DOUBLE-ENDED AZIMUTH DRIVE FERRY



Piping System and Mechanical Calculations

Prepared for: NCDOT • Raleigh, North Carolina

Ref: 18026-200-505-1 Rev. - August 10, 2018



PREPARED BY

Elliott Bay Design Group – North Carolina, PLLC 5305 Shilshole Ave. NW, Ste. 100 Seattle, WA 98107

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
-	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:

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:

EBDG – NC, PLLC	
18026-200-505-1	

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:

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

Table 3-2: Auxiliary Seawater Demands

- 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	Pipe	Schedule	d, ID	Design Vel	ocity	V
	Rate	Size			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.

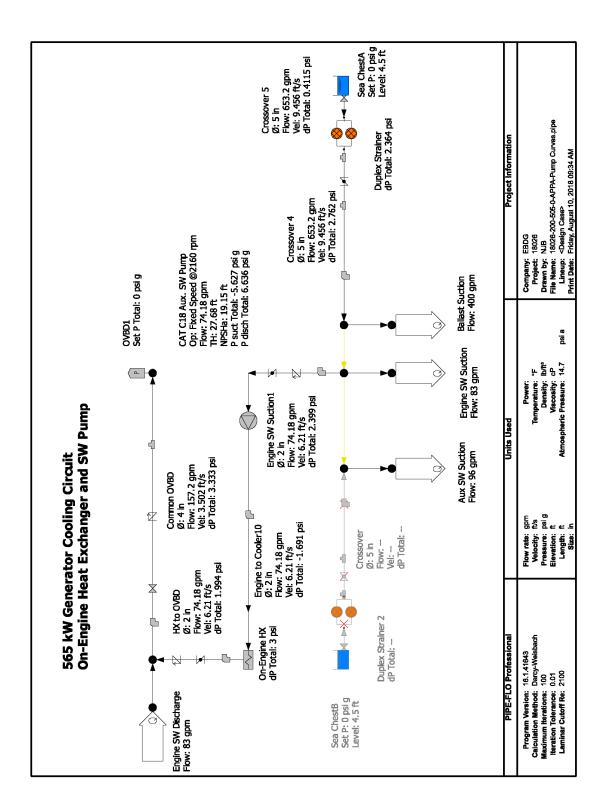
5.4 Freshwater Cooling System Pressure Calculations

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.





DOUBLE-ENDED AZIMUTH DRIVE FERRY

File Name: 18028-200-505-0-APPA-Pump Curves.pipe Lineue: 18028-200-505-0-APPA-Pump Curves.pipe Progam Name: PIPE-FLO Professional Version: 16.1.41643	ump Curves.pipe	Calculation Laminar C Max Ib Percent T Allowable D	Calculation Method: Darry-Weisbach Laminar Cutoff Re: 2100 Max Herardions: 100 Percent Tolerance: 0.01 Allowable Deviation: 1 %	Com Pr Atmospheric Pres		EBDG 18026 NJB Friday, August 10, 2018 09:34 AM 14.7 psi a	
Specification Name	Material	Absolute	lecifica	ations Sizing Criteria		Design Limits	
Valve Table	Schedule	Hazen Will	Hazen Williams C Factor		Velocity	Pressure	Reynolds Number
Cu-Ni 90-10 CL200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200		6E-05 in 0.0 150	Min: Max:	: ft/s ft/s	psig psig	
			Fluid Zones				
Fluid Zone Name Table Name	Ter	Temperature Pressure Relat	Fiuld State Relative Molecular Mass	Density Viscosity	Vapol	Vapor Pressure Specifi Critical Pressure Spec	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Seawater 85F Seawater 3.5% Salinity		85 °F 0 psig	Liquid 29	63.8 lb/ft³ 0.871 cP	0.5846 3199	.5846 psia 3199 psia	1
			Centrifugal Pump	ŝ			
Pump Name	Test Speed Operating Speed	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate Power	Efficiency NP BEP Efficiency NP	NPSHa Design NPSH NPSHr Margin Ratio
CAT C18 Aux. SW Pump Fixed Speed @2160 rpm	2160 mm 2160 mm	5.5 ft -5.627 psig	5.5 ft 6.636 psig	27.68 ft 12.26 psi	74.18 gpm -	- 19.1 %	19.15 ft – –
Company: CAT Curve: Manual Pump Type:		Size: Diameter: 2 in POR: from	י פ ו				
			Pipelines				
Pipeline Name	Size	Inlet Device	Flow Rate	Inlet Total Pressure	Total dP	Outlet Total Pressure	a V&F Friction Factor
Specification Fluid Zone	Inside Diameter Length	Inlet Elevation Outlet Device Outlet Elevation	Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Stattc Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total Head Loss	Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	
Common OVBD	4 in	Engine SW Suction2	157.2 apm	3.333 psi a	3.333 psi	0 psid	0.01607
Cu-Ni 90-10 CL200 Seawater 85F	4.282 in 15 ft	1.75 ft OVBD1 8.5 ft	3.502 ft/s 136200 0.01697	3.248 psig 9.273 ft 9.082 ft	0.7729 ft	-0.08443 psig 8.5 ft 8.309 ft	3.34 0.2822 psl 0.6369 ft
Crossover	5 L	Duplex Strainer 2	1	1	1	1	1
Cu-NI 90-10 CL200	5.312 In	1.75 ft	I	I		I	3.18
Seawater 85F	20 ft	Node 1 2.5 ft	11	11	I	11	1 1
Crossover 2 Crubii 00-10 CI 200	5 in 5 313 in	Node 1 3 5 A	96 gpm 130 fr/s	-3.229 psig	2.949E-03 psi	-3.232 psi g -3.245 psi g	0.01533
Seawater 85F	5 H	5" Duplex Strainer 1 2.5 ft	67055 0.01963		6.656E-03 ft		0 psi
Messages: Reversed flow							
Crossovar 3	5 11	5" Duplex Strainer 1	253.2 gpm	-3.212 psig	0.01683 psl	-3.229 psi g	0.01533
Cu-NI 90-10 CL200	5.312 In	2.5 ft	3.665 ft/s	8	4 00E00 0	8	0.00
Seawater dor	۲ ۵	o" Duplex Surainer 2 2.5 ft	0.01611	4.05 ft	11 86/20.0	-4.786 п -4.997 ft	sd tr
Messages: Reversed flow							
PIPE-FLO Professional	Version: 16.1.41643	5	List Report		Friday, August 10, 2018 09:34 AM	2018-09:34 AM	Pace 1

			Pipelines				
Pipeline Name	Size		Flow Rate	Inlet Total Pressure	Total dP	Outlet Total Pressure	-
Specification Fluid Zone	Inside Dlameter Length	r Inlet Elevation Outlet Device Outlet Elevation	Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total Head Loss	Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	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 psig -1.065 psig 0.735 ft -0.6546 ft	2.762 psi 5.485 ft	-3.212 psig -3.828 psig -4.75 ft -8.139 ft	0.01533 3.18 1.959 psi 4.423 ft
Crossover 5 C⊔-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 psig 1.378 psig 7 ft 5.61 ft	0.4115 psi 0.9289 ft	1.582 psig 0.9665 psig 6.071 ft 4.681 ft	0.01533 0.62 0.3833 psl 0.8652 ft
Engine SW Suction1 Cu-Ni 90-10 CL200 Seawater 86F	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 0.01738		2.399 psl 2.415 ft		0.01869 2.90 0.736 psi
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		-1.691 psi 1.683 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 fVs 124602 0.01736	5.327 psig 5.061 psig 12.02 ft 11.42 ft	1.994 psi 2.751 ft	3.333 psig 3.067 psig 9.273 ft 8.674 ft	0.01869 3.46 0.9182 psl 2.073 ft
Pipe 1 cu-NI 90-10 CL200 Seewater 85F	2 II 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 psig -3.561 psig -4.788 ft -5.538 ft	0.03563 psl 0.8304 ft	-3.264 psig -3.597 psig -5.618 ft -6.369 ft	0.01869 0.00 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 psig -3.759 psig -4.75 ft -5.984 ft	-0.07051 psi 0.5909 ft	-3.141 psig -3.688 psig -5.341 ft -6.575 ft	0.01607 0.00 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 psig 3.368 psig 10.1 ft 9.353 ft	0.3679 psi 0.8304 ft	3.333 psig 3 psig 9.273 ft 8.523 ft	0.01869 0.00 0 psl
Pipe 4 Cu-NI 90-10 CL200 Seewater 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 psig -3.676 psig -4.795 ft -5.798 ft	0.1463 psl 1.08 ft	-3.378 psig -3.823 psig -5.875 ft -6.879 ft	0.01869 0.00 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	5 		1.1		0.62
Tank Name Fluid Zone Tank Geometry	Bottom Elevation Su Liquid Level Bo Liquid Volume Toi	Surface Pressure Hy Bottom Pressure N Total Tank Volume	Hydraulic Grade Net Flow Rate	Pipeline Name Per	Connecting Pipelines Penetration Height Pipeline F	Pipelines Pipeline Flow Rate Pressure at Penetration	essure at Penetration
PIPE-FLO Professional	Version: 16.1.41643	1643	List Report		Friday, August 10, 2018 09:34 AM	118 09:34 AM	Page 2

Sea ChestA		0 psig	7 ft					
Seawater 85F	4.5 ft	1.994 psig	-653.2 gpm					
Unspecified	I	ı						
				Crossover 5	5 0 ft	653.2 gpm		1.994 psig
Sea ChestB	2.5 ft	0 psig	1					
Seawater 85F	4.5 ft		'					
Unspecified	ı	ı						
				Sea Chest Crossover3	30 ft	I	1.994	1.994 psig
			Fixed dP	Devices				
Fixed dP Device Name	Inlet Elevation		Outlet Elevation	ę	Flow Rate			
	Inlet Pressure		Outlet Pressure	Head Loss				
On-Engine HX	0 ft 8.327 osio		0 ft 5.327 osi a	3 psi 6.772 ft	74.18 gpm			
		l	Curve dP	Pevices				
Curve dD Device Name	Inlet Flevation		Outlet Elevation	ę	Flow Rate			
curve un bevice name Description	Inter Pressure			ur Head Loss				
Duplex Strainer Miller Lehman Duplex 6"	2.5 ft 1.582 psig		1.75 ft -0.4497 psig	2.364 psi 5.336 ft	653.2 gpm			
Duplex Strainer 2 Miler Leaman Duplex 6"	2.5 ft -		1.75 ft _	11	I			
			Noc	des				
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 psig	-5.694 ft			
Engine SW Suction2			1.75 ft	3.333 psig	8.759 ft			
Node 1			2.5 ft	-3.232 psi g	-5.311 ft			
			Pressure B	soundaries				
Pressure Boundary Name			Elevation	Pressure	Hydraulic Grade	Flow Rate		
OVBD1			8.5 ft	0 psig	8.309 ft	157.2 gpm		
			Flow De	Flow Demands				
Flow Demand Name			Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction	
Aux SW Suction			1.75 ft	-3.378 psig	-6.879 ft	96 gpm	Flow out	
Ballast Suction			1.75 ft	-3.141 psig	-6.575 ft	400 gpm	Flow out	
Engine SW Discharge			1.75 ft	3.701 psig	9.353 ft	83 gpm	Flow in	
Engine SW Suction			1.75 ft	-3.264 psi g	-6.369 ft	83 anm	Flow out	

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List Report

Version: 16.1.41643

PIPE-FLO Professional

Lineup: <design ca<br="">rogram Name: PIPE-FLO F Version: 16.1.41643</design>		Centrifugal Pump	Date:		
Centrifugal Pump Name		Continugai Fumps	,		
Operation CAT C18 Aux. SW Pump Fixed Speed @2160 rpm	Company: CAT Type:			Test Speed: 2160 rpm Impeller Diameter: 2 in	
	Size: Curve: Manual P	ump		POR: from to	-
		Tanks			
fank Name					
Sea ChestA					
Sea ChestB					
Fixed dP Device Name	Fixed dP	Fixed dP Devices			
On-Engine HX	3 psi	Curve dP Devices			
Curve dP Device Name	Curve De				
Duplex Strainer	Miller Lei	nman Duplex 6"			
Duplex Strainer 2	Miler Lea	nan Duplex 6"			
		Pipelines			
Pipeline	Specification	Şizə	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 Tae - 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°)	
IX 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	
	Pip	eline Material Sum	mary _		
ipecification	Material	Size ·	rotal Lengti	n 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 radlus, r/d 1 (90°) 5 x Elbow - Standard 90° 2 x Swing Check - Vertical	

	Pij	peline Materi	al 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

PIPE-FLO Professional

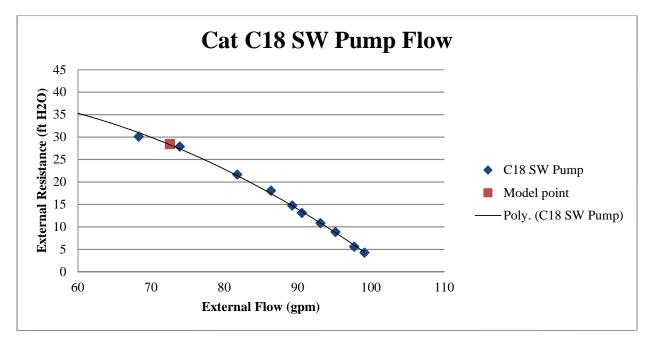
Version: 16.1.41643

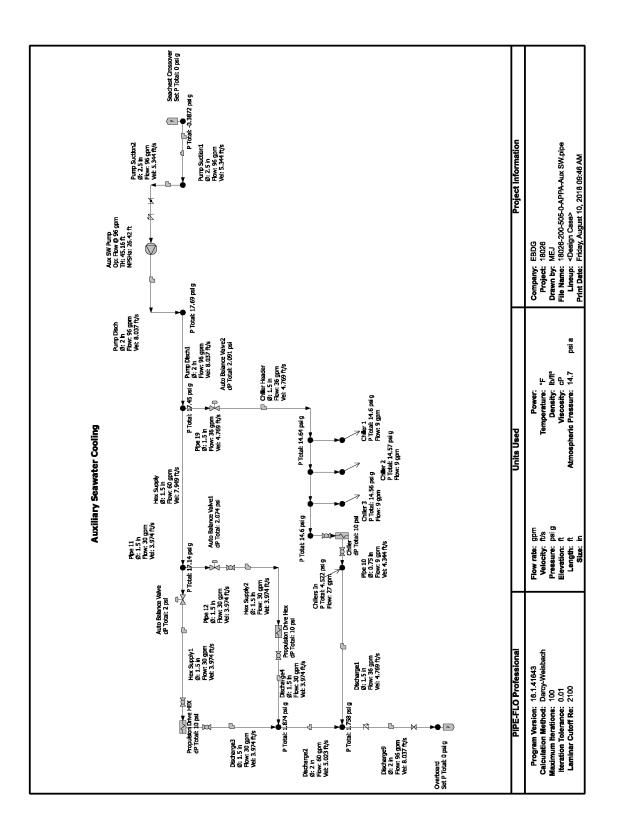
Bill of Materials Report

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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 Lineup: Obsign Case> Progam Name: PIPE-FLO Professional Version: 16.1.4.1643	edid.WS Xu	Calculation Method: Da Laminar Cutoff Re: 21 Max Iteratione: 10 Percent Tolerance: 0.0 Allowable Deviation: 1	Calculation Method: Darcy-Weisbach Laminar Cutoff Re: 2100 Max Itaratione: 100 Percent Tolerance: 0.01 Nilowable Deviation: 1 %	Company: Project: by: Date: Atmospheric Preseure:	Company: EBDG Project: 18026 by: MEJ Date: Friday, August 1 Pressure: 14.7 psi a	pany: EBDG ojest: 18028 by: MEJ Detes: Friday, August 10, 2018 09:47 AM sure: 14.7 psia	AM	
	11111		heeline			Ĩ		
specification name Valve Table	material Schedule	Aussolute A Hazen Willa	Ausolute Kougnness Hazen Williams C Factor		Velocity	Pressure	\$1 E	Reynolds Number
Cu-Ni 90-10 CL200 standard	Copper Nickel MIL-T-16420K Schedule: Class 200		6E-05 in 0.0 150	Σž	Min: ft/s Max: ft/s	psig psig		
			Fluid Zones					
Fluid Zone Name Table Name	Tempe	Temperature F Pressure Relativ	Fiuld State Relative Molecular Mass	Density Viscosity	Vapo Critic	Vapor Pressure Critical Pressure	Specific He Specific I	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Seawater 85F Seawater 3.5% Salinity	80	85 °F 0 psig	Liquid 29	63.8 lb/ff* 0.871 cP	0.55	0.5846 psia 3199 psia		
			Sizing Pumps			·	l	
Pump Name	<i>a</i> , <i>o</i> ,	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow	Flow Rate	NPSHa	
Aux SW Pump		5.5 ft -2.408 psig	5.5 ft 17.6 psig	45.16 ft 20.01 psi	96	96 gpm 26	26.42 ft	
Messages: Calculated results based on minimum or zero dP at Most Hydraulically Remote Loop.	minimum or zero dP at Most	Hydraulically Remot	e Loop.					
			Sizing Control Valve	s			l	
Sizing Valve Name Operational Mode and Set Point	Flow Coefficient	Elevation	Inlet Pressure Outlet Pressure	dP Head Loss	Flov	Flow Rate	Allowable dP min Allowable dP max	dP min dP max
Auto Balance Valve FCV @ 30 gpm	21.45 CV	2.5 ft	17.13 psig 15.13 psig	2 psi 4.514 ft	30	шdб	N 1	
Messages: This device controls the flow rate in the Most Hydraulically Remote Loop.	w rate in the Most Hydraulica	lly Remote ∟oop.						
Auto Balance Valve1 FCV @ 30 gpm	21.07 CV	2.5 ft	17.13 psig 15.06 psig	2.074 psi 4.682 ft	30	mqg	2 psi 80 psi	
Auto Balance Valve2 FCV @ 36 gpm	25.18 Cv	2.5 ft	17.44 psig 15.35 psig	2.091 psi 4.721 ft	38	шdб	N 1	
			Pipelines					
Pipeline Name Specification Fluid Zone	Size Inside Diameter Langth	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Plpe 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 Au 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 psig 15.19 psig 37.15 ft 36.79 ft	0.7111 psi 0.8552 ft	14.64 14.48 36.29 35.94	psig psig ft	0.01975 1.11 0.1732 psi 0.391 ft
Chiller Header1 Cu-Ni 90-10 CL200 Security BEE	1.5 in 1.756 in 2.4	Node 7 3.25 ft Node 6	18 gpm 2.385 fVs 38023	14.61 psig 14.57 psig 26.24 e	0.01195 psi	14.6 14.56 36.21	psig bsig	0.01975 0.00
	2	3.25 ft	0.02233	36.15 ft		36.12	: #2	2 ≓
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DOUBLE-ENDED AZIMUTH DRIVE FERRY

List Report

			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 Stattc 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 1.758 in 2 ft	Node 8 3.25 ft Node 7	27 gpm 3.577 ft/s 57050	14.64 psig 14.55 psig 36.29 ft	0.02459 psi 0.05549 ft	14.61 psig 14.53 psig 36.24 ft	0.01975 0.00 0 psi
Chiller Header3 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 2 ft	3.25 ft Node 6 3.25 ft Node 1	0.02042 9 gpm 1.192 fVs 19017		3.515E-03 psi 7.934E-03 ft	36.04 ft 14.6 psig 14.58 psig 36.2 ft	0 ft 0.01975 0.00 0 psl
Discharge1 Cu-NI 90-10 CL200 Seawater 85F	1.5 m 1.756 m 15 ft	3.25 ft Chillers in 3.25 ft Node 4	0.02628 36 gpm 4.769 fVs 76087	36.19 ft 4.522 psig 4.365 psig 13.46 ft	2.764 psl 0.9895 ft	36.18 ft 1.758 psig 1.601 psig 12.47 ft	0 ft 0.01975 0.83 0.1299 psi
Discharge2 Cu-Ni 90-10 CL200 Seawater 85F	2 in 2.209 in 3 ft	0.00 Node 3 Node 4 8.5 ft	5.023 ft/s 100780 0.01811		0.1162 psi 0.2623 ft		0.01869 0.37 0.06494 psi
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 psig 3.205 psig 13.48 ft 13.23 ft	1.439 psi 0.7493 ft	1.874 psig 1.765 psig 12.73 ft 12.48 ft	0.01975 1.01 0.1094 psl 0.2469 ft
Discharge4 Cu-NI 90-10 CL200 Seawater 85F	1.5 h 1.756 h 10 ft	Propulsion Drive Hex 6 ft Node 3 8.5 ft	30 gpm 3.974 fVs 63389 0.01997	3.239 psig 3.13 psig 13.31 ft 13.07 ft	1.365 psl 0.5818 ft	1.874 psig 1.765 psig 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 96 gpm 8.037 ft/s 161248 0.01651	1.758 psig 1.313 psig 12.47 ft 11.46 ft	1.758 psi 3.968 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 fVs 126778 0.01734	17.45 psig 17.02 psig 41.89 ft 40.91 ft	0.3093 psi 0.6981 ft	17.14 psig 16.71 psig 41.19 ft 40.21 ft	0.01975 0.00 0 psl
Hex Supply1 Cu-NI 90-10 CL200 Seawater 85F	1.5 n 1.756 n 10 ft	Auto Balance Valve 2.5 ft Propulsion Drive HEX 3 ft	30 gpm 3.974 ft/s 63389 0.01997	15.13 psig 15.03 psig 36.66 ft 36.42 ft	0.4915 psl 0.6094 ft	14.64 psig 14.53 psig 36.05 ft 35.81 ft	0.01975 1.12 0.1216 psi 0.2745 ft
Hex Supply2 Cu-tN 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 psig 14.95 psig 36.49 ft 36.25 ft	0.4915 psi 0.6094 ft	14.57 psig 14.46 psig 35.88 ft 35.64 ft	0.01975 1.12 0.1216 psi 0.2745 ft
Pipe 10 Cu-Ni 90-10 CL200 Seewater 85F	0.75 in 0.92 in 0.5 ft	Chiller 3.25 ft Chillers In 3.25 ft	9 gpm 4.344 fVs 36297 0.02266	4.55 psig 4.42 psig 13.52 ft 13.23 ft	0.02827 psi 0.06381 ft	4.522 psig 4.392 psig 13.46 ft 13.16 ft	0.02328 0.07 9.074E-03 psl 0.02048 ft
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DOUBLE-ENDED AZIMUTH DRIVE FERRY

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			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 Stattc 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 Seewater 85F	1.5 in 1.756 in 0.5 ft	Node 5 2.5 ft Auto Balance Valve 2.5 e	30 gpm 3.974 ft/s 63389	17.14 psig 17.03 psig 41.19 ft	7.419E-03 psi 0.01675 ft	17.13 psig 17.03 psig 41.18 ft	0.01975 0.00 0 psi
Pipe 12 Cu-Ni 90-10 CL200 Seawater 85F	1.5 in 1.756 in 0.5 ft	2.5 ft Node 5 2.5 ft Auto Balance Valve1	3.974 fbs 63389 0.01007	17.03 psig 17.03 psig 41.19 ft	7.419E-03 psi 0.01675 ft		0.00 0.00 0 psl
Pipe 15 Cu-NI 90-10 CL200 Seawater 85F	0.75 h 0.92 h 1 ft	2.5 ft Node 1 3.25 ft Chiller 3.25 ft	9 gpm 9 gpm 4.344 ft/s 36297 0.02266		0.04747 psl 0.1071 ft		0.02328 0.0728 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 8 3.25 ft Chiller 3 3.25 ft	9 gpm 4.344 ft/s 36297 0.02266		0.03839 psi 0.08666 ft		0.00 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 fVs 36297 0.02266	14.61 psig 14.48 psig 36.24 ft 35.94 ft	0.03839 psi 0.08666 ft	14.57 psig 14.44 psig 36.15 ft 35.86 ft	0.02328 0.00 0 psl
Pipe 18 Cu-Ni 90-10 CL200 Seawater 85F	0.75 ln 0.92 ln 1 ft	Node 8 3.25 ft Chiller 1 3.25 ft	9 gpm 4.344 fVs 36297 0.02266	14.64 psig 14.51 psig 36.29 ft 36.6 ft	0.03839 psl 0.08666 ft	14.6 psig 14.47 psig 36.2 ft 35.21 ft	0.02328 0.00 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 36 gpm 76067 0.01922	17.45 psig 17.29 psig 41.89 ft 41.54 ft	0.01028 psi 0.02321 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-Engline HX 2.5 ft	96 gpm 8.037 fVs 161248 0.01651	17.6 psig 17.15 psig 45.22 ft 44.22 ft	-0.09237 psi 2.792 ft	17.69 psig 17.25 psig 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 At	On-Engine HX 2.5 ft Node 2 2.5 ft	96 gpm 8.037 ft/s 161248 0.01651	17.69 psig 17.25 psig 42.43 ft 41.43 ft	0.2393 psl 0.5401 ft	17.45 psig 17.01 psig 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 psig -0.1966 psig 2.5 ft 2.056 ft	0.3872 psi 0.8739 ft	-0.3872 psig -0.5838 psig 1.626 ft 1.182 ft	0.01782 1.82 0.3573 psi 0.8065 ft
Pump Suction2 Cu-Ni 90-10 CL200 Seewater 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 fVs 131486 0.01714	-0.3872 paig -0.5838 paig 1.626 ft 1.162 ft	2.021 psi 1.562 ft	-2.408 psig -2.605 psig 0.06384 ft -0.3798 ft	0.01782 3.14 0.6175 psi 1.394 ft
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DOUBLE-ENDED AZIMUTH DRIVE FERRY

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EBDG – NC, PLLC 18026-200-505-1

Fixed dP Device Name Ini Ini Chiller	Inlet Elevation	Outlet Elevation	db D	Flow Rate			
	Inlet Pressure	Outlet Pressure	Head Loss				
-	3.25 ft 14.55 psig	3.25 ft 4.55 psig	10 psi 22.57 ft	mdb 6			
Propulsion Drive HEX 1	3 ft 14.64 psig	6 ft 3.313 psig	10 psi 22.57 ft	30 gpm			
Propulsion Drive Hex 1	3 ft 14.57 psig	6 ft 3.239 psig	10 psi 22.57 ft	30 gpm			
Node Name	l	No Elevation	nces Pressure	Hydraulic Grade		l	
Node 1		3.25 ft	14.6 pslg	36.04 ft			
Node 2		2.5 ft	17.45 psig	41.11 ft			
Node 3		8.5 ft	1.874 psig	12.44 ft			
Node 4		8.5 ft	1.758 psl g	11.88 ft			
Node 5		2.5 ft	17.14 psig	40.7 ft			
Node 6		3.25 ft	14.6 psig	36.07 ft			
Node 7		3.25 ft	14.61 pslg	36.04 ft			
Node 8		3.25 ft	14.64 psig	36.01 ft			
On-Engine HX		2.5 ft	17.69 psig	41.43 ft			
Pressure Boundary 1		2.5 ft	-0.3872 psl g	1.182 ft			
		Pressure	e Boundaries				
Pressure Boundary Name		Elevation	Pressure	Hydraulic Grade	Flow Rate		
Overboard		8.5 ft	0 psig	7.496 ft	96 gpm		
Seachest Crossover		2.5 ft	0 psig	2.056 ft	96 gpm		
		Flow Dei	mands				
Flow Demand Name		Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction	
Chiller 1		3.25 ft	14.6 psig	36.91 ft	mqg 8	Flow out	
Chiller 2		3.25 ft	14.57 psi g	35.86 ft	mqg 8	Flow out	
Chiller 3		3.25 ft	14.56 psl g	35.83 ft	9 gpm	Flow out	
Chillers In		3.25 ft	4.522 psi g	13.13 ft	27 gpm	Flow in	

PIPE-FLO Professional

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List Report

File Name: 18026-200-50 Lineup: <design case<="" th=""><th></th><th></th><th>Company: Project:</th><th>18026</th><th></th><th></th></design>			Company: Project:	18026		
Program Name: PIPE-FLO Pro Version: 16.1.41643	fessional			MEJ Friday, August 10, 2018 09:47 /	M	
		Sizing Pumps	Data.	111day, August 10, 2010 08.477	ואנר	
Sizing Pump Name				Design Point		
Operation					al Head	
Aux SW Pump Flow @ 96 gpm				96 gpm 48	5.16 ft	
		Sizing Valves				
Sizing Valve Name	Operation		Flow	dP	Sizing F Coeffic	
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	Fixed dD Daviese	36 gpm	2.091 psi	25.18	Cv
Fixed dP Device Name	Fixed dP	Fixed dP Devices				
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		
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 1 x Ball 1 x Reducer - Enlargem		5 in - C
Discharge4	Cu-Ni 90-10 CL200	1.5 in	10 ft	3 x Elbow - Long radius 1 x Ball 1 x Reducer - Enlargem		5 in - (
Discharge9	Cu-NI 90-10 CL200	2 in	15 ft	2 x Pipe Bend - r/d 1.5 (1 x Swing Check - Vertio 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 3 x Elbow - Long radius 1 x Ball		in - 0
Hex Supply2	Cu-Ni 90-10 CL200	1.5 in	10 ft	3 x Elbow - Long radius 1 x Reducer - Contractio 1 x Ball		in - 0
Pipe 10	Cu-Ni 90-10 CL200	0.75 in	0.5 ft	1 x Bali		
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		4	
Pump Disch	Cu-Ni 90-10 CL200	2 in	6 ft	6 x Elbow - Short radius	, r/d 1 (90°)	
Pump Disch1 Pump Suction1	Cu-NI 90-10 CL200 Cu-Ni 90-10 CL200	2 In 2.5 in	6 ft 2 ft	1 x Tee - Flow Thru Brai 3 x Elbow - Long radius	nch	

		Pipelines	1	
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)
	Pij	peline Material S	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

PIPE-FLO Professional

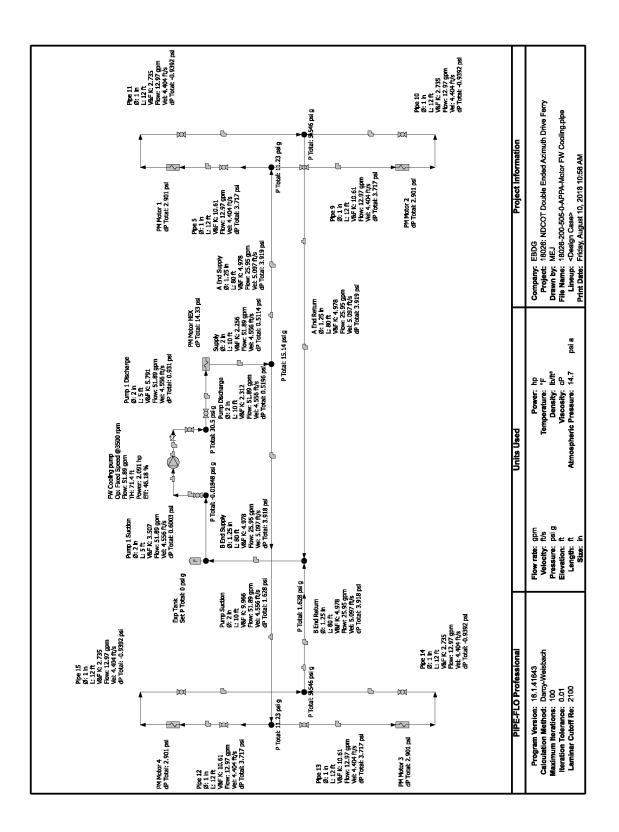
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Bill of Materials Report

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FRESHWATER COOLING SYSTEM PIPE-FLO MODEL



EBDG – NC, PLLC 18026-200-505-1

Version: 16.1.41643	Progam Name: PIPE-FLO Professional Version: 16.1.41643	Max Iterations: 10 Percent Tolerance: 0.(Allowable Deviation: 1	Max Iterations: 100 Percent Tolerance: 0.01 Ilowable Deviation: 1 %	by: Date: Atmospheric Pressure:	by: MEJ Date: Friday, August 10, 2018 10:58 AM ressure: 14.7 psia	ust 10, 2018 10:58, si a	AM	
			Pipe Specification					
Specification Name	Material	Absolute Roughness		Sizing Criteria		Design	atta	
Valve Table	Schedule	Hazen Williams C Factor	ns C Factor		Velocity	Pressure		Reynolds Number
Sch 10 Stainless standard	Stainless A53-B36.19 Schedule:10S	1.800E-03 in 140	B in 0.0) Fluid Zones	Min: Max:	r: C: A/s	psi g psi g	8 8	
Fluid Zone Name Table Name	Ter	Temperature F Pressure Relativ	Fiuld State Relative Molecular Mass	Density Viscosity	Vapor Critica	Vapor Pressure Critical Pressure	Specific He Specific I	Specific Heat Capacity (cp) Specific Heat Ratio (k)
30% Ethylene Glycol 30% Dowtherm SR-1	5	100.4 °F 10 psig	Llquid 22.61 Centrifugal Pumps	64.65 lb/ff* 1.301 cP	0.82	0.8264 psia 1575 psia	1	
Pump Name	Test Speed Operating Speed	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate Power E	Efficiency BEP Efficiency	NPSHa NPSHr	Design NPSH Margin Ratio
FW Cooling pump Fixed Speed @3500 rpm	3500 rpm 3500 rpm	0 ft -0.6187 psig	0 ft 31.44 psig	71.4 ft 32.05 psi	51.89 gpm 2.091 hp	46.18 % 47 %	29.52 ft 10 ft	I
Company: Ampos Pumps Curve: Catallog Pump Type: Z-SERIES		Size: 1.5x1.25SS Diameter: 4.75 in POR: from -	55SS - to - Pitelines					
Pipeline Name	Size	iniet Device	Flow Rate	Inlet Total Pressure	Total dP	Outlet Total Pressure	1.	V&F Friction Factor
Specification Fluid Zone	Inside Diameter Length	Inlet Elevation Outlet Device Outlet Elevation	Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Stattc Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total Head Loss	Outtet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade		V&F Resistance K V&F dP V&F Head Loss
A End Return	1.25 in	Node 5 0 B	25.95 gpm	5.546 psig	3.919 psi		psi g	0.02074
scri 10 statiness 30% Ethylene Glycol	1.442 IN 80 ft	оп Pressure Boundary 2 0 ft	0.025 0.025	5.365 psig 12.35 ft 11.95 ft	8.729 ft	1.44/ 3.626 1 3.223 1	n Bert	4.36 0.9022 psl 2.01 ft
A End Supply Sch 10 Stainiess 30% Ethylane 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 psig 14.96 psig 33.73 ft 33.33 ft	3.919 psl 8.729 ft	11.23 11.04 25 24.6	psig psig 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	5.548 psig 5.365 psig 12.35 ft 11.95 ft	3.918 psi 8.728 ft	1.628 1.447 3.626 3.223	psig psig g g g g g g g g g g g g g g g g g g	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 Mator HEX1 0 ft Node 6 0 ft	25.95 gpm 5.097 ft/s 45301 0.025	15.14 paig 14.96 paig 33.73 ft 33.33 ft	3.918 psi 8.728 ft	11.23 11.04 25 24.6	psig Psig g	0.02074 4.98 0.9022 psl 2.01 ft
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List Report

EBDG – NC, PLLC

18026-200-505-1

Job: 18026 Rev. -

:	;	•	i				
Pipeline Name Specification Fluid Zone	size Inside Dlameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Kate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Stattc Pressure Inlet Energy Grade Inlet Hydraulic Grade	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	Ē	PM Motor 2	12.97 apm	4.607 Dsi 0	-0.9392 nsi	5.548 psi a	0.02224
Sch 10 Stainless	1.097 in	4 f	4.404 ft/s	4.472 psi g		5.411 psi g	2.73
30% Ethylene Glycol	12 ft	Node 5	29774	¢	1.908 ft	12.35 ft	0.37 psi
		0 ft	0.02739	13.96 ft		12.05 ft	0.8242 ft
Pipe 11	5 7	PM Motor 1	12.97 gpm	4.607 psig	-0.9392 psi	5.546 psig	0.02224
Sch 10 Stainless	1.097 in	4 ft	4.404 ft/s			ä	2.73
30% Ethylene Giycol	12 ft	Node 5	29774	æ	1.908 ft	æ	0.37 psl
		ΟΨ	0.02739	13.96 ft		12.05 ft	0.8242 ft
Dine 13	5	Node 6	12 G7 Gnm	11 23 nel n	3 717 nel	7 508 nel n	0 02224
Sch 10 Stainless	1.097 In	Ê O	4.404 ft/s			8	10.61
30% Ethylene Glycol	12 ft	PM Motor 4	29774	e.	4.28 ft	e de	1.435 psi
		4 ft	0.02739	24.7 ft		20.42 ft	3.196 ft
Pine 13	t.	Node 6	12.97 anm	11.23 nsi n	3.717 nsi	7.508 nsi a	0.02224
Sch 10 Stainless	1.097 in	θΨ	4.404 ft/s	8		8	10.61
30% Ethylene Givcol	12 ft	PM Motor 3	29774	25 ft	4.28 ft		1.435 psi
		4 ft	0.02739			20.42 ft	3.196 ft
Pipe 14	- E	PM Motor 3	12.97 apm	4.607 psi a	-0.9392 psi	5.546 psi a	0.02224
Sch 10 Stainless	1.097 in	4 ft	4.404 ft/s	8		8	2.73
30% Ethylene Glycol	12 ft	Node 7	29774	. ∉	1.908 ft	. ∉	0.37 psl
•		ΟĤ	0.02739	13.96 ft		12.05 ft	0.8242 ft
Pipe 15	-	PM Motor 4	12.97 gpm	4.607 psi g	-0.9392 psl	5.546 psi g	0.02224
Sch 10 Stainless	1.097 In	4 ft	4.404 fVs		-		2.73
30% Ethylene Glycol	12 ft	Node 7	29774	L e	1.908 ft	l e	0.37 psi
•		ΟĤ	0.02739	13.96 ft			0.8242 ft
Pipe 17	2 in	Exp Tank	51.89 gpm	0 psig	0.01848 psi	-0.01848 psig	0.0188
Sch 10 Stainless	2.157 in	υΨ	4.556 ft/s	-0.1448 psig		-0.1633 psi g	0.00
30% Ethylene Glycol	1 ft	Flow Demand 1	60570	υΨ	0.04115 ft	-0.04115 ft	0 psi
		Û Û	0.02293	-0.3226 ft		-0.3637 ft	0 ft
Pipe 5	5 7	Node 2	12.97 gpm	11.23 psig	3.717 psi	7.508 psig	0.02224
Sch 10 Stainless	1.097 in	0 ff	4.404 ft/s	11.09 psig		7.373 psi g	10.61
30% Ethylene Glycol	12 ft	PM Matar 1	29774 0 02730	25 ft 24 7 ft	4.28 ft	20.72 ft 20.42 ft	1.435 psl 3.106 #
	:			:		:	1 0010
Pipe 9 Sch 10 Stainiass	1 II 1 007	Node 2	12.97 gpm 4 404 6 /e	11.23 psig 11.00 psig	3.717 psl	7.508 psig 7.373 psig	0.02224
2011 10 Otaliilooo 2004 Ethidono Chicol	# CT	DM Motor 2	601 FOF.F	Š. ¢	4 00 1	Š. ¢	1 495 mai
oux cuiviere divou	1 2	4 ft	0.02739	24.7 ft		20.42 ft	3.196 ft
Pumo 1 Discharoe	2 in	FW Cooling pump	51.89 apm	31.44 Dsi a	0.931 psi	30.5 psi a	0.0188
Sch 10 Stainless	2.157 in	ų ų	4.556 ft/s	8		8	6.79
30% Ethylene Glycol	5 ft	Node 1	60570	. ∉ .	2.074 ft		0.8386 psi
		0 #	0.02293	69.7 ft			1.868 ft
Pump 1 Suction	2 in	Flow Demand 1	51.89 gpm	g	0.6003 psi	ŝ	0.0188
Sch 10 Stainless	2.157 in	0 I	4.556 ft/s				3.51
30% Ethylene Glycol	5 11	FW Cooling pump	60570		1.337 ft	-1.378 ft	0.5079 psl
		0 H	0.02293	-0.3637 ft		-1.701 ft	1.131 ft
DIDE EL O Ductocolourol							

