MARINE MAMMAL MONITORING
FINAL REPORT (REV 1)

P454 Multi-Mission Drydock – Test Pile Program
Naval Base Kitsap Bremerton, Washington

Harbor Seal

Prepared for

Naval Facilities Engineering Command Northwest

Prepared by

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ACRONYMS AND ABBREVIATIONS

BSS	Beaufort Sea State
cfm	cubic feet per minute
dB	decibel(s)
ESA	Endangered Species Act
ft	feet
ft^2	square feet
GPS	global positioning system
in	inch(es)
km	kilometer(s)
lb	pound
LOA	Letter of Authorization
m	meter(s)
m^2	square meter(s)
MAMU	Marbled Murrelet Observer
mi	mile(s)
MC	Monitoring Coordinator
MMO	Marine Mammal Observer
MMPA	Marine Mammal Protection Act
MMMP	Navy's Marine Mammal Monitoring Plan
Navy	U.S. Department of the Navy
NBK	Naval Base Kitsap
NMFS	National Marine Fisheries Service
RMS	root mean square
µPa	micropascal
U.S.	United States

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INTRODUCTION

The United States (U.S.) Department of the Navy (Navy) conducted the Test Pile Project to test pile and coffer dam installation and removal methods at Naval Base Kitsap (NBK) Bremerton. NBK Bremerton is located in the Puget Sound region of Washington State. The specific installation and removal location is within the area of the Puget Sound Naval Shipyard and Intermediate Maintenance Facility.

The purpose of the project was to test the installation and removal of temporary steel pipe piles and steel sheet piles. In-water construction included vibratory and impact pile driving and extraction, and monitoring effort for these activities was conducted from 22 August 2023 through 1 November 2023. The project installed forty-five 36-inch (in)-diameter steel pipe piles and thirty 14-inch steel sheet piles. Vibratory installation was used to the extent practicable to drive steel pipe piles and steel sheet piles to minimize high sound pressure levels associated with impact pile driving. Impact pile driving was required to "proof" piles or when vibratory installation failed to fully drive a pile to the proper depth. The number of impact pile strikes varied depending on the substrate at each pile location and the pile size and type. Impact pile strikes did not exceed 6,000 per construction day. A bubble curtain was employed during impact installation of steel pipe piles where water depths were greater than 0.67 meters (m) (2 feet [ft]). All piles installed as part of the Test Pile Project were removed using either a vibratory hammer, direct pull, or by cutting the piles off at the mudline at the end of the project.

Pile driving and pile extraction produce underwater noise which can harass and injure marine species. To minimize potential impacts of this noise on marine species, a noise attenuating device (i.e., bubble curtain) was used during impact hammer operations for steel piles. In addition, marine mammal monitoring was conducted during all pile driving by National Marine Fisheries Service (NMFS)-approved observers. Because pile driving and extraction produce underwater noise levels above behavioral harassment (Level B) and injury (Level A) thresholds for marine mammals, prior to the beginning of construction, the Navy assessed potential pile-driving impacts to marine mammal species known to occur in the action area and estimated the number of Level A and Level B exposures to each species. In accordance with the Marine Mammal Protection Act (MMPA), the Navy submitted this information to NMFS in their Letter of Authorization (LOA) request for authorization of the incidental, but not intentional, taking of marine mammal species during pile-driving and extraction activities at NBK Bremerton, Washington, subject to the provisions of the MMPA and the Regulations Governing Taking of Marine Mammals Incidental to U.S. Navy Marine Structure Maintenance and Pile Replacement in Washington (NMFS 2023). As a result, NMFS issued the LOA for non-injurious, temporary harassment (Level B) takes of humpback whales (*Megaptera novaeangliae*), minke whales (*Balaenoptera acutorostrata*), gray whales (*Eschrichtius robustus*), killer whales (*Orcinus orca* – transients and residents), Dall's porpoises (*Phocoenoides dalli*), harbor porpoises (*Phocoena phocoena*), California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), elephant seals (*Mirounga angustirostris*), and harbor seals (*Phoca vitulina*). The LOA did not include non-serious injury (Level A) takes (NMFS 2023).

This report summarizes the marine mammal monitoring efforts conducted during the in-water work window for this project (22 August to 1 November 2023). To ensure compliance with the LOA, marine mammal monitoring was conducted during in-water pile driving and extraction in accordance with the Navy's *Marine Mammal Monitoring Plan (MMMP) for the Test Pile Project at NBK Bremerton* (DoN 2023a) and Navy's *Endangered Species Act (ESA)/Marine Mammal Protection Act (MMPA) Monitoring and Construction Restriction Requirements* (DoN 2023b). Marble murrelet monitoring and sound source verification was also conducted during this work window. Descriptions of these efforts are included in separate reports (DoN 2024; The Greenbusch Group Inc. 2024).

METHODS

PROJECT AREA

The Project Area is located at NBK Bremerton which is in the Puget Sound region of Washington State. The specific installation and removal location is within the area of the Puget Sound Naval Shipyard and Intermediate Maintenance Facility (**Figures 1** and **2**).

Monitoring and Shutdown Zones

Under Section 101 (a)(5)(D) of the MMPA, NMFS issued the Navy a LOA for the incidental takes of marine mammals during in-water construction (NMFS 2023) The term "take," as defined in Section 3 (16 U.S. Code 1362) of the MMPA, means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." "Harassment" was further defined in the 1994 amendments to the MMPA, which provided two levels of "harassment." Level A harassment includes any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild. Level B harassment is any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (50 Code of Federal Regulations, Part 216, Subpart A, Section 216.3-Definitions). Level A harassment from underwater noise can lead to permanent threshold shift, which is a form of auditory injury, while Level B harassment from underwater noise can lead to temporary hearing threshold shift. All of these forms of harassment constitute "incidental take" under the MMPA and the ESA.

Level A Zone: The isopleth for this injury threshold zone was based on the new harassment criteria for marine mammals using cumulative sound exposure level metrics and peak pressure rather than the previously used decibel (dB) root mean square (RMS) metric (see NMFS 2018). The Level A zone was based on the maximum calculated radius for pinnipeds and cetaceans during installation of 36-in steel and concrete piles with impact techniques and for vibratory pile installation. This zone ranged from 1 to 882 m depending on the species and type of pile driving (**Tables 1** through **3**).

Shutdown Zone: The shutdown zones are slightly larger than the Level A zones so that pile driving operations can be shut down before a marine mammal enters the injury zone in order to minimize the potential for injuries to the mammal. This zone ranged from 10 to 900 m depending on the species and type of pile driving (**Tables 1** through **3**).

Level B Zone: The isopleth for this behavioral threshold zone was based on the following harassment criteria for marine mammals: 160 dB RMS referenced to 1 micropascal (µPa) (dB re 1 µPa) for impulsive underwater sounds from pile driving and 120 dB RMS re 1 µPa for non-impulsive underwater sounds. This zone ranged from 464 m (impacting steel piles) to a maximum of 13,600 (vibratory pile driving) (**Tables 1** through **3**).

Figure 1. Location of Naval Base Kitsap Bremerton, Washington.

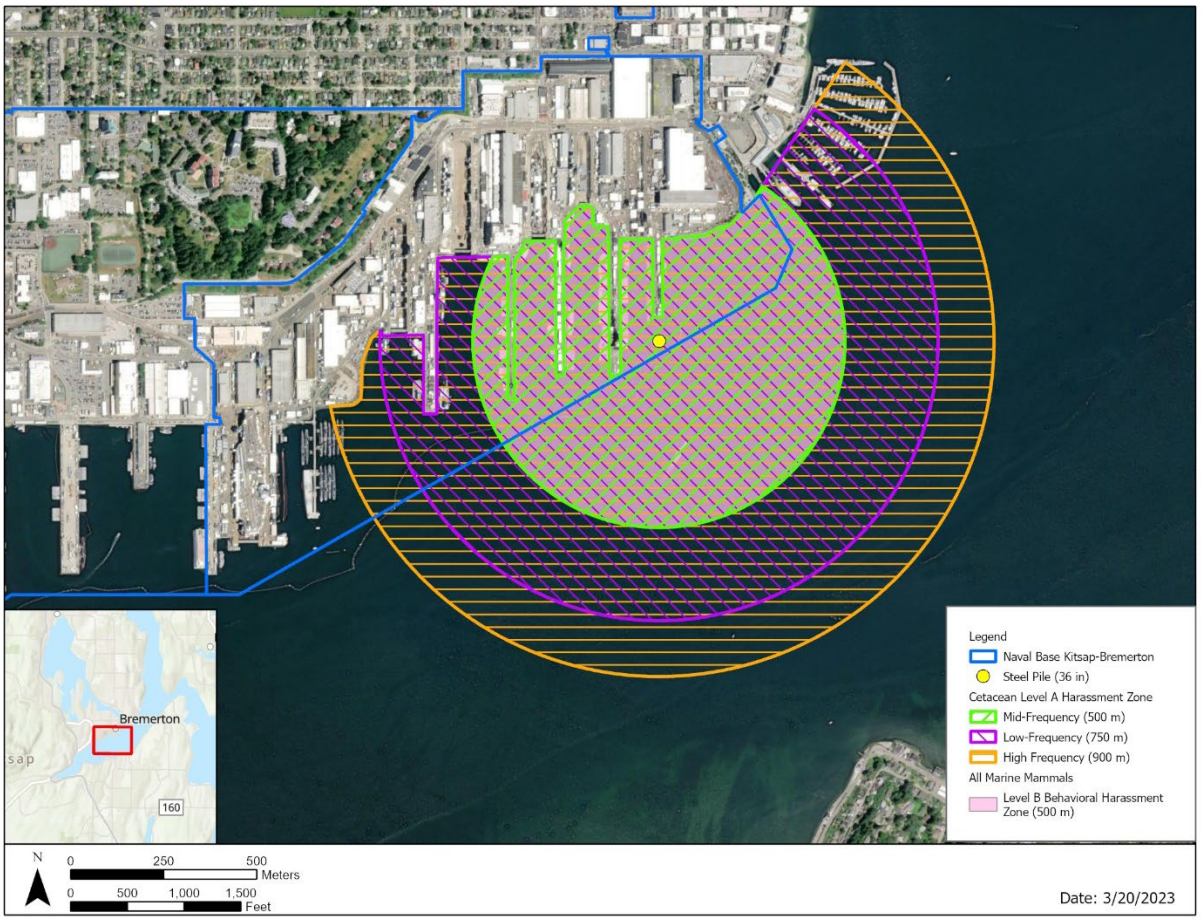


Figure 2. Location of Project Area and example of marine mammal visual monitoring zones for 36-inch impact driven steel piles.

Table 1. Behavior and injury harassment monitoring and shutdown zones for attenuated impact driving of 36-inch steel piles during installation

Marine Mammal Functional Hearing Groups (with commonly occuring species)	Level B Harassment Zone		Level A Harassment Zone (Injury Threshold)	Shutdown Zone[1]
	Behavior Threshold	Monitoring Zone		
High Frequency Cetaceans: Dall's Porpoise, Harbor Porpoise	464 m	500 m (For pinnipeds and mid-frequency cetaceans) Monitoring would occur out to the furthest Level A shutdown zone for cetaceans (up to 750-900 m)	882 m	900 m
Mid Frequency Cetaceans: Southern Resident Killer Whale Transient Killer Whale			26 m	500 m
Low Frequency Cetaceans: Gray Whale, Humpback Whale			741 m	750 m
Phocids: Elephant Seal, Harbor Seal			397 m	400 m
Otariids: California Sea Lion, Steller Sea Lion			44 m	50 m

Notes: A bubble curtain will be used to attenuate impact pile driving sound by 8 dB (Navy, 2015); monitoring would occur out to the furthest shutdown zone.

[1] Real time locations of killer whales, gray whales, and humpback whales will be provided to the Marine Mammal Lead prior to pile driving. If these species are nearing or moving toward the Level B monitoring zones, pile driving can be delayed or shut down until the marine mammals move away. The shutdown encompasses the injury zone. Additionally, a Behavioral Harassment Monitoring Zone will be established that will encompass as much of the Behavioral Harassment Zone that can be practicably monitored from Protected Species Observer positions. All pile driving shall cease should any cetaceans be detected within the Behavioral Harassment Zone.

dB = decibel(s); m = meter(s)

Table 2. Behavior and injury harassment monitoring and shutdown zones for vibratory driving of 36-inch piles during installation or removal

Marine Mammal Functional Hearing Groups (with commonly occuring species)	Level B Harassment Zone		Level A Harassment Zone (Injury Threshold)	Shutdown Zone
	Behavior Threshold	Monitoring Zone		
High Frequency Cetaceans: Dall's Porpoise, Harbor Porpoise	13,600 m (Truncated by land masses and islands)	400 m[1]	141.5 m	400 m[1]
Mid Frequency Cetaceans: Killer Whale			8.5 m	
Low Frequency Cetaceans: Gray Whale. Humpback Whale			95.7 m	
Phocids: Elephant Seal, Harbor Seal			58.2 m	60 m
Otariids: California Sea Lion, Steller Sea Lion			4.1 m	10 m

[1] Pile driving shall cease should any cetaceans be detected in this zone.

dB = decibel(s); m = meter(s)

Table 3. Behavior and injury harassment monitoring and shutdown zones for vibratory driving of 14-inch sheet piles during installation or removal

Marine Mammal Functional Hearing Groups (with commonly occuring species)	Level B Harassment Zone		Level A Harassment Zone (Injury Threshold)	Shutdown Zone
	Behavior Threshold	Monitoring Zone		
High Frequency Cetaceans: Dall's Porpoise, Harbor Porpoise	7,400 m	400 m[1]	24 m	400 m[1]
Mid Frequency Cetaceans: Southern Resident Killer Whale Transient Killer Whale			1 m	
Low Frequency Cetaceans: Gray Whale, Humpback Whale			16 m	
Phocids: Elephant Seal, Harbor Seal			10 m	15 m
Otariids: California Sea Lion, Steller Sea Lion			1 m	10 m

[1] Pile driving shall cease should any cetaceans be detected in this zone.

dB = decibel(s); m = meter(s)

Observer Monitoring Locations

Three marine mammal observers monitored for marine mammals during impact pile driving and vibratory pile driving. Observers were positioned at land-based sites off Base and pier sites on Base (**Figures 3** through **4**). Of these monitoring location options, observer sites were chosen each day based on the operations to be conducted that day, visibility, and weather conditions.

