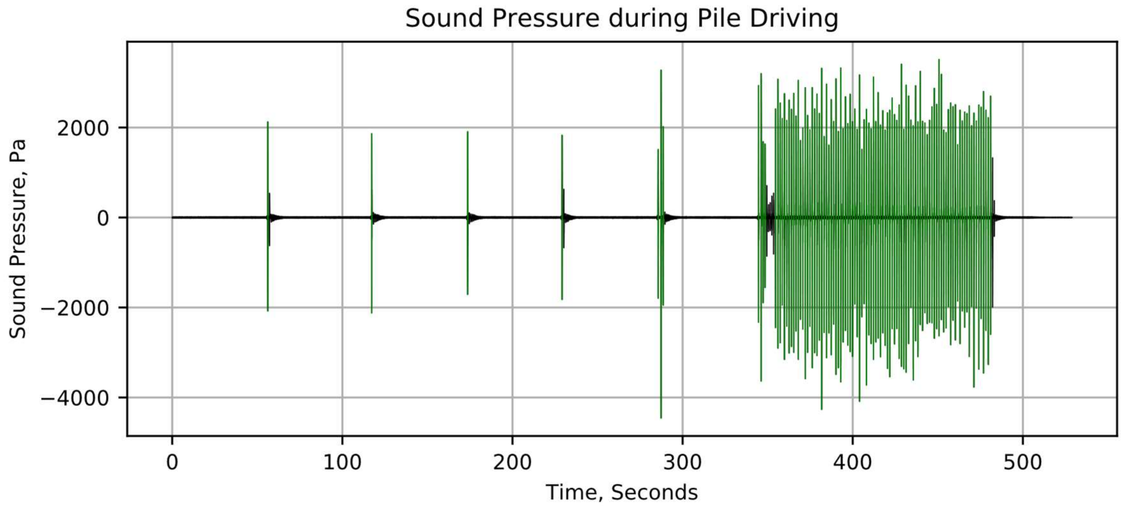
APPENDIX

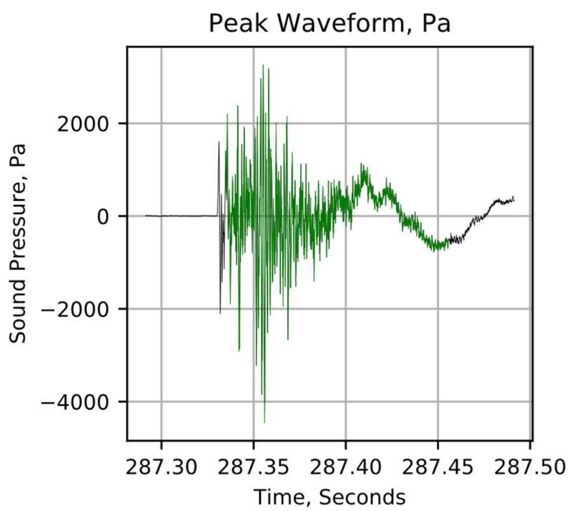
Table of Contents

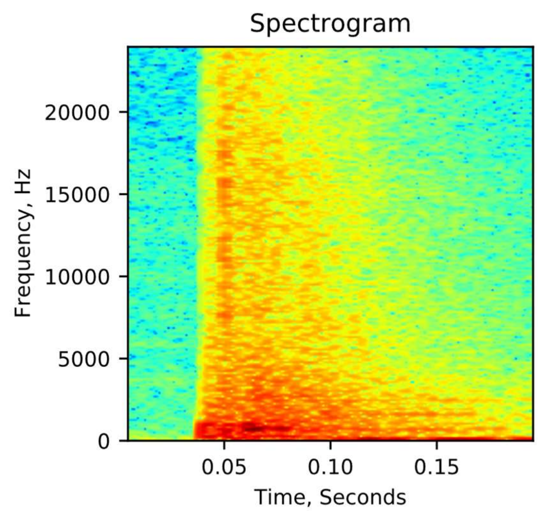
1.0 NORTH TRESTLE 36-INCH STEEL PIPE PILES

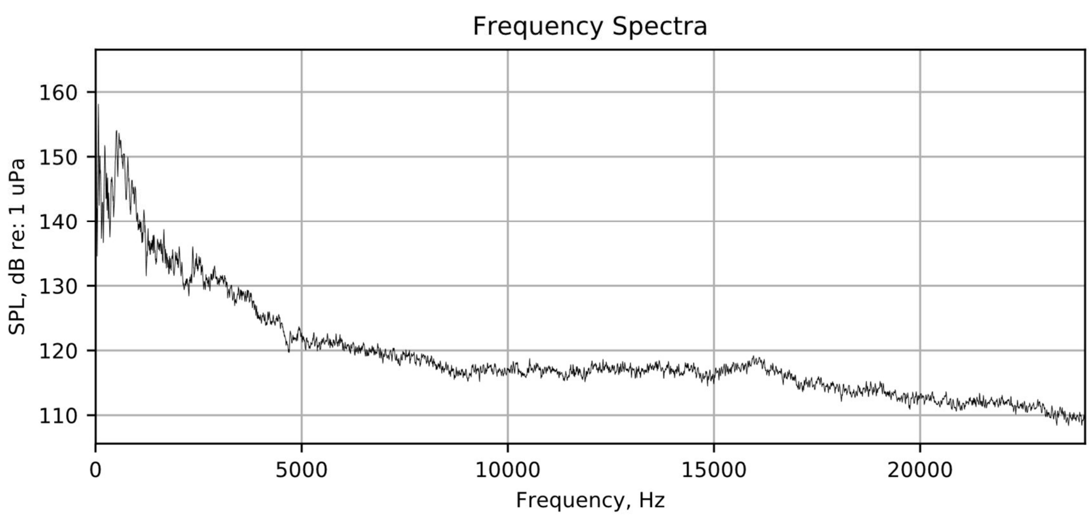
PILE N9.5-NG

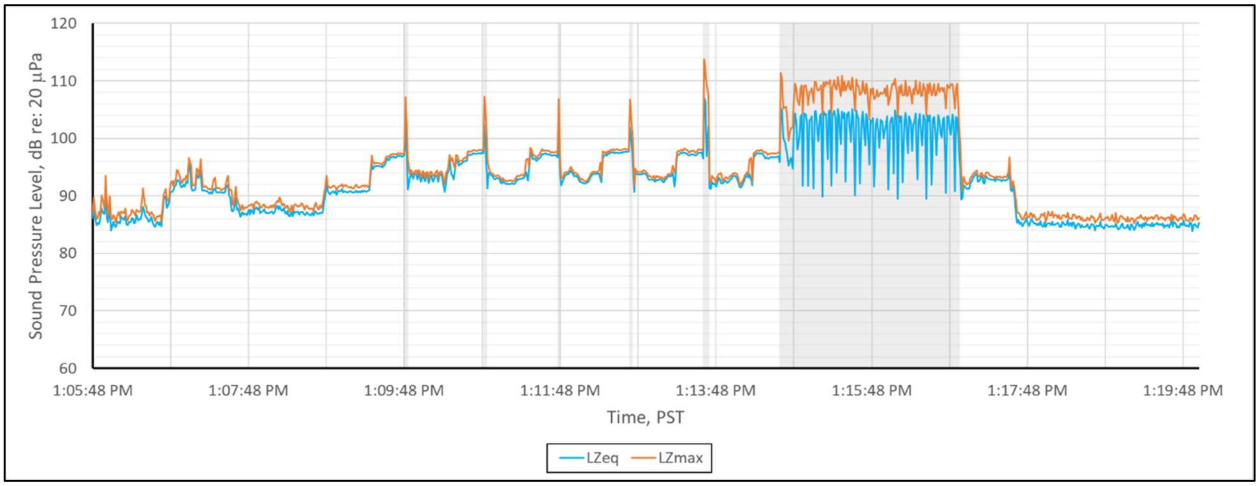
October 21, 2020







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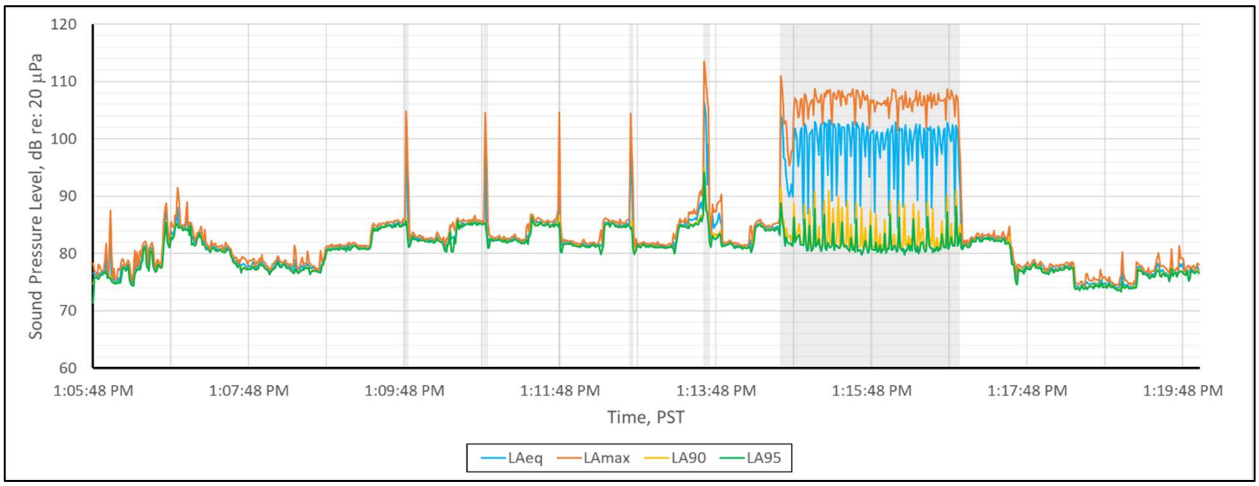
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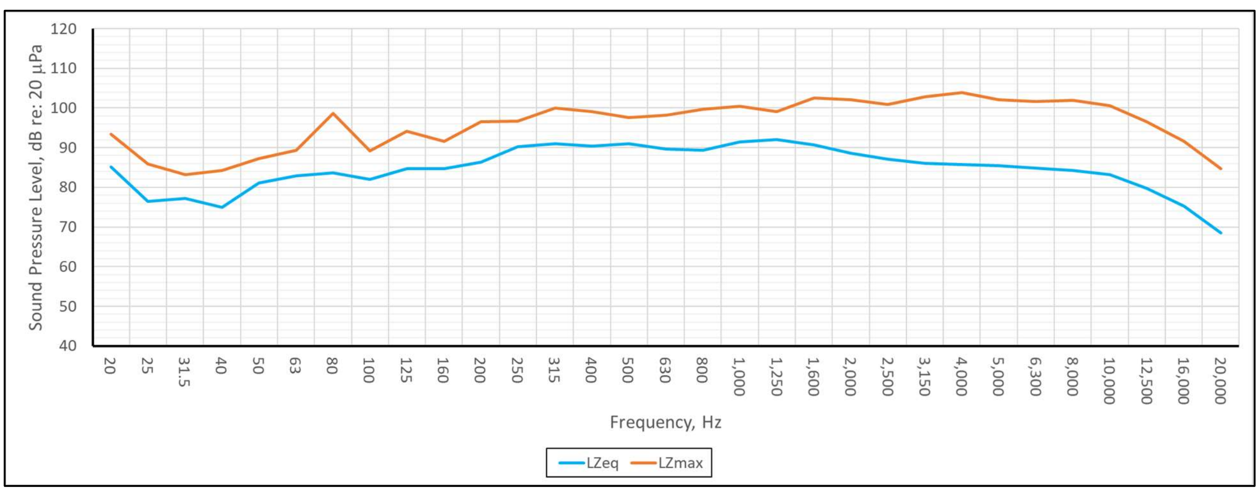
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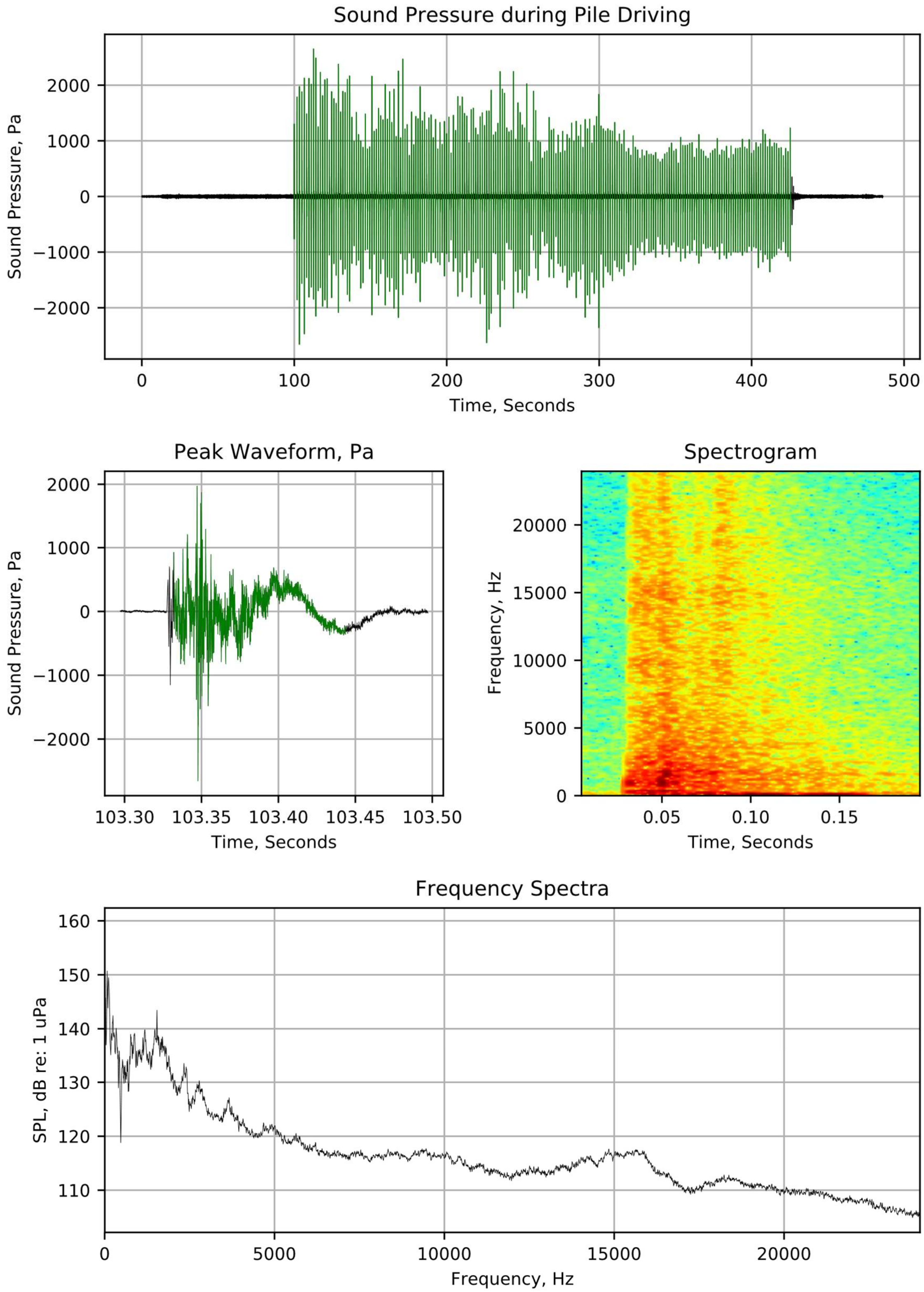
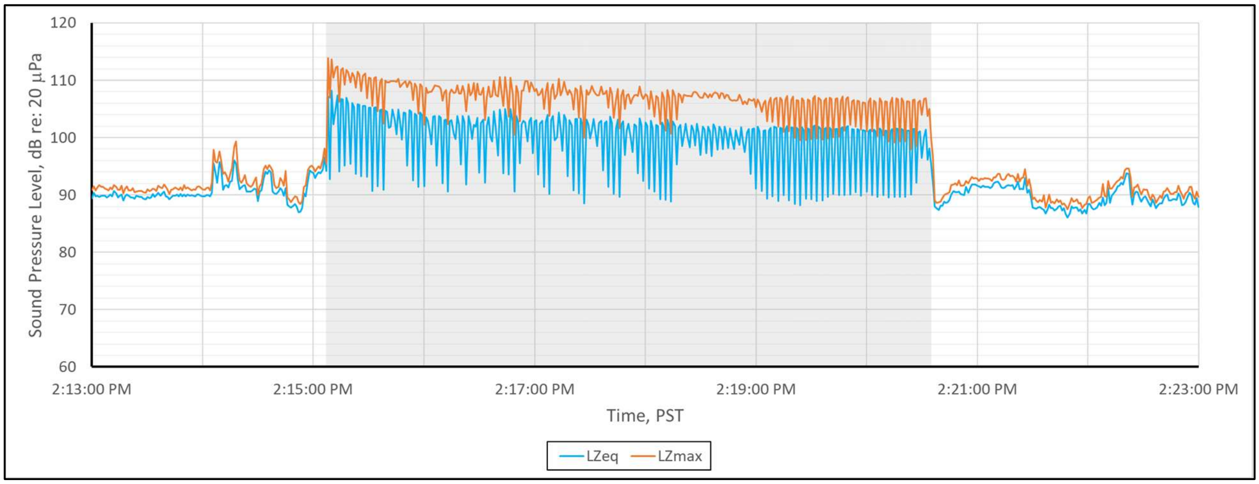
PILE N9-NG

