Filed December 18, 2021, 11:54 am

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DEPARTMENT OF HEALTH

STATE OF HAWAII

In the Matter of the Emergency Order to UNITED STATES NAVY For Emergency Change-In-Service and Defueling of 20 Underground Storage Tanks, Red Hill Bulk Fuel Storage Facility	DOCKET NO. 21-UST-EA-02 WRITTEN TESTIMONY OF DAVID M. NORFLEET; CERTIFICATE OF SERVICE

WRITTEN TESTIMONY OF DAVID M. NORFLEET

1. I provide this written testimony on behalf of the Honolulu Board of Water Supply (BWS) in the above-captioned contested case before the Hawaii Department of Health (DOH).

2. I am the Head of Department for Labs and Testing within Energy Systems at DNV GL USA, Inc. (DNV). DNV, operating in over 100 countries, is the leading technical advisor to the global oil and gas industry, providing consistent, integrated services within technical and marine assurance and advisory, risk management and offshore classification, to enable safe, reliable, and enhanced performance in projects and operations. Within my Department, the Incident Investigation Section, which I managed previously, conducts over 100 failure investigations each year for the oil and gas industry.

3. I have substantial experience in corrosion and degradation/failure mechanisms associated with oil and gas assets, including underground storage tanks (USTs) and associated pipeline infrastructure.

4. I have a Ph.D. in Materials Science and Engineering from The Ohio State University. Additionally, I have a Master's degree and a Bachelor of Science degree in Materials Science and Engineering, also from The Ohio State University.

5. I am a Licensed Professional Engineer in the state of Illinois.

6. I am a member or former member of the American Society for Materials (ASM International), the American Society for Mechanical Engineers (ASME), the National Association of Corrosion Engineers (NACE) (now the Association of Material Protection and Performance), the American Society for Testing and Materials (ASTM), and the International Metallographic Society (IMS). As a member of these professional associations, I have written

various articles on failure analysis and other topics, and I have served on various committees, including committees on failure analysis.

7. I have consulted in cases presiding before both federal and state courts, and have been accepted as an expert in these matters.

8. I was previously asked to provide my expert opinion in *In the Matter of the Application of United States Navy For an Underground Storage Tank Permit for the Red Hill Bulk Fuel Storage Facility*, Docket No. 19-UST-EA-01.

9. In developing my expert opinion, I reviewed the Navy's redacted Red Hill Bulk Fuel Storage Facility (RHBFSF) UST system permit application as well as available fuel release documentation, technical data, UST inspection reports, environmental investigations and analyses, and other relevant documents regarding the Navy's historical and current operations at the RHBFSF. I also relied upon conversations with my colleagues at DNV, BWS personnel, its legal counsel, and consultants.

10. My expert opinions in the Navy's RHBFSF UST system permit application proceeding, and the data and analyses that support my opinions, are set forth in a report dated December 29, 2020, which was prepared under my supervision. This report is attached to this testimony as Exhibit A. I reaffirm the opinions therein, as modified below.

11. Since preparing my expert report, I reviewed additional materials related to the Navy's operation of the RHBFSF, including additional fuel release documentation, technical data, UST system inspection reports, environmental investigations and analyses, and other relevant documents regarding the Navy's recent operations at the RHBFSF. I also engaged in further conversations with my colleagues at DNV, BWS personnel, its legal counsel, and consultants.

12. My key findings and opinions include that the available information clearly demonstrates:

a. Fuel releases from the RHBFSF UST system have occurred episodically throughout the history of the RHBFSF and, as currently configured and operated, will continue to occur unless and until the facility is defueled. At least 76 fuel release incidents at the RHBFSF have occurred, involving nearly 200,000 gallons of product. An updated summary of these fuel releases is attached to this testimony as Exhibit B. Based on my experience, releases from fuel transport and storage infrastructure are likely underreported. Because all releases are likely not documented and because the documented releases do not all have volume estimates, these figures likely underrepresent the total number of releases and volume of fuel released from the RHBFSF UST system.

