0.02021 0.01754 1.05
Inlet Device: Node 6			Outlet Device: Node 2				
Pipe 10 Steel A53 sch 80 Sea Water	2 in 1.939 in 21 ft	1 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -9.011 psi g	-- --	-- -- 4.50
Inlet Device: Void1			Outlet Device: Node 6				

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
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
SWBD Room Sea Water	1 ft 1 ft	0 psi g 0.4447 psi g	2 ft	Pipe 1	0 ft	140 gpm	0.4447 psi g
Engine Room	0 ft 1 ft	0 psi g --	--	Pipe 8	0 ft	--	0.4447 psi g
Void1 Sea Water	1 ft 1 ft	0 psi g --	--	Pipe 10	0 ft	--	0.4447 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	2.5 ft	-8.661 psi g	-19.13 ft
Node 2	2.5 ft	-9.36 psi g	-19.27 ft
Node 3	2.5 ft	-9.71 psi g	-20.05 ft
Node 6	2.5 ft	-9.011 psi g	-18.48 ft

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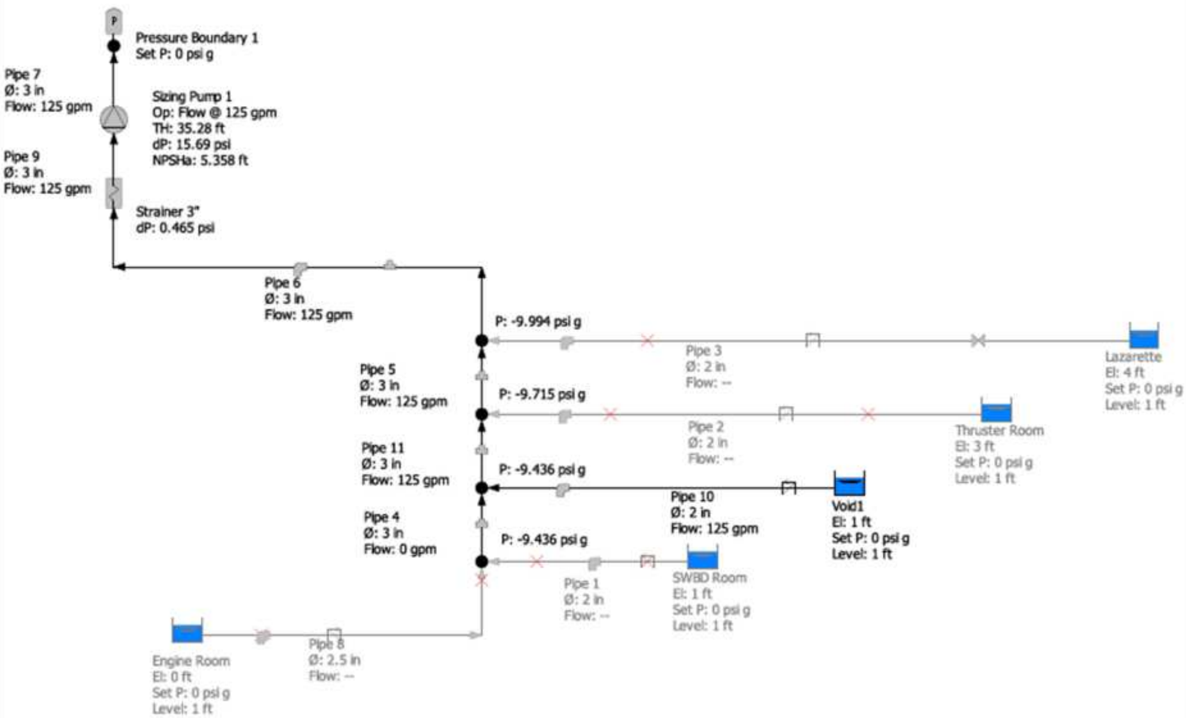
Pressure Boundaries				
Pressure Boundary Name	**Elevation**	**Pressure**	**Hydraulic Grade**	**Flow Rate**
Pressure Boundary 1	9.5 ft	0 psi g	8.781 ft	140 gpm



Project Information

Company: EBDG
Project: 18026
Drawn by: NJB
File Name: 18026-529 Bilge.pipe
Lineup: Void A
Print Date: Thursday, May 17, 2018 10:37 AM

PIPE-FLO Professional

Program Version: 16.0.40539
Calculation Method: Darcy-Weisbach
Maximum Iterations: 100
Iteration Tolerance: 0.01
Laminar Cutoff Re: 2100

Units Used

Flow rate:		**Power:**	
Velocity:	ft/s	**Temperature:**	°F
Pressure:	psi g	**Density:**	lb/ft³
Elevation:	ft	**Viscosity:**	cP
Length:	ft	**Atmospheric Pressure:**	14.7 psi a
Size:	in		

List Report

File Name: 18026-529 Bilge.pipe
Lineup: Void A
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Thursday, May 17, 2018 10:39 AM

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	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
Sea Water Seawater 3.5% Salinity	60 °F	0 psi g	Liquid	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- 29

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -12.06 psi g	2.5 ft 3.631 psi g	35.28 ft 15.69 psi		5.358 ft

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
Pipe 1 Steel A53 sch 80 Sea Water	2 in 1.939 in 6 ft	1 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -9.436 psi g	-- --	-- -- 4.50
	Inlet Device: SWBD Room		Outlet Device: Node 1				
Pipe 2 Steel A53 sch 80 Sea Water	2 in 1.939 in 40 ft	3 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -9.715 psi g	-- --	-- -- 4.78
	Inlet Device: Thruster Room		Outlet Device: Node 2				
Pipe 3 Steel A53 sch 80 Sea Water	2 in 1.939 in 72 ft	4 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -9.994 psi g	-- --	-- -- 5.47
	Inlet Device: Lazarette		Outlet Device: Node 3				
Pipe 5 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	125 gpm 6.072 ft/s 115943	0.6272 ft 0.6029 ft	-9.715 psi g -9.994 psi g	0.2789 psi 0.2681 psi	0.02045 0.01754 1.05
	Inlet Device: Node 2		Outlet Device: Node 3				
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 24 ft	2.5 ft 9.5 ft	125 gpm 6.072 ft/s 115943	1.164 ft 0 ft	3.631 psi g 0 psi g	3.631 psi 0 psi	0.02045 0.01754 0.00
	Inlet Device: Sizing Pump 1		Outlet Device: Pressure Boundary 1				
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft	0 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -9.436 psi g	-- --	-- -- 4.50
	Inlet Device: Engine Room		Outlet Device: Node 1				

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
Pipe 6 Steel A53 sch 80 Sea Water	3 in 2.9 in 56 ft	2.5 ft 2.5 ft	125 gpm 6.072 ft/s 115943	3.459 ft 0.7436 ft	-9.994 psi g -11.53 psi g	1.538 psi 0.3307 psi	0.02045 0.01754 1.30
	Inlet Device: Node 3		**Outlet Device:** Strainer 3"				
Pipe 9 Steel A53 sch 80 Sea Water	3 in 2.9 in 3 ft	2.5 ft 2.5 ft	125 gpm 6.072 ft/s 115943	0.1455 ft 0 ft	-12 psi g -12.06 psi g	0.06469 psi 0 psi	0.02045 0.01754 0.00
	Inlet Device: Strainer 3"		**Outlet Device:** Sizing Pump 1				
Pipe 4 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	0 gpm 0 ft/s 0	0 ft 0 ft	-9.436 psi g -9.436 psi g	0 psi 0 psi	-- 0.01754 1.05
	Inlet Device: Node 1		**Outlet Device:** Node 6				
Pipe 11 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	125 gpm 6.072 ft/s 115943	0.6272 ft 0.6029 ft	-9.436 psi g -9.715 psi g	0.2789 psi 0.2681 psi	0.02045 0.01754 1.05
	Inlet Device: Node 6		**Outlet Device:** Node 2				
Pipe 10 Steel A53 sch 80 Sea Water	2 in 1.939 in 21 ft	1 ft 2.5 ft	125 gpm 13.58 ft/s 173406	20.72 ft 12.91 ft	0.4447 psi g -9.436 psi g	9.881 psi 5.743 psi	0.02095 0.01928 4.50
	Inlet Device: Void1		**Outlet Device:** Node 6				

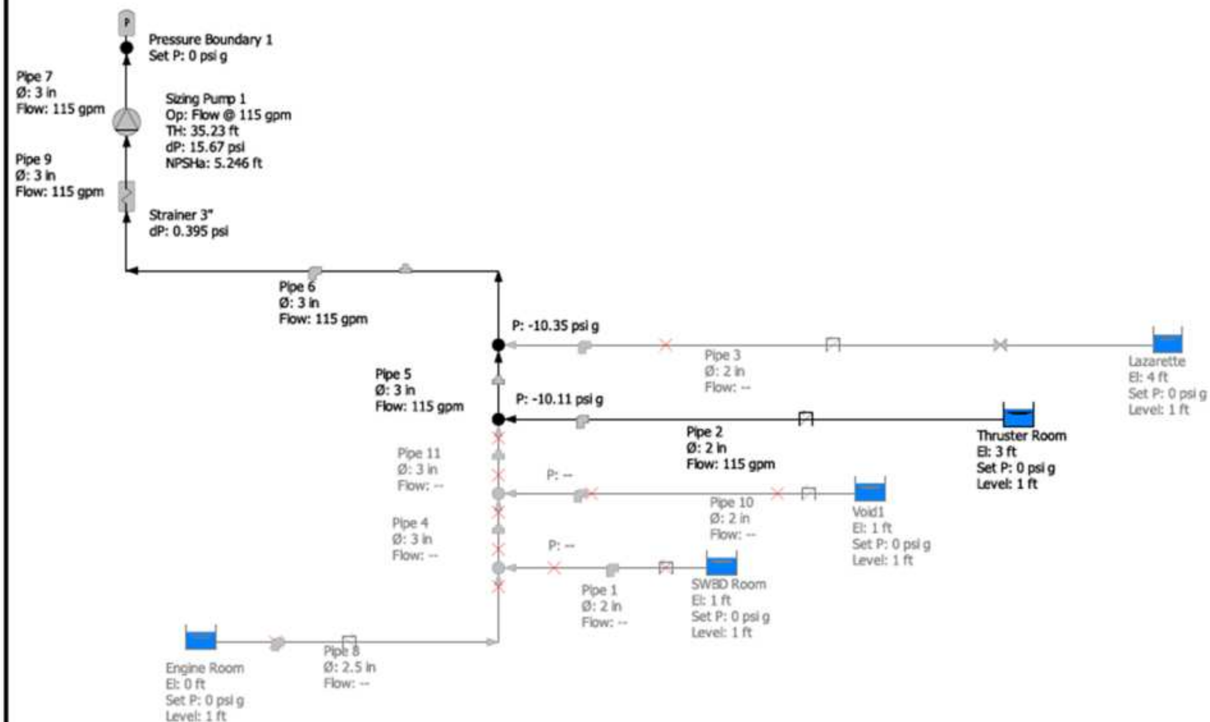
Tanks

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
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
SWBD Room Sea Water	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
Void1 Sea Water	1 ft 1 ft	0 psi g 0.4447 psi g	2 ft	Pipe 10	0 ft	125 gpm	0.4447 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	2.5 ft	-9.436 psi g	-18.72 ft
Node 2	2.5 ft	-9.715 psi g	-19.92 ft
Node 3	2.5 ft	-9.994 psi g	-20.54 ft
Node 6	2.5 ft	-9.436 psi g	-19.86 ft