October 21, 2020

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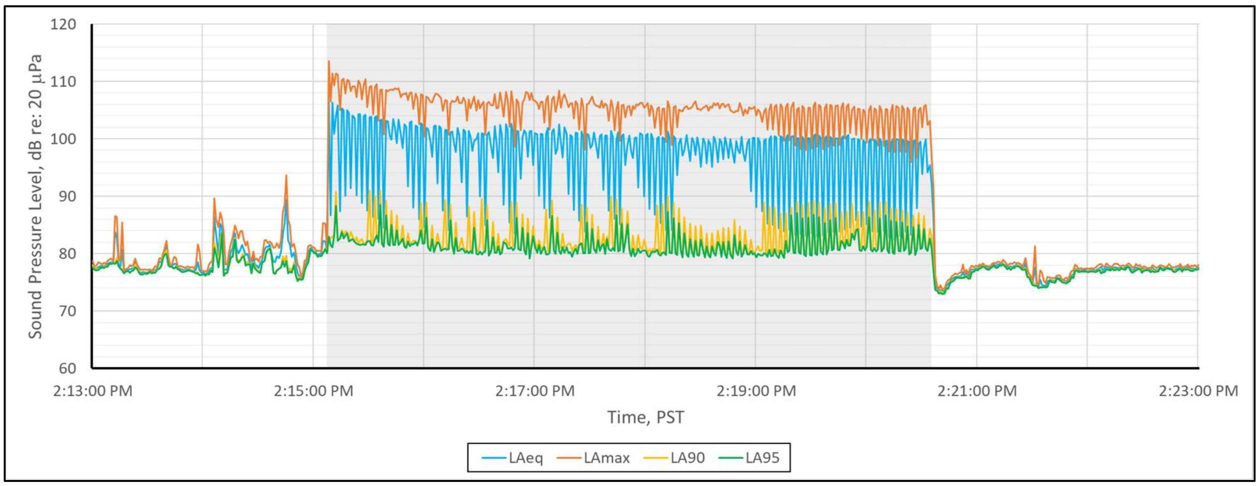
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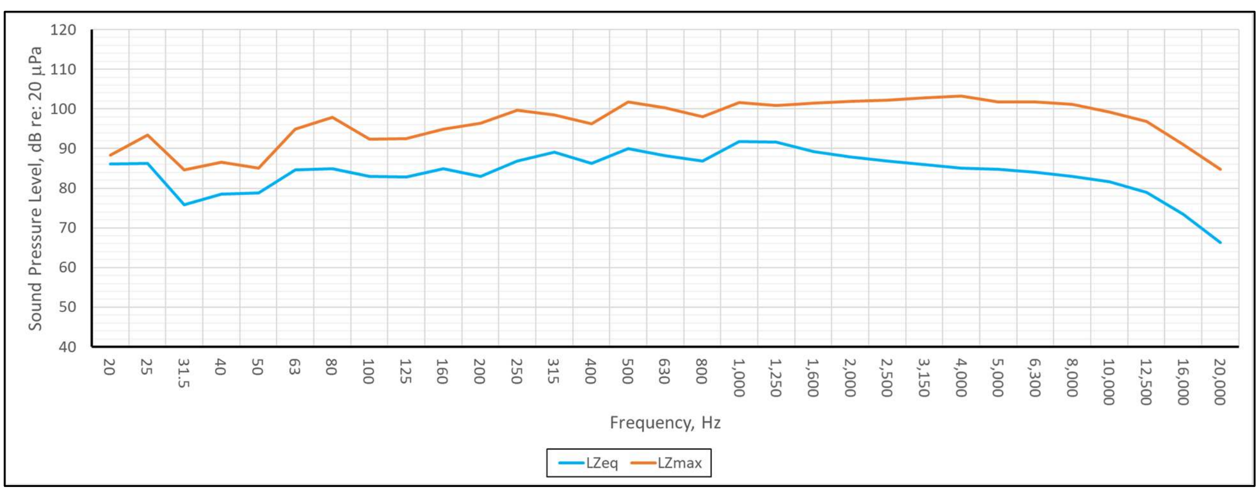
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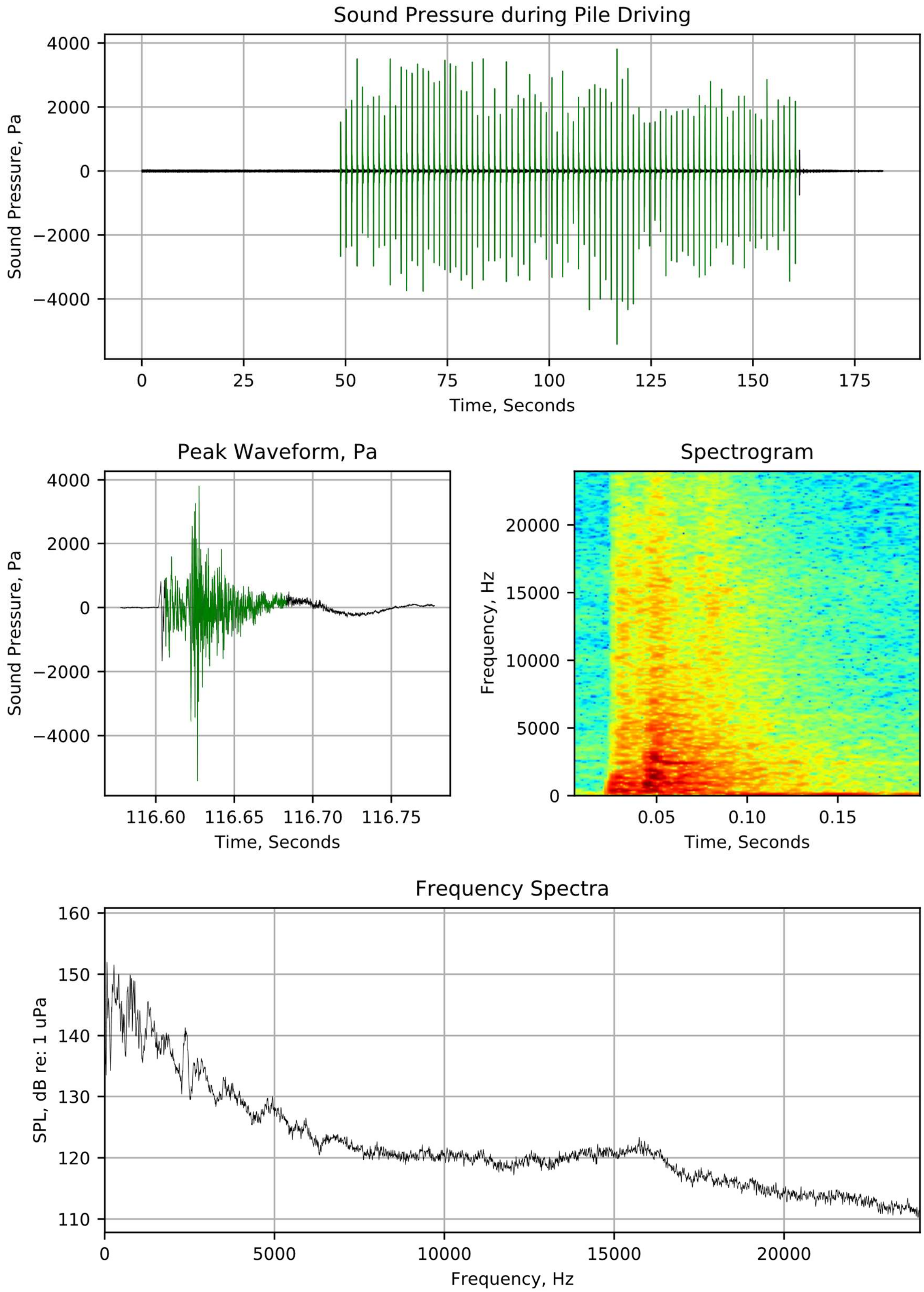
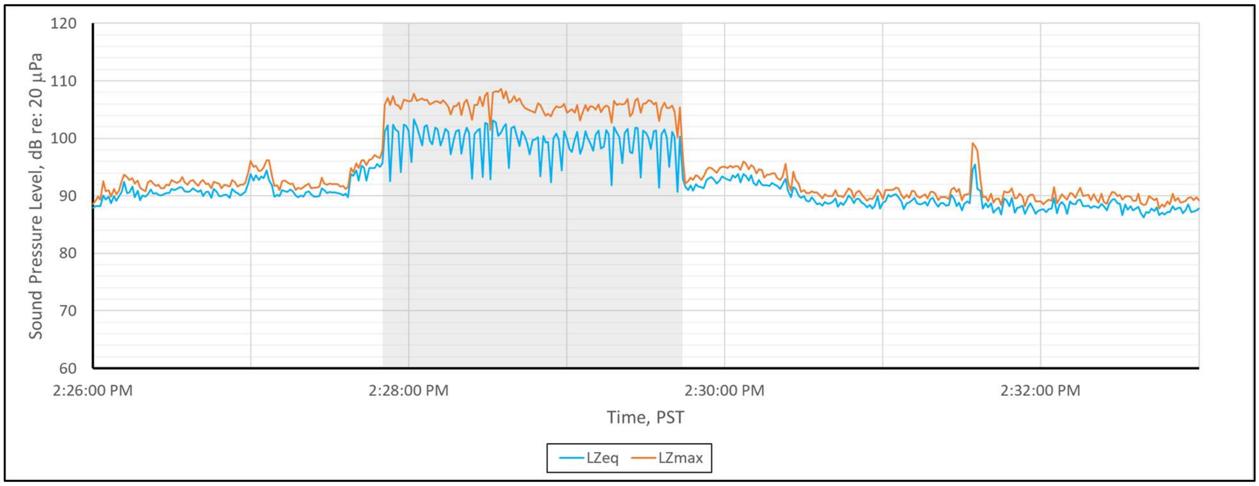
PILE N9-NF.7

October 21, 2020

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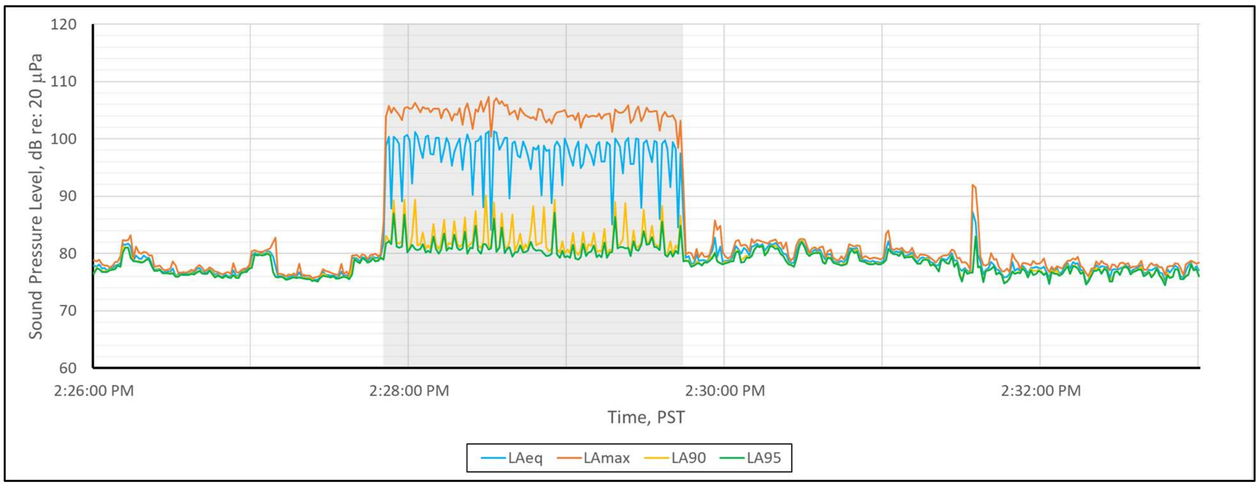
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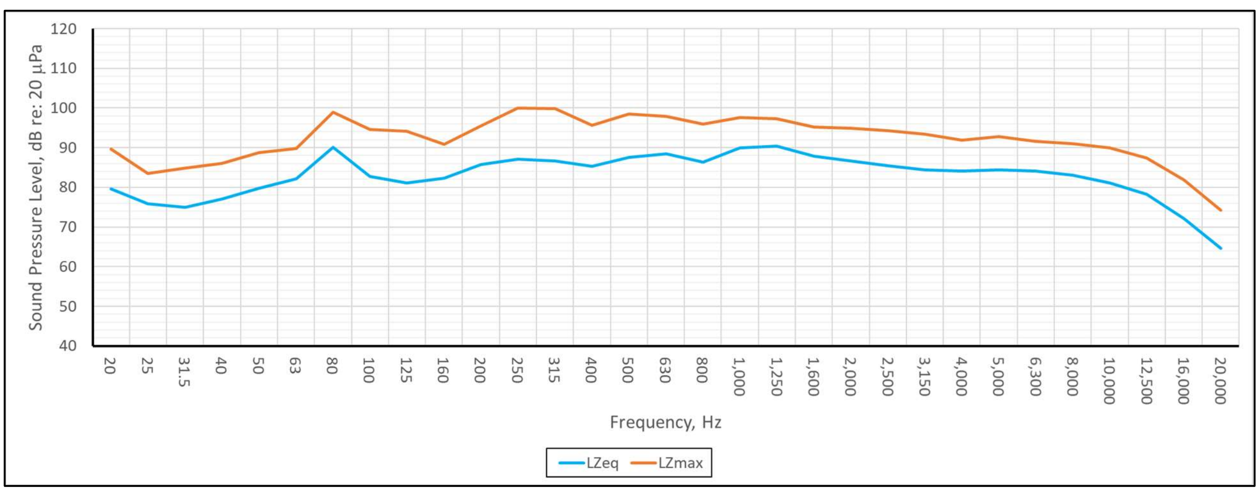
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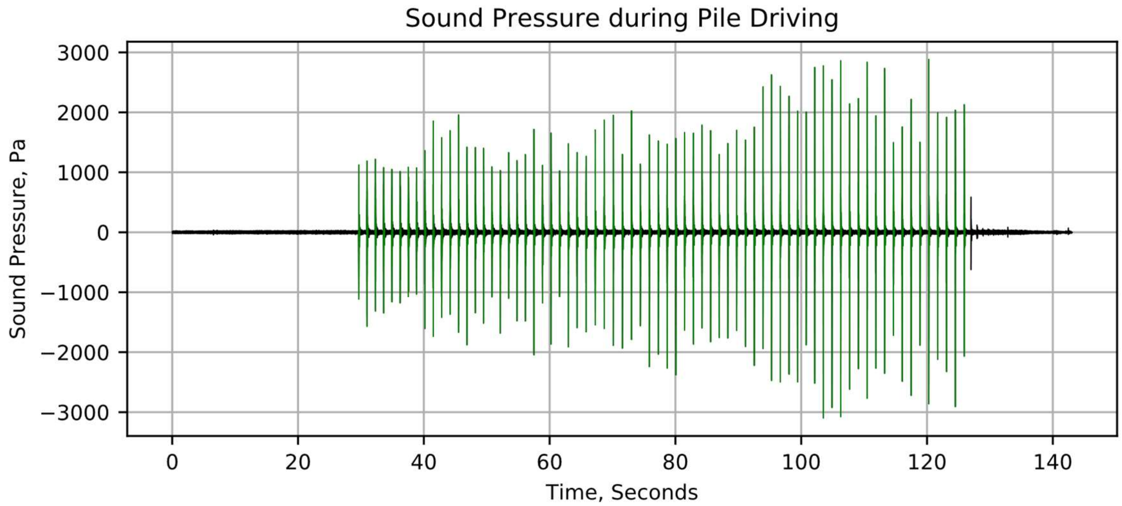
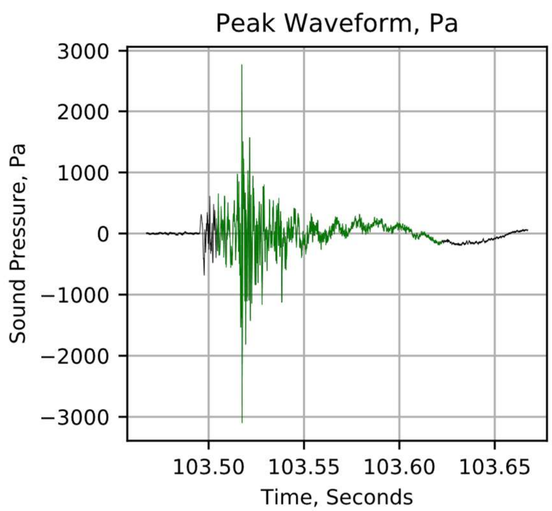
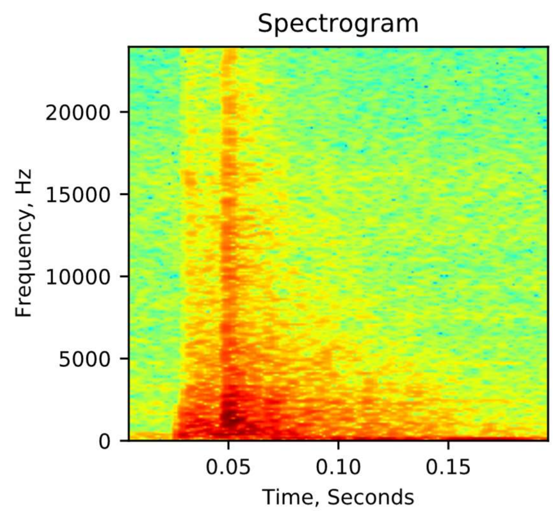
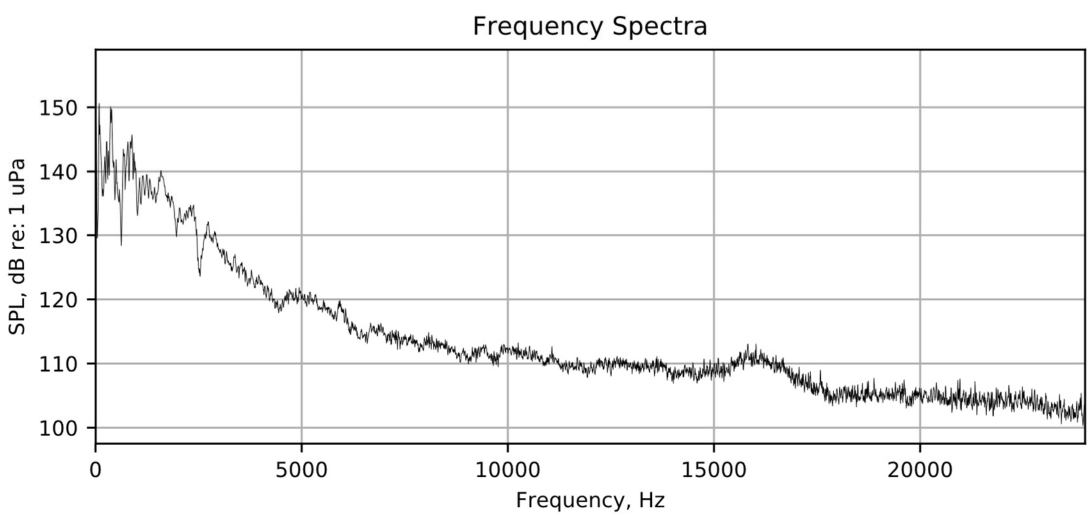
PILE N9-NF.4