b. More fuel releases from the RHBFSF UST system are inevitable because the integrity management strategy that the Navy is currently implementing will not prevent future releases of regulated substances for the operational life of the RHBFSF UST system. There is ongoing corrosion occurring on the backsides of the RHBFSF USTs and given the construction methodology and configuration of the tanks, the Navy cannot mitigate this backside corrosion. Therefore, the Navy's only option for preventing future releases is to identify and repair areas of each UST where the corrosion is present before it breaches the internal surface of the steel liner. The equipment and methodology the Navy currently utilizes does not and cannot accurately identify or size the corrosion that is occurring. As a result, the Navy cannot reliably repair corrosion damage and breaches will continue to occur.

c. The Navy is significantly underestimating the risk of future fuel releases from the RHBFSF UST system pipelines. Pipe failure rates utilized in Navy risk assessments are not consistent with recent data published by the oil and gas industry. Further, given the age of the RHBFSF facility, it has likely not benefited from all the improvements implemented in the oil and gas industry.

d. The RHBFSF UST system has reached an end-of-life phase. This end-of-life phase is demonstrated by, among other things: Tanks 1 and 19 having been taken out of service; the most recent repairs to the RHBFSF UST system having been unlike any previous repairs at the facility and having required extensive design and construction considerations; and the Navy having been forced to alter the way it operates the RHBFSF UST system (e.g., by reducing the maximum fuel height and, by extension, the amount of fuel it stores in the USTs in response to the unmitigated corrosion afflicting them).

e. The manner in which the Navy is conducting root cause analyses, and creating actions from their findings, is insufficient to identify the fundamental root causes and prevent future releases. The analysis, findings and recommendations do not follow current industry practices, which go beyond identifying human error as the root cause of failure. Human error cannot be prevented, such that modern fuel transportation and storage systems are designed and operated with engineering controls, proper management of change, and a positive safety culture that anticipates human error and reduces the consequences of those human errors. The Navy is missing key opportunities to learn from prior events and make meaningful change to their management systems and engineering controls.

13. It is also my opinion that the best way to eliminate the risk that future fuel releases will impact drinking water resources is by moving the RHBFSF USTs and corresponding infrastructure to (or replacing it at) another location that does not have the potential to adversely impact Oahu's sole-source groundwater aquifer.

I, DAVID M. NORFLEET, do declare under the penalty of law that the foregoing is true and correct to the best of my knowledge.

DATED: Columbus, Ohio, December 18, 2021.

DAVID M. NORFLEET

EXHIBIT A

DNV·GL

Expert Report

Evaluation of Underground Storage Tanks at the Red Hill Bulk Fuel Storage Facility

Prepared for
Honolulu Board of Water Supply

Report No.: O-AP-LIS / DNOR (10202111)
December 29, 2020

Project Name:	Red Hill Bulk Fuel Storage Facility – Contested Case Hearing	
Customer:	Morgan, Lewis & Bockius LLP / Honolulu Board of Water Supply	
Contact Person:	Ella Foley Gannon / David K. Brown	
Date of Issue:	December 29, 2020	
Project No.:	10202111	
Organization Unit:	Incident Investigation	
Report No.:	O-AP-LIS / DNOR	

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Task and Objective:

Please see Executive Summary.

Prepared, Verified, and Approved by

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Keywords

Executive Summary

DNV GL USA, Inc. (DNV GL) submits this report on behalf of the Honolulu Board of Water Supply (BWS) to provide its expert opinion on certain technical issues to be considered in connection with the Hawaii Department of Health (DOH) contested case hearing concerning the application of the United States Department of the Navy (Navy) for a permit to operate the underground storage tanks (USTs) at the Red Hill Bulk Fuel Storage Facility (RHBFSF) located in Honolulu, Hawaii. The opinions expressed in this expert report specifically address whether or not the Navy can operate the RHBFSF USTs in compliance with applicable legal and regulatory requirements. In developing the expert opinions set forth in this report, DNV GL reviewed the Navy's redacted permit application as well as available fuel release documentation, technical data, UST inspection reports, environmental investigations and analyses, and other relevant documents regarding the Navy's historical and current operations at the RHBFSF. Based on this information, DNV GL has concluded that the Navy cannot demonstrate compliance with the technical requirements necessary to operate the RHBFSF USTs in accordance with Hawaii law.