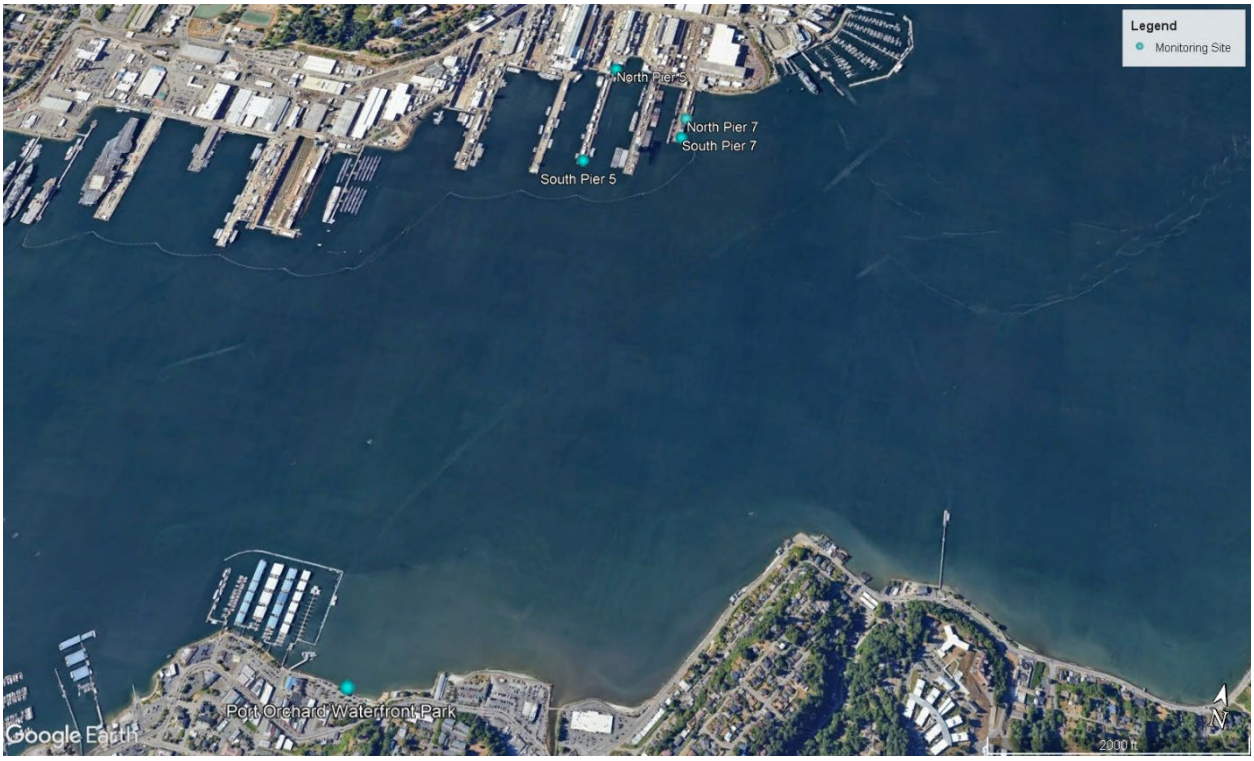


Figure 3. Land-based observer monitoring sites were located on Base and off Base in order to maximize coverage of Level A zones and Level B zones.

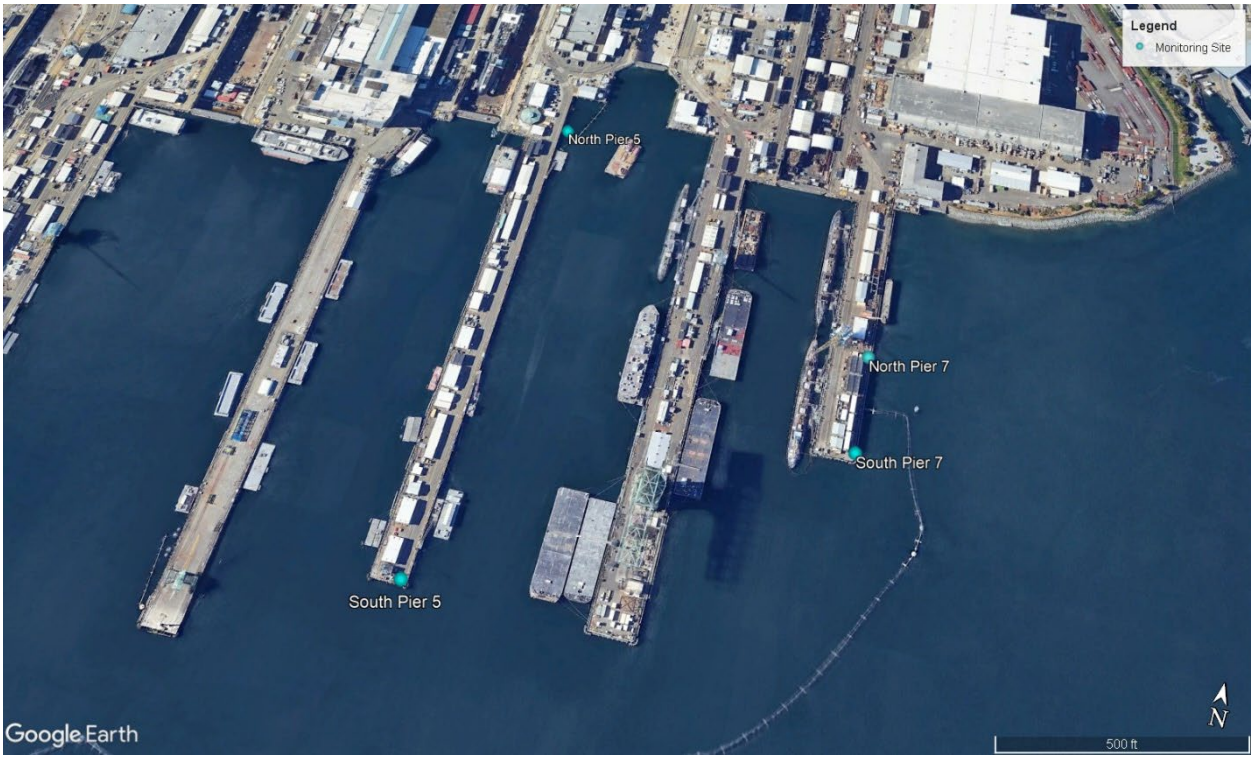


Figure 4. Four of the observer monitoring sites were located around the construction site.

VISUAL MONITORING PROTOCOLS

All in-water construction was conducted during daylight hours. Marine mammal sightings were recorded before, during, and after pile driving/extraction activities. Observers followed the monitoring protocols outlined in the Navy's LOA and MMMP (DoN 2023a; DoN 2023b). Observers tracked and reported authorized takes. Operations were shut down when a nonauthorized species entered the pertinent take zone and when the authorized number of takes were met for a particular species and take zone.

Table 4. Authorized Level B takes

Species	Level B Takes Authorized
California sea lion	2,318
Steller sea lion	19
Harbor seal	370
Elephant Seal	2
Humpback Whale	4
Minke Whale	4

Species	Level B Takes Authorized
Gray Whale	4
Killer Whale Transient	12
Killer Whale Southern Resident	40
Dall's Porpoise	29
Harbor Porpoise	267

No Level A takes were authorized.

During periods of reduced visibility due to poor weather and high sea states, the entire shutdown zone and surrounding waters had to be visible to the naked eye in order for operations to continue. Pile-driving operations were not initiated until visibility was deemed acceptable in the shutdown zones by the observers.

Pre-Activity Monitoring

Before pile driving or extraction could commence, observers monitored the zones for a minimum of 15 minutes.

- If a marine mammal was sighted in a shutdown zone or was approaching a shutdown zone, the start of pile driving was delayed until the animal left the shutdown zone voluntarily and was visually confirmed outside of the shutdown zone or if 15 minutes had elapsed without re-detection of the animal.
- If a marine mammal was not sighted in or approaching a shutdown zone, then the observers gave the "all clear" to the Monitoring Coordinator (MC) who then notified the pile driving foreman that pile driving could commence.

During Activity Monitoring

During pile-driving and extraction activities, observers continued to monitor the zones and implemented the following protocols:

- If a cetacean entered or approached the shutdown zone for cetaceans, pile driving ceased until the animal voluntarily left the zone. If a pinniped entered the shutdown zone for pinnipeds, pile driving ceased until the animal voluntarily left the zone.
- If a pinniped was observed within or entering the Level B zone during pile driving, a take was recorded, behaviors documented, and the shutdown zone monitor was alerted to the position of the animal; however, that pile segment was completed without cessation unless the animal approached the shutdown zone for pinnipeds at which point all pile driving activities were halted.
- Once a shutdown ("all-stop") was initiated, pile-driving activities were delayed until the animal left the shutdown zone voluntarily, was visually confirmed outside the shutdown zone, or if 15 minutes had elapsed without re-detection of the animal (i.e., the zone was deemed clear of marine mammals).
- As of 28 September 2023, these protocols were updated for harbor seals. If a harbor seal was observed in the Level A exposure zone, pile driving would shut down. Pile driving would restart after 30 minutes from which the animal has moved outside that zone or since the last time the animal was observed. MMOs would notify the Navy describing details of the Level A

exposure, estimated time exposed to pile driving, how the animal responded, etc. The Navy would contact NMFS Office of Protected Resources within 24 hours and provide a report based on the MMO observations.

- Under certain construction circumstances where initiating the shutdown and clearance procedures could result in an imminent concern for human safety, the Navy point of contact was to be notified prior to re-initiation of pile driving. These situations did not occur during this project period.

Post-Activity Monitoring

After the completion of pile driving/extraction, observers continued monitoring the zones for at least 30 minutes. Observers recorded all marine mammal sightings data, including any unusual or abnormal behavior. If any injured, sick, or dead marine mammals had been observed, the U.S. Navy was to notify NMFS immediately. One dead harbor seal was observed during the project period and reported to NMFS along with photos. This seal was found dead at Port Orchard Waterfront Park on 1 November 2023. There were no obvious signs of trauma. We learned that locals had seen the dead seal in the same location on 26 October 2023, and it appeared to have been dead quite some time at that point. The locals had phoned the NOAA Marine Stranding Network at 1-866-767-6114. During that week, the Navy conducted impact and vibratory pile driving on 23 and 24 October.

DATA COLLECTION METHODS

The observers used a variety of monitoring and communication equipment, including VHF (very high frequency) radios, hand-held global positioning system (GPS) units, spotting scopes, laser rangefinders, binoculars with reticles, cell phones for recording data and communicating with the team, green and red flags as backup for radio communication, marine mammal identification guides, and backup datasheets printed on waterproof paper. Personal protective equipment included hardhats, steel-toed boots, gloves, hearing and eye protection, and Type 3 personal floatation devices.

All data were recorded using a smartphone application developed via the epicollect5 mobile data-gathering platform. This application included all of the data fields from the NMFS-approved Marine Mammal Observation Record Form (**Appendix A**) and allowed observers to quickly and accurately record sightings, weather, and construction activity data and continuously upload the data to a cloud-based storage site throughout each monitoring day to minimize accidental loss of data.

Data recorded during marine mammal monitoring included

- date and time that pile driving begins and ends;
- method of installation for each pile;
- time and location (GPS estimate and zone [Level A, shutdown, etc.]) of marine mammal sightings;
- construction activities occurring during each marine mammal sighting;
- weather parameters (e.g., percent cover, percent glare, visibility);
- Beaufort Sea State (BSS);
- species, numbers, and if possible, sex and age class of marine mammals;
- marine mammal behavior patterns observed, including bearing from observer and direction of travel;
- distance of marine mammals from pile-driving activities; and
- occurrence of pile driving delay or shutdown due to marine mammal presence in shutdown zones.

Environmental conditions (weather parameters and BSS) were recorded when observers began monitoring each day and during each sighting and were updated regularly as conditions changed throughout each monitoring day.

At the end of each monitoring day, the MC reviewed all uploaded data for accuracy, combined the uploaded data into a daily file, and copied the new day's data into the master database file. All data files were stored in the cloud-based epicollect5 platform and Google Drive as a backup.

REPORTING

At the end of each monitoring day, the MC prepared a summary report of the day's monitoring efforts. These reports included the observer monitoring locations used, observer names, updated take numbers, monitoring effort start and end times, day start and end times, an activities summary, and a description of any issues or delays.

ADDITIONAL MITIGATION MEASURES

In addition to continuous visual monitoring of the Level A and Level B zones, mitigation measures included use of a bubble curtain (sound attenuation device) which was used during all impact driving events. The bubble curtain system consisted of an air supply (1600-cubic feet per minute [cfm] compressors), a manifold, and seven to eight rings that surrounded the pile to create a column of air around the pile. The manifold acted as a distribution center from the air compressors to 1-in air hoses that supplied air to each ring. Typically, seven rings were used when impact driving. The eighth ring acted as a spare and was utilized when driving in deeper water (offshore crane piles and dolphin piles). Air hoses supplied air to the rings that escaped through many small holes drilled around the entire circumference of each ring.

Initial calculations indicated that three air compressors (each 1600 cfm) would be required to provide the required 8 dB of sound attenuation; however, when performing initial tests of the system, it was found that when using all three air compressors, the bottom ring would float off of the mudline, thus diminishing the sound reduction. Using one air compressor (1600 cfm) provided 8 dB of sound attenuation without floating the bottom ring of the bubble curtain. See **Appendix B** for design specifications of the air bubble curtain system.