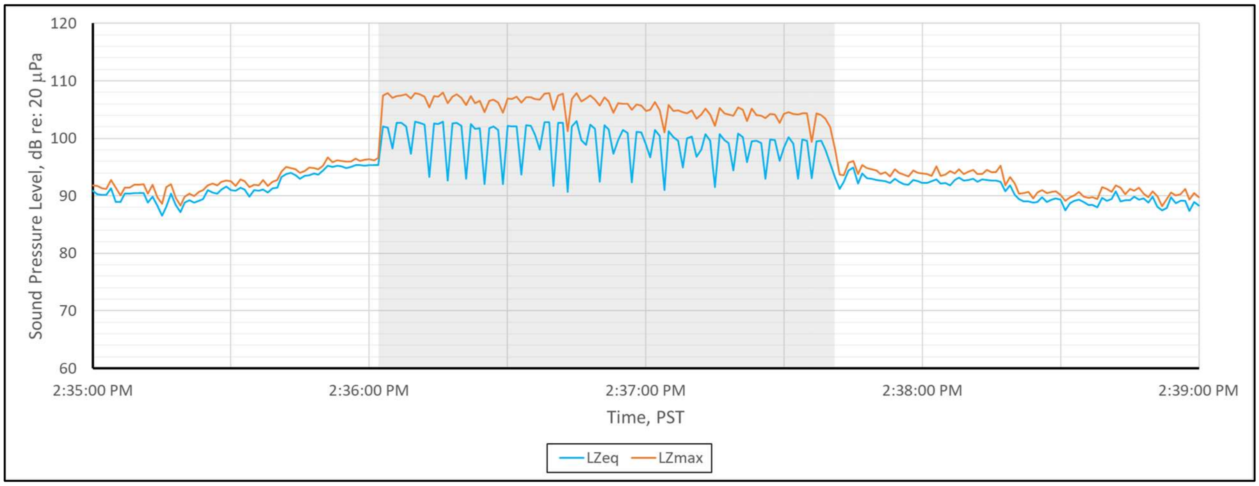
October 21, 2020







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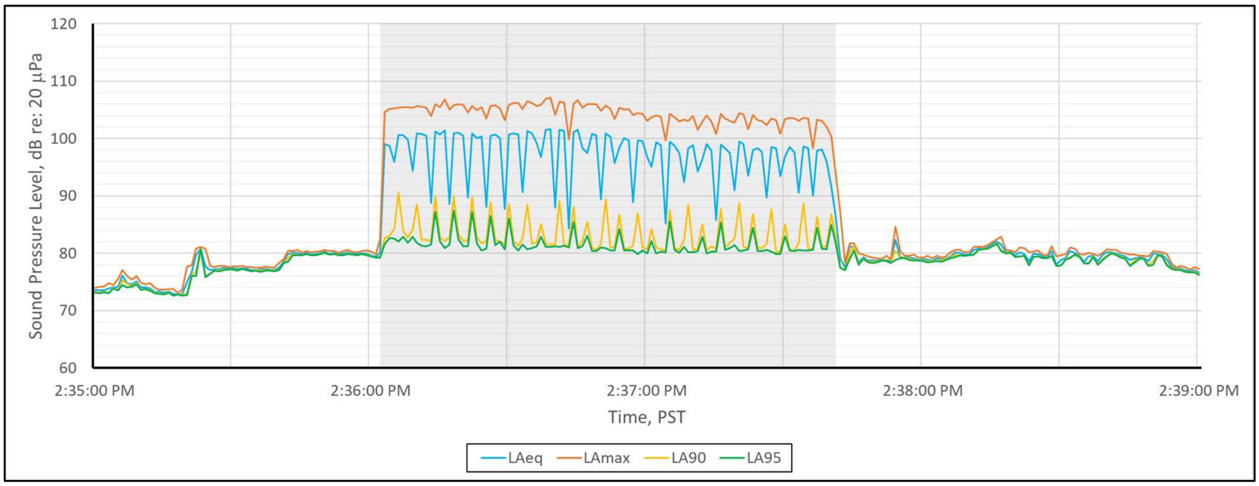
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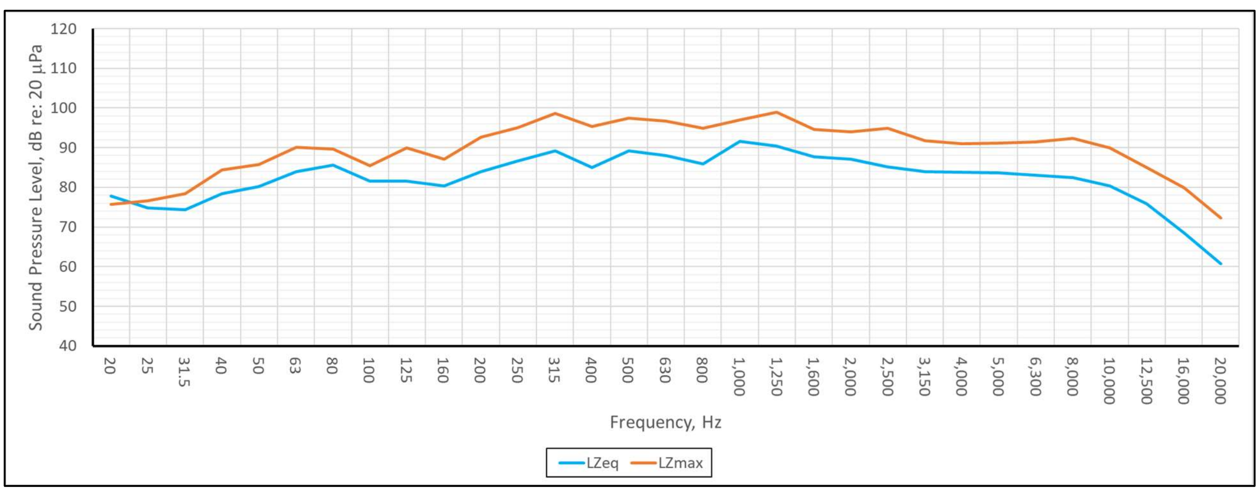
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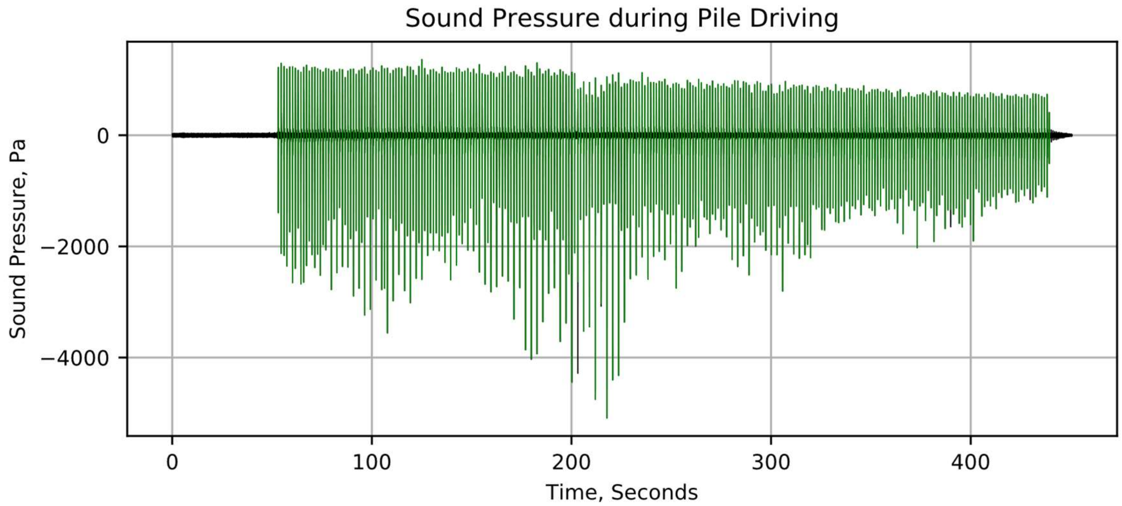
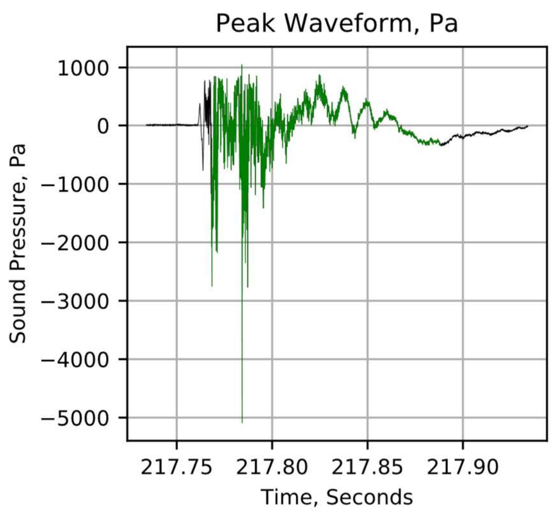
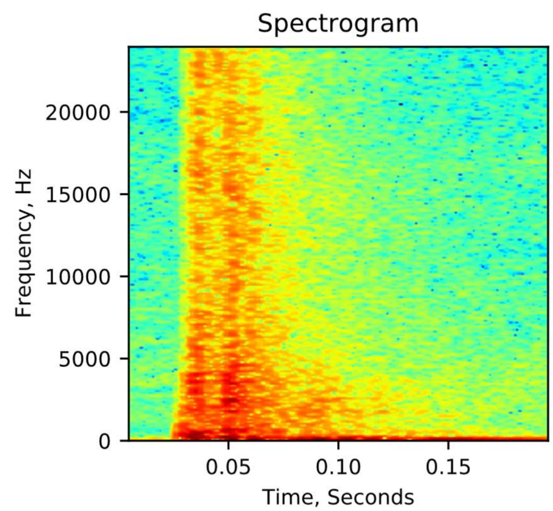
LZmax

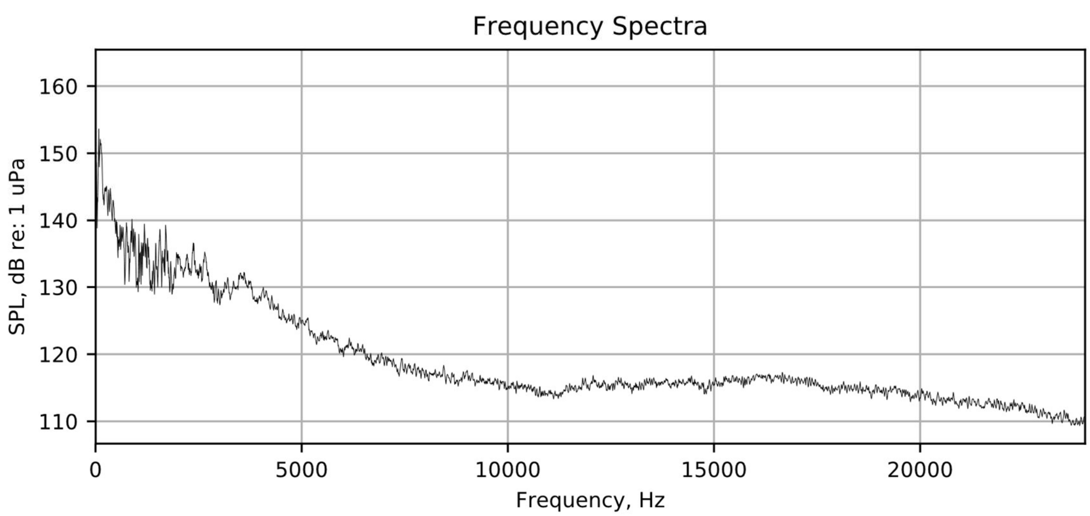
PILE N8-NF.5

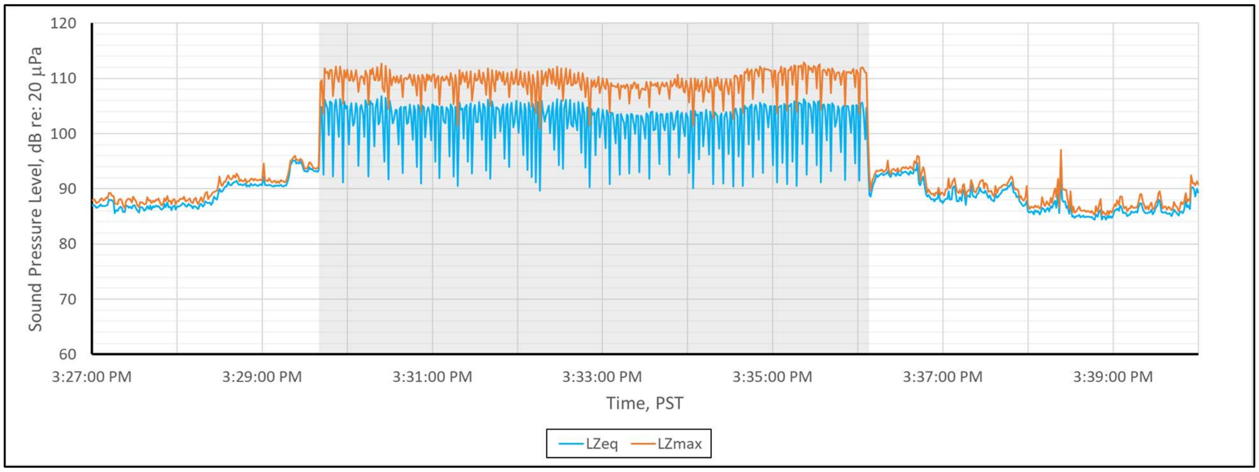
October 21, 2020







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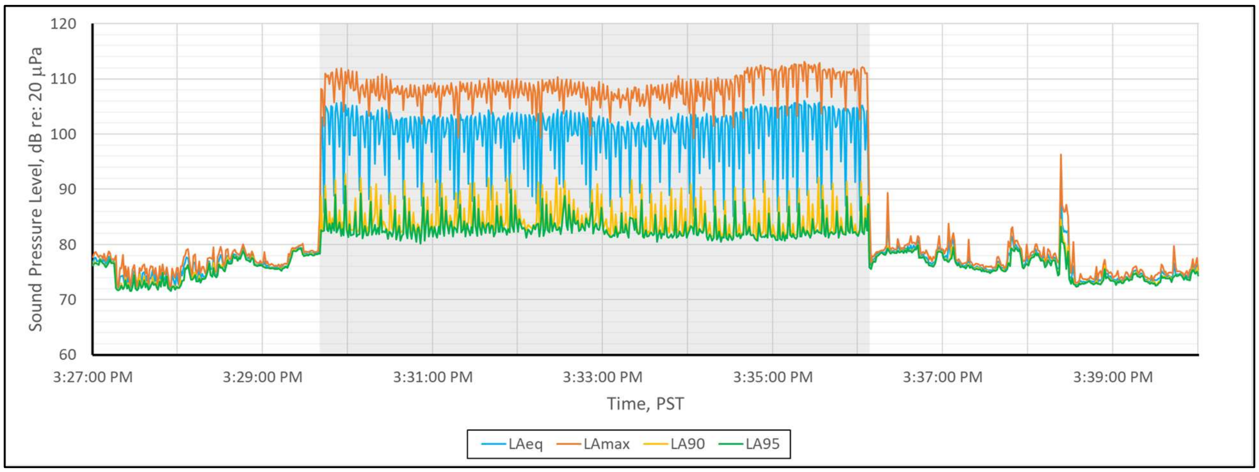
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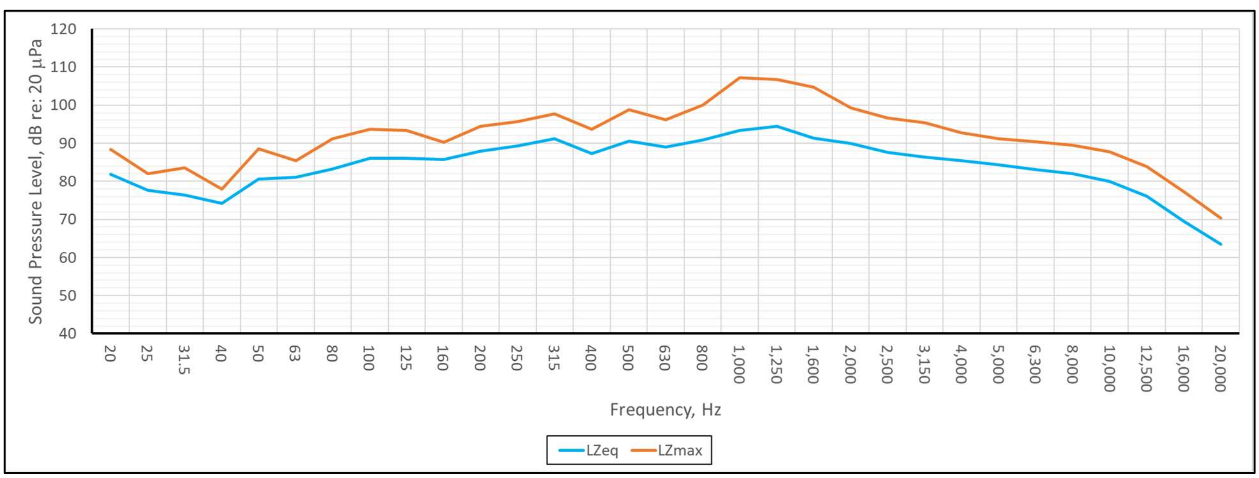
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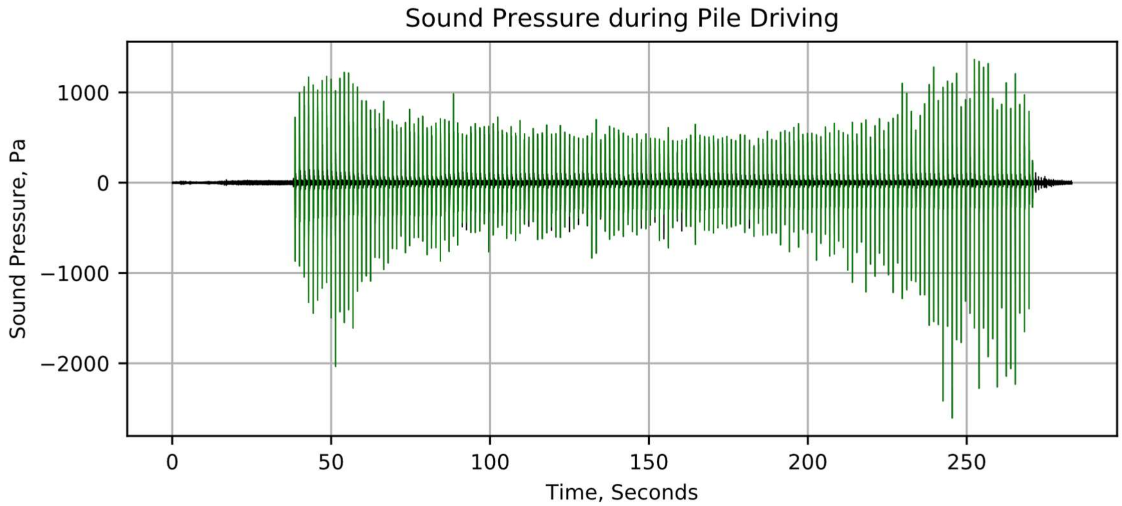
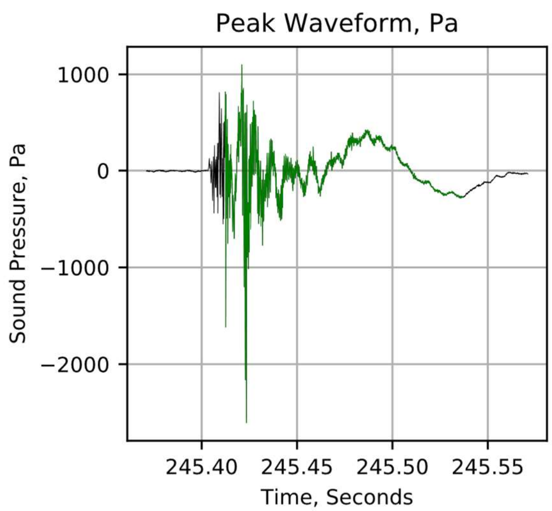
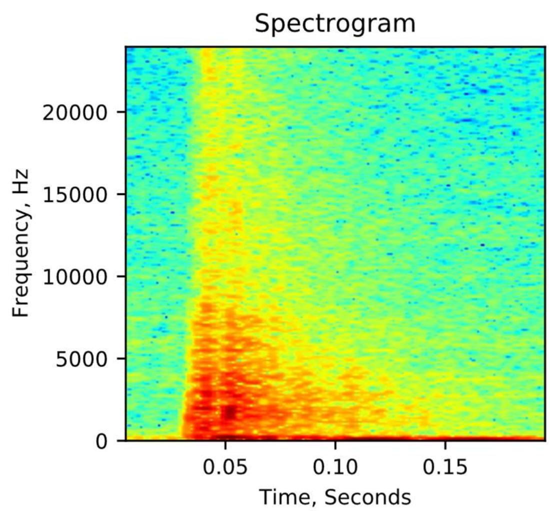
LZmax