Specifically, DNV GL finds that the available information clearly demonstrates the following:

- <u>More fuel releases from the RHBFSF USTs are inevitable</u>. The integrity management strategy the Navy is currently conducting will not prevent future releases of the stored regulated substances for the operational life of the RHBFSF USTs. There is ongoing corrosion occurring on the backsides of the RHBFSF USTs and given the construction methodology and configuration of the tanks, the Navy cannot mitigate this backside corrosion. Therefore, the Navy's only option for preventing future releases is to identify and repair areas of each tank where the corrosion is present before it breaches the internal surface of the steel liner. The equipment and methodology the Navy currently utilizes does not and cannot accurately identify or size the corrosion that is occurring. As a result, the Navy cannot reliably repair corrosion damage and breaches will occur. That leaks have and will occur from these USTs is reflected throughout the documented history of the RHBFSF and is consistent with the Navy's own risk assessment. The Navy simply cannot demonstrate that it can safely operate the RHBFSF USTs without fuel releases for the operational life of the tank system, a requirement under Hawaii law as well as for all other operators in the oil and gas industry nationally.
- <u>The RHBFSF USTs are not adequately protected from corrosion</u>. The Navy's destructive testing results make clear that corrosion is occurring on the backside of the steel liners of the RHBFSF USTs that the Navy cannot accurately inspect or directly repair. Navy inspections have documented that corrosion afflicting the USTs has progressed into through-wall holes, resulting in conduits for fuel releases to the environment. The

concrete surrounding the steel liners does not meet the design or regulatory intent to **completely isolate** the steel liner from the corrosive species and electrolytes found in the ground and cannot be reasonably considered as corrosion protection. The condition of the concrete is facilitating transport of this corrosive environment to the external surface of the steel liner allowing for unmitigated backside corrosion to occur on all of the RHBFSF USTs. Despite this clear and present threat to UST integrity, the Navy has not employed *any* of the available UST corrosion protection measures at the RHBFSF.

- The Navy has not established that they have met or can meet the minimum release detection requirements. The Navy claims in its permit application that it can satisfy leak rate detection obligations, but the data necessary to properly evaluate the Navy's claim has been redacted from its permit application and the unredacted information indicates that the Navy has not consistently or properly tested all of the USTs. The Navy's permit application indicates that of the 18 USTs the Navy currently uses, 4 USTs were not tested in 2018 since they were out of service for repairs at the time of testing, and an additional 4 USTs were not tested with fuel at "high level" at the Navy's request. Not testing the tanks at "high level" could potentially result in using for fuel storage a portion of a tank that has not been subject to a leak test. There is insufficient information in the Navy's permit application or other available documentation to demonstrate that the Navy is capable of meeting release detection requirements. Accordingly, it should be assumed that the Navy cannot meet them.

It is further the opinion of DNV GL that these deficiencies cannot be addressed without significant structural upgrades. The only way to eliminate the risk that future fuel releases will impact drinking water resources is by moving the RHBFSF USTs and corresponding infrastructure to (or replacing it at) another location that does not have the potential to adversely impact Oahu's sole-source groundwater aquifer. If the RHBFSF is to remain at its current location, upgrading the USTs to tank-within-a-tank secondary containment, something the Navy acknowledges can be accomplished, is the best and most protective way to address these recognized tank integrity issues.