Pressure Boundaries				
Pressure Boundary Name	**Elevation**	**Pressure**	**Hydraulic Grade**	**Flow Rate**
Pressure Boundary 1	9.5 ft	0 psi g	8.927 ft	125 gpm



Project Information	
Company:	EBDG
Project:	18026
Drawn by:	NJB
File Name:	18026-529 Bilge.pipe
Lineup:	Thruster A
Print Date:	Thursday, May 17, 2018 10:38 AM

PIPE-FLO Professional	
Program Version:	16.0.40539
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used			
Flow rate:		Power:	
Velocity:	ft/s	Temperature:	°F
Pressure:	psi g	Density:	lb/ft³
Elevation:	ft	Viscosity:	cP
Length:	ft	Atmospheric Pressure:	14.7 psi a
Size:	in		

List Report

File Name: 18026-529 Bilge.pipe
Lineup: Thruster A
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Thursday, May 17, 2018 10:39 AM

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	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
Sea Water Seawater 3.5% Salinity	60 °F	0 psi g	Liquid	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- 29

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -12.11 psi g	2.5 ft 3.555 psi g	35.23 ft 15.67 psi		5.246 ft

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
Pipe 1 Steel A53 sch 80 Sea Water	2 in 1.939 in 6 ft	1 ft 2.5 ft	-- -- --	-- --	0.4447 psi g --	-- --	-- -- 4.50
	Inlet Device: SWBD Room		Outlet Device: Node 1				
Pipe 2 Steel A53 sch 80 Sea Water	2 in 1.939 in 40 ft	3 ft 2.5 ft	115 gpm 12.49 ft/s 159534	24.24 ft 11.59 ft	0.4447 psi g -10.11 psi g	10.56 psi 5.152 psi	0.02107 0.01928 4.78
	Inlet Device: Thruster Room		Outlet Device: Node 2				
Pipe 3 Steel A53 sch 80 Sea Water	2 in 1.939 in 72 ft	4 ft 2.5 ft	-- -- --	-- --	0.4447 psi g -10.35 psi g	-- --	-- -- 5.47
	Inlet Device: Lazarette		Outlet Device: Node 3				
Pipe 5 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	115 gpm 5.586 ft/s 106668	0.531 ft 0.5103 ft	-10.11 psi g -10.35 psi g	0.2362 psi 0.227 psi	0.02065 0.01754 1.05
	Inlet Device: Node 2		Outlet Device: Node 3				
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 24 ft	2.5 ft 9.5 ft	115 gpm 5.586 ft/s 106668	0.9944 ft 0 ft	3.555 psi g 0 psi g	3.555 psi 0 psi	0.02065 0.01754 0.00
	Inlet Device: Sizing Pump 1		Outlet Device: Pressure Boundary 1				
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft	0 ft 2.5 ft	-- -- --	-- --	0.4447 psi g --	-- --	-- -- 4.50
	Inlet Device: Engine Room		Outlet Device: Node 1				

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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
Pipe 6 Steel A53 sch 80 Sea Water	3 in 2.9 in 56 ft **Inlet Device:** Node 3	2.5 ft 2.5 ft	115 gpm 5.586 ft/s 106668 **Outlet Device:** Strainer 3"	2.95 ft 0.6294 ft	-10.35 psi g -11.66 psi g	1.312 psi 0.2799 psi	0.02065 0.01754 1.30
Pipe 9 Steel A53 sch 80 Sea Water	3 in 2.9 in 3 ft **Inlet Device:** Strainer 3"	2.5 ft 2.5 ft	115 gpm 5.586 ft/s 106668 **Outlet Device:** Sizing Pump 1	0.1243 ft 0 ft	-12.06 psi g -12.11 psi g	0.05528 psi 0 psi	0.02065 0.01754 0.00
Pipe 4 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft **Inlet Device:** Node 1	2.5 ft 2.5 ft	-- -- -- **Outlet Device:** Node 6	-- --	-- --	-- --	-- -- 1.05
Pipe 11 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft **Inlet Device:** Node 6	2.5 ft 2.5 ft	-- -- -- **Outlet Device:** Node 2	-- --	-- -10.11 psi g	-- --	-- -- 1.05
Pipe 10 Steel A53 sch 80 Sea Water	2 in 1.939 in 21 ft **Inlet Device:** Void1	1 ft 2.5 ft	-- -- -- **Outlet Device:** Node 6	-- --	0.4447 psi g --	-- --	-- -- 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
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	115 gpm	0.4447 psi g
SWBD Room Sea Water	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
Void1 Sea Water	1 ft 1 ft	0 psi g --	--	Pipe 10	0 ft	--	0.4447 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	2.5 ft	--	--
Node 2	2.5 ft	-10.11 psi g	-21.7 ft
Node 3	2.5 ft	-10.35 psi g	-21.26 ft
Node 6	2.5 ft	--	--

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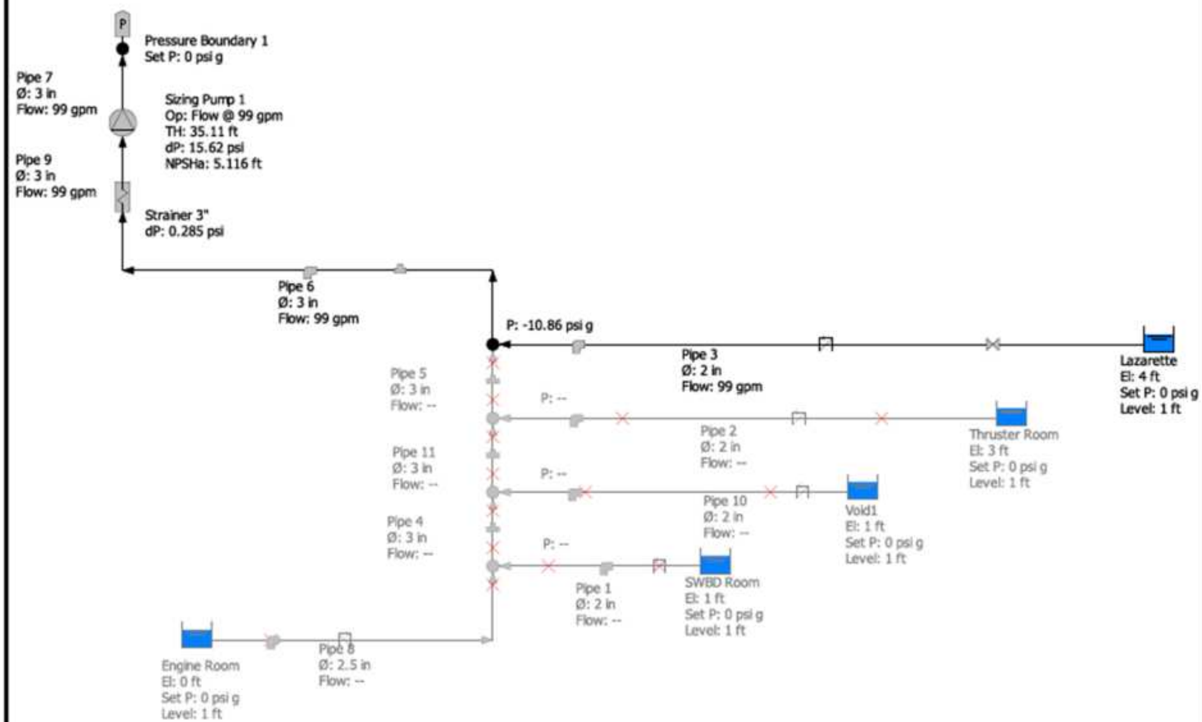
Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psi g	9.015 ft	115 gpm



Project Information

Company: EBDG
Project: 18026
Drawn by: NJB
File Name: 18026-529 Bilge.pipe
Lineup: Lazarette
Print Date: Thursday, May 17, 2018 10:38 AM

PIPE-FLO Professional	
Program Version:	16.0.40539
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used			
Flow rate:		**Power:**	
Velocity:	ft/s	**Temperature:**	°F
Pressure:	psi g	**Density:**	lb/ft³
Elevation:	ft	**Viscosity:**	cP
Length:	ft	**Atmospheric Pressure:**	14.7 psi a
Size:	in		

List Report

File Name: 18026-529 Bilge.pipe
Lineup: Lazarette
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Thursday, May 17, 2018 10:40 AM

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	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
Sea Water Seawater 3.5% Salinity	60 °F	0 psi g	Liquid	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- 29

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	2.5 ft -12.17 psi g	2.5 ft 3.447 psi g	35.11 ft 15.62 psi		5.116 ft