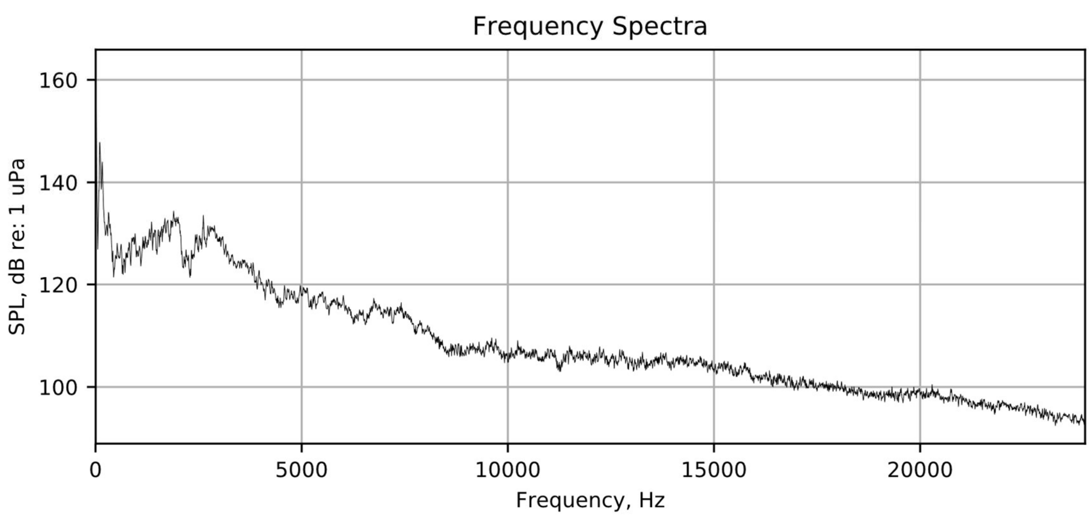
PILE N7-NF.5

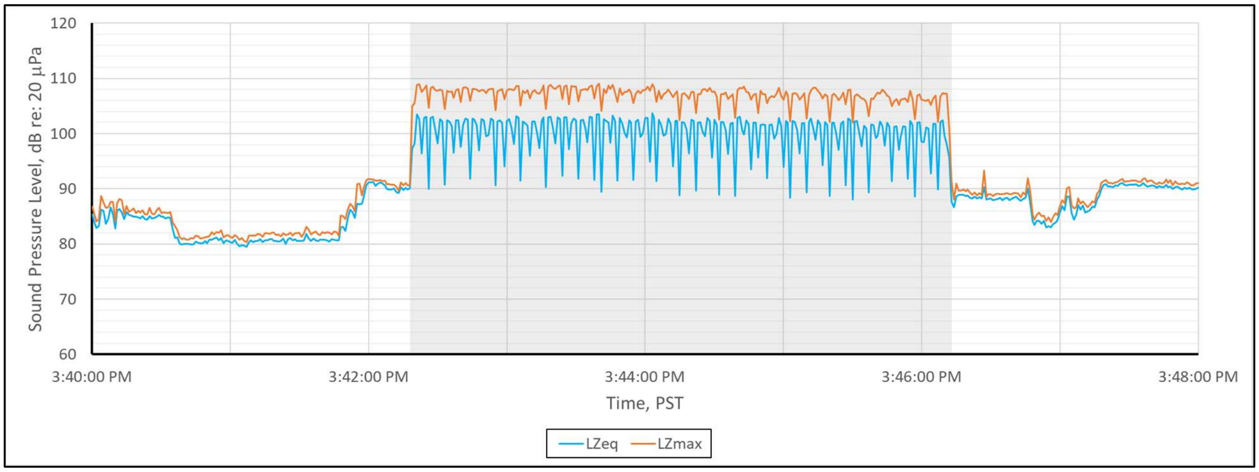
October 21, 2020







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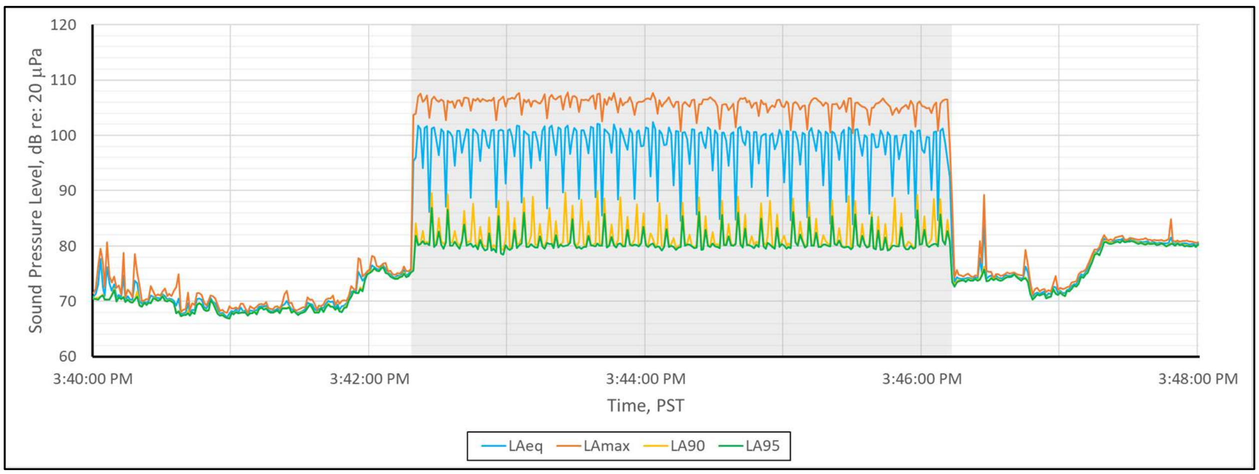
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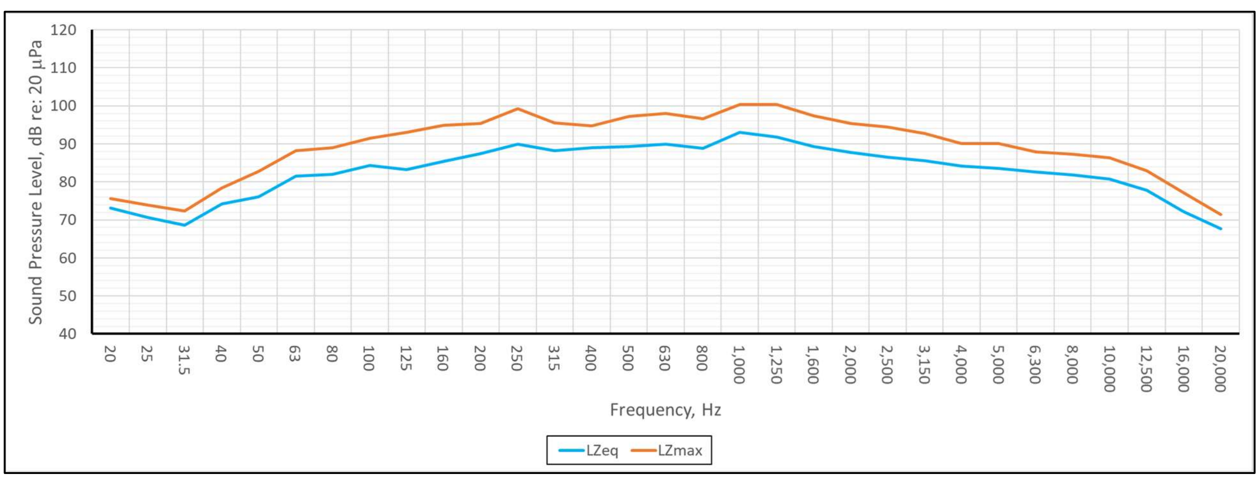
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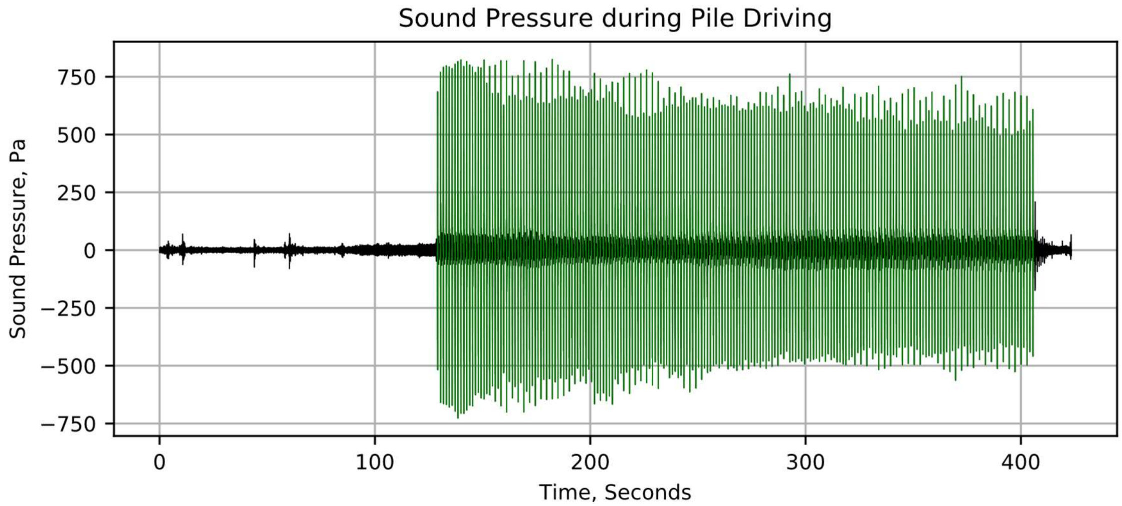
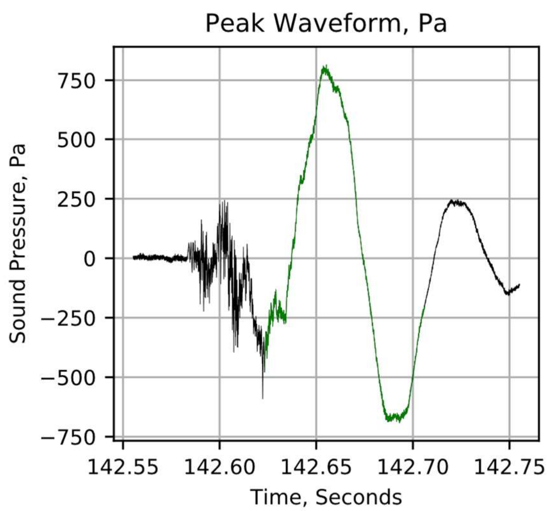
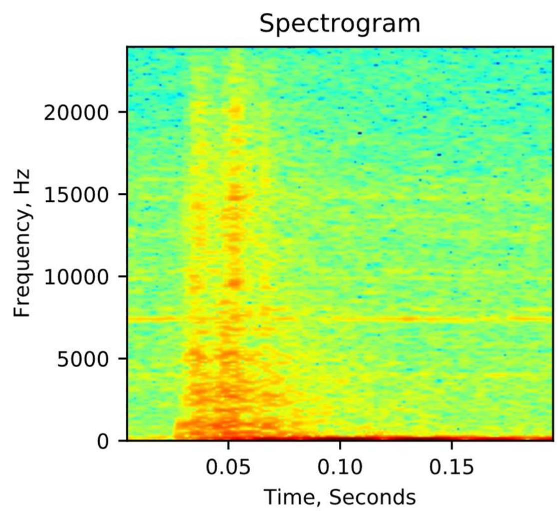
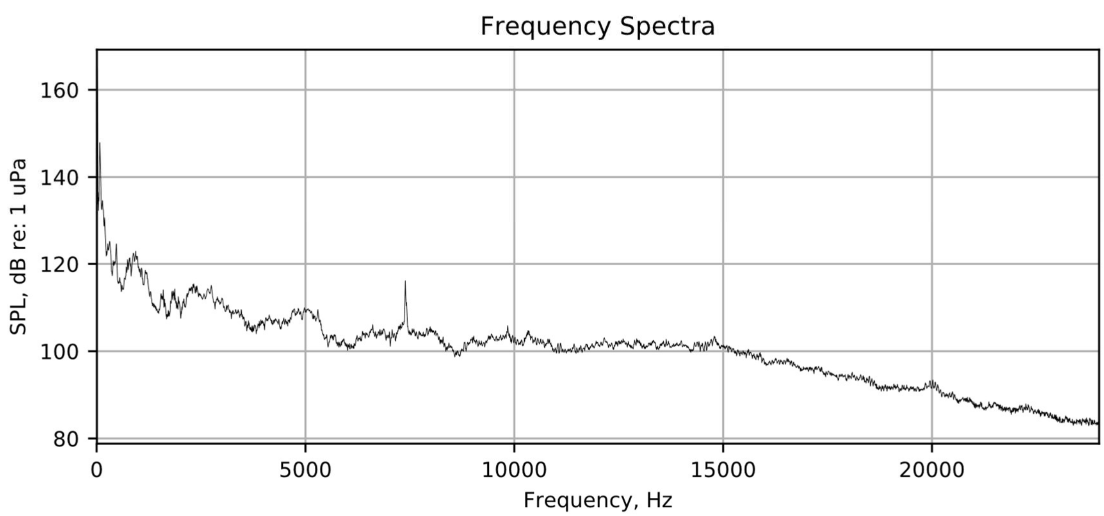
PILE N6-NG

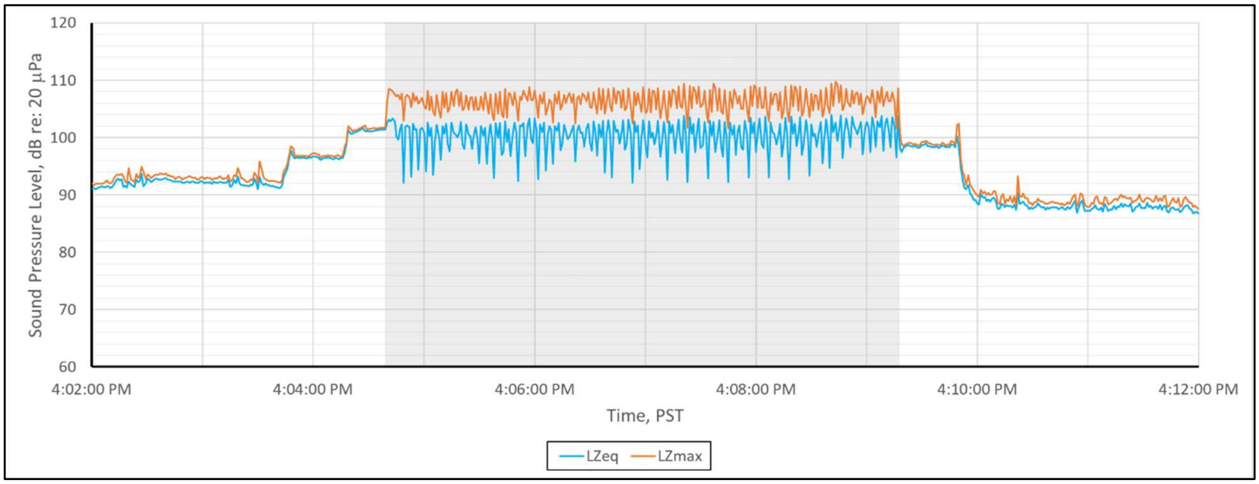
October 21, 2020







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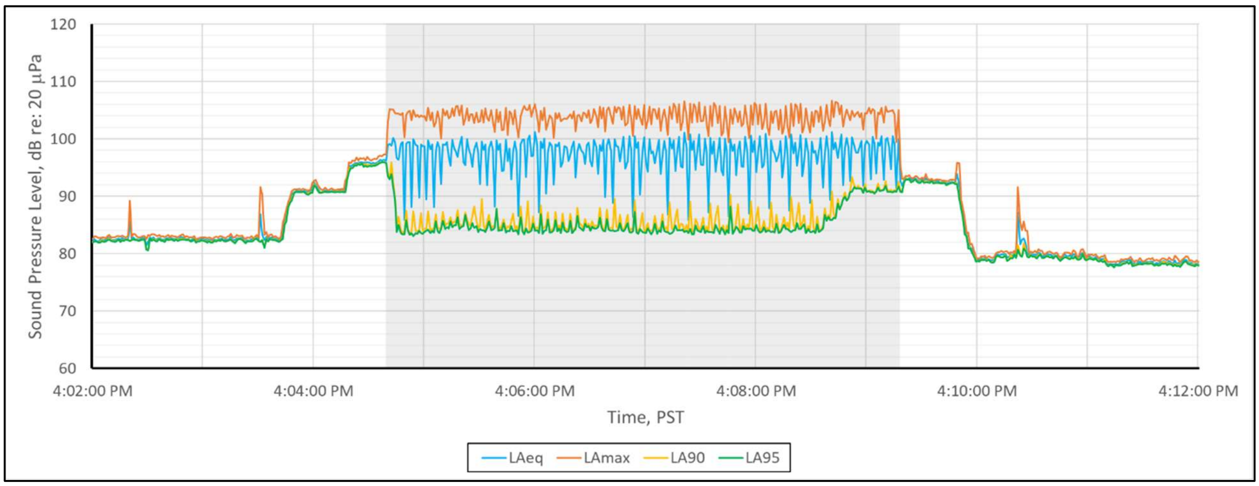
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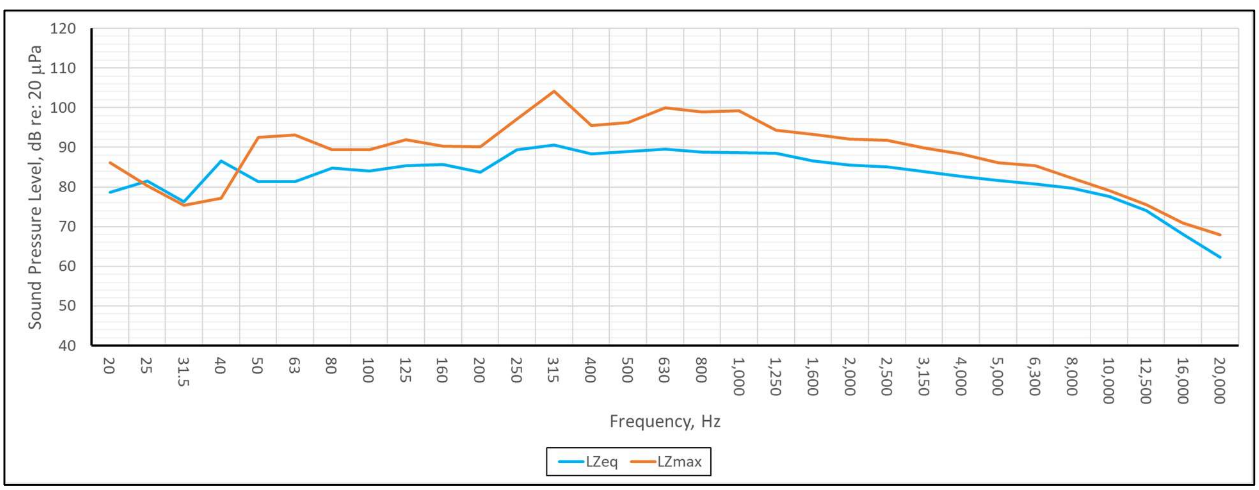
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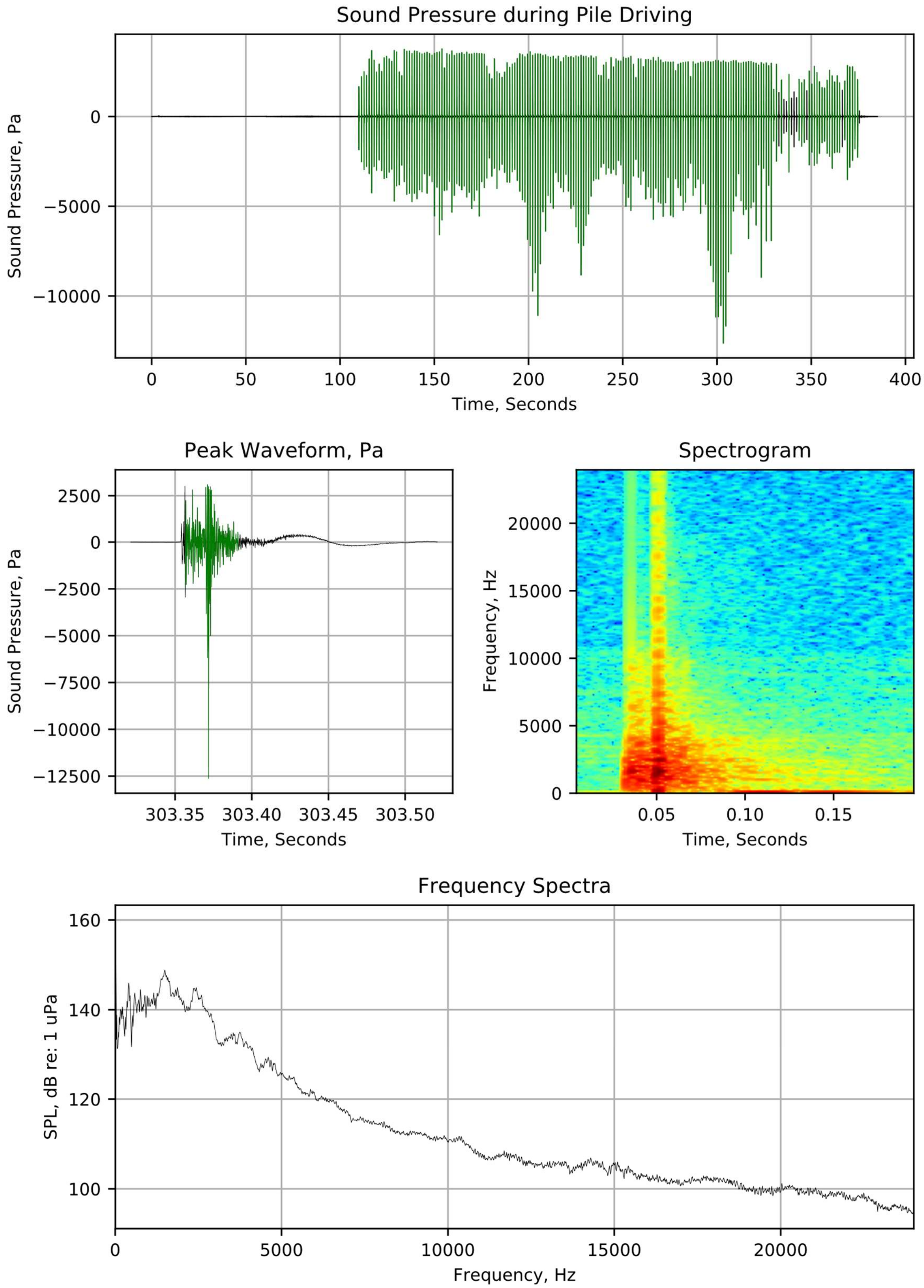
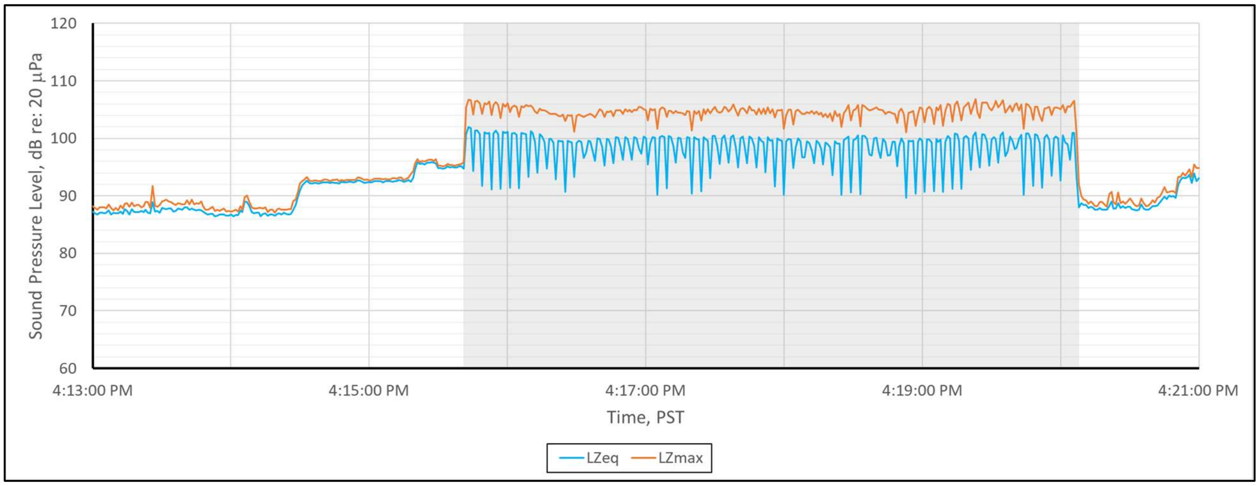
PILE N6-NF.5