PROJECT STAFF

All observers were biologists with prior training and experience in conducting marine mammal monitoring or surveys (**Table 5**). They were skilled in their ability to identify marine mammal species and describe relevant behaviors that may occur in proximity to in-water construction activities. One of these observers served as the MC who was responsible for coordinating the observer team and maintaining radio communication with the pile-driving supervisor during start-up, operation, shutdowns, and restarts. The MC prepared the daily reports, tracked takes, reviewed the data, and maintained the database. In addition to having a Bachelor of Science degree in biology and over 8 years of relevant experience, the MC also had at least 4 years of pile driving monitoring experience over the past 8 years. The MC was also skilled in leading complex teams of marine mammal and marbled murrelet observers during pile driving projects. The Observer Program Manager oversaw the recruitment, orientation, scheduling, and management of qualified observers for monitoring; developed monitoring data collection protocols and tools; checked the database for completeness; and prepared monitoring reports. During impact driving, two of the marine mammal observers who were also certified marbled murrelet observers, would serve as dedicated marbled murrelet observers while the third observer served as the dedicated marine mammal observer. During vibratory driving, all three marine mammal observers monitored for marine mammals.

Table 5. Monitoring team

Position*	Name	Affiliation
Program Manager	Amy Whitt	Azura Consulting LLC
MC/MMO/MAMU	Stefanie Hawks-Johnson	Saltwater Inc.
MMO/MAMU	Debaran Kelso	Saltwater Inc.
MMO/MAMU	Kari Williamson	Saltwater Inc.
MMO	Mollie Stanfield	Saltwater Inc.

*MC = Monitoring Coordinator; MMO = Marine Mammal Observer; MAMU = Marbled Murrelet Observer

RESULTS

PILE-DRIVING ACTIVITIES

Pile-driving activities conducted during construction included pile driving and extraction.

Piles Installed

- 24-in piles – 9 each (steel). All piles driven with both vibratory and impact hammer
- 36-in piles – 26 each (steel). All piles driven with both vibratory and impact hammer (extra two were driven and extracted at platform 1 to moor derrick to)
- 18 flat sheet piles driven in frame as well as six Z-sheet piles driven adjacent to sheet pile driving frame.
    - Roughly 15-30 minutes per pile
- Impact driving 24- and 36-in piles with offshore swinging leads and spotter and leads
    - Roughly 5 minutes of driving per pile average

Piles Removed

- 36-in, 24-in, and all sheet piles were pulled with the exception of six sheet piles at platform 3 and 7- to 36-in piles at platform 2. All piles pulled with a vibratory hammer
    - Vibratory extraction time varied from 4-15 minutes per pile
    - Vibratory extraction was attempted on all piles. Some couldn't be removed and were cut off below mudline by divers.

The pile embedment ranged from 25 to 46 ft with an average of 32 ft. The impact or vibratory hammer force used to drive/extract piles was as follows:

Delmag D100-13

- Energy/Blow= 265,520 ft-lbs. Max

AFE 325-6 Vibratory Hammer

- Drive Force = 270 tons
- Eccentric Moment = 7,000 in-lbs.

Delmag D19-52 Impact Hammer

- Energy/Blow = 48,680 ft-lbs. Max

Delmag D-180 Impact Hammer

- Energy/Blow = 271,644 to 443,913 ft-lbs

MONITORING EFFORT

Monitoring effort began on 22 August 2023 and ended on 1 November 2023. Vibratory pile driving began on 22 August 2023, and impact pile driving began on 25 August 2023. Observers were onsite for a total of 38 days. Monitoring effort was conducted on 22 days and within approximately 283 hours during this time period which includes periods of active pile driving activity and periods between pile driving events (**Table 6**).

Table 6. Summary of monitoring effort (days that included impact pile driving operations are highlighted in blue)

Date	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Total Time (hh:mm:ss)
8/21/2023	6:45:00	18:00:00	11:45:00
8/22/2023	7:45:00	16:30:00	8:45:00
8/23/2023	7:45:00	18:00:00	10:15:00
8/24/2023	7:45:00	16:30:00	8:45:00
8/25/2023	7:45:00	15:30:00	7:45:00
8/28/2023	7:45:00	16:45:00	9:00:00
8/29/2023	7:45:00	13:00:00	5:25:00
8/30/2023	11:15:00	16:59:00	5:25:00
8/31/2023	7:45:00	18:15:00	10:30:00
9/1/2023	7:45:00	14:59:00	6:30:00
9/5/2023	7:45:00	14:15:00	6:15:00
9/6/2023	7:45:00	14:15:00	6:15:00
9/7/2023	7:45:00	16:45:00	9:00:00
9/8/2023	7:45:00	12:00:00	4:15:00
9/11/2023	7:45:00	18:00:00	10:15:00
9/12/2023	7:45:00	12:15:00	4:30:00
9/13/2023	7:45:00	17:15:00	9:30:00
9/14/2023	9:15:00	14:00:00	4:45:00
9/15/2023	7:45:00	15:30:00	7:45:00
9/18/2023	12:30:00	15:00:00	2:30:00
9/19/2023	8:00:00	15:45:00	7:45:00
9/20/2023	8:00:00	16:15:00	8:15:00
9/21/2023	8:15:00	16:00:00	7:45:00

Date	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Total Time (hh:mm:ss)
9/22/2023	8:00:00	17:15:00	9:15:00
9/25/2023	7:15:00	17:30:00	10:15:00
9/26/2023	7:00:00	16:30:00	9:30:00
9/27/2023	6:45:00	9:00:00	2:15:00
9/28/2023	9:15:00	12:00:00	2:45:00
9/29/2023	9:00:00	15:00:00	6:00:00
10/3/2023	13:00:00	17:15:00	4:15:00
10/4/2023	9:30:00	19:15:00	9:45:00
10/11/2023	7:30:00	14:45:00	7:15:00
10/13/2023	7:30:00	16:45:00	9:15:00
10/23/2023	7:45:00	17:30:00	9:45:00
10/24/2023	7:30:00	13:45:00	6:15:00
10/30/2023	7:30:00	16:00:00	8:30:00
10/31/2023	7:30:00	16:00:00	8:30:00
11/1/2023	7:30:00	15:15:00	7:30:00

ENVIRONMENTAL CONDITIONS

The BSS ranged from 0 (calm) to 2 (light breeze) during the monitoring period with swells between 0 and 3 ft in height. Visibility ranged from poor (0.5 kilometers [km]) to excellent (15 km). See **Attachment A** for all environmental data recorded during monitoring.

MARINE MAMMAL SIGHTINGS

All marine mammal sightings data are provided in **Attachment B.** Four marine mammal species were sighted during the project period (**Table 7**). California sea lions were the most common species sighted with 332 sightings. Other pinniped sightings included Steller sea lions and harbor seals. California sea lions and harbor seals were sighted during each month of the project period (August – November). Peak sightings were during September for both species (**Figure 5**). Note that during November, monitoring only occurred during one day.

The most common behaviors exhibited by harbor seals during and without pile driving operations were milling and slow traveling. During pile driving operations, observers noticed slightly more looking around behavior (4 percent during versus 2 percent without pile driving). Other behaviors observed included fast travel, resting/hauled out, and feeding.

During the majority of the California sea lion sightings, the most common behaviors observed (during and without pile driving operations) were slow travel. Other behaviors observed included fast travel, milling, feeding, resting/hauled out, and socializing. Observed changes in behavior during pile driving included porpoising, flushing, leaping, swimming away from pile, hauling out, barking, and fast travel.

One Steller sea lion was observed resting/hauled out during the monitoring period when no pile

driving was occurring. The only cetaceans observed were two harbor porpoises slow traveling when no pile driving was occurring.

Table 7. Summary of marine mammal sightings

Species	Total # Sightings	# Sightings during Pile Driving Operations	Mean Group Size	Closest Distance to Pile Site (m)
Harbor porpoise (*Phocoena phocoena vomerina*)	1	0	2	1800
Steller sea lion (*Eumetopias jubatus monteriensis*)	1	0	1	140
California sea lion (*Zalophus californianus*)	332	230	13*	8
Harbor seal (*Phoca vitulina richardii*)	207	122	1	20

*Large group sizes ranging from 1 to 303 were sighted near Port Orchard Waterfront Park. Group sizes on Base ranged from 1 to 85.

m = meters

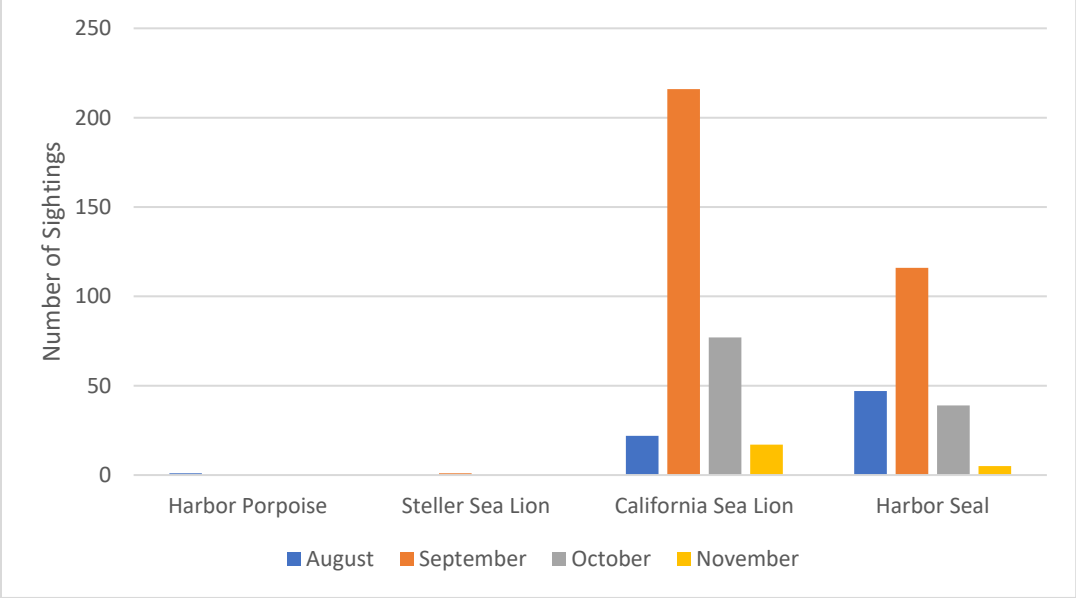


Figure 5. Sightings of marine mammals per month.

MARINE MAMMAL TAKES

The total Level B takes for marine mammals are summarized in **Table 8** and shown per month on **Figure 6**. All takes were observed takes; no extrapolations were allowed via the LOA. No takes were exceeded. No Level A takes were authorized. At 10:26 am on 6 September 2023, one harbor seal was recorded within the Level A zone (397 m) during impact pile driving. The harbor seal was sighted slow traveling 200 m from the pile. Pile-driving operations were shut down and the Navy was contacted. No changes in behavior were observed. Prior to this shutdown, a harbor seal was sighted

at 9:54 am 250 m from the pile prior to pile driving. It cleared the zone and resulted in a 10-minute delay to pile driving. The harbor seal sighted at 200 m at 10:26 am may have been the same seal, but individual identification could not be confirmed. The Navy notified NMFS Office of Protected Resources of the Level A exposure.

Table 8. Summary of Level B takes.

Species	Level B Takes Authorized	Level B Takes Used
California Sea Lion	2,318	524
Steller Sea Lion	19	0
Harbor seal	370	96
Elephant Seal	2	0
Humpback Whale	4	0
Minke Whale	4	0
Gray Whale	4	0
Killer Whale Transient	12	0
Killer Whale Southern Resident	40	0
Dall's Porpoise	29	0
Harbor Porpoise	267	0

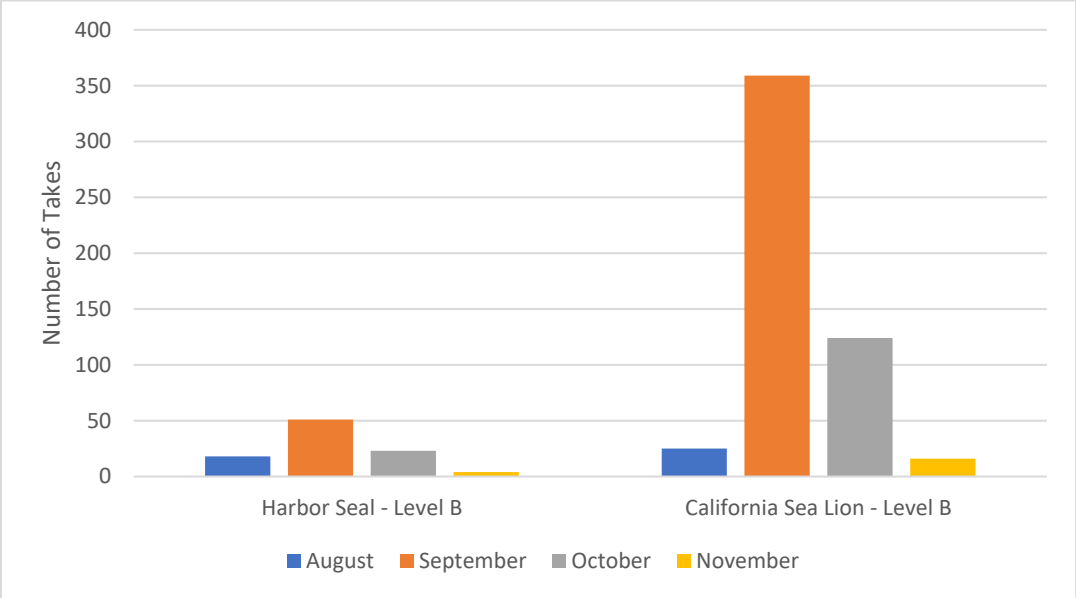


Figure 6. Level B takes of marine mammals per month.

CONSTRUCTION DELAYS AND SHUTDOWNS

Construction operations were delayed by a total of approximately 4 hours and 5 minutes and shut down for a total of 1 hour and 38 minutes due to the presence of animals (**Table 9**). Delays and shutdowns were during impact and vibratory pile driving operations. We recorded a total of 24 shutdowns and 13 delays to the onset of pile driving. All shutdowns except one were due to the presence of California sea lions (**Table 10**). California sea lions accounted for one of the delays, while the rest were due to the presence of harbor seals (**Table 10**).