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
Pipe 1 Steel A53 sch 80 Sea Water	2 in 1.939 in 6 ft	1 ft 2.5 ft	-- -- --	-- --	0.4447 psi g --	-- --	-- -- 4.50
Inlet Device: SWBD Room			**Outlet Device:** Node 1				
Pipe 2 Steel A53 sch 80 Sea Water	2 in 1.939 in 40 ft	3 ft 2.5 ft	-- -- --	-- --	0.4447 psi g --	-- --	-- -- 4.78
Inlet Device: Thruster Room			**Outlet Device:** Node 2				
Pipe 3 Steel A53 sch 80 Sea Water	2 in 1.939 in 72 ft	4 ft 2.5 ft	99 gpm 10.76 ft/s 137338	26.91 ft 9.834 ft	0.4447 psi g -10.86 psi g	11.3 psi 4.374 psi	0.02132 0.01928 5.47
Inlet Device: Lazarette			**Outlet Device:** Node 3				
Pipe 5 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	-- -- --	-- --	-- -10.86 psi g	-- --	-- -- 1.05
Inlet Device: Node 2			**Outlet Device:** Node 3				
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 24 ft	2.5 ft 9.5 ft	99 gpm 4.809 ft/s 91827	0.7503 ft 0 ft	3.447 psi g 0 psi g	3.447 psi 0 psi	0.02103 0.01754 0.00
Inlet Device: Sizing Pump 1			**Outlet Device:** Pressure Boundary 1				
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft	0 ft 2.5 ft	-- -- --	-- --	0.4447 psi g --	-- --	-- -- 4.50
Inlet Device: Engine Room			**Outlet Device:** Node 1				

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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
Pipe 6 Steel A53 sch 80 Sea Water	3 in 2.9 in 56 ft	2.5 ft 2.5 ft	99 gpm 4.809 ft/s 91827	2.217 ft 0.4664 ft	-10.86 psi g -11.84 psi g	0.9861 psi 0.2074 psi	0.02103 0.01754 1.30
	Inlet Device: Node 3		**Outlet Device:** Strainer 3"				
Pipe 9 Steel A53 sch 80 Sea Water	3 in 2.9 in 3 ft	2.5 ft 2.5 ft	99 gpm 4.809 ft/s 91827	0.09379 ft 0 ft	-12.13 psi g -12.17 psi g	0.04171 psi 0 psi	0.02103 0.01754 0.00
	Inlet Device: Strainer 3"		**Outlet Device:** Sizing Pump 1				
Pipe 4 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	-- -- --	-- --	-- --	-- --	-- -- 1.05
	Inlet Device: Node 1		**Outlet Device:** Node 6				
Pipe 11 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft	2.5 ft 2.5 ft	-- -- --	-- --	-- --	-- --	-- -- 1.05
	Inlet Device: Node 6		**Outlet Device:** Node 2				
Pipe 10 Steel A53 sch 80 Sea Water	2 in 1.939 in 21 ft	1 ft 2.5 ft	-- -- --	-- --	0.4447 psi g --	-- --	-- -- 4.50
	Inlet Device: Void1		**Outlet Device:** Node 6				

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
Lazarette Sea Water	4 ft 1 ft	0 psi g 0.4447 psi g	5 ft	Pipe 3	0 ft	99 gpm	0.4447 psi g
Thruster Room Sea Water	3 ft 1 ft	0 psi g --	--	Pipe 2	0 ft	--	0.4447 psi g
SWBD Room Sea Water	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
Void1 Sea Water	1 ft 1 ft	0 psi g --	--	Pipe 10	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	-10.86 psi g	-22.99 ft
Node 6	2.5 ft	--	--

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psi g	9.141 ft	99 gpm

Bill of Materials Report

File Name: 18026-529 Bilge.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 16.0.40539

Company: EBDG
Project: 18026
by: NJB
Date: Thursday, May 17, 2018 10:40 AM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	Steel A53 sch 80	2 in	6 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 - :
Pipe 2	Steel A53 sch 80	2 in	40 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 - :
Pipe 3	Steel A53 sch 80	2 in	72 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 - :
Pipe 5	Steel A53 sch 80	3 in	0.5 ft	1 x Tee - Flow Thru Branch
Pipe 7	Steel A53 sch 80	3 in	24 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
Pipe 6	Steel A53 sch 80	3 in	56 ft	1 x Elbow - Long radius, r/d 1.5 (90°) 1 x Tee - Flow Thru Branch
Pipe 9	Steel A53 sch 80	3 in	3 ft	
Pipe 4	Steel A53 sch 80	3 in	0.5 ft	1 x Tee - Flow Thru Branch
Pipe 11	Steel A53 sch 80	3 in	0.5 ft	1 x Tee - Flow Thru Branch
Pipe 10	Steel A53 sch 80	2 in	21 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 - :

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Steel A53 sch 80	Steel A53-B36.10 Schedule: 80	2 in	139.00 ft	12 x Elbow - Long radius, r/d 1.5 (90°) 1 x Gate - Wedge Disc 4 x Reducer - Enlargement (2 in x 3 in - 3.5 in) 4 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	84.50 ft	1 x Elbow - Long radius, r/d 1.5 (90°) 4 x Tee - Flow Thru Branch

Appendix I

Ballast System, Dwg. 18026-200-529-1

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 [1] [2].
- 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	Schedule	d, ID	Design Velocity			V
					Nominal		Limit	
	gpm	(NPS)		in	ft/s		ft/s	ft/s
Ballast Pump Suction (1 pump)	**200**	**4**	**CL 200**	4.282	$3.0\sqrt{d}$	6.21	12	4.46
Ballast Pump Discharge (1 pump)	**200**	**4**	**CL 200**	4.282	$5.0\sqrt{d}$	10.35	12	4.46
Ballast Loading (1 tank)	**100**	**3**	**CL 200**	3.310	$5.0\sqrt{d}$	9.10	12	3.73
Ballast Unloading (1 tank)	**100**	**3**	**CL 200**	3.310	$3.0\sqrt{d}$	5.46	12	3.73
Ballast Main Suction (2 pumps)	**400**	**4**	**CL 200**	4.282	$3.0\sqrt{d}$	6.21	12	8.91
Ballast Main Discharge (2 pumps)	**400**	**4**	**CL 200**	4.282	$5.0\sqrt{d}$	10.35	12	8.91

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.

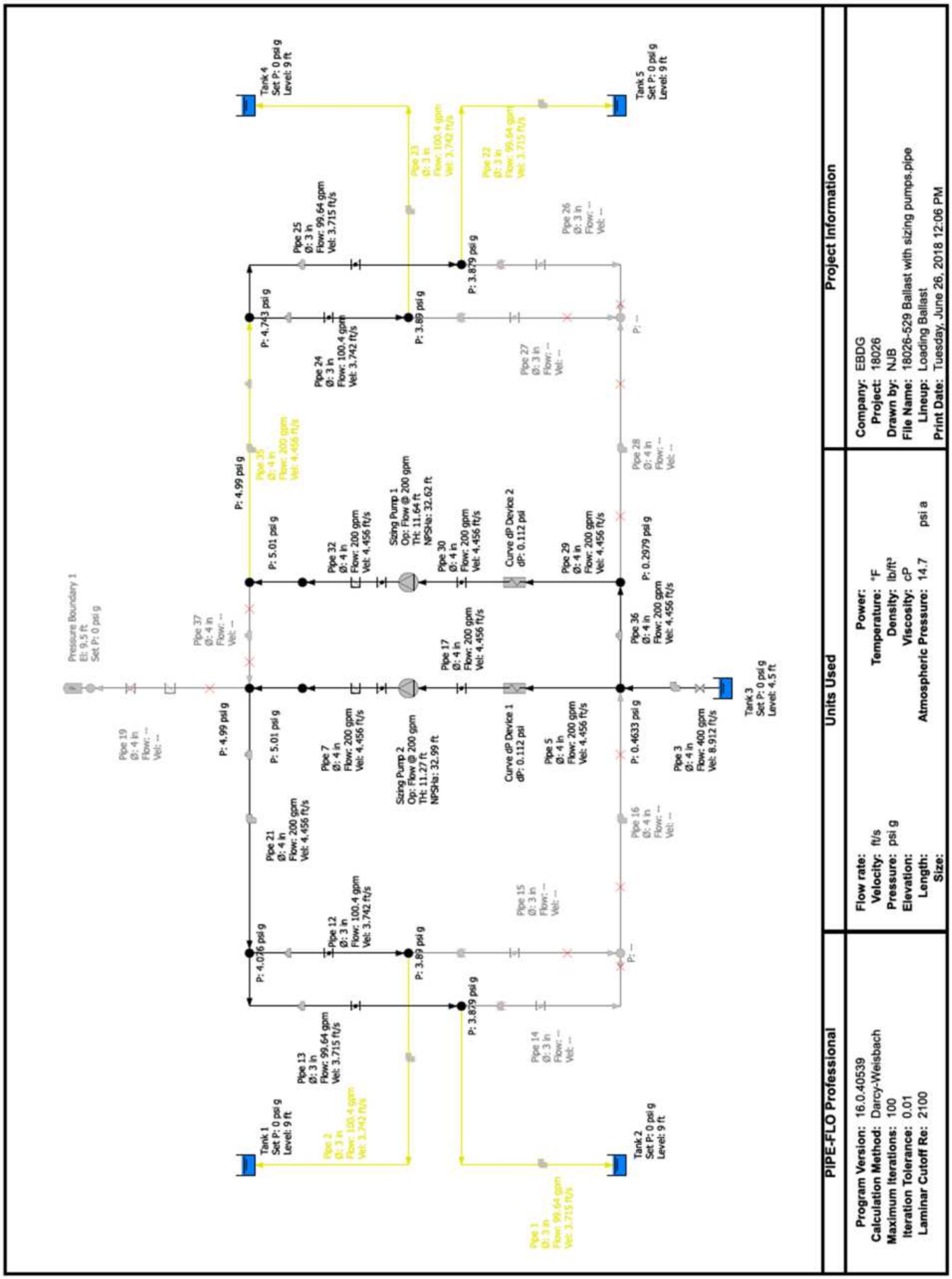
6 REFERENCES

[1] Elliott Bay Design Group, "NCDOT Z-Drive Ferry: Profiles and Arrangements," 18026-200-101-1, Seattle, WA.

