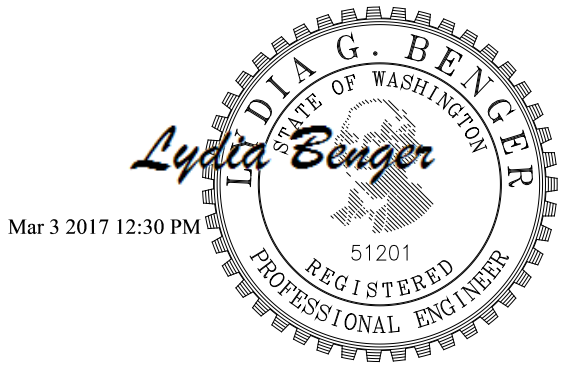

NORTH CAROLINA D.O.T. PEDESTRIAN FERRY

Mechanical Calculations

Prepared for: NCDOT • Raleigh, NC

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REVISIONS

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1 PURPOSE

This report documents the calculations used in support of piping and machinery system designs for the North Carolina D.O.T. Pedestrian Ferry. The subject vessel is a new design for a 92 ft long x 26 ft wide, catamaran type, fast passenger ferry, which will be owned and operated by the North Carolina Department of Transportation (NCDOT).

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

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

2 REGULATORY FRAMEWORK

The Pedestrian Ferry is inspected by the US Coast Guard under the provisions of 46 CFR Subchapter T. The vessel structure and bilge system are designed in accordance with Lloyd's Register Rules and Regulations for the Classification of Special Service Craft, 2016. Therefore, all piping and mechanical system design shall comply with the respective requirements of these agencies.

Appendix A

HVAC

1 DESCRIPTION

This appendix documents the calculations used in designing the machinery ventilation and passenger and crew space HVAC systems. These calculations establish minimum ventilation and cooling loads and identify appropriate duct sizes, trunk sizes, and fan and heat pump ratings.

2 PROCEDURE

Calculations are presented in the following sequence:

- Passenger Space cooling loads and exhaust fan sizing
- Pilothouse cooling load
- Engine Room ventilation and supply fan sizing
- Jet Room ventilation and exhaust fan sizing

3 GIVEN AND ASSUMED PARAMETERS

- The following environmental conditions were used to determine the HVAC loads:

Environmental Condition	
Cooling Outside Air Dry Bulb Temperature (F)	88
Cooling Outside Air Relative Humidity (%)	75
Cooling Sea Water Temperature (F)	85
Air Conditioned Spaces Temperature (F)	72
Air Conditioned Spaces Humidity (%)	55
Machinery Space Temperature (F)	115
Heating Outside Air Temperature	40
Heating Accommodations Indoor Air Temperature	68
Heating Machinery Space Indoor Air Temperature	50

- Passenger Space and Pilothouse will be served by mini-split heat pump units. Mini-split units will provide cooling and heating to each space.
- Machinery Spaces will not be supplied with any auxiliary heating.
- Compartment areas and volumes have been estimated based upon arrangements, [1].
- The outside air requirement for the Passenger Space was determined using ASHRAE 62.1 Ventilation for Acceptable Indoor Air Quality, [2].
- Passenger Space window glass solar factor (GSF) was modified for geographic location, and an assumed window film per ASHRAE fundamentals in accordance with the RLF method of Chapter 17.

- The Engine Rooms will be provided with mechanical supply and natural exhaust.
- The Jet Rooms will be provided with natural supply and mechanical exhaust.
- All other below deck spaces are provided with natural supply and exhaust.
- Engine Room ventilation is calculated assuming two propulsion engines, Caterpillar C18's rated for 800 HP at 2100 RPM and one generator, Northern Lights M40C3 rated for 40 kW. Heat rejection and air requirements at 100% MCR are tabulated below, [3] [4].

Engine Room Equipment Loads	
Propulsion Engine Heat Rejection (btu/min)	1815
Propulsion Engine Consumption Air (cfm)	1856
Generator Engine Cooling Air Required (cfm)	805
Generator Engine Consumption Air (cfm)	114

- Engine Room exhaust air is based upon supply air minus the consumption air of two engines running at 100% MCR.
- Engine Room supply fans have variable frequency drive motors that determine speed based upon a positively pressurized engine room.

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Passenger Space Cooling Loads and Exhaust Fan Sizing

Based upon the attached cooling load calculations, the estimated total cooling load for the Passenger Space is approximately 120,000 btu/hr or 10 tons of cooling. The passenger space will be served by four equally sized mini split heat units, each sized for 3.0 tons of cooling. This selection will provide margin and redundancy.

The Passenger Space will be served by an exhaust fan located in the overhead at the aft end of the accommodations. At minimum this fan shall exhaust approximately 600 cfm of air at an estimated static pressure of 1.3 inches H2O.

5.2 Pilothouse Cooling Load

Based upon the attached cooling load calculations, the estimated total cooling load for the Pilothouse is approximately 36,000 btu/hr or 3.0 tons of cooling. The Pilothouse will be served by two equally sized mini split heat units, each sized for 2 tons of cooling. This selection will provide margin and redundancy.

5.3 Engine Room Ventilation and Supply Fan Sizing

Based upon the attached calculations a ventilation rate of 10,400 cfm is required to provide cooling and combustion air to the Engine Rooms.

One fan, providing 10,400 cfm, will supply air the each Engine Room. The calculated static pressure is 0.7 inches H2O.

5.4 Jet Room Ventilation and Exhaust Fan Sizing

Based upon the attached calculations a minimum ventilation rate of 157 cfm is required to provide 10 air changes per hour in the Jet Rooms.

One fan, providing 200 cfm, will supply air the each Jet Room. The calculated static pressure is 1.5 inches H2O.

REFERENCES

[1] Elliott Bay Design Group, "Profiles and Arrangements," 16109-003-101 , Seattle, WA.

[2] ASHRAE, "Standard 62.1-2010 Ventilaton for Acceptable Indoor Air Quality," 2010.

[3] Caterpillar, "Performance Data [EM0270]," 11/10/2016.

[4] Mitsubishi, "ISM Toyota Mistubishi Marine Genset Specs," 2/2016.

Passenger Space	Deck Area: 940 ft²	Volume: 7050 ft³
Space No:	Height: 7.5 ft	

Lighting Load Calculation

Description	Area (ft2)	LC, (Btu/hr/ft²)	qs (btuh)		qt (btuh)
Type of Lighting	940	7	6,580		6,580
		Lighting Totals:	6,580		6,580

Equipment Load Calcultion

Description	qs (btuh)	ql (btuh)		Qty	Use Factor	q_s (btuh)	q_l (btuh)	q_t (btuh)
Coffee Maker (commercial)	6,500	2,000		0	1			
Electric motor, (5 HP x 2545 / .87)	14,626			0	0.5			
					Equipment Totals:	0	0	0

Personnel Load Calcultion

Description	Gender	Type	q_s (btuh)	q_l (btuh)		Count	q_s (btuh)	q_l (btuh)	q_t (btuh)
SEATED AT REST	male	1-P1	240	160		0			
SEATED AT REST	mixed	1-P2	210	140		100	21,000	14,000	35,000
						Personnel Totals:	21000	14000	35000

Ventilation Requirements

Type	Description	Rate	Unit	Qty	OA (cfm)		EX (cfm)
People Outdoor Air Rate	Public Assembly	5	cfm/person	100 people	500		
Area Outdoor Air Rate	Public Assembly	0.06	cfm/sq ft	940 ft³	56		
					556		

	Heating Outside Air Temp	40 °F	Cooling Outside Air Temp 88 °F
	Heating Inside Air Temp	68 °F	Cooling Design Temp: 72 °F

Heating and Cooling Load Calculation					**Heating**				**Cooling Season**					
Description	Load Key	Insul Type		Area (ft²)	T (°F)	ΔT	U or GSF	q_w (btuh)	T (°F)	ΔT	U or GSF	q_s (btuh)	q_l (btuh)	q_t (btuh)
Exterior - Weather (Solar)	Over	090-D1	☼↓	812.0	40	28	0.238	5,411	123	51	0.274	11,347		11,347
Pilot House	Over	090-D4	I↓I	175.0	68	0	0.219		72	0	0.243			
Void Space	Belw	090-U4	I↑I	620.0	40	28	0.260	4,514	88	16	0.282	2,797		2,797
Exterior - Weather	Belw	090-U2	W↑I	320.0	40	28	0.293	2,625	88	16	0.278	1,423		1,423
Exterior - Weather (Solar)	Fwd	090-H1	☼↔	148.0	40	28	0.259	1,073	108	36	0.287	1,529		1,529
Exterior - Weather	Fwd	090-H2	W↔I	148.0	40	28	0.259	1,073	88	16	0.260	616		616
Exterior - Windows (Shaded)	Fwd	001-H2	W↔I	37.0	40	28	1.130	1,171	88	16	1.130	669		669
Exterior - Windows (Solar)	Fwd	001-H1	☼↔	37.0	40	28	1.130	1,171	108	36	75	2,775		2,775
Exterior - Weather	Aft	090-H2	W↔I	234.0	40	28	0.259	1,697	88	16	0.260	973		973
Exterior - Weather (Solar)	Port	090-H1	☼↔	217.0	40	28	0.259	1,574	108	36	0.287	2,242		2,242
Exterior - Windows (Solar)	Port	001-H1	☼↔	90.0	40	28	1.130	2,848	108	36	75	6,750		6,750
Exterior - Windows (Shaded)	Stbd	001-H2	W↔I	90.0	40	28	1.130	2,848	88	16	1.130	1,627		1,627
Exterior - Weather	Stbd	090-H2	W↔I	217.0	40	28	0.259	1,574	88	16	0.260	903		903
LIGHTS	Lght											6,580		6,580
EQUIPMENT	Eqpt													
PERSONNEL	Pers											21,000	14,000	35,000
Ventilation	OA								88	16		9,258	35,208	44,466
							Space Totals:	27,578			Totals:	70,490	49,208	119,698

Passenger Space Exhaust Fan Total Pressure Calculation

Input Variables

Supply Air Temperature (T_{IN}) =	88	°F
Humidity Ratio	0.0217	lb/lb dry air
Air In Specific Volume (r_{IN}) =	14.29	ft³ / lb dry air
Supply air specific weight	0.070	lb/cu ft
Supply air viscosity	3.89E-07	lb-s/sq ft²
Supply air density	0.0022	slugs/cu ft
Max Temperature (T_{OUT}) =	90.0	°F
Air out Specific Volume (r_{OUT}) =	14.34	ft³ / lb dry air
Exhaust air specific weight	0.070	lb/cu ft
Exhaust air viscosity	4.02E-07	lb-s/sq ft²
Exhaust air density	0.0022	slugs/cu ft

Description	height (in)	width (in)	h/w	eqiv dia (in)	hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Supply Ducting														
Inlet Grill, 45 deg taper	6	6	-	-	6.00	0.20		1	200	1019	4.74E+04	0.024	0.100	0.45
Elbow, R/D = 1.5			-	-	6.00	0.20		1	200	1019	4.74E+04	0.024	0.330	1.48
Round Ducting			-	-	6.00	0.20	12	1	200	1019	4.74E+04	0.024	0.586	2.62
Tee, branch			-	-	4.00	0.09		1	100	1146	3.55E+04	0.027	0.500	2.83
Duct			-	-	4.00	0.09	8	1	100	1146	3.55E+04	0.027	0.638	3.61
Diffuser, L/D = 3	10	10			10.00	0.55		1	100	183	1.42E+04	0.030	0.200	0.03
Tee, branch					4.00	0.09		1	100	1146	3.55E+04	0.000	0.500	2.83
Round Ducting					4.00	0.09	4	1	100	1146	3.55E+04	0.027	0.319	1.81
Elbow					4.00	0.09		1	100	1146	3.55E+04	0.027	0.330	1.87
Diffuser, L/D = 3					10.00	0.55		1	100	183	1.42E+04	0.030	0.200	0.03
													Segment total pressure	17.56

Description	height (in)	width (in)	h/w		hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Exhaust Vent														
Exhaust Grill, 45 deg Taper, 50% open	12.00	12.00	1.00	-	12.00	0.50		1	400	800	7.19E+04	0.021	0.100	0.28
Damper, D/Do = .9, 50 Deg					8.00	0.35		1	400	1146	6.87E+04	0.022	9.600	54.37
Ducting					8.00	0.35	12	1	400	1146	6.87E+04	0.022	0.404	2.29
Wye, Converging, 45 deg, main					6.00	0.20		1	500	2546	1.14E+05	0.022	0.130	3.64
Duct					6.00	0.20	8	1	500	2546	1.14E+05	0.022	0.352	9.84
Wye, Converging, 45 deg, main					6.00	0.20		1	600	3056	1.37E+05	0.022	0.130	5.24
Duct					6.00	0.20	4	1	600	3056	1.37E+05	0.022	0.173	6.97
Fan					6.00	0.20		1	600	3056	1.37E+05	0.022	0.000	0.00
Louver	10.00	10.00			10.00	0.52		1	600	1152	8.63E+04	0.021	3.600	20.61
													Segment total pressure	*103.23*