Table 9. Summary of mitigation delays and shutdowns

Date	Vibratory Driving	Impact Driving	Total Delays	Total Delay Time (hh:mm:ss)	Total Shutdowns	Total Shutdown Time (hh:mm:ss)	Notes
8/21/2023	N	N	0	0	0	0	No production. Onsite mobilization day.
8/22/2023	Y	N	0	0	0	0	
8/23/2023	Y	N	1	0:01:00	0	0	
8/24/2023	Y	N	0	0	0	0	
8/25/2023	Y	Y	0	0	0	0	
8/28/2023	N	Y	0	0	0	0	
8/29/2023	N	Y	0	0	0	0	
8/30/2023	Y	N	0	0	0	0	
8/31/2023	Y	N	0	0	0	0	
9/1/2023	Y	Y	0	0	1	0:15:00	
9/5/2023	N	Y	1	0:15:00	0	0	Habor seal/Shutdown Delay resulted in the decision to stop pile work for the day
9/6/2023	N	Y	1	0:10:00	1	0:05:00	Level A exposure. During impact a harbor seal popped up 200 m from the pile activity at 10:26. Shutdown was initiated and Navy contacted because there were no Level A takes permitted.
9/7/2023	Y	Y	1	0:25:00	0	0	
9/8/2023	Y	Y	0	0	0	0	
9/11/2023	Y	Y	0	0	0	0	
9/12/2023	Y	Y	0	0	0	0	One harbor seal entered the shutdown zone 35 minutes prior to impact but was not seen again
9/13/2023	N	Y	1	0:10:00	1	0:15:00	
9/14/2023	Y	N	0	0	0	0	
9/15/2023	Y	Y	0	0	0	0	
9/18/2023	N	N	1	1:14:00	0	0	Harbor seal sighted multiple times in the shutdown zone preventing pile driving from starting to avoid a Level A take

Date	Vibratory Driving	Impact Driving	Total Delays	Total Delay Time (hh:mm:ss)	Total Shutdowns	Total Shutdown Time (hh:mm:ss)	Notes
9/19/2023	N	Y	0	0	0	0	Harbor seal sighted in shutdown zone 30 minutes prior to impacting. Two California sea lions flushed into the water during impact and were showing signs of disorientation-shaking their heads multiple times before porpoising away.
9/20/2023	Y	N	1	0:10:00	0	0	
9/21/2023	Y	Y	0	0	1	0:03:00	
9/22/2023	Y	Y	0	0	0	0	
9/25/2023	Y	Y	2	1:13:00	1	0:02:00	
9/26/2023	Y	Y	1	0:05:00	7	0:07:00	
9/27/2023	Y	N	0	0	0	0	
9/28/2023	Y	N	0	0	0	0	
9/29/2023	N	Y	1	0:04:00	9	0:48:00	
10/3/2023	Y	N	0	0	0	0	
10/4/2023	Y	N	0	0	0	0	
10/11/2023	Y	N	0	0	0	0	
10/13/2023	Y	N	0	0	0	0	
10/23/2023	Y	N	0	0	0	0	Z sheet driving
10/24/2023	Y	N	0	0	0	0	Z sheet driving impact
10/30/2023	Y	Y	1	0:03:00	2	0:02:00	14" sheet piles and Z sheets
10/31/2023	Y	Y	1	0:15:00	1	0:01:00	
11/1/2023	Y	N	0	0	0	0	

Table 10. Marine mammal sightings resulting in mitigation delays and shutdowns

Date	Time	Species*	Distance to Pile (m)	Behavior	Group Size - Best Estimate	# of Calves /Pups	Constr. Activity	Zone	#Animals in Zone	Mitigation	Comments
9/1/2023	13:30:00	CS	50	Resting/Hauled Out	6	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	6 animals flushed at the beginning of impact. 1 in shutdown zone headed west and out of zone, 15 minutes delay to clear area again. 5 animals in LEVEL B Harassment zone when flushed into the water
9/5/2023	12:31:00	HS	40	Slow Traveling	1	0	Soft Start (Impact-Steel)	Shutdown Zone	1	Delay Onset of Pile Driving	Entered zone before SS. HS reappeared multiple times from 1231 till 1400. Manson decided to quit pile work at 1346. Very probable that it is the same seal observed at Pier 5. Same markings/very little natural habitat for multiple seals
9/6/2023	9:54:00	HS	250	Milling	1	0	Soft Start (Impact-Steel)	Shutdown Zone	1	Delay Onset of Pile Driving	Observed in shut down zone. Observed at 1001 outside of zone. Gave all clear to continue work
9/6/2023	10:26:57	HS	200	Slow Traveling	1	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	Appeared in zone at 200m heading East, 1032 seen out of zone 550m
9/13/2023	10:53:00	CS	50	Flushed then surfaced multiple times shaking his head.	1	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	
09/18/2023	13:04:53	HS	250	Slow Traveling	1	0	Soft Start (Impact-Steel)	Shutdown Zone	0	Delay Onset of Pile Driving	Seen westbound at 250m, reappeared at 247 milling 1308, 248m at 1314, 1322 at 250m, 200m at 1330, 45m at 1349, 95m at 1406, 50m at 1412
09/20/2023	11:22:00	HS	60	Milling	1	0	Vibe (install/extract)	Shutdown Zone	1	Delay Onset of Pile Driving	Seen at 60m at 1133. Delayed 10 minutes
09/21/2023	13:12:27	CS	30	Resting/Hauled Out	2	0	Soft Start (Impact-Steel)	Level B Harassment Zone	2	Shutdown Pile Driving	One individual hauled out at 30m on a can, 2 more at 50m hauled out, 2 more at 65m hauled in out. 2 flushed at start of impact, headed S observed again at 120m
09/25/2023	12:55:00	HS	90	Slow Traveling	1	1	Soft Start (Impact-Steel)	Shutdown Zone	1	Delay Onset of Pile Driving	Entered zone at 120 m, dove N, 1258 100m milling, 1301 90m S Dive, 1305 200m south dove

Date	Time	Species*	Distance to Pile (m)	Behavior	Group Size - Best Estimate	# of Calves /Pups	Constr. Activity	Zone	#Animals in Zone	Mitigation	Comments
09/25/2023	13:17:00	CS	34	Fast Traveling	3	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	
09/26/2023	8:55:00	CS	44	Resting/Hauled Out	1	0	Soft Start (Impact-Steel)	Shutdown Zone	1	Shutdown Pile Driving	Observed again at 120m out of zone.
09/26/2023	8:59:00	CS	53	Resting/Hauled Out	1	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	Observed again at 70m out of zone continued south
09/26/2023	9:02:00	CS	53	Resting/Hauled Out	1	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	Seen again at 90m out of zone. Continuing south
09/26/2023	11:28:00	CS	38	Resting/Hauled Out	2	0	Soft Start (Impact-Steel)	Shutdown Zone	2	Shutdown Pile Driving	Flushed into water on the second SS, observed again at 80m still swimming south out of the zone
09/26/2023	14:39:00	HS	350	Slow Traveling	1	0	Soft Start (Impact-Steel)	Shutdown Zone	1	Delay Onset of Pile Driving	Seen traveling SW out of zone.
09/26/2023	15:01:00	CS	45	Resting/Hauled Out	4	0	Impact Pile Driving (Steel)	Shutdown Zone	4	Shutdown Pile Driving	
09/26/2023	15:07:00	CS	45	Resting/Hauled Out	2	0	Impact Pile Driving (Steel)	Shutdown Zone	2	Shutdown Pile Driving	Flushed into zone but observed traveling out of zone quickly
09/29/2023	11:01:00	CS	8	Milling	1	0	Soft Start (Impact-Steel)	Shutdown Zone	1	Shutdown Pile Driving	Ss startled another CS 15m from can (head lift)
09/29/2023	11:13:00	CS	50	Fast Traveling	1	0	Soft Start (Impact-Steel)	Shutdown Zone	1	Shutdown Pile Driving	Gave extra time for observance of any behavior changes and observed none. No animals in zone when given all clear to continue with impact
09/29/2023	11:17:00	CS	10	Slow Traveling	1	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	

Date	Time	Species*	Distance to Pile (m)	Behavior	Group Size - Best Estimate	# of Calves /Pups	Constr. Activity	Zone	#Animals in Zone	Mitigation	Comments
09/29/2023	11:19:00	CS	10	Fast Traveling	3	0	Impact Pile Driving (Steel)	Shutdown Zone	3	Shutdown Pile Driving	
09/29/2023	11:22:00	CS	45	Fast Traveling	3	0	Impact Pile Driving (Steel)	Shutdown Zone	2	Shutdown Pile Driving	
09/29/2023	12:25:00	CS	42	Resting/Hauled Out	5	0	Soft Start (Impact-Steel)	Shutdown Zone	1	Shutdown Pile Driving	
09/29/2023	12:28:00	CS	42	Fast Traveling	2	0	Impact Pile Driving (Steel)	Shutdown Zone	2	Shutdown Pile Driving	
09/29/2023	13:28:00	CS	30	Slow Traveling	4	0	Soft Start (Impact-Steel)	Shutdown Zone	4	Delay Onset of Pile Driving	Had 3 milling in zone and a total of four at max hauling out on water fence for 10 min. Finally cleared zone at 1351
09/29/2023	13:51:00	CS	35	Slow Traveling	3	0	Impact Pile Driving (Steel)	Shutdown Zone	3	Shutdown Pile Driving	One hauled out at 1357 till 1408, no behavior changes from noise of impact
09/29/2023	13:58:00	CS	35	Slow Traveling	1	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	
10/30/2023	13:11:00	CS	50	Resting/Hauled Out	1	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	CS was closest to us.
10/30/2023	13:15:00	CS	55	Fast Traveling	1	0	Impact Pile Driving (Steel)	Shutdown Zone	1	Shutdown Pile Driving	CS hauls back out south of shutdown zone so they resume work shortly after.
10/31/2023	10:48:00	CS	55	Slow Traveling/Hauled Out	2	0	Impact Pile Driving (Steel)	Shutdown Zone	2	Shutdown Pile Driving	2 CS went in after 3 min of impact hammer on. Showed some irritation. Moved quickly south & out of zone

*HS = Harbor Seal; HP = Harbor Porpoise; CS = California Sea Lion

LITERATURE CITED

DoN (Department of Navy). 2023a. Marine mammal monitoring plan for the Test Pile Project at Naval Base Bremerton (July 2023-February 2024) under the Marine Structure Maintenance and Pile Replacement Program. Prepared by Naval Facilities Engineering Command Northwest, Silverdale, Washington.

DoN (Department of Navy). 2023b. Endangered Species Act (ESA)/Marine Mammal Protection Act (MMPA) monitoring and construction restriction requirements. P454 Multi-Mission Drydock – Test Pile Program, Puget Sound Naval Shipyard and Intermediate Maintenance Facility - Bangor, Bremerton, WA.

DoN (Department of Navy). 2024. Marbled murrelet monitoring report. P454 Multi-Mission Drydock – Test Pile Program, Naval Base Kitsap Bremerton, Washington. Prepared for Naval Facilities Engineering Command Northwest by Azura Consulting LLC under subcontract to Saltwater Inc.

NMFS (National Marine Fisheries Service). 2018. 2018 Revision to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (Version 2.0). Underwater acoustic thresholds for onset of permanent and temporary threshold shifts. NOAA Technical Memorandum NMFS-OPR-59. U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

NMFS (National Marine Fisheries Service). 2023. Letter of authorization for U.S. Department of the Navy, Naval Base Kitsap Bremerton, Washington.

The Greenbusch Group Inc. 2024. P454 Multi-mission Drydock Test Pile Program: Hydroacoustic monitoring report. Prepared for Manson Construction and Naval Facilities Engineering Command by The Greenbusch Group, Inc.

APPENDIX A: MARINE MAMMAL OBSERVATION RECORD FORM

Observer Name: ________________________ Page____________of_______________

MARINE MAMMAL OBSERVATION RECORD FORM

Project Name: ____________________ Monitoring Location: ________________________________ Time Effort Initiated: ______________

Date: ___________________________ (Pier, Vessel, Name of Site, or Description) Time Effort Completed: ____________

Event Code	Time (Start End)	Lat	Long	Cue (circle)	Species	Dist to Animal from Obs	Dir Relative to Obs	Beh Code	Group Size (min/max/best) # Calves/Pups	Const Code	Zone Code	# Animals in Zone	Miti-gation & Type	BSS	Swell	Visibility %Glare	Weather Code
	: : : :			Animal Blow Splash Bird Other		m or km	°		/ / __calves/pups				Y N DE SD		Height (ft): Dir:	km %	
	: : : :			Animal Blow Splash Bird Other		m or km	°		/ / __calves/pups				Y N DE SD		Height (ft): Dir:	km %	
	: : : :			Animal Blow Splash Bird Other		m or km	°		/ / __calves/pups				Y N DE SD		Height (ft): Dir:	km %	
	: : : :			Animal Blow Splash Bird Other		m or km	°		/ / __calves/pups				Y N DE SD		Height (ft): Dir:	km %	
	: : : :			Animal Blow Splash Bird Other		m or km	°		/ / __calves/pups				Y N DE SD		Height (ft): Dir:	km %	
	: : : :			Animal Blow Splash Bird Other		m or km	°		/ / __calves/pups				Y N DE SD		Height (ft): Dir:	km %	

Event Code:
ON = Effort On
OFF = Effort Off
WC = Weather Change
S = Sighting

Behavior Code:
M = Milling
ST = Slow Traveling
FT = Fast Traveling
F = Feeding/Foraging
R = Resting/Hauled Out
S = Socializing

Construction Code:
SSV = Soft Start-Vibratory
SSI = Soft Start-Impact
V = Vibratory Pile Driving
I = Impact Pile Driving
PC = Pneumatic Chipping
DP = Dead Pull
ST = Stabbing
NONE = No Pile Driving