[2] Elliott Bay Design Group, "NCDOT Z-Drive Ferry: Bilge and Ballast System Schematic," 18026-200-529-1, Seattle, WA.

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

BALLAST SYSTEM PIPE-FLO MODEL



List Report

File Name: 18026-529 Ballast with sizing pumps.pipe
Lineup: Loading Ballast
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Tuesday, June 26, 2018 12:07 PM

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
Copper Nickel Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	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
Sea Water Seawater 3.5% Salinity	60 °F	0 psi g	Liquid	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- 29

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 2	2.5 ft 0.2289 psi g	2.5 ft 5.239 psi g	11.27 ft 5.01 psi		32.99 ft
Sizing Pump 1	2.5 ft 0.06345 psi g	2.5 ft 5.239 psi g	11.64 ft 5.176 psi		32.62 ft

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
Pipe 1 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	99.64 gpm 3.715 ft/s 80970	1.723 ft 0.4739 ft	4.003 psi g 3.879 psi g	-0.1234 psi 0.2108 psi	0.01889 0.01702 2.21
Inlet Device: Tank 2			**Outlet Device:** Node 1				
Pipe 2 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	100.4 gpm 3.742 ft/s 81561	1.746 ft 0.4808 ft	4.003 psi g 3.89 psi g	-0.113 psi 0.2138 psi	0.01887 0.01702 2.21
Inlet Device: Tank 1			**Outlet Device:** Node 2				
Pipe 12 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	4 ft 4 ft	100.4 gpm 3.742 ft/s 81561	0.4186 ft 0.3889 ft	4.076 psi g 3.89 psi g	0.1862 psi 0.1729 psi	0.01887 0.01702 1.79
Inlet Device: Node 7			**Outlet Device:** Node 2				
Pipe 13 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	4 ft 4 ft	99.64 gpm 3.715 ft/s 80970	0.442 ft 0.3832 ft	4.076 psi g 3.879 psi g	0.1966 psi 0.1704 psi	0.01889 0.01702 1.79
Inlet Device: Node 7			**Outlet Device:** Node 1				
Pipe 14 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	4 ft 4 ft	-- -- --	-- --	3.879 psi g --	-- --	-- -- 1.79
Inlet Device: Node 1			**Outlet Device:** Node 8				

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
Pipe 15 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	4 ft 4 ft	-- -- --	-- --	3.89 psi g --	-- --	-- -- 1.79
	Inlet Device: Node 2		**Outlet Device:** Node 8				
Pipe 16 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	4 ft 2.5 ft	-- -- --	-- --	-- 0.4633 psi g	-- --	-- -- 0.45
	Inlet Device: Node 8		**Outlet Device:** Node 4				
Pipe 5 Copper Nickel Class 200 Sea Water	4 in 4.282 in 1.5 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.02237 ft 0 ft	0.4633 psi g 0.4534 psi g	9.949E-03 psi 0 psi	0.01725 0.01607 0.00
	Inlet Device: Node 4		**Outlet Device:** Curve dP Device 1				
Pipe 17 Copper Nickel Class 200 Sea Water	4 in 4.282 in 2 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.2529 ft 0.2231 ft	0.3414 psi g 0.2289 psi g	0.1125 psi 0.09921 psi	0.01725 0.01607 0.72
	Inlet Device: Curve dP Device 1		**Outlet Device:** Sizing Pump 2				
Pipe 3 Copper Nickel Class 200 Sea Water	4 in 4.282 in 10 ft	0 ft 2.5 ft	400 gpm 8.912 ft/s 251273	0.9582 ft 0.4363 ft	2.001 psi g 0.4633 psi g	1.538 psi 0.194 psi	0.01509 0.01607 0.35
	Inlet Device: Tank 3		**Outlet Device:** Node 4				
Pipe 7 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.5157 ft 0.471 ft	5.239 psi g 5.01 psi g	0.2293 psi 0.2095 psi	0.01725 0.01607 1.53
	Inlet Device: Sizing Pump 2		**Outlet Device:** Sizing Valve 5				
Pipe 20 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.04474 ft 0 ft	5.01 psi g 4.99 psi g	0.0199 psi 0 psi	0.01725 0.01607 0.00
	Inlet Device: Sizing Valve 5		**Outlet Device:** Node 5				
Pipe 22 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	99.64 gpm 3.715 ft/s 80970	1.723 ft 0.4739 ft	4.003 psi g 3.879 psi g	-0.1234 psi 0.2108 psi	0.01889 0.01702 2.21
	Inlet Device: Tank 5		**Outlet Device:** Node 9				
Pipe 23 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	100.4 gpm 3.742 ft/s 81561	1.746 ft 0.4808 ft	4.003 psi g 3.89 psi g	-0.113 psi 0.2138 psi	0.01887 0.01702 2.21
	Inlet Device: Tank 4		**Outlet Device:** Node 10				
Pipe 29 Copper Nickel Class 200 Sea Water	4 in 4.282 in 1.5 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.02237 ft 0 ft	0.2979 psi g 0.2879 psi g	9.949E-03 psi 0 psi	0.01725 0.01607 0.00
	Inlet Device: Node 15		**Outlet Device:** Curve dP Device 2				
Pipe 30 Copper Nickel Class 200 Sea Water	4 in 4.282 in 2 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.2529 ft 0.2231 ft	0.1759 psi g 0.06345 psi g	0.1125 psi 0.09921 psi	0.01725 0.01607 0.72
	Inlet Device: Curve dP Device 2		**Outlet Device:** Sizing Pump 1				

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
Pipe 32 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft **Inlet Device:** Sizing Pump 1	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637 **Outlet Device:** Sizing Valve 7	0.5157 ft 0.471 ft	5.239 psi g 5.01 psi g	0.2293 psi 0.2095 psi	0.01725 0.01607 1.53
Pipe 33 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft **Inlet Device:** Sizing Valve 7	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637 **Outlet Device:** Node 16	0.04474 ft 0 ft	5.01 psi g 4.99 psi g	0.0199 psi 0 psi	0.01725 0.01607 0.00
Pipe 28 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft **Inlet Device:** Node 15	2.5 ft 2.5 ft	-- -- -- **Outlet Device:** Node 11	-- --	0.2979 psi g --	-- --	-- -- 0.45
Pipe 24 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft **Inlet Device:** Sizing Valve 8	2.5 ft 4 ft	100.4 gpm 3.742 ft/s 81561 **Outlet Device:** Node 10	0.4186 ft 0.3889 ft	4.743 psi g 3.89 psi g	0.8533 psi 0.1729 psi	0.01887 0.01702 1.79
Pipe 25 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft **Inlet Device:** Sizing Valve 8	2.5 ft 4 ft	99.64 gpm 3.715 ft/s 80970 **Outlet Device:** Node 9	0.442 ft 0.3832 ft	4.743 psi g 3.879 psi g	0.8637 psi 0.1704 psi	0.01889 0.01702 1.79
Pipe 26 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft **Inlet Device:** Node 9	4 ft 2.5 ft	-- -- -- **Outlet Device:** Node 11	-- --	3.879 psi g --	-- --	-- -- 1.79
Pipe 27 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft **Inlet Device:** Node 10	4 ft 2.5 ft	-- -- -- **Outlet Device:** Node 11	-- --	3.89 psi g --	-- --	-- -- 1.79
Pipe 36 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft **Inlet Device:** Node 4	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637 **Outlet Device:** Node 15	0.372 ft 0.2974 ft	0.4633 psi g 0.2979 psi g	0.1654 psi 0.1323 psi	0.01725 0.01607 0.96
Pipe 37 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft **Inlet Device:** Node 16	2.5 ft 2.5 ft	-- -- -- **Outlet Device:** Node 5	-- --	4.99 psi g 4.99 psi g	-- --	-- -- 0.96
Pipe 21 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft **Inlet Device:** Node 5	2.5 ft 4 ft	200 gpm 4.456 ft/s 125637 **Outlet Device:** Node 7	0.5556 ft 0.4363 ft	4.99 psi g 4.076 psi g	0.9142 psi 0.194 psi	0.01725 0.01607 1.41
Pipe 35 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft **Inlet Device:** Sizing Valve 8	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637 **Outlet Device:** Node 16	0.5556 ft 0.4363 ft	4.743 psi g 4.99 psi g	0.2471 psi 0.194 psi	0.01725 0.01607 1.41

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
Pipe 19 Copper Nickel Class 200 Sea Water	4 in 4.282 in 15 ft	2.5 ft 9.5 ft	-- -- --	-- --	4.99 psi g 0 psi g	-- --	-- -- 2.53
Inlet Device: Node 5			Outlet Device: Pressure Boundary 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
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 0.4534 psi g	2.5 ft 0.3414 psi g	0.112 psi 0.2518 ft	200 gpm
Curve dP Device 2 Eaton model 72	2.5 ft 0.2879 psi g	2.5 ft 0.1759 psi g	0.112 psi 0.2518 ft	200 gpm