	FT	in H2O
supply air total pressure	**17.56**	**0.236**
exhaust air total pressure	**103.23**	**1.389**
Total	**120.79**	**1.626**
15% design margin	**138.90**	**1.869**

Exhaust Fan Static Pressure	
Fan Dia (in)	6.00
Fan area (ft2)	0.20
flowrate (cfm)	600
velocity (fpm)	3056
fan velocity pressure	0.5411
Static Pressure for fan selection (in H20)	**1.328**

Pilothouse		Deck Area:	175 ft²		Volume:	1225 ft³
Space No:		Height:	7 ft			

Lighting Load Calculation

Description	Area (ft2)	LC, (Btu/hr/ft²)	qs (btuh)		qt (btuh)
LED lighting	175	7	1,225		1,225
		Lighting Totals:	1,225		1,225

Equipment Load Calcultion

Description	qs (btuh)	ql (btuh)		Qty	Use Factor	q_s (btuh)	q_l (btuh)	q_t (btuh)
Misc Electronics, (5 HP x 2545 / .87)	14,626			1	0.5	7,313		7,313
					Equipment Totals:	7313	0	7313

Personnel Load Calcultion

Description	Gender	Type	q_s (btuh)	q_l (btuh)		Count	q_s (btuh)	q_l (btuh)	q_t (btuh)
SEATED AT REST	male	1-P1	240	160		3	720	480	1,200
SEATED AT REST	mixed	1-P2	210	140		0			
						Personnel Totals:	720	480	1200

Ventilation Requirements

Type	Description	Rate	Unit	Qty		OA (cfm)		EX (cfm)
By Occupancy	Low Occupancy	15	cfm/person	3	people	45		
Rate of Change	AC, Pilot House	1	ach	1225	ft³	20		
Sanitary Fixtures		50	cfm/fixture	0	fixture			
						45		

Heating Outside Air Temp	40 °F	Cooling Outside Air Temp	88 °F
Heating Inside Air Temp	68 °F	Cooling Design Temp:	72 °F

Heating and Cooling Load Calculation					**Heating**				**Cooling Season**					
Description	Load Key	Insul Type		Area (ft²)	T (°F)	ΔT	U or GSF	q_w (btuh)	T (°F)	ΔT	U or GSF	q_s (btuh)	q_l (btuh)	q_t (btuh)
Pilot House Top	Over	090-D1	☼↓	150.0	40	28	0.238	1,000	123	51	0.274	2,096		2,096
Passenger Space	Belw	090-U4	I↑I	155.0	68	0	0.260		72	0	0.282			
Exterior - Weather (Solar)	Fwd	090-H1	☼↔	104.0	40	28	0.259	754	108	36	0.287	1,075		1,075
Exterior - Weather	Fwd	090-H2	W↔I	0.0	40	28	0.259		88	16	0.260			
Exterior - Windows (Solar)	Fwd	001-H1	☼↔	92.0	40	28	1.130	2,911	108	36	160	14,720		14,720
Exterior - Windows (Shaded)	Aft	001-H2	W↔I	24.0	40	28	1.130	759	88	16	1.130	434		434
Exterior - Weather	Aft	090-H2	W↔I	72.0	40	28	0.259	522	88	16	0.260	300		300
Exterior - Weather (Solar)	Port	090-H1	☼↔	28.0	40	28	0.259	203	108	36	0.287	289		289
Exterior - Weather	Port	090-H2	W↔I	28.0	40	28	0.259	203	88	16	0.260	116		116
Exterior - Windows (Solar)	Port	001-H1	☼↔	16.5	40	28	1.130	522	108	36	160	2,640		2,640
Exterior - Windows (Shaded)	Port	001-H2	W↔I	16.5	40	28	1.130	522	88	16	1.130	298		298
Exterior - Windows (Shaded)	Stbd	001-H2	W↔I	33.0	40	28	1.130	1,044	88	16	1.130	597		597
Exterior - Weather	Stbd	090-H2	W↔I	56.0	40	28	0.259	406	88	16	0.260	233		233
LIGHTS	Lght											1,225		1,225
EQUIPMENT	Eqpt											7,313		7,313
PERSONNEL	Pers											720	480	1,200
Ventilation	OA								88	16		749	2,848	3,596
						Space Totals:		8,847			Totals:	32,805	3,328	36,132

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.

Equipment Loads

Main engines Heat Rejection, qe =	1,815.00	*btu/min*
Main engines Consumption Air, Qe =	1,856.20	*cfm*
Number of Engines Operating, Ne =	2.00	
Generator Cooling Air, Vg =	805.00	*cfm*
Generator Consumption Air, Qg =	114.00	*cfm*
Number of Engines Operating, Ng =	1.00	

Inlet Air Conditions

Summer Air In Temperature (TIN) =	88.00	*°F*
Humidity Ratio	0.022	*lb/lb dry air*
Air In Enthalpy (hIN) =	45.03	*Btu / lb*
Air In Specific Volume (rIN) =	14.29	*ft³ / lb dry air*

Exhaust Air Conditions

Max Temperature (TOUT) =	115.00	*°F*
Air Out Enthalpy (hOUT) =	51.77	*Btu / lb*
Air out Specific Volume (rOUT) =	14.99	*ft³ / lb dry air*

Other Givens

Volume of Space (V) =	1,900	*ft³*
Minutes per air change (MA) =	10.00	*min*

Calculated Airflow based on Total Heat Loads

Total Heat Rejection (Qe) =	3630	*Btu / min*	
D Enthalpy (Dh) =	6.74	*Btu / lb*	*Dh = hOUT - hIN*
Required CFM (Heat Load) =	8500	*cfm*	*CFM = (Qe / Dh x rIN) + Vg*

Calculated Exhaust Airflow

cooling air (V)=	8,500	*cfm*	*(maximum of required airflows)*
inlet air specific volume =	14.29	*ft3/lb*	
exhaust air specific volume =	14.99	*ft3/lb*	
expansion =	4.93%		
exhaust air =	8,919	*cfm*	*CFM = V / rIN * rOUT*

Results

cooling air =	8,500	*cfm*	*(maximum of required airflows)*
consumption air =	3,826	*cfm*	
total intake air =	**10,413**	*cfm*	*(50% combustion air from cooling air)*
total exhaust air =	**6,701**	*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	10400	cfm
Exhaust air flow rate	6600	ft/min

Description	height (in)	width (in)	h/w	eqiv dia (in)	hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Supply Ducting														
Inlet Demister	40	30	1.33	36.75	34.29	8.33		1	10400	1248	3.32E+05	0.016	5.500	36.95
Round Fabricated Fire Damper			-	-	30.00	4.91		1	10400	2119	4.93E+05	0.015	0.100	1.94
Fan			-	-	24.00	3.14		1	10400	3310	6.16E+05	0.016	0.000	0.00
Flexible Duct / Round Duct			-	-	32.00	5.59	0.50	1	10400	1862	4.62E+05	0.015	0.003	0.04
Discharge Aft to Gen, R/D = 1.5, 45 deg			-	-	32.00	5.59		1	10400	1862	4.62E+05	0.015	1.200	17.95
Screen (wire mesh)			-	-	32.00	5.59		1	10400	1862	4.62E+05	0.015	0.500	7.48
													Segment total pressure	64.35

Description	height (in)	width (in)	h/w		hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Exhaust Vent														
Damper	27.00	20.00	1.35		22.98	3.75		1	6600	1760	2.90E+05	0.017	0.370	4.94
Inlet	27.00	20.00	1.35		22.98	3.75		1	6600	1760	2.90E+05	0.017	0.500	6.68
Rectangular ducting	40.00	28.00	1.43	-	32.94	7.78	10	1	6600	849	2.00E+05	0.017	0.062	0.19
Exhaust Louver with insect screen	42	42	1.00	-	42.00	9.19		1	6600	718	2.16E+05	0.016	3.600	8.01
													Segment total pressure	*19.83*

	FT	in H2O
supply air total pressure	64.35	0.866
exhaust air total pressure	19.83	0.267
Total	84.18	1.133
15% design margin	96.81	1.303

Supply Fan Static Pressure	
Fan Dia (in)	24.00
Fan area (ft2)	3.14
flowrate (cfm)	10400
velocity (fpm)	3310
fan velocity pressure	0.6074
Static Pressure for fan selection (in H20)	**0.696**

Jet Room Ventilation

Approach

The minimum required airflow to the Jet Room is calculated based on minimum airflow of 10 air change per hour.

Inlet Air Conditions

Summer Air In Temperature (TIN) =	88.00	*°F*
Humidity Ratio	0.022	*lb/lb dry air*
Air In Enthalpy (hIN) =	45.03	*Btu / lb*
Air In Specific Volume (rIN) =	14.29	*ft³ / lb dry air*

Exhaust Air Conditions

Max Temperature (TOUT) =	90.00	*°F*
Air Out Enthalpy (hOUT) =	45.53	*Btu / lb*
Air out Specific Volume (rOUT) =	14.34	*ft³ / lb dry air*

Other Givens

Volume of Space (V) =	940	*ft³*	
Minutes per air change (MA) =	6.00	*min*	*10 ACH*

Calculated Airflow based on minimum air exchanges:

Volume of Space (V) =	940	*ft³*	
Air exchanges / min (AC)=	6	*min/AC*	
Required CFM(Air Exchange) =	157	*cfm*	*CFM = V/MA*

Jet 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}) =	90.0	°F
Air out Specific Volume (r_{OUT}) =	14.34	ft³ / lb dry air
Exhaust air specific weight	0.070	lb/cu ft
Exhaust air viscosity	4.02E-07	lb-s/sq ft^2
Exhaust air density	0.0022	slugs/cu ft
Supply air flow rate	200	cfm
Exhaust air flow rate	200	ft/min

Description	height (in)	width (in)	h/w	eqiv dia (in)	hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Exhaust Ducting														
Gooseneck inlet with screen			-	-	4.03	0.09		1	200	2258	7.05E+04	0.024	1.400	30.78
4" Sch 40 pipe			-	-	4.03	0.09	5	1	200	2258	7.05E+04	0.024	0.364	8.01
Fan			-	-	4.00	0.09		1	200	2292	7.11E+04	0.024	0.000	0.00
Sudden Expansion, fan outlet			-	-	4.03	0.09		1	200	2258	7.05E+04	0.024	0.510	11.21
Screen			-	-	4.03	0.09		1	200	2258	7.05E+04	0.024	0.240	5.28
													Segment total pressure	55.29

Description	height (in)	width (in)	h/w		hyd diam (in)	area (sq ft)	length (ft)	qty	q (cfm)	v (ft/min)	Re	f	K	h_L (ft)
Supply Vent														
Inlet - Projecting			-	-	4.03	0.09		1	200	2258	6.82E+04	0.025	0.550	12.09
4" Sch 40 pipe			-	-	4.03	0.09	5	1	200	2258	6.82E+04	0.025	0.366	8.04
Gooseneck outlet with screen			-	-	4.03	0.09		1	200	2258	6.82E+04	0.025	2.000	43.98
													Segment total pressure	*64.11*

	FT	in H2O
exhaust air total pressure	55.29	0.744
supply air total pressure	64.11	0.863
Total	119.40	1.607
15% design margin	137.31	1.848

Supply Fan Static Pressure	
Fan Dia (in)	4.00
Fan area (ft2)	0.09
flowrate (cfm)	200
velocity (fpm)	2292
fan velocity pressure	0.3043
Static Pressure for fan selection (in H20)	**1.544**

Appendix B

Fuel Oil System

1 DESCRIPTION

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

2 PROCEDURE

Calculations are presented in the following sequence:

- Pipe size calculations
- Engine fuel pump suction pressure calculations

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

3 GIVEN AND ASSUMED PARAMETERS

- Maximum fuel flow rate to each main engine is 3.53 gpm, from [1].
- Maximum fuel flow rate to each generator is 0.16 gpm, from [2].
- Piping system lengths, routing, fittings, etc. are estimated based on the Profiles and Arrangements, and Fuel Oil Diagram [3] [4].
- Listed main engine fuel system design constraints [1]:

Table 1: Main Engine Fuel System Design Constraints

Engine	Maximum
Allowable supply line restriction to main engine	4.37 psi
Allowable return line restriction to main engine	3.93 psi

- Pressure drop across the Racor 791000MAVM triplex fuel filter for a flowrate of 3.53 gpm is 1 psi, from [5].
- Pressure drop across the Racor 1000MAM fuel filter is for a flowrate of .016 gpm is 0.03 psi, from [6].
- Tank and engine elevations were estimated from [3],all elevations are in reference to the vessel's baseline:

Table2: Elevations

Elevation Point	Elevation
Fuel tank low fuel level	3.5 feet
Fuel tank high fuel level	7.5 feet
Main Engine fuel inlet	4 feet
Main Engine fuel outlet	5.8 feet
Generator fuel inlet	4.25 feet
Generator fuel outlet	4.8 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, [7]. The following table shows the flow rates of fuel occurring in the system, and the resulting pipe/tube sizes.