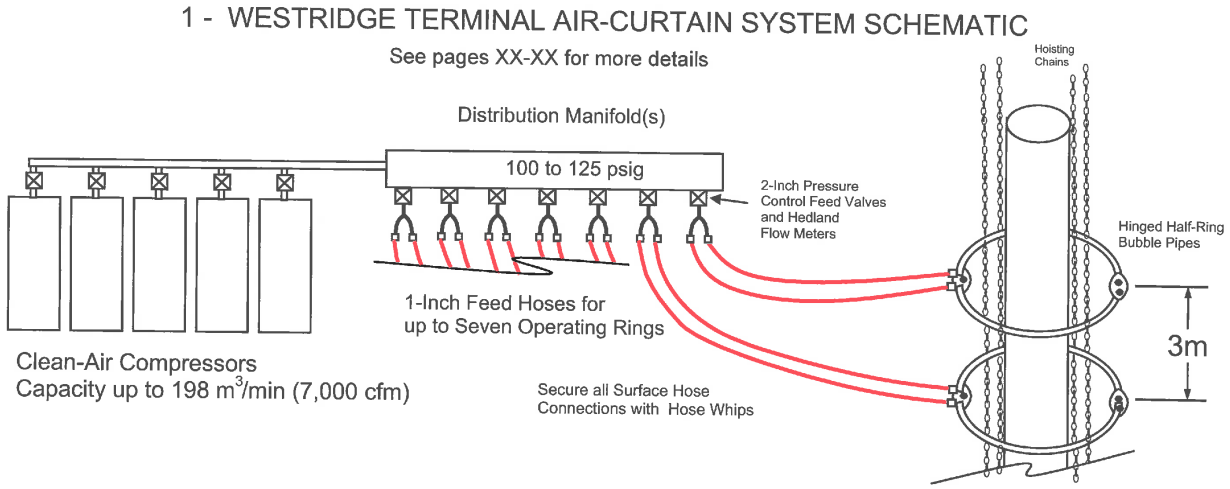
Zone Code:
A = Level A Harassment Zone
B = Level B Harassment Zone
S = Shutdown Zone
N = No Active Pile Driving
O = Outside Active Pile Driving Zones

Mitigation Code:
DE = Delay Onset of Pile Driving
SD = Shutdown Pile Driving

Weather Code:
S = Sunny
PC = Partly Cloudy
MC = Mostly Cloudy
L = Light Rain
R = Steady Rain
F = Fog
O = Overcast

Comments:

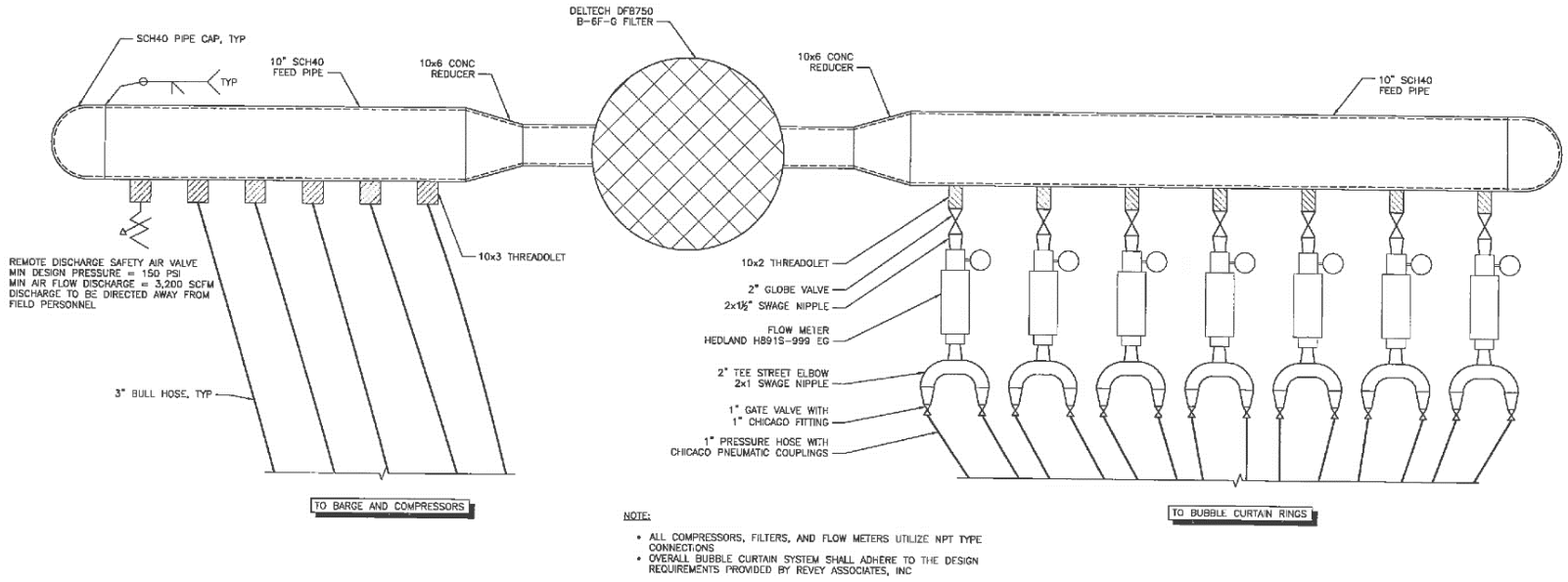
APPENDIX B: BUBBLE CURTAIN SPECIFICATIONS & PERFORMANCE



Typical Manifold Construction

25.4mm Pressure Hoses with Chicago Pneumatic Couplings

Bubble Rings on a Pipe Pile



MANIFOLD DIAGRAM

System Design Calculations:

Compressed Air Bubble Curtain

Design:	**US Naval Base Kitsap - Bangor** **Seawolf Class Service Pier** **Seawolf Class Service Pier Pile Driving Project**
For:	**Manson Construction Company** **Seattle, Washington**
System:	**Bubble Curtain Performance Calculations**
System Number:	**2020-40-300-72-1**
Date:	**14-Jul-20**
By:	**jwk**

WEST SOUND MARITIME, INC.
P.O. BOX 505 QUILCENE, WASHINGTON 98376 PHONE (206)595-9203 info@westsoundmaritime.com

Bubble Curtain Performance Calculations	Sheet: 1 of: 28

A. REVISIONS

For: US Naval Base Kitsap - Bangor	By: jwk	Date: 14-Jul-20

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B. TABLE OF CONTENTS

For: **US Naval Base Kitsap - Bangor**	By: jwk	Date: 14-Jul-20

Bubble Curtain Performance Calculations	Sheet: 3 of: 29

C. REFERENCES

1) Amendment 003_Attachment: P-834 ESA
FY17 MCON P-834 SEAWOLF Class Service Pier (1554182)
Naval Base Kitsap - Bangor, Silverdale, WA
Endangered Specis Act (ESA)/Marine Mammal Protection Act (MMPA) Monitoring and Construction Restriction Requirements
205 pages
No date shown.

For references made to bubble curtain design requirements, please see pages 4, 39, 59, 198.

2) SR 525
Mukilteo Ferry Terminal (Phase 2)
Marine Structures
Unconfined Bubble Curtain Arrangement
4 pages
Dated: 9-21-2018

For other supporting reference material, please see the APPENDIX of this report.

For: **US Naval Base Kitsap - Bangor**	By: jwk	Date: 14-Jul-20

Bubble Curtain Performance Calculations	Sheet: 4 of: 29

D. 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 required for the work being done at the Seawolf Service Pier at US Navy Submarine Base Bangor in Bangor, Washington.

The air system and bubble curtain design requirements will follow the requirements established by the Washington State Department of Transportation that are required for pile driving projects at all Washington State Ferry Terminals. The performance criteria for this system are detailed in the ASSUMPTIONS section of this report.

The unconfined bubble curtain assembly equipment consists of an air compressor that will deliver supply air to a fabricated air system manifold. The manifold splits the supply air into (up to) sixteen supply hoses that provide supply air to the eight air bubble distribution rings that are positioned around the pile being driven. The air bubbler distribution rings are positioned at regular 7-FT intervals beginning at the mud line and spaced vertically up to the water surface.

This set of calculations will establish the required compressor capacity (flow rate and required discharge pressure) that will be needed to supply air to the (8) air bubble distribution rings in water depths up to 56-feet deep. The air flux density delivered to each air distribution ring will be a minimum of 32.91-SCFM per foot of ring (i.e. ring circumference).

The air flowrates to each air distribution ring will be measured using an air flow meter to ensure that the required air flowrates to each ring are maintained. Air flow rate data will be recorded and dated by contractor personnel, as necessary.

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.

For: US Naval Base Kitsap - Bangor	By: jwk	Date: 14-Jul-20

Bubble Curtain Performance Calculations	Sheet: 5 of: 29

E. ASSUMPTIONS & CRITERIA

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

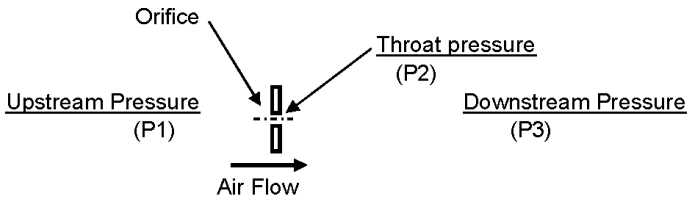
   SCFM = Air as measured at "standard" conditions (Temp = 60-F, 14.7-PSIA)

   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.



For: US Naval Base Kitsap - Bangor	By: jwk	Date: 14-Jul-20

Bubble Curtain Performance Calculations	Sheet: 6 of: 29

D. ASSUMPTIONS & CRITERIA

5) An orifice is a round sharp edged hole in a thin plate. The holes in the air distribution pipe are assumed to behave as 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 separately, in other documents.

7) 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.

8) 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 75-FT long. Rubber-lined hose assumed to be equivalent to steel pipe with regard to friction of air passing through the hose. (This is a conservative approach.)

9) The compressor will either be an "oil free" type, or will be filtered using a coalescing The sizing and selection of the fillter will be provided elsewhere, by others.

10) For the unconfined bubble curtain arrangement, there will be up to (8) bubbler rings spaced at 7-FT intervals (first ring being positioned on mud) suitable for depths of up to 56-FT deep (water depth).

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

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

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

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

15) 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)

For: **US Naval Base Kitsap - Bangor**	By: jwk	Date: 14-Jul-20

Bubble Curtain Performance Calculations	Sheet: 7 of: 29

D. ASSUMPTIONS & CRITERIA

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

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

18) Max. water depth of rings: **56** FT

19) 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.

20) It is assumed that the air flow meters that are installed in each bubbler ring air supply line (located at the discharge manifold) will provide air flow rate information in to the system operators. Manson Construction will provide air flow meters as required by the project specification. Flow meter output will aid in the delivery of the proper air flowrate needed to achieve the required air flux density at the air distribution rings at the various water depths required.

21) It is assumed that all compressed air piping has been selected and fabricated for system pressures up to 200-PSIG.

22) Compressed air assumed values:

Air pressure (free air)	=	**0**	PSIG	(atmospheric)
Air temperature (free air)	=	**60**	DEG F	
Air density (free air)	=	**0.0764**	LBm/FT^3	
Air pressure (compressed air)	=	**200**	PSIG	
Air temperature (compressed air)	=	**100**	DEG F	(compressor is water cooled)
Air density (compressed air)	=	**1.0350**	LBm/FT^3	

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

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Bubble Curtain Performance Calculations	Sheet: 8 of: 29

F. CONCLUSION

The performance of the USN Naval Base - Kitsap Seawolf Class Service Pier pile driving compressed air system and bubble curtain equipment will satisfy the intent of the Washington State Department of Transportation system requirements as described in this report.

The following detailed calculations indicate that a total air flow rate of 4,747-SCFM is required to supply a depths down to 56-FT when using up to (8) bubbler rings at depth increments of 7-FT. Three identical air compressors will be used to deliver the system compressed air requirements. Each compressor is rated at 1,600-SCFM at a discharge pressure of 150-PSIG.

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. (19) explains some of the unknowns and variables that will affect system performance. The free air required for the system is 4,747-SCFM. The three air compressors will deliver 4,800-SCFM.

The final performance of the system will be controlled by adjustment of the globe valves (throttling valves) provided in the supply lines to each air hose at the discharge manifold. By adjusting the throttling valves to match the information developed in this set of calculations, the air delivered to each air distribution ring will be adequate to satisfy the specified quantity of air to each ring.

With all three compressors running, the system can provide the required air for the eight air distribution rings when located at the depths shown in this set of calculations.

The worst case (i.e. deepest) air distribution ring requires (approx.) 593-SCFM at a total compressed air pressure of (approx.) 45-PSIG. Since the air compressors can develop 150-PSIG, there is adequate margin in the system to accommodate any unforseen additional pressure drops in the branch lines.

When all (8) rings are being used at the noted water depths, a depth of 56-FT will equal the maximum limit that this sytem can accommodate. As mentioned, there is ample margin on the air pressure available. If (8) rings (or fewer) are used at lesser water depths, this system will have margins available both in the compressor flowrates available and in the system air pressure delivered.

See sheet 11 of these calculations for the branch line air pressure requirements.