EBDG – NC, PLLC 18026-200-505-1

			Pipelines		l		
Pipeline Name	Size	Inlet Device	Flow Rate	Inlet Total Pressure	Total dP	Outlet Total Pressure	V&F Friction Factor
Specification Fluid Zone	Inside Dlameter Length	Inlet Elevation Outlet Device Outlet Elevation	Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Stattc Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total Head Loss	Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Resistance K V&F dP V&F Head Loss
Pump Discharge Sch 10 Stainless	2 in 2 157 in	Node 1 C	51.89 gpm 4.556 ft/s	30.5 psig 30.36 psig	0.5196 psi	29.98 psig 29.84 psig	0.0188 2.31
30% Ethylene Glycol	10 #	PM Motor HEX 0 ft	60570 0.02293	67.95 ft 67.63 ft	1.157 ft	iee	0.3348 psi 0.7459 ft
Dime Sudlen	c T	Presente Roundary 2	51 BD Anm	2	1 628 nei		0.0188
Sch 10 Stainless	2 157 in		4 556 ft/s	1.020 paig	194 0701	-0144R nsin	9910.0
30% Ethylene Glycol	-10 -14	Exp Tank	60570	Ĺ œ	3.626 ft		1.443 psl
		0 ft	0.02293	3.304 ft		-0.3226 ft	3.215 ft
Supply	2 In	PM Motor HEX	51.89 gpm	15.65 psi g	0.5114 psl	15.14 psig	0.0188
Sch 10 Stainless	2.157 In	0 ft	4.556 ft/s	15.51 pslg		15 psig	2.26
30% Ethylene Glycol	10 ft	PM Motor HEX1 0 ft	60570 0.02293	34.87 ft 34.55 ft	1.139 ft	33.73 ft 33.41 ft	0.3267 psi 0.7277 ft
			Fixed dP Devices				
Fixed dP Device Name	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	vation Issure	dP Head Loss	Flow Rate		
PM Motor 1	4 ft 7.508 psig	4 ft 4.607 psig	Dia d	2.901 psi 6.461 ft	12.97 gpm		
PM Motor 2	4 ft 7.508 neio	4 ft 4 f07 nsi o		2.901 psi 6.461 ft	12.97 gpm		
	Bied ono:		7.5	1 12-2			
PM Metor 3	4 ft 7.508 psig	4 ft 4.607 p	ft psig	2.901 psi 6.461 ft	12.97 gpm		
PM Motor 4	4 ft 7.508 psig	4 ft 4.607 psig	ai g	2.901 psi 6.461 ft	12.97 gpm		
PM Motor HEX	0 ft 29.98 psig	0 ft 15.65 psig	2 jū	14.33 psi 31.92 ft	51.89 gpm		
			Nodes				
Node Name		Elevation		Pressure Hydra	Hydraulic Grade		
Flow Demand 1		0	ft -0.01848 psig		-0.3637 ft		
Node 1		0	ft 30.5	psi g	67.63 ft		
Node 2		H 0		11.23 psig 24	24.67 ft		
Node 5		0	ft 5.546	5.546 psi g 12	12.02 ft		
Node 6		0	ft 11.23	11.23 psig 24	24.67 ft		
Node 7		0	ft 5.546	5.546 psig 12	12.02 ft		
PM Motor HEX1		0	ft 15.14		33.36 ft		
Pressure Boundary 2		o	ft 1.628	psi g	3.25 ft		
Pressure Boundary Name		Elevation		Pressure Hydra	Hydraulic Grade	Flow Rate	
Exp Tank		o	۳ ۳	0 psig -0.3226	26 ft	51.89 gpm	
PIPE-FLO Professional	Version: 16.1.41643	2	List Report		Friday, August 10, 2018 10:58 AM	018 10:58 AM	Page 3

File Name: 180 Lineup: <de rogram Name: PiP Version: 16.4</de 	E-FLO Professional	cooling.pi		ıgal Pumps	by:	EBDG 18026: NDCOT Double E MEJ Friday, August 10, 2018 1		h Drive Ferry
Centrifugal Pump N Operation	ame							
FW Cooling pump Fixed Speed @35	Size	y: Ampox a: Z-SER a: 1.5x1. a: Catalo	IES 25SS g Pump			Test Speed: Impeller Dlameter: POR: from	3500 rpm 4.75 in 	to –
Fixed dP Device Na	me	Fixed		IP Devices				
PM Motor 1		2.901	si					
PM Motor 2		2.901						
PM Motor 3		2.901	si					
PM Motor 4		2.901 p	si					
PM Motor HEX		14.33 p		elines				
Pipeline	Specification			Size	Length	Valves and Fitting]6	
A End Return	Sch 10 Stainle	S S	1.	25 in	80 ft	6 x Elbow - Standa 1 x Tee - Flow Thr		
A End Supply	Sch 10 Stainle	S S	1.	25 in	80 ft	6 x Elbow - Standa 1 x Tee - Flow Thr		
B End Return	Sch 10 Stainle	88	1.	25 in	80 ft	6 x Elbow - Standa 1 x Tee - Flow Thr		
B End Supply	Sch 10 Stainle	55	1.	25 in	80 ft	6 x Elbow - Standa 1 x Tee - Flow Thr		
Pipe 10	Sch 10 Stainle	S S		1 in	12 ft	4 x Elbow - Standa 1 x Ball	ard 90°	
Pipe 11	Sch 10 Stainle	88		1 in	12 ft	4 x Elbow - Standa 1 x Ball	ard 90°	
Pipe 12	Sch 10 Stainle	55		1 in	12 ft	4 x Elbow - Standa 1 x Ball 1 x 3-way ball valv		
Pipe 13	Sch 10 Stainle	55		1 In	12 ft	4 x Elbow - Standa 1 x Ball 1 x 3-way ball valv		
Pipe 14	Sch 10 Stainle	55		1 in	12 ft	4 x Elbow - Standa 1 x Ball	ard 90°	
Pipe 15	Sch 10 Stainle	S S		1 in	12 ft	4 x Elbow - Standa 1 x Ball	ard 90°	
Pipe 17	Sch 10 Stainle	88		2 in	1 ft			
Plpe 5	Sch 10 Stainle	S S		1 In	12 ft	4 x Elbow - Standa 1 x Ball 1 x 3-way ball valv		
Pipe 9	Sch 10 Stainle	5 5		1 in	12 ft	4 x Elbow - Standa 1 x Ball 1 x 3-way ball valv		
Pump 1 Discharge	Sch 10 Stainle	88	:	2 in	5 ft	4 x Elbow - Standa 1 x Ball 1 x Tae - Flow Thr 1 x Swing Check - 1 x Reducer - Enla	u Branch Angled	in x 1.25 in - :
Pump 1 Suction	Sch 10 Stainle	88	:	2 in	5 ft	4 x Elbow - Standa 1 x Tee - Flow Thr 1 x Ball 1 x Reducer - Con	u Branch	x 1.5 ln - 3 lr
Pump Discharge	Sch 10 Stainle	88	:	2 in	10 ft	4 x Elbow - Standa 1 x Ball	ard 90°	
Pump Suction	Sch 10 Stainle	55		2 in	10 ft	4 x Elbow - Standa 1 x Air Separator	ard 90°	

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 - 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

PIPE-FLO Professional

Version: 16.1.41643

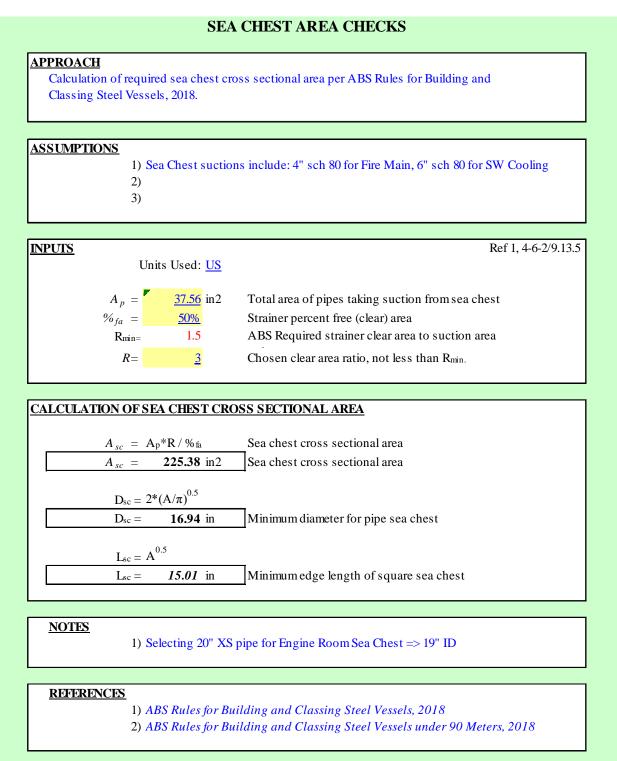
Bill of Materials Report

Friday, August 10, 2018 10:58 AM

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EBDG - NC, PLLC 18026-200-505-1

SEA CHEST SIZING



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 18	800 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 ₂ O

• 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 ₂ O

- 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 H₂0. 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 H₂0. 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 H₂O, 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 ft³/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			COMPRESSOR OUTLET PRES		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]:

	1450	0201	
EXHAUST SYSTEM			
THE INSTALLED SYSTEM MUST COMPLY WITH THE SYSTEM LIMITS BELOW FOR ALL EMISSIONS COMPLIANCE.	CERTIFIED ENGINES TO ASSU	IRE REGULATORY	
COMPLIANCE.			
MAXIMUM ALLOWABLE SYSTEM BACK PRESSURE	40	IN-H20	
	40 WET	IN-H20	

Harco 2458VRSA10 backpressure calculated using [5]:

	Silencer		ame of	ltem #	Silencer	Name of	
	Model		Model		Model	Model	
1	SFH		Critical Grade	10	RFH	Residential Grade	
2	LPRS		Critical Grade	11	RSL	Residential Grade	
3	SCSC		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.	
8	CFH	Crit	ical grade	17	М	Industrial Grade	
9	HCY	Crit	cal Grade	18	EXT	Extreme grade	
ntroduce nlet/Outle FOR TUB ACFM		CERS ONLY) Temp.+ 460 2275		$F = 9x\frac{C}{5} + 3$	Introdu & Elbo	Kg/s luce Temp. (C) ce BP of Piping bws $\frac{PS}{r} = 7936.56x1 \frac{Kg}{Second}$	
	$Area(ft)^2$	$=\frac{\pi x(0.083)}{\pi x(0.083)}$	33 <i>xdiameter)</i> 4	2 - = 0.7854.	$xd^2x0.006$	59444 = 0.005454 xa	
Flow Dutlet Flo Temp (F) CFM		0.545 709.7 3623	33xdiameter) 4		$xd^2x0.006$	59444 = 0.005454 <i>xa</i>	

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)	
Exhaust stack temperature	431° (105 ekW), 419°C (90 ekW), 404°C (66 ekW), 395°C (51 ekW)
Exhaust stack temperature	
Engine exhaust connection	
Max, allowable system backpressure	15 kPa (60 in H=0)

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

ltem #	Silencer	N	lame of	ltem #	Silencer	Name	of
	Model		Model		Model	Mode	el
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 G	rade S.A.
5	VRS	Crit	ical Grade	14	RSL	Residential G	rade S.A.
6	CFHI	Crit	ical Grade	15	VRSA	Critical Grad	de S. A.
7	CSCS	Crit	ical grade	16	VCSA	Super Critical C	Grade S. A.
8	CFH	Crit	ical grade	17	М	Industrial	Grade
9	HCY	Crit	ical Grade	18	EXT	Extreme	grade
Introduce i Introduce Introduce Introduce Inlet/Outle (FOR TUB ACFM Calculate	Max. BP of E t Configurat ULAR SILEN = <u>Exhaust</u> Outlet Flow	M Outlet (in) Engine ion ICERS ONLY) tTemp.+ 460 2275 w Area		$F = 9x\frac{C}{5} + 3$	or Introdu & Elbo 2 $1\frac{Ll}{H}$	$\frac{2s}{r} = 7936.56x1$	
Cutlet Flo Outlet Flo Temp (F) CFM		$=$ $\frac{0.087}{759}$ 578	$\frac{333 \times diameter)^2}{4}$	= 0.7854 <i>x</i>	xd ² x0.006	59444 = 0.005	5454 <i>xd</i> ²
Calculate Velocity ft/min (V)				5]		662 0
Calculate	Back Press	sure (in H2O)	P = cx	$\frac{V^2}{4005^2} x \frac{1}{(T)}$	$\frac{530}{+460)} =$		9.
loto Evho	unt Valanitur	bould not over	ad 0000 ft/min an all				0

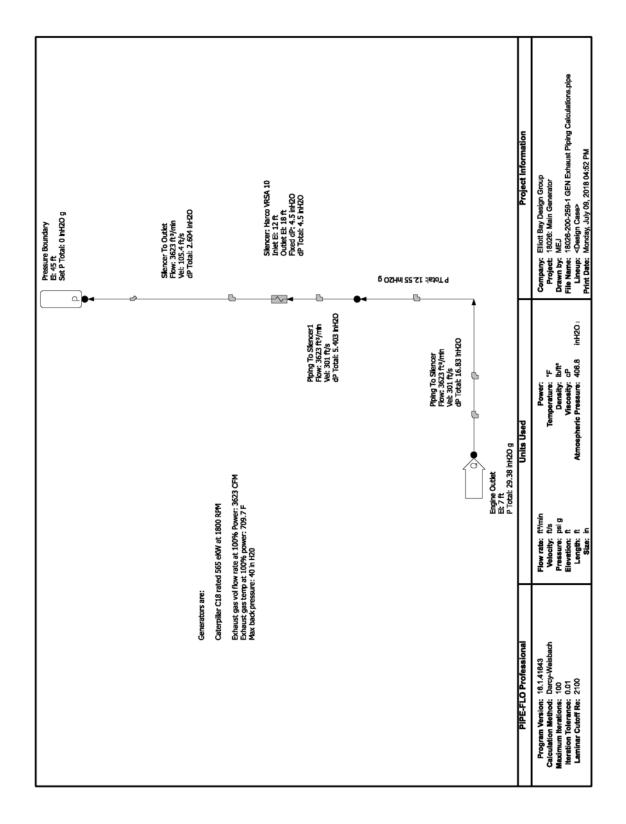
CALCULATION OF BACK PRESSURE OF SILENCER

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



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The Specifications Interface Stand Specifications	Version: 16.1.41643		Percent 16 Allowable D	olerance: 0.01 eviation: 1 %	Atmospheric Pres	Jate: Monday, July sure: 406.8 inHi	09, 2018 04:53 PM 20 a	
Mental Montal Montal Calify Classical Montal <				Pipe Specification	-			
Scholder Face Millione Face Millione Reprinder Millione <threprinder millione<="" th=""> <threprint< th=""> Repr</threprint<></threprinder>	Specification Name	Material	Absolute		g Criteria	100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100	Design Limits	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Service State 10 State 7	Vatve Table	Schedule	Hazen Will	ams C Factor	1	Velocity	Pressure	Reynolds Number
Search AGE (31) 1.00E-(3) in (31)	Steel, Sch 10 standard	Steel A53-B36.10 Schedule:10	1.800E		Mir Mao		psig psig	
Standback JADDE JADDE Matrix	Steel, Sch 20 standard	Steel A53-B36.10 Schedule:20	1.800E		Mir Mao		psig psig	
Tangenture Tangenture Funder frame Vagor Pressure Specific Heat Capacity 700/11 700/1	Steel, Sch 40 standard	Steel A53-B36.10 Schedule:40	1.800E	Fluid Zon	Mir Mao		psi g psi g	
TOB.T TOB.T <th< td=""><td>Fluid Zone Name Table Name</td><td>ē -</td><td></td><td>Fluid State tive Molecular Mass</td><td>Density Viscosity</td><td>Vapor I Critical</td><td></td><td>Heat Capacity (cp) c Heat Ratio (k)</td></th<>	Fluid Zone Name Table Name	ē -		Fluid State tive Molecular Mass	Density Viscosity	Vapor I Critical		Heat Capacity (cp) c Heat Ratio (k)
Stan Init Divice Criticitie Flattion Flattion Total Presente Outer Energion Writ Flattion Flattion Mark	Engine Exhaust (Air at 709.7F) Air	~ ~		Ges 28.96	0.03557 lb/ff* 0.03193 cP	6.137E+06 15151		27 BTU/Ib*F 1.372
Index Truck weiger (name Truck weiger (name </td <td>Pipeline Name</td> <td>Size</td> <td>Inlet Device</td> <td>Flow Rate</td> <td>Inlet Total Pressure</td> <td>Total dP</td> <td>Outlet Total Pressure</td> <td>V&F Friction Factor</td>	Pipeline Name	Size	Inlet Device	Flow Rate	Inlet Total Pressure	Total dP	Outlet Total Pressure	V&F Friction Factor
06.7F) 6 in 257.66 ft Engine Outer 11 ft 3623 ft/min 28-36 int/20 g 12.56 int/20 g 12.56 int/20 g 12.56 int/20 g 0.01 7.00.7F) 27.66 ft Non 11 ft 2823 ft/min 2823 ft/min 2823 ft/min 2823 ft/min 2824 ft/min 1748 7.03 7.00.7F) 2.01755 283 ft/min 2823 ft/min 2823 ft/min 2824 ft/min 2846 ft 7.03 7.00.7F) 2.01755 283 ft/min 2823 ft/min 2823 ft/min 783 ft 7.03 7.04 7.03 7.00.7F) 2.0.755 2.0.74 int/20 g 2.0.74 int/20 g 2.0.74 int/20 g 0.01 7.00.7F) 2.0.55 ft Remonentiamoversion 0.01755 2.0.84 int/20 g 2.0.74 int/20 g 0.01 7.00.7F) 2.0.55 ft Remonentiamoversion 2.0.64 int/20 g 2.0.74 int/20 g 0.01 7.00.7F) 2.0.55 ft Peanue benutavy 0.01755 2.0.84 int/20 g 2.0.74 int/20 g 0.01 7.00.7F 2.0.55 ft Peanue benutavy 0.016 ft/20 g 2.0.64	specification Fluid Zone	Inside Diameter Langth	Inter Elevation Outlet Device Outlet Elevation	Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total Head Loss	Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F RESISTANCE K V&F dP V&F Head Loss
(00.17) 27.66 ft Nota i 522176 4305 ft 2458 ft 1486 ft 7.73 (00.77) 6 in 11 ft 2001725 2897 ft 7863 ft 7866 ft 7166 ft 7.73 (00.77) 6 in 11 ft 301 ft 2823 ft 2456 ft 716 ft 7.73 (00.77) 2 ft 800 ft 2 ft 301 ft 2456 ft 7863 ft 716 ft 7.73 (00.775) 1 ft 301 ft 2 504 ft 783 ft 783 ft 900 ft 603 ft 904 ft (00.775) 1 ft 165 ft 1424 ft 383 ft 383 ft 1657 ft 900 ft 901 ft 1728 145 ft 147 ft 1728 145 ft 145 ft 147 ft 167 ft 147 ft 167 ft 1728 147 ft 1728 147 ft	Piping To Silencer Steel. Sch 40	6 in 6.065 in	Engine Outlet 7 ft	3623 ft*/min 301 ft/s	29.38 inH20 g 19.76 inH20 g	16.83 inH2O	12.55 inH2O g 2.924 inH2O g	
(00.7) (00.61 t) (00.61 t) (00.61 t) (00.71 t) (Engine Exhaust (Air at 709.7F)	27.66 ft	Node 1 11 ft	252176 0.01725	4305 ft 2897 ft	2458 ft	1846 ft 438.6 ft	211.22
10 in Stanoar: Harox VRAX 10 323 P/Inin 2.604 inH2O g 2.604 inH2O g 0 inH2O g 0.013 703.7F) 10.25 in 18 f 105.4 f/s 1.424 inH2O g 2.604 inH2O g 0 inH2O g 1.43 703.7F) 72.35 in 78.06 inH2O g 0.01769 2.604 inH2O g 1.43 703.7F) 7.85 inH2O g 0.01769 2.604 inH2O g 1.42 1.42 71.75 7.6 7.83 in 353.9 it 353.9 it 2.52.9 71.75 7.60 inH2O g 0.01769 2.604 inH2O g 2.604 inH2O g 2.614 71.75 Flord dP 2.663 if 353.9 it 353.9 it 2.52.9 71.15 12 if 7.145 inH2O g 0.01769 6.68.2 it 4.51.20 71.45 1.145 7.145 1.142 f 3.63.8 it 3.63.8 it 71.45 1.145 7.65 inH2O g 6.68.2 it 4.51.1120 g 3.63.8 if 3.63.8 if 3.63.8 if 3.73.6 if 71.45 1.160 2.604 inH2O g 6.68.2 it <td< td=""><td>Piping To Silencer1 Steel, Sch 40 Engine Exhaust (Air at 709.7F)</td><td></td><td>Node 1 11 ft Stiencer: Harco VRSA 10 12 ft</td><td>3623 ft?/min 301 ft/s 252176 0.01725</td><td>12.55 inH20 g 2.924 inH20 g 1846 ft 438.6 ft</td><td>5.403 inH2O 789.3 ft</td><td>7.145 inH20 g -2.479 inH20 g 1057 ft -350.6 ft</td><td></td></td<>	Piping To Silencer1 Steel, Sch 40 Engine Exhaust (Air at 709.7F)		Node 1 11 ft Stiencer: Harco VRSA 10 12 ft	3623 ft?/min 301 ft/s 252176 0.01725	12.55 inH20 g 2.924 inH20 g 1846 ft 438.6 ft	5.403 inH2O 789.3 ft	7.145 inH20 g -2.479 inH20 g 1057 ft -350.6 ft	
Intellevation Outlet Elevation Outlet Elevation Outlet Elevation Outlet Elevation Plow Rate 10 12 ft 18 ft 4,5 int20 36.3 ft/min 10 7.145 int20 g 2.604 int20 g 658.2 ft 36.3 ft/min 11 18 ft 1.5 int20 g 36.3 ft/min 1.5 int20 g 36.3 ft/min 11 1.1 ft 1.2.5 int20 g 4.8.6 ft 4.8.6 ft 1.5 int20 g	Silencer To Outlet Steel, Sch 20 Engine Exhaust (Air at 709.7F)		Silencer: Harco VRSA 10 18 ft Pressure Boundary 45 ft	3623 ft/min 105.4 ft/s 149214 0.01769	2.604 inH20 g 1.424 inH20 g 398.9 ft 226.3 ft	2.604 inH2O 353.9 ft	0 inH2Og -1.18 inH2Og 45 ft -127.6 ft	
Initi Pressure Outlet Pressure Head Lose 10 12 ft 18 ft 4.5 inH2O 3623 ft/min 7.145 inH2Og 2.604 inH2Og 658.2 ft 3623 ft/min Notes 11 ft 12.55 inH2Og 436.6 ft Version: 16.1.41643 List Report	Fixed dP Device Name	Inlet Elevation		FIXED OF DEVICOS	đ	Flow Rate		
7.145 init20.g 2.604 init20.g 658.2 ft 7.145 init20.g 658.2 ft Hydraulic Grade 11 11 12.55 init20.g 438.6 ft Version: 16.1.41643 List Report Monday, July 09, 2018 04:53 PM	Silencer: Harco VRSA 10	Inlet Pressure 12 ft		Pressure	Head Loss 4.5 inH20	3623 ft ^a /min		
Elevation Pressure Hydraulic Grade 11 ft 12.55 inH2O g 438.6 ft Version: 16.1.41643 List Report Monday, July 09, 2018 04:53 PM		7.145 inH2C		inH2O g Nodes	658.2 ft			
11 ft 12.55 inH2O g 438.6 ft Version: 16.1.41643 List Report Monday, July 09, 2018 04:53 PM	Node Name		Eleva	1.000		lic Grade		
Version: 16.1.41643 List Report List Report	Node 1		F			u 9.		
	PPE-FLO Professional	Version: 16.1.416	8	List Report		fonday, July 09, 20	18 04:53 PM	Page 1

NCDOT

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List Report

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PIPE-FLO Professional

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File Name: 18026-200 Lineup: <design c<br="">Program Name: PIPE-FLO Version: 16.1.41643</design>	Professional	ulations.pipe Fixed dP Devi	Project: by: Date:	Elliott Bay Design Group 18026: Main Generator MEJ Monday, July 09, 2018 04:53 PM
Fixed dP Device Name	Fixe		1685	
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 S	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)

PIPE-FLO Professional

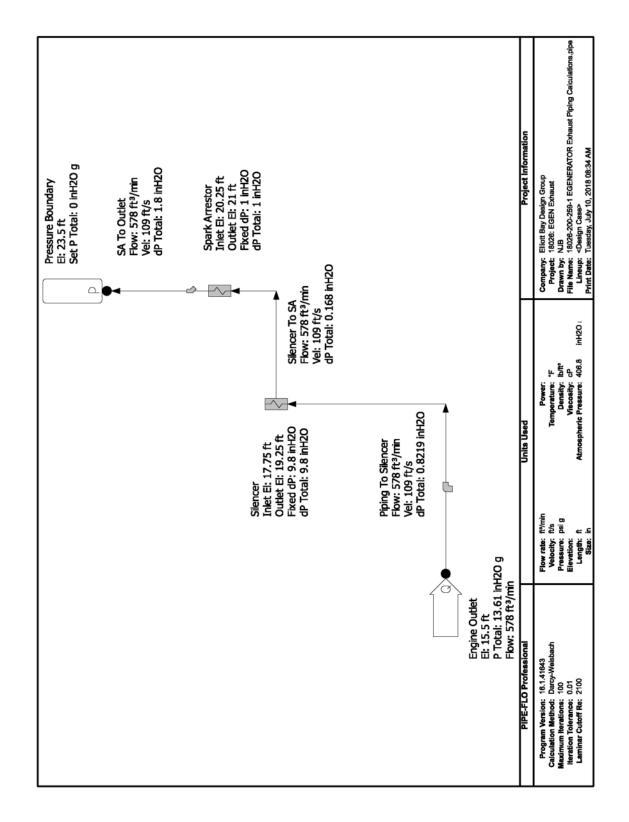
Version: 16.1.41643

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EMERGENCY GENERATOR EXHAUST MODEL



File Name: 18028-200-269-1 EGENERATOR Exhaust Piping Calculat Lineup:	EDATOP Extranet Biolog Color						
Progam Name: PIPE-FLO Protessional Version: 16.1.41643		1998 1998	Catcutation Method: Darcy-Weisbach Laminar Cutoff Re: 2100 Max Ibrations: 100 Percent Tolerance: 0.01 Allowabio Deviation: 1 %	Con Pr Atmospheric Prei		Elliott Bay Design Group 18028: EGEN Exhaust NJB Morday, July 09, 2018 04:51 PM 406.8 inH2O a	
			Pipe Specification	15			
Specification Name Value Table	Material Schedule	Absolute F	Absolute Roughness Sizin	Sizing Criteria	Valveity	Design Limits	Demolds Number
	annaine				ABIOCILÀ	aineesiL	Indition entitles
Steel, Sch 10	Steel A53-B36.10	1.800E-03 in	03 in 0.0	Min:	ft/s	Bisq	
standard	Schedule: 10	140		Max		Bisd	
Steel, Sch 20	Steel A53-B36.10	1.800E-03 in	03 in 0.0	Min:		pisq	
standard	Schedule:20	140	0	Max:	fVs	psi g	
Steel, Sch 40	Steel A53-B36.10	1.800E-03 in	03 in 0.0	Min:	fVs	psi g	
standard	Schedule:40	140		Max:		psi g	
			Fluid Zones				
Fluid Zone Name Table Name	Tempe Pres	Temperature I Pressure Rolati	Fluid Stats Relative Molecular Mass	Density Viscosity	Vapor	Vapor Pressure Specific Critical Pressure Specific	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Engine Exhaust (Air at 713F) Air	759 29.98	759 °F 29.98 inH2O g	Gas 28.96	0.03492 lb/ff* 0.03279 cP	7.181E+0		0.2543 BTU/Ib*F 1.369
			Pipelines				
Pipeline Name	Size	Inlet Device	Flow Rate	Inlet Total Pressure	Total dP	Outlet Total Pressure	V&F Friction Factor
Specification Fluid Zone	neter	Inlet Elevation Outlet Device Dutlet Elevation	Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total Head Loss	Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	
Plping To Silencer	4 in	Engine Outlet	•	1	4	1	1
Steel, Sch 40	4.028 in	15.5 ft	1	1		1	0.33
Engine Exhaust (Air at 713F)	5 11	Silencer	1	3	ĵ	ì	1
		17.75 ft	I	ı		1	1
SA To Outlet	4 Li	Sperk Arrestor	1	1	1	T	1
Steel, Sch 40	2	21 ft	1	1		ı	1.24
Engine Exhaust (Air at 713F)	3 A Pr	Pressure Boundary 23.5 ft	11	11	ĩ	11	1.1
Silencer To SA	4 in	Stlencer		3	1	1	1
Steel, Sch 40	4.026 in	19.25 ft	ı	1		ı	0.00
Engine Exhaust (Air at 713F)	2 ft	Spark Arrestor	ı	1	i	1	ı
		11 CZ-02	Fixed dP Device	1		Ē	ŧ
				•			
Fixed dP Device Name	Iniet Elevation Iniet Pressure	Outlet Elevation Outlet Pressure	evation essure	dP Head Loss	Flow Rate		
Silencer	17.75 ft	19.25 ft		3	ı		
		1	6	1			
Spark Arrestor	20.25 ft -	21 #	-	L.I	Ē		
PIPE-FLO Professional	Version: 16.1.41643		List Report	-	Monday, July 09, 2018 04:51 PM	18 04:51 PM	Page 1

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PIPE-FLO Professional

		Bill of Materials Rep	port	
Lineup: <c< th=""><th>026-200-259-1 EGENERATOR Exha Design Case> PE-FLO Professional .1.41643</th><th></th><th>Project: by: Date:</th><th>Elliott Bay Design Group 18026: EGEN Exhaust NJB Monday, July 09, 2018 04:50 PM</th></c<>	026-200-259-1 EGENERATOR Exha Design Case> PE-FLO Professional .1.41643		Project: by: Date:	Elliott Bay Design Group 18026: EGEN Exhaust NJB Monday, July 09, 2018 04:50 PM
		Fixed dP Devic	95	
Fixed dP Device Na	ame	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 Su	mmary	
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°

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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:

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.

Pipe Segment	Flow	Pipe	Schedule	d, ID	Design Vel	ocity	V
	Rate	Size			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

Table 3: Fuel Oil System Pipe Sizes and Velocities

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

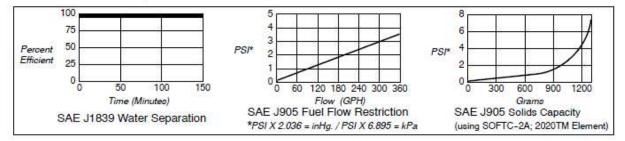
From [1]:

	10 - 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]:

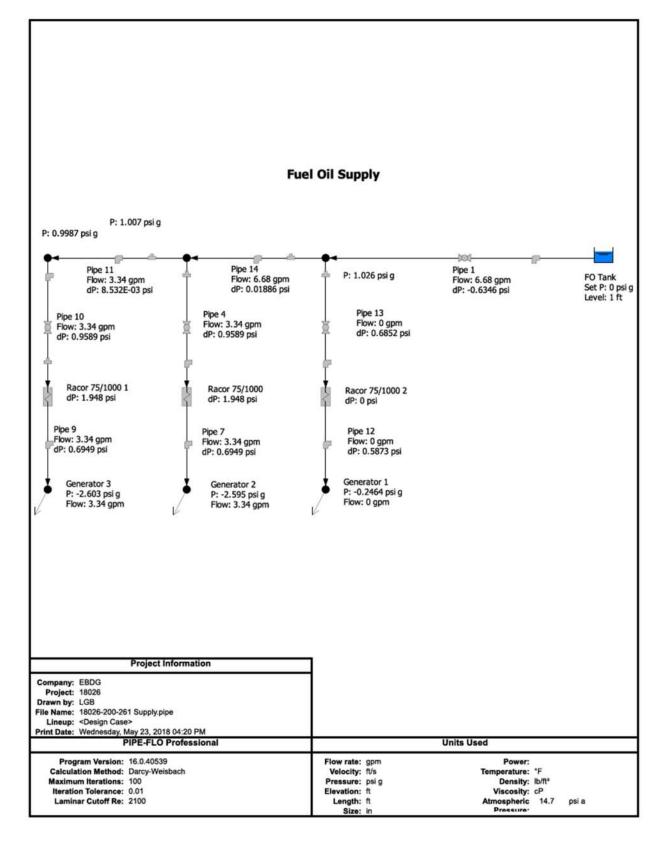
Performance Graphs - These results are from controlled laboratory tests. Field results may vary by application.