October 21, 2020

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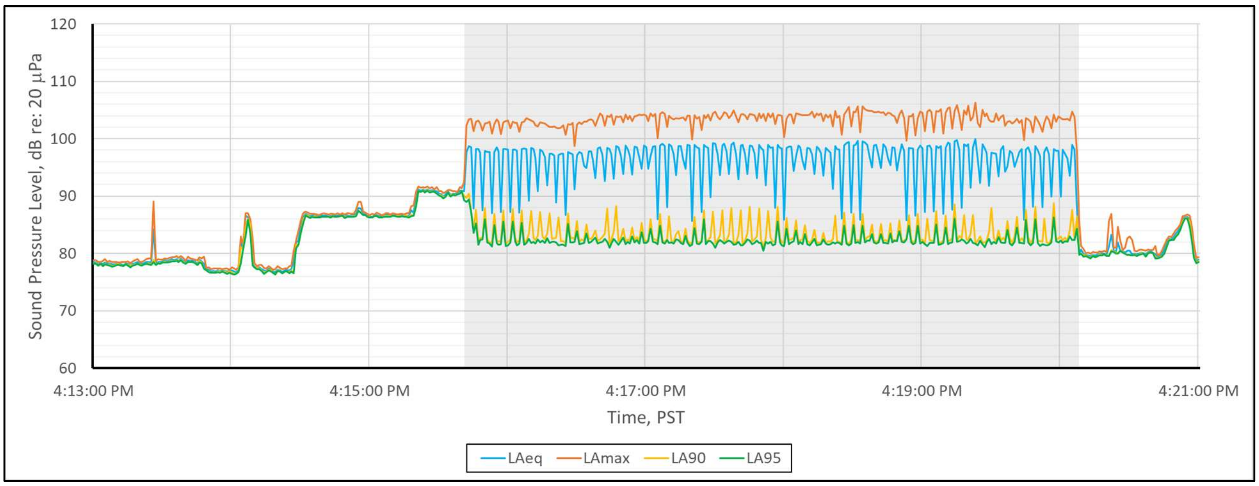
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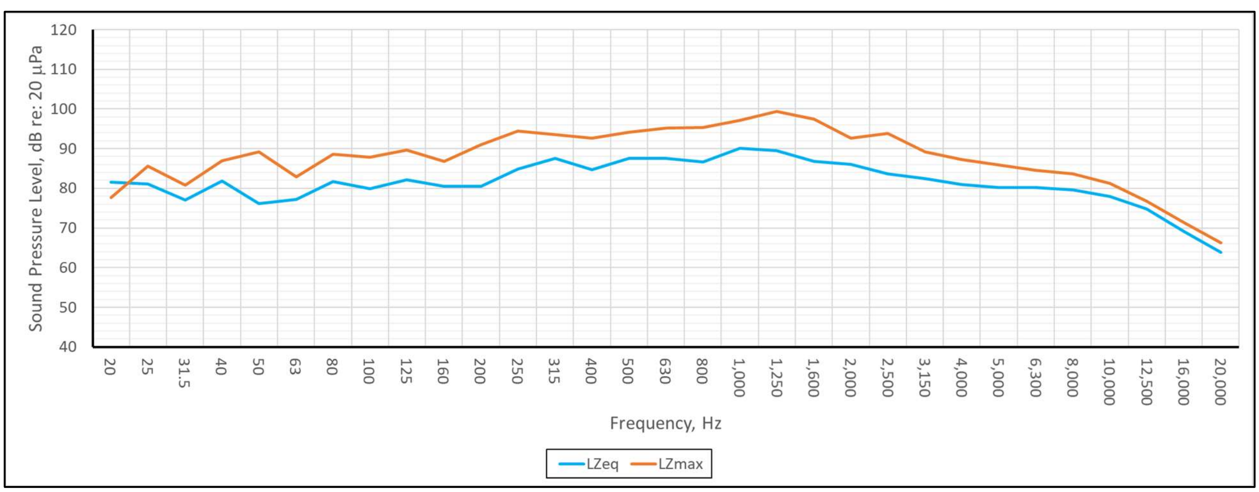
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12,500
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Frequency, Hz
LZeq
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2.0 PILE DRIVER INFORMATION

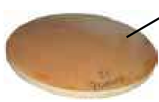
DELMAG D100-52 SINGLE ACTING DIESEL IMPACT HAMMER

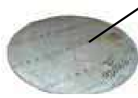
APE D100-52 Single Acting Diesel Impact Hammer

D100-52 in a bottom drive.

Optional Variable Throttle Control.

Cushion material.





Typical 54" offshore.

MODEL D100-52 (10.0 metric ton ram)

SPECIFICATIONS	
Stroke at maximum rated energy	135 in (343 cm)
Maximum rated energy (Setting 4)	248,063 ft-lbs (334.88 kNm)
Setting 3	220,776 ft-lbs (298.05 kNm)
Setting 2	191,008 ft-lbs (257.86 kNm)
Minimum rated energy (Setting 1)	158,760 ft-lbs (214.33 kNm)
(Variable throttle allows for infinite fuel settings)	
Maximum obtainable stroke	150 in (381 cm)
Maximum obtainable energy	288,488 ft-lbs (391 kNm)
Speed (blows per minute)	34-53

WEIGHTS (Approximate)	
Piston	22,050 lbs (10,000 kg)
Anvil	4,670 lbs (2,118 kg)
Anvil cross sectional area	482.8 in² (3114.83 cm²)
Hammer weight (includes hydraulic trip device)	47,000 lbs (21,318 kg)
Typical operating (weight with offshore leader)	Consult Factory

CAPACITIES	
Fuel tank (runs on diesel or bio-diesel)	40.3 gal (153 liters)
Oil tank	8.3 gal (31.5 liters)

CONSUMPTION	
Diesel or Bio-diesel fuel	7.8gal/hr (30 liters/hr)
Lubrication	0.67 gal/hr (2.5 liters/hr)
Grease	8 to 10 pumps every 20 minutes of operation time.

STRIKER PLATE	
Weight	1,036 lbs (470 kg)
Diameter	25 in (57.15 cm)
Area	491 in² (3167.74 cm²)
Thickness	8 in (20.32 cm)

CUSHION MATERIAL	
Type/Qty	Micarta / 2 each
Diameter	25 in (57.15 cm)
Thickness	1 in (25.4 mm)
Type/Qty	Aluminum / 3 each
Thickness	1/2 in (12.7 mm)
Diameter	25 in (57.15 cm)
Total Combined Thickness	3.5 in (8.89 cm)
Area	491 in² (3167.74 cm²)
Elastic-modulus	285 ksi (1,965 mpa)
Coeff. of restitution	0.8

STANDARD OFFSHORE LEADER	
8"x54" for 48" piles and under	Consult Factory

MINIMUM BOX LEAD SIZE/OPERATING LENGTH	
Minimum box leader size	8 in x 37 in (20.32 cm x 94 cm)
Operating length for offshore leader	396 in (1005.84 cm)

Corporate Offices
7032 South 196th
Kent, Washington 98032 USA
(800) 248-8498 & (253) 872-0141
(253) 872-8710 Fax

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e-mail: ape@apevibro.com

Note: All specifications are subject to change without notice 08/20/2012

3.0 BUBBLE CURTAIN INFORMATION

System Design Calculations:

Compressed Air Bubble Curtain

Design: **Washington State DOT**
Colman Dock Project

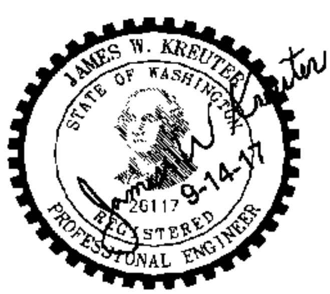
For: **Pacific Pile & Marine, LLC**
Seattle, Washington

System: **Bubble Curtain Performance Calculations**

System Number: **2017-47-72-1B**

Date: **14-Sep-17**

By: **jwk**



Rev B

VANGUARD MARINE, PLLC
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Bubble Curtain Performance Calculations	Sheet: 1 of: 23

A. REVISIONS

REV A

Date	Item	Description
9-14-2017	1)	Corrected quantity of air bubbler rings used for "confined bubbler ring" needed when driving batter piles. The original quantity used WAS (7), and now IS (1). HDPE Ring only needs to protrude a minimum distance of 0.50-FT (6-IN) above water level in order to function as required. See sheets 19-22.

REV B

Date	Item	Description
9-14-2017	1)	Modified calculations to consider and include air manifold and pertinence of it in system performance (including available air flow rate). Added sheet 12. Modified calculation CONCLUSION to suit.

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 2 of: 23

B. TABLE OF CONTENTS

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 3 of: 23

C. DISCUSSION

The following calculations are provided to demonstrate the performance of a Bubble Curtain Assembly design that will be used to generate a noise attenuating curtain of bubbles during pile driving associated with work being conducted as part of the rebuilding of the Washington State DOT Colman Dock in Seattle, WA. A previously constructed bubble curtain system will be used (and modified) to satisfy the contractual requirements associated with the noise attentuation portion of the project specification. The bubble curtain system is to engulf in bubbles over the full depth of the water column at all times that the impact pile driver is in use.

The bubble curtain equipment will take two general forms: 1) Unconfined bubble curtain arrangement, and 2) Confined bubble curtain arrangement. The unconfined arrangement will be used to provide noise attenuation for vertical piles that are being driven into the mud. The confined arrangement will be used while driving batter piling.

The unconfined bubble curtain assembly equipment consists of air compressors that will deliver supply air to a fabricated air system manifold. The manifold splits the supply air into (up to) fourteen supply hoses that provide supply air to (up to) seven air bubbler rings that are positioned around the pile being driven. The air bubbler rings are positioned at regular 7-FT intervals beginning at the mud line and spaced vertically up to the water surface. The confined bubble curtain system includes ONLY one ring at the mud line.

This set of calculations will establish the number of air compressors required (including rated output) to satisfy the WSDOT specified air bubble flux density of 32.91-CFM per foot of bubbler ring. This installation will consist of three bubbler rings used in water depths of up to 50-FT deep.

It is assumed that the existing equipment has been fabricated in accordance the the intent of the project specificaions and that the equipment performs as described in the specifications. The purpose of this set of caclulations is to serve as a check on equipment performance and to establish, using the characteristics of compressible gas (ie. Compressed air) the flowrate and pressure of air delivered to the equipment to achieve the specified bubble flux for the water depths required and the as-built bubbler rings (with the established air orifice size and count).

Assumptions made to support this set of calculations are shown on next sheet.

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 4 of: 23

D. ASSUMPTIONS & CRITERIA

1) The following industry accepted nomenclature is used throughout this analysis:

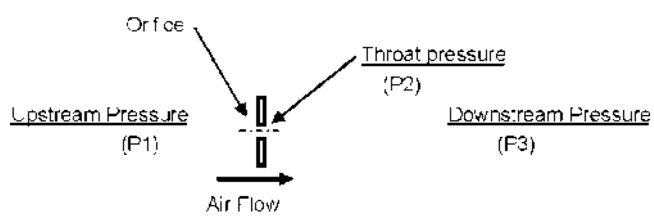
   SCFM = Air as measured at "standard" conditions (Temp = 60-F, 14.7-PSIA)

   ACFM = Air as measured at "actual" conditions (Temp = xx-F, xx-PSIA)

2) The pressure drop calculations made to estimate the frictional losses in the system air piping consider the "longest run" in the system. If the system will perform as required through the longest run, performance through all shorter runs of piping will be at least as good as determined for the longest run.

3) The bubble curtain is created by delivering compressed air to a pipe formed into a ring that has several holes drilled through the pipe ring that allow air bubbles to discharge. The drilled holes act as "orifices" through which the compressed air passes. Any reference to orifices in this set of calculations indicates these holes.

4) Compressed gases, when passing through an orifice, will demonstrate different behaviors depending upon flow and pressure parameters. If the upstream pressure (upstream of the orifice) is high enough, and the downstream pressure is low enough, the upstream pressure will cause enough flow through the orifice to create what is known as a "critical flow" condition. For fully developed "critical flow", the velocity of the gas through the throat of the orifice reaches a sonic velocity. If this occurs, it can be shown that the behavior of the gas can be predicted using certain formulae. If the downstream pressure is higher, the relative pressures cannot reach "critical flow" and instead achieve what is referred to as "subcritical flow". In this case, different formulae are used to predict the behavior of the gas. In these calculations, it is shown that the submergence of the bubbler ring under the static head of the water column prevents full "critical" flow from developing. Instead, the air flow calculations are based on "subcritical" flow, as shown in the calculations.



Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 5 of: 23

D. ASSUMPTIONS & CRITERIA

5) An orifice is a round sharp edged hole in a thin plate. The holes in the fish ring pipe are assumed to behave as do orifices - rather than like any form of nozzle. Critical ratios for compressed (perfect) gases apply accurately to rounded entrance nozzles. Their application to sharp edge orifices is rather approximate. In practice, the critical ratio is applied to either nozzle or orifice.

   For air between 0-DEG F and 250-DEG F, the critical ratio for air is: $r_c = 0.528$.

6) The air system schematic and details are shown in the Washington State Department of Transportation guidance drawing set, Drawing Numbers "S03.70" thru "S03.75" dated with "Submittal Date" of 2-28-2017 in all cases. These drawings developed for the Multimodal Terminal at Colman Dock.

7) The Bubble Curtain performance specification is provided in Washington Department of Transportation - Ferries Division project specification for the Seattle Multimodal Terminal at Colman Dock. See pages 255 through 258 (dated 2-28-2017).

8) The assumed hose size between the air compressors and the air system supply manifold assembly is 3"-Nom and the hose length is assumed to be 100-FT long. The hose is rubber-lined and assumed to be equivalent to steel pipe.

9) The assumed hose size between the air system supply manifold assembly and the (furthest) air bubbler ring is assumed to be 1"-Nom and the hose length is assumed to be 200-FT long. Rubber-lined hose assumed to be equivalent to steel pipe.

10) The compressor air will be filtered for oil mist prior to delivery to the system. The sizing and selection of the fillter will be provided elsewhere, by others.

11) For the unconfined bubble curtain arrangement, there will be up to (7) bubbler rings spaced at 7-FT intervals (first ring being positioned on mud) suitable for depths of up to 50-FT deep (water depth). The confined bubble curtain arrangement will be fabricated from a combination of steel with HDPE tube, also sized for 50-FT depths.

12) The seawater temperature (avg.) is assumed to be: **50** F

13) The specific gravity of seawater assumed is: **1.03** - -

14) The assumed atmospheric pressure is: **14.696** PSI

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 6 of: 23

D. ASSUMPTIONS & CRITERIA

15) The assumed air temperature of the compressed air: **60** F

16) Criteria for the unconfined ring as follows:
The bubbler ring diameter is assumed to be: **68.875** IN
The number of holes in each ring (per WSDOT dwg): 1,134 holes
(assumes 1"-deducted from length of each half, each end)

17) Criteria for the confined ring as follows:
The bubbler ring diameter is assumed to be: **62.875** IN
The number of holes in each ring (per WSDOT dwg): 1,053 holes
(assumes 1"-deducted from length of each half, each end)

18) Bubbler ring hole (orifice) diameter: **0.0625** IN

19) Air flux density required per foot of ring: **32.91** SCFM per FT

20) Max. water depth of rings: **50** FT

21) While the calculations provided in this report are accurate and reflect current industry calculation methods. It must be noted that due to variations in air and water temperatures, variations in barometric pressure and variations of piping and system components used (final dimensions and equipment arrangement), there will be variations in the system performance. On the other hand, these variations should be fairly small and while the actual performance will change based on these variables, the purpose of these calculations is maintained and the system performance will, from a practical point of view, match what is shown in this report.

22) It is assumed that the air flow meters that are installed in each bubbler ring air supply line (located at the manifold) will provide air flow rate information in Standard Cubic Feet per Minute (SCFM) to the system operators. This is per flow meter information provided by WSDOT. As a result, it is further assumed that the operators will adjust air flow throttling valves to achieve the target air flow rates to each air bubble ring as calculated in this set of calculations.

23) It is assumed that all compressed air piping has been selected and fabricated for system pressures up to 300-PSIG.

24) Other assumptions as noted in the body of this set of calculations.

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 7 of: 23

E. CONCLUSION

The performance of the Washington State Colman Dock Bubble Curtain equipment when used as described by this set of calculations should provide the specified air bubble flux required to attenuate pile driving noise.

One air compressor described in the body of the calculations will provide the specified, required flowrate of air required to satisfy the contract specification for water depths to 30-FT deep. Two compressors (operated in parallel with one manifold) will provide the required air for depths to 50-FT deep.