Table 3: Fuel Oil System Pipe Sizes and Velocities

Pipe Segment	Flow Rate gpm	Pipe/Tube Size (NPS/0.065 Wall)	ID in	Design Velocity (ft/s) Nominal	Limit	V ft/s
Fill Rate	50	2" Sch 80	1.940	6.96	12.00	5.29
Supply Main (2 me, 1 gen)	7.22	1.5" Tube	1.370	2.34	7.00	1.53
Return main (2 me, 1 gen)	7.22	1.5" Tube	1.370	5.85	12.00	1.53
Main Engine - Supply	3.53	1" Tube	0.870	1.87	7.00	1.86
Generator - Supply	0.16	0.5" Tube	0.370	1.22	7.00	0.46
Main Engine - Return	3.53	1" Tube	0.870	4.66	12.00	1.86
Generator - Return	0.16	0.5" Tube	0.370	3.04	12.00	0.46

5.2 Engine Fuel Suction Pressure Calculations

The main engines are supplied with fuel pumps used to draw fuel from fuel tanks. The attached system model confirms that the piping systems are compatible with the engines' fuel supply allowable line restriction requirements. As listed above, the maximum fuel line restriction is 4.37 psi. The attached model shows the calculated pressure loss to be 1.95 psi.

Due to the very low fuel flow rate of the generators compared to the fuel filter and tubing size, the calculated pressure loss for the generator fuel suction is 0.85 psi.

5.3 Engine Fuel Return Pressure Calculations

The attached model of the fuel system's return piping confirms that the backpressure at the main engines does not exceed the listed maximum value of 3.93psi. The return line restriction at the main engines was found to be 1.35 psi.

The generators fuel return line restriction was found to be 1.5 psi as shown in the attached model.

6 REFERENCES

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

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

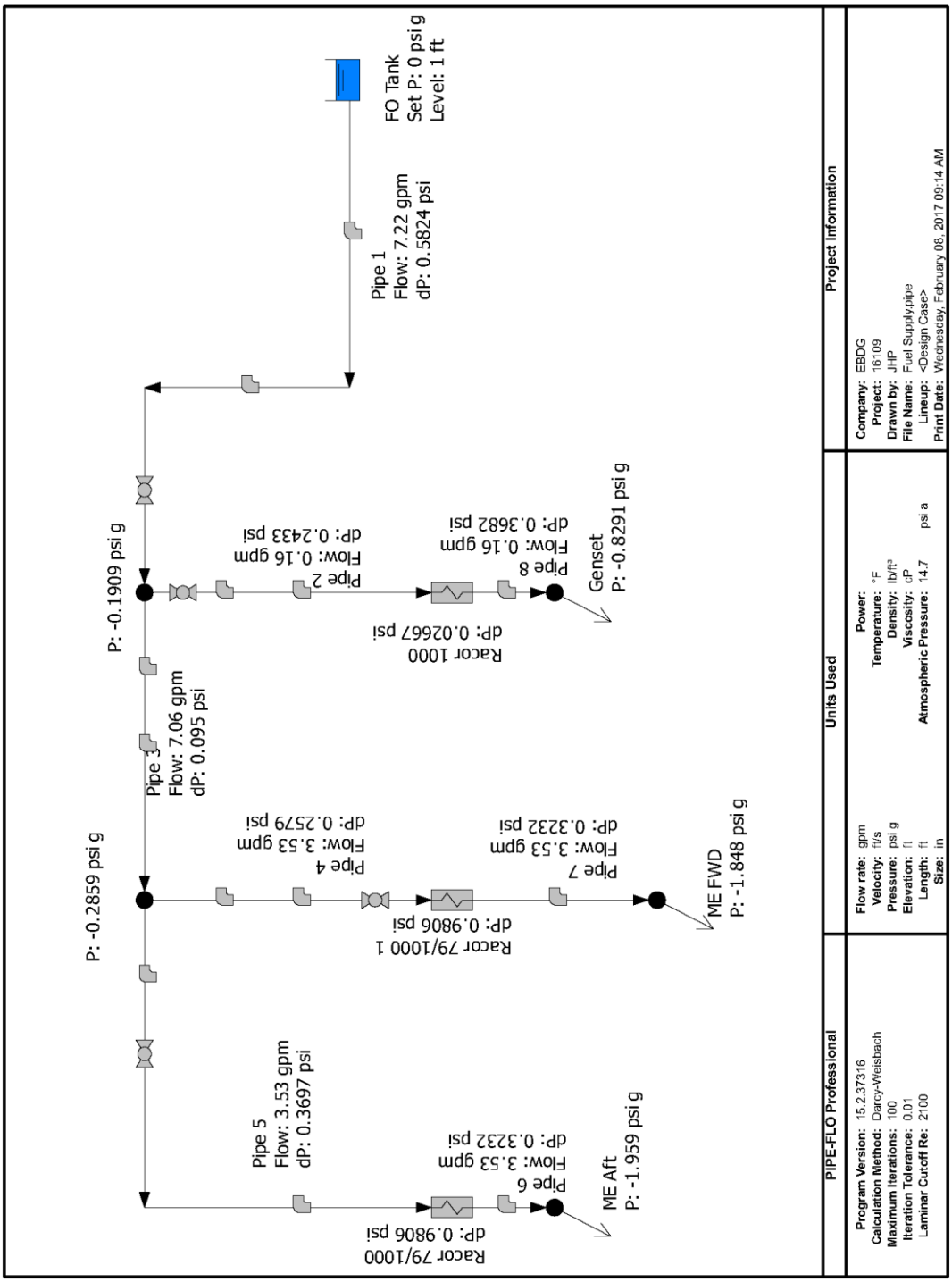
[3] Elliott Bay Design Group, "NCDOT Pedestrian Ferry: Profiles and Arrangements," 16109-003-101-1, Seattle, WA.

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

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

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

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


FO Tank
Set P: 0 psi g
Level: 1 ft
Pipe 1
Flow: 7.22 gpm
dP: 0.5824 psi
P: -0.1909 psi g
Pipe 2
Flow: 0.16 gpm
dP: 0.2433 psi
Pipe 8
Flow: 0.16 gpm
dP: 0.3682 psi
Genset
P: -0.8291 psi g
Racor 1000
dP: 0.02667 psi
Pipe 3
Flow: 7.06 gpm
dP: 0.095 psi
P: -0.2859 psi g
Pipe 4
Flow: 3.53 gpm
dP: 0.2579 psi
Pipe 7
Flow: 3.53 gpm
dP: 0.3232 psi
ME FWD
P: -1.848 psi g
Racor 79/1000 1
dP: 0.9806 psi
Pipe 5
Flow: 3.53 gpm
dP: 0.3697 psi
Pipe 6
Flow: 3.53 gpm
dP: 0.3232 psi
ME Aft
P: -1.959 psi g
Racor 79/1000
dP: 0.9806 psi
PIPE-FLO Professional
Program Version: 15.2.37316
Calculation Method: Darcy-Weisbach
Maximum Iterations: 100
Iteration Tolerance: 0.01
Laminar Cutoff Re: 2100
Units Used
Flow rate: gpm
Velocity: ft/s
Pressure: psi g
Elevation: ft
Length: ft
Size: in
Power:
Temperature: °F
Density: lb/ft³
Viscosity: cP
Atmospheric Pressure: 14.7 psi a
Project Information
Company: EBDG
Project: 16109
Drawn by: JHP
File Name: Fuel Supply.pipe
Lineup: <Design Case>
Print Date: Wednesday, February 08, 2017 09:14 AM

List Report

File Name: Fuel Supply.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

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

Company: EBDG
Project: 16109
by: JHP
Date: Wednesday, February 08, 2017 09:14 AM

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria	Design Limits: Velocity	Design Limits: Pressure	Design Limits: Reynolds Number
ASTM-A-269 .120 Wall standard	SSteel ASTM-A-269 Schedule:.12	6E-05 in 100	0.0	to ft/s	to psi g	to
ASTM-A-269 .049 Wall standard	SSteel ASTM-A-269 Schedule:.049	6E-05 in 100	0.0	to ft/s	to psi g	to
ASTM-A-269 .083 Wall standard	SSteel ASTM-A-269 Schedule:.083	6E-05 in 100	0.0	to ft/s	to psi g	to
ASTM-A-269 0.065 Wall standard	SSteel ASTM-A-269 Schedule:.065	6E-05 in 100	0.0	to ft/s	to psi g	to

Fluid Zones

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

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Elevation / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number	Total Head Loss / V&F Head Loss	Inlet Pressure / Outlet Pressure	Total dP / V&F dP	Pipe Friction Factor / V&F Friction Factor / V&F Resistance K
Pipe 1 ASTM-A-269 0.065 Wall Fuel 3	1.5 in 1.37 in 25 ft	2.5 ft 3.5 ft	7.22 gpm 1.571 ft/s 1477	0.4875 ft 0.1233 ft	0.3915 psi g -0.1909 psi g	0.5824 psi 0.04829 psi	0.04333 0.02101 3.21
Inlet Device: FO Tank			**Outlet Device:** Node 1				
Pipe 3 ASTM-A-269 0.065 Wall Fuel 3	1.5 in 1.37 in 10 ft	3.5 ft 3.5 ft	7.06 gpm 1.537 ft/s 1444	0.2426 ft 0.1002 ft	-0.1909 psi g -0.2859 psi g	0.095 psi 0.03923 psi	0.04432 0.02101 2.73
Inlet Device: Node 1			**Outlet Device:** Node 2				
Pipe 5 ASTM-A-269 0.065 Wall Fuel 3	1 in 0.87 in 15 ft	3.5 ft 3.5 ft	3.53 gpm 1.905 ft/s 1137	0.9443 ft 0.2874 ft	-0.2859 psi g -0.6556 psi g	0.3697 psi 0.1125 psi	0.05629 0.02363 5.10
Inlet Device: Node 2			**Outlet Device:** Racor 79/1000				
Pipe 6 ASTM-A-269 0.065 Wall Fuel 3	1 in 0.87 in 5 ft	3.5 ft 4 ft	3.53 gpm 1.905 ft/s 1137	0.3256 ft 0.1066 ft	-1.636 psi g -1.959 psi g	0.3232 psi 0.04175 psi	0.05629 0.02363 1.89
Inlet Device: Racor 79/1000			**Outlet Device:** ME Aft				
Pipe 4 ASTM-A-269 0.065 Wall Fuel 3	1 in 0.87 in 10 ft	3.5 ft 3.5 ft	3.53 gpm 1.905 ft/s 1137	0.6587 ft 0.2208 ft	-0.2859 psi g -0.5437 psi g	0.2579 psi 0.08644 psi	0.05629 0.02363 3.91
Inlet Device: Node 2			**Outlet Device:** Racor 79/1000 1				

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Elevation / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number	Total Head Loss / V&F Head Loss	Inlet Pressure / Outlet Pressure	Total dP / V&F dP	Pipe Friction Factor / V&F Friction Factor / V&F Resistance K
Pipe 7	1 in	3.5 ft	3.53 gpm	0.3256 ft	-1.524 psi g	0.3232 psi	0.05629
ASTM-A-269 0.065 Wall	0.87 in	4 ft	1.905 ft/s	0.1066 ft	-1.848 psi g	0.04175 psi	0.02363
Fuel 3	5 ft		1137				1.89
	Inlet Device: Racor 79/1000 1		**Outlet Device:** ME FWD				
Pipe 2	0.5 in	3.5 ft	0.16 gpm	0.6215 ft	-0.1909 psi g	0.2433 psi	0.5281
ASTM-A-269 0.065 Wall	0.37 in	3.5 ft	0.4774 ft/s	0.01476 ft	-0.4342 psi g	5.780E-03 psi	0.03012
Fuel 3	10 ft		121.2				4.17
	Inlet Device: Node 1		**Outlet Device:** Racor 1000				
Pipe 8	0.5 in	3.5 ft	0.16 gpm	0.1906 ft	-0.4608 psi g	0.3682 psi	0.5281
ASTM-A-269 0.065 Wall	0.37 in	4.25 ft	0.4774 ft/s	8.535E-03 ft	-0.8291 psi g	3.341E-03 psi	0.03012
Fuel 3	3 ft		121.2				2.41
	Inlet Device: Racor 1000		**Outlet Device:** Genset				