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



EBDG – NC, PLLC 18026-200-505-1

		2	List Report	l			
File Name: 18026-200-261 Supply.pipe Lineup: <design case=""> Progam Name: PIPE-FLO Professional Version: 16.0.40539</design>	Supply.pipe ssional	Calculation Method: Laminar Cutoff Re: Max Iterations: Iteration Tolerance: Atmospheric Pressure: Pipe	Darcy-Weisbach 2100 100 0.01 14.7 psi a e Specifications	Company: Project: by: Date:	EBDG 18026 LGB Wednesday, May 23, 2018 04:20 PM	2018 04:20 PM	
Specification Name Valve Table	Material Schedule H	Absolute Roughness Hazen Williams C Factor	Sizing Criteria	Velocity	Design Lin Pressure	Design Limits Pressure	Reynolds Number
ASTM A53 Sch 40 standard	Steel A53-B36.10 Schedule:40	1.800E-03 in 140	0.0	to ft/s	ą	psi g	9
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		Liquid Pipelines	56.38 lb/ft ^a 10.19 cP	0.2171 psia 3199 psia		1-
Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Elevation ter 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 Intet Device: FO Tank	3.5 ft 1.75 ft	6.68 gpm 0.6337 ft/s 905.7 Outlet Device: Node	0.1292 ft 0.0252 ft : Node 1	0.3915 psi g 1.026 psi g	-0.6346 psi 9.866E-03 psi	0.07067 0.01899 3.98
Pipe 9 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 3 ft Inlet Device: Racor 75/1000 1	3.5 ft 5 ft 01	3.34 gpm 2.009 ft/s 1136 Outlet Device	0.34 gpm 0.2748 ft 009 ft/s 0.1204 ft 1136 Outlet Device: Generator 3	-1.909 psi g -2.603 psi g	0.6949 psi 0.04713 psi	0.05634 0.02398 1.92
Pipe 10 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft Inlet Device: Node 6	1.75 ft 3.5 ft	3.34 gpm 2.009 ft/s 1136 Outlet Device	1.34 gpm 0.6993 ft 009 ft/s 0.1844 ft 1136 Outlet Device: Racor 75/1000 1	0.9987 psi g 0.03976 psi g	0.9589 psi 0.07219 psi	0.05634 0.02398 2.94
Pipe 7 ASTM A53 Sch 40 Fuel 3	0.75 in 0.324 in 3 ft Inlet Device: Racor 75/1000	3.5 ft 5 ft	3.34 gpm 2.009 ft/s 1136 Outlet Device	1.34 gpm 0.2748 ft 009 ft/s 0.1204 ft 1136 Outlet Device: Generator 2	-1.9 psig -2.595 psig	0.6949 psi 0.04713 psi	0.05634 0.02398 1.92
Pipe 4 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 10 ft Inlet Device: Node 5	1.75 ft 3.5 ft	3.34 gpm 2.009 ft/s 1136 Outlet Device	1.34 gpm 0.6993 ft 009 ft/s 0.1844 ft 1136 Outlet Device: Racor 75/1000	1.007 psi g 0.04829 psi g	0.9589 psi 0.07219 psi	0.05634 0.02398 2.94
Pipe 11 ASTM A53 Sch 40 Fuel 3	2 in 2.067 in 15 ft Inlet Device: Node 5	1.75 ft 1.75 ft	3.34 gpm 0 0.3193 ft/s 2.22 452.8 Outlet Device: Node 6	0.02179 ft 2.287E-03 ft : Node 6	1.007 psig 0.9987 psig	8.532E-03 psi 8.955E-04 psi	0.1413 0.01899 1.44
Pipe 12 ASTM A53 Sch 40 Fuel 3	0.75 in 0.824 in 3 ft Inlet Device: Racor 75/1000 2	3.5 A 5 A 0 2	0 gpm 0 ft/s 0 Outlet Device	0 gpm 0 ft 0 ft/s 0 ft 0 Outlet Device: Generator 1	0.3409 psi g -0.2464 psi g	0.5873 psi 0 psi	0.02398
PIPE-FLO Professional	List	List Report		Wednesday, May 23, 2018 04:20 PM	018 04:20 PM		Page 1

DOUBLE ENDED AZIMUTH DRIVE FERRY

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Pipeline Name Specification Fluid Zone	Ē	Size I Inside Diameter O Length	Inlet Elevation Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number	Total Head Loss V&F Head Loss	Inlet Pressure Outlet Pressure	ssure	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 0.824 10 Inlet Device: Node 1	0.75 in 0.824 in 10 ft tode 1	1.75 ft 3.5 ft	0 gpm 0 ft 0 ft/s 0 ft 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 ft 0 ft acor 75/1000 2	1.026 0.3409	psig psig	0.6852 psi 0 psi	- 0.02398 2.94
Pipe 14 ASTM A53 Sch 40 Fuel 3	2 2.067 15 Inlet Device: Node 1	2 in 2.067 in 15 ft tode 1	1.75 ft 1.75 ft	6.68 gpm 0. 0.6387 ft/s 9.14 905.7 Outlet Device: Node 5	0.04816 ft 9.149E-03 ft ode 5	1.026	psig 0 psig 3.5	0.01886 psi 3.582E-03 psi	0.07067 0.01899 1.44
Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	ade Pipeline Name		Connecting Pipelines Penetration Height Pipeline F	Pipelines Pipeline Flow Rate		Pressure at Penetration
Fo Tank Fuel 3	35 A 1 A	0 psi g 0.3915 psi g	4.5 ft Curve	4.5 ft Curve dP Devices	Pipe 1 0	¥	6.68 gpm	mqg	0.3915 psi g
Curve dP Device Name Description	Inlet E Inlet P	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	Head	dP Head Loss	Flow Rate			
Racor 75/1000 1 Racor 75/1000	3.5 ft 0.03976 psig	3.5 ft 976 psig	3.5 ft -1.909 psig	1.9	1.948 psi 4.976 ft	3.34 gpm			
Racor 75/1000 Racor 75/1000	3.5 ft 0.04829 psig	3.5 ft 829 psig	3.5 ft -1.9 psig	1.97	1.948 psi 4.976 ft	3.34 gpm			
Racor 75/1000 2 Racor 75/1000	3.5 0.3409	3.5 ft 0.3409 psig	3.5 ft 0.3409 psig	Nodes	0 psi 0 ft	mqg 0			
Node Name			Elevation	Pressure	Hydraulic Grade	Grade			
Node 1			1.75 ft	1.026 psi g	4.367 ft	E			
Node 5			1.75 ft	1.007 psi g	4.299 ft	æ			
Node 6		l	1.75 ft Flov	0.9987 psig Flow Demands	4.269 ft	e			l
Flow Demand Name			Elevation	Pressure	Hydraulic Grade		Flow Rate	Flow Di	Flow Direction
Generator 3			5 ft	-2.603 psi g	-1.712 ft			Flov	Flow out
Generator 2			5 ft	-2.595 psi g	-1.691 ft			Flov	Flow out
Generator 1			5 ft	-0.2464 psi g	4.371 ft			Flov	Flow out

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	1	Bil	of Materials Rep	oort		
Lineup: Program Name:	18026-200-261 Supply.pipe <design case=""> PIPE-FLO Professional 16.0.40539</design>		0 1 1		EBD 1802 LGB Wed	26
			Pipelines			
Pipeline	Specifi	cation	Size	Le	ngth	Valves and Fittings
Pipe 1	ASTMA	153 Sch 40	2 in	40) ft	1 x Ball 6 x Elbow - Standard 90* 1 x Entrance - Sharp Edged
Pipe 9	ASTM /	53 Sch 40	0.75 in	:	3 ft	4 x Pipe Bend - r/d 1 (90°)
Pipe 10	ASTMA	53 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 A	53 Sch 40	0.75 in	:	3 ft	4 x Pipe Bend - r/d 1 (90°)
Pipe 4	ASTM A	53 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	ASTMA	53 Sch 40	2 in	1	5 ft	4 x Pipe Bend - r/d 1.5 (90°) 1 x Tee - Flow Thru Run
Pipe 12	ASTM	53 Sch 40	0.75 in	:	3 ft	4 x Pipe Bend - r/d 1 (90*)
Pipe 13	ASTMA	53 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	ASTMA	53 Sch 40	2 in		5 ft	4 x Pipe Bend - r/d 1.5 (90°) 1 x Tee - Flow Thru Run
		P	ipeline Material Su	mmary		
Specification	Material		Size	Total Length		Valves & Fittings
ASTM A53 Sch 4	40 Steel A53-B3 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 4	0 Steel A53-B3 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

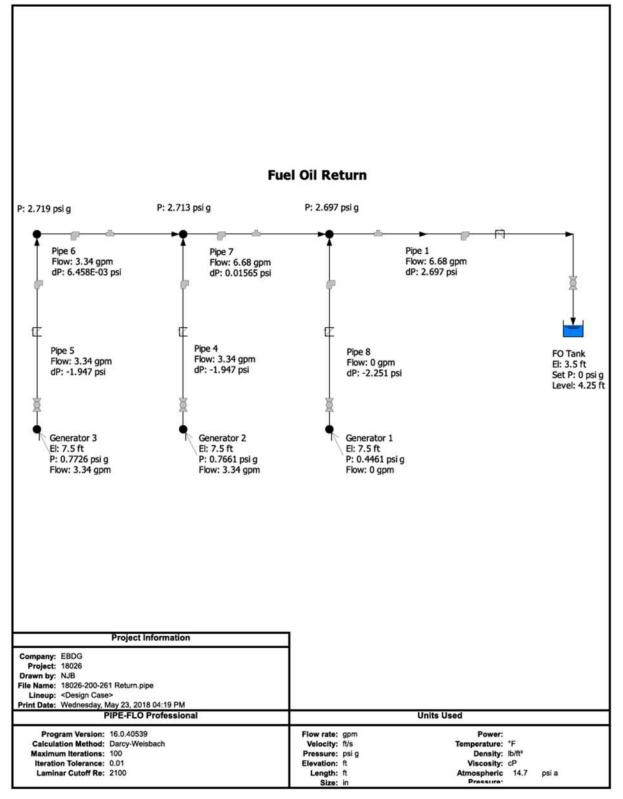
PIPE-FLO Professional

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FUEL OIL RETURN PIPE-FLO MODEL



File Name: 18026-200-261 Returm pipe Lineup: -Design Case> Progam Name: PiPE-FLO Professional Version: 16.0.40539 Specification Material Specification Name Material Valve Table Material ASTM-A-269 Schedule ASTM A-269 Schedule	A	Calculation Method: Darcy Laminar Cutoff Re: 2100 Max Iterations: 100 Iteration Tolerance: 0.01	Calculation Method: Darcy-Weisbach Laminar Cutoff Re: 2100 Max Iterations: 100	Company: Project: hur			
wait		Atmospheric Pressure: 14.7	e: 0.01 e: 14.7 psia	Date:	by: NJB ate: Wednesday, May 23, 2018 04:19 PM	3, 2018 04:19 PM	
Wail		P Absolute Roughness	pe Specifications Sizing Criteria		Desig	Design Limits	
Wait		Hazen Williams C Factor		Velocity	Pret	Pressure	Reynolds Number
		6E-05 in 100	0.0	to ft/s	to	psi g	to
Eluid Zone Name		1.800E-03 in 140	0.0	to ft/s	to	psi g	to
Etuid Zone Name			Fluid Zones				
Table Name Temperature		Pressure Fl	Fluid State	Density Viscosity	Vapor Pressure Critical Pressure		Specific Heat Ratio (k) Relative Molecular Mass
Fuel 3 Tuel 3 Max 50 *F		0 psig l	Liquid	56.38 lb/ft ³ 10.19 cP	0.2171 psia 3199 psia		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	e V&F dP	Pipe Friction Factor V&F Friction Factor V&F Resistance K
Pipe 1	2 in	1.75 ft	6.68 apm	0.1393 ft	2.697 psi q		0.07067
ASTM A 53 Sch 40	2.067 in		0.6387 ft/s	0.03527 ft	0 psig	0.01381 psi	
Fuel 3 40 Inlet Device: Node 1	40 ft Node 1		905.7 Outlet Device: FO Tank	: FO Tank			5.56
Pipe 4	0.75 in	7.5 ft	3.34 gpm	0.7776 ft	0.7661 psi q	-1.947 psi	0.05634
ASTM A 53 Sch 40	0.824 in		2.009 ft/s	0.2627 ft	2.713 psi g	0.1028 psi	0.02398
Inlet Device:	10 ft Generator 2		1136 Outlet Device: Node 2	c Node 2			4.19
Pipe 5	0.75 in	7.5 ft	3.34 gpm	0.7776 ft	0.7726 psi g	-1.947 psi	0.05634
ASTM A 53 Sch 40	0.824 in	1.75 ft	2.009 ft/s	0.2627 ft	2.719 psig	0.1028 psi	0.02398
Fuel 3 Inlet Device: (10 ft Generator 3		1136 Outlet Device: Node 3	c Node 3			4.19
Pipe 6	2 in		3.34 gpm		2.719 psi g		0.1413
ASTM A 53 Sch 40	2.067 in	1.75 ft	0.3193 ft/s	3.491E-03 ft	2.713 psi g	1.367E-03 psi	0.01899
Inlet Device: Node 3	Node 3		Outlet Device: Node 2	: Node 2			07:7
Pipe 7	2 in	1.75 ft	6.68 apm	0.03997 ft	2.713 psi q	0.01565 psi	0.07067
ASTM A 53 Sch 40	2.067 in		0.6387 ft/s	0.01396 ft	2.697 psi g	5.467E-03 psi	0.01899
Fuel 3 Inlet Device: 1	10 ft Node 2		905.7 Outlet Device: Node 1	c Node 1			2.20
Pipe 8	0.75 in	7.5 ft	0 gpm	0 11	0.4461 psi g	-2.251 psi	ı
ASTM A 53 Sch 40	0.824 in	1.75 ft	0 ft/s	U U	2.697 psi g	0 psi	0.02398
Tuer 3 Tuer 3 Tuer 3 Tuer 3 Tuer 4 Tu	TO II Generator 1		Outlet Device: Node 1	c Node 1			4.10

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Tank Name	Bottom Elevation	Surface Pressure	Hydraulic Grade		Connecti	Connecting Pipelines	
Fluid Zone	Liquid Level	Bottom Pressure		Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
FO Tank	3.5 ft 1.25 a	0 psig	7.75 ft				
ruel 3	11 C2-4	1.004 psi g		Pipe 1	5 ft	6.68 gpm	0 psig
			Nodes	5			
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 psig	8.664 ft		
			Flow Demands	nands			
Flow Demand Name			Elevation	Pressure	Hydraulic Grade	Flow Rate Flor	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

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		1	Bill of Materials Repo	ort		
Lineup: Program Name:	18026-200-261 Return.pipe <design case=""> PIPE-FLO Professional 16.0.40539</design>				18026 NJB	
			Pipelines			
Pipeline	Specif	ication	Size	Lei	ngth	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 Sum	mary		
Specification	Material		Size	Total Length		Valves & Fittings
ASTM A 53 Sch	40 Steel A53-B3 Schedule: 4		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-B3 Schedule: 4		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 Swipo Check - Vedical

1 x Swing Check - Vertical 3 x Tee - Flow Thru Branch

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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].

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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 ₂ O
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 $104^{\circ}F(40^{\circ}C)$
 - 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.

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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

- 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 ek W @ 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) = $145.00 _{\text{F}}$	
Inside Temperature (Ti) = $117.50 _{\circ \text{F}}$	
Area = $2,038.00 \text{ ft}^2$	
Heat Transfer Coefficient (U) = $0.12 \text{ btuh/ft}^{2} \text{F}$	
	q=U x A * (Ts -Ti)/60
Side Shell (port)	
Temperature (T0) = 95.00 °F	
Inside Temperature (Ti) = $117.50 \circ F$	
Area = 300.00 ft^2	
Heat Transfer Coefficient (U) = $1.32 \text{ btuh/ft}^2 ^\circ\text{F}$	
	q=U x A * (To -Ti)/60
Side Shell (stbd)	
Temperature (To) = $95.00 \circ_{\rm F}$	
Inside Temperature (Ti) = $117.50 _{\circ \text{F}}$	
Area = 230.00 ft^2	
Heat Transfer Coefficient (U) = $1.32 \text{ btuh/ft}^{2} \text{F}$	
	q=U x A * (To - Ti)/60
Wetted Shell	
Water Temperature (Tw) = 86.00 °F	
Inside Temperature (Ti) = $117.50 _{\circ}\text{F}$	
Inside Temperature (Ti) = $117.50 ^{\circ}\text{F}$ Area = $2,087.00 \text{ ft}^2$	
Heat Transfer Coefficient (U) = $0.80 \text{ btuh/ft}^{2} ^{\circ}\text{F}$	
Heat Gain (q) = -877.64 btu/min	q=U x A * (Tw - Ti)/60
Total Heat Load = 6,282.10 btu/min	
····· ································	

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	Inlet Air Conditions	
Summer Air In Temperature (TIN) =	<u>95.00</u> °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 ft ³ / lb dry air	[5], Ch. 1, Eqn 28
	khaust Air Conditions	
Max Temperature (TOUT) =		
Air Out Enthalpy (hOUT) =	53.02 Btu / lb	[5], Ch. 1, Eqn 32
Air out Specific Volume (rOUT) =	$15.12 ft^3 / lb dry air$	[5], Ch. 1, Eqn 28
	Other Givens	
V.1		
Volume of Space $(V) =$	$20,184 ft^3$	[2]
Minutes per air change $(MA) =$	10.00 min	6 ACH
Calculated Airflow base	ed 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	O(M = (QC) D(X) M(V)
cooling + combustion air =	17,874 cfm	
Calculated Airflo	ow based on minimum air excha	anges:
Volume of Space $(V) =$	$20,184 ft^3$	
Air exchanges / min (AC)=	10 min/AC	
Required CFM(Air Exchange) =	2,018 cfm	CFM = V/MA
	culated 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	width	w/h	eqiv	hyd diam	area	length	qty	q	v	Re	f	к	hL
	(in)	(in)		dia (in)	(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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			-	- 1	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
											Seg	ment tota	l pressure	142.29

Description	height	width	h/w		hyd diam	area	length	qty	q	v	Re	f	к	h∟
	(in)	(in)			(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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
											Seg	ment tota	l 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% desi	gn 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

S Lighting Load Calculati Description Lighting Equipment Load Calcul	Space No: ion	SWBD			H	leight:	615 11						6018	
Description Lighting	ion							n						
Lighting						-								
Lighting							Area (ft	2)	LC, (Btu/h	r/ft ²⁾		qs (btuh)		qt (btuh)
							, ,	615			7	4,305		4,305
										Lighti	ng Totals:	4,305		4,305
	otion		-							Light	ing Found	1,000		1,500
Description		_		qs (btuh)	ql (b	tub)		Q	tv	Liso	Factor	q _s (btuh)	q _l (btuh)	q _t (btuh)
*	5 1-110				ų (t	(uii)				0.30		· · ·	qi (buil)	
Propulsion Switchboard (2.5	·····			8,709	ļ				1		1	8,709		8,709
VFD Drive Cabinets (6.2 kW	/ ea)			21,260				4	4		1	85,038		85,038
					<u> </u>									
					[
				1										
									E	Juipme	nt Totals:	93747	0	93747
Personnel Load Calcula	tion		-							<u> </u>				1
Description		Туре	_	q _s (btuh)	a d	tub)	1			Count		q _s (btuh)	q1 (btuh)	q _t (btuh)
Description	-	Type		q _s (otuir)	q _l (b	(uii)		1		Count		q _s (btuil)	q _l (buil)	qt (Oturi)
									P	ersonr	el Totals:	0	0	(
Ventilation Requireme	nts													
Туре	De	escription		Rate	U	nit		Qty				OA (cfm)		EX (cfm)
ASHRA	E Low Oc	cupancy		5	cfm/p	erson		0	people					
				0.06	cfm/st	f		615	· · · · · · · · · · · · · · · · · · ·			37		
			•••••							•••••				
												37		
	_				AbuT		27	0		Cert	0.1.1		05	0 _E
				ating Outside eating Inside				°F °F				e Air Temp esign Temp:		°F °F
Heating and Cooling Lo	ad Calan	lation	Не	aung mside	AIFTE		Heating					ing Seaso		1
Description	Load	Insul	—	Area (ft ²)	Т	ΔT	U or	qw (btuh)	T (°F)	ΔT	U or	q _s (btuh)	q ₁ (btuh)	q _t (btuh)
Description	Key	Туре		Area (it)	(°F)		GSF	q _w (ouur)	1(1)		GSF	q _s (built)	qi (oturi)	qt (Diuii)
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		86	-9	1.198	-6,868		-6,868
Engine Room	Fwd	C-2	t	316.0	45	0	0.120		115	20	0.120	758		758
Port shell above WL	Port	C-2	1	98.0	27	18	0.120		115	20	0.120	235		235
Void	Aft	C-2	Ι	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	ļ	220.0	70	-25	0.120	-660	74	-21	0.120	-554		-554
			ļ	ļ										
			ļ	ļ			ļ							
			↓	ļ										
	.		 	.										
			↓	.				·····						
			ł	 										
LICHTS			<u> </u>	 								1 205		4 204
<u>LIGHTS</u> EQUIPMENT	Lght		ł	 								4,305		4,305
	Eqpt		ł	 			·····					93,747		93,747
PERSONNEL	Pers		t				<u> </u>							

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 (rout) =	14.99 ft3 / lb dry air
Exhaust air specific weight	0.067 lb/cu ft
	0.067 lb/cu ft
Exhaust air specific weight	0.067 lb/cu ft
Exhaust air specific weight Exhaust air viscosity	0.067 lb/cu ft 3.93E-07 lb-s/sq ft ²
Exhaust air specific weight Exhaust air viscosity	0.067 lb/cu ft 3.93E-07 lb-s/sq ft ²

Description	height	width	h/w		hyd diam	area	length	qty	q	v	Re	f	к	hL
	(in)	(in)			(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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
											Seg	ment tota	pressure	7.35

Description	height	width	w/h	eqiv	hyd diam	area	length	qty	q	v	Re	f	к	h∟
	(in)	(in)		dia (in)	(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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
											Seg	ment tota	l 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

95 °F
0.0217 lb/lb dry air
14.29 ft ³ / lb dry air
0.070 lb/cu ft
3.93E-07 lb-s/sq ft2
0.0022 slugs/cu ft
95.0 °F
90.0 F
14.99 ft ³ / lb dry air
14.99 ft ³ / lb dry air
14.99 ft³ / lb dry air 0.067 lb/cu ft
14.99 ft ³ / lb dry air 0.067 lb/cu ft 3.93E-07 lb-s/sq ft ²
14.99 ft ³ / lb dry air 0.067 lb/cu ft 3.93E-07 lb-s/sq ft ²

Description	height	width	w/h	eqiv	hyd diam	area	length	qty	q	v	Re	f	к	h
	(in)	(in)		dia (in)	(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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
											Seg	ment tota	l pressure	32.81
Description	height	width	h/w		hyd diam	area	length	qty	q	v	Re	f	К	hL
	(in)	(in)			(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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
											Seg	ment tota	l 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 1	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 $(T0) =$		
Inside Temperature $(Ti) =$	115.00 °F	
Area =	138.00 ft^2	
Heat Transfer Coefficient $(U) =$	1.39 btuh/ft ² °F	
Heat Transfer Coefficient (U) = Heat Gain (q) =	-63.94 btu/min	q=U x A * (To -Ti)/60
Side Shell		
Temperature (To) = Inside Temperature (Ti) =	95.00 °F	
Inside Temperature $(Ti) =$	<u>115.00</u> °F	
	292.00 ft ²	
Heat Transfer Coefficient $(U) =$		
Heat $Gain(q) =$	-130.33 btu/min	q=U x A * (To -Ti)/60
Wetted Shell	0.4.00	
Water Temperature $(Tw) =$		
Inside Temperature (Ti) $=$		
	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	
÷	0.022 lb/lb dry air	
Air In Enthalpy $(hIN) =$		[5], Ch. 1, Eqn 32
Air In Specific Volume (rIN) =		-
	0 0	
	Exhaust Air Conditions	
Max Temperature (TOUT) = $\frac{1}{2}$	115.00 °F	
Air Out Enthalpy (hOUT) =	51.77 Btu / lb	[5], Ch. 1, Eqn 32
Air out Specific Volume (rOUT) =	14.99 ft ³ / lb dry air	[5], Ch. 1, Eqn 28
	Other Givens	
Volume of Space $(V) =$		[2]
Minutes per air change $(MA) =$	10.00 min	6 ACH
	ulated Airflow based on Total	Heat Load
	(518) <i>Btu / min</i>	
	4.99 Btu / lb	Dh = hOUT - hIN
Required CFM (Heat Load) =		$CFM = (Qe / Dh \ x \ rIN)$
consumption air $(Qc)=$		
$\operatorname{cooling} + \operatorname{combustion} \operatorname{air} =$	(1,500) cfm	
Calculate	d Airflow based on minimum a	air exchanges:
Volume of Space $(V) =$	$8,054 ft^3$	8
Air exchanges $/ \min (AC) =$	10 min/AC	
Required CFM(Air Exchange) =	805 cfm	CFM = V/MA
	Calculated Exhaust Airflo	
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)=	- <i>cfm</i>	
exhaust air =	834 cfm	CFM = V / rIN * rOUT - Qc
Total intake air=	Results	(minimum airflam)
total make $air =$	800 cfm	(minimum airflow)
iotai exhaust all =	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	ft ³ / Ib 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 / Ib 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

Suppiy	air now	rate	1000	CII
Exhaust	air flow	rate	1000	cfi

Description	height	width	w/h	eqiv	hyd diam	area	length	qty	q	v	Re	f	к	hL
	(in)	(in)		dia (in)	(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(ft)
Supply Ducting														
nlet 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	T.		-	-	12.00	0.79		1	1000	1273	1.18E+05	0.020	0.600	4.20
Elbow r/d = 1	T		-	-	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)	1		-	-	10.00	0.55		1	500	917	7.11E+04	0.022	1.600	5.80
	******	L	••••••	••••••	•••••••		••••••	••••••		•••••••	Seg	ment tota	l pressure	69.97
Description	height	width	h/w		hyd diam	area	length	qty	q	v	Re	f	к	h∟
	(in)	(in)			(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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
		h	L	k	a		••••••	•	•	•	Seo	mont tota	l pressure	13.71

}		FT	in H2O
supply ai	r total pressure	69.97	0.942
exhaust ai	r 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) = $145.00 {}^{\circ}\text{F}$	
Inside Temperature (Ti) = 113.00 °F	
Area = 766.00 ft^2	
Heat Transfer Coefficient (U) = $0.12 \text{ btuh/ft}^{2} \text{F}$	
Heat Gain (q) = 49.02 btu/min	q=U x A * (Ts - Ti)/60
Side Shell and Ballast Tanks	
Temperature (T0) = $95.00 ^{\circ}\text{F}$ Inside Temperature (Ti) = $113.00 ^{\circ}\text{F}$	
Inside Temperature (11) = $113.00 _{\text{F}}$	
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) = $95.00 _{\text{F}}$	
Temperature (To) = $95.00 ^{\circ}F$ Inside Temperature (Ti) = $113.00 ^{\circ}F$	
Area = 280.00 ft^2	
Heat Transfer Coefficient (U) = $1.34 \text{ btuh/ft}^2 \text{°F}$	
Heat Transfer Coefficient (U) = $1.34 \text{ btuh/ft}^2 \text{°F}$ Heat Gain (q) = -112.48 btu/min	q=U x A * (To - Ti)/60
Wetted Shell	
Water Temperature (Tw) = $86.00 ^{\circ}F$	
Inside Temperature (Ti) = 113.00 °F	
Area = $1,084.00$ ft ²	
Heat Transfer Coefficient (U) = $0.80 \text{ btuh/ft}^2 \text{°F}$	
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		
Air In Enthalpy (hIN) =	an a	[5], Ch. 1, Eqn 32
Air In Specific Volume $(rIN) =$		-
All In Specific Volume (InV) –	14.47 Jl ⁵ / lD ary air	[5], Ch. 1, Eqn 28
	Exhaust Air Conditions	
Max Temperature (TOUT) =		
Air Out Enthalpy (hOUT) =	Characterization and the state of the state	[5], Ch. 1, Eqn 32
Air out Specific Volume (rOUT) =		_
	Other Givens	
Volume of Space $(V) =$	9,312 <i>ft</i> ³	[2]
Minutes per air change $(MA) =$	10.00 min	6 ACH
	w based on Total Heat Load	and Air Consumption
	311 Btu / min	
	2.25 Btu / lb	
Required CFM (Heat Load) =		$CFM = (Qe / Dh \ x \ rIN)$
consumption air (Qc)=		
cooling + combustion air =	2,005 cfm	(50% combustion air from cooling air)
Calculated	Airflow based on minimum	air exchanges:
Volume of Space $(V) =$		
Air exchanges / min (AC)=	·	
C	931 cfm	CFM = V/MA
	5	
	Calculated Exhaust Airfle	ow
	2,005 cfm	(maximum of required airflows)
÷	14.47 ft3/lb	
exhaust air specific volume (rOUT)=	14.71 ft3/lb	
expansion =	1.62%	
consumption air $(Qc)=$	- <i>cfm</i>	
exhaust air =	2,038 cfm	CFM = V / rIN * rOUT - Qc
Total intake air=	Results	(haved on heat load and air communities)
total exhaust air =	2,000 cfm 2,000 cfm	(based on heat load and air consumption)
iotai exitatist all =	2,000 CJM	

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 / Ib 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 / Ib 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	ofm

Description	height	width	w/h	eqiv	hyd diam	area	length	qty	q	v	Re	f	к	hL
	(in)	(in)		dia (in)	(in)	(sq ft)	(ft)	4.7	(cfm)	(ft/min)				(ft)
Supply Ducting	()	()			()	(17	()		(* 7	()				
Inlet Demister, 0.5" H2O	15	20	1.33	18.38	17.14	2.08	Г	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
	••••••	h	••••••	******	******************	·····	*	•	••••••	••••••	Sea	ment tota	pressure	72.95

Description	height	width	h/w		hyd diam	area	length	qty	q	v	Re	f	к	hL
	(in)	(in)			(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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
											Seg	ment tota	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% des	ign 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

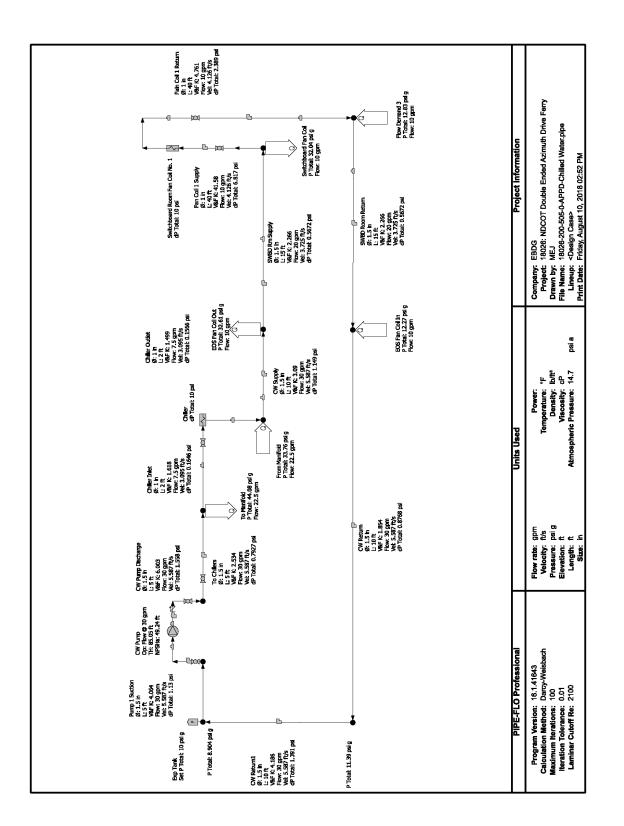
nput Variables	
Supply Air Temperature (T _{IN}) =	88 °F
Humidity Ratio	0.0217 lb/lb dry air
Air In Specific Volume (r _{IN}) =	14.29 ft ³ / lb dry air
Supply air specific weight	0.070 lb/cu ft
Supply air viscosity	3.89E-07 lb-s/sq ft2
Supply air density	0.0022 slugs/cu ft
Max Temperature (T _{OUT}) =	115.0 °F
Air out Specific Volume (r _{OUT}) =	14.99 ft ³ / 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	width	h/w		hyd diam	area	length	qty	q	v	Re	f	к	h L
	(in)	(in)			(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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
					*******		•••••••	*~~~~~				ment total		15.82

Description	height	width	w/h	eqiv	hyd diam	area	length	qty	q	v	Re	f	к	h L
	(in)	(in)		dia (in)	(in)	(sq ft)	(ft)		(cfm)	(ft/min)				(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
											Seg	ment 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% desi	gn margin	34.83	0.469

CHILLED WATER PIPING



			FIST MAN				
File Name: 18028-200-505-0-APPD-Chilled Water.pipe Lineup: -Oesign Cases- Progam Name: PIPE-FLO Professional Version: 16.1.41643	-Chilled Water.pipe	Calculatio Laminar (Max) Percent 1 Allowable 1	Catoulation Method: Darcy-Weisbach Laminar Cutoff Re: 2100 Max tterations: 100 Percent Tolerance: 0.01 Allowable Deviation: 1 %	Company: Project: by: Date: Atmospheric Pressure:	Company: EBDG Project: 18028: NDCOT by: MEJ Date: Friday, August ' Pressure: 14.7 psi a	mpany: EBDG Project: 18028: NDCOT Double Ended Azimuth Drive Fenry MeJa Date: Friday, August 10, 2018 02:52 PM ressure: 14.7 pei a	. Drive Ferry
Specification Name	Material	Absolute	Absolute Roughness Sizin	Sizing Criteria	l	Design Limits	
Valve Table	Schedule	Hazen Will	Hazen Williams C Factor		Velocity	Pressure	Reynolds Number
Type K Copper Pipe standard	Copper Tube H23 Schedule:K	G	6E-05 in 0.0 140	Min: Max:	1: ft/s K: ft/s	psig psig	
			Fluid Zones				
Fluid Zone Name Table Name		Temperature Pressure Reis	Fiuld State Relative Molecular Mass	Density Viscosity	Vapor Critica	Vapor Pressure Specific Critical Pressure Speci	Specific Heat Capacity (cp) Specific Heat Ratio (k)
30% Ethylene Glycol 30% Dowtherm SR-1		38 °F 10 psig	Llquid 22.61	65.45 lb/ft ³ 3.475 cP	0.0905	0.09051 psla 1575 psla	1
Pump Name		Suction Elevation Suction Pressure	Sizing Pumps Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	late NPSHa	
CW Pump		0 ft 7.774 psig		85.05 ft 38.66 psi	308	gpm 49.24 ft	
Pipeline Name	Size		Flow Rate	Inlet Total Pressure	Total dP	Outlet Total Pressure	<u>۲</u>
Specification Fluid Zone	Inside Diameter Length	er Inlet Elevation Outlet Device Outlet Elevation	Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total Head Loss	Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	 V&F Resistance K V&F dP V&F Head Loss
CW Pump Discharge	1.5 in	CW Pump	30 apm	46.43 psi a	1.558 psi	44.87 psi a	0.0206
Type K Copper Pipe	1.481 in	0 H	5.587 ft/s	46.21 psig		44.65 psi g	6.00
30% Ethylene Glycol	5 ft	Node 1 0 ft	19325 0.02619	102.2 ft 101.7 ft	3.427 ft	98.72 ft 98.24 ft	1.324 psi 2.912 ft
CW Beturn	15 in	EOS Fan Coil In	30 000	12.77 nei n	0 8768 nei	11 30 nei n	0.0206
Type K Copper Pipe	1.481 in	0 ft	5.587 ft/s	12.05 psig		11.17 psig	1.85
30% Ethylene Glycol	10 A	Pressure Boundary 2 0 ft	19325 0.02619	26.99 ft 26.51 ft	1.929 ft	25.06 ft 24.58 ft	0.4089 psi 0.8995 ft
CW Return1	1.5 in	Pressure Boundary 2	30 gpm	11.39 psig	1.391 psi	10 psig	0.0206
Type K Copper Pipe	1.481 in	υĥ	5.587 ft/s	11.17 psig			4.19
30% Ethylene Glycol	10 ft	Exp Tank 0 ft	19325 0.02619	25.06 ft 24.58 ft	3.06 ft	22 ft 21.52 ft	0.923 psi 2.031 ft
CW Supply	1.5 in	From Manifold	30 gpm	33.76 psig	1.149 psi	32.61 psig	0.0206
Type K Copper Pipe	1.481 in	υű	5.587 ft/s	33.54 psig		8	3.09
30% Ethylene Glycol	10 ft	EOS Fan Coil Out 0 ft	19325 0.02619	74.27 ft 73.79 ft	2.529 ft		0.6814 psi 1.499 ft
Chiller Inlet	1 in 1 in	To Manifold	7.5 gpm	44.08 psi g	0.1646 psi		0.02281
lype K Copper Pipe 30% Ethylene Givcol	ni cee.u fi c	Chiller	3/11 02/03	44.01 psig 96.98 ft	0.3622 #	ä.∉	1.62 0.1094 nsi
	-	0 Ű	0.03384	96.83 ft	1 7700-0	96.47 ft	0.2407 ft
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Pipeline Name	Size	Inlet Device	Flow Rate	Inlet Total Pressure	Total dP	Outlet Total Pressure	V&F Friction Factor
Specification Fluid Zone	Inside Diameter Length	Inlet Elevation Outlet Device Outlet Elevation	Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Stattc Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total Head Loss	Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Resistance K V&F dP V&F Head Loss
Chiller Outlet	Ë	Chiller	7.5 gpm	33.91 psig	0.1566 psi	DSI	0.02281
Type K Copper Pipe	0.995 in	ΟΨ	3.095 ft/s	33.85 psi g		33.69 psig	1.50
30% Ethylene Glycol	2 ft	From Manifold	7191 0.03384	74.62 ft 74.47 ft	0.3446 ft	74.27 ft 74.12 ft	0.1014 psi
						:	
Fain Coll 1 Return	⊆.	writchboard Koom Fan Coll No.	mdg 01	15.22 psi g	Z.389 psi		0.02281
Type K Copper Pipe	0.995 in	4 0 H	4.126 t/s			ã,	4.76
30% Ethylene Glycol	40 #	riow Uemano 3 0 ft	9568 0.03132	33.23 ft 33.23 ft	11 /92.6	28.24 TT 27.97 ft	0.5/20 psi
Ean Coll 1 Sumply	÷	Switchboard Fan Coll	10 anm	32.04 helo	6.817 nel		0.02284
Twe K Copper Ploe	0.995 In	9 1 0	4 126 fils	31.92 Del 0		2 2	41.58
30% Ethylene Glycol	e		9588 0.03132		15 ft	┇╾╾	1 fr
Pine 17	1.5 in	Exo Tank	30 anm	10 Dei o	1.096 nsi	8.904 nsi n	0.0206
Type K Copper Pipe	1.481 in	0 ft	5.587 ft/s			8	4.76
30% Ethylene Glycol	1 ft	Node O ff	19325 0.07819	∉∊	2.412 ft	∉∉	1.05 psi 2.309 ft
	1	n obeli				: 1	
rump i succion Tune K Conner Dine	ni 1.5.1 ri 1.481 t		5 587 file	o.au4 psig BR83 peig		7.553 hein	0.UZU0
1946 N. Cupper Inipe 30%. Ethniene Givnol	= +	CW Pump	10205		9 ABC #	ŝ.	0.8061 nel
	-	0 ft	0.02619	19.1 ft		16.62 ft	1.972 ft
SWRD Rm Supply	15 In	EOS Fan Coll Out	20 anm		0.5672 nsl	32.04 nsl n	0.0206
Type K Copper Ploe	1.481 In	e o	3.725 ft/s	32.51 DS 0			2.27
30% Ethylene Givcol		Switchboard Fan Coil	12884		1.248 ft	Ĺ 🖶	0.2221 nsi
		0 ft	0.02898	-		70.28 ft	0.4686 ft
SWBD Room Return	1.5 in	Flow Demand 3	20 gpm	12.83 psig	0.5672 psi	12.27 psi g	0.0206
Type K Copper Pipe	1.481 in	υΨ	3.725 ft/s	12.74 psig		12.17 psig	2.27
30% Ethylene Glycol	15 ft	EOS Fan Coil In 0 ft	12884 0.02898	28.24 ft 28.02 ft	1.248 ft	26.99 ft 26.77 ft	0.2221 psi 0.4886 ft
To Chillers	1.5 in	Node 1	30 gpm	44.87 psi g	0.7927 psi	44.08 psi g	0.0206
Type K Copper Pipe	1.481 in	0 ft	5.587 ft/s	44.65 psig			2.53
30% Ethylene Glycol	5 ft	To Manifold 0 ft	19325 D 02619	98.72 ft 98.24 ft	1.744 ft	96.98 ft 96.5 ft	0.5588 psl
		;	Fixed dP Devices				
Fixed dP Device Name	Inlet Elevation	Outlet Elevation	ation	÷	Flow Rate		
	Inlet Pressure		ssure	Head Loss			
Chiller	t o	4 0 1		10 psl	7.5 gpm		
	43.91 psig	33.91 pslg	B	22 ft			
Switchboard Room Fan Coil No. 1	0 ft 25.22 psig	0 ft 15.22 psig	6	10 psi 22 ft	10 gpm		
			Nodes				
Node Name		Elevation		Pressure Hydrau	Hydraulic Grade		
Node		0 #		8.904 pslg 1	19.1 ft		
Node 1		0		44.87 psig 98	98.24 ft		
	Visition: 45 A 44649		Lind Dansed	•	10 23-24 204 40 10 10 10 10 10 10 10 10 10 10 10 10 10		1