Nodes

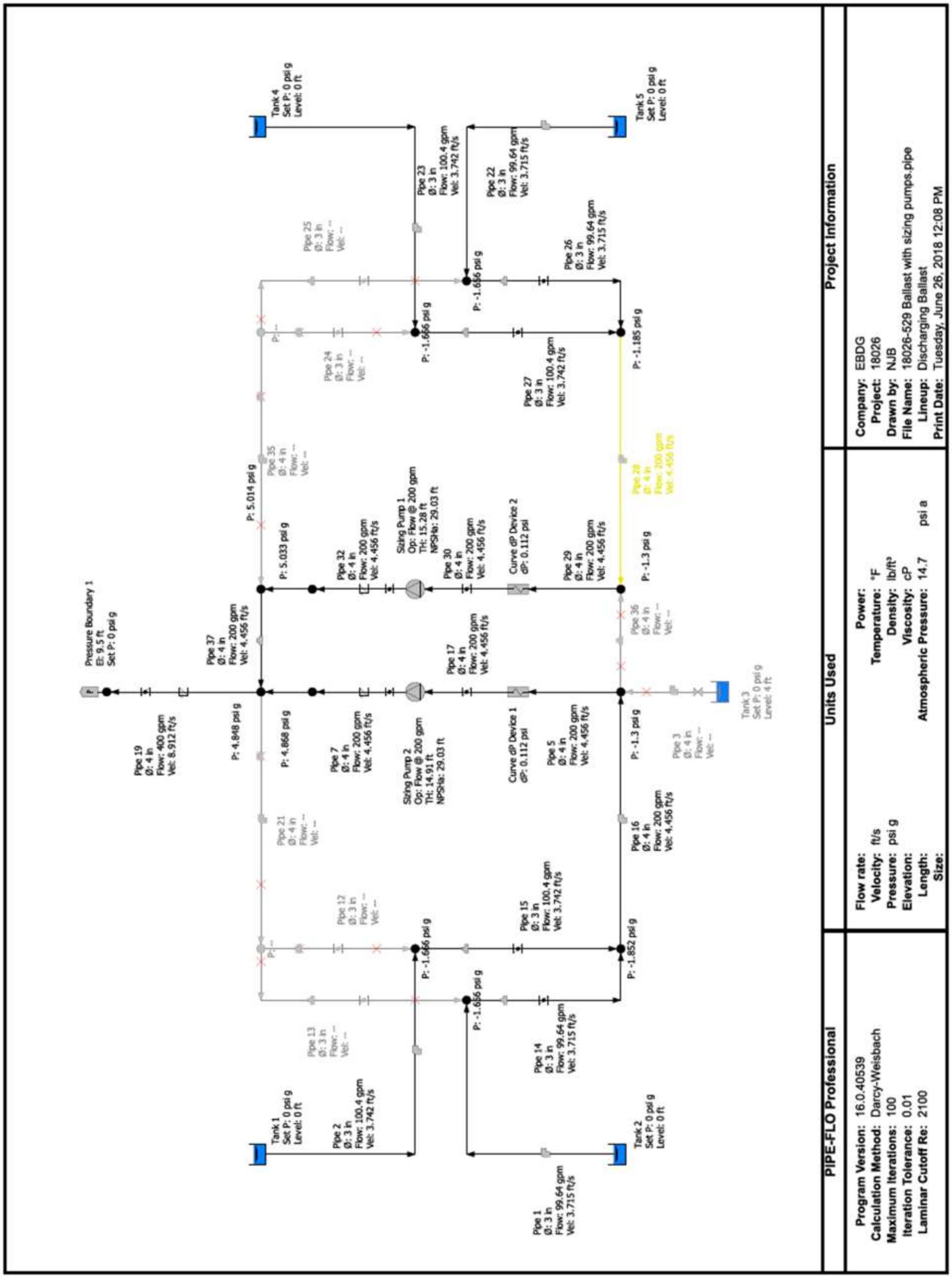
Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	4 ft	3.879 psi g	12.51 ft
Node 2	4 ft	3.89 psi g	12.53 ft
Node 4	2.5 ft	0.4633 psi g	2.925 ft
Node 5	2.5 ft	4.99 psi g	13.41 ft
Node 7	4 ft	4.076 psi g	12.92 ft
Node 8	4 ft	--	--
Sizing Valve 5	2.5 ft	5.01 psi g	13.46 ft
Node 9	4 ft	3.879 psi g	12.51 ft
Node 10	4 ft	3.89 psi g	12.53 ft
Node 15	2.5 ft	0.2979 psi g	2.861 ft

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 16	2.5 ft	4.99 psi g	13.41 ft
Sizing Valve 7	2.5 ft	5.01 psi g	13.46 ft
Node 11	2.5 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	--	--


PIPE-FLO Professional
Program Version: 16.0.40539
Calculation Method: Darcy-Weisbach
Maximum Iterations: 100
Iteration Tolerance: 0.01
Laminar Cutoff Re: 2100
Units Used
Flow rate:
Velocity: ft/s
Pressure: psi g
Elevation:
Length:
Size:
Power:
Temperature: °F
Density: lb/ft³
Viscosity: cP
Atmospheric Pressure: 14.7 psi a
Project Information
Company: EBDG
Project: 18026
Drawn by: NJB
File Name: 18026-529 Ballast with sizing pumps.pipe
Lineup: Discharging Ballast
Print Date: Tuesday, June 26, 2018 12:08 PM
Tank 1
Set P: 0 psi g
Level: 0 ft
Tank 2
Set P: 0 psi g
Level: 0 ft
Tank 3
Set P: 0 psi g
Level: 4 ft
Tank 4
Set P: 0 psi g
Level: 0 ft
Tank 5
Set P: 0 psi g
Level: 0 ft
Pressure Boundary 1
El: 9.5 ft
Set P: 0 psi g
Sizing Pump 1
Op: Flow @ 200 gpm
TH: 15.28 ft
NPSHa: 29.03 ft
Sizing Pump 2
Op: Flow @ 200 gpm
TH: 14.91 ft
NPSHa: 29.03 ft
Curve dP Device 1
dP: 0.112 psi
Curve dP Device 2
dP: 0.112 psi
Pipe 19
Ø: 4 in
Flow: 400 gpm
Vel: 8.912 ft/s

List Report

File Name: 18026-529 Ballast with sizing pumps.pipe
Lineup: Discharging Ballast
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Tuesday, June 26, 2018 12:09 PM

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
Copper Nickel Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	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
Sea Water Seawater 3.5% Salinity	60 °F	0 psi g	Liquid	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- 29

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 2	2.5 ft -1.534 psi g	2.5 ft 5.097 psi g	14.91 ft 6.632 psi		29.03 ft
Sizing Pump 1	2.5 ft -1.534 psi g	2.5 ft 5.263 psi g	15.28 ft 6.797 psi		29.03 ft

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
Pipe 1 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	99.64 gpm 3.715 ft/s 80970	1.723 ft 0.4739 ft	0 psi g -1.656 psi g	1.656 psi 0.2108 psi	0.01889 0.01702 2.21
	Inlet Device: Tank 2		Outlet Device: Node 1				
Pipe 2 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	100.4 gpm 3.742 ft/s 81561	1.746 ft 0.4808 ft	0 psi g -1.666 psi g	1.666 psi 0.2138 psi	0.01887 0.01702 2.21
	Inlet Device: Tank 1		Outlet Device: Node 2				
Pipe 12 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	4 ft 4 ft	-- -- --	-- --	-- -1.666 psi g	-- --	-- -- 1.79
	Inlet Device: Node 7		Outlet Device: Node 2				
Pipe 13 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	4 ft 4 ft	-- -- --	-- --	-- -1.656 psi g	-- --	-- -- 1.79
	Inlet Device: Node 7		Outlet Device: Node 1				
Pipe 14 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	4 ft 4 ft	99.64 gpm 3.715 ft/s 80970	0.442 ft 0.3832 ft	-1.656 psi g -1.852 psi g	0.1966 psi 0.1704 psi	0.01889 0.01702 1.79
	Inlet Device: Node 1		Outlet Device: Node 8				

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
Pipe 15 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	4 ft 4 ft	100.4 gpm 3.742 ft/s 81561	0.4186 ft 0.3889 ft	-1.666 psi g -1.852 psi g	0.1862 psi 0.1729 psi	0.01887 0.01702 1.79
	Inlet Device: Node 2		**Outlet Device:** Node 8				
Pipe 16 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	4 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.2581 ft 0.1388 ft	-1.852 psi g -1.3 psi g	-0.5523 psi 0.06173 psi	0.01725 0.01607 0.45
	Inlet Device: Node 8		**Outlet Device:** Node 4				
Pipe 5 Copper Nickel Class 200 Sea Water	4 in 4.282 in 1.5 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.02237 ft 0 ft	-1.3 psi g -1.31 psi g	9.949E-03 psi 0 psi	0.01725 0.01607 0.00
	Inlet Device: Node 4		**Outlet Device:** Curve dP Device 1				
Pipe 17 Copper Nickel Class 200 Sea Water	4 in 4.282 in 2 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.2529 ft 0.2231 ft	-1.422 psi g -1.534 psi g	0.1125 psi 0.09921 psi	0.01725 0.01607 0.72
	Inlet Device: Curve dP Device 1		**Outlet Device:** Sizing Pump 2				
Pipe 3 Copper Nickel Class 200 Sea Water	4 in 4.282 in 10 ft	0 ft 2.5 ft	-- -- --	-- --	1.779 psi g -1.3 psi g	-- --	-- -- 0.35
	Inlet Device: Tank 3		**Outlet Device:** Node 4				
Pipe 7 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.5157 ft 0.471 ft	5.097 psi g 4.868 psi g	0.2293 psi 0.2095 psi	0.01725 0.01607 1.53
	Inlet Device: Sizing Pump 2		**Outlet Device:** Sizing Valve 5				
Pipe 20 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.04474 ft 0 ft	4.868 psi g 4.848 psi g	0.0199 psi 0 psi	0.01725 0.01607 0.00
	Inlet Device: Sizing Valve 5		**Outlet Device:** Node 5				
Pipe 22 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	99.64 gpm 3.715 ft/s 80970	1.723 ft 0.4739 ft	0 psi g -1.656 psi g	1.656 psi 0.2108 psi	0.01889 0.01702 2.21
	Inlet Device: Tank 5		**Outlet Device:** Node 9				
Pipe 23 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	100.4 gpm 3.742 ft/s 81561	1.746 ft 0.4808 ft	0 psi g -1.666 psi g	1.666 psi 0.2138 psi	0.01887 0.01702 2.21
	Inlet Device: Tank 4		**Outlet Device:** Node 10				
Pipe 29 Copper Nickel Class 200 Sea Water	4 in 4.282 in 1.5 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.02237 ft 0 ft	-1.3 psi g -1.31 psi g	9.949E-03 psi 0 psi	0.01725 0.01607 0.00
	Inlet Device: Node 15		**Outlet Device:** Curve dP Device 2				
Pipe 30 Copper Nickel Class 200 Sea Water	4 in 4.282 in 2 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.2529 ft 0.2231 ft	-1.422 psi g -1.534 psi g	0.1125 psi 0.09921 psi	0.01725 0.01607 0.72
	Inlet Device: Curve dP Device 2		**Outlet Device:** Sizing Pump 1				