The following detailed calculations indicate that a total air flow rate of 4,186-SCFM is required to supply a depth of 50-FT. The air compressors, set to operate at a discharge pressure of 200-PSIG, will deliver approximately 4,643-SCFM to the bubbler rings.

When used as described here, the expected air bubble flux will be approximately 33-CFM per foot of bubbler ring. The required flux is 33-CFM per foot of ring. ASSUMPTION No. (21) explains some of the unknowns and variables that will affect system performance. It should also be noted that the required air flow rates necessary to achieve this air flux density exceed the compressor ratings by approximately 1%. However, given the variables described, it is nearly impossible to expect the system to perform exactly as described by this set of calculations. It is still expected that the system described in this report will satisfy the intent of the Washington State performance specification.

The final performance of the system will be controlled by the air flow meters and throttling valves provided as part of the system. Operators should adjust the throttling valves to supply 600-SCFM to each bubbler ring - for all depths.

Using the approach described above (with the valves throttled accordingly), the total pressure required in the system is approximately 100-PSIG. The compressors are rated to deliver a maximum output pressure of 200-PSIG.

This flux density and the associated calculations are valid for both the unconfined bubble curtain assembly AND the confined bubble curtain assembly.

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Bubble Curtain Performance Calculations	Sheet: 8 of: 23

E. CONCLUSION

Calculations show that, for the confined bubble curtain arrangement, the 72-IN Dia. HDPE tube must protrude at least 6-IN above the surface of the water so that there will be enough head in the column of water to prevent water from being pumped out of the top of the HDPE tube. This assumes one bubbler ring being used at depth.

Specific attention should be paid to the pipe branch sizes identified in this set of calculations, the hose sizes and the hose lengths. While there is SOME margin in the system (ie. Capacity of equipment vs. system design requirements), longer hoses and smaller piping could quickly result in elimination of this margin.
The sizes shown for hose, valves, pipe and fittings in this set of calculations must be adhered to in order to meet the WSDOT system performance requirements.

It is assumed that the Contractor who will be using this equipment will satisfy the requirements of the specification and any and all safety regulatory requirements for the maintenance and use of this type of equipment.

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations | Sheet: 9 of: 23

F. AIR FLOWRATE REQUIRED FOR BUBBLE CURTAIN

1) Criteria

Required flux density per foot of ring:	32.91	SCFM per FOOT
Total number of bubble curtain rings is:	**7**	- -
Each ring has a nominal diameter of:	68.875	IN
Length of each bubbler pipe is:	18	FT

Using Boyles Law and the depth at each ring, the total free air required is:

Ring No.	Ring Depth (Ft)	Free Air Req'd (SCFM)	Actual Air at depth (ACFM)
1	50.00	593	236
2	43.00	593	257
3	36.00	593	284
4	29.00	593	316
5	22.00	593	356
6	15.00	593	408
7	8.00	593	478
		4,154	2,334

2) Compressor selection -

Manufacturer =	**Doosan**	
Model =	**XHP1170WCAT**	
F.A.D. =	**1,170**	CFM
Rated Operating Pressure =	**200**	PSIG (pressure relief valve set to this)
BHP output =	**540**	HP
Quantity required =	**4**	- -

Project: **Colman Dock Project** | By: jwk | Date: 14-Sep-17 **REV B**

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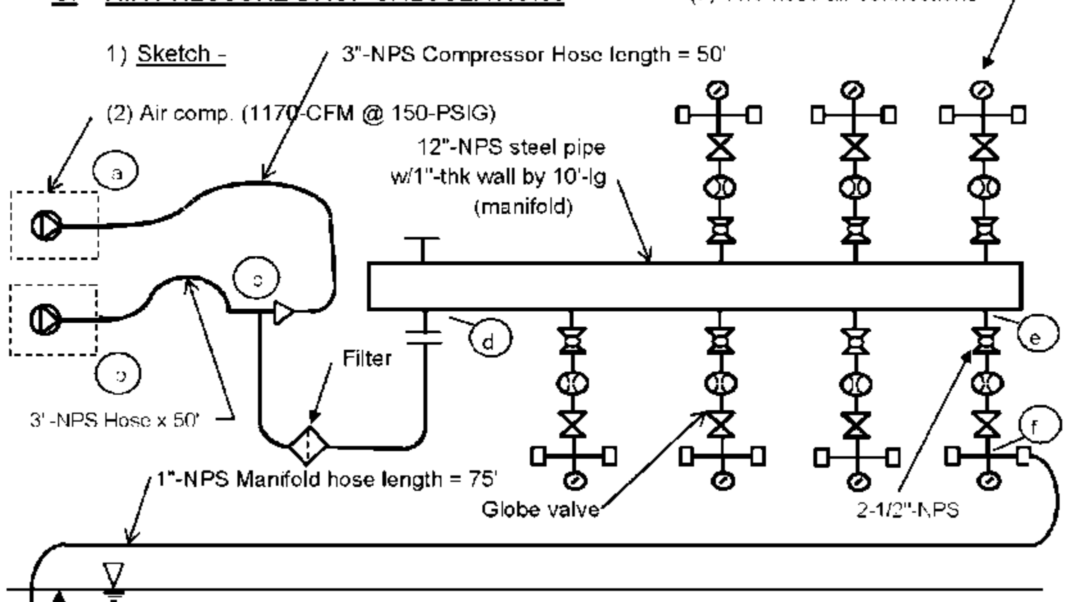
G. AIR PRESSURE DROP CALCULATIONS

1) Sketch -



Branch	Flow Rate	Qty	Description	Unit Eq. Lgth (FT)	Total Eq. Lgth (FT)	Delta P (PSI)
a - c	1,170	50	LF 3"-NPS Rubber hose		50.0	
		1	3"-NPS Tee - branch	15.3	15.3	
b - c	1,170	50	LF 3"-NPS Rubber hose		50.0	
		1	3"-NPS Tee - branch	15.3	15.3	
c - d	1,170	20	LF 3"-NPS Rubber hose		20.0	
		1	Oil Filter (1-1/4"-NPS)			0.7
d - e	2,340	10	LF 12-NPS pipe	10.0	10.0	
e - f	1,170	1	2-1/2"-NPS Ball valve	0.6	0.6	
		1	Flow Meter (2"-NPS RCM, bronze)			5.0
		1	2-1/2"-NPS Globe valve	65.8	65.8	
		1	2-1/2" Tee - branch	11.6	11.6	
	585	1	Reducer 2-1/2" x 1"	15.0	15.0	
f - g	585	75	LF 1"-NPS Hose		75.0	

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations Sheet: 11 of: 23

G. AIR PRESSURE DROP CALCULATIONS

3) Pressure Drop Calculation Summary -

Flowrate out of each compressor = 1170 SCFM
Rated pressure at compressor = 200 PSI

Branch	Size (IN)	Inlet Air Pressure (PSI)	Pipe & Ftg Pressure Loss (PSI)	Other Pressure Loss (PSI)	Total Pressure Loss (PSI)
a - c	**3**	200.00	0.377		0.377
b - c	**3**	200.00	0.377		0.377
c - d	**3**	199.62	0.116		0.116
d - e	**12**	199.51	0.000	**0.700** (filter)	0.700
e - f	**2-1/2**	198.81	1.628	**5.000** (flowmeter) **26.000** (valve)	32.628
f - g	**1**	166.18	14.097		14.097
Ring	**2-1/2**	152.08	**0.700** (estimated)		0.700

Delta Z = 50 FT = 21.65 PSIG

NOTE: Adjust throttling valve at manifold until pressure in gauge is: **45** PSIG
This will provide a "ring inlet pressure" at the ring inlet as shown next sheet.
Performance of the bubbler ring with this air pressure shown next sheet.

The total pressure required in the system is: 93.5 PSIG

The compressor output pressure is: 200.0 PSIG

Project: **Colman Dock Project** | By: jwk | Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 12 of: 23

H. AIR RECEIVER STORAGE vs. SYSTEM AIR REQUIREMENTS

1) Discussion -

The manifold shown on the previous sheet acts as an air receiver and, while it doesn't provide a meaningful amount of air storage, it does serve an important function in the system. If it is assumed that the compressor keeps the receiver full as it is operating, this reservoir of pressurized air provides the needed air supply to the hoses that supply pressurized air to the bubbler rings at the required water depths.

The air supply in the receiver is stored at 150-PSIG and is supplied by a constant air flow rate of 1,170-SCFM from the air compressor. The air pressure that is required in the system (supply to the bubbler rings) is required at a lower supply pressure and, as a result, the actual available air in the system is calculated as shown below.

Air supply rate to Receiver	=	1,170	CFM
Air pressure delivered to receiver	=	200	PSIG
Air supply rate required per ring	=	593	CFM
Max Air pressure required to ring	=	93	PSIG (at 50-FT depth)
Available flow rate at required pressure (using Boyle's Law)	=	2,322	CFM per compressor
Available air flowrate (2) compressors	=	4,643	CFM
Total required air flow rate required for seven rings (down to 50-FT)	=	4,154	CFM

Therefore, ONE compressor per pile driving set-up will provide the required air necessary to supply the air bubbler rings at the specified flow rate down to depths of thirty feet of water.

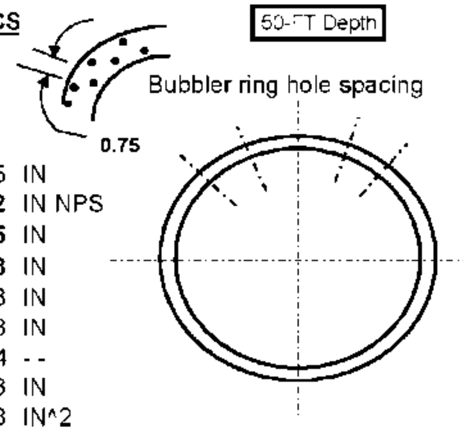
Therefore, TWO compressors per pile driving set-up will provide the required air necessary to supply the air bubbler rings at the specified flow rate down to depths of fifty feet of water.

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations | Sheet: 13 of: 23

I. UNCONFINED RING AIR FLOWRATE CALCS

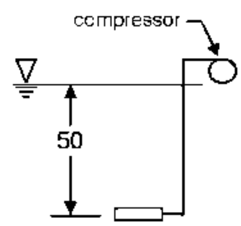
50-FT Depth



(4) holes every 3/4" of length

1) Sketch:

Ring Nom Diameter	=	68.875	IN
Ring Pipe Size	=	**2-1/2**	IN NPS
Pipe OD	=	**2.875**	IN
Pipe ID (Sch 80)	=	**2.323**	IN
Ring OD	=	70.313	IN
Ring OD	=	67.438	IN
No. of Holes in ring	=	1,134	- -
Hole Diameter	=	0.063	IN
Hole Area	=	0.003068	IN^2
Total bubble area in ring	=	3.48	IN^2
	=	0.02	FT^2
Air Temperature	=	60	DEG F
Air Density (atm. pressure)	=	**0.0757**	LBm/FT^3
Air density at (P1), below	=	**0.1919**	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**22.86**	PSIG
Frictional losses in ring	=	0.69	PSIG (estimated value)
Pressure (P1) at orifice	=	22.2	PSIG
Pressure (P2) at throat	=	21.6	PSIG
Pressure (P3) at outlet	=	21.6	PSIG (water column pressure)
Ratio (P3/P1)	=	0.97	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00067	LB / SEC
Volume. flowrate thru orifice	=	0.208	ACFM through each orifice
	=	0.523	SCFM through each orifice

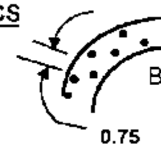
Flow rate through ring	=	593	SCFM
Flow rate per foot of ring	=	32.9	SCFM > 32.91-SCFM

Project: **Colman Dock Project** | By: jwk | Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations | Sheet: 14 of: 23

I. UNCONFINED RING AIR FLOWRATE CALCS

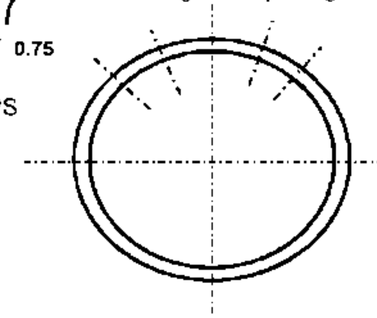
43-FT Depth



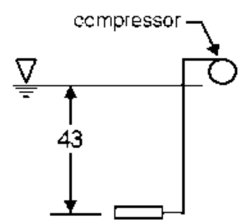
(4) holes every 3/4" of length

Bubbler ring hole spacing

1) Sketch:



Ring Nom Diameter	=	68.875	IN
Ring Pipe Size	=	2-1/2	IN NPS
Pipe OD	=	2.875	IN
Pipe ID (Sch 80)	=	2.323	IN
Ring OD	=	70.313	IN
Ring OD	=	67.438	IN
No. of Holes in ring	=	1,134	- -
Hole Diameter	=	0.063	IN
Hole Area	=	0.003068	IN^2
Total bubble area in ring	=	3.48	IN^2
	=	0.02	FT^2
Air Temperature	=	60	DEG F
Air Density (atm. pressure)	=	0.0757	LBm/FT^3
Air density at (P1), below	=	**0.1767**	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**19.76**	PSIG
Frictional losses in ring	=	0.59	PSIG (estimated value)
Pressure (P1) at orifice	=	19.2	PSIG
Pressure (P2) at throat	=	18.6	PSIG
Pressure (P3) at outlet	=	18.6	PSIG (water column pressure)
Ratio (P3/P1)	=	0.97	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00067	LB / SEC
Volume. flowrate thru orifice	=	0.227	ACFM through each orifice
	=	0.524	SCFM through each orifice

Flow rate through ring	=	594	SCFM

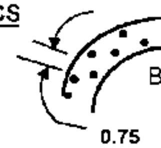
Flow rate per foot of ring	=	32.9	SCFM > 32.91-SCFM

Project: **Colman Dock Project** | By: jwk | Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 15 of: 23

I. UNCONFINED RING AIR FLOWRATE CALCS

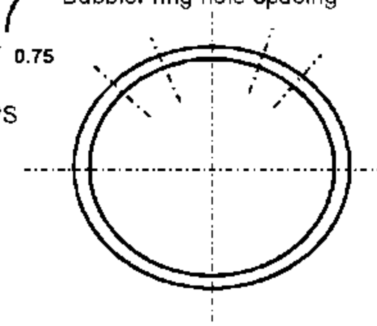
36-FT Depth



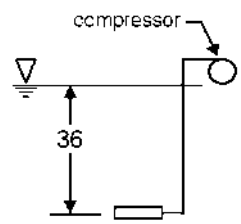
(4) holes every 3/4" of length

Bubbler ring hole spacing

1) Sketch:



Ring Nom Diameter	=	68.875	IN
Ring Pipe Size	=	2-1/2	IN NPS
Pipe OD	=	2.875	IN
Pipe ID (Sch 80)	=	2.323	IN
Ring OD	=	70.313	IN
Ring OD	=	67.438	IN
No. of Holes in ring	=	1,134	- -
Hole Diameter	=	0.06250	IN
Hole Area	=	0.00307	IN^2
Total bubble area in ring	=	3.47808	IN^2
	=	0.02415	FT^2
Air Temperature	=	60	DEG F
Air Density (atm. pressure)	=	0.07570	LBm/FT^3
Air density at (P1), below	=	**0.15390**	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**16.65**	PSIG
Frictional losses in ring	=	0.50	PSIG (estimated value)
Pressure (P1) at orifice	=	16.2	PSIG
Pressure (P2) at throat	=	15.6	PSIG
Pressure (P3) at outlet	=	15.6	PSIG (water column pressure)
Ratio (P3/P1)	=	0.97	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00064	LB / SEC
Volume. flowrate thru orifice	=	0.251	ACFM through each orifice
	=	0.527	SCFM through each orifice

Flow rate through ring	=	597	SCFM

Flow rate per foot of ring	=	33.1	SCFM > 32.91-SCFM

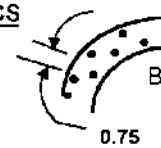
Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 16 of: 23

I. UNCONFINED RING AIR FLOWRATE CALCS

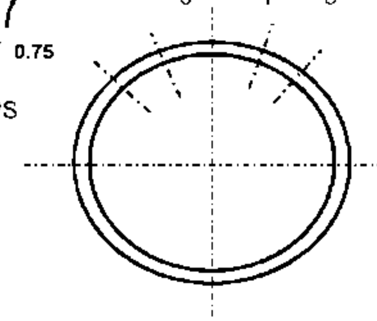
29-FT Depth

(4) holes every 3/4" of length

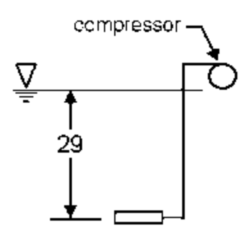


Bubbler ring hole spacing

1) Sketch:



Ring Nom Diameter	=	68.875	IN
Ring Pipe Size	=	2-1/2	IN NPS
Pipe OD	=	2.875	IN
Pipe ID (Sch 80)	=	2.323	IN
Ring OD	=	70.313	IN
Ring OD	=	67.438	IN
No. of Holes in ring	=	1,134	- -
Hole Diameter	=	0.06250	IN
Hole Area	=	0.00307	IN^2
Total bubble area in ring	=	3.47808	IN^2
	=	0.02415	FT^2
Air Temperature	=	60	DEG F
Air Density (atm. pressure)	=	0.07570	LBm/FT^3
Air density at (P1), below	=	**0.14200**	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**13.53**	PSIG
Frictional losses in ring	=	0.41	PSIG (estimated value)
Pressure (P1) at orifice	=	13.1	PSIG
Pressure (P2) at throat	=	12.6	PSIG
Pressure (P3) at outlet	=	12.6	PSIG (water column pressure)
Ratio (P3/P1)	=	0.97	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00066	LB / SEC
Volume. flowrate thru orifice	=	0.277	ACFM through each orifice
	=	0.524	SCFM through each orifice

Flow rate through ring	=	594	SCFM

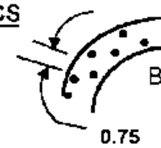
Flow rate per foot of ring	=	33.0	SCFM > 32.91-SCFM

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 17 of: 23

I. UNCONFINED RING AIR FLOWRATE CALCS

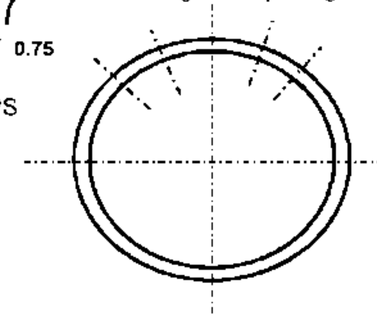
22-FT Depth



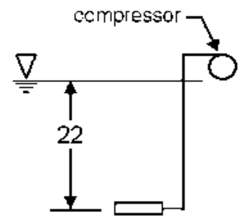
(4) holes every 3/4" of length

Bubbler ring hole spacing

1) Sketch:



Ring Nom Diameter	=	68.875	IN
Ring Pipe Size	=	2-1/2	IN NPS
Pipe OD	=	2.875	IN
Pipe ID (Sch 80)	=	2.323	IN
Ring OD	=	70.313	IN
Ring OD	=	67.438	IN
No. of Holes in ring	=	1,134	- -
Hole Diameter	=	0.06250	IN
Hole Area	=	0.00307	IN^2
Total bubble area in ring	=	3.47808	IN^2
	=	0.02415	FT^2
Air Temperature	=	60	DEG F
Air Density (atm. pressure)	=	0.07570	LBm/FT^3
Air density at (P1), below	=	**0.12830**	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**10.40**	PSIG
Frictional losses in ring	=	0.31	PSIG (estimated value)
Pressure (P1) at orifice	=	10.1	PSIG
Pressure (P2) at throat	=	9.5	PSIG
Pressure (P3) at outlet	=	9.5	PSIG (water column pressure)
Ratio (P3/P1)	=	0.97	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00067	LB / SEC
Volume. flowrate thru orifice	=	0.313	ACFM through each orifice
	=	0.528	SCFM through each orifice