Tanks

Tank Name / Fluid Zone	Bottom Elevation / Liquid Level	Surface Pressure / Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
FO Tank	2.5 ft	0 psi g	3.5 ft				
Fuel 3	1 ft	0.3915 psi g					
				Pipe 1	0 ft	7.22 gpm	0.3915 psi g

Curve dP Devices

Curve dP Device Name / Description	Inlet Elevation / Inlet Pressure	Outlet Elevation / Outlet Pressure	dP / Head Loss	Flow Rate
Racor 79/1000	3.5 ft	3.5 ft	0.9806 psi	3.53 gpm
Racor 79/1000	-0.6556 psi g	-1.636 psi g	2.504 ft	
Racor 1000	3.5 ft	3.5 ft	0.02667 psi	0.16 gpm
Racor 1000	-0.4342 psi g	-0.4608 psi g	0.06811 ft	
Racor 79/1000 1	3.5 ft	3.5 ft	0.9806 psi	3.53 gpm
Racor 79/1000	-0.5437 psi g	-1.524 psi g	2.504 ft	

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	3.5 ft	-0.1909 psi g	2.986 ft
Node 2	3.5 ft	-0.2859 psi g	2.72 ft

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
ME Aft	4 ft	-1.959 psi g	-1.061 ft		Flow out
ME FWD	4 ft	-1.848 psi g	-0.7753 ft		Flow out
Genset	4.25 ft	-0.8291 psi g	2.129 ft		Flow out

Bill of Materials Report

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

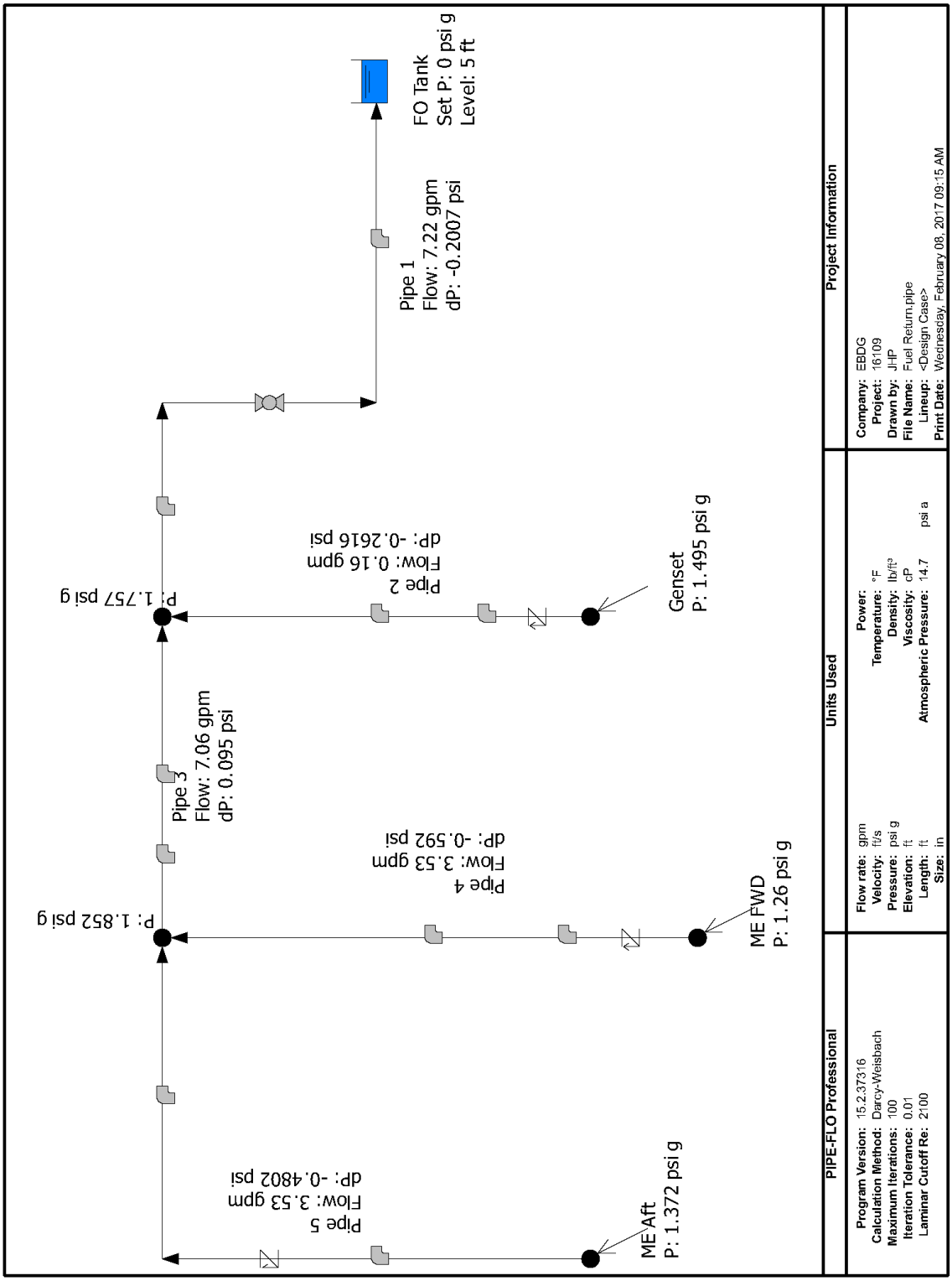
Company: EBDG
Project: 16109
by: JHP
Date: Wednesday, February 08, 2017 09:15 AM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	ASTM-A-269 0.065 Wall	1.5 in	25 ft	3 x Elbow - Standard 90° 3 x Pipe Bend - r/d 1 (90°) 1 x Ball
Pipe 3	ASTM-A-269 0.065 Wall	1.5 in	10 ft	2 x Pipe Bend - r/d 1 (90°) 3 x Elbow - Standard 90°
Pipe 5	ASTM-A-269 0.065 Wall	1 in	15 ft	1 x Ball 4 x Pipe Bend - r/d 1 (90°) 4 x Elbow - Standard 90° 1 x Reducer - Contraction (1 in x 1.5 in -
Pipe 6	ASTM-A-269 0.065 Wall	1 in	5 ft	4 x Pipe Bend - r/d 1 (90°)
Pipe 4	ASTM-A-269 0.065 Wall	1 in	10 ft	3 x Pipe Bend - r/d 1 (90°) 3 x Elbow - Standard 90° 1 x Ball 1 x Reducer - Contraction (1 in x 1.5 in -
Pipe 7	ASTM-A-269 0.065 Wall	1 in	5 ft	4 x Pipe Bend - r/d 1 (90°)
Pipe 2	ASTM-A-269 0.065 Wall	0.5 in	10 ft	3 x Pipe Bend - r/d 1 (90°) 2 x Elbow - Standard 90° 1 x Reducer - Contraction (0.5 in x 1.5 in 1 x Ball
Pipe 8	ASTM-A-269 0.065 Wall	0.5 in	3 ft	4 x Pipe Bend - r/d 1 (90°)

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
ASTM-A-269 0.065 Wall	SSteel ASTM-A-269 Schedule: .065	0.5 in	13.00 ft	1 x Ball 2 x Elbow - Standard 90° 7 x Pipe Bend - r/d 1 (90°) 1 x Reducer - Contraction (0.5 in x 1.5 in - 0 in)
ASTM-A-269 0.065 Wall	SSteel ASTM-A-269 Schedule: .065	1 in	35.00 ft	2 x Ball 7 x Elbow - Standard 90° 15 x Pipe Bend - r/d 1 (90°) 2 x Reducer - Contraction (1 in x 1.5 in - 0 in)
ASTM-A-269 0.065 Wall	SSteel ASTM-A-269 Schedule: .065	1.5 in	35.00 ft	1 x Ball 6 x Elbow - Standard 90° 5 x Pipe Bend - r/d 1 (90°)


FO Tank
Set P: 0 psi g
Level: 5 ft
Pipe 1
Flow: 7.22 gpm
dP: -0.2007 psi
Genset
P: 1.495 psi g
Pipe 2
Flow: 0.16 gpm
dP: -0.2616 psi
P: 1.757 psi g
Pipe 3
Flow: 7.06 gpm
dP: 0.095 psi
ME FWD
P: 1.26 psi g
Pipe 4
Flow: 3.53 gpm
dP: -0.592 psi
P: 1.852 psi g
ME Aft
P: 1.372 psi g
Pipe 5
Flow: 3.53 gpm
dP: -0.4802 psi
PIPE-FLO Professional
Program Version: 15.2.37316
Calculation Method: Darcy-Weisbach
Maximum Iterations: 100
Iteration Tolerance: 0.01
Laminar Cutoff Re: 2100
Units Used
Flow rate: gpm
Velocity: ft/s
Pressure: psi g
Elevation: ft
Length: ft
Size: in
Power:
Temperature: °F
Density: lb/ft³
Viscosity: cP
Atmospheric Pressure: 14.7 psi a
Project Information
Company: EBDG
Project: 16109
Drawn by: JHP
File Name: Fuel Return.pipe
Lineup: <Design Case>
Print Date: Wednesday, February 08, 2017 09:15 AM

List Report

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

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

Company: EBDG
Project: 16109
by: JHP
Date: Wednesday, February 08, 2017 09:16 AM

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria	Design Limits Velocity		Pressure		Reynolds Number
ASTM-A-269 .120 Wall standard	SSteel ASTM-A-269 Schedule:.12	6E-05 in 100	0.0	to	ft/s	to	psi g	to
ASTM-A-269 .049 Wall standard	SSteel ASTM-A-269 Schedule:.049	6E-05 in 100	0.0	to	ft/s	to	psi g	to
ASTM-A-269 .083 Wall standard	SSteel ASTM-A-269 Schedule:.083	6E-05 in 100	0.0	to	ft/s	to	psi g	to
ASTM-A-269 0.065 Wall standard	SSteel ASTM-A-269 Schedule:.065	6E-05 in 100	0.0	to	ft/s	to	psi g	to

Fluid Zones

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

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Elevation Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number	Total Head Loss V&F Head Loss	Inlet Pressure Outlet Pressure	Total dP V&F dP	Pipe Friction Factor V&F Friction Factor V&F Resistance K
Pipe 1	1.5 in	3.5 ft	7.22 gpm	0.4875 ft	1.757 psi g	-0.2007 psi	0.04333
ASTM-A-269 0.065 Wall	1.37 in	2.5 ft	1.571 ft/s	0.1233 ft	1.958 psi g	0.04829 psi	0.02101
Fuel 3	25 ft		1477				3.21
	Inlet Device: Node 1		**Outlet Device:** FO Tank				
Pipe 2	0.5 in	4.8 ft	0.16 gpm	0.6318 ft	1.495 psi g	-0.2616 psi	0.5281
ASTM-A-269 0.065 Wall	0.37 in	3.5 ft	0.4774 ft/s	0.02511 ft	1.757 psi g	9.832E-03 psi	0.03012
Fuel 3	10 ft		121.2				7.09
	Inlet Device: Genset		**Outlet Device:** Node 1				
Pipe 4	1 in	5.8 ft	3.53 gpm	0.788 ft	1.26 psi g	-0.592 psi	0.05629
ASTM-A-269 0.065 Wall	0.87 in	3.5 ft	1.905 ft/s	0.3501 ft	1.852 psi g	0.1371 psi	0.02363
Fuel 3	10 ft		1137				6.21
	Inlet Device: ME FWD		**Outlet Device:** Node 2				
Pipe 5	1 in	5.8 ft	3.53 gpm	1.074 ft	1.372 psi g	-0.4802 psi	0.05629
ASTM-A-269 0.065 Wall	0.87 in	3.5 ft	1.905 ft/s	0.4167 ft	1.852 psi g	0.1632 psi	0.02363
Fuel 3	15 ft		1137				7.39
	Inlet Device: ME Aft		**Outlet Device:** Node 2				
Pipe 3	1.5 in	3.5 ft	7.06 gpm	0.2426 ft	1.852 psi g	0.095 psi	0.04432
ASTM-A-269 0.065 Wall	1.37 in	3.5 ft	1.537 ft/s	0.1002 ft	1.757 psi g	0.03923 psi	0.02101
Fuel 3	10 ft		1444				2.73
	Inlet Device: Node 2		**Outlet Device:** Node 1				

Tanks

Tank Name / Fluid Zone	Bottom Elevation / Liquid Level	Surface Pressure / Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
FO Tank Fuel 3	2.5 ft 5 ft	0 psi g 1.958 psi g	7.5 ft				
				Pipe 1	0 ft	7.22 gpm	1.958 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	3.5 ft	1.757 psi g	7.961 ft
Node 2	3.5 ft	1.852 psi g	8.18 ft