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1.0 INTRODUCTION

1.1 Engagement

DNV GL was retained by Morgan, Lewis & Bockius LLP on behalf of its client, the Honolulu Board of Water Supply (BWS), to provide its expert opinion on certain technical issues to be considered in connection with the Hawaii Department of Health (DOH) contested case hearing concerning the application of the United States Department of the Navy (Navy) for a permit to operate the underground storage tanks (USTs) at the Red Hill Bulk Fuel Storage Facility (RHBFSF) located in Honolulu, Hawaii. DNV GL was asked to review the Navy's redacted permit application as well as available fuel release documentation, technical data, UST inspection reports, environmental investigations and analyses, and other relevant documents regarding the Navy's historical and current operations at the RHBFSF and to provide expert opinions and prepare this report as to:

- Whether or not the RHBFSF USTs, as they are configured and proposed to be operated in the Navy's permit application, comply with the Hawaii state law requirement that all USTs and UST systems be designed, constructed, installed, upgraded, maintained, repaired, and operated to prevent releases of the stored regulated substances for the operational life of the tank or tank system;
- Whether or not the RHBFSF USTs, as they are configured and proposed to be operated in the Navy's permit application, comply with applicable Hawaii regulatory requirements for corrosion protection; and
- Whether or not the RHBFSF USTs, as they are configured and proposed to be operated in the Navy's permit application, comply with applicable Hawaii regulatory requirements for release detection.

This report provides a statement of and the technical bases for DNV GL's opinions on these issues.

1.2 Qualifications and experience

DNV GL, operating in over 100 countries, is the leading technical advisor to the global oil and gas industry, providing consistent, integrated services within technical and marine assurance and advisory, risk management and offshore classification, to enable safe, reliable and enhanced performance in projects and operations.

David M. Norfleet, Ph.D., P.E., is the Head of Section for the Incident Investigation Section within the Pipeline Services Department at DNV GL. Dr. Norfleet's resume is included with this report (Appendix A). He has substantial experience in corrosion and degradation/failure mechanisms associated with oil and gas assets, including tanks. Each year the Incident Investigation Section conducts over 100 failure investigations for the oil and gas industry. Dr. Norfleet has consulted on cases presiding before both federal and state courts, and has been accepted as an expert in these matters. DNV GL is being compensated for his services at a rate of $360 per hour.

Robin Pitblado, Ph.D., C.Eng., is a Senior Vice President at DNV GL Oil & Gas Division. Dr. Pitblado's resume is included with this report (Appendix A). Dr. Pitblado is one of DNV GL's most experienced risk engineers and for several years was responsible for risk technology used in DNV GL globally. He is the principal author of two books and co-authored 5 more books on risk methodologies. He has conducted major accident investigations for offshore installations and railways, including giving evidence to a Royal Commission in Australia and providing depositions in another fatality accident. DNV GL is being compensated for his services at a rate of $395 per hour.

Robert Barbeauld is a Principal Engineer at DNV GL Oil & Gas Division. Mr. Barbeauld's resume is included with this report (Appendix A). He has over 30 years of experience with Colonial Pipeline Company and retired as the Vice President of Technical Services. In that capacity he was responsible for Asset Integrity, Engineering, Supervisory Control and Data Acquisition (SCADA), Controls Engineering, and Environmental Departments. DNV GL is being compensated for his services at a rate of $360 per hour.

1.3 Documents relied upon

The documents that were made available, reviewed in part or in whole, and/or considered in developing these expert opinions are cited and referenced within this report (Appendix B). In preparing these opinions, DNV GL also relied upon conversations with BWS personnel, its legal counsel, and consultants.

1.4 Declaration

This report was prepared by DNV GL under the supervision of Dr. Norfleet. The conclusions and opinions expressed within this report are based on DNV GL's knowledge, experience, training, and review of the information and documents that have been produced to date. DNV GL reserves the right to clarify, supplement, or retract the conclusions and opinions should new information become available.