Flow rate through ring	=	599	SCFM

Flow rate per foot of ring	=	33.2	SCFM > 32.91-SCFM

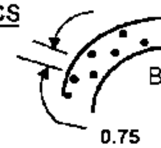
Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations | Sheet: 18 of: 23

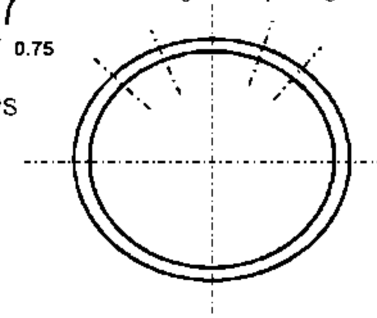
I. UNCONFINED RING AIR FLOWRATE CALCS

15-FT Depth

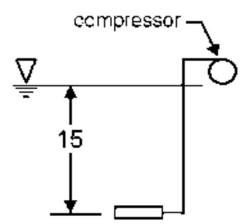
(4) holes every 3/4" of length



1) Sketch:



Ring Nom Diameter	=	68.875	IN
Ring Pipe Size	=	2-1/2	IN NPS
Pipe OD	=	2.875	IN
Pipe ID (Sch 80)	=	2.323	IN
Ring OD	=	70.313	IN
Ring OD	=	67.438	IN
No. of Holes in ring	=	1,134	- -
Hole Diameter	=	0.06250	IN
Hole Area	=	0.00307	IN^2
Total bubble area in ring	=	3.47808	IN^2
	=	0.02415	FT^2
Air Temperature	=	60	DEG F
Air Density (atm. pressure)	=	0.07570	LBm/FT^3
Air density at (P1), below	=	**0.15390**	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**7.23**	PSIG
Frictional losses in ring	=	0.22	PSIG (estimated value)
Pressure (P1) at orifice	=	7.0	PSIG
Pressure (P2) at throat	=	6.5	PSIG
Pressure (P3) at outlet	=	6.5	PSIG (water column pressure)
Ratio (P3/P1)	=	0.97	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00092	LB / SEC
Volume. flowrate thru orifice	=	0.357	ACFM through each orifice
	=	0.527	SCFM through each orifice

Flow rate through ring	=	598	SCFM

Flow rate per foot of ring	=	33.1	SCFM > 32.91-SCFM

Project: **Colman Dock Project** | By: jwk | Date: 14-Sep-17 **REV B**

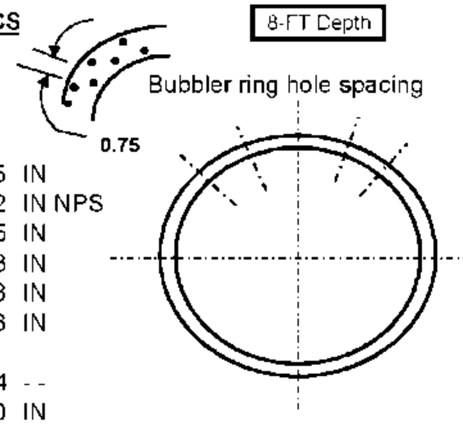
Bubble Curtain Performance Calculations | Sheet: 19 of: 23

I. UNCONFINED RING AIR FLOWRATE CALCS

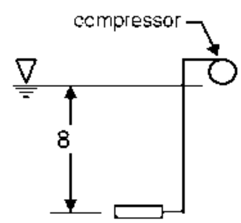
8-FT Depth

(4) holes every 3/4" of length

1) Sketch:



Ring Nom Diameter	=	68.875	IN
Ring Pipe Size	=	2-1/2	IN NPS
Pipe OD	=	2.875	IN
Pipe ID (Sch 80)	=	2.323	IN
Ring OD	=	70.313	IN
Ring OD	=	67.438	IN
No. of Holes in ring	=	1,134	- -
Hole Diameter	=	0.06250	IN
Hole Area	=	0.00307	IN^2
Total bubble area in ring	=	3.47808	IN^2
	=	0.02415	FT^2
Air Temperature	=	60	DEG F
Air Density (atm. pressure)	=	0.07570	LBm/FT^3
Air density at (P1), below	=	0.15390	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**3.99**	PSIG
Frictional losses in ring	=	0.12	PSIG (estimated value)
Pressure (P1) at orifice	=	3.9	PSIG
Pressure (P2) at throat	=	3.5	PSIG
Pressure (P3) at outlet	=	3.5	PSIG (water column pressure)
Ratio (P3/P1)	=	0.97	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00107	LB / SEC
Volume. flowrate thru orifice	=	0.417	ACFM through each orifice
	=	0.527	SCFM through each orifice

Flow rate through ring	=	598	SCFM

Flow rate per foot of ring	=	33.2	SCFM > 32.91-SCFM

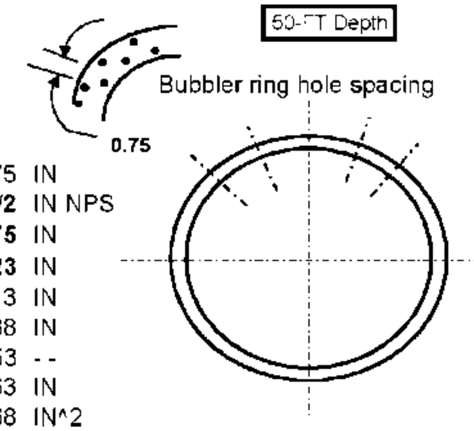
Project: **Colman Dock Project** | By: jwk | Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations | Sheet: 20 of: 23

J. CONFINED RING AIR FLOWRATE CALCS

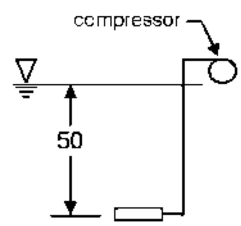
50-FT Depth

(4) holes every 3/4" of length



1) Sketch:

Ring Nom Diameter	=	62.875	IN
Ring Pipe Size	=	**2-1/2**	IN NPS
Pipe OD	=	**2.875**	IN
Pipe ID (Sch 80)	=	**2.323**	IN
Ring OD	=	64.313	IN
Ring OD	=	61.438	IN
No. of Holes in ring	=	1,053	- -
Hole Diameter	=	0.063	IN
Hole Area	=	0.003068	IN^2
Total bubble area in ring	=	3.23	IN^2
	=	0.02	FT^2
Air Temperature	=	60	DEG F
Air Density (atm. pressure)	=	**0.0757**	LBm/FT^3
Air density at (P1), below	=	**0.1919**	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**22.86**	PSIG
Frictional losses in ring	=	0.69	PSIG (estimated value)
Pressure (P1) at orifice	=	22.2	PSIG
Pressure (P2) at throat	=	21.6	PSIG
Pressure (P3) at outlet	=	21.6	PSIG (water column pressure)
Ratio (P3/P1)	=	1.59	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00067	LB / SEC
Volume. flowrate thru orifice	=	0.208	ACFM through each orifice
	=	0.523	SCFM through each orifice

Flow rate through ring	=	551	SCFM
Flow rate per foot of ring	=	33.5	SCFM > 32.91-SCFM

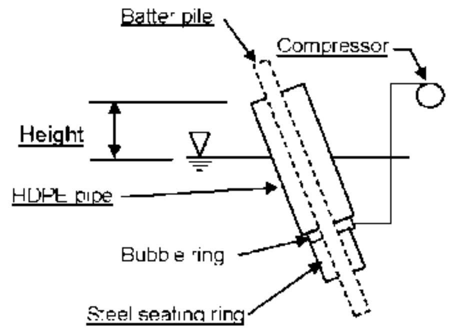
Project: **Colman Dock Project** | By: jwk | Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 21 of: 23

J. CONFINED RING AIR PUMP EFFECT (HDPE TUBE LENGTH CALC)

1) Discussion

The confined bubble curtain arrangement is shown in simplified sketch below.



The confined bubble curtain arrangement will differ from the unconfined assembly in two ways: 1) The ring diameter is slightly smaller, and 2) There will only be (1) bubbler ring used in the assembly rather than (7). The (1) ring will be placed at the bottom of an external HDPE tube (shown above) that will be positioned over the batter pile (driven at an angle as shown). The air will be supplied to the ring and the result will be that the air and water will mix within the HDPE tube to create the air barrier needed to attenuate the noise during pile driving.

The calculation that follows, however, is necessary to verify that the confined arrangement will not result in a "pumping action" of the water inside of the HDPE tube that is positioned around the batter pile to the extent that the water in the confinement tube is displaced by the air bubbles emitting from the ring.
The tube height above the water surface will be determined by using the required air volume (in the bubble curtain rings) and from this, will determine the static head that the air can "lift". This "lift" height will define the height above water surface that the HDPE pipe must extend.

If the height of the tube above the waterline is adequate to limit the flow of water out of the tube, the arrangement will be considered acceptable.

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 22 of: 23

J. CONFINED RING AIR PUMP EFFECT (HDPE TUBE LENGTH CALC)

2) Behavior of air & water in confinement tube

a) Assume, in the worst case, that the water depth for the batter being driven is 50-FT of water. This means that the amount of air in the HDPE confinement tube will be at a maximum due to the requirement at this depth for the (1) bubbler ring that delivering the required amount of air.

b) Also assume that this set of calculations is based on air having a density at the midpoint depth (ie. 25-FT deep). This means that the air between 25-FT and 50-FT will be more compressed due to the water column (ie. air more dense) and that the air between 25-FT and the surface will have a lower density (due to less static head acting on the air. The two should average out to be close to the actual conditions over the entire water column height of 50-FT. Assumed air density is: **0.1326** LB/FT^3

c) The assumed density of the seawater over the range of the 50-FT depth is assumed to be 64.2-LB/FT^3.

d) Steady state volume of air in tube

Air out of each orifice at 25-FT depth	=	**0.296**	ACFM	(use this value)
		0.526	SCFM	
Orifice count per ring	=	1,053	- -	
Total ring count	=	1	- -	
Total air flow into confined pipe	=	551	CFM	
Assumed OD of HDPE tube	=	**72**	IN	
HDPE wall thickness	=	**1.375**	IN	
Assumed HDPE tube ID	=	69.25	IN	
Assumed length of HDPE tube	=	**55**	FT	
Total volume of HDPE tube	=	1,439	FT^3	

Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

Bubble Curtain Performance Calculations	Sheet: 23 of: 23

J. CONFINED RING AIR PUMP EFFECT (HDPE TUBE LENGTH CALC)

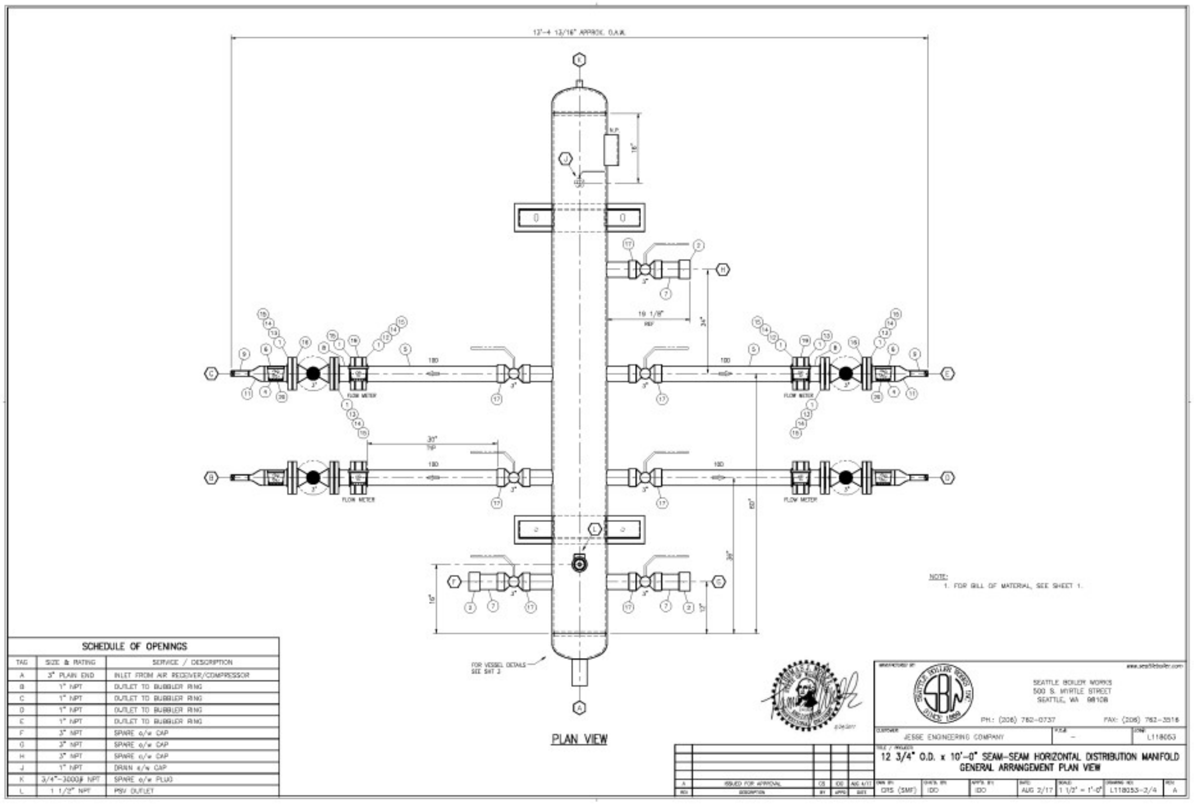
3) Behavior of air & water in confinement tube — 72"-DIA.

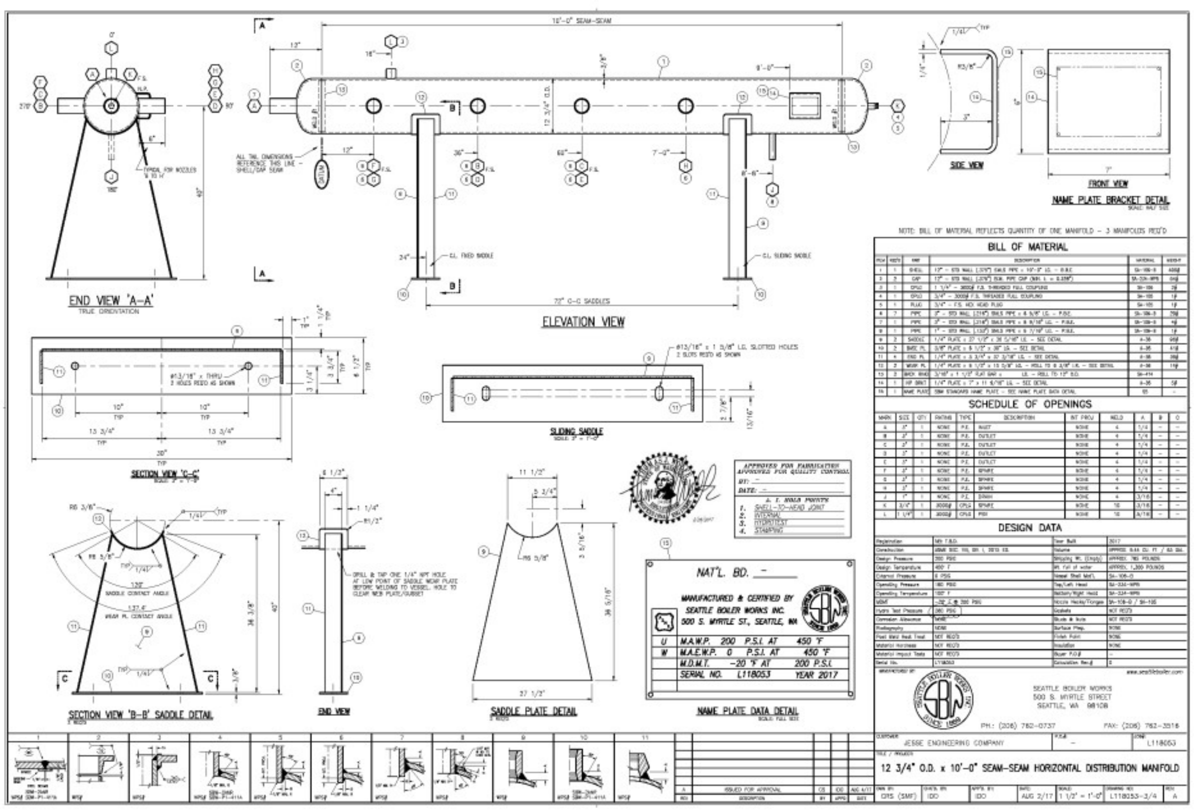
Pumping rate	=	**0.01**	GAL/DAY
Pipe diameter	=	**72.00**	IN
Submergence	=	**50.0**	FT
Lift	=	**0.5**	FT
cross-sectional area of pipe	=	28.274	FT^2
Pipe volume	=	1,427.85	FT^3
Pipe volume	=	7.48	GAL/FT^3
Vl (Flow rate)	=	0	GPM
A (Pipe area)	=	28.274	FT^2
L (Lift)	=	0.5	FT
D (Pipe diameter)	=	72	IN
Lf (density of fluid)	=	**64.2**	LBm/FT^3
S (submergence)	=	50.00	FT
Lg (Gas density)	=	**0.0765**	LBm/FT^3
Vg (Gas flow)	=	709	CFM
Actual flowrate out of (1) ring	=	551	CFM
Pressure	=	21.89	PSI

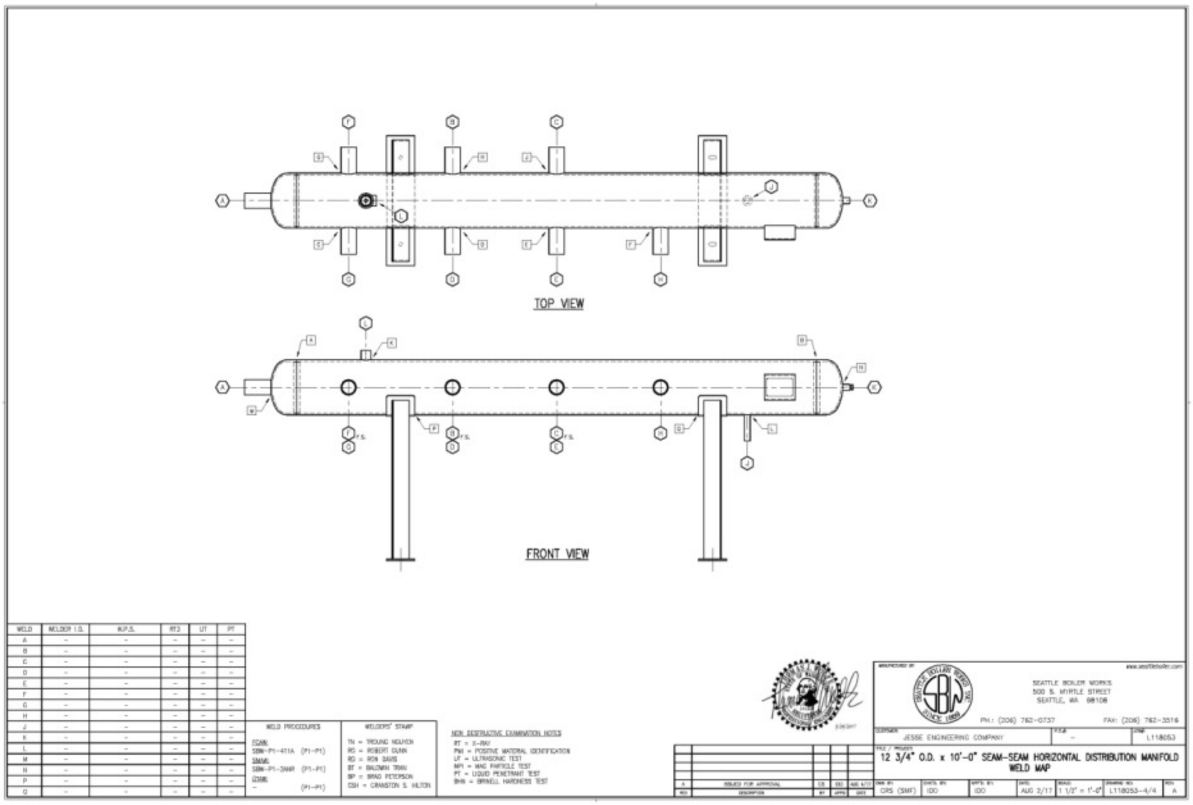
NOTE: This calculation shows that at a flowrate of 709-CFM and a tube length extending 0.5-FT (6-IN) MINIMUM above the surface, water will begin pumping out of the top of the HDPE tube.