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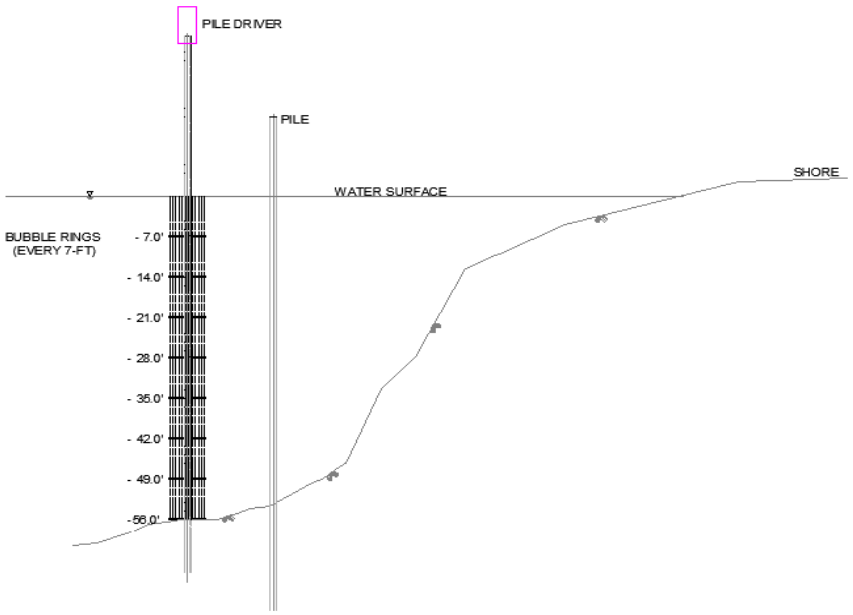
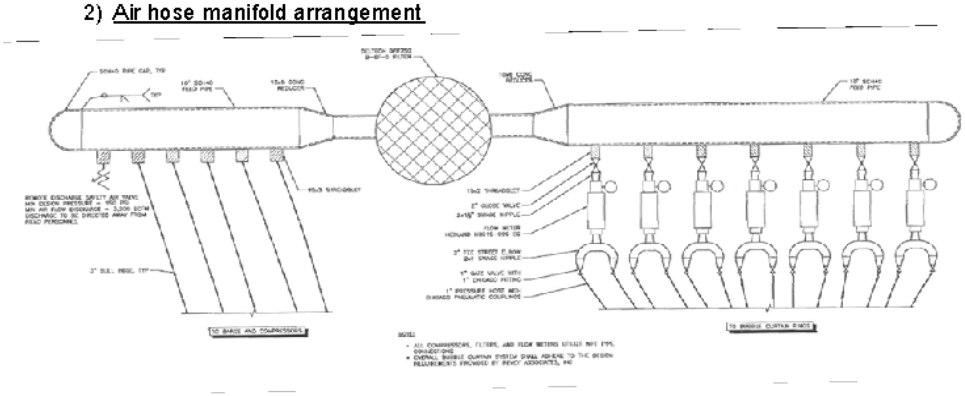
G. PILE DRIVING AIR BUBBLE CURTAIN ARRANGEMENT

1) Sketch



2) Air hose manifold arrangement



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H. 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:	**8**	- -
Each ring has a nominal diameter of:	68.875	IN
Length of each bubbler pipe is:	18.03	FT

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

Ring No.	Ring Depth (Ft)	Air pressure at depth (PSIA)	Free Air Req'd (SCFM)	Actual Air at depth (ACFM)
1	7.00	17.82	593.4	489.5
2	14.00	20.94	593.4	416.5
3	21.00	24.06	593.4	362.5
4	28.00	27.18	593.4	320.8
5	35.00	30.30	593.4	287.8
6	42.00	33.42	593.4	260.9
7	49.00	36.54	593.4	238.6
8	56.00	39.67	593.4	219.9
			4,747	2,596

2) Compressor selection -

Manufacturer =	**Sullair**	
Model =	**1600**	
F.A.D. =	**1,600**	SCFM
Rated Operating Pressure =	**150**	PSIG (pressure relief valve set to this)
BHP output =	**540**	HP
Quantity required =	**3**	- -
Total free air available =	4,800	SCFM
Total free air required =	4,747	SCFM

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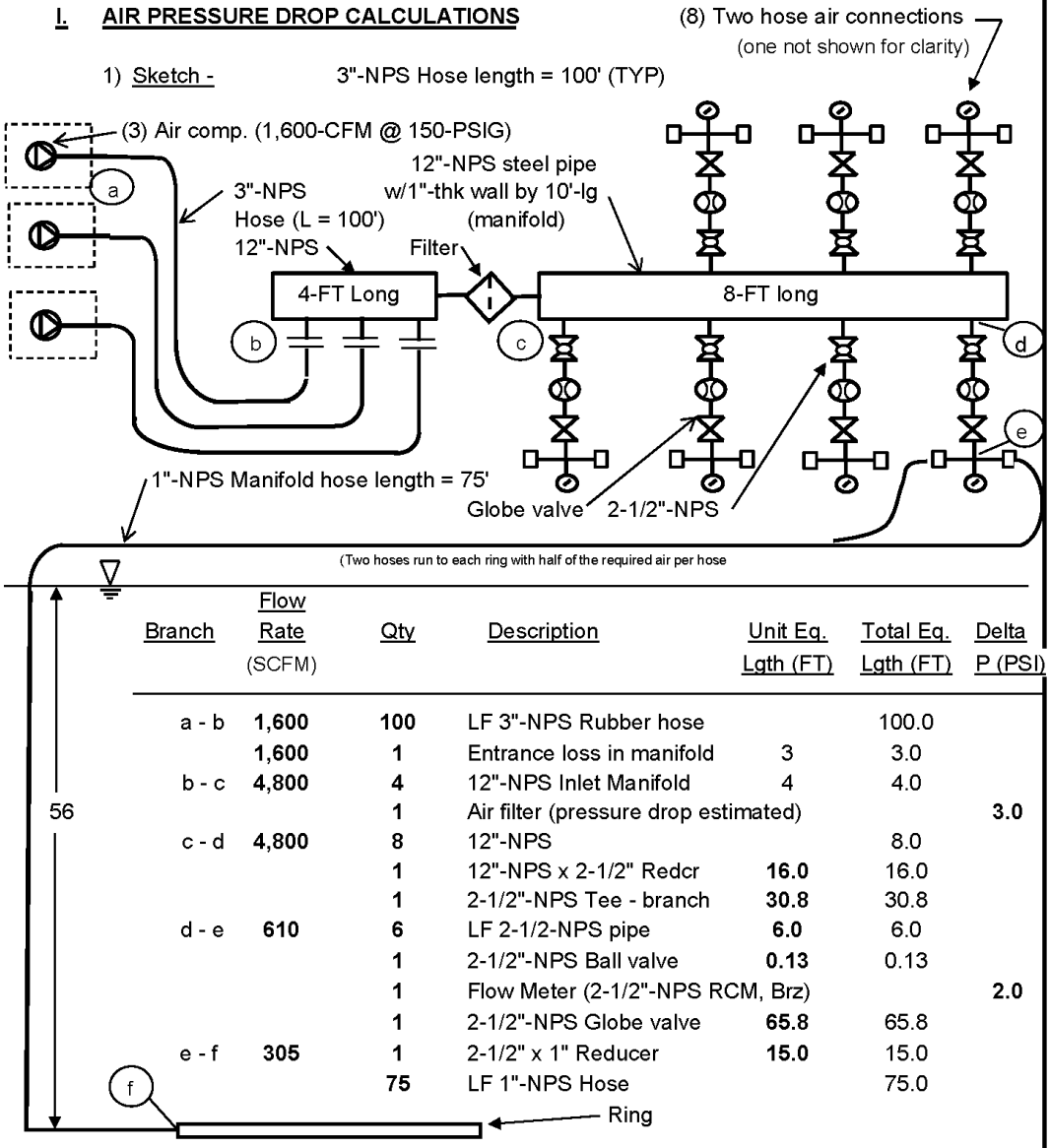
Bubble Curtain Performance Calculations	Sheet: 11 of: 29

I. AIR PRESSURE DROP CALCULATIONS

1) Sketch - 3"-NPS Hose length = 100' (TYP)



Branch	Flow Rate (SCFM)	Qty	Description	Unit Eq. Lgth (FT)	Total Eq. Lgth (FT)	Delta P (PSI)
a - b	**1,600**	**100**	LF 3"-NPS Rubber hose		100.0	
	1,600	**1**	Entrance loss in manifold	3	3.0	
b - c	**4,800**	**4**	12"-NPS Inlet Manifold	4	4.0	
		1	Air filter (pressure drop estimated)			**3.0**
c - d	**4,800**	**8**	12"-NPS		8.0	
		1	12"-NPS x 2-1/2" Redcr	**16.0**	16.0	
		1	2-1/2"-NPS Tee - branch	**30.8**	30.8	
d - e	**610**	**6**	LF 2-1/2-NPS pipe	**6.0**	6.0	
		1	2-1/2"-NPS Ball valve	**0.13**	0.13	
		1	Flow Meter (2-1/2"-NPS RCM, Brz)			**2.0**
		1	2-1/2"-NPS Globe valve	**65.8**	65.8	
e - f	**305**	**1**	2-1/2" x 1" Reducer	**15.0**	15.0	
		75	LF 1"-NPS Hose		75.0	

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Bubble Curtain Performance Calculations	Sheet: 12	of: 29

I. AIR PRESSURE DROP CALCULATIONS

2) Pressure Drop Calculation Summary -

Flowrate out of each compressor = 1600 SCFM
Rated pressure at compressor = 150 PSI

Branch	Size (IN)	Inlet Air Pressure (PSI)	Pipe & Ftg Pressure Loss (PSI)	Other Pressure Loss (PSI)	Total Pressure Loss (PSI)
a - b	**3**	150.00	1.413		1.413
b - c	**12**	150.00	0.001	3.000 (filter)	3.001
c - d	**12**	147.00	0.007		0.007
d - e	**2-1/2**	146.99	0.429		0.429
e - f	**1**	146.56	10.490	2.000 (flowmeter)	12.490
Ring	**2-1/2**	0.00	**0.500** (estimated)		0.500

Dynamic losses through piping system = 17.84 PSIG

Static losses (delta Z) 56 FT = 24.97 PSIG

Total Dynamic Head (dynamic + static) = 42.81 PSIG

The compressor(s) discharge pressure is : 150 PSIG.
Throttle branch pressure globe valves so that the pressure gauge reading is as follows:

Ring Depth	Dynamic Losses	Static Losses	Branch TDH	SCFM Delivered	ACFM Delivered	Pressure Gauge Reading	
7	17.84	3.12	20.96	593	489	17	PSIG
14	17.84	6.24	24.08	593	416	20	PSIG
21	17.84	9.36	27.20	593	362	23	PSIG
28	17.84	12.48	30.32	593	321	26	PSIG
35	17.84	15.61	33.45	593	288	29	PSIG
42	17.84	18.73	36.57	593	261	32	PSIG
49	17.84	21.85	39.69	593	239	35	PSIG
56	17.84	24.97	42.81	593	220	39	PSIG

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Bubble Curtain Performance Calculations	Sheet: 13 of: 29

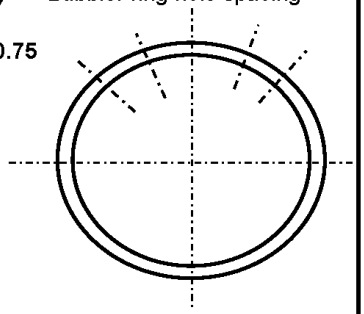
J. UNCONFINED RING AIR FLOWRATE CALCS

56-FT Depth

(4) holes every 3/4" of length

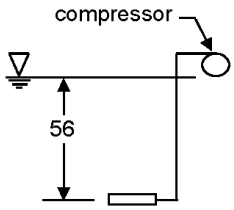
Bubbler ring hole spacing

0.75



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)	=	0.0764	LBm/FT^3
Air density at (P1), below	=	**0.2063**	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**25.99**	PSIG
Frictional losses in ring	=	0.50	PSIG (estimated value)
Pressure (P1) at orifice	=	25.5	PSIG
Pressure (P2) at throat	=	25.0	PSIG
Pressure (P3) at outlet	=	25.0	PSIG (water column pressure)
Ratio (P3/P1)	=	0.98	> 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	=	0.192	ACFM through each orifice
	=	0.525	SCFM through each orifice

Flow rate through ring	=	596	SCFM

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

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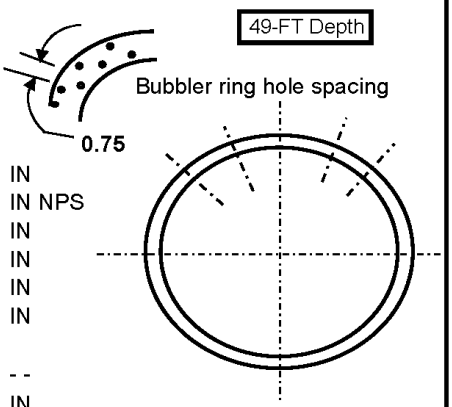
Bubble Curtain Performance Calculations	Sheet: 14 of: 29

J. UNCONFINED RING AIR FLOWRATE CALCS



(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)	=	0.0764	LBm/FT^3
Air density at (P1), below	=	**0.1920**	LBm/FT^3

2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**22.25**	PSIG
Frictional losses in ring	=	0.50	PSIG (estimated value)
Pressure (P1) at orifice	=	21.8	PSIG
Pressure (P2) at throat	=	21.2	PSIG
Pressure (P3) at outlet	=	21.2	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)	=	0.00068	LB / SEC
Volume. flowrate thru orifice	=	0.212	ACFM through each orifice
	=	0.526	SCFM through each orifice

Flow rate through ring	=	596	SCFM
Flow rate per foot of ring	=	33.1	SCFM > 32.91-SCFM

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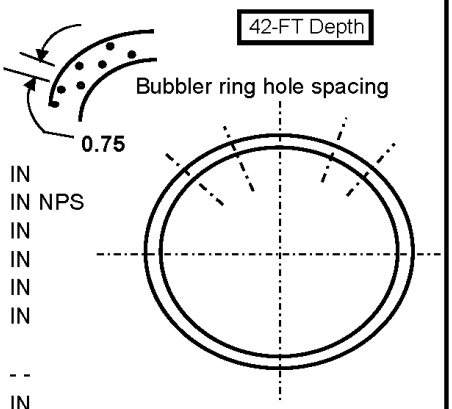
Bubble Curtain Performance Calculations	Sheet: 15 of: 29

J. UNCONFINED RING AIR FLOWRATE CALCS



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)	=	0.07640	LBm/FT^3
Air density at (P1), below	=	**0.15390**	LBm/FT^3

2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**19.24**	PSIG
Frictional losses in ring	=	0.50	PSIG (estimated value)
Pressure (P1) at orifice	=	18.7	PSIG
Pressure (P2) at throat	=	18.2	PSIG
Pressure (P3) at outlet	=	18.2	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)	=	0.00059	LB / SEC
Volume. flowrate thru orifice	=	0.232	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

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Bubble Curtain Performance Calculations	Sheet: 16	of: 29