DOUBLE-ENDED AZIMUTH DRIVE FERRY

8/10/18

		NODES			
Node Name	Elevation	Pressure	Hydraulic Grade		
Pressure Boundary 2	0 11 0	11.39 pslg	24.58 ft		
	Pressu	Pressure Boundaries			
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	
Exp Tank	0 ft	10 psig	21.52 ft	30 gpm	
	Flow	Flow Demands			
Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
EOS Fan Coll In	0 11 0	12.27 psl g	26.64 ft	10 gpm	Flow In
EOS Fan Coil Out	υu	32.61 psig	71.39 ft	10 gpm	Flow out
Flow Demand 3	0 ft	12.83 psig	28 ft	10 gpm	Flow in
From Manifold	t o	33.76 pslg	73.96 ft	22.5 gpm	Flow In
Switchboard Fan Coil	0 ft	32.04 psig	70.26 ft	10 gpm	Flow out
To Manifold	0 ft	44.08 psig	96.66 ft	22.5 gpm	Flow out

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Pile Name: 18026-200-30 Lineup: <design case<br="">Program Name: PIPE-FLO Pro Version: 16.1.41643</design>		Sizing Pumpa	by: Date:		e Ended Azimuth Drive Ferry 8 02:53 PM
Sizing Pump Name Operation				Desig Flow Rate	gn Point Total Head
CW Pump Flow @ 30 gpm				30 gpm	85.05 ft
Fixed dP Device Name	Fixed d	Fixed dP Devic	85		
Chiller	10 ps	I			
Switchboard Room Fan Coil No	p.1 10 ps	i			
		Pipelines			
Pipeline	Specification	Size	Length	Valves and Fit	tings
CW Pump Discharge	Type K Copper Pipe	1.5 in	5 ft	4 x Elbow - Sta 1 x Ball 1 x Tee - Flow 1 x Swing Cher 1 x Reducer - E	Thru Branch
CW Return	Type K Copper Pipe	1.5 in	10 ft	3 x Elbow - Sta	indard 90°
CW Return1	Type K Copper Pipe	1.5 in	10 ft	4 x Elbow - Sta 1 x Air Separat	
CW Supply	Type K Copper Pipe	1.5 in	10 ft	3 x Elbow - Sta 3 x Tee - Flow	
Chiller Inlet	Type K Copper Pipe	1 in	2 ft	1 x Tee - Flow 1 x Reducer - 0 1 x Ball	Thru Branch Contraction (1 in x 1.25 in - 0 in)
Chiller Outlet	Type K Copper Pipe	1 In	2 ft	1 x Tee - Flow 1 x Reducer - E	Thru Branch Enlargement (1 in x 1.25 in - 0 in)
Fain Coil 1 Retum	Type K Copper Pipe	1 in	40 ft	4 x Elbow - Sta 1 x Ball 1 x Tee - Flow 1 x Tee - Flow 1 x Reducer - E	Thru Run
Fan Coil 1 Supply	Type K Copper Pipe	1 in	40 ft		
Pipe 17	Type K Copper Pipe	1.5 in	1 ft	1 x 1 PSI Allow	ance for Suction Strainer
Pump 1 Suction	Type K Copper Pipe	1.5 in	5 ft	4 x Elbow - Sta 1 x Tee - Flow 1 x Ball 1 x Reducer - (
SWBD Rm Supply	Type K Copper Pipe	1.5 in	15 ft	1 x Tee - Flow 3 x Elbow - Sta	
SWBD Room Return	Type K Copper Pipe	1.5 in	15 ft	3 x Elbow - Sta 1 x Tee - Flow	
To Chillers	Type K Copper Pipe	1.5 in	5 ft	4 x Elbow - Sta 1 x Ball	Indard 90°
Pagelantian		ipeline Material Su		Vehro- 8 Fild	-
Specification Type K Copper Pipe	Material Copper Tube H23 Schedule: K	Size 1 in	Total Length 84.00 ft	1 x 3-way ball va 1 x 4 PSI allowa 3 x Ball 8 x Elbow - Stan 2 x Reducer - Co	live nce for auto flow control valve dard 90° ontraction (1 in x 1.25 in - 0 in) ilargement (1 in x 1.25 in - 0 in) nu Branch

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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 Bail 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 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 Branch

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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/ft²/°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 H (BT	Heat Load UH)	
	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	29,562	44,444	16,000	60,444
Lounge				
EOS	14,170	22,388	3,200	25,588

REFERENCES

- 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

 $\begin{array}{l} CF_{\texttt{len}}{=} U(\Delta t{\text{-}}0.46{^{*}}DR) + PXI \; x \; SGHC \; x \; IAC \; X \; FF_s \\ q_{\texttt{len}}{=} \; A \; x \; CF_{\texttt{len}} \end{array}$

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) FFs taken from ASHRAE Fundamentas Table 13, single family detached column (see descriptions on page 17.1)

9) Worst combination of PXI and FFs, West Facing, used for calculation

U=	0.60 BTU/h-SF-°	F fenestration NFRC heating U-factor
$\Delta t =$	21 °F	cooling design temperautre difference
DR=	12 °F	cooling daily range
PXI=	237 btu/h-SF	peak exterior irradiance
SHGC=	0.47	rated or estimated solar heat gain coefficient
IAC=	1	interior shading attenuation coefficient
$FF_s =$	0.56	fenstration solar load factor

Cf_{fen}= 71.67 BTUH/sf fenestration cooling load

Use Cf_{fen}= 75 BTUH/sf

ROOM LOAD CALCULATIONS

Pilothouse (SB)					Deck	Area:	144	ft^2			Vo	lume:	1152	ft ³
Sr	ace No:	:		1		leight:		ft						
Lighting Load Calculatio						0								
Description							Area (ft.	2)	LC, (Btu/hı	/ft ²⁾		qs (btuh)		qt (btuh)
Lighting	-		-		-	_	r lica (ita	-/ 144	LC, (Dtain	/ 10	7	1,008		1,00
												-,		-,
		1								Light	ng Totals:	1,008		1,00
										Ligitu	ng Totais.	1,008		1,00
Equipment Load Calculat	lon				1.0					X X				
Description				qs (btuh)	ql (b			-	ty		Factor	q _s (btuh)		q _t (btuh)
Coffee Maker (commercial)				6,500	2,0	00		1			0.5	3,250	1,000	4,25
Electronics				7,000				1			1	7,000		7,00
				l					E.	minm	ent Totals:	10250	1000	1125
									E	1 april	In TOtals.	10230	1000	1123
Personnel Load Calculati		lar.		(. 1)				_		~ .	_	(. 1)		(1.1)
Description	Gender			q _s (btuh)	q _l (b			1	(Count		q _s (btuh)	A4 , ,	q _t (btuh)
SEATED AT REST	male	1-P1		240		160				1		240	160	40
SEATED AT REST	mixed	1-P2		210		140				0				
									Р	erson	nel Totals:	240	160	40
Ventilation Requirement	s													
Туре	D	escription		Rate	U	nit		Qty				OA (cfm)		EX (cfm)
By Occupancy		A		15	cfm/p				people			15		· · · · · · · · · · · · · · · · · · ·
Rate of Change					ach			1152	<u> </u>			19		
Sanitary Fixtures	7 IC, 1 IK				cfm/fi	rturo			π fixture					
Sainary Fixines		1		50	ciiivii	xiure		0	lixture			20		
										~ "	- ···	20		0
				ting Outside				°F				e Air Temp		°F
	10.1.	1.4.	Не	ating Inside	Air Ie			°F		(esign Temp:		Г
Heating and Cooling Loa Description	Load	Insul		L (0 ²)	Т	ΔT	Heating U or		T (°F)	ΔT	U or	ing Seaso		a (htula)
Description	Key	Туре		Area (ft ²)	1 (°F)		GSF	$q_w \left(\text{btuh} \right)$	1(1)	Δ1	GSF	q _s (btuh)	q1 (btuh)	qt (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		0.120	1,234	74	0	0.120	012		01.
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	· · · · · · · · · · · · · · · · · · ·	95	21	160	3,520		3,52
Exterior - Windows (Shaded)		001-H2	W↔I		COLUMN TWO IS NOT	43	1.130			21	1.130			522
Exterior - Weather	Aft	C-2		46.0	27	43	0.120	237	95	21	0.120	116		11
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		25
Exterior - Windows (Solar)	Port	001-H1	∯↔ ₩I	30.1	27	43	1.130		125	51	160			4,81
	Port	001-H2 C-2	W↔I	39.9	27	43 43	1.130		95	21	1.130	947		94
Exterior - Weather (Shaded) Exterior - Windows (Shaded)	Stbd Stbd	001-H2	W↔I	180.0 52.0	27 27	43	0.120	929 2,527	95 95	21 21	0.120	454 1,234		454
ILAIGHUI - WILLIOWS (SHADED)	Stbd Lght	1001-H2		32.0	27	43	1.130	2,327	93	21	1.130	1,234		1,23
	டதாட											10,250	1,000	11,250
LIGHTS	Fapt	1										10,250	1,000	11,20
LIGHTS EQUIPMENT	Eqpt Pers											240	160	400
LIGHTS	Eqpt Pers OA				27	43		1,066	95	21		240 437	160 1,152	400

Crew Lounge					Deck	Area:	240	ft^2			Vo	lume:	1920	ft ³
St	bace No:			1		Height:		ft					1,20	-
Lighting Load Calculatio	n					0								
Description							Area (ft2	2)	LC, (Btu/h	r/ft ²⁾		qs (btuh)		qt (btuh)
Lighting								240			7	1,680		1,680
										Light	ing Totals:	1,680		1,680
Equipment Load Calculat	tion									0	0		1	
Description	.1011	_		qs (btuh)	ql (b	otuh)		Q	tv	Use	Factor	q _s (btuh)	q ₁ (btuh)	q _t (btuh)
Coffee Maker (commercial)				6,500	2,0	,		1	-		0.5	3,250	1,000	4,250
Electronics				6,000	2,0			1			1	6,000	1,000	6,00
				3,000				1			0.3	900		90
Microwave				·····										
Refrigerator				1,670				1			1	1,670		1,67
														L
									E	quipm	ent Totals:	11820	1000	1282
Personnel Load Calculati	ion													
Description	Gender	Туре		q _s (btuh)	qı (b	otuh)			(Count		q _s (btuh)	q1 (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				
	•								P	erson	nel Totals:	960	640	160
Ventilation Requirement	ts													
Туре		escription		Rate	U	nit		Qty				OA (cfm)		[
By Occupancy			-		cfm/p		-		people	-		48		
					F				<u></u>					
Sanitary Fixtures				50	cfm/fi	vturo		1	fixture			50		
Bankary Tixtares				50	ciiivii	Ature		1	lixture		Chosen:			
			Ц	ating Outsic	lo Air '	Tamm	27	⁰ E		Cool		e Air Temp		°F
				Heating Insid		_		°F				esign Temp:		°F
Heating and Cooling Loa	d Calcu	lation		reading make			Heating					ing Seaso		-
Description	Load	Insul	1	Area (ft ²)	Т	ΔT	U or	qw (btuh)	T (°F)	ΔT	U or	q _s (btuh)	q ₁ (btuh)	q _t (btuh)
*	Key	Туре		ruca (it)	(°F)		GSF	-1w (******)	, í		GSF	13 (0100)	-II (* 1111)	11 (00000)
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		36
Exterior - Weather (Solar)	Fwd	C-2	**	81.0	27	43	0.120	418	115	41	0.120	399		399
	Fwd		∯↔ W…I	9.0	27	43	0.610			41	75.000			67
Exterior - Windows (Shaded)	Aft	002-H2	W↔I	6.0	27	43	0.610	157	95	21	0.610	A need need need need need need need nee		212
Exterior - Weather Exterior - Weather (Solar)	Aft Port	C-2 C-2	·····	84.0 195.0	27 27	43 43	0.120	433	95 115	21 41	0.120	212 959		95
Exterior - Weather (Solar)	Port		\	195.0	27	43	0.120	393	115	41	75.000			1,12
Exterior - Whitelows (Solar)	Stbd	C-2		128.0	27	43	0.010	660	95	21	0.120	323		32
Uptakes	Stbd	C-2 C-2		70.0	27	43	0.120	361	115	41	0.120			344
Exterior - Windows (Shaded)	Stbd	002-H2	W↔I	12.0	27	43	0.610	315	95	21	0.610			15
LIGHTS	Lght											1,680		1,68
EQUIPMENT	Eqpt											11,820	1,000	12,82
PERSONNEL	Pers											960	640	1,60
Ventilation	OA				27	43		2,666	95	21		1,092	2,880	3,972
						Spac	e Totals:	7,936			Totals:	20,966	4,520	25,48

* This calculation sheet assumes sun on forward and port sides

Passenger Lounge					Deck	Area:	640	ft^2			Vo	lume:	5120	ft^3
SI	ace No:	:				leight:		ft						
Lighting Load Calculation	n					-								
Description							Area (ft	2)	LC, (Btu/h	r/ft ²⁾		qs (btuh)		qt (btuh)
Lighting								640			7	4,480		4,480
										Light	ing Totals:	4,480		4,480
Equipment Load Calculat	ion									Ligin	ing round	1,100		1,100
Description	1011						l	0	ty	Use	Factor	q _s (btuh)	q ₁ (btuh)	q _t (btuh)
Description				1				×		0.50	of detor	q _s (otur)	qi (otali)	qt (otur)
									E	quipm	ent Totals:	0	0	
Personnel Load Calculati	on													
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	11,20
		•							F	Person	nel Totals:	6720	4480	1120
Ventilation Requirement	s													
Туре		escription		Rate	U	nit		Qty				OA (cfm)		
per ASHRAE 62.1		People OA	Rate		cfm/p			32				160		
I Contraction of the second se		Area OA			cfm/ct			640				38		
			Sum									198		
			buii								Chosen:			
			He	ating Outsic	lo Air'	Temn	27	°F	I	Cool		e Air Temp	95	°F
				Heating Insid				°F				esign Temp:		°F
Heating and Cooling Loa	d Calcu	lation		reading min			Heating					ing Seaso		
Description	Load	Insul		Area (ft ²)	Т	ΔT	U or	qw (btuh)	T (°F)	ΔT	U or	q _s (btuh)	q ₁ (btuh)	q _t (btuh)
-	Key	Туре		r nou (n)	$(^{\circ}F)$		GSF	1			GSF	15 \ /	1. ()	" " 、 <i>"</i>
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	0.51	74	0	0.120	1.500		
Engine Room Voids	Belw Belw	C-2 C-2		317.0 209.0	45 27	25 43	0.120	951 1,078	115 115	41 41	0.120	1,560 1,028		1,56
Exterior - Weather	Fwd	C-2 C-2		84.0	27	43	0.120	433	95	21	0.120	212		212
Exterior - Windows (Shaded)		002-H2	W↔I			43	0.610			21	0.610			7
Exterior - Weather	Aft	C-2		84.0	27	43	0.120	433		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		7
Exterior - Weather	Port	C-2		423.0		43	0.120	2,183	95	21	0.120	1,066		1,06
Engine Room	Port	C-2		180.0	27	43	0.120	929	115	41	0.120	886		886
EOS	Port	C-2	West	162.0	70	0	0.120		74	0	0.120			
Exterior - Windows (Shaded) Exterior - Weather (Solar)	Port Stbd	002-H2 C-2	vv ↔I	0.0 506.0	27 27	43 43	0.610		95 125	21 51	0.610	3,097		3.09
Exterior - Weather (Solar) Exterior - Windows (Solar)	Stbd		W↔I	254.0	27	43	0.120		125	51	75.000	19,050		19,05
LIGHTS	Lght	002-112		254.0			0.010	0,002	125	- 51	75.000	4,480		4,480
EQUIPMENT	Eqpt	1										.,		.,
PERSONNEL	Pers											6,720	4,480	11,20
Ventilation	OA				27	43		10,664	95	21		4,368	11,520	15,888
						Spac	e Totals:	29,562			Totals:	44,444	16,000	60,44

* This calculation sheet assumes sun on starboard side only

FOG														
EOS					Deck	Area:	360	ft ²			Vo	olume:	2880	ft ³
S	pace No:	:			H	leight:	8	ft						
Lighting Load Calculati	on						-							
Description							Area (ft2	2)	LC, (Btu/h	r/ft ²⁾		qs (btuh)		qt (btuh)
Lighting								360			7	2,520		2,520
										Light	ing Totals	2,520		2,520
Equipment Load Calcula	tion													
Description				qs (btuh)	ql (t	otuh)		Q	ty	Use	e Factor	q _s (btuh)	q ₁ (btuh)	q _t (btuh)
Switchboard / Electronics				10,000				1	1		1	10,000		10,000
				•					E	quipm	ent Totals	10000	0	10000
Personnel Load Calculat	tion													
Description	Gender	Туре		q _s (btuh)	q1 (t	otuh)				Count		q _s (btuh)	q ₁ (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				
	1								F	Person	nel Totals	480	320	800
Ventilation Requirement	nts													
Туре	1	escription		Rate	U	nit		Qty				OA (cfm)		
By Occupancy		A	_		cfm/p	-	-		people	_		30		
Rate of Chang		1 5			ach			2880				48		
Sanitary Fixture					cfm/fi	xture			fixture					
	~							-			Chosen:	50		
			He	ating Outsid	le Air	Temp	27	°F	I	Cool		e Air Temp		°F
				Heating Insid			70	°F				esign Temp:		°F
Heating and Cooling Los	ad Calcu	lation		0			Ieating					ling Seaso		
Description	Load	Insul		Area (ft ²)	Т	ΔΤ	U or	qw (btuh)	T (°F)	ΔΤ	U or	q _s (btuh)	q1 (btuh)	q _t (btuh)
-	Key	Туре			$(^{\circ}F)$		GSF				GSF			
Exterior - Weather	Over	C-2		96.0	27	43	0.120	495	95	21	0.120	242		242
Passenger Lounge EOS Floor	Over Belw	C-2 0-D4	I↓I	264.0 360.0	70 32	0	0.120	9,508	74 86	0	0.120	3,460		2 460
Engine Room	Fwd	C-2		123.0	55	- 38 - 15	0.693	9,308	115	41	0.801	<u>5,460</u> 605		3,460 605
Engine Room - Windows	Fwd	002-H2	W↔I	24.0	55	15	0.610	220		41	0.610			600
Void	Aft	C-2		147.0	55	15	0.120	265	115	41	0.120			723
Engine Room	Port	C-2		210.0		15					0.120			1,033
Engine Room - Windows	Port	002-H2	W↔I	30.0		15					0.610	The state of the local local local local local local local local local		750
Exterior - Weather (solar)	Stbd	C-2		144.0	27	43	0.120	743	125	51	0.120	881		881
LIGHTS	Lght	1										2,520		2,520
														10,000
EQUIPMENT	Eqpt											10,000	222	
					27	43		2,666	95	21		10,000 480 1,092	320 2,880	800 3,972

* 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

EBDG – NC, PLLC 18026-200-505-1

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.

Pipe Segment	Flow	Pipe	Schedule	d, ID	Design Velo	ocity	V
	Rate	Size			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

Table 5-1: Nominal Pipe Velocity

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

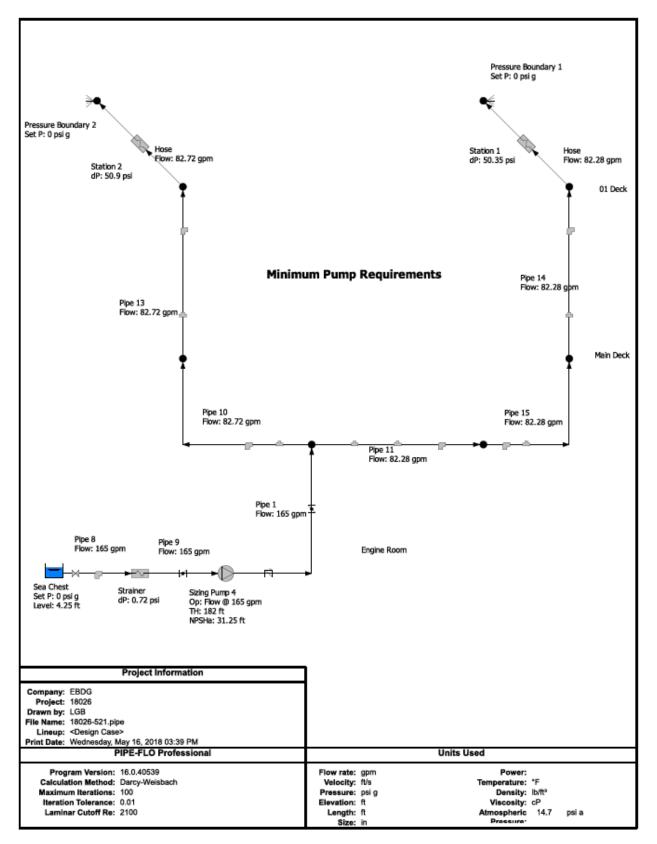
From the enclosed system model, the minimum fire main pump operating point is 165 gpm at a total dynamic head of 182 feet H2O while discharging from the two most remote fire stations with a pitot pressure of 50 psig. The system provides NPSH of 31.5 feet H2O. The client's preferred pump is also modeled.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



EBDG – NC, PLLC 18026-200-505-1

				5	List Report					
File Name: 18026-521.pipe Lineup: <design case=""> Progam Name: PIPE-FLO Professional Version: 16.0.40539</design>	e Name: 18026-521.pipe Lineup: <design case=""> n Name: PIPE-FLO Professio Version: 16.0.40539</design>	onal	Calculati Lamina Max Iteration Atmospheri	Calculation Method: Laminar Cutoff Re: Max Iterations: Iteration Tolerance: Atmospheric Pressure:	Darcy 2100 100 14.7	3	Company: EBDG Project: 18026 by: LGB Date: Wedne	pany: EBDG bjett: 18026 by: LGB Date: Wednesday, May 16, 2018 03:41 PM	2018 03:41 PM	
Specification Name Valve Table	9	Material Schedule	Absolute Roughness Hazen Williams C Factor	ighness C Factor	e opecimications Sizing Criteria	Velocity	2	Design Limits Pressure	Limits	Reynolds Number
CuNi Ciass 200 standard		Copper Nickel MIL-T-16420K Schedule: Class 200	6E-05 In 150	E.	0.0	2	fus	٩	psi g	2
					Fluid Zones					
Fluid Zone Name Table Name		Temperature	Pressure	Fluid	Fluid State	Density Viscosity		Vapor Pressure Critical Pressure		Specific Heat Ratio (k) Relative Molecular Mass
Seawater Seawater 3.5% Salinity	linity	60 °F	0 psig	5	Liquid Sizina Pumps	64.04 lb/ft ² 1.206 cP		0.2513 psia 3199 psia		- 29
Pump Name			Suction Elevation Suction Pressure		Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	3427	NPSHa	
Sizing Pump 4			2.5 ft -0.5463 psi g		2.5 ft 80.41 psig Pipelines	182 ft 80.95 psi		31.	31.25 ft	
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	SSO	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 Inlet Device: Sizing Pump 4	2.5 11 19 4	# # 5 F	165 gpm 6.152 fts 134088 Outlet Device: Node	1.815 ft 1.451 ft e: Node 2		80.41 psig 75.82 psig	4.587 psi 0.6455 psi	0.01705 0.01702 2.47
Hose CuNi Class 200 Seawater		1.5 in 1.756 in 150 ft Inlet Device: Node 1	24	e e # #	82.28 gpm 10.9 fVs 126044 Outlet Device: Station 1	32.86 ft 0 ft e: Station 1		64.97 psi g 50.36 psi g	14.61 psi 0 psi	0.01736 0.01975 0.00
Pipe 4 CuNi Class 200 Seawater		1.5 in 1.756 in 0.01 ft Inlet Device: Station 1	24	e e	82.28 gpm 10.9 ft/s 126044 Outlet Device	2.13 gpm 2.191E-03 ft 0.9 ft/s 0.6 ft 126044 Outlet Device: Pressure Boundary 1		9.742E-04 psig 0 psig	9.742E-04 psi 0 psi	0.01736 0.01975 0.00
Hose CuNi Class 200 Seawater			24	==	82.72 gpm 10.96 ft/s 126707 Outlet Device: Station 2	33.17 ft 0 ft e: Station 2		65.65 psi g 50.9 psi g	14.75 psi 0 psi	0.01734 0.01975 0.00
Pipe 7 CuNi Class 200 Seawater		1.5 in 1.756 in 0.01 ft Inlet Device: Station 2	24	u u u	82.72 gpm 10.96 fVs 126707 Outlet Device	2.72 gpm 2.211E-03 ft .06 ft/s 0 ft 126707 0 ttessure Boundary 2 Outlet Device: Pressure Boundary 2		9.835E-04 psig 0 psig	9.835E-04 psi 0 psi	0.01734 0.01975 0.00
Pipe 8 CuNi Class 200 Seawater		3 in 3.31 in 5 ft Inlet Device: Sea Chest	2.5	tt د د	165 gpm 6.152 ft/s 134088 Outlet Device: Strainer	0.6544 ft 0.6544 ft e: Strainer		1.89 psi g 0.4064 psi g	1.484 psi 0.291 psi	0.01705 0.01702 1.11
PIPE-FLO Professional	onal	3	List Report			Wednesday, May 16, 2018 03:41 PM	ay 16, 201	8 03:41 PM		Page 1

DOUBLE ENDED AZIMUTH DRIVE VERRY

8/10/18

EBDG – NC, PLLC 18026-200-505-1

Rate locicity Total Head Loss Inter Pressure Outlet Pressure Total dia At an applicable Total dia At an applicable Total dia At an applicable Total dia At an applicable Total dia At an applicable <thtotal applicable<="" dia="" th=""> <thtotal applicable<="" th=""></thtotal></thtotal>				Pipelines			l	
Image Image Control Priority former Value Control Value Value <th>Dineline Name</th> <th>Class</th> <th>Intel Elevel</th> <th></th> <th>Total Hand I and</th> <th>Inlat Presents</th> <th>Total dB</th> <th>Dine Eriction Eactor</th>	Dineline Name	Class	Intel Elevel		Total Hand I and	Inlat Presents	Total dB	Dine Eriction Eactor
Lungth Lungth <thlungth< th=""> <thlungth< th=""> <thlungth< td="" th<=""><td>Pipeline Name Specification</td><td>size Inside Diam</td><td></td><td></td><td>V&F Head Loss</td><td>Unter Pressure</td><td>V&F dP</td><td>V&F Friction Factor</td></thlungth<></thlungth<></thlungth<>	Pipeline Name Specification	size Inside Diam			V&F Head Loss	Unter Pressure	V&F dP	V&F Friction Factor
31 15 6 15 16 16 0.0000 0.0000	Fluid Zone	Length		Reynolds Number				V&F Resistance K
31 5 1 55 1 55 1 50 0000 0000 2 11 25 1 1 20 0 0000 0	Pipe 9	3 in	2.5 ft	165 apm	0.5231 ft			0.01705
Intel Device: 2.1 Other Device: 2.1 0.14000 0.1302 <th0.1302< th=""> <th< td=""><td>CuNI Class 200</td><td>3.31 In</td><td>2.5 ft</td><td>6.152 ft/s</td><td>0.4504 ft</td><td></td><td>0.2003 psi</td><td>0.01702</td></th<></th0.1302<>	CuNI Class 200	3.31 In	2.5 ft	6.152 ft/s	0.4504 ft		0.2003 psi	0.01702
Intel Device: Stanier Outer Device: Stanier Stanier <td>Seawater</td> <td>2 1</td> <td></td> <td>134088</td> <td></td> <td></td> <td></td> <td>0.77</td>	Seawater	2 1		134088				0.77
15 11 12 13<		Strainer		Outlet Device				
1730 III 1730 IIII 1730 IIII 1730 IIII 1730 IIII 1730 IIII 1730 IIIII 1730 IIIII 1730 IIIII 1730 IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII		191		00.00				A 41740
Inductor Control <		HI 0'I	= 4	10 00 m	0.1/3 1			0.010.0
InterDevice: Notice:	CUNI Class 200	UI 00/1	11 1 7	10.9 105	11 767.1			C/RLO'O
Instant End Instant End Instant End Instant End Instant End End <thend< th=""> <thend< th=""> <thend< th=""></thend<></thend<></thend<>	Seaward			Outlet Device	Node 1			16.0
1.15.n 1.15.n 1.1 0.017 1.53.n 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.017 0.016 0.017 0.015 <t< td=""><td></td><td></td><td>1.00</td><td></td><td>3</td><td></td><td></td><td></td></t<>			1.00		3			
1,700 7,11 1,700 7,71 1,700 1	Pipe 13	11.5 III	14 1	82./2 gpm	6.77 ft			0.01/34
Inter Device: NOI T33 T11 Q0160 To the Device: Noise T33 T33 <th< td=""><td>CUNI Class 200</td><td>1.756 in</td><td>24 ft</td><td>10.96 ft/s</td><td>2.347 ft</td><td></td><td></td><td>0.01975</td></th<>	CUNI Class 200	1.756 in	24 ft	10.96 ft/s	2.347 ft			0.01975
InterConcer Outer Device: Noter Outer Device: Note Device:	Seawater			126707				1.26
31 11 82.36 90% 10.17 55.27 91 0.1505 91 0.0166 Inter Device: Note: Note:<		Inlet Device: Node 6		Outlet Device	Node 3			
331 11 306 10 303 1 553 10 0.000 Inter Device: 200 11 11 553 10 0.575 0.000 2.31 Inter Device: 200 11 11 653 0.000 2.31 0.000 And 200 14 0.000 0.	Pine 11	el el		82 28 anm	1017 #			0.01967
Interformer Construction Construction </td <td>CuNI Class 200</td> <td>331 10</td> <td></td> <td>3 068 11/6</td> <td>0 3385 #</td> <td></td> <td></td> <td>0.01702</td>	CuNI Class 200	331 10		3 068 11/6	0 3385 #			0.01702
Inter Devices: Notes: Notes: <th< td=""><td>Controlor</td><td></td><td></td><td>60000</td><td>1 00000</td><td></td><td></td><td>10.00</td></th<>	Controlor			60000	1 00000			10.00
International 11 ft 2.33 pin 3.03 pin 7.53 pin 0.0161 1.1 2.00 rise 1.3 ft 7.53 pin 0.0161 0.0161 1.1 1.1 0.0161 0.0161 0.0161 0.0161 0.0161 1.1 1.1 0.0161 0.0161 0.0161 0.0161 0.0161 1.1 1.1 0.0161 0.0161 0.0161 0.0161 0.0161 1.1 1.1 0.0161 0.0161 0.0161 0.0161 0.0161 1.1 0.0161 0.0161 0.0161 0.0161 0.0161 0.0161 1.1 0.0161 0.0161 0.0161 0.0161 0.0161 0.0161 1.1 0.0161 0.0161 0.0161 0.0161 0.0161 0.0161 1.1 0.0161 0.0161 0.0161 0.0161 0.0161 0.0161 1.1 0.017 0.0161 0.0161 0.0161 0.0161 0.0161 0.017 0.017	in the second se			Outlet Device	Node 9			10.3
2.20 Mort Elevention Active	100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100						140000000000000000000000000000000000000	
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Inter Device: No.0166 1.03166 1.0316 <t< td=""><td>CuNi Class 200</td><td>2.209 in</td><td></td><td>6.888 ft/s</td><td>1.3 ft</td><td>bsi</td><td></td><td>0.01869</td></t<>	CuNi Class 200	2.209 in		6.888 ft/s	1.3 ft	bsi		0.01869
Intel Device: Notes Outlet Device: Notes 3033 7.582 pig 2.71 pig 0.00161 2.200 1.67 1.67 7.311 pig 2.73 pig 2.73 pig 2.13 1.01 2.20 1.11 6.927 pig 1.67 7.311 pig 2.737 pig 2.14 0.00161 2.14 0.00161 </td <td>Seawater</td> <td></td> <td></td> <td>100196</td> <td></td> <td></td> <td></td> <td>1.76</td>	Seawater			100196				1.76
200 11 10 8.73 gm 10030 7.84 pig 0.0161 201 100733 10233 1.827 h 7.811 pig 0.733 0.0163 201 201 0.0164 0.0164 0.0164 0.0164 0.0164 201 1.00733 suffer Device: Note Family 7.811 pig 0.0164 Bottom Function Suffer Pressure Modual Conde Pipeline Name Preneration Heigin Pipeline File 0.0164 1404 8040 4.25 m 7.80 pig 4.25 m 1.80 pig 1.80 pig </td <td></td> <td></td> <td></td> <td>Outlet Device</td> <td>Node 8</td> <td></td> <td></td> <td></td>				Outlet Device	Node 8			
2001 11 0.000 12.10 13.11 19.91 0.733 19.01 0.000 2.00 Intel Device: Node 0.0000 <t< td=""><td>Dire 10</td><td>nic</td><td></td><td>82 72 ADM</td><td></td><td></td><td></td><td>0.01811</td></t<>	Dire 10	nic		82 72 ADM				0.01811
Title Title <th< td=""><td>CuNi Class 200</td><td>0 200 C</td><td></td><td>6 975 1/5</td><td>1 627 ft</td><td>73 11 nsi a</td><td></td><td>0.01869</td></th<>	CuNi Class 200	0 200 C		6 975 1/5	1 627 ft	73 11 nsi a		0.01869
Init Device: Notation Outient Device: Notation Bottom Freesure: Initial Initial Initial Initial Bottom Freesure: Nydraulic Orteding Pipeline Connecting Pipelines Pressure at Peneration Heightin Uquid Leveration 0 pisig 4.25 ft Pipeline Connecting Pipelines 1.39 pisit 1.89 pisig 4.25 ft Pipeline Pipeline Pipeline 1.30 pisit 1.89 pisig 4.25 ft Pipeline Pipeline Pipeline 1.30 pisit 1.80 pisig 0.25 ft 0.1 1.65 gpm 1.89 pisit 1.31 pisit 2.4 ft 8.03 pisit 8.272 gpm 1.80 pisit 1.32 pisit 0.01014 Pressure 0.01141 Flowed Loss 1.13.2 ft 1.13.2 ft 2.5 ft 0.3135 pisit 1.13.2 ft 8.278 gpm 1.13.2 ft 2.6 ft 0.3135 pisit 1.13.2 ft 1.65 gpm 1.13.2 ft 2.6 ft 0.3135 pisit 8.228 gpm 1.13.2 ft 1.13.2 ft 2.6 ft 0.3135 pisit	Seawater	20 ft		100723				2.18
Tanks Tanks Battom Fewation Surface Preasure Liquid Level Mydraulic Grade Connecting Plailines Preserve at Point Uquid Level Battom Preasure Liquid Level 1,69 psig 4.25 ft Connecting Plailines Preserve at Point 4,25 ft 1,69 psig 4.25 ft Pipelio Preserve Preserve <td></td> <td></td> <td></td> <td>Outlet Device</td> <td>Node 6</td> <td></td> <td></td> <td>2</td>				Outlet Device	Node 6			2
Bottom Elevation Surface Pressure Liquid Level Modalia Production Region Connecting Pleatines Pressure Pleatine Pleatine <t< td=""><td></td><td></td><td></td><td>Tanks</td><td></td><td></td><td></td><td></td></t<>				Tanks				
Liguid Level Other Presume of the Presume	Tank Name			soulie Grada		Connection Dinallo		
0 ft 0 pig 4.25 ft 1.69 pig 4.25 ft 1.69 pig 1.60 pig 1.61 pig 1.65 pig 1.61 pig 1.6	Fluid Zone			I		n Height Pipelin		essure at Penetration
0 ft 4.25 ft 0 psig 4.25 ft Curve dP Devices Pipe 8 0 ft 165 gpm 139 psi 180 psig • Curve dP Devices • Device Pipe 8 0 ft 165 gpm 138 psi 180 psi • Intel Flexation Outlet Flexation Outlet Flexation Outlet Flexation 168 psi 168 psi 138 psi • Intel Flexation Outlet Flexation Outlet Flexation 0.72 psi 168 pm 168 pm • 24 ft 0.3156 psig 0.325 psi 0.325 psi 82.28 gpm 168 pm • 24 ft 0.3156 psig 0.325 psi 82.38 gpm 168 pm 168 pm • 25 ft 0.3156 psig 0.325 psi 82.38 gpm 168 pm 168 pm • 24 ft 76.82 psig 113.2 ft 76.82 psig 168.2 ft 168.2 ft • 11 ft 76.82 psig 168.2 ft 168.2 ft 168.2 ft 168.2 ft • 144 ft 76.82 psig 168.2 ft 168.2 ft 168.2 ft 168.2 ft								
4.25 ft 1.89 psig Pipe 8 0 ft 165 gpm 1.89 psi note the evention Curve ctP Drives Pipe 8 0 ft 165 gpm 1.89 psi note the evention Outlet Freevention Outlet Freevention Outlet Freevention Ref 165 gpm 1.89 psi 2.6 ft 0.3136 psig 9.835E-04 psig 114.4 ft 6.0.72 psi 165 gpm 2.6 ft 0.3136 psig 0.3136 psig 1.14.4 ft 8.2.72 gpm 2.6 ft 0.3136 psig 8.2.72 psi 8.2.72 gpm 2.6 ft 0.3136 psig 8.2.72 psi 8.2.72 gpm 2.6 ft 0.3136 psig 8.2.72 gpm 165 gpm 2.6 ft 0.3136 psig 8.2.72 gpm 8.2.72 gpm 1.11 ft 7.582 psig 8.2.72 gpm 1.11 ft 7.582 psig 8.2.73 gpm 1.11 ft 7.582 psig 8.2.73 gpm 1.11 ft 7.582 psig 8.2.73 gpm 1.11 ft 7.582 psig 161 ft 1.11 ft 7.582 psig 168 ft 1.11 ft 7.582 psig 168 ft 1.11 ft 7.582 psig 168 ft	Sea Chest	ŧ	0 psig					
Pipe 8 0.11 165 gpm 1.38 ps Curve dP Devices Curve dP Devices Device 1.65 gpm 1.65 gpm 1.68 psm Intel Fressure Outlet Fressure Head Loss Head Loss Flow Rate 1.68 psm 2.6 ft 2.6 ft 0.0164 psig 9.835E.04 psig 82.72 gpm 82.72 gpm 2.5 ft 2.5 ft 0.215 psig 165 gpm 82.72 gpm 2.7 kg 0.3136 psig 0.3156 psig 165 gpm 82.72 gpm 2.6 ft 0.3136 psig 156 gpm 82.73 gpm 82.78 gpm 2.8 ft 0.3136 psig 156 gpm 165 gpm 82.78 gpm 2.8 ft 0.3136 psig 113.2 ft 82.28 gpm 82.28 gpm 3.036 psig 9.742E.04 psig 82.38 gpm 82.28 gpm 82.28 gpm 11 ft Nodes 113.2 ft 113.2 ft 113.2 ft 12 ft Nodes 181.6 ft 114.1 ft 114.1 ft	Seawater	E	9 psig					
Intellevation Outlet Flevation Outlet Flevation Iow Rate 24 ft 0utlet Fressure Head Loss 50.9 psi 82.72 gpm 24 ft 50.9 psi 9.8356-04 psi 60.9 psi 82.72 gpm 50.9 psi 9.8356-04 psi 0.72 psi 165 gpm 0.4064 psi 0.3136 psi 16.619 ft 165 gpm 0.4064 psi 0.3136 psi 13.21 ft 82.28 gpm 0.4064 psi 0.4056 psi 9.742E-04 psi 82.28 gpm 0.4064 psi 0.4056 psi 9.742E-04 psi 82.28 gpm 0.4064 psi 0.4064 psi 13.2 ft 82.28 gpm 0.4064 psi 0.4064 psi 13.2 ft 82.28 gpm 0.4064 psi 0.4064 psi 13.2 ft 9.7426 psi 0.4064 psi 0.4064 psi 13.2 ft 9.7426 psi 0.4064 psi 0.4064 psi 13.2 ft 9.63.2 ft 0.4064 psi 0.4064 psi 14.6 ft 16.8 ft 0.4064 psi 0.4064 psi 14.6 ft 16.8 ft 0.4064 psi 0.4064 ps					•		65 gpm	1.89 psi g
Intellievation Outlet Elevation Outlet Elevation Intellievation Outlet Elevation Head Loss Head Los Head Loss Head Loss				Curve dP Davices				
Inter Pressure Outlet Pressure Head Loss 24 ft 24 ft 50.9 psi 82.72 gpm 50.9 psig 9.835E-04 psig 114.4 ft 82.72 gpm 2.5 ft 0.3136 psig 0.3136 psig 1619 ft 165 gpm 2.5 ft 0.3136 psig 0.3136 psig 1619 ft 82.28 gpm 2.4 ft 24 ft 60.35 psi 82.28 gpm 82.28 gpm 2.4 ft 7.41 50.35 psi 82.28 gpm 82.28 gpm 2.4 ft 50.35 psi 9.742E-04 psig 113.2 ft 82.28 gpm 50.36 psig 9.742E-04 psig 706s 161 ft 13.2 ft 2.4 ft 75.82 psig 161 ft 163 ft 163 ft 2.4 ft 75.82 psig 161 ft 163 ft 163 ft 2.4 ft 64.97 psig 163 ft 163 ft 163 ft 2.4 ft 64.97 psig 163 ft 163 ft 163 ft	Curve dP Device Name	Inlet Elevation	Outlet Eler			low Rate		
24 ft 24 ft 50.9 psi 82.72 gpm 50.9 psig 9.835E-04 psig 114.4 ft 82.72 gpm 2.5 ft 0.3136 psig 0.3136 psig 15.619 ft 165 gpm 2.4 ft 2.5 ft 0.3136 psig 82.28 gpm 2.4 ft 50.35 psig 82.28 gpm 2.4 ft 73.6 psig 82.28 gpm 2.4 ft 50.35 psig 82.28 gpm 2.4 ft 7048 113.2 ft 50.36 psig 9.742E-04 psig 82.28 gpm 2.4 ft 7048 113.2 ft 11 ft 75.82 psig 181 ft 2.4 ft 64.97 psig 181 ft 2.4 ft 64.97 psig 168.2 ft	Description	Inlet Pressure	Outlet Pre		ead Loss			
50.9 psig 9.835E-04 psig 114.1 1 2.5 ft 2.5 ft 0.72 psi 165 gpm 2.6 ft 0.3136 psig 0.3136 psig 1519 ft 165 gpm 2.4 ft 2.4 ft 0.72 psi 165 gpm 165 gpm 2.4 ft 2.4 ft 6.0.315 psi 82.28 gpm 167 gpm 2.4 ft 7.6 psi 72.28 ft 82.28 gpm 167 gpm 2.4 ft 7.6 psi 82.28 gpm 82.28 gpm 167 gpm 2.4 ft Nodes Nodes Nodes 161 ft 167 gpm 11 ft 75.82 psig 181 ft 181 ft 181 ft 181 ft 2.4 ft 6.437 psig 168.2 ft 168.2 ft 168.2 ft 168.2 ft List Report Mednesday, May 16, 2018 03:41 PM 168.24 PM </td <td>Station 2</td> <td></td> <td></td> <td></td> <td></td> <td>2.72 gpm</td> <td></td> <td></td>	Station 2					2.72 gpm		
2.5 ft 2.5 ft 0.72 psi 165 gpm 0.4064 psig 0.3136 psig 1.519 ft 165 gpm 24 ft 24 ft 50.35 psi 82.28 gpm 50.36 psig 9.742E-04 psig 113.2 ft 82.28 gpm 50.36 psig 9.742E-04 psig Nodes Nodes A A A 153.2 ft 165.2 ft A A A 153.2 ft 161.4 ft A A A A 163.2 ft A 11.1 ft 75.82 psig 161.1 ft 24 ft 64.97 psig 163.2 ft List Report List Report Mednesday, May 16, 2018 03:41 PM	5/8" Nozzle	50.9 psi g	9.835E-04 ps		14.4 R			
0.4064 psig -0.3136 psig 1.619 n 24 N 24 82.28 gm 50.36 psig 9.742E-04 psig 82.28 gm 50.36 psig Nodes Nodes Nodes Nodes Nodes Flewation Pressure Nydrault Grade 11 75.82 psig 181 1 24 64.97 psig 163.24 1 List Report	Strainer	2.5 ft	2.5 ft		0.72 psi	165 gpm		
24 ft 24 ft 24 ft 50.35 psi 82.28 gpm 50.36 psig 9.742E-04 psig 113.2 ft 82.28 gpm Flevation Elevation Pressure Mydraulic Grade 11 ft 75.82 psig 181 ft 24 ft 64.97 psig 168.2 ft List Report	Eaton Model 72 3"	0.4064 psi g	-0.3136 ps		.619 ft			
S0.36 psig 9.742E-04 psig 113.2 ft Nodes Nodes Hydraulic Grade Elevation Pressure Hydraulic Grade 11 ft 75.82 psig 181 ft 24 ft 64.97 psig 168.2 ft List Report Ueta Reday, May 16, 2018 03:41 PM	Station 1				DSI	2.28 apm		
Nodes Elevation Pressure Hydraulic Grade 11 ft 75.82 psi g 181 ft 24 ft 64.97 psi g 168.2 ft List Report List Report Wednesday, May 16, 2018 03:41 PM	5/8" Nozzle	50.36 psi g	9.742E-04 ps					
Elevation Pressure Hydraulic Grade 11 ft 75.82 psi g 181 ft 24 ft 64.97 psi g 168.2 ft List Report Mednesday, May 16, 2018 03:41 PM				Nodes				
11 ft 75.82 psi g 181 ft 24 ft 64.97 psi g 168.2 ft List Report Wednesday, May 16, 2018 03:41 PM	Node Name		Elevatio			ade		
24 ft 64.97 psig 168.2 ft List Report Wednesday, May 16, 2018 03:41 PM	Node 2		111					
24 ft 64.97 psig 168.2 ft List Report Wednesday, May 16, 2018 03:41 PM								
List Report List Report	Node 1		24 f					
List Report			11110		A at the second s	M0 11-00 010		C 1110
		C19	unday t		weanesday, may 10, 2	ML 14:00 010		7 aße 4