Flow Demands

Flow Demand Name	Elevation	Pressure	Hydraulic Grade	Flow Rate	Flow Direction
ME Aft	5.8 ft	1.372 psi g	9.247 ft		Flow in
ME FWD	5.8 ft	1.26 psi g	8.962 ft		Flow in
Genset	4.8 ft	1.495 psi g	8.616 ft		Flow in

Bill of Materials Report

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

Company: EBDG
Project: 16109
by: JHP
Date: Wednesday, February 08, 2017 09:16 AM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	ASTM-A-269 0.065 Wall	1.5 in	25 ft	3 x Elbow - Standard 90° 3 x Pipe Bend - r/d 1 (90°) 1 x Ball
Pipe 2	ASTM-A-269 0.065 Wall	0.5 in	10 ft	3 x Pipe Bend - r/d 1 (90°) 2 x Elbow - Standard 90° 1 x Reducer - Contraction (0.5 in x 1.5 in 1 x Swing Check - Angled
Pipe 4	ASTM-A-269 0.065 Wall	1 in	10 ft	3 x Pipe Bend - r/d 1 (90°) 3 x Elbow - Standard 90° 1 x Reducer - Contraction (1 in x 1.5 in - 1 x Swing Check - Angled
Pipe 5	ASTM-A-269 0.065 Wall	1 in	15 ft	4 x Pipe Bend - r/d 1 (90°) 4 x Elbow - Standard 90° 1 x Reducer - Contraction (1 in x 1.5 in - 1 x Swing Check - Angled
Pipe 3	ASTM-A-269 0.065 Wall	1.5 in	10 ft	2 x Pipe Bend - r/d 1 (90°) 3 x Elbow - Standard 90°

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
ASTM-A-269 0.065 Wall	SSteel ASTM-A-269 Schedule: .065	0.5 in	10.00 ft	2 x Elbow - Standard 90° 3 x Pipe Bend - r/d 1 (90°) 1 x Reducer - Contraction (0.5 in x 1.5 in - 0 in) 1 x Swing Check - Angled
ASTM-A-269 0.065 Wall	SSteel ASTM-A-269 Schedule: .065	1 in	25.00 ft	7 x Elbow - Standard 90° 7 x Pipe Bend - r/d 1 (90°) 2 x Reducer - Contraction (1 in x 1.5 in - 0 in) 2 x Swing Check - Angled
ASTM-A-269 0.065 Wall	SSteel ASTM-A-269 Schedule: .065	1.5 in	35.00 ft	1 x Ball 6 x Elbow - Standard 90° 5 x Pipe Bend - r/d 1 (90°)

Appendix C

Sea Chests and Seawater Cooling

1 DESCRIPTION

This appendix documents the calculations used in designing the seawater cooling system. These calculations establish minimum sea chest area and seawater suction pipe sizes. Estimated losses through the system piping are not calculated as the system heat exchangers are supplied by the engine manufacturers and all cooling lines discharge into wet exhaust systems designed and provided by others.

2 PROCEDURE

Calculations are presented in the following sequence:

- Seawater pipe nominal velocity calculation
- Sea chest cross sectional area

Initial pipe sizes are based on the nominal velocity limits found in [1], Chapter 20, Table 3.

3 GIVEN AND ASSUMED PARAMETERS

- Seawater system is to be constructed of sch 40 aluminum pipe.
- System pipe lengths, routing and fittings are estimated based on the Profiles and Arrangements, [2].
- Total area of pipes connected to an individual sea chest is 7.393 square inches based upon one 3 inch sch 40 suction pipe.

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Pipe Nominal Velocity Calculation

Pipe sizes are based on the nominal velocity limits found in [1]. Table 1 shows the flows occurring in all branches of the system, and the resulting pipe sizes:

Table 1: Nominal Pipe Velocities

Pipe Segment	Flow Rate	Pipe Size	ID	Design Velocity (ft/s)		V
	gpm	(NPS)	in	Nominal	Limit	ft/s
Main Engine	100	3" Sch 40	3.068	5.25	15.00	4.23
Generator	11.3	1" Sch 40	1.049	3.07	15.00	4.09
Fire Pump	50	2" Sch 40	2.067	4.31	15.00	4.66
Main Engine & Generator	111.3	3" Sch 40	3.068	5.25	15.00	4.70
Jet Oil Cooler	4	1" Hose	1.000	5.00	15.00	1.59

5.2 Sea Chest Cross Sectional Area

From the calculations below, the minimum cross sectional area for the sea chest is 51.6 square inches.

INPUTS

Units Used: US

A_p =	7.39	in2	Total area of pipes taking suction from sea chest
$\%_{fa}$ =	50%		Strainer percent free (clear) area
R_{min}=	1.5		ABS Required strainer clear area to suction area
R=	3		Chosen clear area ratio, not less than $R_{min.}$

CALCULATION OF SEA CHEST CROSS SECTIONAL AREA

A_{sc} =	A_p*R / $\%_{fa}$		Sea chest cross sectional area
A_{sc} =	**44.36**	in2	Sea chest cross sectional area

REFERENCES

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

[2] Elliott Bay Design Group, "Profiles and Arrangements," 16109-003-101 , Seattle, WA.

Appendix D

Fire Main

1 DESCRIPTION

This appendix documents the calculations used in designing the fire main system. These calculations establish required pump capacity and quantity in accordance with regulatory requirements. Estimated losses through the system piping are calculated to establish the total dynamic head (TDH) of the fire pump.

2 PROCEDURE

Calculations are presented in the following sequence:

- Fire main pipe nominal velocity calculation
- Fire pump total dynamic head (TDH)

Minimum fire pump capacity is based upon the requirements found in [1].

Initial pipe sizes are based on the nominal velocity limits found in [2], Chapter 20, Table 3.

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

3 GIVEN AND ASSUMED PARAMETERS

- Fire main system is to be constructed of sch 40 aluminum piping.
- System pipe lengths, routing and fittings are estimated based on the Profiles and Arrangements, [3].
- In accordance with [1], the fire pump is required to produce 50 gpm with a 60 psig discharge pressure at the outlet of the pump.
- System will be equipped with 1-1/2" UL listed fire hoses and USCG approved nozzles.

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Pipe Nominal Velocity Calculation

Pipe sizes are based on the nominal velocity limits found in [2]. Table 1 shows the flows occurring in all branches of the system, and the resulting pipe sizes:

Table 1: Nominal Pipe Velocities

Pipe Segment	Flow Rate gpm	Pipe Size (NPS)	ID in	Design Velocity (ft/s) Nominal	Limit	V ft/s
Firemain Suction	50	2" Sch 40	2.067	4.31	15.00	4.66
Firemain Discharge	50	2" Sch 40	2.067	7.19	15.00	4.66
Firemain Branch	50	1-1/2" Sch 40	1.610	6.34	15.00	7.67

5.2 Fire Pump TDH and NPSH Calculation

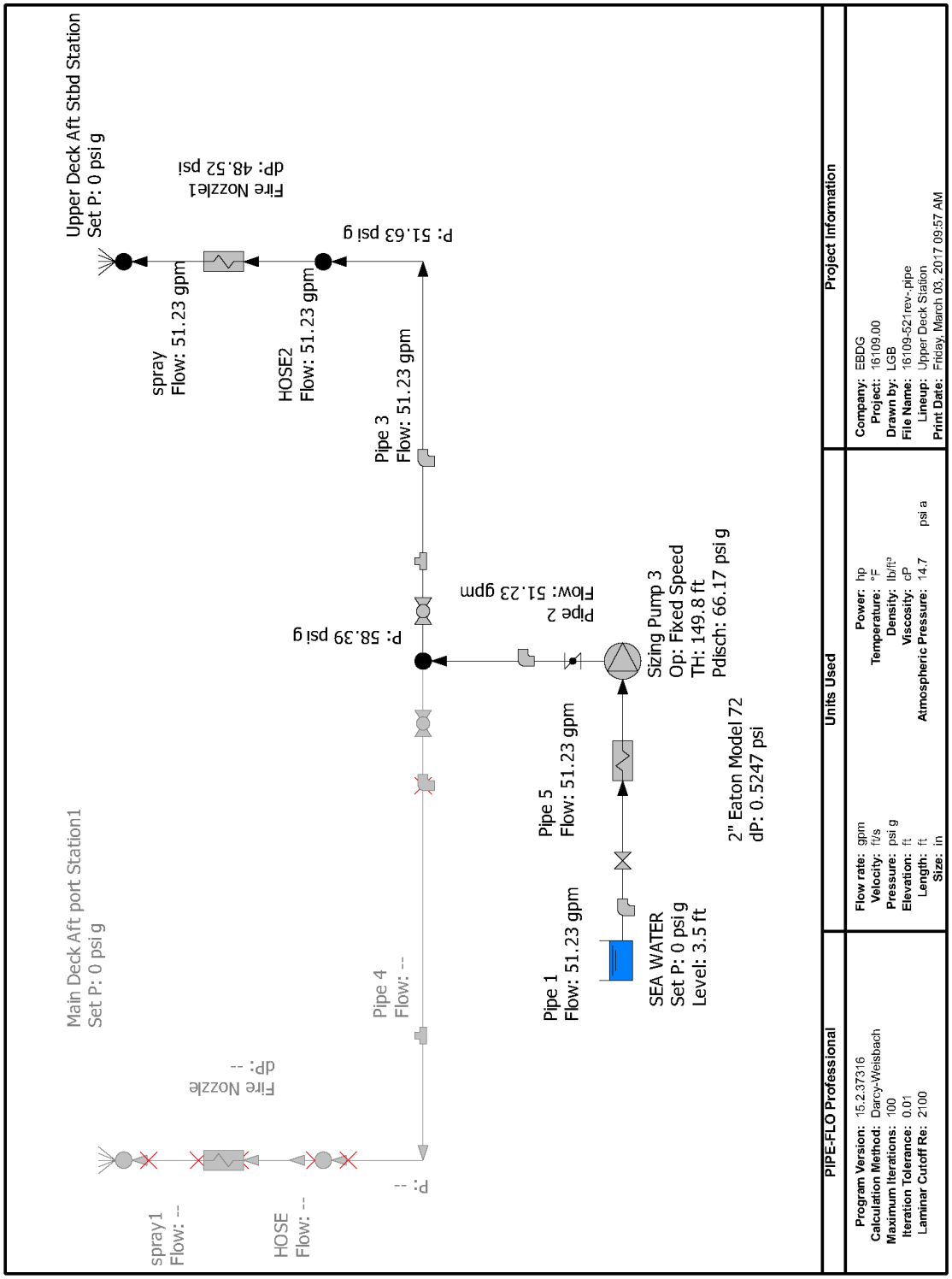
From the attached PIPE-FLO model, the fire pump is required to produce about 150 feet TDH at the required flow rate of 51 gpm.

REFERENCES

[1] USCG, "46 CFR, Chapter I, Subchapter T, Part 181 Fire Protection Equipment," 12/8/2016.

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

[3] Elliott Bay Design Group, "Profiles and Arrangements," 16109-003-101 , Seattle, WA.