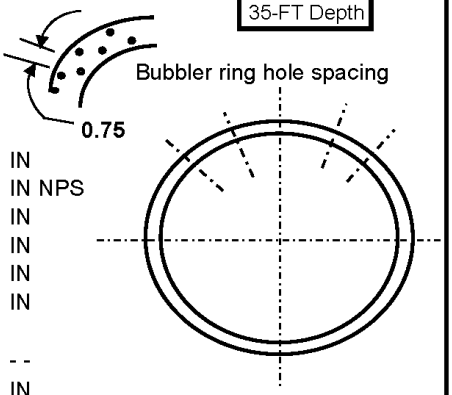
J. UNCONFINED RING AIR FLOWRATE CALCS

35-FT Depth

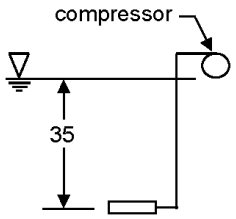
(4) holes every 3/4" of length

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)	=	0.07640	LBm/FT^3
Air density at (P1), below	=	**0.1611**	LBm/FT^3



2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**16.22**	PSIG
Frictional losses in ring	=	0.50	PSIG (estimated value)
Pressure (P1) at orifice	=	15.7	PSIG
Pressure (P2) at throat	=	15.2	PSIG
Pressure (P3) at outlet	=	15.2	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)	=	0.00068	LB / SEC
Volume. flowrate thru orifice	=	0.255	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

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Bubble Curtain Performance Calculations	Sheet: 17 of: 29

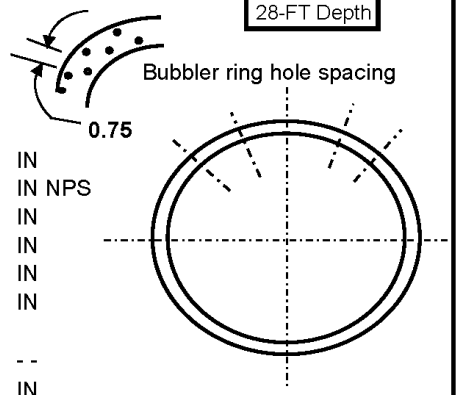
J. UNCONFINED RING AIR FLOWRATE CALCS

28-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)	=	0.07640	LBm/FT^3
Air density at (P1), below	=	**0.1443**	LBm/FT^3

2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**13.19**	PSIG
Frictional losses in ring	=	0.50	PSIG (estimated value)
Pressure (P1) at orifice	=	12.7	PSIG
Pressure (P2) at throat	=	12.1	PSIG
Pressure (P3) at outlet	=	12.1	PSIG (water column pressure)
Ratio (P3/P1)	=	0.96	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00068	LB / SEC
Volume. flowrate thru orifice	=	0.282	ACFM through each orifice
	=	0.526	SCFM through each orifice

Flow rate through ring	=	596	SCFM

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

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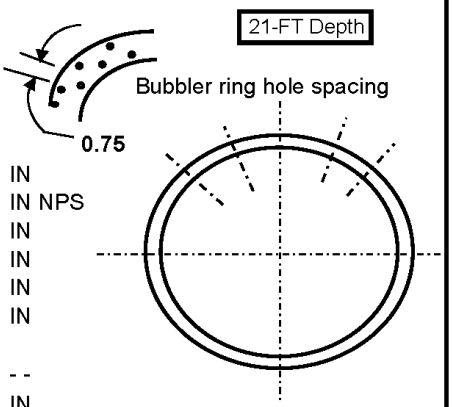
J. UNCONFINED RING AIR FLOWRATE CALCS



(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)	=	0.07640	LBm/FT^3
Air density at (P1), below	=	**0.15390**	LBm/FT^3

2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**10.15**	PSIG
Frictional losses in ring	=	0.50	PSIG (estimated value)
Pressure (P1) at orifice	=	9.6	PSIG
Pressure (P2) at throat	=	9.1	PSIG
Pressure (P3) at outlet	=	9.1	PSIG (water column pressure)
Ratio (P3/P1)	=	0.96	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00081	LB / SEC
Volume. flowrate thru orifice	=	0.317	ACFM through each orifice
	=	0.525	SCFM through each orifice

Flow rate through ring	=	596	SCFM
Flow rate per foot of ring	=	33.0	SCFM > 32.91-SCFM

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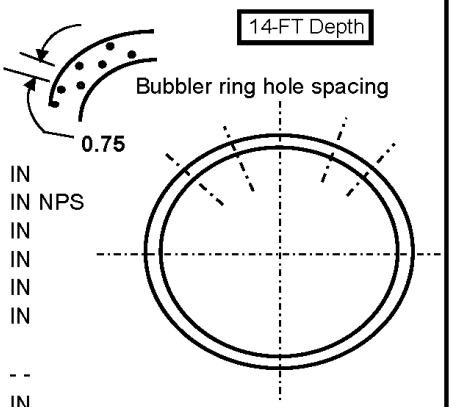
J. UNCONFINED RING AIR FLOWRATE CALCS



(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)	=	0.07640	LBm/FT^3
Air density at (P1), below	=	0.12000	LBm/FT^3

2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**7.07**	PSIG
Frictional losses in ring	=	0.50	PSIG (estimated value)
Pressure (P1) at orifice	=	6.6	PSIG
Pressure (P2) at throat	=	6.1	PSIG
Pressure (P3) at outlet	=	6.1	PSIG (water column pressure)
Ratio (P3/P1)	=	0.95	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00073	LB / SEC
Volume. flowrate thru orifice	=	0.364	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

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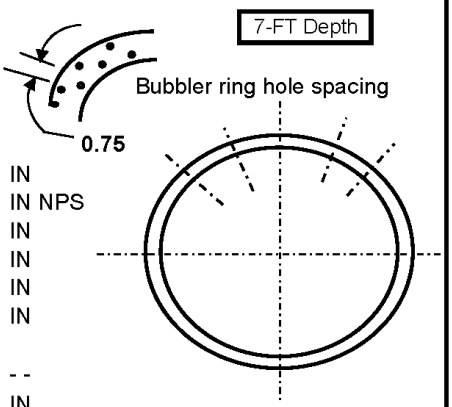
J. UNCONFINED RING AIR FLOWRATE CALCS



(4) holes every 3/4" of length

1) Sketch:

Ring Nom Diameter	=	68.875	IN
Ring Pipe Size	=	68.875	IN NPS
Pipe OD	=	2-1/2	IN
Pipe ID (Sch 80)	=	2.875	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	=	0.06250	IN^2
Total bubble area in ring	=	0.00307	IN^2
	=	3.47808	FT^2
Air Temperature	=	60	DEG F
Air Density (atm. pressure)	=	0.07640	LBm/FT^3
Air density at (P1), below	=	0.12000	LBm/FT^3

2) Flowrate through orifice calculations:

Pressure at ring inlet	=	**3.91**	PSIG
Frictional losses in ring	=	0.50	PSIG (estimated value)
Pressure (P1) at orifice	=	3.4	PSIG
Pressure (P2) at throat	=	3.0	PSIG
Pressure (P3) at outlet	=	3.0	PSIG (water column pressure)
Ratio (P3/P1)	=	0.95	> 0.528
Flow type	=	**Subcritical**	(Greater than critical ratio)
Orifice Discharge Coeff. (C)	=	**0.61**	- - (Sharp edged)
Mass Flow rate thru orifice (W)	=	0.00086	LB / SEC
Volume flowrate thru orifice	=	0.428	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

For: **US Naval Base Kitsap - Bangor**	By: jwk	Date: 14-Jul-20

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J. AIR FLOW METER OUTPUT READINGS

1) Air flow meter output reading

Since the air that is delivered to the air flow meter from the compressor will be compressed to 150-PSIG, the air flow meter will reflect a lower flow rate (not the 1,600-SCFM).

Compressor discharge rate - free air = 1,600 SCFM
Compressor discharge pressure = 150 PSIG

Since the flow meters are located on the system side of the discharge manifold, it is assumed that the maximum air pressure at the meters will reflect the pressure drop in the air lines up to the point in the system where the flow meters are installed. It is estimated that the pressure drop in the system between the air compressor and the flow meters will be (approx.) 4.42-PSIG (see calculations, above) which means that the maximum air pressure at the meters will be 150.00-PSIG - 4.42-PSIG, or **145.6-PSIG**.

Actual flowrate into air flow meter = 147 ACFM

Not knowing whether the air flow meter will show output in terms of "free air" (SCFM) or if the output is in terms of "compressed air" (ACFM) at 150-PSIG, the following table is provided as reference.

Compressors Running	Compressor Output (SCFM)	Compressor Output (ACFM)
1	1,600	147
2	3,200	293
3	4,800	440

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K. APPENDIX

1) Air distribution ring assembly information

2) Air compressor information

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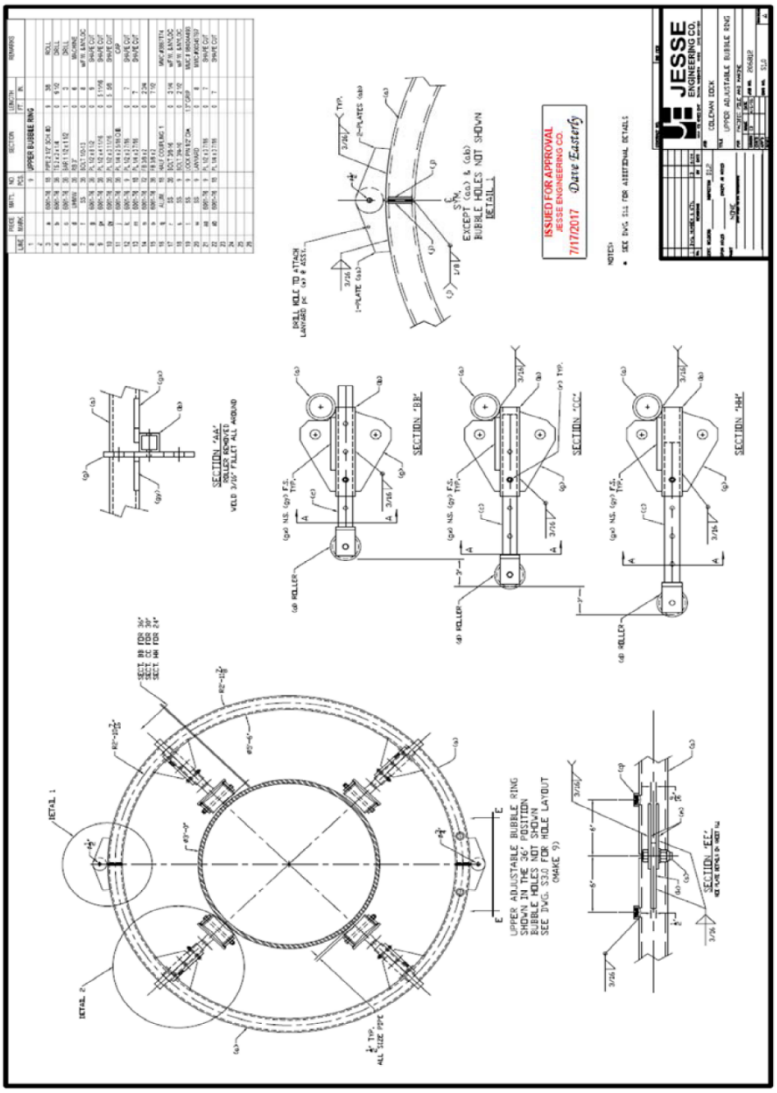
Bubble Curtain Performance Calculations	Sheet: 23 of: 29

K. APPENDIX

1) Air distribution ring assembly information



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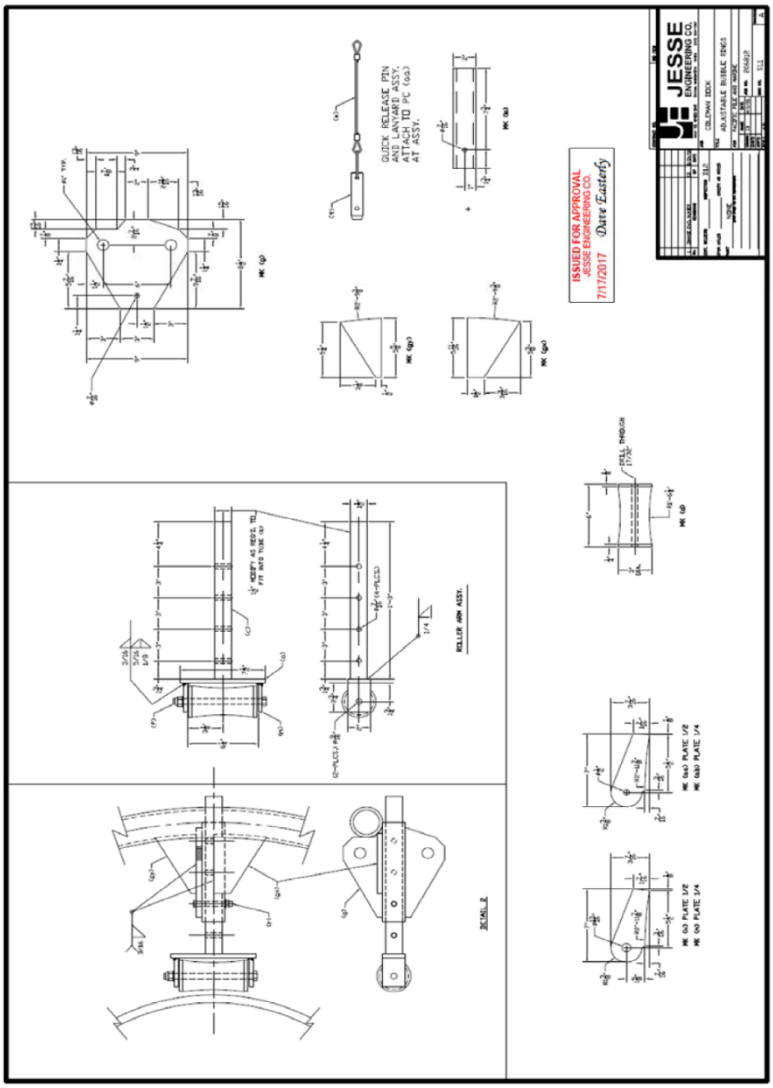
K. APPENDIX