DOUBLE ENDED AZIMUTH DRIVE VERRY

8/10/18

EBDG – NC, PLLC 18026-200-505-1

Job: 18026 Rev. -

By: Page: NJB F-7

		NODES		
Node Name	Elevation	Pressure	Hydraulic Grade	
Node 3	24 ft	65.65 psi g	169.7 ft	
Node 6	14 R	73.11 psig	177.1 ft	
Node 8	14 R	72.16 psig	175 ft	
Node 9	11 R	75.37 psi g	180 ft	
	Pressure E	No cu		
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	24 ft	0 psig	22.15 ft	82.28 gpm
Pressure Boundary 2	24 ft	0 psig	22.13 ft	82.72 gpm

PIPE-FLO Professional

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List Report

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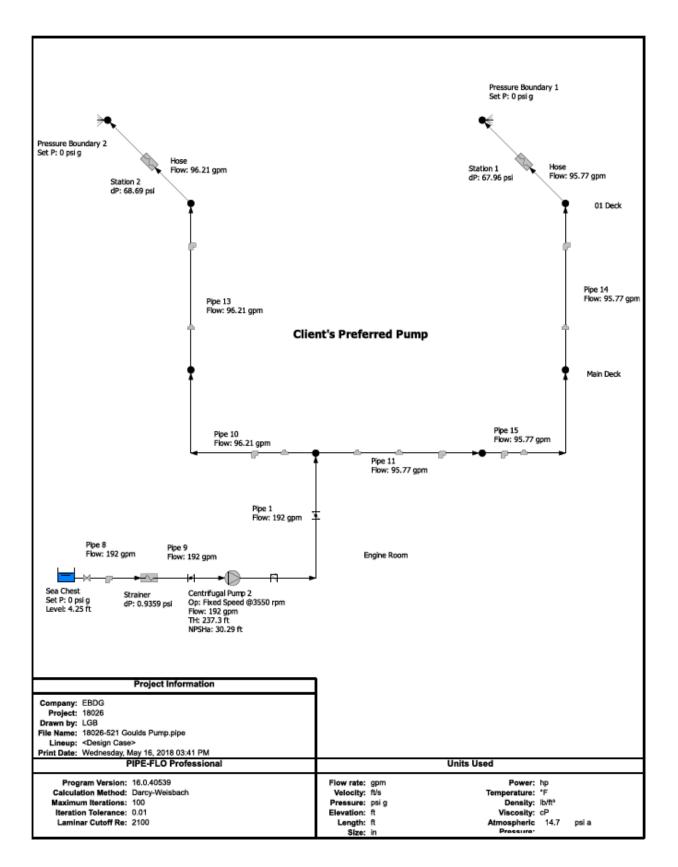
		Bill	of Materials Re	port		
Lineup: Program Name:	18026-521.pipe <design case=""> PIPE-FLO Professional 16.0.40539</design>			Company: Project: by: Date:	180) LGB	26
veraion.	10.0.10000		Pipelines	Date.	1100	aneaday, may 10, 2010 00.401 m
Pipeline	Specif	lication	Size	Ler	gth	Valves and Fittings
Pipe 1	CuNi (Class 200	3 in	10	ft	1 x Butterfly 1 x Swing Check - Angled
Hose	CuNi (ass 200	1.5 in	150	ft	
Pipe 4	CuNi C	ass 200	1.5 in	0.01	ft	
Hose	CuNi (lass 200	1.5 in	150	ft	
Pipe 7	CuNi (lass 200	1.5 in	0.01	ft	
Pipe 8	CuNi (Jass 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	lass 200	3 in	2	ft	1 x Butterfly
Pipe 14	CuNi (lass 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, n/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 (Xass 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 C	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, n'd 1.5 (90°)
Pipe 10	CuNi C	Class 200	2 in	20	ft.	3 x Elbow - Long radius, n/d 1.5 (90°) 1 x Reducer - Contraction (2 in x 3 in - 0 1 x Tee - Flow Thru Branch
		Pi	peline Material S	ummary		
Specification	Material		Size	Total Length		Valves & Fittings
CuNi Class 200	Copper Nick Schedule: (el MIL-T-16420K 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 Nick Schedule: (el MIL-T-16420K Class 200	2 in	60.00 ft		8 x Elbow - Long radius, n'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 Nick Schedule: (el MIL-T-16420K Class 200	3 in	82.00 ft		2 x Butterfly 6 x Elbow - Long radius, r/d 1.5 (90") 1 x Entrance - Sharp Edged 1 x Gate - Wedge Disc 1 x Swing Check - Angled 1 x Tee - Flow Thru Branch 1 x Tee - Flow Thru Run

PIPE-FLO Professional

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EBDG – NC, PLLC 18026-200-505-1

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.

EBDG – NC, PLLC	Job: 18026	By:	NJB
18026-200-505-1	Rev	Page:	G-2

Pipe Segment	Flow	Pipe	Schedule	d, ID	Design Velo	ocity	V
	Rate	Size			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

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

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

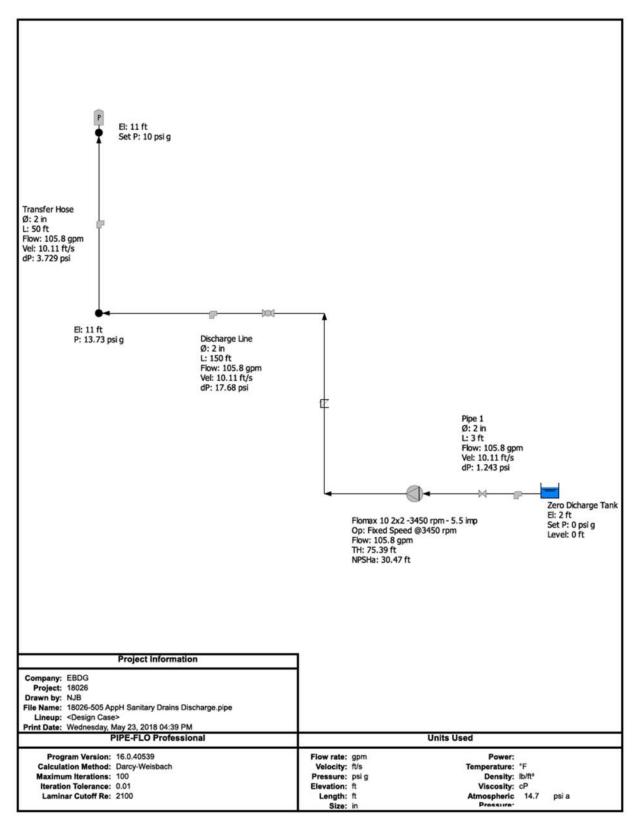
5.2 Zero Discharge Pump TDH and NPSH Calculation

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



EBDG – NC, PLLC 18026-200-505-1

		l	l	List Report							
File Name: 18026-505 AppH Sanitary Drains Discharge.pipe Lineup: -Oesign Case> Progam Name: PIPE-FLO Professional Version: 16.0.40539	Sanitary Drains Discharge. sional		Calculation Method: Darc Laminar Cutoff Ro: 2100 Max Iterations: 100 Iteration Tolerance: 0.01 Atmospheric Pressure: 14,7 Atmospheric Pressure: 14,7	y-We	isbach psi a cations		Company: E Project: 1 by: N Date: V	EBDG 18026 NJB Wednesday,	EBDG 18026 NJB Wednesday, May 23, 2018 04:40 PM	04:40 PM	
Specification Name Valve Table	Material Schedule	Absol Hazen V	Absolute Roughness Hazen Williams C Factor		Sizing Criteria	Velo	Velocity		Design Limits Pressure		Reynolds Number
Carbon Steel SCH 80 standard	Steel A53-B36.10 Schedule:80	1.8	1.800E-03 in 140	0.0		đ	fivs		ę	psi g	ę
Plastic Pipe standard	PVC PIPE D1785 Schedule:40		6E-05 in 140	0.0 Eluid Zones		9	ft/s		ą	6 isq	ą
Fluid Zone Name Table Name	Temperature		Pressure	Fluid State		Density Viscosity		Vapor F Critical	Vapor Pressure Critical Pressure	SF	Specific Heat Ratio (k) Relative Molecular Mass
Water Water	60 °F	0	psi g	Liquid		62.37 lb/ft* 1.105 cP		0.2564 3199	0.2564 psia 3199 psia		1 85
Pump Name	Test Speed Operating Speed	2004	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure		Total Head dP	Flow Rate Power		Efficiency BEP Efficiency	y NPSHa	Ha Design NPSH Hr Margin Ratio
Flomax 10 2x2 -3450 rpm - 5.5 imp Fixed Speed @3450 rpm	3450 3450	rpm rpm	2.5 ft -1.243 psig	2.5 ft 31.41 psig		75.39 ft 32.65 psi	105.8 gpm 	mdi	1	30.47 6.922	। स.स.
Company: Flomax Curve: Manual Pump Type:		Size: Diameter: POR:	Size: 10 2x2 meter: 5.5 in POR: from -	to - Pipeline:							
Pipeline Name Specification Fluid Zone	Ins	Size Inside Diameter Length	Inlet Elevation Outlet Elevation	1000	Flow Rate Fluid Velocity Reynolds Number	Total Head Loss V&F Head Loss	d Loss d Loss	Inlet Pressure Outlet Pressure	essure essure	Total dP V&F dP	Pipe Friction Factor V&F Friction Factor V&F Resistance K
Discharge Line Plastic Pipe Water	2 Inlet Device: Fic	2 in 2.6 ft 2.067 in 11 ft 150 ft Flomax 10 2x2 -3450 rpm - 5.5 imp	2.5 ft 11 ft 0 rpm - 5.5 imp	105.8 10.11 146 O u	105.8 gpm 10.11 ft/s 146322 Outlet Device:	15.8 gpm 32.32 ft 0.11 ft/s 9.024 ft 146322 Outlet Device: Pressure Boundary	2 ft 1 ft ndary	31.41 psig 13.73 psig	psig psig	17.68 psi 3.908 psi	0.01683 0.01899 5.68
Pipe 1 Plastic Pipe Water	2 Inlet Device: Ze	2 in 2.067 in 3 ft Zero Dicharge Tank	2 ft 2.5 ft	105.8 10.11 146 O u	105.8 gpm 10.11 ft/s 146322 Outlet Device:	5.8 gpm 2.369 ft -1.2. 3.11 ft/s 1.903 ft -1.2. 146322 Outlet Device: Flomax 10 2x2 -3450 rpm - 5.5 imp	9 ft 3 ft 2 -3450 rpm -	0 psig -1.243 psig	psi g psi g	1.243 psi 0.8245 psi	0.01683 0.01899 1.20
Transfer Hose Plastic Pipe Water	2 Inlet Device: Pr	2 in 2.067 in 50 ft Pressure Boundary	5 F F	105.8 10.11 1463 Out l	105.8 gpm 10.11 ft/s 146322 Outlet Device:	5.8 gpm 8.61 ft 0.11 ft/s 0.845 ft 146322 Outlet Device: Pressure Boundary 1	i fi 5 fi ndary 1	13.73	psi g psi g	3.729 psi 0.366 psi	0.01683 0.01899 0.53
Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure		Hydraulic Grade	Pipeline	Pipeline Name	Connec Penetration Height	Connecting Height	Connecting Pipelines Height Pipeline Fic	w Rate Pr	Pipelines Pipeline Flow Rate Pressure at Penetration
Zero Dicharge Tank Water	2 # 0 #	0 psig 0 psig		2 ft							
PIPE-FLO Professional		List Report				Wednesday	Wednesday, May 23, 2018 04:40 PM	I8 04:40 PN	-		Page 1

DOUBLE ENDED AZIMUTH DRIVE FERRY

8/10/18

EBDG – NC, PLLC 18026-200-505-1

PIPE-FLO Professional

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List Report

	Bill	of Materials Re	Materials Report Company: EBDG Project: 18026 by: NJB Date: Wedne		
Lineup: Program Name:	18026-505 AppH Sanitary Drains Discharge.pipe <design case=""> PIPE-FLO Professional 16.0.40539</design>	1			
		Pipelines			
Pipeline	Specification	Size	Lei	ngth	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	1	3ft	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°)
	Pij	peline Material Su	ummary		
Specification	Material	Size	Total Length	ĕ	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°) 4 x Suite Check / Voticel

1 x Swing Check - Vertical

PIPE-FLO Professional

Bill of Materials Report

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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.

Pipe Segment	Flow	Pipe	Schedule	d, ID	Design Vel	ocity	V
	Rate	Size			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

Table 5-1: Nominal Pipe Velocity

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,"

EBDG – NC, PLLC
18026-200-505-1

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

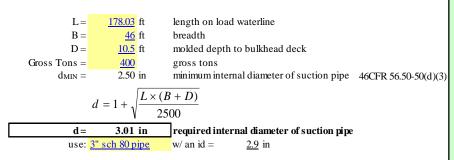
APPROACH

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

ASSUMPTIONS

1. Unit Systemused 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)



CALCULATION OF PIPE SIZE FOR SUCTION OF EACH BRANCH

B = D = d_{MIN} =

d_{MAX} =

46CFR 56.50-50(d)(2)

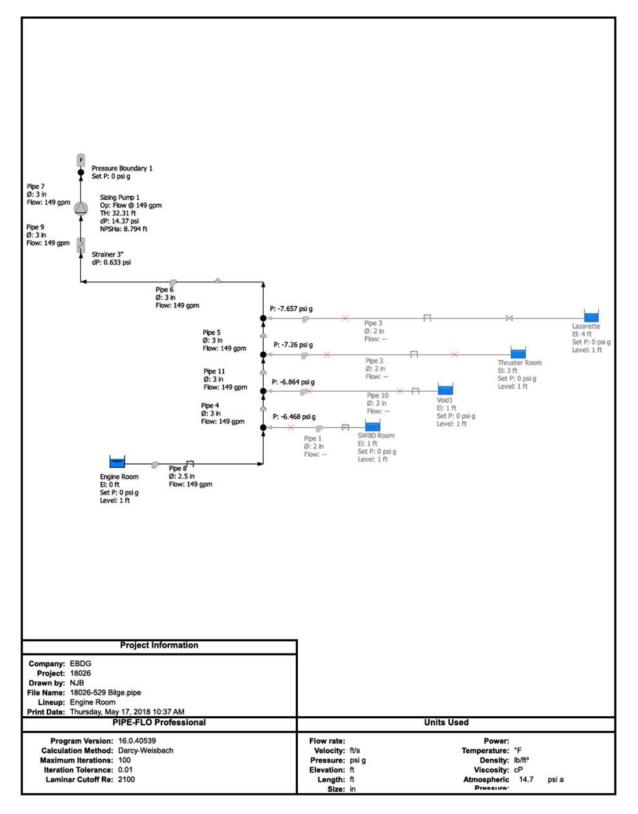
c =	see table	ft	compartment length
B =	46	ft	breadth
D =	10.5	ft	molded depth to bulkhead deck
min =	2	in	minimum internal diameter of branch suction pipe
лах =	4	in	maximum internal diameter of branch suction pipe
d =	see table	in	required internal diameter of branch suction pipe
id =	see table	in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

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

Compartment	с	d	pipe selected	id	PASS
	(ft)	(in)		(in)	
Lazarette A	<u>11.8</u>	2.000	<u>2" sch 80 pipe</u>	<u>1.939</u>	PASS
Thruster Room A	<u>32</u>	2.098	<u>2" sch 80 pipe</u>	<u>1.939</u>	PASS
<u>Void A</u>	<u>16</u>	2.000	<u>2" sch 80 pipe</u>	<u>1.939</u>	PASS
Engine Room	<u>48</u>	2.345	<u>21/2" sch 80 pipe</u>	<u>2.323</u>	PASS
SWBD Room	<u>16</u>	2.000	<u>2" sch 80 pipe</u>	<u>1.939</u>	PASS
<u>Void B</u>	<u>16</u>	2.000	<u>2" sch 80 pipe</u>	<u>1.939</u>	PASS
Thruster Room B	<u>32</u>	2.098	<u>2" sch 80 pipe</u>	<u>1.939</u>	PASS
Lazarette B	<u>11.8</u>	2.000	<u>2" sch 80 pipe</u>	1.939	PASS

CALCULA	FION OF PUM		
	d =	3.01 in	required diameter of main bilge suction
	a =	7.10 in ²	required cross sectional area of main bilge suction
	$\mathbf{v} =$	400 ft / min	required pump suction velocity
	V =	148 gpm	required pump capacity

BILGE SYSTEM PIPE-FLO MODEL



					1 1-4 14					
					LIST KEPOLT					
File Name: Lineup: Progam Name:	File Name: 18026-529 Bilge.pipe Lineup: Engine Room Progam Name: PIPE-FLO Professional	pe onal	1977	Calculation Method: Laminar Cutoff Re: Max Iterations:		Company: Project: by:				
Version:	Version: 16.0.40539		Atm	Iteration Tolerance: 0.01 Atmospheric Pressure: 14.7	ance: 0.01 sure: 14.7 psia	Da	Date: Thursday	Thursday, May 17, 2018 10:38 AM	10:38 AM	
					Pipe Specifications					
Specification Name	ame	Material	Abso	Absolute Roughness	s Sizing Criteria			Design Limits	lits	
Valve Table		Schedule	Hazen	Hazen Williams C Factor	tor	Velocity		Pressure		Reynolds Number
Steel A53 sch 80 standard		Steel A53-B36.10 Schedule:80	1.1	1.800E-03 in 140	0.0	to ft/s	s	q	psi g	ą
					Fluid Zones					
Fluid Zone Name Table Name		Temperature	Pre	Pressure	Fluid State	Density Viscosity	Criti	Vapor Pressure Critical Pressure	~ œ	Specific Heat Ratio (k) Relative Molecular Mass
Sea Water Seawater 3.5% Salinity	talinity	60 *F	0	0 psig	Liquid	64.04 lb/ft ^a 1.206 cP	0.2	0.2513 psia 3199 psia		- 29
					Sizing Pumps					
Pump Name			Suction	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa	ŧ	
Sizing Pump 1			-10.5	2.5 ft -10.53 psig	2.5 ft 3.835 psig	32.31 ft 14.37 psi		8.794	e	
					Lipellies		l		l	
Pipeline Name Specification Fluid Zone		Si Inside I Len	Size Inside Diameter Length	Inlet Elevation Outlet Elevation	on Flow Rate ion Fluid Velocity Reynolds Number	Total Head Loss V&F Head Loss er	Inlet Outle	Inlet Pressure Outlet Pressure	Total dP V&F dP	Pipe Friction Factor V&F Friction Factor V&F Resistance K
Dine 1			nic	4		2	DAA	0.4447 nei n	,	0
Steel A53 sch 80		1.939 in	1.5	2.5 ft			-6.4	6.468 psi g	1	
Sea Water			6 A		1			•		4,50
		Inlet Device: SWBD Room	Room		Outlet Device: Node 1	ce: Node 1				
Pipe 2			2 in	3 ft	,	,	0.44	0.4447 psi g	1	ı
Steel A53 sch 80		1.939 in	.c			ı	-7-	26 psi g	1	1
Sea Water		40 Inlet Device: Thruste	40 ft Thruster Room		- Outlet Devi	 Outlet Device: Node 2				4.78
Pipe 3			2 in	4 ft	,	1	0.4447		I	1
Steel A53 sch 80		1.939 in	E.	2.5 ft	ı	ı	-7.657	57 psi g	ı	1
Sea Water		/2 n Inlet Device: Lazarette	/2 ft arette		- Outlet Devi	Outlet Device: Node 3				5.47
a trait			0 In		140	0 000	-	T DE aci a	100 00 0	000000
Steel A53 ech 80		00		4 4 C	7 237 Ale	0.0303 1	-1-	-7.657 nei o	0.381 psi	
Sea Water		0.5	0.5 ft	1 0.7	138204		0.1	Ried In	ied inc'n	
		Inlet Device: Node 2	:		Outlet Devi	Outlet Device: Node 3				
Pipe 7			3 in		149 gpm	1.623 ft	3.8	3.835 psi g	3.835 psi	0.02008
Steel A53 sch 80		2.9	2.9 in	9.5 ft	7.237 fVs	0 U		0 psig	0 psi	Ö
Sea Water		24 Inlet Device: Sizing I	24 ft Sizing Pump 1		138204 Outlet Devi	138204 Outlet Device: Pressure Boundary 1				0.00
Pipe 8		2.0	2.5 in	80	149 apm	13.04 ft	0.4447	47 psi a	6.913 psi	0.02033
Steel A53 sch 80		2.323 In	1	2.5 ft	11.28 ft/s	8.892 ft	-6.4	-6.468 psi g	3.954 psi	
Sea Water		20 ft Inlet Device: Engine Room	e Room		0utlet Devi	172532 Outlet Device: Node 1				4.50
PIPE-FLO Professional	tional		List Report			Thursday May 17, 2018 10:38 AM	2018 10:38	AM		Page 1
						to fam (famous)		I		

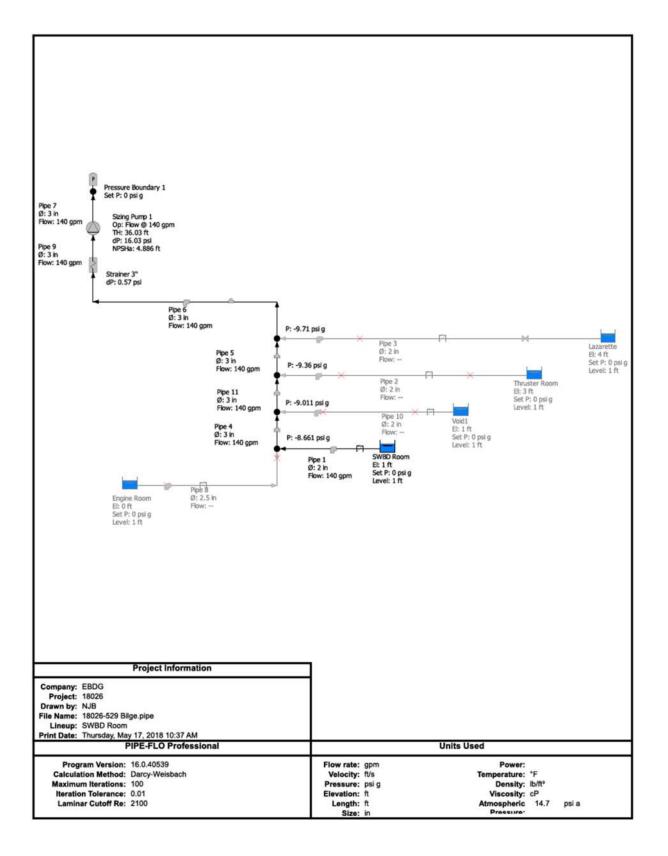
lineline Mama			Intel Elevelon	Claur Date	Total Hand and	Intat Descense	Total aD	Dine Eriction Eacto
Pipeline Name Specification	-	size Inside Diameter	Outlet Elevation	Fluid Velocity	V&F Head Loss	Outlet Pressure	V&F dP	V&F Friction Factor
Fluid Zone		Length		Reynolds Number				V&F Resistance K
Pipe 6		3 in		149 apm	4.843 ft	-7.657 psi g	2.154 psi	0.02008
Steel A53 sch 80		2.9 in	2.5 ft	7.237 fVs	1.057 ft	-9.811 psi g	0.4699 psi	0.01754
Sea Water		56 ft		138204				1.30
	Inlet Device:	ice: Node 3		Outlet Device: Strainer 3"	trainer 3"			
Pipe 9		3 in		149 gpm	0.2029 ft	-10.44 psi g	0.09022 psi	0.02008
Steel A53 sch 80		2.9 in	2.5 ft	7.237 fVs	t o	-10.53 psi g	0 psi	0.01754
Sea Water	3 1	3 H		138204				00.00
	Inlet Device:	Strainer 3"		Outlet Device: Sizing Pump 1	izing Pump 1			
Pine 4		3 in		149 anm	0.8905 ft	-6.468 psi o	0.396 psi	0.02008
Steel A53 sch 80		2.9 in	2.5 ft	7.237 ft/s	0.8567 ft	-6.864 psi q	0.381 psi	0.01754
Sea Water		0.5 ft		138204				1.05
	Inlet Device:	ice: Node 1		Outlet Device: Node 6	ode 6			
Pina 11		3 in		149 anm	0.8905 ft	-6 864 nsi a	0.396 psi	0.02008
Steel A53 sch 80		2.9 in	2.5 ft	7.237 ft/s	0.8567 ft	-7.26 psi g	0.381 psi	0.01754
Sea Water	0.5 ft	0.5 ft		138204				1.05
	Inlet Device:	Node 6		Outlet Device: Node 2	ode 2			
Pipe 10		2 in	1 1			0.4447 psi g	,	
Steel A53 sch 80		1.939 in	2.5 ft		1	-6.864 psi g	1	ı
Sea Water		21 ft		1				4.50
	Inlet Device: Void1	Void1		Outlet Device: Node 6	ode 6			
				Tanks				
Tank Name	Bottom Elevation	Surface Pressure	Ire Hydraulic Grade	8		ting	88	
Fluid Zone	Liquid Level	Bottom Pressure	2	Pipeline Name	Name Penetration Height		e Flow Rate Pr	Pipeline Flow Rate Pressure at Penetration
Lazarette	4 8	0 psig	,					
Sea Water	f	1						
2					Pipe 3 0 1	¥		0.4447 psi g
Thruster Room	3 ft	0 psig	1					
Sea Water		ı			C and			0.4447 nel a
					>	-		Bied / ++++*'n
SWBD Room	÷ -	0 psig	1					
Sea Water		ı			Pipe 1 0 1	*	1	0.4447 psi g
Engine Room	0.11	0 psi a	-	-				
	- -	0.4447 psi g		6				
					Pipe 8 0 1	f 1	149 gpm	0.4447 psi g
Void1	1 H	0 psig	I					
Sea Water		1						
					Pipe 10 0 ft	-		0.4447 psi g
				Nodes				
Node Name			Elevation	Pressure	Hydraulic Grade	ade		
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			25.0	-7.657 psi o	-15 53 @			
			-	Rind son's	u 00:01			
Node 6			2.5 ft	-6.864 psi g	-13.75 11			

8/10/18

EBDG – NC, PLLC 18026-200-505-1

By: Page: NJB H-8

	Pressure Boundaries	ndaries			Ì
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Ĺ
Pressure Boundary 1	# 0 0	o Sig	89 989. 1	P49 94	
PIPE-FLO Professional	List Report	Thur	Thursday, May 17, 2018 10:38 AM	Page 3	je 3