Upper Deck Aft Stbd Station
Set P: 0 psi g
Fire Nozzle1
dP: 48.52 psi
P: 51.63 psi g
spray
Flow: 51.23 gpm
HOSE2
Flow: 51.23 gpm
Pipe 3
Flow: 51.23 gpm
P: 58.39 psi g
Pipe 2
Flow: 51.23 gpm
Sizing Pump 3
Op: Fixed Speed
TH: 149.8 ft
Pdisch: 66.17 psi g
2" Eaton Model 72
dP: 0.5247 psi
Pipe 5
Flow: 51.23 gpm
Pipe 1
Flow: 51.23 gpm
SEA WATER
Set P: 0 psi g
Level: 3.5 ft
Main Deck Aft port Station1
Set P: 0 psi g
Pipe 4
Flow: --
Fire Nozzle
dP: --
P: --
spray1
Flow: --
HOSE
Flow: --
PIPE-FLO Professional
Program Version: 15.2.37316
Calculation Method: Darcy-Weisbach
Maximum Iterations: 100
Iteration Tolerance: 0.01
Laminar Cutoff Re: 2100
Units Used
Flow rate: gpm
Velocity: ft/s
Pressure: psi g
Elevation: ft
Length: ft
Size: in
Power: hp
Temperature: °F
Density: lb/ft³
Viscosity: cP
Atmospheric Pressure: 14.7 psi a
Project Information
Company: EBDG
Project: 16109.00
Drawn by: LGB
File Name: 16109-52 rev-.pipe
Lineup: Upper Deck Station
Print Date: Friday, March 03, 2017 09:57 AM

List Report

File Name: 16109-521rev-.pipe
Lineup: Upper Deck Station
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

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

Company: EBDG
Project: 16109.00
by: LGB
Date: Friday, March 03, 2017 09:55 AM

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria	Design Limits: Velocity	Pressure	Reynolds Number
CuNi Class 200 standard	Copper Nickel MIL-T-16420K Schedule:Class 200	6E-05 in 150	0.0	to ft/s	to psi g	to
Al B241 sch 40 standard	Aluminum B241 Schedule:40	6E-05 in 140	0.0	to ft/s	to psi g	to

Fluid Zones

Fluid Zone Name / Table Name	Temperature	Pressure	Fluid State	Density / Viscosity	Vapor Pressure / Critical Pressure	Specific Heat Ratio (k) / Relative Molecular Mass
Seawater	65 °F	0 psi g	Liquid	64 lb/ft³	0.2997 psi a	--
Seawater 3.5% Salinity				1.127 cP	3199 psi a	29

Centrifugal Pumps

Pump Name	Test Speed / Operating Speed	Suction Elevation / Suction Pressure	Discharge Elevation / Discharge Pressure	Total Head / dP	Flow Rate / Power	Efficiency / BEP Efficiency	NPSHa / NPSHr	Design NPSH Margin Ratio
Sizing Pump 3 Fixed Speed	3500 rpm 3500 rpm	2 ft -0.4013 psi g	2 ft 66.17 psi g	149.8 ft 66.57 psi	51.23 gpm 4.279 hp	46.2 % 51 %	31.49 ft 9.998 ft	--
Company: Ampco Pumps Curve: Catalog Pump Type: Z-SERIES		Size: 1.5x1.25SS Diameter: 6 in POR: from -- to --						
Sizing Pump 2 Fixed Speed	3500 --	2 ft --	2 ft --	-- --	-- --	-- 51 %	-- --	--
Company: Ampco Pumps Curve: Catalog Pump Type: Z-SERIES		Size: 1.5x1.25SS Diameter: 6 in POR: from -- to --						

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Elevation / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number	Total Head Loss / V&F Head Loss	Inlet Pressure / Outlet Pressure	Total dP / V&F dP	Pipe Friction Factor / V&F Friction Factor / V&F Resistance K
Pipe 2 Al B241 sch 40 Seawater	2 in 2.067 in 35 ft	2 ft 16 ft	51.23 gpm 4.899 ft/s 71293	3.493 ft 2.018 ft	66.17 psi g 58.39 psi g	7.775 psi 0.897 psi	0.01946 0.01899 5.41
Inlet Device: Sizing Pump 3			**Outlet Device:** Node 1				
Pipe 4 Al B241 sch 40 Seawater	1.5 in 1.61 in 30 ft	16 ft 16 ft	-- -- --	-- --	58.39 psi g --	-- --	-- -- 9.28
Inlet Device: Node 1			**Outlet Device:** Node 2				
Pipe 3 Al B241 sch 40 Seawater	1.5 in 1.61 in 15 ft	16 ft 23 ft	51.23 gpm 8.074 ft/s 91529	8.225 ft 6.128 ft	58.39 psi g 51.63 psi g	6.767 psi 2.724 psi	0.01852 0.02018 6.05
Inlet Device: Node 1			**Outlet Device:** Node 3				

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Elevation Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number	Total Head Loss V&F Head Loss	Inlet Pressure Outlet Pressure	Total dP V&F dP	Pipe Friction Factor V&F Friction Factor V&F Resistance K
Pipe 1 Al B241 sch 40 Seawater	2 in 2.067 in 5 ft	0 ft 2 ft	51.23 gpm 4.899 ft/s 71293	1.117 ft 0.9065 ft	1.556 psi g 0.1702 psi g	1.385 psi 0.4029 psi	0.01946 0.01899 2.43
	Inlet Device: SEA WATER		**Outlet Device:** 2" Eaton Model 72				
Pipe 5 Al B241 sch 40 Seawater	2 in 2.067 in 2.5 ft	2 ft 2 ft	51.23 gpm 4.899 ft/s 71293	0.1053 ft 0 ft	-0.3545 psi g -0.4013 psi g	0.0468 psi 0 psi	0.01946 0.01899 0.00
	Inlet Device: 2" Eaton Model 72		**Outlet Device:** Sizing Pump 3				
HOSE Al B241 sch 40 Seawater	1.5 in 1.61 in 50 ft	16 ft 16 ft	-- -- --	-- --	-- --	-- --	-- -- 0.00
	Inlet Device: Node 2		**Outlet Device:** Fire Nozzle				
spray1 Al B241 sch 40 Seawater	1.5 in 1.61 in 0.01 ft	16 ft 16 ft	-- -- --	-- --	-- 0 psi g	-- --	-- -- 0.00
	Inlet Device: Fire Nozzle		**Outlet Device:** Main Deck Aft port Station1				
HOSE2 Al B241 sch 40 Seawater	1.5 in 1.61 in 50 ft	23 ft 23 ft	51.23 gpm 8.074 ft/s 91529	6.991 ft 0 ft	51.63 psi g 48.52 psi g	3.107 psi 0 psi	0.01852 0.02018 0.00
	Inlet Device: Node 3		**Outlet Device:** Fire Nozzle1				
spray Al B241 sch 40 Seawater	1.5 in 1.61 in 0.01 ft	23 ft 23 ft	51.23 gpm 8.074 ft/s 91529	1.398E-03 ft 0 ft	6.214E-04 psi g 0 psi g	6.214E-04 psi 0 psi	0.01852 0.02018 0.00
	Inlet Device: Fire Nozzle1		**Outlet Device:** Upper Deck Aft Stbd Station				

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	 Penetration Height	 Pipeline Flow Rate	 Pressure at Penetration
SEA WATER Seawater	0 ft 3.5 ft	0 psi g 1.556 psi g	3.5 ft				
				Pipe 1	0 ft	51.23 gpm	1.556 psi g
Fire Nozzle 1/2 Fire Nozzle	16 ft --		16 ft --	-- --	--		
Fire Nozzle1 1/2 Fire Nozzle	23 ft 48.52 psi g		23 ft 6.214E-04 psi g	48.52 psi 109.2 ft	51.23 gpm		

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	16 ft	58.39 psi g	146.7 ft
Node 2	16 ft	--	--
Node 3	23 ft	51.63 psi g	138.1 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Upper Deck Aft Stbd Station	23 ft	0 psi g	21.99 ft	51.23 gpm
Main Deck Aft port Station1	16 ft	0 psi g	--	--

Bill of Materials Report

File Name: 16109-521rev-.pipe
Lineup: Upper Deck Station
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16109.00
by: LGB
Date: Friday, March 03, 2017 09:55 AM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 2	Al B241 sch 40	2 in	35 ft	8 x Elbow - Standard 90° 1 x Butterfly
Pipe 4	Al B241 sch 40	1.5 in	30 ft	1 x Reducer - Contraction (1.5 in x 2 in - 8 x Elbow - Standard 90° 1 x Tee - Flow Thru Branch 1 x Globe - 90°, Plug In Flow Path
Pipe 3	Al B241 sch 40	1.5 in	15 ft	4 x Elbow - Standard 90° 1 x Tee - Flow Thru Run 1 x Reducer - Contraction (1.5 in x 2 in - 1 x Globe - 90°, Plug In Flow Path
Pipe 1	Al B241 sch 40	2 in	5 ft	1 x Gate - Plug Type 4 x Elbow - Standard 90°
Pipe 5	Al B241 sch 40	2 in	2.5 ft	
HOSE	Al B241 sch 40	1.5 in	50 ft	
spray1	Al B241 sch 40	1.5 in	0.01 ft	
HOSE2	Al B241 sch 40	1.5 in	50 ft	
spray	Al B241 sch 40	1.5 in	0.01 ft	

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Al B241 sch 40	Aluminum B241 Schedule: 40	1.5 in	145.02 ft	12 x Elbow - Standard 90° 2 x Globe - 90°, Plug In Flow Path 2 x Reducer - Contraction (1.5 in x 2 in - 0 in) 1 x Tee - Flow Thru Branch 1 x Tee - Flow Thru Run
Al B241 sch 40	Aluminum B241 Schedule: 40	2 in	42.50 ft	1 x Butterfly 12 x Elbow - Standard 90° 1 x Gate - Plug Type

Appendix E

Sanitary Drains and Sewage Discharge

1 DESCRIPTION

This appendix documents the calculations used in designing the sewage discharge system. These calculations establish minimum discharge pipe sizes and required pump capacity. Estimated losses through sewage discharge piping are calculated to establish total dynamic head required for the sewage discharge pump.

2 PROCEDURE

Calculations are presented in the following sequence:

- Sewage discharge pump capacity calculations
- Sewage discharge pipe nominal velocity calculations
- Sewage pump total dynamic head (TDH) calculation

Initial sewage pump capacity is based on the desire to empty the sewage-holding tank in approximately 5 minutes.

Initial pipe sizes are also based on the nominal velocity limits found in [1], Chapter 20, Table 3.

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

3 GIVEN AND ASSUMED PARAMETERS

- Sewage discharge piping is to be constructed of aluminum.
- System pipe lengths, routing and fittings are estimated based on Profiles and Arrangements [2].
- Shore side facilities are conservatively estimated as 50 feet of 2 inch hose and 200 feet of 2 inch schedule 80 steel piping with a storage tank elevation of 20 feet.

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Sewage Discharge Pump Capacity Calculation

The sewage pump capacity is based on the ability to empty the sewage-holding tank in approximately 5 minutes. With a tank of 200 gallon this results in a pump capable of approximately 40 gpm.

5.2 Pipe Nominal Velocity Calculation

Initial pipe sizes are also based on the nominal velocity limits found in [1]. Table 1 shows the flows occurring in all portions of the system, and the resulting pipe sizes:

Table 1: Nominal Pipe Velocities

Pipe Segment	Flow Rate gpm	Pipe Size (NPS)	ID in	Design Velocity (ft/s) Nominal	Limit	V ft/s
Pump Suction	40	3" Sch 80	2.900	5.11	15.00	1.89
Sewage Discharge	40	2" Sch 80	1.940	6.96	15.00	4.23

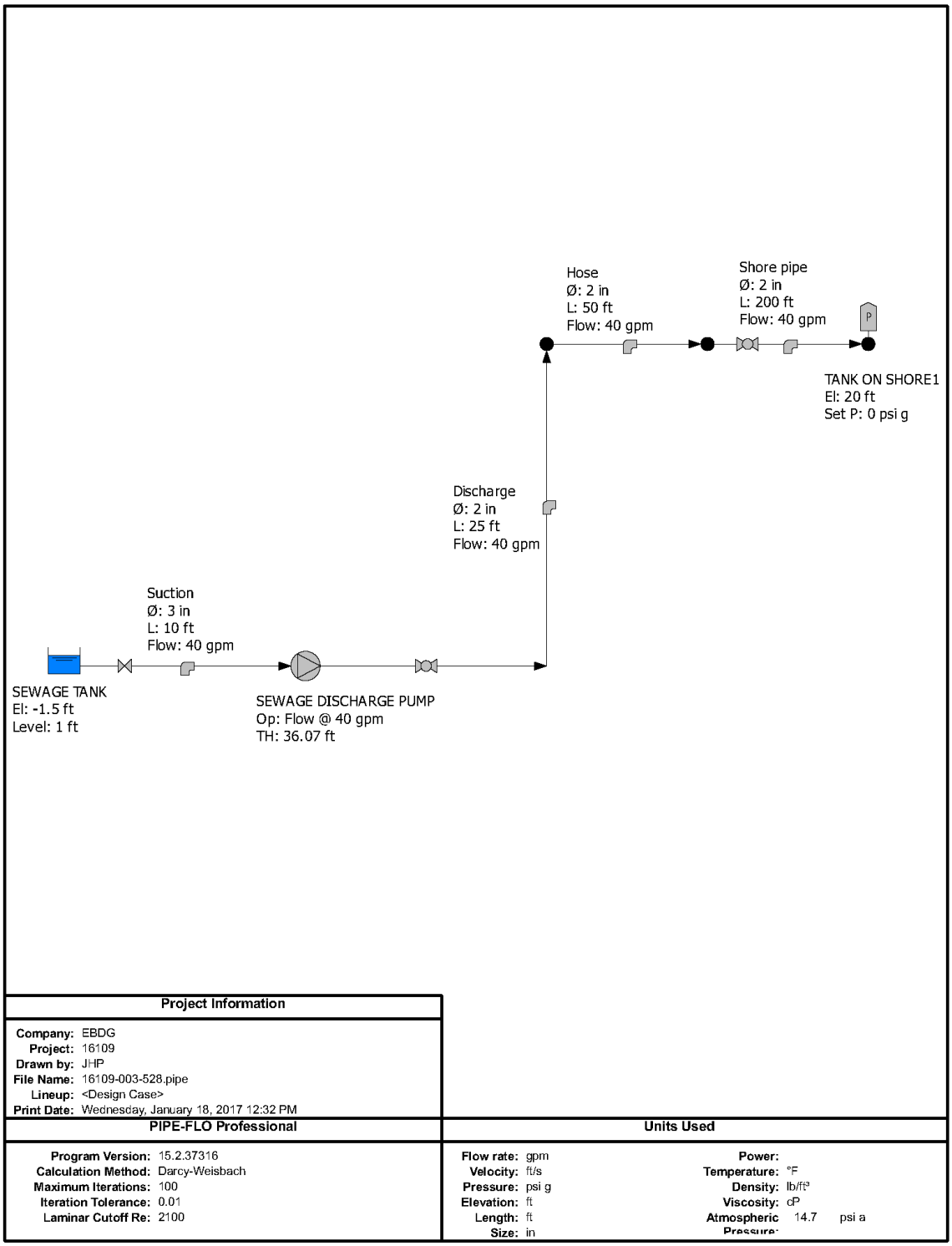
5.3 Sewage Pump TDH Calculation

From the attached PIPE-FLO model, the sewage discharge pump is required to produce about 36 feet TDH at 40 gpm.