2.0 GENERAL BACKGROUND

The RHBFSF is a 144-acre military installation located on the island of Oahu, Hawaii. The Navy stores nearly 200 million gallons of jet and marine diesel fuel at the RHBFSF in large, field-constructed USTs 100 feet above the high-quality groundwater aquifer from which the

BWS provides drinking water to the residents of Oahu. The 20 RHBFSF USTs were field constructed from December 1940 through 1943 by mining into a volcanic mountain ridge approximately 2.5 miles northeast of Pearl Harbor. Two of the RHBFSF USTs are permanently out of service and, at least recently, two or three are generally empty while undergoing inspections or repairs. This leaves 15 or 16 approximately 80-year old USTs, with a total capacity of around 187.5 to 200 million gallons, in operation directly above Oahu's sole-source aquifer.

These USTs at the RHBFSF are described in American Petroleum Institute (API) 653 inspection reports for Tanks 6, 15, and 16 as "an underground concrete tank with a steel liner" [B-190, B-191, B-192]. The structural portion of the tank that supports the hydrostatic pressure of a column of fluid 100 feet in diameter and approximately 187 feet high (the approximate current fluid height allowed by the Navy) is the reinforced concrete shell embedded in the rock formation. The 0.250-inch thick liner serves as a membrane to provide containment of the fluid. There is evidence of groundwater on the backside of the liner, which indicates that there are pathways for water to reach the steel liner through the concrete and, in turn, pathways for leaked fuel to reach the environment. As such, the concrete structure does not provide fluid containment, only structure for the steel liner membrane. Without the concrete, a traditional steel tank constructed from the same material used for the steel liner (A36 steel per the destructive testing done by the Navy) would need a minimum shell thickness of at least 1.94 inches on the lowest course [1] to withstand the hydrostatic pressure of the stored liquid.[2]

The size and scope of these USTs is unprecedented in the oil and gas industry. By way of example, a typical gas station holds around 25,000 gallons of fuel, and the RHBFSF can store about 10,000 times that amount.[3] Because of their field-constructed nature, the RHBFSF USTs are a massive patchwork of concrete, metal plates and welding—over 1.3 acres of steel plate and several miles of welds per UST—and each RHBFSF UST is large enough for the Statue of Liberty or Aloha Tower to sit inside.

The Navy has described the RHBFSF USTs as follows: (Note: Emphasis added to this and all subsequent quotes signified by bold type).

> "Tanks 1 to 4 are 100 feet 0 inches diameter, 238 feet 6 inches overall height, and have a nominal storage capacity of 285,148 barrels (Bbl) each. Tanks 5 to 20 are 100 feet 0 inches diameter, 250 feet 6 inches overall height, and have a nominal storage capacity of 301,934 Bbl each. The top of the tanks (top of the upper dome) is 110 feet

[2] API 650 13 Edition, March 2020 Section 5.6.3 Calculation of Thickness by the 1 Foot Method.

[3] https://www.epa.gov/ust/evaluating-fuel-leak-and-aging-infrastructure-red-hill-hawaii-largest-underground-fuel-storage.

to 175 feet below ground. The bottoms of the tanks range in elevation from 123 feet to 151 feet above sea level. The tanks are arranged in two rows of 10 tanks, spaced 200 feet on center. 100 feet of lava rock separates the tanks from each other. The primary structure of the tanks consists of an upper dome, barrel, and lower dome.

Tanks 1 to 20 were constructed by excavating the lava rock formation of Red Hill to create a cavity for each tank which was then lined with Gunite, reinforced concrete, and a 1/4-inch thick steel liner. The upper dome was constructed first. The lava rock was excavated to create a cavity for the upper dome. Steel framing and liner plates were then installed, followed by filling the cavity between the liner plates and lava rock with reinforced concrete, 4 feet thick.

After the upper dome was constructed, the barrel and lower dome were excavated. The rock face was lined with 6 inches of Gunite (i.e. spray-applied concrete, also known as shotcrete) to seal the rock face. In some locations additional grouting into the lava was required to fill voids. The barrel is constructed of reinforced concrete (2 feet 6 inches thick minimum at the top, 4 feet thick minimum at the bottom). **The steel liner plates on the barrel are arranged 5-feet tall horizontal courses and served as forms for placing concrete. Horizontal steel angles were welded to the backside of the steel plates at the top and bottom of the plates. All horizontal and vertical joints in the steel liner are butt welded plates. Reinforcing steel for concrete was then placed in the forms. The horizontal angles were then anchored to the reinforcing steel with 3/4-inch diameter anchor rods.** ….