ILISE REPORT Second representes (0)								1		
Consistention Consis consistention Consistention C				Ľ	st Report					
Material Alterial Alterial Alterial Despiration Despiration Served.cis Material Criteria Despiration Despiration Despiration Despiration Relation	File Name: 18026-529 E Lineup: SWBD Roor rogam Name: PIPE-FLO P Version: 16.0.40539	n n rofessional	Calculati Lamina Max Iteration Atmospheri	on Method: r Cutoff Re: t Iterations: Tolerance: c Pressure:	Darcy-Weisbach 2100 0.01 14.7 psi a	°.	Project: 1 by: Date: 1	BDG 8026 UB hursday, May 17, 201	8 10:39 AM	
Generation Home Nutrient C Fractor Number No. Home Number Numb	nacification Name	Material	Absolute Roi	Pipe	Specifications Siring Criteria	l	L	Design	inite	l
Steriot.cs.05.01 (1) (1.000-C.01 (1.000) (1.000	alve Table	Schedule	Hazen Williams	C Factor	BIINTID BIITTO	Veloci	ţ	Pressul		Reynolds Number
FIGICACONE Timperature Pressure FUId State Under Fresure Maper Fresure Map	teel A53 sch 80 andard	Steel A53-B36.10 Schedule:80	1.800E-03 140		0.0	ą	ft/s	þ	psi g	to
Torperture Torperure Torperture Torpertu				-	iuid Zones					
00 15 0 μig Ligid 0.010 μig 0.0313 μig Station Freewords 0.0010 μic.more 0.0010 μic.more 0.0313 μig Station Freewords 0.0010 μic.more 0.0010 μic.more 0.0313 μig 0.0313 μig Station Freewords 0.0010 μic.more 0.0010 μic.more 0.0010 μic.more 0.0313 μig 0.0314 μic.more Station Freewords 0.0014 Fleewords 0.0014 Hice 0.0016 Hice 0.0016	uid Zone Name ble Name	Temperature	Pressure	Fluid	State	Density Viscosity		Vapor Pressure Critical Pressure	Sr	Specific Heat Ratio (k) Relative Molecular Mass
Suction Freework Discharge Freework Oot Intervation Total Head Flow Rate WESha Suction Freework Discharge Freework Total Head Flow Rate Net Standing	a Water aawater 3.5% Salinity	60 *F	0 psig	r Idu	bi	64.04 lb/ft ³ 1.206 cP		0.2513 psia 3199 psia		- 29
Suction Pressure Other Pressure dP Suction Pressure dP 2.5 ft 2.6 ft 3.003 pi 4.866 ft -12.27 psig 3.003 pi 4.866 ft -12.27 psig 3.003 pi 3.003 pi 4.866 ft -12.27 psig 3.003 pi 3.004447 psig 9.106 psi -119.99 in 2.6 ft 1.877 ft 0.4447 psig 7.204 psi Inter Device: Nucleo Number Net to pressure Total topsic 0.4447 psig 7.204 psi	ump Name		Suction Elevation		arge Elevation	Total Head	Flow		SHa	l
25 ft Inter Devices 25 ft Inter Devices 25 ft Inter Devices 25 ft Inter Devices 36.03 psi Inter Devices 4.080 ft Inter Pressure 4.080 ft Inter Pressure Inter Devices Variation Flow Rate 0.014 ft Pressure 0.014 ft Pressure Variation Inter Devices Variation Flow Rate 0.014 ft Pressure 0.014 ft Pressure Variation Inter Devices 1.939 in 2.6 ft 1.6.2 ft 0.4447 psig 9.106 psi Inter Devices 1.939 in 2.6 ft 1.6.2 ft 0.4447 psig 7.204 psig Inter Devices 1.939 in 2.6 ft 0.0141 Devices 0.0447 psig 7.704 psig </td <td></td> <td></td> <td>Suction Pressu</td> <td></td> <td>arge Pressure</td> <td>đþ</td> <td></td> <td></td> <td></td> <td></td>			Suction Pressu		arge Pressure	đþ				
Stan Inint Elevation Fluid Velocity Val Head Loss Outlat Pressure Voi de Pressure Length Length 1 ft 140 spinor 1697 ft 0.4447 psig 9.106 psi Length 2.5 ft 1531 fts 16.2 ft 3661 psig 7.204 psig 7.204 psig Iniet Device: 9.106 psi 1332 fts 15.2 ft 3.661 psig 7.204 psig 7.204 psig Iniet Device: 1393 in 2.5 ft 13221 fts 3.661 psig 7.204 psig 7.204 psig Iniet Device: 1393 in 2.5 ft 0.4441 psig 7.204 psig	zing Pump 1		2.5 ft -12.27 psig	e	2.5 ft .754 psig	36.03 ft 16.03 psi		4.8	36 ft	
Size Inde Elevation Flow Ratio Flow Noticity Total Hoad Loss (Matel Pressure Langth Number (Langth) Total Hoad Loss (Matel Pressure Reynolde Number Total Hoad Loss (Matel Pressure Number Total Hoad Loss (Matel Pressure Reynolde Number Total Hoad Loss (Matel Pressure Reynolde Num					saunadiu					
2in 1 ft 140 gpm 18.97 ft 0.4447 psig 15.31 fts 15.21 fts 15.21 fts 9.661 psig 1001 2.5 ft 15.21 fts 16.2 ft 9.661 psig 1101 2.5 ft 0.1642 fs 9.661 psig 9.661 psig 2.81 1.839 in 2.5 ft - - 0.4447 psig 1.839 in 2.5 ft - - - 0.4447 psig 1.839 in 2.5 ft - - - - - 1.839 in 2.5 ft -<	peline Name becification uid Zone	Siz Inside C Len		Elevation	Flow Rate Fluid Velocity Reynolds Number		Loss	Inlet Pressure Outlet Pressure	Total dP V&F dP	Pipe Friction Factor V&F Friction Factor V&F Resistance K
1.839 in 6 ft 15.21 ft/s 16.2 ft 8.661 psig Inlet Device: Str 0.4447 psig 9.36 psig 2 in 3 ft - - - 1.939 in 2 ft - - - - 1.939 in 2 ft - - - - - 1.939 in 2 ft -	pe 1	2			140 gpm	18.97 1		BS	9.106 psi	0.02079
Inter Device: SWBD Room 194215 Inter Device: SWBD Room 3.ft - <td< td=""><td>eel A53 sch 80</td><td>1.939</td><td></td><td></td><td>15.21 ft/s</td><td>16.2 1</td><td>-</td><td>-8.661 psi g</td><td>7.204 psi</td><td>0.01928</td></td<>	eel A53 sch 80	1.939			15.21 ft/s	16.2 1	-	-8.661 psi g	7.204 psi	0.01928
2 1 3 1 - - - 0.4447 psi g 40 1 - - - - - - - - - - - - - 0.4447 psi g 40 1 - - - - - - 0.4447 psi g 40 1 - - - - - - - - 0.4447 psi g 1 1 -	a Water	6 Inlat Davice: SWBD	ft Zoom		194215 Outlet Device	- Node 1				4.50
1.33 and the flow of th								A 4447 TAL		
Init Device: Thruster Room Outlet Device: Node 2 Outlet Device: Node 2 1339 11 25 ft 0.4447 95 ft - - -0.447 95 gt 1339 1 25 ft 0.11et Device: 0.7463 1 - - -9.71 95 gt 1101 2.5 ft 0.5 ft 0.7863 ft - - - -9.71 95 gt 2.9 in 2.5 ft 6.8 ft/s 0.7863 ft - </td <td>pe z naj A53 ech RN</td> <td>1 030</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>-0 36 nei o</td> <td></td> <td></td>	pe z naj A53 ech RN	1 030						-0 36 nei o		
Inter Device: Thister Room Outlet Device: 0.01447 psig 1.939 1 2.5 ft - - -	a Water	40			,			R 64 000		4.78
2in 4 ft - - - 0.447 psig 1339 in 2.5 ft 0 -		Inlet Device: Ihruste	L KOOM		Outlet Device	: Node 2				
1339 in 2.5 ft -9.71 psig 72 ft 2.5 ft 0utt Device: Node 3 -9.71 psig 1nlet Device: Lazartie 0.5 ft 140 gpm 0.7863 ft -9.71 psig 2.9 in 2.5 ft 6.8 ft/s 0.7663 ft -9.71 psig 2.9 in 2.5 ft 6.8 ft/s 0.7653 ft -9.71 psig 2.9 in 2.5 ft 6.8 ft/s 0.7563 ft -9.71 psig 2.9 in 2.5 ft 129856 0.7563 ft -9.71 psig 2.9 in 2.5 ft 129856 0.7663 ft -9.71 psig 2.9 in 2.5 ft 140 gpm 1.442 ft 3.754 psig 2.9 in 9.5 ft 6.8 ft/s 0.6 ft 0 ft 0 psig 2.9 in 9.5 ft 0.0161 Device: Pressure Boundary 1 2.56 ft - - - - - - - - - - - - - - - - - - 0.6447 psig - - - - - - - - 0.6447 psig - -	pe 3	2			,	1		0.4447 psi g	3	ı
72 ft Inlet Device: Lazarette 1 Inlet Device: Lazarette Outlet Device: Node 3 3 in 2.5 ft 140 gpm 0.7653 ft -9.36 psi g 2.9 in 2.5 ft 140 gpm 0.7553 ft -9.36 psi g 1 1 28956 Outlet Device: Node 3 0.7563 ft -9.71 psi g 2.9 in 2.5 ft 128956 0.7563 ft -9.71 psi g 1 1 28956 Outlet Device: Node 3 0.7563 ft -9.71 psi g 2.9 in 9.5 ft 128956 0.7442 ft 3.754 psi g 2.9 in 9.5 ft 6.8 ft/s 0.6 ft 0 psi g 2.9 in 2.5 ft 0.0161 Device: Pressure Boundary 1 0 psi g 2.2 sin 0.ft - - - 2.3 sin 2.5 ft - - - -	eel A53 sch 80	1.939			,			-9.71 psi g	1	ı
3in 2.5 ft 140 gpm 0.7863 ft -9.36 psig 2.9 in 2.5 ft 6.8 ft/s 0.7563 ft -9.36 psig 0.5 ft 10 gpm 0.7563 ft -9.36 psig 0.5 ft 10 gpm 1.79856 -9.71 psig 0.5 ft 10 gpm 1.442 ft -9.75 psig 2.9 in 2.5 ft 140 gpm 1.442 ft 3.754 psig 2.9 in 2.5 ft 120 gpm 1.442 ft 0 psig 2.9 in 9.5 ft 1.40 gpm 1.442 ft 0 psig 2.9 in 2.5 ft 1.20856 0.0 ft 0 psig 2.3 in 2.5 ft 0.0 ft - - 0.6447 psig 2.3 in 2.5 ft - - - 0.661 psig 2.3 in 2.6 ft - - - - 0.661 psig 2.0 ft - - - - - 0.6447 psig 2.3 in 2.6 ft - - - - 0.6447 psig 2.0 ft - - - - - -	a Water	72 Inlet Device: Lazaret	et e		 Outlet Device	:: Node 3				5.47
2.9 in 2.5 it 6.8 ñ/s 0.7563 it -9.71 psig 0.5 it 2.5 it 128856 0.15653 it -9.71 psig 1 1.28856 1.28856 1.0063 0 it 0 psig 2.9 1 2.5 ft 140 pm 1.442 it 0 psig 2.9 1 9.5 ft 1.40 pm 1.442 it 0 psig 2.9 1 9.5 ft 1.28856 0.01 0.01 0.01 0.01 2.5 1 1.28056 0.0161 Device: Pressure Boundary 1 0.0447 psig 2.5.1 0.11 2.5.1 0.01 - - 0.0447 psig 2.0 1 2.5.1 0.01 - - 0.0447 psig 2.0 1 - 0.01 - - - 0.661 psig 2.0 1 - - - 0.0161 - - 0.0447 psig 10161 Device: Engine Round - - - - 0.0447 psig 2.0	De 5	3		ŧ	140 apm	0.7863 1		-9.36 psi a	0.3497 psi	0.02021
0.5 ft 129856 Inlet Device: Node 2 Outlet Device: Node 3 3 in 2.5 ft 140 gm 1.442 ft 3.754 psi g 2.9 in 9.5 ft 68 ft/s 0 ft 0 psi g 2.4 ft 129856 0utlet Device: Node 3 3.754 psi g 2.9 in 9.5 ft 68 ft/s 0 ft 0 psi g 2.4 ft 129856 0.447 psi g 0 ft 0 4447 psi g 2.5 ft 0 ft - - 0.4447 psi g 2.33 in 2.5 ft - - 0.4447 psi g 2.0 ft -	eel A53 sch 80	2.9		5 ft	6.8 ft/s	0.7563 1	-	-9.71 psi g	0.3364 psi	0.01754
Inlet Device: Node 2 Outlet Device: Node 3 3in 2.5 ft 140 gpm 1.442 ft 3.754 psi g 3.754 2.9 in 9.5 ft 6.8 ft/s 0 ft 0 psi g 0 2.9 in 9.5 ft 6.8 ft/s 0 ft 0 psi g 0 2.4 ft 122856 0 ft 0 ft 0 psi g 0 2.5 in 0 ft - 0 ft 2.6 ft - 0.4447 psi g - 2.5 in 0 ft - - 0.661 psi g -	ea Water	0.5	ŧ		129856					1.05
3in 2.5 ft 140 gpm 1.442 ft 3.754 psig 3.754 2.9 in 9.5 ft 6.8 ft/s 0 ft 0 psig 0 2.4 ft 1.29856 1.29856 0 ft 0 psig 0 Inlet Device: Sizing Pump 1 Outlet Device: Pressure Boundary 1 0 ft 2 ft - - 0.4447 psig - 2.5 ft - - 0 ft - - - - 0.4447 psig - - 2.323 in 2.5 ft -		Inlet Device: Node 2			Outlet Device	: Node 3				
2.9 in 9.5 ft 6.8 ñ/s 0 ft 0 psig 0 24 ft 11965 129856 0 psig 0 psig 0 Inlet Device: Sizing Pump 1 Outlet Device: Pressure Boundary 1 0.4447 psig - 25 in 0 ft - - - - 25 in 2.5 ft - - - - 2.323 in 2.5 ft - - - - 2.0 ft - - - - - 2.0 ft - - - - - 1 Inlet Device: Engine Room Outlet Device: Node 1 - - - 1 List Report Thursdav, May 17, 2018 10:39 AM	pe 7	е С		ų s	140 gpm	1.442 1	-	3.754 psi g	3.754 psi	0.02021
24 ft 129856 Iniet Device: Sizing Pump 1 Outlet Device: Pressure Boundary 1 2.5 in 0 ft - - 0.447 psi g - 2.5 in 0 ft - - 0.447 psi g - 2.33 in 2.5 ft -	eel A53 sch 80	2.9		1 2	6.8 ft/s	0	-	0 psig	0 psi	0.01754
2.5 in 0 ft - 0.447 psi g 2.323 in 2.5 ft - 0.447 psi g 2.0 ft	ea Water	24 Inlet Device: Sizing F	ft Vump 1		129856 Outlet Device	: Pressure Bounds	ary 1			0.00
2.323 in 2.5 ft		30			0			0.4447 nei n	2	9
List Report Cuttet Device: Node 1 Thursday, May 17, 2018 10:39 AM	ipe o teel A53 ech BD	505 G		= =				Bild the bild		
Inlet Device: Engine Room Outlet Device: No List Report	aa Water	200		=	, 1			Ried Innin-		4.50
List Report		Inlet Device: Engine	Room		Outlet Device	: Node 1				
	PIPE-FLO Professional		List Report			Thursday, Ma	y 17, 2018	10:39 AM		Page 1

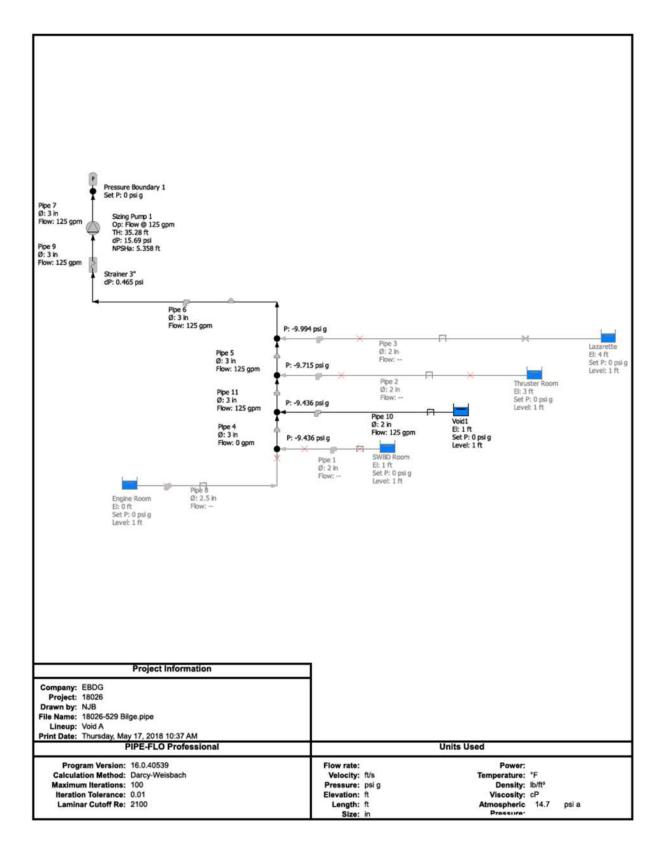
EBDG – NC, PLLC 18026-200-505-1 By: NJB Page: H-11

State Intercent (arcgin) Table (arcgin) Float (arcs) (arcgin) Float (arcs) (arcgin) Total (arcs) (arcs) Float (arcs) (arcs) Total (arcs) (arcs) </th <th></th> <th></th> <th></th> <th></th> <th>Pipelines</th> <th></th> <th></th> <th></th> <th></th>					Pipelines				
Index Densities Outed Envelores Reprind Minnery Wet Meat Loss Outed Previous Wet Meat Loss 1 25 64 Reprind Minnery 0.253 1.31 1.31 0.0001 0.0001 1.31 0.0001	Pipeline Name		Size	Inlet Elevation	Flow Rate	Total Head Loss	Inlet Pressure	Total dP	Pipe Friction Factor
3 1 0	Specification Fluid Zone	-		Outlet Elevation	Fluid Velocity Reynolds Number	V&F Head Loss	Outlet Pressure	V&F dP	V&F Friction Factor V&F Resistance K
3 In a the Device: 3 in a the Device: 2 in a the Device	ipe 6 Steel A53 sch 80 Sea Water		3 in 2.9 in 56 ft			328	psi	1.911 psi 0.4148 psi	0.02021 0.01754 1.30
Interform 25 ft 140 gpm 07853 ft -661 pag 0.344 pag 0.0073 0.5 ft 0.5 ft 140 gpm 07853 ft -6011 pag 0.3447 pag 0.017 0.5 ft 0.5 ft 0.0410 brekete. Node 0.0783 ft -9.011 pag 0.3447 pag 0.0783 0.5 ft 0.5 ft 0.0410 brekete. Node 0.0783 ft -9.011 pag 0.3447 pag 0.0783 0.6 ft 0.7863 ft 0.661 brekete. Node 0.7863 ft -9.011 pag 0.3447 pag 0.0783 0.6 ft 0.7863 ft 0.661 brekete. Node 0.7863 ft -9.011 pag 0.0783 0.011 0.7 ft 0.7863 ft 0.661 brekete. Node 0.7863 ft -9.011 pag 0.0783 1.8 breketer 0.011 ft 0.011 pag 0.011 pag 0.011 pag 0.011 1.8 breketer 0.011 pag 0.7863 ft 0.661 ft 0.011 pag 0.011 1.8 breketer 0.011 pag 0.011 pag 0.011 pag 0.011 pag 0.011 pag 0.011 pag 1.8 breketer <t< td=""><td>Pipe 9 Steel A53 sch 80 Sea Water</td><td>Inlat Davice: S</td><td>3 in 2.9 in 3 ft trainer 3"</td><td></td><td>140 gpm 6.8 ft/s 129856 Duriter Device: S</td><td></td><td>psi</td><td>0.08017 psi 0 psi</td><td>0.02021 0.01754 0.00</td></t<>	Pipe 9 Steel A53 sch 80 Sea Water	Inlat Davice: S	3 in 2.9 in 3 ft trainer 3"		140 gpm 6.8 ft/s 129856 Duriter Device: S		psi	0.08017 psi 0 psi	0.02021 0.01754 0.00
3 in 0.5 in 0.5 in 0.5 in 1.8866 2.5 in 1.8866 1.40 gpm 1.2866 0.7865 in 1.2866 -0.7865 in 0.7865 in 1.2886 -0.7865 in 0.7865 in 1.2886 0.03447 psig 0.7865 in 1.2886 0.03447 psig 0.7865 in 1.2886 0.017 psig 0.7865 in 0.7865 in 1.2886 -0.011 psig 0.7865 in 1.2886 0.01441 psig 0.7865 in 1.2896 0.01441 psig 0.7865 in 1.480 -0.01441 psig 0.7865 in 1.480 -0.01447 psi 0.7865 in 1.480 -0.01447 psi 0.7865 in 1.480 -0.01447 psi 0.7865 in 1.480 -0.01447 psi 0.7865 in 1.480 -0.01447 psi 0.780	ipe 4 steel A53 sch 80 sea Water	Inlet Device: N	3 in 2.9 in 0.5 ft		140 gpm 6.8 ft/s 129856 Outlet Device: N		psi	0.3497 psi 0.3364 psi	0.02021 0.01754 1.05
2in 1 model 1	ipe 11 steel A53 sch 80 sea Water	Inlet Device: N	3 in 2.9 in 0.5 ft tode 6		140 gpm 6.8 ft/s 129856 Outlet Device: N	0.7863	psi	0.3497 psi 0.3364 psi	0.02021 0.01754 1.05
Bottom Elevation Surface Pressure Liquid Levei Hydraulic Grade Bottom Pressure Pipeline Row Rate Pressure at Pen Liquid Levei Bottom Pressure Bottom Pressure Pipeline Flow Mane Connecting Pipelines Pressure at Pen 1 - - 0 psig - - 04447 Psig Pressure at Pen 0.4447 Psig - 0.4447 Psig - 0.4447 Psig 0.4447	ipe 10 steel A53 sch 80 sea Water	Inlet Device: V	2 in 1.939 in 21 ft 6id1		- - - - - - - - - - - - - - - - - - 			1.1	4.50
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	ank Name Iuid Zone	Bottom Elevation Liquid Level	Surface Pressur Bottom Pressur				ting	es e Flow Rate Pr	essure at Penetration
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$.azarette sea Water	4 R 1 R	0 psig	T		0			0.4447 psi g
1 ft 0 psig 2 ft 1 ft 0 sig 2 ft 0 ft 0 psig 0 ft 140 gpm 0.4447 psi 0 ft 0 psig - - 0.4447 psi 1 ft - - Pipe 1 0 ft - 0.4447 psi 1 ft - - Pipe 10 0 ft - 0.4447 psi 1 ft - - Pipe 10 0 ft - 0.4447 psi 1 ft - - Pipe 10 0 ft - 0.4447 psi 1 ft - - Pipe 10 0 ft - 0.4447 psi 1 ft - - Pipe 10 0 ft - 0.4447 psi 1 ft - - Pipe 10 0 ft - 0.4447 psi 1 ft - - Pipe 10 0 ft - 0.4447 psi 1 ft - - Pipe 10 0 ft - 0.4447 psi 1 ft - - 25 ft 9.56 psi g -19.27 ft - 0.4447 psi	hruster Room sea Water	3 H H		I		0	-	1	0.4447 psi g
0 ft 0 psig - 0 (447 psi) 1 ft 0 psig - 0 (447 psi) 1 ft 0 psig - 0 (447 psi) 1 ft - 0 (147 psi) 1 ft	SWBD Room Sea Water		0 psig 0.4447 psig	2	¥	0	-05	140 gpm	0.4447 psi g
1 ft 0 psig 0.447 ps 1 ft	ingine Room		psi	1		0		1	0.4447 psi g
Elevation Pressure Hydraulic Grade 2.5 ft -8.661 psig -19.13 ft 2.5 ft -9.36 psig -19.27 ft 2.5 ft -9.36 psig -19.27 ft 2.5 ft -9.71 psig -19.27 ft 2.5 ft -9.71 psig -18.48 ft	old1 ea Water			1		0	-	1	0.4447 psi g
2.5 ft -8.661 psig -19.13 ft 2.5 ft -9.36 psig -19.27 ft 2.5 ft -9.71 psig -20.05 ft 2.5 ft -9.011 psig -18.48 ft	lode Name			Elevation		Hydraulic Gr	ade		
2.5 ft -9.36 psig -19.27 ft 2.5 ft -9.71 psig -20.05 ft 2.5 ft -9.011 psig -18.48 ft	lode 1			2.5 ft	-8.661 psi g	-19.13 ft			
2.5 ft -9.011 psig -18.48 ft	lode 2 Jode 3			2.5 A	-9.36 psi g	-19.27 ft			
List Report	Node 6 PIPF-FLO Professional		List Report	2.5 ft	-9.011 psig	-18,48 ft -18,48 ft Thursdav May 17, 2018 10:39 AM	18 10:39 AM		Page 2

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DOUBLE-ENDED AZIMUTH DRIVE FERRY

	Pressure Boundaries	Idarles		
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	ਵ ਪੁ ਤ	o s s	8.781 #	66 64
PIPE-FLO Professional	List Report	Thurs	Thursday, May 17, 2018 10:39 AM	Page 3



			I iet Rannt				
			List Neport				
File Name: 18026-529 Bilge.pipe Lineup: Void A Progam Name: PiPE-FLO Professional Version: 16.0.40539	ige pipe ofessional	Calculation Method: Darc Laminar Cutoff Re: 2100 Max Iterations: 100 Iteration Tolerance: 0.01 Atmospheric Pressure: 14.7	Calculation Method: Darcy-Weisbach Laminar Cutoff Re: 2100 Max Iterations: 100 Iteration Tolerance: 0.01 nospheric Pressure: 14.7 psi a	Company: EBDG Project: 18026 by: NJB Date: Thursd	EBDG 19026 NJB Thursday, May 17, 2018 10:39 AM	18 10:39 AM	
			ripe sp				
Specification Name Valve Table	Material Schedule H	Absolute Koughness Hazen Williams C Factor	ss Sizing Griteria ictor	Velocity	Pressure		Reynolds Number
Steel A53 sch 80 standard	Steel A53-B36.10 Schedule:80	1.800E-03 in 140	0.0	to ft/s	ą	psi g	ą
			Fluid Zones				
Fluid Zone Name Table Name	Temperature	Pressure	Fluid State	Density Viscosity	Vapor Pressure Critical Pressure	S	Specific Heat Ratio (k) Relative Molecular Mass
Sea Water Seawater 3.5% Salinity	60 *F	0 psig	Liquid Sisten Bimme	64.04 lb/ft* 1.206 cP	0.2513 psi a 3199 psi a		- 29
Pump Name	ซี ซี	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head Flo dP	Flow Rate NP	NPSHa	
Sizing Pump 1		2.5 ft -12.06 psig	2.5 ft 3.631 psig Pipolines	35.28 ft 15.69 psi	5.3	5.358 ft	
Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Intet Elevation ter Outlet Elevation	ion Flow Rate tion 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	2 in 1 030 in	1 # 25	11	11	0.4447 psi g		11
Sea Water	6 ft Inlet Device: SWBD Room	2					4.50
Dina 2				ľ	0.4447 nei n	2	6
Steel A53 sch 80	1.939 in	2.5 ft	1		-9.715 psig	1	1
Sea Water	40 ft Inlet Device: Thruster Room	F	 Outlet Device: Node 2	ce: Node 2			4.78
Pipe 3 Steel A53 sch 80	2 in 1.939 in	4 ft 2.5 ft	1 1	11	0.4447 psi g -9.994 psi a	i i	1 1
Sea Water	72 ft Inlet Device: Lazarette		- Outlet Device: Node 3				5.47
Pipe 5	3in	2.5 ft	125 gpm	0.6272 ft	-9.715 psi g	0.2789 psi	0.02045
Sea Water	0.5 ft 0.5 ft Inlet Device: Node 2	11 617	0.012 US 115943 Outlet Device: Node 3	0,0043	fied tees	1007.0	1.05
Pipe 7 Steel A53 sch 80 Sea Water		2.5 ft 9.5 ft	125 gpm 6.072 fVs 115943	1.164 ft 0 ft	3.631 psig 0 psig	3.631 psi 0 psi	0.02045 0.01754 0.00
	Inter Device: Sizing Fump 1			Outlet Device: Pressure boundary 1	Contraction Contraction		
Pipe 8	2.5 in	¥ 0	ı	1	0.4447 psi g	ı	ī
Steel A53 sch 80 Sea Water	2.323 in 20 ft	2.5 ft	. '	I	-9.436 psi g	ı	4.50
	Inlet Device: Engine Room		Outlet Device: Node 1	ce: Node 1			
PIPE-FI O Professional	l sei l	I let Banort		Thursday May 17, 2018 10:39 AM	118 10-39 AM		Page 1

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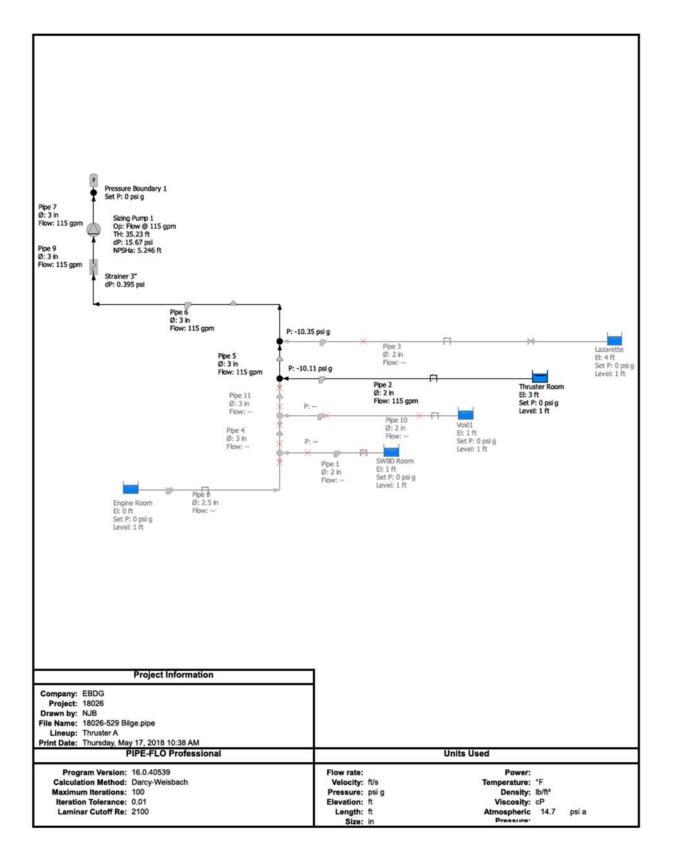
EBDG – NC, PLLC 18026-200-505-1 By: NJI

riperine vane Specification Fluid Zone	4	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 2.9 56 Inlet Device: Node 3	3 in 2.9 in 56 ft Vode 3	2.5 ft 2.5 ft	125 gpm 6.072 ft/s 115943 Outlet Device: S	3.459 ft 0.7436 ft Strainer 3"	-9.994 psig -11.53 psig	1.538 psi 0.3307 psi	0.02045 0.01754 1.30
Pipe 9 Steel A53 sch 80 Sea Water	Inlet Device: 5	3 in 2.9 in 3 ft Strainer 3"	2.5 ft 2.5 ft	125 gpm 6.072 ft/s 115943 Outlet Device: S	0.1455 ft 0 ft Sizing Pump 1	-12 psi g -12.06 psi g	0.06469 psi 0 psi	0.02045 0.01754 0.00
Pipe 4 Steel A53 sch 80 Sea Water	Inlet Device: 7	3 in 2.9 in 0.5 ft Node 1	2.5 ft 2.5 ft	0 gpm 0 ft/s 0 0 Outlet Device: Node 6	0 ft 0 ft ode 6	-9.436 psi g -9.436 psi g	0 psi 0 psi	0.01754
Pipe 11 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft Inlet Device: Node 6	3 in 2.9 in 0.5 ft Vode 6	2.5 ft 2.5 ft	125 gpm 6.072 tts 115943 Outlet Device: Node 2	0.6272 ft 0.6029 ft ode 2	-9.436 psi g -9.715 psi g	0.2789 psi 0.2681 psi	0.02045 0.01754 1.05
Pipe 10 Steel A53 sch 80 Sea Water	1.93 2 Inlet Device: Void1	2 in 1.939 in 21 ft /oid1	1 ft 2.5 ft	125 gpm 13.58 ft/s 173406 Outlet Device: Node 6 Tanks	20.72 ft 12.91 ft ode 6	0.4447 psig -9.436 psig	9.881 psi 5.743 psi	0.02095 0.01928 4.50
Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	e Hydraulic Grade e	irade Pipeline Name	Connec Vame Penetration Height	ting	es e Flow Rate Pr	Pipelines Pipeline Flow Rate Pressure at Penetration
Lazarette Sea Water	4 t t t	0 psig	1		Pipe 3 0 ft			0.4447 psi g
Thruster Room Sea Water	€ E n -	0 psig -	1		Pipe 2 0 ft		1	0.4447 psi g
SWBD Room Sea Water	e e 	0 psig -	1		Pipe 1 0 ft		1	0.4447 psi g
Engine Room	и и и и	0 psig 	1		Pipe 8 0 ft			0.4447 psi g
void1 Sea Water	## 	0 psig 0.4447 psig	2	n Nodes	Pipe 10 0 ft		125 gpm	0.4447 psi g
Node Name Node 1			Elevation 25.8	Pressure -0.436 nei o	Hydraulic Grade	ade		
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	-19.86 ft		

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	Pressure [Pressure Boundaries		
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressura Boundary 1	ମ ଜ ୦ ୦	o o	8.927 ft	125 gm
PIPE-FLO Professional	List Report	ŧ	Thursday, May 17, 2018 10:39 AM	M Page 3



			I tat Danced				
			List Report				
File Name: 18026-529 Bilge.pipe Lineup: Thruster A Progam Name: PIPE-FLO Professional Version: 16.0.40539	ige.pipe ofessional	Calculation Method: Darc Laminar Cutoff Re: 2100 Max Iterations: 100 Iteration Tolerance: 0.01 Atmospheric Pressure: 14.7	Calculation Method: Darcy-Weisbach Laminar Cutoff Ro: 2100 Max Iterations: 100 Iteration Tolerance: 0.01 Iteration Tolescure: 14.7 psi a	Company: Project: by: Date:	my: EBDG bet: 18026 by: NJB ste: Thursday, May 17, 2018 10:39 AM	18 10:39 AM	
			Pipe Sp			l	l
Specification Name Valve Table	Material Schedule Ha	Absolute Roughness Hazen Williams C Factor	ss Sizing Criteria ctor	Velocity	Design Limits Pressure	Limits	Reynolds Number
Steel A53 sch 80 standard	Steel A53-B36.10 Schedule:80	1.800E-03 in 140	0.0	to fVs		psi g	Q
			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 psig	Liquid Sisting Primos	64.04 lb/ft ^a 1.206 cP	0.2513 psia 3199 psia		- 29
Pump Name	2n S	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head F	Flow Rate N	NPSHa	
Sizing Pump 1		2.5 ft -12.11 psig	2.5 ft 3.555 psig Pipelines	35.23 ft 15.67 psi	5.2	5.246 ft	
Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Elevation er Outlet Elevation	on Flow Rate tion Fluid Velocity Reynolds Number	Total Head Loss V&F Head Loss r	Inlet Pressure Outlet Pressure	Total dP V&F dP	Pipe Friction Factor V&F Friction Factor V&F Resistance K
Pipe 1	2 in	# + + + + + + + + + + + + + + + + + + +	I	ı	0.4447 psi g	ı	I
Sea Water	6 ft Inlet Device: SWBD Room				I	ı	4.50
Dina 2		* *	115 Anm	VC VC	0.4447 nei n	10 56 nei	0.00107
Steel A53 sch 80 Sea Water	1.939 in 40 ft	2.5 A	12.49 ft/s 159534	11.59 ft	-10.11 psi g	5.152 psi	0.01928
	Inter Device: I nuster Koom		Outlet Device: Node Z	Z about :ac			
Pipe 3 Steel A53 sch 80 Sea Water	2 In 1.939 in 72 ft Inlet Device: Lazareite	4 ft 2.5 ft	- - Outlet Device: Node 3	e: Node 3	0.4447 psi g -10.35 psi g	11	- 5.47
Pipe 5	31	2.5 ft	115 gpm	0.531 ft	-10.11 psi g	0.2362 psi	0.02065
Steel A53 sch 80 Sea Water	2.9 in 0.5 ft Inlet Device: Node 2	2.5 ft	5.586 ft/s 106668 Outlet Device: Node 3	0.5103	-10.35 psi g	0.227 psi	0.01754
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 24 ft Inlet Device: Sizing Pump 1	2.5 ft 9.5 ft	115 gpm 5.586 ft/s 106668 Outlet Devic	115 gpm 0.9944 ft 566 fVs 0 ft 106668 Outlet Device: Pressure Boundary 1	3.555 psi g 0 psi g	3.555 psi 0 psi	0.02065 0.01754 0.00
Pipe 8	2.5 in	ų f	ī	1	0.4447 psi g	ĩ	L
Steel A53 sch 80 Sea Water	2.323 in 20 ft Inlet Device: Engine Room	2.5 ft	- Outlet Device: Node 1	e: Node 1	ı	ı	4.50
PIPE-FLO Professional	List R	List Report		Thursday. May 17, 2018 10:39 AM	2018 10:39 AM		Page 1