6 REFERENCES

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

[2] Elliott Bay Design Group, "Profiles and Arrangements," 16109-003-101-1, Seattle, WA.



Project Information

Company:	EBDG
Project:	16109
Drawn by:	JHP
File Name:	16109-003-528.pipe
Lineup:	<Design Case>
Print Date:	Wednesday, January 18, 2017 12:32 PM

PIPE-FLO Professional

Program Version:	15.2.37316
Calculation Method:	Darcy-Weisbach
Maximum Iterations:	100
Iteration Tolerance:	0.01
Laminar Cutoff Re:	2100

Units Used

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

List Report

File Name: 16109-003-528.pipe
Lineup: <Design Case>
Progam Name: PIPE-FLO Professional
Version: 15.2.37316

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

Company: EBDG
Project: 16109
by: JHP
Date: Wednesday, January 18, 2017 12:33 PM

Pipe Specifications

Specification Name / Valve Table	Material / Schedule	Absolute Roughness / Hazen Williams C Factor	Sizing Criteria	Design Limits: Velocity	Pressure	Reynolds Number
AL B241 sch 80	Aluminum B241	6E-05 in	0.0	to ft/s	to psi g	to
standard	Schedule:80	140				
Steel A53-B36.10 Sch 80	Steel A53-B36.10	1.800E-03 in	0.0	to ft/s	to psi g	to
standard	Schedule:80	140				

Fluid Zones

Fluid Zone Name / Table Name	Temperature	Pressure	Fluid State	Density / Viscosity	Vapor Pressure / Critical Pressure	Specific Heat Ratio (k) / Relative Molecular Mass
Water	50 °F	0 psi g	Liquid	62.41 lb/ft³	0.1782 psi a	--
Water				1.269 cP	3199 psi a	18

Sizing Pumps

Pump Name	Suction Elevation / Suction Pressure	Discharge Elevation / Discharge Pressure	Total Head / dP	Flow Rate	NPSHa
SEWAGE DISCHARGE PUMP	-1.5 ft	-1.5 ft	36.07 ft		34.25 ft
	0.3256 psi g	15.96 psi g	15.64 psi		

Pipelines

Pipeline Name / Specification / Fluid Zone	Size / Inside Diameter / Length	Inlet Elevation / Outlet Elevation	Flow Rate / Fluid Velocity / Reynolds Number	Total Head Loss / V&F Head Loss	Inlet Pressure / Outlet Pressure	Total dP / V&F dP	Pipe Friction Factor / V&F Friction Factor / V&F Resistance K
Suction	3 in	-1.5 ft	40 gpm	0.2488 ft	0.4334 psi g	0.1078 psi	0.02281
AL B241 sch 80	2.9 in	-1.5 ft	1.943 ft/s	0.1934 ft	0.3256 psi g	0.08384 psi	0.01754
Water	10 ft		34379				3.30
	Inlet Device: SEWAGE TANK		**Outlet Device:** SEWAGE DISCHARGE PUMP				
Discharge	2 in	-1.5 ft	40 gpm	2.324 ft	15.96 psi g	5.991 psi	0.02087
AL B241 sch 80	1.939 in	10 ft	4.346 ft/s	1.376 ft	9.969 psi g	0.5962 psi	0.01928
Water	25 ft		51418				4.69
	Inlet Device: SEWAGE DISCHARGE PUMP		**Outlet Device:** VESSEL CONNECTION				
Hose	2 in	10 ft	40 gpm	3.004 ft	9.969 psi g	3.469 psi	0.02373
Steel A53-B36.10 Sch 80	1.939 in	15 ft	4.346 ft/s	0.8491 ft	6.5 psi g	0.368 psi	0.01928
Water	50 ft		51418				2.89
	Inlet Device: VESSEL CONNECTION		**Outlet Device:** TANK ON SHORE				
Shore pipe	2 in	15 ft	40 gpm	9.997 ft	6.5 psi g	6.5 psi	0.02373
Steel A53-B36.10 Sch 80	1.939 in	20 ft	4.346 ft/s	1.376 ft	0 psi g	0.5962 psi	0.01928
Water	200 ft		51418				4.69
	Inlet Device: TANK ON SHORE		**Outlet Device:** TANK ON SHORE1				

Tanks

Tank Name / Fluid Zone	Bottom Elevation / Liquid Level	Surface Pressure / Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
SEWAGE TANK	-1.5 ft	0 psi g	-0.5 ft				
Water	1 ft	0.4334 psi g					

Tanks

Tank Name / Fluid Zone	Bottom Elevation / Liquid Level	Surface Pressure / Bottom Pressure	Hydraulic Grade	Connecting Pipelines: Pipeline Name	Penetration Height	Pipeline Flow Rate	Pressure at Penetration
SEWAGE TANK Water	-1.5 ft 1 ft	0 psi g 0.4334 psi g	-0.5 ft				
				Suction	0 ft	40 gpm	0.4334 psi g

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
VESSEL CONNECTION	10 ft	9.969 psi g	32.71 ft
TANK ON SHORE	15 ft	6.5 psi g	29.7 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
TANK ON SHORE1	20 ft	0 psi g	19.71 ft	40 gpm

Bill of Materials Report

File Name: 16109-003-528.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16109
by: JHP
Date: Wednesday, January 18, 2017 12:32 PM

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Suction	AL B241 sch 80	3 in	10 ft	6 x Elbow - Standard 90° 1 x Gate - Double Disc
Discharge	AL B241 sch 80	2 in	25 ft	8 x Elbow - Standard 90° 1 x Ball
Hose	Steel A53-B36.10 Sch 80	2 in	50 ft	5 x Elbow - Standard 90°
Shore pipe	Steel A53-B36.10 Sch 80	2 in	200 ft	8 x Elbow - Standard 90° 1 x Ball

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
AL B241 sch 80	Aluminum B241 Schedule: 80	2 in	25.00 ft	1 x Ball 8 x Elbow - Standard 90°
AL B241 sch 80	Aluminum B241 Schedule: 80	3 in	10.00 ft	6 x Elbow - Standard 90° 1 x Gate - Double Disc
Steel A53-B36.10 Sch 80	Steel A53-B36.10 Schedule: 80	2 in	250.00 ft	1 x Ball 13 x Elbow - Standard 90°

Appendix F

Bilge System

1 DESCRIPTION

This appendix documents the calculations used in designing the bilge system. These calculations establish required pump capacity and quantity in accordance with regulatory requirements. Estimated losses through bilge system piping are calculated to establish the total dynamic head (TDH) for all of the bilge pumps.

2 PROCEDURE

Calculations are presented in the following sequence:

- Bilge pump capacity and quantity calculations
- Bilge pipe nominal velocity calculations
- Bilge pump TDH calculation

Bilge pump capacity calculations are based on the requirements found in [1].

Initial pipe sizes are also based on the nominal velocity limits found in [2], Chapter 20, Table 3.

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

3 GIVEN AND ASSUMED PARAMETERS

- Each water tight compartment will be equipped with a submersible bilge pump. Each Engine Room will be equipped with two submersible bilge pumps. The forward most void will be equipped with a manual pump.
- Bilge system is to be constructed of flexible hose and schedule 80 aluminum pipe.
- Bilge overboard discharges are assumed to be 9 feet above baseline.
- System pipe lengths, routing and fittings are estimated based on the Profiles and Arrangements, [3].

4 FORMULAS

(not used)

5 CALCULATIONS

5.1 Bilge Pipe Size and Pump Capacity Calculation

From the attached calculations, each demi-hull is required to have a total bilge pump capacity of 30 cubic meters per hour, or 136 gallons per minute. Each pump must have minimum capacity of 7.7 cubic meters per hour, or 34 gallons per minute. However, per [1], the required minimum bilge pump capacity is 8 cubic meters per hour, or 35 gallons per minute.

5.2 Bilge Pipe Nominal Velocity Calculation

Initial pipe sizes are also based on the nominal velocity limits found in [2]. Table 1 shows the flows occurring in all portions of the system, and the resulting pipe sizes:

Table 1: Nominal Bilge Pipe Velocities

Pipe Segment	Flow Rate gpm	Pipe Size (NPS)	ID in	Design Velocity (ft/s) Nominal	Limit	V ft/s
Bilge Hose	35	2" ID Hose	2.000	7.07	15.00	3.48
Bilge Overboard	35	1-1/2" Sch 80	1.500	6.12	15.00	6.19

5.3 Bilge Pump Total Head and Net Positive Suction Head (NPSH) Calculation

From the attached PIPE-FLO model, each bilge pump is required to produce about 10 feet TDH at the required flow rate of 35 gpm.

6 REFERENCES

[1] Lloyd's Register, "Rules and Regulations for the Classification of Special Service Craft," 2015.

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

[3] Elliott Bay Design Group, "Profiles and Arrangements," 16109-003-101-0, Seattle, WA.

Size of Bilge Main Suction Pipes

Per Lloyd's Register Rules and Regulations for the Classification of Special Service Craft
Chapter 15, Section 12, Paragraph 12.3.1

Where a bilge main is fitted in each hull, it's internal diameter dm is not to be less than that required by the following formula:

$$d_m = 1.68\sqrt{L(B+D)} + 25\ [mm]$$

where
B = breadth of a demi-hull in meters
D = moulded depth to the watertight deck, in meters
L = Length of craft in meters

B =	9 feet	2.74 meters
D =	11.5 feet	3.51 meters
L =	92 feet	28.04 meters
dm =	47.24 mm	1.86 inch

Size of Bilge Branch Suctions

Per Lloyd's Register Rules and Regulations for the Classification of Special Service Craft
Chapter 15, Section 12, Paragraph 12.3.2

The diameter db of a branch bilge suction pipes is to be not less than that required by the following formula

$$d_b = 2.15\sqrt{C(B+D)} + 12.5\ [mm]$$

where
C = length of the compartment in meters

Space	C (ft)	C (m)	db (mm)	db (in)
Jet Room	10.00	3.05	29.50	1.16
Engine Room	22.00	6.71	37.71	1.48
Tank Room	32.00	9.75	42.90	1.69
Void 2	12.00	3.66	31.12	1.23

Total Capacity Fixed Submersible Pumps

Per Lloyd's Register Rules and Regulations for the Classification of Special Service Craft
Chapter 15, Section 12, Paragraph 12.4.5