1) Air distribution ring assembly information



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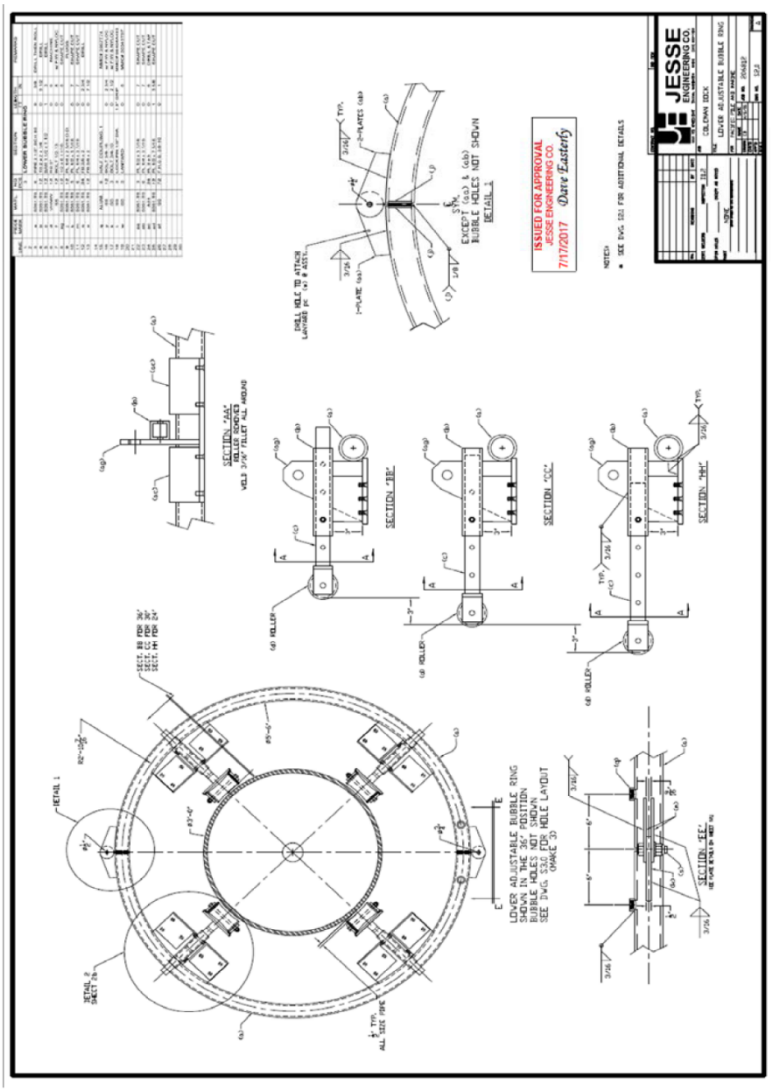
K. APPENDIX

1) Air distribution ring assembly information



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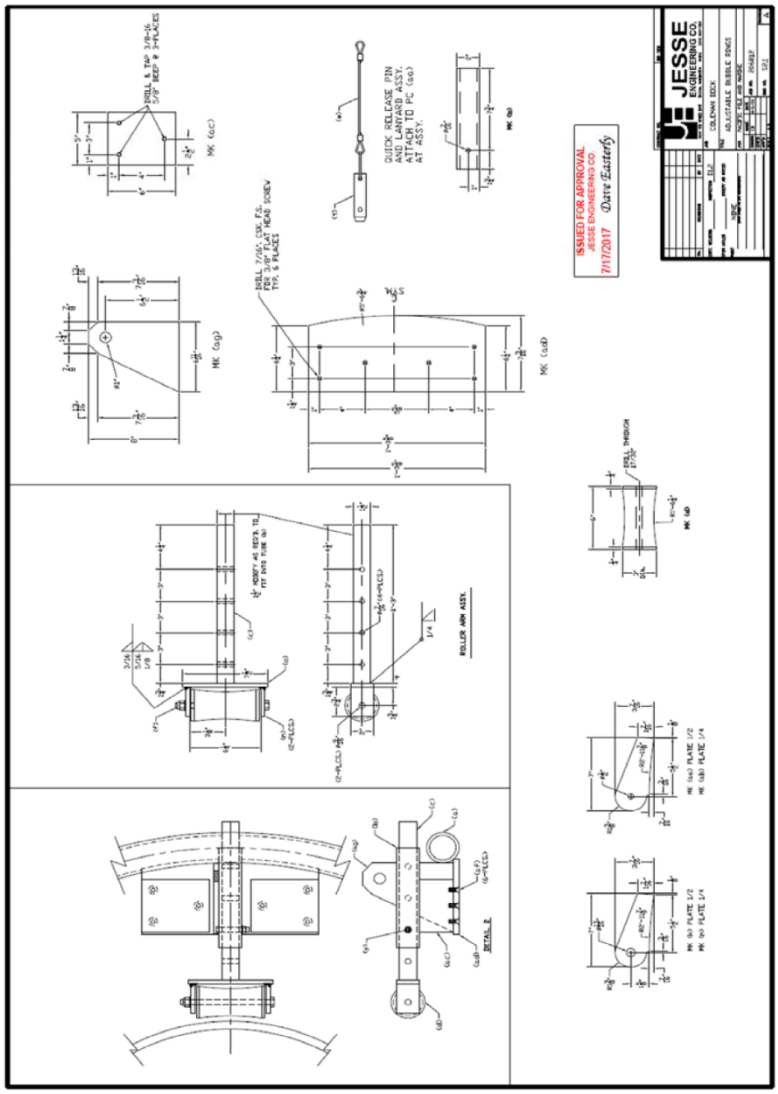
K. APPENDIX

1) Air distribution ring assembly information



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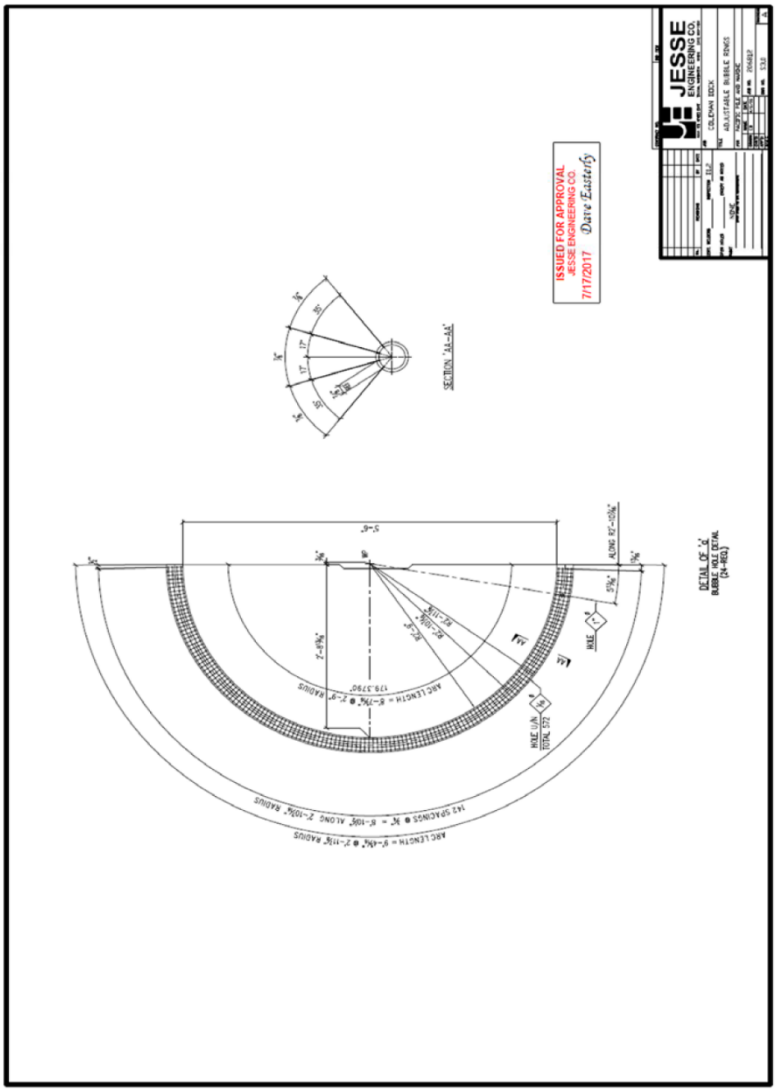
K. APPENDIX

1) Air distribution ring assembly information



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Bubble Curtain Performance Calculations	Sheet: 28 of: 29

K. APPENDIX

2) Air compressor information

Sullair Interim Tier 4 1600 Family of Portable Air Compressors

MODEL 1300H
1300 cfm at 150 psig
36.8 m³/min at 10 bar

MODEL 1300HH
1300 cfm at 200 psig
36.8 m³/min at 14 bar

MODEL 1450HH
1450 cfm at 175 psig
41.1 m³/min at 12 bar

MODEL 1600
1600 cfm at 100 psig
45.3 m³/min at 7 bar

MODEL 1600H
1600 cfm at 150 psig
45.3 m³/min at 10 bar

SULLAIR.
Always air. Always there.

For: **US Naval Base Kitsap - Bangor**	By: jwk	Date: 14-Jul-20

Bubble Curtain Performance Calculations	Sheet: 29 of: 29

K. APPENDIX

2) Air compressor information

Designed for Total Accessibility and Reliability

Gauges and a LCD graphic display on the controller indicate:
- Discharge pressure and temperature
- Ambient air temperature
- Separator restriction
- Aftercooler air temperature
- Engine speed
- Hours of operation
- Voltage
- Engine coolant temperature
- Engine coolant low-level shutdown
- Fuel level and usage rate
- Fuel pressure and temperature
- Percent engine load
- Engine air temperature
- Engine oil pressure
- Engine exhaust module soot level
- Engine boost pressure
- Compressor and engine status

Additional Controller Features
- Engine diagnostic service port
- Diagnostic messages displayed on LCD screen
- Retrievable shutdown history includes all monitored system parameters at time of shutdown
- Back lit switches and gauges for night use
- E-stop, and auto and remote start capability
- Indicator lights for:
  - Low fuel
  - High compressor temperature
  - compressor shutdown and warning
  - Engine shutdown and warning
  - Low fuel shutdown

0 to 100% Capacity Control
- Automatic inlet valve and unloaded starting

Complete Fluid Containment
- Heavy duty frame with complete fluid containment
- Bulkhead drain valves for all fluids are provided

Improved Serviceability
- Double doors on both sides of the compressor
- Serviceable components within easy reach

Two-Stage Dry Type Air Filters
- Filters incorporate safety elements and are positioned to draw cool ambient air

Two Mounting Options
- Highway towable tandem-axle (with Torflex® axles) includes electric brakes, oil bath wheel bearings, wheel chocks, restraining tow chains
- Less running gear on mounting rails with fork pockets

Low Emissions Engine Technology
- Complies with interim Tier 4 emissions legislation

Air End Warranty
- 5-year or 10,000-hour warranty when continuously serviced at the recommended intervals with Sullair AWF Compressor Fluid and filters

Quiet Operation
- Meets US EPA sound requirements of 76 dBA@7 meters

Additional Features
- No stacked coolers - allows for easy cleaning
- Cooler access panels
- Cold box design
- Fuel cooler is standard provided
- Single point lift
- Cabin lights
- (4) Heavy Duty Frame tie-downs
- Dedicated d-ring for service hose safey lanyard
- Controls at cold end of package
- Additional 3/4" discharge valves
- Strobe light and siren provide visual and audible alerts for warning conditions
- Durable powder coat finish
- Galvanized canopy panels
- Remote fuel fill
- Stacked fuel valve for switching between internal and external tanks

Customize the compressor to meet your specific requirement with Sullair options:
- Fork truck pockets
- Engine block heater
- Aftercooler
- Filtration for instrument quality air
- Spark arrestor muffler
- Aftercooler shutters
- Stainless steel canopy
- Air inlet shut-off valve
- Special paint

SULLAIR INTERIM TIER 4 1600 FAMILY PORTABLE AIR COMPRESSORS

WEIGHTS AND DIMENSIONS

Designated Model	Weight (wet) lbs	kg	Weight (dry) lbs	kg	Length (drawbar) in	mm	Length (canopy) in	mm	Width in	mm	Height in	mm	Track Width in	mm	Tire Size (load range)
Tandem Axle (DTQ)	21000	9525	19000	8618	262	6655	210	5334	102	2591	101	2565	91	2311	245/70R17.5 (H)
Less Running Gear (DLQ)	20000	9072	18000	8165	–	–	210	5334	90	2286	86	2184	–	–	

ENGINE SPECIFICATIONS

Engine Make	Engine Type	Engine Model	Displacement in³	liter	Cylinders	Bore and Stroke in	mm	Rated Speed rpm	Rated Power hp	kW
Caterpillar (Interim Tier 4 Emission Compliant)	Diesel	C15	928	15.2	6	5.40 x 6.7	137 x 170	1800	475 hp*	354
									540 hp	403

*1300H, 1600 models only

MODELS AND RATINGS

Delivery @ Rated Pressure	Rated Pressure	Pressure Range
MODEL 1300H		
1300 acfm (613 l/s, 36.8 m³/min)	150 psig (10 bar)	85–150 psig (5.8–10 bar)
MODEL 1300HH		
1300 acfm (613 l/s, 36.8 m³/min)	200 psig (14 bar)	85–200 psig (5.8–14 bar)
MODEL 1450HH		
1450 acfm (685 l/s, 41.1 m³/min)	175 psig (12 bar)	85–175 psig (5.8–12 bar)

Delivery @ Rated Pressure	Rated Pressure	Pressure Range
MODEL 1600		
1600 acfm (755 l/s, 45.3 m³/min)	100 psig (7 bar)	85–100 psig (5.8–7 bar)
MODEL 1600H		
1600 acfm (755 l/s, 45.3 m³/min)	150 psig (10 bar)	85–150 psig (5.8–10 bar)

Capacity per CAGI/PNEUROP PN2CPTC3. (Annex D to ISO 1217)

SULLAIR. Always air. Always there.

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Sullair is preserving the planet one compressor at a time.

Sullair
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Michigan City, IN 46360
Telephone: 219-879-5451
www.sullair.com

SSL-1413EN 1307R

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