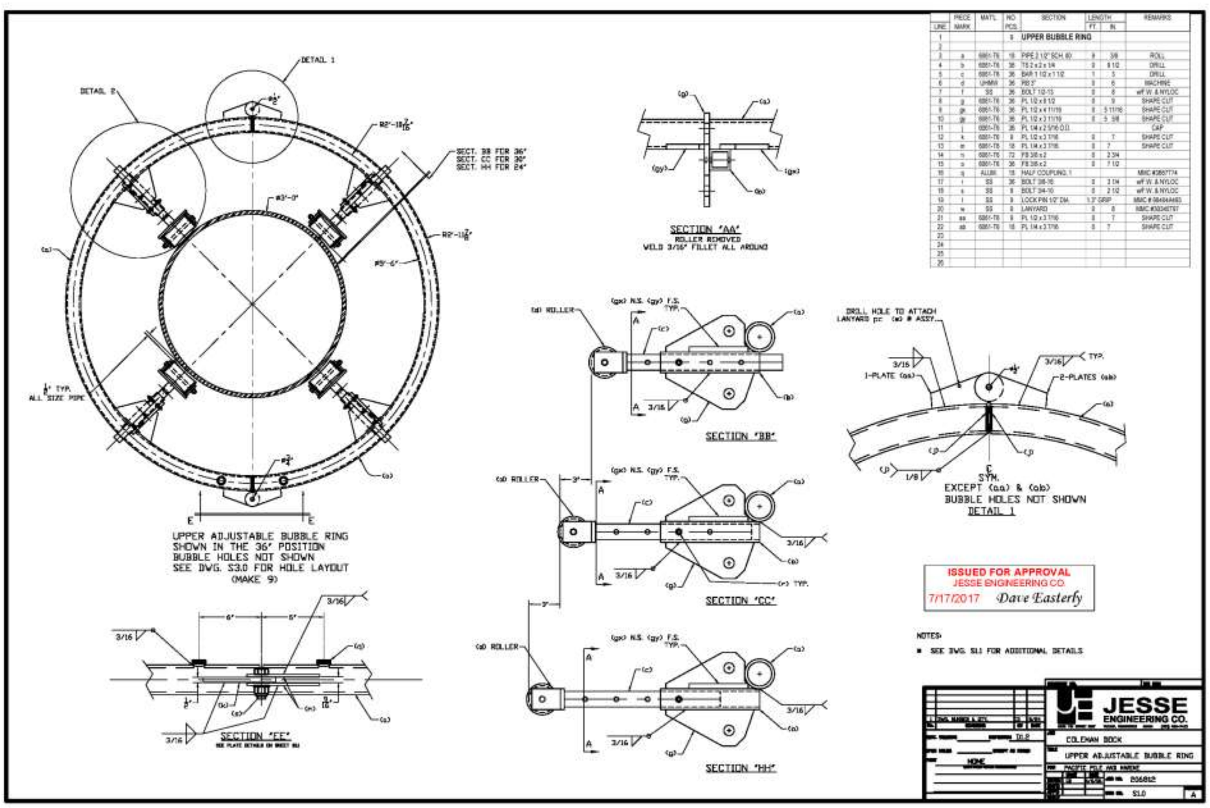
For the required air flowrate of 551-CFM (calculated in earlier calc.) the water will stay in the tube.

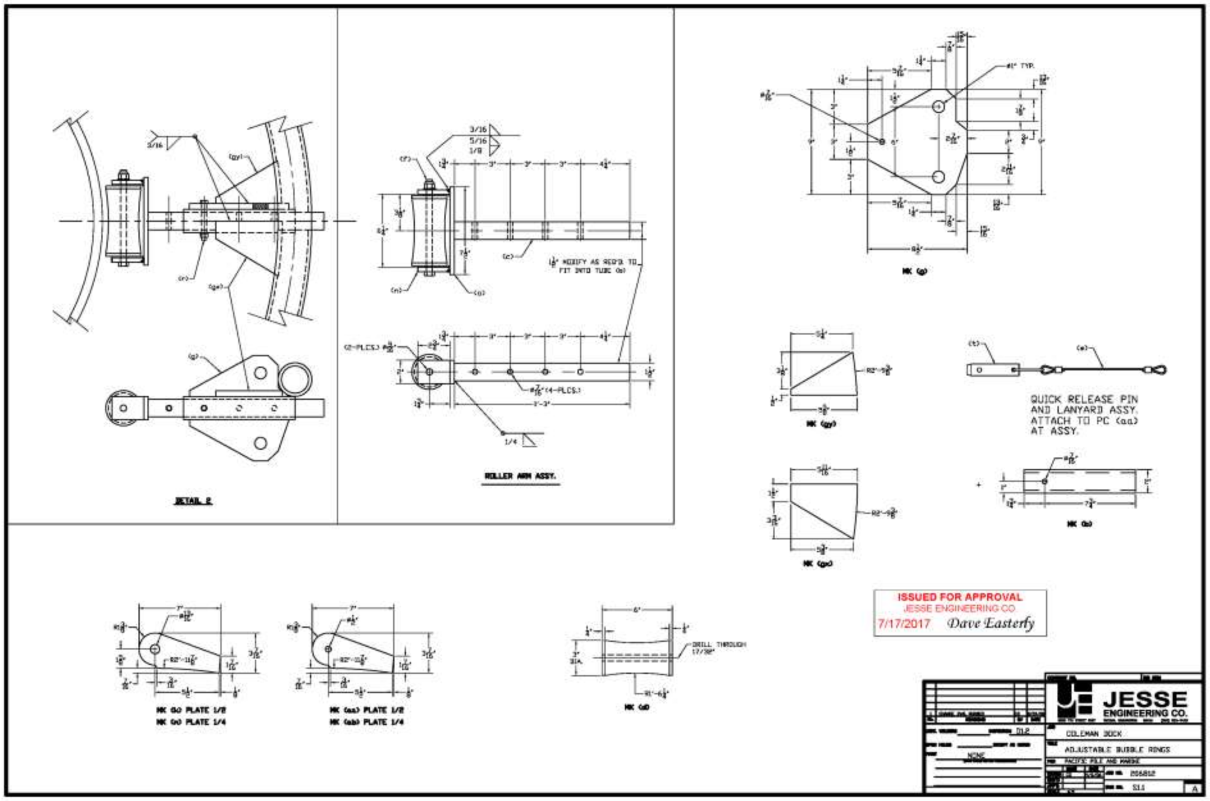
Project: **Colman Dock Project**	By: jwk	Date: 14-Sep-17 **REV B**

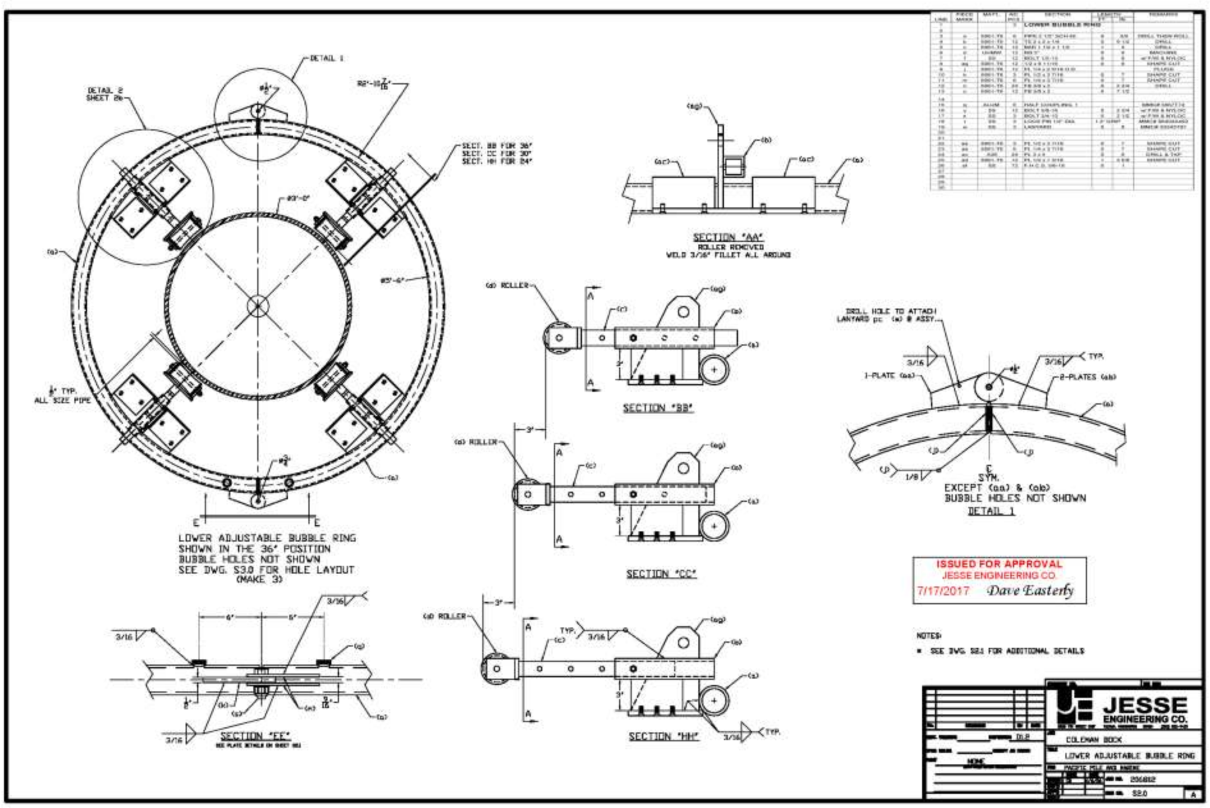


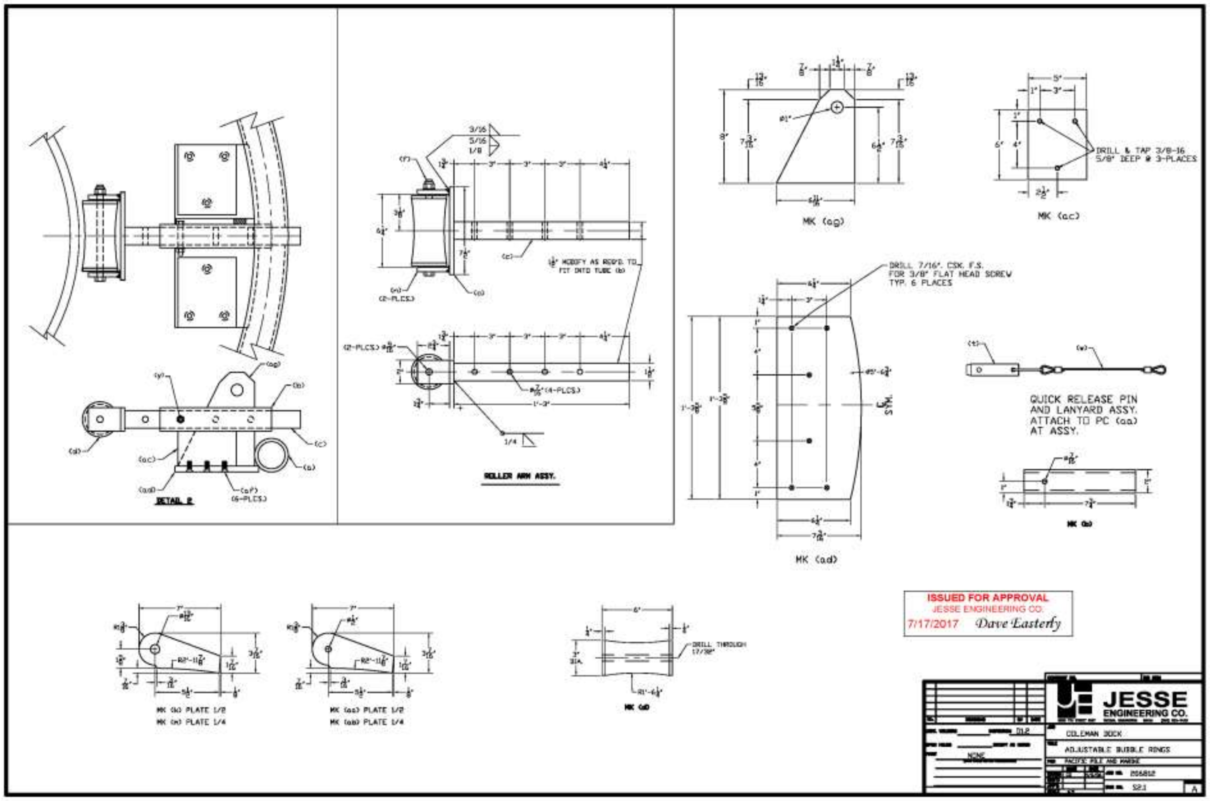


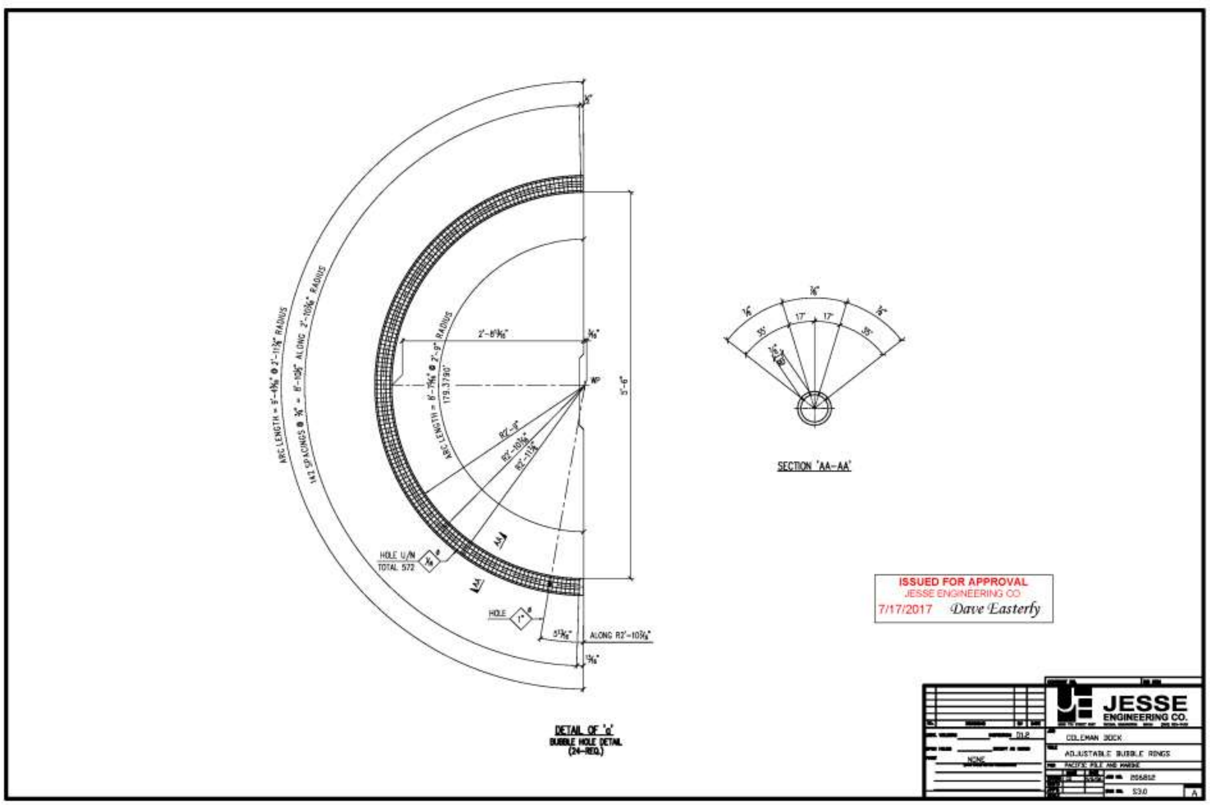

TOP VIEW
FRONT VIEW
SEATTLE BOILER WORKS
500 S. MYRTLE STREET
SEATTLE, WA 98108
JESSE ENGINEERING COMPANY
12 3/4" O.D. x 10'-0" SEAM-SEAM HORIZONTAL DISTRIBUTION MANIFOLD WELD MAP


UPPER ADJUSTABLE BUBBLE RING SHOWN IN THE 36" POSITION BUBBLE HOLES NOT SHOWN SEE DWG. S3.0 FOR HOLE LAYOUT (MAKE 9)
SECTION "AA"
SECTION "BB"
SECTION "CC"
SECTION "HH"
SECTION "EE"
DETAIL 1
ISSUED FOR APPROVAL
JESSE ENGINEERING CO.
7/17/2017 Dave Easterly
NOTES:
SEE DWG. S11 FOR ADDITIONAL DETAILS
JESSE ENGINEERING CO.
COLEMAN DOCK
UPPER ADJUSTABLE BUBBLE RING


ROLLER ARM ASSY.
DETAIL 2
QUICK RELEASE PIN AND LANYARD ASSY. ATTACH TO PC (aa) AT ASSY.
ISSUED FOR APPROVAL
JESSE ENGINEERING CO.
7/17/2017 Dave Easterly
JESSE ENGINEERING CO.
COLEMAN DOCK
ADJUSTABLE BUBBLE RINGS
PACIFIC PILE AND MARINE
206812
S11


LOWER ADJUSTABLE BUBBLE RING SHOWN IN THE 36" POSITION
BUBBLE HOLES NOT SHOWN
SEE DWG. S3.0 FOR HOLE LAYOUT (MAKE 3)
SECTION "AA"
ROLLER REMOVED
WELD 3/16" FILLET ALL AROUND
SECTION "BB"
SECTION "CC"
SECTION "EE"
SECTION "HH"
DETAIL 1
EXCEPT (aa) & (ab) BUBBLE HOLES NOT SHOWN
ISSUED FOR APPROVAL
JESSE ENGINEERING CO.
7/17/2017 Dave Easterly
NOTES:
SEE DWG. S2.1 FOR ADDITIONAL DETAILS
JESSE ENGINEERING CO.
COLEMAN DOCK
LOWER ADJUSTABLE BUBBLE RING
206812
S2.0


ROLLER ARM ASSY.
DETAIL 2
MK (ag)
MK (ac)
DRILL & TAP 3/8-16 5/8" DEEP @ 3-PLACES
DRILL 7/16", CSK. F.S. FOR 3/8" FLAT HEAD SCREW TYP. 6 PLACES
MK (ad)
QUICK RELEASE PIN AND LANYARD ASSY. ATTACH TO PC (aa) AT ASSY.
ISSUED FOR APPROVAL
JESSE ENGINEERING CO.
7/17/2017 Dave Easterly
JESSE ENGINEERING CO.
COLEMAN DOCK
ADJUSTABLE BUBBLE RINGS
PACIFIC PILE AND MARINE


SECTION 'AA-AA'
DETAIL OF 'a'
BUBBLE HOLE DETAIL
(24-REQ.)
ISSUED FOR APPROVAL
JESSE ENGINEERING CO.
7/17/2017 Dave Easterly
JESSE ENGINEERING CO.
COLEMAN DOCK
ADJUSTABLE BUBBLE RINGS
PACIFIC PILE AND MARINE