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	Inlet Device	Outlet Device
Pipe 32 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.5157 ft 0.471 ft	5.263 psi g 5.033 psi g	0.2293 psi 0.2095 psi	0.01725 0.01607 1.53	Sizing Pump 1	Sizing Valve 7
Pipe 33 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.04474 ft 0 ft	5.033 psi g 5.014 psi g	0.0199 psi 0 psi	0.01725 0.01607 0.00	Sizing Valve 7	Node 16
Pipe 28 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.2581 ft 0.1388 ft	-1.3 psi g -1.185 psi g	0.1148 psi 0.06173 psi	0.01725 0.01607 0.45	Node 15	Node 11
Pipe 24 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	2.5 ft 4 ft	-- -- --	-- --	-- -1.666 psi g	-- --	-- -- 1.79	Sizing Valve 8	Node 10
Pipe 25 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	2.5 ft 4 ft	-- -- --	-- --	-- -1.656 psi g	-- --	-- -- 1.79	Sizing Valve 8	Node 9
Pipe 26 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	4 ft 2.5 ft	99.64 gpm 3.715 ft/s 80970	0.442 ft 0.3832 ft	-1.656 psi g -1.185 psi g	-0.4705 psi 0.1704 psi	0.01889 0.01702 1.79	Node 9	Node 11
Pipe 27 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	4 ft 2.5 ft	100.4 gpm 3.742 ft/s 81561	0.4186 ft 0.3889 ft	-1.666 psi g -1.185 psi g	-0.4809 psi 0.1729 psi	0.01887 0.01702 1.79	Node 10	Node 11
Pipe 36 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	2.5 ft 2.5 ft	-- -- --	-- --	-1.3 psi g -1.3 psi g	-- --	-- -- 0.96	Node 4	Node 15
Pipe 37 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.372 ft 0.2974 ft	5.014 psi g 4.848 psi g	0.1654 psi 0.1323 psi	0.01725 0.01607 0.96	Node 16	Node 5
Pipe 21 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	2.5 ft 4 ft	-- -- --	-- --	4.848 psi g --	-- --	-- -- 1.41	Node 5	Node 7
Pipe 35 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	2.5 ft 2.5 ft	-- -- --	-- --	-- 5.014 psi g	-- --	-- -- 1.41	Sizing Valve 8	Node 16

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
Pipe 19 Copper Nickel Class 200 Sea Water	4 in 4.282 in 15 ft	2.5 ft 9.5 ft	400 gpm 8.912 ft/s 251273	3.901 ft 3.118 ft	4.848 psi g 0 psi g	4.848 psi 1.387 psi	0.01509 0.01607 2.53
Inlet Device: Node 5			**Outlet Device:** Pressure Boundary 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
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

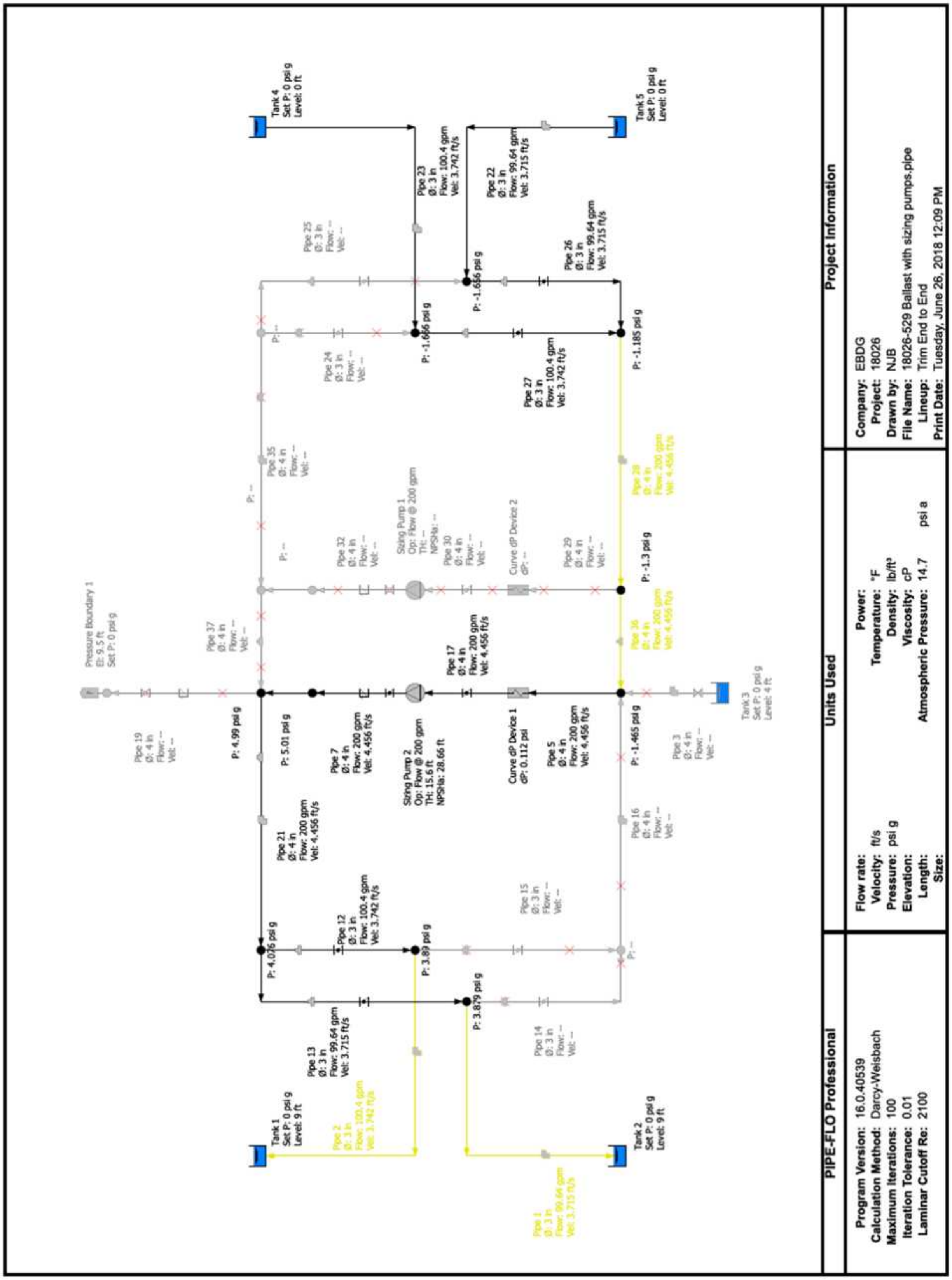
Curve dP Device Name Description	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss	Flow Rate
Curve dP Device 1 Eaton model 72	2.5 ft -1.31 psi g	2.5 ft -1.422 psi g	0.112 psi 0.2518 ft	200 gpm
Curve dP Device 2 Eaton model 72	2.5 ft -1.31 psi g	2.5 ft -1.422 psi g	0.112 psi 0.2518 ft	200 gpm

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	4 ft	-1.656 psi g	0.06294 ft
Node 2	4 ft	-1.666 psi g	0.03646 ft
Node 4	2.5 ft	-1.3 psi g	-0.7313 ft
Node 5	2.5 ft	4.848 psi g	12.78 ft
Node 7	4 ft	--	--
Node 8	4 ft	-1.852 psi g	-0.4115 ft
Sizing Valve 5	2.5 ft	4.868 psi g	13.14 ft
Node 9	4 ft	-1.656 psi g	0.06294 ft
Node 10	4 ft	-1.666 psi g	0.03646 ft
Node 15	2.5 ft	-1.3 psi g	-0.7313 ft

Nodes			
Node Name	**Elevation**	**Pressure**	**Hydraulic Grade**
Node 16	2.5 ft	5.014 psi g	13.46 ft
Sizing Valve 7	2.5 ft	5.033 psi g	13.51 ft
Node 11	2.5 ft	-1.185 psi g	-0.4115 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


PIPE-FLO Professional
Program Version: 16.0.40539
Calculation Method: Darcy-Weisbach
Maximum Iterations: 100
Iteration Tolerance: 0.01
Laminar Cutoff Re: 2100
Units Used
Flow rate:
Velocity: ft/s
Pressure: psi g
Elevation:
Length:
Size:
Power:
Temperature: °F
Density: lb/ft³
Viscosity: cP
Atmospheric Pressure: 14.7 psi a
Project Information
Company: EBDG
Project: 18026
Drawn by: NJB
File Name: 18026-529 Ballast with sizing pumps.pipe
Lineup: Trim End to End
Print Date: Tuesday, June 26, 2018 12:09 PM

List Report

File Name: 18026-529 Ballast with sizing pumps.pipe
Lineup: Trim End to End
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Tuesday, June 26, 2018 12:09 PM

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
Copper Nickel Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	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
Sea Water Seawater 3.5% Salinity	60 °F	0 psi g	Liquid	64.04 lb/ft³ 1.206 cP	0.2513 psi a 3199 psi a	-- 29

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 2	2.5 ft -1.7 psi g	2.5 ft 5.239 psi g	15.6 ft 6.939 psi		28.66 ft
Sizing Pump 1	2.5 ft --	2.5 ft --	-- --		--