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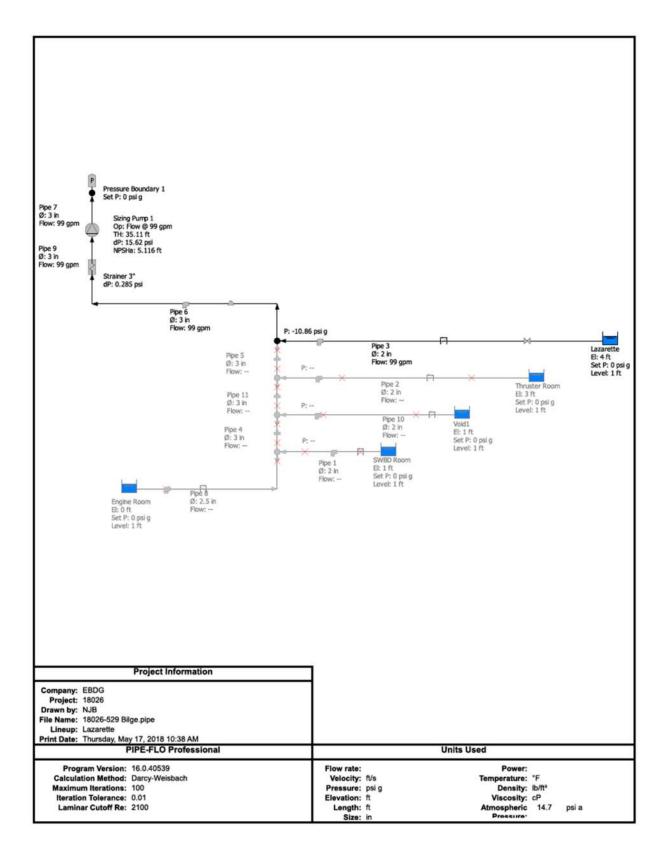
Fluid Zone	4	Inside Diameter C	Outlet Elevation	Fluid Velocity	V&F Head Loss	Inlet Pressure Outlet Pressure	V&F dP	V&F Friction Factor
				Reynolds Number				V&F Resistance K
Pipe 6		3 in		115 gpm	2.95 ft	-10.35 psi a	1.312 psi	0.02065
Steel A53 sch 80		2.9 in	2.5 ft	5.586 ft/s	0.6294 ft	-11.66 psi g	0.2799 psi	0.01754
Sea Water		56 ft		106668				1.30
	Inlet Device: Node 3	Vode 3		Outlet Device: Strainer 3 ^a	trainer 3"			
Pipe 9		3 in		115 gpm	0.1243 ft	-12.06 psi g	0.05528 psi	0.02065
Steel A53 sch 80		2.9 in	2.5 ft	5.586 ft/s	U (1	-12.11 psig	0 psi	0
Sea Water		3#		106668				00.00
	Iniet Device:	Strainer 3		Outlet Device: Sizing Pump 1	I dund bring			
Pipe 4		3 in	2.5 ft	1	1	ı	I	ı
Steel A53 sch 80		2.9 in		1	1	ı	ı	1
Sea Water		0.5 ft		ı				1.05
	Inlet Device: Node 1	Vode 1		Outlet Device: Node 6	ode 6			
Pipe 11		3 in		,		,	1	,
Steel A53 sch 80		2.9 in	2.5 ft	I	ı	-10.11 psi g	ı	ı
Sea Water		0.5 ft		1				1.05
	Inlet Device: Node 6	Vode 6		Outlet Device: Node 2	ode 2			
Pipe 10		2 in	1 ft	,		0.4447 psi g	ı	,
Steel A53 sch 80		1.939 in	2.5 ft	1			1	1
Sea Water		21 ft		1				4.50
	Inlet Device: Void1	/oid1		Outlet Device: Node 6	ode 6			
				Tanks				
Tank Name	Bottom Elevation	Surface Pressure	e Hydraulic Grade			Connecting Pipelines		
Fluid Zone	Liquid Level	Bottom Pressure		Pipeline Name		Penetration Height Pipelir	low Rate	Pressure at Penetration
Lazarette	4 ft	0 psi a	1					
Sea Water								
					Pipe 3 0	æ	1	0.4447 psi g
Thruster Room	3 #	0 psig	4	#				
Sea Water	4	0.4447 psi g						- 111 L 111 C
					n zadu	=	mdg cit	0.4441 psi g
SWBD Room	e	0 psig	1					
Sea Water	L L	ı			Pipe 1 0	ť	1	0.4447 psi g
Engine Room	40	0 psi a	1					
					Pipe 8 0	ŧ	1	0.4447 psi g
Void1		0 psig	1					
Sea Water	1 1	ı						
					Pipe 10 0	шо		U.4447 psig
				SODON				
Node Name			Elevation	Pressure	Hydraulic Grade	irade		
Node 1			2.5 ft	1	1			
Node 2			2.5 A	-10.11 psi g	-21.7 ft	-		
Node 3			2.5 ft	-10.35 psi g	-21.26 ft			
Node 6			25.8					
			-					1

NCDOT

DOUBLE-ENDED AZIMUTH DRIVE FERRY

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	Pressure Boundaries	oundaries			l
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	ĺ
Pressure Boundary 1	ਵ ਯ ਡ	o o	900 44	Rg 21	
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			List Report				
File Name: 18026-559 Bilge.pipe Lineup: Lazarette Progam Name: PiPE-FLO Professional Version: 16.0.40539	pipe ssional	Calculation Method: Laminar Cutoff Re: Max Iterations: Iteration Tolerance: Atmospheric Pressure: Pire	odt: Darcy-Weisbach Re: 2100 ms: 100 ne: 14.7 Pine 14.7 Pine Steefifications	Company: Project: by: Date:	EBDG 18026 NJB Thursday, May 17, 2018 10:40 AM	8 10:40 AM	
Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria	Velocity	Design Limits Pressure	mits	Revnolds Number
Steel A53 sch 80 standard	-B36.10 80	1.800E-03 in 140	0.0	to ft/s	9	psi g	to
			Fluid Zones			l	l
Fluid Zone Name Table Name	Temperature	Pressure	Fluid State	Density Viscosity	Vapor Pressure Critical Pressure	æ	Specific Heat Ratio (k) Relative Molecular Mass
Sea Water Seawater 3.5% Salinity	60 *F	0 psi g	Liquid	64.04 lb/ft ^a 1.206 cP	0.2513 psia 3199 psia		- 29
Pump Name	0.0	Suction Elevation	bischarge Elevation Discharge Elevation	Total Head Flow	Flow Rate NPS	NPSHa	
Sizing Pump 1			2.5 ft 3.447 psig Pinalinas	35.11 ft 15.62 psi	5,116	a a	
Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Elevation eter Outlet Elevation		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 Inlet Device: SWBD Room	1 ft 2.5 ft	Outlet Device: Node 1	: Node 1	0.4447 psi g 	1.1	4 .50
Pipe 2 Steel A53 sch 80 Sea Water	2 in 1.939 in 40 ft Inlet Device: Thruster Room	3 ft 2.5 ft	- - Outlet Device: Node 2	: Node 2	0.4447 psi g 	11	- - 4,78
Pipe 3 Steel A53 sch 80 Sea Water	2 in 1.939 in 72 ft Inlet Device: Lazarette	4 ft 2.5 ft	99 gpm 10.76 fVs 137338 Outlet Device: Node 3	26.91 ft 9.834 ft 1: Node 3	0.4447 psi g -10.86 psi g	11.3 psi 4.374 psi	0.02132 0.01928 5.47
Pipe 5 Steel A53 sch 80 Sea Water	3 in 2.9 in 0.5 ft Inlet Device: Node 2	2.5 ft 2.5 ft	- Outlet Device: Node	: Node 3	 -10.86 psi g	11	- - 1.05
Pipe 7 Steel A53 sch 80 Sea Water	3 in 2.9 in 24 ft Inlet Device: Sizing Pump 1	2.5 ft 9.5 ft	99 gpm 4.809 ft/s 91827 Outlet Device	99 gpm 0.7503 ft 809 ft/s 0 ft 91827 Outlet Device: Pressure Boundary 1	3.447 psig 0 psig	3.447 psi 0 psi	0.02103 0.01754 0.00
Pipe 8 Steel A53 sch 80 Sea Water	2.5 in 2.323 in 20 ft Inlet Device: Engine Room	0 ft 2.5 ft	- - Outlet Device: Node 1	: Node 1	0.4447 psi g	1.1	+ 1 1 + 50
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Specification Fluid Zone	-	size Inside Diameter Length	Intet Elevation Outlet Elevation	Flow Kate 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
Pine 6		3 in		man 99	2.217 #	-10.86 psi o	0.9861 ns	0.02103
Steel A53 sch 80		10 D C	# 10 C	4 809 ft/c		-11 84 nei n	0 207A nei	
Sea Water		56 ft		91827				
	Inlet Device: Node 3	Node 3		Outlet Device: Strainer 3"	trainer 3"			
Pipe 9		3 in	2.5 ft	mdg 99	0.09379 ft	-12.13 psi g	0.04171 psi	0.02103
Steel A53 sch 80		2.9 in	2.5 ft	4.809 ft/s	U U	-12.17 psi g	o psi	0
Sea Water	Inlat Davice.	3 ft Device: Strainer 3"		91827 Outlet Davice: Sizing Pilmo 1	Izina Dumn 1			00.00
		-10			- Auto - Russ	24.53	ų.	100
Pipe 4 Steel A53 sch 80		ni oc	# 20					
Sea Water		0.5 ft		1				1.05
	Inlet Device: Node 1	Node 1		Outlet Device: Node 6	lode 6			12200
Pipe 11		3 in		1	1	,	1	1
Steel A53 sch 80		2.9 in	2.5 ft	1	ı	1	1	ı
Sea Water		0.5 ft						1.05
	Iniet Device: Node b	ADDE D	3	Outlet Device: Node z	7 abo			
Pipe 10		2 in	# -	1	1	0.4447 psi g	1	
Steel A53 sch 80		1.939 in	2.5 ft	1	1	1	ı	1
Ed Water	Inlet Device: Void1	Void1		Outlet Device: Node 6	ode 6			00.4
				Tanks				
Tank Name	Bottom Elevation	Surface Pressure	re Hydraulic Grade	Grade		Connecting Pipelines	105	
Fluid Zone	Liquid Level	Bottom Pressure		Pipeline Name	Name Penetration Height		low Rate	Pressure at Penetration
Lazarette Sea Water	4 t t	0 psig 0.4447 psig	\$	ŧ	Pine 3		00 00	0.4447 psi o
	1.2							0
Inruster Koom Sea Water	= e= o +-	Bisd D	I		Pipe 2 0	æ	ı	0.4447 psi g
SWBD Room	1 H	0 psig	E.					
Sea Water	1 8	t			Pipe 1 0	Ľ	I)	0.4447 psi g
Engine Room	ų O	0 psig	I					
	1.1.1.1	ŧ			Pipe 8 0	u		0.4447 psi g
Void1	£ .	0 psig	I					
Sea Water		ı			Pipe 10 0 ft	-	1	0.4447 psi a
				Nodes		ł		
Node Name			Elevation	Pressure	Hydraulic Grade	ade		
Node 1			2.5 ft	Ē	4) (1)			
Node 2			2.5 A	1	13			
Node 3			2.5 A	-10.86 psi g	-22.99 ft			
Node 6			2.5 ft	1				

	Pressure Boundarles	darles		
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressue Boundary 1	ਵ ਨੂੰ	o isg ig	87 87 84	E 8
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			Bill of Materials R	eport		
Lineup: Program Name:	18026-529 Bilge.pipe <design case=""> PIPE-FLO Professional 16.0.40539</design>				1802 NJB	26
			Pipelines			
Pipeline	Specific	cation	Size	Le	ngth	Valves and Fittings
Pipe 1	Steel A	i3 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 AS	53 sch 80	2 in	4	0 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 At	53 sch 80	2 in	7	2 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 As	53 sch 80	3 in	0.	5 ft	1 x Tee - Flow Thru Branch
Pipe 7	Steel AS	53 sch 80	3 in	2	4 ft	
Pipe 8	Steel As	53 sch 80	2.5 in	2	0 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 A	53 sch 80	3 in	5	6 ft	1 x Elbow - Long radius, r/d 1.5 (90°) 1 x Tee - Flow Thru Branch
Pipe 9	Steel AS	53 sch 80	3 in		3 ft	
Pipe 4	Steel As	53 sch 80	3 in	0.	5 ft	1 x Tee - Flow Thru Branch
Pipe 11	Steel As	i3 sch 80	3 in	0.	5 ft	1 x Tee - Flow Thru Branch
Pipe 10	Steel A	i3 sch 80	2 in	2	1 ft	2 x Elbow - Long radius, r/d 1.5 (90°) 1 x Stop Check - Angled 1 x Reducer - Enlargement (2 in x 3 in - 3
			Pipeline Material S	ummary		
Specification	Material		Size	Total Lengt	1	Valves & Fittings
Steel A53 sch 80) Steel A53-B3 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-B30 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-B30 Schedule: 80		3 in	84.50 ft		1 x Elbow - Long radius, r/d 1.5 (90°) 4 x Tee - Flow Thru Branch

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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.

Pipe Segment	Flow	Pipe	Schedule	d, ID	Des	ign Velo	ocity	V
	Rate	Size			Non	ninal	Limit	
	gpm	(NPS)		in	ft/	′s	ft/s	ft/s
Ballast Pump Suction (1 pump)	200	4	CL 200	4.282	3.0 √d	6.21	12	4.46
Ballast Pump Discharge (1 pump)	200	4	CL 200	4.282	5.0 √d	10.35	12	4.46
Ballast Loading (1 tank)	100	3	CL 200	3.310	5.0 √d	9.10	12	3.73
Ballast Unloading (1 tank)	100	3	CL 200	3.310	3.0 √d	5.46	12	3.73
Ballast Main Suction (2 pumps)	400	4	CL 200	4.282	3.0 √d	6.21	12	8.91
Ballast Main Discharge (2 pumps)	400	4	CL 200	4.282	5.0 √d	10.35	12	8.91

Table 5-1: Nominal Pipe Velocity

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.

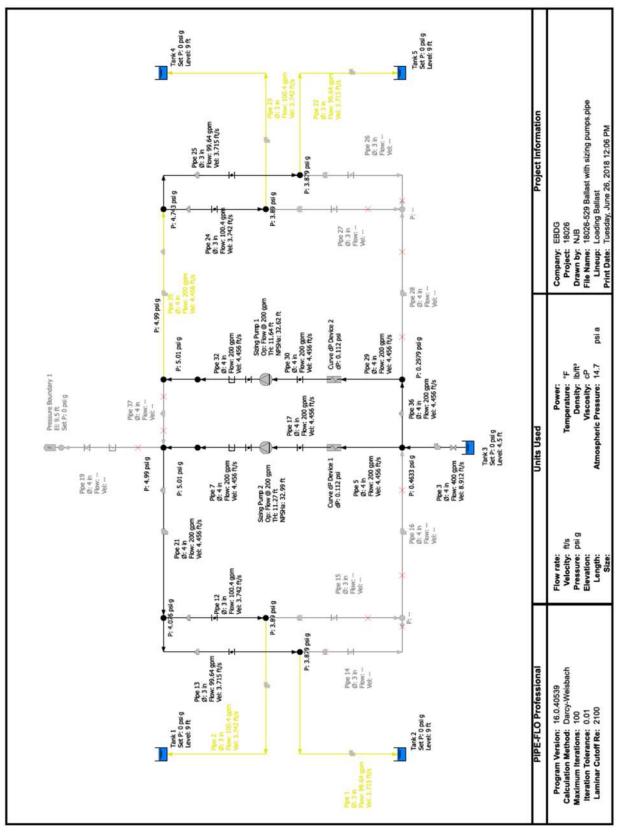
For trimming ballast water from one end to the other, the enclosed system model predicts that the ballast pump is required to produce 17.3 feet H2O TDH at the required flowrate of 200 gpm. Calculated NPSH available for the ballast pump in this condition is approximately 28 feet H2O.

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: Lineup: Progam Name: Version:	File Name: 18026-529 Ballast with: Lineup: Loading Ballast Progam Name: PIPE-FLO Professional Version: 16.0.40539	File Name: 18026-529 Ballast with sizing pumps.pipe Lineup: Loading Ballast Jam Name: PIPE-FLO Professional Version: 16.0.40539	Calculation Method: Darc Laminar Cutoff Re: 2100 Max Iterations: 100 Iteration Tolerance: 0.01 Atmospheric Pressure: 14.7	Calculation Method: Darcy-Weisbach Laminar Cutoff Re: 2100 Max Tolerations: 100 Iteration Tolerance: 10.01 nospheric Pressure: 14.7 psi a	Company: Project: by: Date:	pany: EBDG oject: 18026 by: NJB Date: Tuesday, June 26, 2018 12:07 PM	s, 2018 12:07 PM	
				Pipe Specifications				
Specification Name	ime	Material	Absolute Roughness	ness Sizing Criteria		Des	Design Limits	
Valve Table		Schedule	Hazen Williams C Factor	Factor	Velocity	Pr	Pressure	Reynolds Number
Copper Nickel Class 200 standard	ass 200	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	sure sure	Specific Heat Ratio (k) Relative Molecular Mass
Sea Water Seawater 3.5% Salinity	alinity	60 °F	0 psig	Liquid	64.04 lb/ft ³ 1.206 cP	0.2513 psia 3199 psia	8	- 29
				Sizing Pumps				
Pump Name			Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head Flud dP	Flow Rate	NPSHa	
Sizing Pump 2			2.5 ft 0.2289 psig	2.5 ft 5.239 psig	11.27 ft 5.01 psi		32.99 ft	
Sizing Pump 1			2.5 ft 0.06345 psig	2.5 ft 5.239 psig Pipelines	11.64 ft 5.176 psi		32.62 ft	
Pipeline Name Specification		Size Inside Diameter	Inlet Elevation meter Outlet Elevation		Total Head Loss V&F Head Loss	Inlet Pressure Outlet Pressure	re Total dP Jre V&F dP	
Fluid Zone		Length	_	Reynolds Number	or			V&F Resistance K
Pipe 1 Copper Nickel Class 200 Sea Water	ass 200	3 in 3.31 in 85 ft Inlet Device: Tank 2	₩ 4 ₩ 4	86 (7	.64 gpm 1.723 ft 715 ft/s 0.4739 ft 80970 Outlet Device: Node 1	4.003 psi g 3.879 psi g	-0.1234 0.2108	psi 0.01889 psi 0.01702 2.21
Pipe 2 Copper Nickel Class 200 Sea Water	ass 200	3 in 3.31 in 85 ft Inlet Device: Tank 1	2 4 E	3 10	0.4 gpm 1.746 ft 742 ft/s 0.4808 ft 81561 Outlet Device: Node 2	4.003 psi g 3.89 psi g	-0.113 0.2138	psi 0.01887 psi 0.01702 2.21
Pipe 12 Copper Nickel Class 200 Sea Water	ass 200	3 in 3.31 in 2 ft Inlet Device: Node 7	44	3.	0.4 gpm 0.4186 ft 742 ft/s 0.3889 ft 81561 Outlet Device: Node 2	4.076 psig 3.89 psig	0.1862 0.1729	psi 0.01887 psi 0.01702 1.79
Pipe 13 Copper Nickel Class 200 Sea Water	ass 200	3 in 3.31 in 4 ft Inlet Device: Node 7	44	86 6 9	.64 gpm 0.442 ft 715 ft/s 0.3832 ft 80970 Outlet Device: Node 1	4.076 psig 3.879 psig	0.1966 0.1704	psi 0.01889 psi 0.01702 1.79
Pipe 14 Copper Nickel Class 200 Sea Water	ass 200	3 in 3.31 in 4 ft Inlet Device: Node 1	44			3.879 psig -		- 1.79
PIPE-FLO Professional	sional	2	List Report		Tuesday, June 26, 2018 12:07 PM	018 12:07 PM		Page 1

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DOUBLE-ENDED AZIMUTH DRIVE FERRY

			Pipelines			l	
Pipeline Name	Size	Inlet Elevation	Flow Rate	Total Head Loss	Inlet Pressure	Total dP	Pipe Friction Factor
Specification Fluid Zone	Inside Diameter Length	Outlet Elevation	Fluid Velocity Reynolds Number	V&F Head Loss	Outlet Pressure	V&F dP	V&F Friction Factor V&F Resistance K
Diat 46	e				- jon 00 c		
Canada Nickel Clean 200	111 C	= 4	1		first so.c	I	ı
Copper Inicher Class 200	11 - 7°0 4 C					i	1 70
20a Malei	Inlet Device: Node 2		Outlet Device: Node 8	lode 8			01-1
Pipe 16	4 in		:		1	1	
Copper Nickel Class 200	4.282 in	2.5 ft	,	,	0.4633 psi a	ı	,
Sea Water	8		:		Ł		0.45
	Inlet Device: Node 8		Outlet Device: Node 4	lode 4			
Dina 6	ci A	95.4	mun 000	A 75000	0.4633 nei n	0 040F_03 nei	0.01726
Copper Nickel Class 200	4.282 in	2.5 ft	4.456 ft/s		0.4534 psi a	o psi	0.01607
Sea Water	1.5 ft	1	125637				00.0
	Inlet Device: Node 4		Outlet Device: (Outlet Device: Curve dP Device 1			
Dine 17	d A	95.0	000 mm	0.2520 #	0 3414 nei n	0 1125 nei	0.01725
Conner Nickel Class 200	ni 282.15	4 4 C	4 456 ft/c		0.2280 nei n	0.00021 nei	0.01607
Sea Water	2 #	:	125637				0.72
	Inlet Device: Curve dP Device 1		Outlet Device: Sizing Pump 2	izing Pump 2			21 2011/05
Pipe 3	4 in	0 #	400 apm	0.9582 ft	2.001 psi a	1.538 psi	0.01509
Copper Nickel Class 200	4.282 in		8.912 f/s		0.4633 psi a	0.194 psi	0.01607
Sea Water	10 ft		251273				0.35
	Inlet Device: Tank 3		Outlet Device: Node 4	lode 4			
Pina 7	4 in	25 A	200 anm	05157 ft	5 239 psi a	0.2293 nsi	0.01725
Copper Nickel Class 200	4.282 in	2.5 ft	4.456 ft/s		5.01 psi a	0.2095 psi	0.01607
Sea Water	3 #		125637				1.53
	Inlet Device: Sizing Pump 2		Device:	Sizing Valve 5			
Pine 20	4 in	2.5 ft	200 apm	0.04474 ft	5.01 psi a	0.0199 psi	0.01725
Copper Nickel Class 200	4.282 in	2.5 ft	4.456 ft/s	0		0 psi	0.01607
Sea Water	3 ft		125637				0.00
	Inlet Device: Sizing Valve 5		Outlet Device: Node 5	lode 5			
Pipe 22	3 in		99.64 apm	1.723 ft	4.003 psi a	-0.1234 psi	0.01889
Copper Nickel Class 200	3.31 in	4 #	3.715 ft/s	0.4739 ft	3.879 psi g	0.2108 psi	0.01702
Sea Water	85 ft		80970				2.21
	iniet Device: Tank 5		Outlet Device: Node 9	lode 9			0.00001100
Pipe 23	3 in		100.4 gpm	1.746 ft	4.003 psi g	-0.113 psi	0.01887
Copper Nickel Class 200	3.31 in	4 ft	3.742 fVs	0.4808 ft	3.89 psi g	0.2138 psi	0.01702
Sea Water	85 ft		81561				2.21
	Inlet Device: Tank 4		Outlet Device: Node 10	lode 10			
Pipe 29	4 in	2.5 ft	200 gpm	0.02237 ft	0.2979 psi g	9.949E-03 psi	0.01725
Copper Nickel Class 200	4.282 in		4.456 ft/s	ų U	0.2879 psi g	o psi	0.01607
Sea Water	1.5 1		125637				0.00
	Inlet Device: Node 15		Outlet Device: (Curve dP Device 2			
Pipe 30	4 in	2.5 ft	200 gpm	0.2529 ft	0.1759 psi g	0.1125 psi	0.01725
Copper Nickel Class 200	4.282 in	2.5 ft	4.456 ft/s	0.2231 ft	0.06345 psi g	0.09921 psi	0.01607
Sea Water	2 ft		125637	200 200			0.72
	Inlet Device: Curve dP Device 2		Outlet Device: Sizing Pump 1	izing Pump 1			
		,					
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			Pipelines				
Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Elevation Outlet Elevation	Flow Rate Fluid Velocity Reynoids 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 0.5157 4.456 ft/s 0.471 125637 Outlet Device: Sizing Valve 7	0.5157 ft 0.471 ft izing Valve 7	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 0.0 4.456 ft/s 126637 Outlet Device: Node 16	0.04474 ft 0 ft lode 16	5.01 psig 4.99 psig	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	ode 11	0.2979 psi g -	1.1	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 0 3.742 fVs 0 81561 Outlet Device: Node 10	0.4186 ft 0.3889 ft lode 10	4.743 psig 3.89 psig	0.8533 psi 0.1729 psi	0.01887 0.01702 1.79
Pipe 25 Copper Nickel Class 200 Sea Water Pipe 26 Copper Nickel Class 200 Sea Water		25 # 4 # 2 4 # 25 #	99.64 gpm 3.715 ft/s 80970 Outlet Device: Node 9 -	0.442 ft 0.3832 ft 0.3832 ft 	4.743 psi g 3.879 psi g 3.879 psi g	0.1704 psi 0.1704 psi -	0.01889 0.01702 1.79 - 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			3.89 psig	L I	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 fts 0 125637 Outlet Device: Node 15	0.372 ft 0.2974 ft lode 15	0.4633 psig 0.2979 psig	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	1 1 ode 5	4.99 psig 4.99 psig	11	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 fVs 125637 Outlet Device: Node	0.5556 ft 0.4363 ft lode 7	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 0 4.456 ft/s 0 125637 Outlet Device: Node 16	0.5556 ft 0.4363 ft iode 16	4.743 psi g 4.99 psi g	0.2471 psi 0.194 psi	0.01725 0.01607 1.41
PIPE-FLO Professional	List Report	Ľ		Tuesday, June 26, 2018 12:07 PM	18 12:07 PM		Page 3

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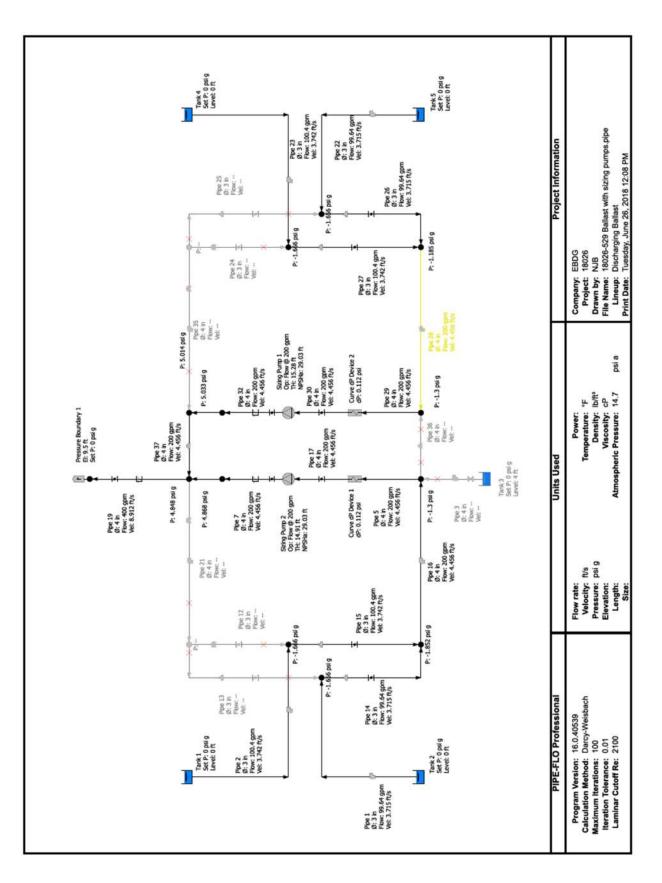
Pipeline Name Specification Fluid Zone	-	Size Inside Diameter Length	Inlet Elevation Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number	Total Head Loss V&F Head Loss	Inlet Pressure Outlet Pressure	ire Total dP ure V&F dP	Pipe Friction Factor V&F Friction Factor V&F Resistance K
Pipe 19		4 in	25 A			4.99 nsi		
Copper Nickel Class 200		4.282 in	9.5 ft	,	ı	0 psig	1	ı
Sea Water	15 Inlet Device: Node 5	15 ft Node 5		- Outlet Device: P	 Outlet Device: Pressure Boundary 1			2.53
				Tanks				
Tank Name	Bottom Elevation	Surface Pressure	re Hydraulic Grade			Connecting Pip	Connecting Pipelines	
Fluid Zone	Liquid Level	Bottom Pressure	9.	Pipeline Name	lame Penetration Height	n Height Pip	peline Flow Rate	Pressure at Penetration
Tank 1	2 ft 9 ft	0 psig 4.003 psig	F	¥				a ina cuo v
								fied cont
Tank 2	2 H 9 H	0 psig 4.003 psig	11	æ	Direct 0		00 64 000	A 003 min
Tank 3	# C	0 psi o	45				11dR 10.00	Ried cont
	4.5 ft	2.001 psi g						
					Pipe 3 0	=	400 gpm	2.001 psi g
Tank 4	5 G	0 psi g	7	ť				
	2 H	first cont		1	Pipe 23 0	¥	100.4 gpm	4.003 psi g
Tank 5	2 ft	0 psig	F	ť				
		4.003 psi g			Pine 22	ŧ	00 64 00	4 003 nei n
			Cur	Curve dP Devices				Ried popt
Curve dP Device Name Description	Inlet I Inlet I	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	Head	dP F Head Loss	Flow Rate		
	c	4	4					
Curve dP Device 1 Eaton model 72	z. 0.453	2.5 п 0.4534 psig	2.5 ft 0.3414 psig	0.112 0.2518	0.112 psi .2518 ft	200 gpm		
Curve dP Device 2 Eaton model 72	2. 0.287	2.5 ft 0.2879 psig	2.5 ft 0.1759 psig	0.112 ps 0.2518 ft	0.112 psi .2518 ft	200 gpm		
				Nodes				
Node Name			Elevation	Pressure	Hydraulic Grade	ade		
Node 1			4 ft	3.879 psig	12.51 ft			
Node 2			4 ft	3.89 psi g	12.53 ft	0.00		
Node 4			2.5 ft	0.4633 psi g	2.925 ft			
Node 5			2.5 ft	4.99 psi g	13.41 ft	2		
Node 7			4 ft	4.076 psi g	12.92 ft	1.12		
Node 8			4 ft	1	Ē			
Sizing Valve 5			2.5 ft	5.01 psig	13.46 ft			
Node 9			4 ft	3.879 psi g	12.51 ft			
Node 10			4 ft	3.89 psig	12.53 ft			
Node 15			2.5 ft	0.2979 psi g	2.861 ft			

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	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	1	1	
Sizing Valve 8	2.5 ft	4.743 psig	12.92 ft	
	Pressure Boun	Idaries		
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psig	ı	1

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			List Report				
File Name: 18026-529 Ballast with sizing pumps.pipe Lineup: Discharging Ballast Progam Name: PIPE-FLO Professional Version: 16.0.40539	last with sizing pumps pipe sliast fessional	Calculation Method: Laminar Cutoff Rec Max Iterations: Iteration Tolerance: Atmospheric Presure:	Calculation Method: Darcy-Weisbach Laminar Cutoff Re. 2100 Max Iterations: 100 Iteration Tolerance: 0.01 nospheric Pressure: 14.7 psi a	Company: Project: by: Date:	pany: EBDG oject: 18026 by: NJB Date: Tuesday, June 26, 2018 12:09 PM	2018 12:09 PM	
	111111		Pipe Sp		ć		
Specification Name Vaive Table	Material Schedule	Absolute Roughness Hazon Williams C Factor	ss Sizing Criteria ctor	Velocity	Pre	Design Limits Pressure	Reynolds Number
Copper Nickel Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	0.0	01 1	ft/s to	psi g	Q
			Fluid Zones				
Fiuid 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 psig	Liquid	64.04 lb/ft ³ 1.206 cP	0.2513 psia 3199 psia		- 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 psig	2.5 ft 5.097 psig	14.91 ft 6.632 psi		29.03 ft	
Sizing Pump 1		2.5 ft -1.534 psig	2.5 ft 5.263 psig Pipelines	15.28 ft 6.797 psi		29.03 ft	
Pipeline Name	Size	Inlet Elevation	on Flow Rate	Total Head Loss		Total dP	Pipe Friction Factor
Specification Fluid Zone	Length		Re		AINSSALL JANNO	2	
Pipe 1 Conner Nickel Class 200	3 in 331 in	2 4	99.64 gpm 3.715 #/c	1.723 ft 0.4730 ft	0 psig	1.656 psi 0.2108 psi	0.01889
Sea Water	85 ft		80970		n	-	
1	ICE: IGUY		Outlet Device: NOGE	_	20 24		
Pipe 2 Copper Nickel Class 200	3 in 3.31 in	4 4	100.4 gpm 3.742 ft/s	1.746 ft 0.4808 ft	0 psig -1.666 psig	1.666 psi 0.2138 psi	0.01887
Sea Water	85 ft Inlet Device: Tank 1	8	81561 Outlet Device: Node 2	ce: Node 2			
Pipe 12	3 in		1	1		1	,
Copper Nickel Class 200	3.31 in	4 ft	ı	ı	-1.666 psi g	ı	1
Sea Water	Z II Inlet Device: Node 7		Outlet Device: Node 2	ce: Node 2			6/°L
Pipe 13	3 in			1	1	1	
Copper Nickel Class 200	3.31 in	4 ft	1	1	-1.656 psig	1	1
Sea Water	4 ft Inlet Device: Node 7		- Outlet Device: Node 1	ce: Node 1			1.79
Pipe 14	3 in	4 ft	99.64 gpm	0.442 ft	-1.656 psi g	0.1966 psi	
Copper Nickel Class 200	3.31 in		3.715 ft/s	0.3832 ft	-1.852 psi g	0.1704	i 0.01702
	Inlet Device: Node 1		Outlet Device: Node 8	ce: Node 8			0
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Pipeline Name Specification	Size Inside Diameter	Inlet Elevation Outlet Elevation	Flow Rate Fluid Velocity	Total Head Loss V&F Head Loss	Inlet Pressure Outlet Pressure	Total dP V&F dP	Pipe Friction Factor V&F Friction Factor
Fiuld Lone	rengu		Keynolas Number				Vor Resistance N
Pipe 15	3 in	4 ft	100.4 gpm	0.4186 ft	-1.666 psi g	0.1862 psi	0.01887
Copper Nickel Class 200	3.31 in	4 ft	3.742 fus	0.3889 ft	-1.852 psi g	0.1729 psi	0.01702
Sea Water	2 ft		81561				1.79
	Inlet Device: Node 2		Outlet Device: Node 8	Vode 8			
Pipe 16	4 in		200 gpm	0.2581 ft	-1.852 psi g	-0.5523 psi	0.01725
Copper Nickel Class 200	4.282 In	2.5 ft	4.456 ft/s	0.1388 ft	-1.3 psi g	0.06173 psi	0.01607
Sea Water	8 ft		125637				0.45
	Inlet Device: Node 8		Outlet Device: Node 4	Vode 4			
	15			4 TCCC0 0	a law C t		0.04735
Pipe 5 Conner Nickel Class 200	11 4 1 282 1	# 2C	4.456. #/e	0.0223/ R	-1.3 psig	a.etan-uo psi	0.01607
Copper Mitan			TEASCH		Rind		
000 11010 000	Inter Device: Node 4		Outlat Davica:	Outlet Device: Curve dP Device 1			00.0
Pipe 17	4 in	2.5 ft	200 gpm	0.2529 ft	-1.422 psi g	0.1125 psi	0.01725
Copper Nickel Class 200			4.456 ft/s	0.2231 ft	-1.534 psi g	0.09921 psi	0.01607
Sea Water	2 ft		125637				0.72
	Inlet Device: Curve dP Device 1		Outlet Device: Sizing Pump 2	sizing Pump 2			
Pipe 3	4 in		1	1	1.779 psi g	ı	1
Copper Nickel Class 200	4.282 in	2.5 ft	1	1	-1.3 psi q	I	1
Sea Water	10 ft		,				0.35
	Inlet Device: Tank 3		Outlet Device: Node 4	Vode 4			
Pipe 7	4 in	25 #	200 gnm	05157 #	5 097 nsi a	0.2293 nsi	0.01725
Conner Nickel Clase 200	ni C8C P	25.4	4 456 6/s	0.471 #		0 2005 nei	0.01607
Saa Watar	4 C		176837				1 53
200 1000	Inlet Device: Sizing Pump 2		Outlet Device: Sizing Valve 5	Sizing Valve 5			001
		9 2 6	000	A 17110	A 000 ani a	0.0400	0.04706
Connect Nickel Class 200		4 3 6	4 4 FG 410	11 4/440.0	9 100 000 to 1	ind celon	20310.0
Copper Nickel Class 200	UI 707't		SUI 004'4		6 isd 0+0.4		10010.0
Lana Mais	3 II Inlet Device: Sizing Valve 5		Outlet Davice: Node 5	Joda 5			0,00
1949 - 1949		000000					2000-000
Pipe 22	3 in	2 ft	99.64 gpm	1.723 ft	0 psig	1.656 psi	0.01889
Copper Nickel Class 200	3.31 in		3.715 ft/s	0.4739 ft	-1.656 psi g	0.2108 psi	0.01702
Sea Water	85 ft		80970				2.21
	Inlet Device: Tank 5		Outlet Device: Node 9	Vode 9			
Pipe 23	3 in		100.4 gpm	1.746 ft	0 psig	1.666 psi	0.01887
Copper Nickel Class 200	3.31 in	4 11	3.742 fVs	0.4808 ft	-1.666 psi g	0.2138 psi	0.01702
Sea Water	85 ft		81561				2.21
	Inlet Device: Tank 4		Outlet Device: Node 10	Vode 10			
Pipe 29	4 İ		200 gpm	0.02237 ft	-1.3 psi g	9.949E-03 psi	0.01725
Copper Nickel Class 200	4.282 in	2.5 ft	4.456 ft/s		-1.31 psi g	0 psi	0.01607
Sea Water	1.5 ft		125637		- 00 - 40 - 10 - 10 - 10 - 10 - 10 - 10	1000 C	0.00
	Inlet Device: Node 15		Outlet Device: (Outlet Device: Curve dP Device 2			
Dice 30	ci M	95.4	200 000	A 2520 #	-1 422 nei n	0 1125 nei	0.01725
Copper Nickel Class 200	4.282 In	2.5 ft	4.456 ft/s		-1.534 psi o	0.09921 psi	0.01607
Sea Water	2 ft		125637				0.72
	Inlet Device: Curve dP Device 2		Outlet Device: Sizing Pump 1	Sizing Pump 1			
DIDE EL O Desfessional	1 ist Based			Trisedary line 26 2018 12:00 DM	MD 00-01 81		C and
	Adau tem			Internay, vulle av, av	10 17'AD LM		Lage

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DOUBLE-ENDED AZIMUTH DRIVE FERRY