Where fixed submersible bilge pumps are fitted, the total capacity, Qt of the pumps in each hull is to be not less than that required by the following formula:

$$Q_t = \frac{13.8}{10^3} * d_m^2 \quad [m^3/hr]$$

Qt =	30.8 m3/hr	136 gpm

Total Capacity Fixed Submersible Pumps

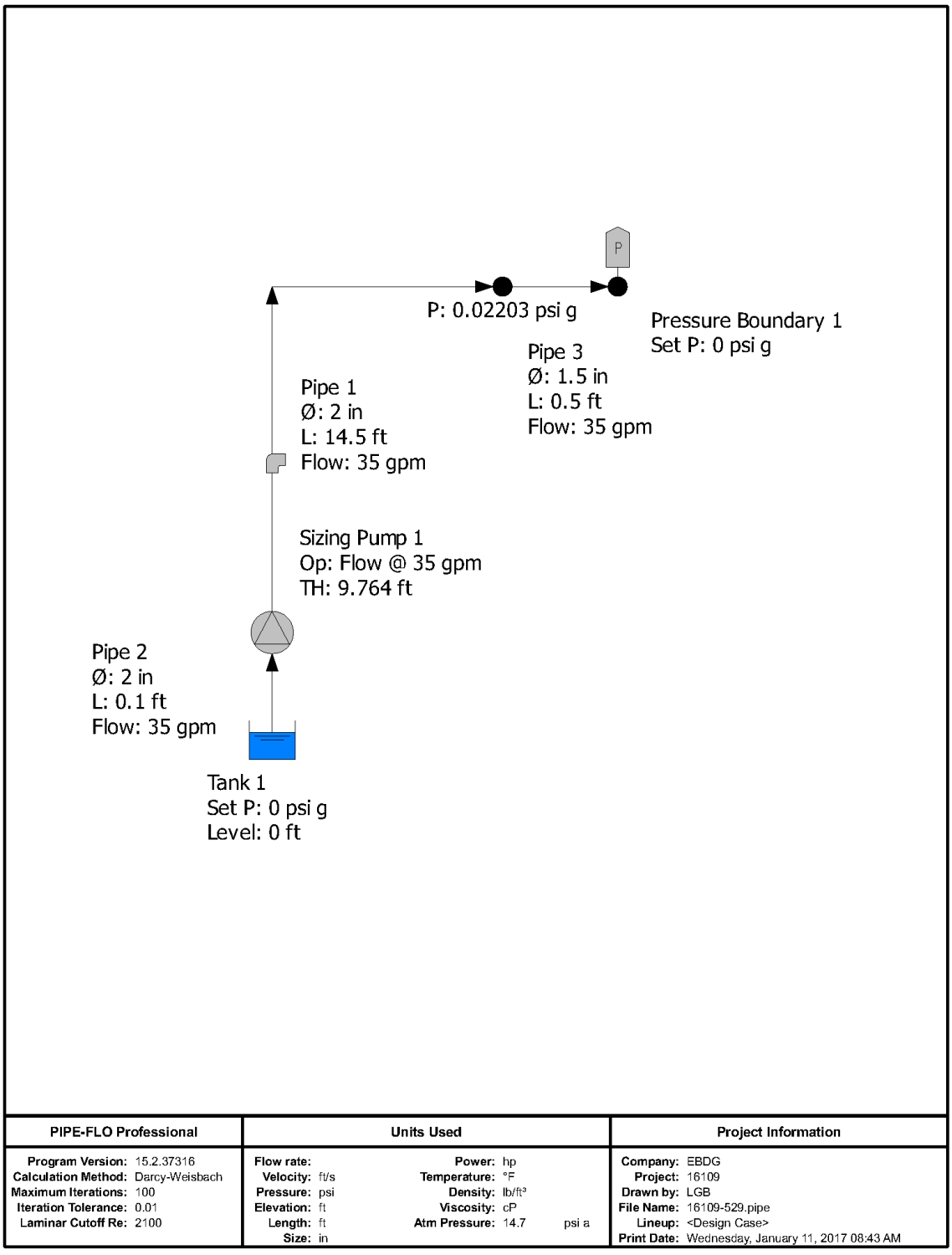
Per Lloyd's Register Rules and Regulations for the Classification of Special Service Craft
Chapter 15, Section 12, Paragraph 12.4.6

The capacity Qn of each submersible pump is to be not less than required by the following formula:

$$Q_n = \frac{Q_t}{(N-1)} \quad [m^3/hr]$$

Where
N = numbe r of fixed submersible pumps in each hull
Qt = Total Cacity as defined above
Qn is in no case to be less than 8 m3/hr

N =	5	
Qn =	7.7 m3/hr	34 gpm



PIPE-FLO Professional		Units Used			Project Information	
Program Version:	15.2.37316	Flow rate:		Power: hp	Company:	EBDG
Calculation Method:	Darcy-Weisbach	Velocity: ft/s		Temperature: °F	Project:	16109
Maximum Iterations:	100	Pressure: psi		Density: lb/ft³	Drawn by:	LGB
Iteration Tolerance:	0.01	Elevation: ft		Viscosity: cP	File Name:	16109-529.pipe
Laminar Cutoff Re:	2100	Length: ft		Atm Pressure: 14.7 psi a	Lineup:	<Design Case>
		Size: in			Print Date:	Wednesday, January 11, 2017 08:43 AM

List Report

File Name:	16109-529.pipe	**Calculation Method:**	Darcy-Weisbach	**Company:**	EBDG
Lineup:	<Design Case>	**Laminar Cutoff Re:**	2100	**Project:**	16109
Progam Name:	PIPE-FLO Professional	**Max Iterations:**	100	**by:**	LGB
Version:	15.2.37316	**Percent Tolerance:**	0.01	**Date:**	Wednesday, January 11, 2017 08:45 AM
		Allowable Deviation:	1 %	**Atmospheric Pressure:**	14.7 psi a

Pipe Specifications

Specification Name Valve Table	Material Schedule	Absolute Roughness Hazen Williams C Factor	Sizing Criteria		Design Limits Velocity	Design Limits Pressure	Design Limits Reynolds Number
Aluminum B241 Sch 80 standard	Aluminum B241 Schedule:80	6E-05 in 140	0.0	Min: Max:	ft/s ft/s	psi g psi g	
Hose standard	Sanitary Tubing Schedule:STD	6E-05 in 100	0.0	Min: Max:	ft/s ft/s	psi g psi g	

Fluid Zones

Fluid Zone Name Table Name	Temperature Pressure	Fluid State Relative Molecular Mass	Density Viscosity	Vapor Pressure Critical Pressure	Specific Heat Capacity (cp) Specific Heat Ratio (k)
Sea Water Seawater 3.5% Salinity	65 °F 0 psi g	Liquid 29	64 lb/ft³ 1.127 cP	0.2997 psi a 3199 psi a	-- --

Sizing Pumps

Pump Name	Suction Elevation Suction Pressure	Discharge Elevation Discharge Pressure	Total Head dP	Flow Rate	NPSHa
Sizing Pump 1	0 ft -1.288E-03 psi g	0 ft 4.338 psi g	9.764 ft 4.34 psi	35 gpm	32.39 ft

Pipelines

Pipeline Name Specification Fluid Zone	Size Inside Diameter Length	Inlet Device Inlet Elevation Outlet Device Outlet Elevation	Flow Rate Fluid Velocity Reynolds Number Pipe Friction Factor	Inlet Total Pressure Inlet Static Pressure Inlet Energy Grade Inlet Hydraulic Grade	Total dP Total Head Loss	Outlet Total Pressure Outlet Static Pressure Outlet Energy Grade Outlet Hydraulic Grade	V&F Friction Factor V&F Resistance K V&F dP V&F Head Loss
Pipe 1 Hose Sea Water	2 in 1.87 in 14.5 ft	Sizing Pump 1 0 ft Node 1 9 ft	35 gpm 4.089 ft/s 53833 0.02067	4.338 psi g 4.223 psi g 9.762 ft 9.502 ft	4.316 psi 0.7119 ft	0.02203 psi g -0.09343 psi g 9.05 ft 8.79 ft	0.01945 0.82 0.09434 psi 0.2123 ft
Pipe 2 Aluminum B241 Sch 80 Sea Water	2 in 1.939 in 0.1 ft	Tank 1 0 ft Sizing Pump 1 0 ft	35 gpm 3.803 ft/s 51918 0.02083	0 psi g -0.09988 psi g 0 ft -0.2247 ft	1.288E-03 psi 2.897E-03 ft	-1.288E-03 psi g -0.1012 psi g -2.897E-03 ft -0.2276 ft	0.01928 0.00 0 psi 0 ft
Pipe 3 Aluminum B241 Sch 80 Sea Water	1.5 in 1.5 in 0.5 ft	Node 1 9 ft Pressure Boundary 1 9 ft	35 gpm 6.354 ft/s 67112 0.01975	0.02203 psi g -0.2569 psi g 9.05 ft 8.422 ft	0.02203 psi 0.04958 ft	0 psi g -0.2789 psi g 9 ft 8.372 ft	0.02054 0.00 0 psi 0 ft

Tanks

Tank Name Fluid Zone	Bottom Elevation Liquid Level	Surface Pressure Bottom Pressure	Hydraulic Grade	Connecting Pipelines Pipeline Name	Connecting Pipelines Penetration Height	Connecting Pipelines Pipeline Flow Rate	Connecting Pipelines Pressure at Penetration
Tank 1	0 ft 0 ft	0 psi g 0 psi g	0 ft				
				Pipe 2	0 ft	35 gpm	0 psi g

PIPE-FLO Professional Version: 15.2.37316 List Report Wednesday, January 11, 2017 08:45 AM Page 1

Nodes

Node Name	Elevation	Pressure	Hydraulic Grade
Node 1	9 ft	0.02203 psi g	8.606 ft

Pressure Boundaries

Pressure Boundary Name	Elevation	Pressure	Hydraulic Grade	Flow Rate
Pressure Boundary 1	9 ft	0 psi g	8.372 ft	35 gpm

Bill of Materials Report

File Name: 16109-529.pipe
Lineup: <Design Case>
Program Name: PIPE-FLO Professional
Version: 15.2.37316

Company: EBDG
Project: 16109
by: LGB
Date: Wednesday, January 11, 2017 08:45 AM

Sizing Pumps

Sizing Pump Name Operation	Design Point Flow Rate	 Total Head
Sizing Pump 1 Flow @ 35 gpm	35 gpm	9.764 ft

Tanks

Tank Name
Tank 1

Pipelines

Pipeline	Specification	Size	Length	Valves and Fittings
Pipe 1	Hose	2 in	14.5 ft	3 x Elbow - Long radius, r/d 1.5 (90°)
Pipe 2	Aluminum B241 Sch 80	2 in	0.1 ft	
Pipe 3	Aluminum B241 Sch 80	1.5 in	0.5 ft	

Pipeline Material Summary

Specification	Material	Size	Total Length	Valves & Fittings
Aluminum B241 Sch 80	Aluminum B241 Schedule: 80	1.5 in	0.50 ft	
Aluminum B241 Sch 80	Aluminum B241 Schedule: 80	2 in	0.10 ft	
Hose	Sanitary Tubing Schedule: STD	2 in	14.50 ft	3 x Elbow - Long radius, r/d 1.5 (90°)

Appendix G

Potable Water

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

System sizing is based on the guidance found in Appendix A of Reference [1].

3 GIVEN AND ASSUMED PARAMETERS

- The system is to be pressurized by a single pump which will cycle on at 40psig and off at 60 psig.
- The heads will be Headhunter brand with less than 1 gpm per flush.
- The potable water consumers on the vessel: 2 heads, 2 lavatories, 1 sink in the food service area and 3 exterior hose bibs.

4 FORMULAS

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

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

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

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

5 CALCULATIONS

5.1 Demand Water Supply Calculations

Table 1: Water Supply

Level	Item	Qty	Water Supply Fixture Units, Table A-2	Item Totals
Main Deck	Food Service Sink	1	1.5	1.5
	Lavatory	2	1	2
	Hose Bib*	1	2.5	2.5
	Hose Bib	2	1	2
	Head	2	5	10
	Total, 03 Deck:			**18**
Total WSFU for Vessel			18	
Supply demand, from [1], Ch A-3, line 1			**30**	**GPM**
Excluding water closets, from [1], Ch A-3, Line 2			**7**	**GPM**
*First hose bib is 2.5 WSFU, additional are 1.0				

Demand flow from Chart A-3, Line 1 is 30 gpm, from [1]. This flow rate is for land side toilets that require 1.6 gpf. The toilets to be installed use less than 1 gpf. For a water system with 2 heads a 10 gpm at 50 psi would be sufficient, per [3].

5.2 Pressure Tank Sizing Calculation

Table 2: Pressure Tank Sizing

	Item	Qty		Note / Reference
(1)	Pump Capacity	10	gpm	
(2)	Minimum Drawdown	5	gallons	
(4)	Peak Demand Estimation	15	gpm	
(5)	Peak Demand Time	0.08	minutes	
(6)	P1 pressure tank precharge	40	psi	
(7)	P2 cutout pressure	60	psi	
(9)	Supplemental Drawdown	0.40	gallons	Eq. 1: [(4) - (1)] * (5)
(10)	Total Required Drawdown	5.40	gallons	Eq. 2: (2) + (9)
(11)	Acceptance Factor	0.27		Eq. 3: 1 - [[(6) + 14.7]/[(7) + 14.7]]
(12)	Total Calculated Tank Size	20	gallons	Eq. 4 (10) / (11)

The toilet manufacture recommends a pressure tank with at least a 2 gallon draw down for a water system with 2 heads [3]. For approximately 5 gallon drawdown, a 20 gallon pressure tank is needed.

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] Scott at Headhunter (2017,Jan. 13), *Headhunter Toilet Questions,* phone call, 01/13/17.