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
Pipe 1 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	99.64 gpm 3.715 ft/s 80970	1.723 ft 0.4739 ft	4.003 psi g 3.879 psi g	-0.1234 psi 0.2108 psi	0.01889 0.01702 2.21
Inlet Device: Tank 2			Outlet Device: Node 1				
Pipe 2 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	100.4 gpm 3.742 ft/s 81561	1.746 ft 0.4808 ft	4.003 psi g 3.89 psi g	-0.113 psi 0.2138 psi	0.01887 0.01702 2.21
Inlet Device: Tank 1			Outlet Device: Node 2				
Pipe 12 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	4 ft 4 ft	100.4 gpm 3.742 ft/s 81561	0.4186 ft 0.3889 ft	4.076 psi g 3.89 psi g	0.1862 psi 0.1729 psi	0.01887 0.01702 1.79
Inlet Device: Node 7			Outlet Device: Node 2				
Pipe 13 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	4 ft 4 ft	99.64 gpm 3.715 ft/s 80970	0.442 ft 0.3832 ft	4.076 psi g 3.879 psi g	0.1966 psi 0.1704 psi	0.01889 0.01702 1.79
Inlet Device: Node 7			Outlet Device: Node 1				
Pipe 14 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	4 ft 4 ft	-- -- --	-- --	3.879 psi g --	-- --	-- -- 1.79
Inlet Device: Node 1			Outlet Device: Node 8				

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
Pipe 15 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	4 ft 4 ft	-- -- --	-- --	3.89 psi g --	-- --	-- -- 1.79
	Inlet Device: Node 2		**Outlet Device:** Node 8				
Pipe 16 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	4 ft 2.5 ft	-- -- --	-- --	-- -1.465 psi g	-- --	-- -- 0.45
	Inlet Device: Node 8		**Outlet Device:** Node 4				
Pipe 5 Copper Nickel Class 200 Sea Water	4 in 4.282 in 1.5 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.02237 ft 0 ft	-1.465 psi g -1.475 psi g	9.949E-03 psi 0 psi	0.01725 0.01607 0.00
	Inlet Device: Node 4		**Outlet Device:** Curve dP Device 1				
Pipe 17 Copper Nickel Class 200 Sea Water	4 in 4.282 in 2 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.2529 ft 0.2231 ft	-1.587 psi g -1.7 psi g	0.1125 psi 0.09921 psi	0.01725 0.01607 0.72
	Inlet Device: Curve dP Device 1		**Outlet Device:** Sizing Pump 2				
Pipe 3 Copper Nickel Class 200 Sea Water	4 in 4.282 in 10 ft	0 ft 2.5 ft	-- -- --	-- --	1.779 psi g -1.465 psi g	-- --	-- -- 0.35
	Inlet Device: Tank 3		**Outlet Device:** Node 4				
Pipe 7 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.5157 ft 0.471 ft	5.239 psi g 5.01 psi g	0.2293 psi 0.2095 psi	0.01725 0.01607 1.53
	Inlet Device: Sizing Pump 2		**Outlet Device:** Sizing Valve 5				
Pipe 20 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.04474 ft 0 ft	5.01 psi g 4.99 psi g	0.0199 psi 0 psi	0.01725 0.01607 0.00
	Inlet Device: Sizing Valve 5		**Outlet Device:** Node 5				
Pipe 22 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	99.64 gpm 3.715 ft/s 80970	1.723 ft 0.4739 ft	0 psi g -1.656 psi g	1.656 psi 0.2108 psi	0.01889 0.01702 2.21
	Inlet Device: Tank 5		**Outlet Device:** Node 9				
Pipe 23 Copper Nickel Class 200 Sea Water	3 in 3.31 in 85 ft	2 ft 4 ft	100.4 gpm 3.742 ft/s 81561	1.746 ft 0.4808 ft	0 psi g -1.666 psi g	1.666 psi 0.2138 psi	0.01887 0.01702 2.21
	Inlet Device: Tank 4		**Outlet Device:** Node 10				
Pipe 29 Copper Nickel Class 200 Sea Water	4 in 4.282 in 1.5 ft	2.5 ft 2.5 ft	-- -- --	-- --	-1.3 psi g --	-- --	-- -- 0.00
	Inlet Device: Node 15		**Outlet Device:** Curve dP Device 2				
Pipe 30 Copper Nickel Class 200 Sea Water	4 in 4.282 in 2 ft	2.5 ft 2.5 ft	-- -- --	-- --	-- --	-- --	-- -- 0.72
	Inlet Device: Curve dP Device 2		**Outlet Device:** Sizing Pump 1				

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
Pipe 32 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	-- -- --	-- --	-- --	-- --	-- -- 1.53
	Inlet Device: Sizing Pump 1		**Outlet Device:** Sizing Valve 7				
Pipe 33 Copper Nickel Class 200 Sea Water	4 in 4.282 in 3 ft	2.5 ft 2.5 ft	-- -- --	-- --	-- --	-- --	-- -- 0.00
	Inlet Device: Sizing Valve 7		**Outlet Device:** Node 16				
Pipe 28 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.2581 ft 0.1388 ft	-1.3 psi g -1.185 psi g	0.1148 psi 0.06173 psi	0.01725 0.01607 0.45
	Inlet Device: Node 15		**Outlet Device:** Node 11				
Pipe 24 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	2.5 ft 4 ft	-- -- --	-- --	-- -1.666 psi g	-- --	-- -- 1.79
	Inlet Device: Sizing Valve 8		**Outlet Device:** Node 10				
Pipe 25 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	2.5 ft 4 ft	-- -- --	-- --	-- -1.656 psi g	-- --	-- -- 1.79
	Inlet Device: Sizing Valve 8		**Outlet Device:** Node 9				
Pipe 26 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft	4 ft 2.5 ft	99.64 gpm 3.715 ft/s 80970	0.442 ft 0.3832 ft	-1.656 psi g -1.185 psi g	-0.4705 psi 0.1704 psi	0.01889 0.01702 1.79
	Inlet Device: Node 9		**Outlet Device:** Node 11				
Pipe 27 Copper Nickel Class 200 Sea Water	3 in 3.31 in 2 ft	4 ft 2.5 ft	100.4 gpm 3.742 ft/s 81561	0.4186 ft 0.3889 ft	-1.666 psi g -1.185 psi g	-0.4809 psi 0.1729 psi	0.01887 0.01702 1.79
	Inlet Device: Node 10		**Outlet Device:** Node 11				
Pipe 36 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637	0.372 ft 0.2974 ft	-1.465 psi g -1.3 psi g	0.1654 psi 0.1323 psi	0.01725 0.01607 0.96
	Inlet Device: Node 4		**Outlet Device:** Node 15				
Pipe 37 Copper Nickel Class 200 Sea Water	4 in 4.282 in 5 ft	2.5 ft 2.5 ft	-- -- --	-- --	-- 4.99 psi g	-- --	-- -- 0.96
	Inlet Device: Node 16		**Outlet Device:** Node 5				
Pipe 21 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	2.5 ft 4 ft	200 gpm 4.456 ft/s 125637	0.5556 ft 0.4363 ft	4.99 psi g 4.076 psi g	0.9142 psi 0.194 psi	0.01725 0.01607 1.41
	Inlet Device: Node 5		**Outlet Device:** Node 7				
Pipe 35 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft	2.5 ft 2.5 ft	-- -- --	-- --	-- --	-- --	-- -- 1.41
	Inlet Device: Sizing Valve 8		**Outlet Device:** Node 16				

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
Pipe 19 Copper Nickel Class 200 Sea Water	4 in 4.282 in 15 ft	2.5 ft 9.5 ft	-- -- --	-- --	4.99 psi g 0 psi g	-- --	-- -- 2.53

Inlet Device: Node 5 **Outlet Device:** Pressure Boundary 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
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 -1.475 psi g	2.5 ft -1.587 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 2	4 ft	3.89 psi g	12.53 ft
Node 4	2.5 ft	-1.465 psi g	-1.103 ft
Node 5	2.5 ft	4.99 psi g	13.41 ft
Node 7	4 ft	4.076 psi g	12.92 ft
Node 8	4 ft	--	--
Sizing Valve 5	2.5 ft	5.01 psi g	13.46 ft
Node 9	4 ft	-1.656 psi g	0.06294 ft
Node 10	4 ft	-1.666 psi g	0.03646 ft
Node 15	2.5 ft	-1.3 psi g	-0.7313 ft

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 16	2.5 ft	--	--
Sizing Valve 7	2.5 ft	--	--
Node 11	2.5 ft	-1.185 psi g	-0.4115 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	--	--

Bill of Materials Report

File Name: 18026-529 Ballast with sizing pumps.pipe
Lineup: Discharging Ballast
Program Name: PIPE-FLO Professional
Version: 16.0.40539

Company: EBDG
Project: 18026
by: NJB
Date: Tuesday, June 26, 2018 12:08 PM

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 2	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 5	Copper Nickel Class 200	4 in	1.5 ft	
Pipe 17	Copper Nickel Class 200	4 in	2 ft	1 x Butterfly
Pipe 3	Copper Nickel Class 200	4 in	10 ft	1 x Elbow - Long radius, r/d 1.5 (90°) 1 x Gate - Wedge Disc
Pipe 7	Copper Nickel Class 200	4 in	3 ft	1 x Swing Check - Vertical 1 x Butterfly
Pipe 20	Copper Nickel Class 200	4 in	3 ft	
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 29	Copper Nickel Class 200	4 in	1.5 ft	
Pipe 30	Copper Nickel Class 200	4 in	2 ft	1 x Butterfly
Pipe 32	Copper Nickel Class 200	4 in	3 ft	1 x Swing Check - Vertical 1 x Butterfly
Pipe 33	Copper Nickel Class 200	4 in	3 ft	
Pipe 28	Copper Nickel Class 200	4 in	8 ft	2 x Elbow - Long radius, r/d 1.5 (90°)
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 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 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 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 19	Copper Nickel Class 200	4 in	15 ft	1 x Swing Check - Vertical 1 x Exit - Rounded 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	364.00 ft	8 x Butterfly 24 x Elbow - Long radius, r/d 1.5 (90°) 4 x Entrance - Inward 8 x Tee - Flow Thru Branch

Pipeline Material Summary				
Specification	**Material**	**Size**	**Total Length**	**Valves & Fittings**
Copper Nickel Class 200	Copper Nickel MIL-T-16420K Schedule: Class 200	4 in	86.00 ft	5 x Butterfly 9 x Elbow - Long radius, r/d 1.5 (90°) 1 x Exit - Rounded 1 x Gate - Wedge Disc 3 x Swing Check - Vertical 4 x Tee - Flow Thru Branch

Appendix J

Lube Oil and Waste Oil System, Dwg. 18026-200-529-2

1 DESCRIPTION

This appendix documents the 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 assumed 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	Schedule	d, ID	Design Velocity			V
					Nominal		Limit	
	gpm	(NPS)		in	ft/s		ft/s	ft/s
Pump Suction	16	1 1/2	SCH 80	1.500	1.0 √d	1.22	4	2.90
Pump Discharge	16	1 1/2	SCH 80	1.500	2.0 √d	2.45	6	2.90

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.