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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: Sizina Pump 1	2.5 ft 2.5 ft	200 gpm 4.456 ft/s 125637 Outlet Device: 5	0.5157 ft 0.471 ft Sizing Valve 7	5.263 psi g 5.033 psi g	0.2293 psi 0.2095 psi	0.01725 0.01607 1.53
Pipe 33 Copper Nickel Class 200 Sea Water		2.5 ft 2.5 ft		0.04474 ft 0.ft 0 ft tode 16	5.033 psi g 5.014 psi g	0.0199 psi 0 psi	0.01725 0.01607 0.00
Pipe 28 Copper Nickel Class 200 Sea Water		2.5 ft 2.5 ft	200 gpm 0 4.456 ft/s 0 125637 Outlet Device: Node 11	0.2581 ft 0.1388 ft lode 11	-1.3 psig -1.185 psig	0.1148 psi 0.06173 psi	0.01725 0.01607 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	- - - Outlet Device: Node 10	t 1 t	 -1.666 psi g	1.1	- - 1.79
Pipe 25 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft Inlet Device: Sizing Valve 8	25 ft 4 ft	- - Outlet Device: Node 9	1 1 ode 9	- -1.656 psi g	1.1	
Pipe 26 Copper Nickel Class 200 Sea Water	3 in 3.31 in 4 ft Inlet Device: Node 9	4 ft 2.5 ft	99.64 gpm 3.715 ft/s c 80970 Outlet Device: Node 11	0.442 ft 0.3832 ft tode 11	-1.656 psig -1.185 psig	-0.4705 psi 0.1704 psi	0.01889 0.01702 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	100.4 gpm 3.742 ft/s 81561 Outlet Device: 1	0.4186 ft 0.3889 ft Node 11	-1.666 psig -1.185 psig	-0.4809 psi 0.1729 psi	0.01887 0.01702 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	- - - Outlet Device: Node 15	tode 15	-1.3 psig -1.3 psig	1.1	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	200 gpm 4.456 ft/s 125637 Outlet Device: Node 5	0.372 ft 0.2974 ft tode 5	5.014 psig 4.848 psig	0.1654 psi 0.1323 psi	0.01725 0.01607 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		tode 7	4.848 psi g -	1.1	
Pipe 35 Copper Nickel Class 200 Sea Water	4 in 4.282 in 8 ft Inlet Device: Sizing Valve 8	2.5 A		n node 16	5.014 psi g	1.1	112
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DOUBLE-ENDED AZIMUTH DRIVE FERRY

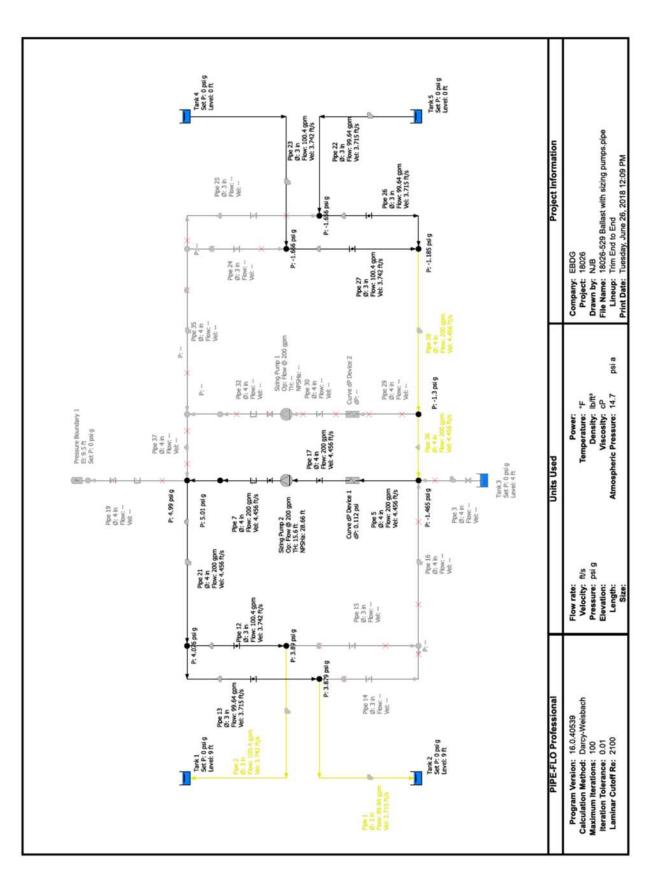
Pipeline Name Specification Fluid Zone	-	Size Inside Diameter Length	Inlet Elevation Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number	Total Head Loss V&F Head Loss	Inlet Pressure Outlet Pressure	ure Total dP sure V&F dP	P Pipe Friction Factor P V&F Friction Factor V&F Resistance K
Pipe 19 Copper Nickel Class 200		4 in 4.282 in	2.5 ft 9.5 ft	400 gpm 8.912 ft/s	3.901 ft 3.118 ft	4.848 psig 0 psig	4.848	psi 0.01509 psi 0.01607
Sea Water	15 Inlet Device: Node 5	15 ft Node 5		251273 Outlet Device: Pressure Boundary 1	ssure Boundary 1			2.63
				Tanks				
Tank Name Fluid Zone	Bottom Elevation Liguid Level	Surface Pressure Bottom Pressure	e Hydraulic Grade	ade Pipeline Name	Connec me Penetration Height	ting	Pipelines Pipeline Flow Rate	Pressure at Penetration
Tank 1	5 ¥ 0 ¥	0 psig 0 psig	2 8					
				ď	Pipe 2 0 1	¥	100.4 gpm	0 psig
Tank 2	8 ¥ 0 ¥	0 psig 0 psig	2 #	۵.	Pipe 1 0 1	æ	99.64 gpm	0 psig
Tank 3	# 4 0 7	0 psig	¥.					
		ı		ď	Pipe 3 0 1	ų	ı	1.779 psi g
Tank 4	2 ft	0 psig	2 8					
		0 psig		Pl¢	Pipe 23 0 1	H.	100.4 gpm	0 psig
Tank 5		0 psig	2 ft					
	U U	0 psi g		Pic	Pipe 22 0 ft		99.64 apm	0 psi a
			Curv	Curve dP Devices			10	
Curve dP Device Name Description	Inlet	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss		Flow Rate		
Curve dP Device 1 Eaton model 72	-1.3	2.5 ft -1.31 psig	2.5 ft -1.422 psig	0.112 psi 0.2518 ft	psi ft	200 gpm		
Curve dP Device 2 Eaton model 72	-1.3	2.5 ft -1.31 psig	2.5 ft -1.422 psig	0.112 psi 0.2518 ft	psi ft	200 gpm		
			i	Nodes				
Node Name			A fi	-1656 peio	D D6204 6	ane		
Node 2				-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 psig	13.14 ft			
Node 9			4 ft	-1.656 psi g	0.06294 ft			
Node 10			4 ft	-1.666 psig	0.03646 ft			
Node 15			2.5 ft	-1.3 psig	-0.7313 ft			
PIPE-FLO Professional		11110111						

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DOUBLE-ENDED AZIMUTH DRIVE FERRY

	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 psig	-0.4115 ft	
Sizing Valve 8	2.5 ft	ı	1	
	Pressure Boundaries	undaries		
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psig	8.266 ft	400 gpm

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					Total Deserves			1			
					LIST KEPOLT						
File Name: Lineup: Progam Name: Version:	File Name: 18026-529 Ballast with Lineup: Trim End to End Progam Name: PIPE-FLO Professional Version: 16.0.40539	File Name: 18026-529 Ballast with sizing pumps.pipe Lineup: Trim End to End Jam Name: PIPE-FLO Professional Version: 16.0.40539	Calcu Larr Itera Atmospl	Calculation Method: Laminar Cutoff Re: Max Iterations: Iteration Tolerance: Atmospheric Pressure:	Calculation Method: Darcy-Weisbach Laminar Cutoff Re: 2100 Max Iterations: 100 Interation: 0.01 nospheric Pressure: 14,7 psi a	0	Company: E Project: by: 1 by: 1 Date: 1	EBDG 18026 NJB Tuesday, Ju	EBDG 18026 NJB Tuesday, June 26, 2018 12:09 PM	12:09 PM	
			÷.	đ.	Specific						
Specification Name	ame	Material	Absolute	Absolute Roughness	Sizing Criteria				Design Limits	nits	
Valve Table		Schedule	Hazen Willi	Hazen Williams C Factor	8	Velocity	city		Pressure		Reynolds Number
Copper Nickel Class 200 standard	tass 200	Copper Nickel MIL-T-16420K Schedule:Class 200	9E	6E-05 in 150	0.0	q	fVs		ą	psi g	ą
					Fluid Zones		l	l	l	l	
Fluid Zone Name Table Name	90	Temperature	Pressure		Fluid State	Density Viscosity		Vapor Critical	Vapor Pressure Critical Pressure	~ æ	Specific Heat Ratio (k) Relative Molecular Mass
Sea Water Seawater 3.5% Salinity	Salinity	60 °F	0 psig		Liquid	64.04 lb/ft ³ 1.206 cP		0.251	0.2513 psia 3199 psia		- 29
					Sizing Pumps						
Pump Name			Suction Elevation Suction Pressure		Discharge Elevation Discharge Pressure	Total Head dP	Flow	Flow Rate	NPSHa	Ł	
Sizing Pump 2			2.5 ft -1.7 psig		2.5 ft 5.239 psig	15.6 ft 6.939 psi			28.66	æ	
Sizing Pump 1			2.5 ft		2.5 ft	1.1			1		
					Pipelines		I	I	l	l	
Pipeline Name Specification		Size Inside Diamoter		Inlet Elevation	Flow Rate Fluid Velocity	Total Head Loss V&F Head Loss	1 Loss	Inlet Pressure	essure	Total dP V&F dP	Pipe Friction Factor
Fluid Zone		Length			Reynolds Number					5	V&F Resistance K
Pipe 1 Copper Nickel Class 200 Sea Water	lass 200	3 in 3.31 in 85 ft Inlet Device: Tank 2		2 ft 4 ft	99.64 gpm 3.715 ft/s 80970 Outlet Device: Node	1.723 0.4739 e: Node 1	e e	4.003	psi g psi g	-0.1234 psi 0.2108 psi	0.01889 0.01702 2.21
Pipe 2		3 in		2 ft	100.4 gpm	1.746	¥	4.003	psi g	-0.113 psi	0.01887
Copper Nickel Class 200 Sea Water	Jass 200	3.31 in 85 ft Inlet Device: Tank 1	-		3.742 ft/s 81561 Outlet Device: Node 2	0.4808 e: Node 2	ť	3.89		0.2138 psi	0.01702
Pipe 12 Copper Nickel Class 200 Sea Water	lass 200	3 in 3.31 in 2 ft Inter Device: Node 7		4 4 E E	100.4 gpm 3.742 fVs 8.1561 Outlet Davice: Node 2	0.4186 0.3889	e: e:	4.076 3.89	psig psig	0.1862 psi 0.1729 psi	0.01887 0.01702 1.79
Pipe 13 Copper Nickel Class 200	lass 200	3 3.31		4 H H H	99.64 gpm 3.715 ft/s	0.442 0.3832	e e	4.076 3.879	psi g psi g	0.1966 psi 0.1704 psi	0.01889 0.01702
Sea Water		4 ft Inlet Device: Node 7			80970 Outlet Device: Node 1	e: Node 1			e R	8	1.79
Pipe 14 Copper Nickel Class 200	lass 200	3 in 3.31 in		4 4 4	1 1	1 1		3.879	3.879 psi g -	1.1	1 1
Sea Water					1						1.79
		Inlet Device: Node 1			Outlet Device: Node 8	e: Node 8					
PIPE-FLO Professional	sional	2	List Report			Tuesday, June 26, 2018 12:09 PM	ne 26, 2018	8 12:09 PM			Page 1

Pipeline Name	Size	Inlet Elevation	Flow Rate	Total Head Loss	Inlet Pressure	Total dP	Pipe Friction Factor
specification Fluid Zone	Length		Reynolds Number	A OL LIAGO COSS	ainegal Janno	YOL U	V&F Resistance K
	3 in		1	ı	3.89 psi g	1	1
Copper Nickel Class 200	3.31 in	4 11	1	1		1	1
Ĭ	2 ft Inlet Device: Node 2		- Outlet Device: Node 8	Vode 8			1.79
	4 in				1	,	
Conner Nickel Class 200	4.282 in	25 #	1	1	-1 465 psi a	1	1
Sea Water	4 8		1		ŝ		0.45
	Inlet Device: Node 8		Outlet Device: Node 4	Vode 4			
	4 in		000 mm	0.02237 #	-1 465 nei n	a adaF_03 nei	0.01725
Copper Nickel Class 200	4.282 in	25 ft	4.456 ft/s	0 11	-1.475 psi o	o psi	0.01607
	1.5 ft		125637		i.		0.00
Inte	Inlet Device: Node 4		Outlet Device: (Outlet Device: Curve dP Device 1			
	1	95.0	200 man	A 2520 A	.1 587 nel n	0 1125 nei	0.01796
Conner Nickel Class 200	11 t	# 40	A AKR 4/6	H 1202.0	0 isd /00'1-	0.00021 051	0.01807
Copper moner crass 200 Sea Water	11 7071		125637		ŝ.		0.72
			Outlet Device: Sizing Pump 2	Sizing Pump 2			
	4 in		,	1	1 779 nsi n		
Conner Nickel Class 200	4.282 in	25 #	1	1	-1.465 psi o	1	1
Sea Water	10 ft		1		Rind partic		0.35
	Inlet Device: Tank 3		Outlet Device: Node 4	Vode 4			
	4 in	25 A	200 000	05157 #	5 239 nel n	0 2293 nsi	0.01725
Copper Nickel Class 200	4.282 in	25 ft	4.456 ft/s			0.2095 psi	0.01607
Sea Water	3 ft		125637				1.53
	Inlet Device: Sizing Pump 2		Outlet Device: \$	Sizing Valve 5			1999 B. 1999 B.
	4 in		200 gpm	0.04474 ft	5.01 psi a	0.0199 psi	0.01725
Copper Nickel Class 200	4.282 in	2.5 ft	4.456 ft/s			0 psi	0.01607
Sea Water	3 8		125637				00.00
	Inlet Device: Sizing Valve 5		Outlet Device: Node 5	Vode 5			
	ei ei		00 64 mm	1 723 #	0 pel 0	1 RKR nel	0.01880
Conner Nickel Class 200	331 in	4	3 715 ft/s	0.4739 ft		0.2108 nsi	0.01702
	85 ft		80970				2.21
Inte	Inlet Device: Tank 5		Outlet Device: Node 9	Vode 9			
	3 in		100.4 gpm	1.746 ft	0 psi a	1.666 psi	0.01887
Copper Nickel Class 200	3.31 in	4 ft	3.742 fVs	0.4808 ft	-1.666 psi g	0.2138 psi	0.01702
	85 ft		81561				2.21
Inte	Inlet Device: Tank 4		Outlet Device: Node 10	Node 10			
	4 in	2.5 ft	1	ı	-1.3 psig	1	ı
Copper Nickel Class 200	4.282 in		,	1	1	ı	ı
Sea Water	1.5 ft		1				0.00
Inte	Inlet Device: Node 15		Outlet Device: Curve dP Device	Curve dP Device 2			
	4 in	2.5 ft	1	1	ı	ı	ı
Copper Nickel Class 200	4.282 in	2.5 ft	ı	ı	ī	ı	ı
	2 ft		,				0.72
Inte	Inlet Device: Curve dP Device 2		Outlet Device: Sizing Pump 1	Sizing Pump 1			
DIPE-FI O Professional	I ist Report	1		Titesday, June 26, 2018 12-09 PM	18 12-09 PM		Pana 2

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Pipeline Name	Size	Inlet Elevation	Flow Rate	Total Head Loss	Inlet Pressure	Total dP	Pipe Friction Factor
Specification Fluid Zone	Inside Diameter Length	Outlet Elevation	Fluid Velocity Reynolds Number	V&F Head Loss	Outlet Pressure	V&F dP	V&F Friction Factor V&F Resistance K
Pipe 32	4 in	2.5 ft		1	1	1	
Copper Nickel Class 200	4.282 in	2.5 ft	1	1	1	ı	ı
Sea Water	34						1.53
	Inlet Device: Sizing Pump 1		Outlet Device: Sizing Valve 7	Sizing Valve 7			
Pipe 33	4 in	2.5 ft	1	ı	1	ı	,
Copper Nickel Class 200	4.282 in	2.5 ft	ı	ī	1	1	1
Sea Water	3 ft Inlet Device: Sizind Valve 7		Outlat Davice: Node 16	Jode 16			0.00
				ġ			
Pipe 28	4 in	2.5 ft	200 gpm	0.2581 ft	-1.3 psi g	0.1148 psi	0.01725
Copper Nickel Class 200	4.282 In	2.5 ft	4,456 11/5	0.1388 ft	-1.185 psig	0.06173 psi	0.01607
Sea Water	8 II		12503/ 0.414 Davies: Node 11	the de			0.45
	Inier Device: Node 10		Outliet Device:	11 abox			
Pipe 24	3 in	2.5 ft	1	1	1	1	1
Copper Nickel Class 200	3.31 in	4 ft	ı	ı	-1.666 psi g	ı	ı
Sea Water	2 ft		1				1.79
	Inlet Device: Sizing Valve 8		Outlet Device: Node 10	Vode 10			
Pipe 25	3 in		1	1	1	1	,
Copper Nickel Class 200	3.31 in	4 #	1	ı	-1.656 psig	ı	1
Sea Water	4 ft		1				1.79
	Inlet Device: Sizing Valve 8		Outlet Device: Node 9	Vode 9			
Pipe 26	3 in	4 ft	99.64 apm	0.442 ft	-1.656 psi a	-0.4705 psi	0.01889
Copper Nickel Class 200	3.31 In	2.5 ft	3.715 ft/s	0.3832 ft	-1.185 psi a	0.1704 psi	0.01702
Sea Water	4 ft		80970				1.79
	Inlet Device: Node 9		Outlet Device: Node 11	Vode 11			
Pipe 27	3 in		100.4 gpm	0.4186 ft	-1.666 psi g	-0.4809 psi	0.01887
Copper Nickel Class 200	3.31 in	2.5 ft	3.742 fUs	0.3889 ft	-1.185 psig		0.01702
Sea Water	2 ft		81561				1.79
	Inlet Device: Node 10		Outlet Device: Node 11	Vode 11			
Pipe 36	4 in	2.5 ft	200 apm	0.372 ft	-1.465 psi a	0.1654 psi	0.01725
Copper Nickel Class 200	4.282 in	2.5 ft	4.456 ft/s	0.2974 ft	-1.3 psi a	0.1323 psi	0.01607
Sea Water	5 #		125637				0.96
	Inlet Device: Node 4		Outlet Device: Node 15	Vode 15			
Pipe 37	4 in		,	ï	1	,	1
Copper Nickel Class 200	4.282 in	2.5 ft	,	1	4.99 psi a	ı	1
Sea Water	5 1		ı				0.96
	Inlet Device: Node 16		Outlet Device: Node 5	Vode 5			
Pipe 21	4 in	2.5 ft	200 gpm	0.5556 ft	4.99 psi a	0.9142 psi	0.01725
Copper Nickel Class 200	4.282 In	4 ft	4.456 ft/s	0.4363 ft	4.076 psi g	0.194 psi	0.01607
Sea Water	8 ft		125637			•	1.41
	Inlet Device: Node 5		Outlet Device: Node 7	Vode 7			ANC (00020)
Pipe 35	4 in	2.5 ft		1	1	1	
Copper Nickel Class 200	4.282 in	2.5 ft		1	1	1	1
Sea Water	8 11		1				1.41
	Inlet Device: Sizing Valve 8		Outlet Device: Node 16	Vode 16			
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Pipeline Name Specification								
Fluid Zone		Size I Inside Diameter O Length	Inlet Elevation Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number	Total Head Loss V&F Head Loss	Inlet Pressure Outlet Pressure	e Total dP re V&F dP	Pipe Friction Factor V&F Friction Factor V&F Resistance K
			4					
		H +	1 0.7	1		4.33 psi g	•	ı
Copper Nickel Class 200		4.202 II	1 0'8	1	1	n psig		1
Sea Water	15 Inlet Device: Node 5	Node 5		Outlet Device: Pressure Boundary 1	ssure Boundary 1			20.7
				Tanks				
Tank Name	Bottom Elevation	Surface Pressure	Hydraulic Grade			Connecting Pipe	elines	
Fluid Zone	Liquid Level	Bottom Pressure		Pipeline Name	me Penetration Height	Height Pipeline Flow Rate	eline Flow Rate	Pressure at Penetration
Tank 1	2 ft	0 psig	11 ft					
	9 H	4.003 psi g			Pire 2 4		100.4 000	4 003 nei n
							111/16 1-2221	Ried cont
Tank 2	2 H 9 H	0 psig 4.003 psig	11 8					
				P	Pipe 1 0 ft		99.64 gpm	4.003 psi g
Tank 3	0 ft	0 psig	•					
	4 f	L		٥	Dine 3 0 #		1	1 770 nei n
			- 1-2		>			Ried citri
Tank 4	2 #	0 psi g	2 ft					
	H 0			JId	Pipe 23 0 ft		100.4 gpm	0 psig
Tent 6		0 nei 0	# C					
I BILL O	4 H N	0 psig						
				20.5	Pipe 22 0 ft		99.64 gpm	0 psig
			Curv	Curve dP Devices)	3
Curve dP Device Name Description	Inlet I Inlet I	Inlet Elevation Inlet Pressure	Outlet Elevation Outlet Pressure	dP Head Loss		Flow Rate		
Curve dP Device 1	2	2.5 ft	2.5 ft	0.112 psi		200 gpm		
Eaton model 72	-1.47	5 psig	-1.587 psi g	0.2518	H			
Curve dP Device 2 Eaton model 72	6	2.5 ft 	2.5 ft 	11		1		
				Nodes				
Node Name			Elevation	Pressure	Hydraulic Grade	de		
Node 1			4 ft	3.879 psi g	12.51 ft			
Node 2			4 ft	3.89 psig	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 #	3	1			
Sizing Valve 5			2.5 ft	5.01 psig	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 psig	-0.7313 ft			
DIDE.EI O Drofessional		1 let Denort			Tiesday line 26 2018 12:09 DM	8 12-00 DM		A and

	Nodes			
Node Name	Elevation	Pressure	Hydraulic Grade	
Node 16	2.5 ft	ı	1	
Sizing Valve 7	2.5 ft			
Node 11	2.5 ft	-1.185 psi g	-0.4115 ft	
Sizing Valve 8	2.5 ft		ı	
.u	Pressure Boundaries	undaries		
Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9.5 ft	0 psig	ı	I

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Pipe 2 Pipe 12 Pipe 13 Pipe 14	Copper	cation Nickel Class 200	Pipelines Size 3 in			
Pipe 1 Pipe 2 Pipe 12 Pipe 13 Pipe 14	Copper		1.0000	Len	ath	Valves and Fittings
Pipe 13 Pipe 14		525777 PP-153 SHUD-5-5	511	10000	ft	6 x Elbow - Long radius, r/d 1.5 (90*) 1 x Entrance - Inward
Pipe 14	-	Nickel Class 200	3 in	85	ft	6 x Elbow - Long radius, r/d 1.5 (90*) 1 x Entrance - Inward
Pipe 13 Pipe 14 Pipe 15	Copper	Nickel Class 200	3 in	2	ft	1 x Butterfly 1 x Tee - Flow Thru Branch
	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	4	ft	1 x Butterfly 1 x Tee - Flow Thru Branch
	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		Nickel Class 200	3 in		ft	6 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Inward
Pipe 23		Nickel Class 200	3 in		ft	6 x Elbow - Long radius, r/d 1.5 (90°) 1 x Entrance - Inward
Pipe 29	and the second	Nickel Class 200	4 in	1.5		
Pipe 30		Nickel Class 200	4 in		ft	1 x Butterfly
Pipe 32		Nickel Class 200	4 in	(2)	ft	1 x Swing Check - Vertical 1 x Butterfly
Pipe 33		Nickel Class 200	4 in		ft	
Pipe 28		Nickel Class 200	4 in		ft	2 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 24	11.1	Nickel Class 200	3 in	101	ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 25		Nickel Class 200	3 in	105	ft	1 x Butterfly 1 x Tee - Flow Thru Branch
Pipe 26		Nickel Class 200	3 in	1.0	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		ft	1 x Tee - Flow Thru Branch
Pipe 37	Copper	Nickel Class 200	4 in		ft	1 x Tee - Flow Thru Branch
Pipe 21		Nickel Class 200	4 in	22	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
		Pip	eline Material Su	ummary		
Specification	Material		Size	Total Length		Valves & Fittings
Copper Nickel Cla	ss 200 Copper Nicke Schedule: Cl	I MIL-T-16420K ass 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

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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

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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.

Pipe Segment	Flow	Pipe	Schedule	d, ID	Desig	gn Velo	ocity	V
	Rate	Size			Nomi	nal	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

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

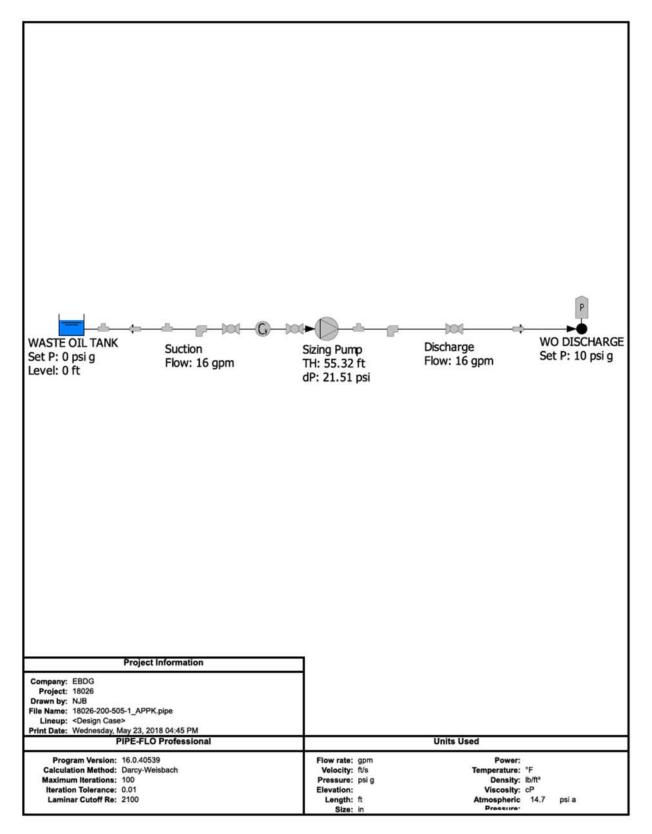
5.2 Frictional Loss and Pump ΔP Calculation

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



EBDG – NC, PLLC 18026-200-505-1

		l	l	List Report	l	l	_		
File Name: 18026-200-505-1_APPK.pipe Lineup: ">Lineup: Color: 18.0.40539 Version: 16.0.40539	l_APPK.pipe ssional	Atm - C	Calculation Method: Daro Laminar Cutoff Re: 2100 Max Iterations: 100 Iteration Tolerance: 0.01 Atmospheric Pressure: 14.7	Calculation Method: Darcy-Weisbach Laminar Cutoff Re: 2100 Max Iterations: 100 Iteration Tolerance: 0.01 nospheric Pressure: 14.7 psi a	Con	Company: EBDG Project: 18026 by: NJB Date: Wednes	pany: EBDG oject: 18026 by: NJB Date: Wednesday, May 23, 2018 04:46 PM	18 04:46 PM	
	l	l		Pipe Specifications	l		l		
Specification Name	Material	Absol	Absolute Roughness	Sizing Criteria	Valocity		Design Limits		Demolds Number
Valve I auto	ampaine				(inclas	- L · · ·	ameear		incline shoulday
standard	Schedule:80	8	1.800E-03 III 140	0.0	2	S71	9	bisd	8
				Fluid Zones					
Fluid Zone Name Table Name	Temperature		Pressure	Fluid State	Density Viscosity	Crit Crit	Vapor Pressure Critical Pressure	S S	Specific Heat Ratio (k) Relative Molecular Mass
SAE 30 Lube Oil SAE 30 Lube	50 *F	40	40 psig	Liquid	55.99 lb/ft* 479.4 cP	0	0.2173 psia 3199 psia		1
				Sizing Pumps					
Pump Name		Suction	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa	Ha	
Sizing Pump		4.501	4 ft -4.501 psig	4 ft 17.01 psig	55.32 ft 21.51 psi		25.66	u	
				Pipeilnes					
Pipeline Name Specification Fluid Zone	E	Size Inside Diameter Length	Inlet Elevation Outlet Elevation	n Flow Rate in 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
							President of the second second second		
Suction Steel A53-B36.10 SAE 30 Lube Oil	Inlet Device: V	1.5 in 1.5 in 8 ft Inlet Device: WASTE OIL TANK	2 H H H	16 gpm 2.905 ft/s 63.12 Outlet Device	16 gpm 9.576 ft 905 ft/s 1.066 ft 63.12 Outlet Device: Sizing Pump	4	0 psig -4.501 psig	4.501 psi 0.4146 psi	1.014 0.02054 8.13
Discharge		1.5 in	4 ft	16 gpm	11.03 ft	11	.01 psi g	7.011 psi	1.014
Steel A53-B36.10 SAE 30 Lube Oil	1.5 in 10 ft Inlet Device: Sizino Pump	1.5 in 10 ft izing Pump	11 A	2.905 ft/s 63.12 Outlet Device	905 ft/s 0.3924 ft 63.12 Outlet Device: WO DISCHARGE		10 psig	0.1526 psi	0
				Tanks				l	
Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure		Hydraulic Grade Pipel	Pipeline Name Pen	Connec Penetration Height	Connecting Pipelines Height Pipeline Flow Rate		Pressure at Penetration
WASTE OIL TANK SAE 30 Lube Oil	2 # 0 #	0 psig 0 psig		2 ft	Suction	u o	16	16 gpm	0 psig
				Pressure Boundaries					
Pressure Boundary Name			Elevation	Pressure		Hydraulic Grade	Flow Rate	ate	
WO DISCHARGE			11 ft	10 psig		36.59 ft	16 gpm	E	
PIPE-FLO Professional		List Report			Wednesday, May 23, 2018 04:46 PM	y 23, 2018 04:4	M S PM		Page 1

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DOUBLE-ENDED AZIMUTH DRIVE FERRY

	B	II of Materials Re	port	
File Name: 18026-2 Lineup: <design Program Name: PIPE-FU Version: 16.0.40</design 	O Professional		Company: EBD Project: 1802 by: NJB Date: Web	26
		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
	1	Pipeline Material Su	immary	
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

2 x Tee - Flow Thru Branch 1 x Tee - Flow Thru Run

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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:

Eq 1: Supplemental Drawdown (gal) = (Peak demand (gpm) – pump capacity(gpm)) × Peak Demand Time (min)

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

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

5 CALCULATIONS

5.1 Demand Water Supply Calculations

			J-1. Waler Suppl			TT	T ()
. .	T.		Water Supply Fixture		Flow Rate	Usage	Total
Level	Item	Qty	Units, Table A-2	Item Totals	(gpm)	Factor	Flow
Bridge Deck	Window Wash**	1	1	1	1.5		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 fo	or Vessel		31.5				14.8
Supply demand	l, from [1], Ch A-3, line	21	40	GPM			
Excluding wate	er closets, from [1], Ch	A-3, Line 2	20	GPM			
* First hose bil	o is 2.5 WSFU, additiona	al are 1.0					
**Window wa	sh WSFU is estimated a	s similar to a sink	ζ				

Table 5-1: Water Supply

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:

	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)

Table 5-2: Pressure Tank Sizing

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:

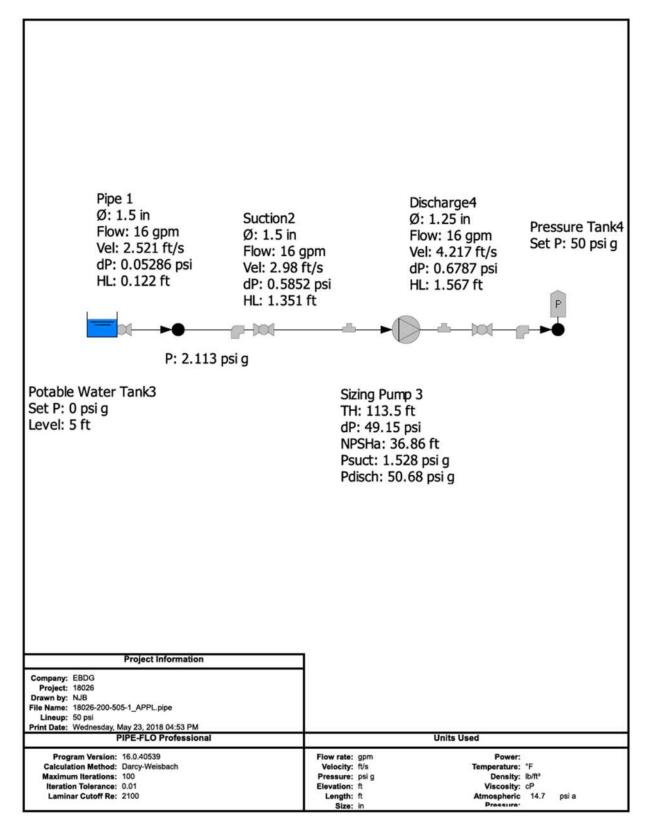
100		
Flow Rate, (gpm)	System NPSHa, ft	Velocity, ft/s
4	38.23	1.05
8	37.94	2.11
12	37.49	3.16
16	36.86	4.22
20	36.08	5.27

Table 5-3: System NPSHa

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



				l ist Renort					
File Name: 18026-200-505-1_APPL.pipe Lineup: 50 psi	-1_APPL.pipe	5	alculation Method: Laminar Cutoff Re:	Calculation Method: Darcy-Weisbach Laminar Cutoff Re: 2100	Co	Company: EBDG Project: 18026	EBDG 18026		
Lineup: 30 par Progam Name: PIPE-FLO Professional Version: 16.0.40539	essional	Atmo	Atmospheric Pressure: 14.7 Atmospheric Pressure: 14.7 Pipe Spi	c 100 c 100 c 0.01 psi a pe Specifications			B adnesday, May 2	rouze Wednesday, May 23, 2018 04:53 PM	
Specification Name Valve Table	Material Schedule	Absolu Hazen W	Absolute Roughness Hazen Williams C Factor	Sizing Criteria	Velocity	~	Desig	Design Limits Pressure	Reynolds Number
Copper Tube, K - Discharge standard	Copper Tube H23 Schedule:K		6E-05 in 140	8.0 ft/s	Q	fuls	15 to 8	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	1.80	1.800E-03 in 140	0.0	9	R/s	9	psi g	to
Fluid Zone Name				Fluid Zones	Density		Vapor Pressure		Specific Heat Ratio (k)
Table Name Potable Water Water	60 *F	ure Pressure 60 psi g		Fluid State Liquid	Viscosity 62.37 lb/ft ^a 1.105 cP		Critical Pressure 0.2564 psi a 3199 psi a		Kelative Molecular Mass - 18
				Sizing Pumps					
Pump Name		Suction Elevation Suction Pressure		Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	ate	NPSHa	
Sizing Pump 3		2.5 ft 1.528 psig	n psig	2.5 ft 50.68 psig Pipelines	113.5 ft 49.15 psi			36.86 ft	
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	sso-	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	Inlet Device: 1	1.5 in 1.481 in 20 ft Sizing Pump 5	2.5 ft 2.5 ft	16 gpm 2.98 ft/s 30894 Outlet Device	16 gpm 1.351 ft 2.88 ft/s 0.827 ft 30894 Outlet Device: Sizing Pump 3		2.113 psi g 1.528 psi g	0.5852 p 0.3582 p	psi 0.02343 psi 0.0206 5.99
Pipe 1 Steel ASTM A53 Potable Water	Inlet Device: 1	1.5 in 1.61 in 2 ft Inlet Device: Potable Water Tank3	2.5 ft 2.5 ft	16 gpm 2.521 ft/s 28419 Outlet Device	16 gpm 0.122 ft 521 fVs 0.08305 ft 28419 Outlet Device: Sizing Pump 5		2.166 psi g 2.113 psi g	0.05286 pr 0.03597 pr	psi 0.02647 psi 0.02018 0.84
Discharge4 Copper Tube, K - Discharge Potable Water	1.245 in 1.245 in 5 ft Inlet Device: Sizing Pump 3	1.25 in 1.245 in 5 ft Sizing Pump 3	2.5 A 2.5 A	16 gpm 4.217 ft/s 36750 Outlet Device Tanks	16 gpm 1.567 ft 217 ft/s 1.267 ft 36750 36750 0utlet Device: Pressure Tank4		50.68 psi g 50 psi g	0.6787 pr 0.5487 p	psi 0.02255 psi 0.02152 4.58
Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	e Hydraulic Grade e		Pipeline Name Pen	Connec Penetration Height	ting	Pipelines Pipeline Flow Rate	Pressure at Penetration
Potable Water Tank3 Potable Water	25 ft 5 ft	0 psig 2.166 psig	77	7.5 ft	Pipe 1	0 H		16 gpm	2.166 psig
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	Bill of	f Materials Rep	oort		
File Name: 18026-200- Lineup: 50 psi Program Name: PIPE-FLO F Version: 16.0.40539				180 NJB	26
		Pipelines			
Pipeline	Specification	Size	Le	ngth	Valves and Fittings
Suction2	Copper Tube, K - Suction	1.5 in	20	0 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 Bail 2 x Tee - Flow Thru Branch 3 x Elbow - Standard 90°
	Pipe	line Material Su	mmary		
Specification	Material	Size	Total Length	1	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

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