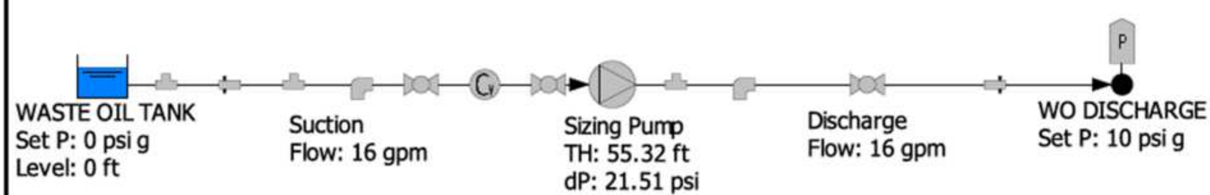
6 REFERENCES

[1] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Profiles and Arrangements," 18026-200-101-1, Seattle, WA.

[2] Elliott Bay Design Group, "NCDOT Double Ended Azimuth Drive Ferry: Lube Oil and Waste Oil Piping Schematic," 18026-200-529-2, Seattle, WA.

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

WASTE OIL SYSTEM PIPE-FLO MODEL



Project Information	
Company:	EBDG
Project:	18026
Drawn by:	NJB
File Name:	18026-200-505-1_APPK.pipe
Lineup:	<Design Case>
Print Date:	Wednesday, May 23, 2018 04:45 PM

PIPE-FLO Professional	
Program Version:	16.0.40539
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used			
Flow rate:	gpm	Power:	
Velocity:	ft/s	Temperature:	°F
Pressure:	psi g	Density:	lb/ft³
Elevation:		Viscosity:	cP
Length:	ft	Atmospheric Pressure:	14.7 psi a
Size:	in		

List Report

File Name: 18026-200-505-1_APPK.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Wednesday, May 23, 2018 04:46 PM

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 standard	Steel A53-B36.10 Schedule:80	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
SAE 30 Lube Oil SAE 30 Lube	50 °F	40 psi g	Liquid	55.99 lb/ft³ 479.4 cP	0.2173 psi a 3199 psi a	– 1

Sizing Pumps

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

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
Suction Steel A53-B36.10 SAE 30 Lube Oil	1.5 in 1.5 in 8 ft	2 ft 4 ft	16 gpm 2.905 ft/s 63.12	9.576 ft 1.066 ft	0 psi g -4.501 psi g	4.501 psi 0.4146 psi	1.014 0.02054 8.13
	Inlet Device: WASTE OIL TANK		Outlet Device: Sizing Pump				
Discharge Steel A53-B36.10 SAE 30 Lube Oil	1.5 in 1.5 in 10 ft	4 ft 11 ft	16 gpm 2.905 ft/s 63.12	11.03 ft 0.3924 ft	17.01 psi g 10 psi g	7.011 psi 0.1526 psi	1.014 0.02054 2.99
	Inlet Device: Sizing Pump		Outlet Device: WO DISCHARGE				

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	Connecting Pipelines Penetration Height	Connecting Pipelines Pipeline Flow Rate	Connecting Pipelines Pressure at Penetration
WASTE OIL TANK SAE 30 Lube Oil	2 ft 0 ft	0 psi g 0 psi g	2 ft				
				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: 18026-200-505-1_APPK.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 16.0.40539

Company: EBDG
Project: 18026
by: NJB
Date: Wednesday, May 23, 2018 04:46 PM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
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
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

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 K

Potable and Sanitary Water System, Dwg. 18026-200-533-1

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 Schedule 40 at the tank connection and Copper Seamless Hard Drawn Type K beyond the tank shut off valve.
- 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:

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

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

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

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

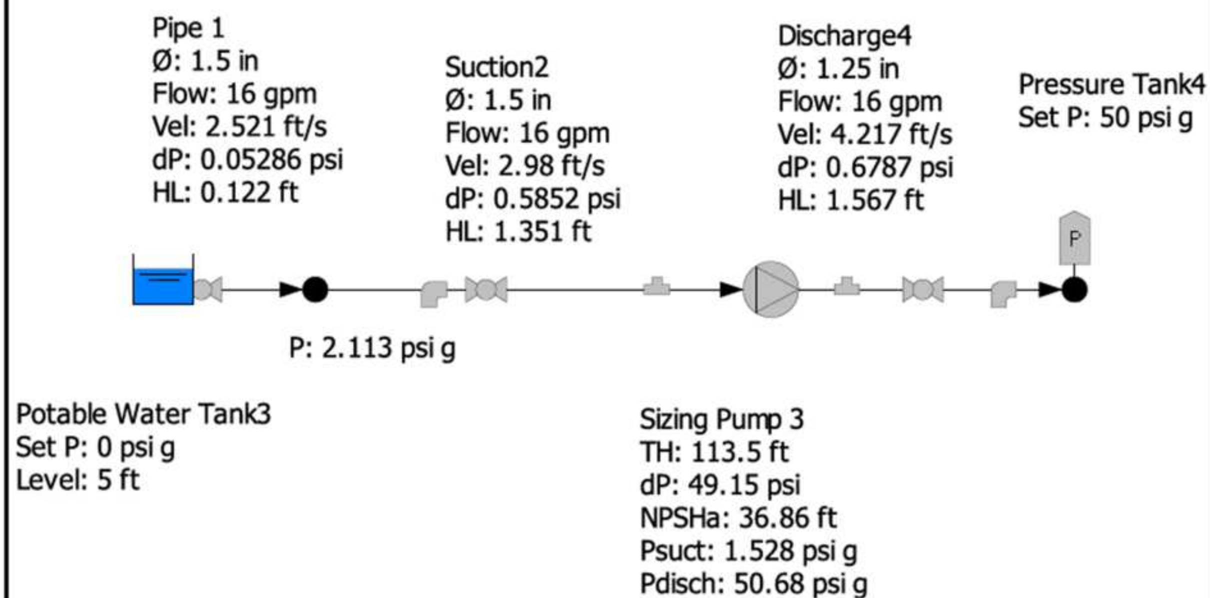
[1] IAPMO/ANSI UPC 1 - 2009: Uniform Plumbing Code, Ontario, CA: International Association of Plumbing and Mechanical Officials, 04/2009.

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

[3] EBDG, "18026-200-101-1 Profiles and Deck Arrangements," 2018.

[4] EBDG, "18026-200-533-1 Potable and Sanitary Water Piping Schematic," 2018.

Potable and Sanitary Water Pipe-Flo Model



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Company:	EBDG
Project:	18026
Drawn by:	NJB
File Name:	18026-200-505-1_APPL.pipe
Lineup:	50 psi
Print Date:	Wednesday, May 23, 2018 04:53 PM

PIPE-FLO Professional	
Program Version:	16.0.40539
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used			
Flow rate:	gpm	Power:	
Velocity:	ft/s	Temperature:	°F
Pressure:	psi g	Density:	lb/ft³
Elevation:	ft	Viscosity:	cP
Length:	ft	Atmospheric Pressure:	14.7 psi a
Size:	in		

List Report

File Name: 18026-200-505-1_APPL.pipe
Lineup: 50 psi
Progam Name: PIPE-FLO Professional
Version: 16.0.40539

Calculation Method: Darcy-Weisbach
Laminar Cutoff Re: 2100
Max Iterations: 100
Iteration Tolerance: 0.01
Atmospheric Pressure: 14.7 psi a

Company: EBDG
Project: 18026
by: NJB
Date: Wednesday, May 23, 2018 04:53 PM

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
Copper Tube, K - Discharge standard	Copper Tube H23 Schedule:K	6E-05 in 140	8.0 ft/s	to ft/s	15 to 80 psi g	to
Copper Tube, K - Suction standard	Copper Tube H23 Schedule:K	6E-05 in 140	4.0 ft/s	to ft/s	to psi g	to
Steel ASTM A53 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
Potable Water Water	60 °F	60 psi g	Liquid	62.37 lb/ft³ 1.105 cP	0.2564 psi a 3199 psi a	– 18

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		36.86 ft

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
Suction2 Copper Tube, K - Suction Potable Water	1.5 in 1.481 in 20 ft	2.5 ft 2.5 ft	16 gpm 2.98 ft/s 30894	1.351 ft 0.827 ft	2.113 psi g 1.528 psi g	0.5852 psi 0.3582 psi	0.02343 0.0206 5.99
Inlet Device: Sizing Pump 5			**Outlet Device:** Sizing Pump 3				
Pipe 1 Steel ASTM A53 Potable Water	1.5 in 1.61 in 2 ft	2.5 ft 2.5 ft	16 gpm 2.521 ft/s 28419	0.122 ft 0.08305 ft	2.166 psi g 2.113 psi g	0.05286 psi 0.03597 psi	0.02647 0.02018 0.84
Inlet Device: Potable Water Tank3			**Outlet Device:** Sizing Pump 5				
Discharge4 Copper Tube, K - Discharge Potable Water	1.25 in 1.245 in 5 ft	2.5 ft 2.5 ft	16 gpm 4.217 ft/s 36750	1.567 ft 1.267 ft	50.68 psi g 50 psi g	0.6787 psi 0.5487 psi	0.02255 0.02152 4.58
Inlet Device: Sizing Pump 3			**Outlet Device:** Pressure Tank4				

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

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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: 18026-200-505-1_APPL.pipe
Lineup: 50 psi
Program Name: PIPE-FLO Professional
Version: 16.0.40539

Company: EBDG
Project: 18026
by: NJB
Date: Wednesday, May 23, 2018 04:53 PM

Pipelines

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

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