The lower dome is similarly constructed of reinforced concrete and lined with 1/4-inch thick steel plates. The floor of the lower dome (20-foot diameter) is flat and consists of 1/2-inch thick steel plates."   [B-174]

The importance of the design feature of using angles attached to the top of the backside of each barrel liner plate course in an overhanging manner was to allow the adjoining barrel liner course plate to be aligned and butt welded to each other as the angle served as a backing strip for this horizontal weld. The angle design was intended to provide a mechanism to collect and detect leaks from the USTs. In addition, the system provided a means to collect and drain backside water. Known as the "tell-tale" leak detection and collection system, this series of tank wall perforations and vertical piping is described in the same report referenced above, Section 3.0 page 6, as follows:

"The original tell-tale system was configured differently for the upper dome, the barrel, and the lower dome. **The upper domes were such that liquid would freely drain down the backside of the steel liner, and pool just above the expansion joint.**

> **This liquid was drained to 11 zones of barrel tell-tales via a liner penetration and connecting piping. The barrel tell-tale system consisted of 11 vertical pipes the height of the barrel, with pipe penetrations every 5 feet through the shell liner, to correspond with the horizontal shell plate width, and embedded angles in the concrete, that in effect is a horizontal "dam" at each of the 26 or 28 shell courses. Thus, there are approximately 352 shell penetrations. The liner plates in the lower dome are fully surrounded by embedded angles,** thus each shell plate has a jumper at its lowest point, to the top of the next plate (a total of 165 jumper liner penetrations). At the bottom of the lower dome, a circular pipe is connected to each of the lowest plates to collect any liquid. The 12 in-tank tell-tale collector pipes penetrated the tank liner, and extended through the tank bottom concrete plug to outlets in the Lower Tunnel. By monitoring the 12 valved outlets in the Lower Tunnel, a breach of any tank surface would be detected. **Likewise, any water buildup between the steel shell liner and concrete barrel could be drained off."**

The effort involved in designing and installing the tell-tale system makes it apparent that the designers and builders of these USTs recognized the need to both detect leaks and have the ability to drain water and/or fuel from the backside of the steel liner. This is consistent with contemporaneous records from the construction period that document water intrusion during the construction of the RHBFSF. [B-12, B-313] This was later recognized by the Navy and highlighted in an Internal Memorandum, dated **March 10th, 1972**, that stated:

> " **1. The suggested threat of potential pollution of the Red Hill potable water aquifer which lies less than 100' under the Red Hill tanks is real. This threat was one of the main reasons for the installation of the tell-tale piping system in each tank. This is also the reason why every effort should be made to continue the incremental funding for follow-on tank repair projects to keep tell-tales open and functioning.**
>
> 2. **The tell-tale system is the only real indicator of leakage in that a certain amount of the fuel is actually recovered as evidence of leakage. The new electronic gaging system is a highly sensitive and very accurate method** of monitoring the fuel in the tank, but it does not compensate for the expansion and contraction of the fuel due to temperature changes. This temperature change is usually the cause for difference between tell-tale quantity and gaging quantity. (One degree change in temperature of full tank equates to 150 bbls of fuel) . The tell-tale quantities will vary in accordance with quantity which might seep through concrete lining and gunite lining behind the plate lining and into the surrounding rock. However, precautions taken during original construction, and the extensive

pressure grouting of the lining system and surrounding rock, made seepage of leaking fuel into the rock very improbable. This, however, is not the case if the tell tales are not working or removed since **a leak through the plate liner in the lower section of the tank, without tell-tale ''relief", would subject the surrounding ground to up to 100 pounds per square inch *(sic)* in head pressures depending upon the height of fuel in the tank above the leak.**

3. A recommended added precaution to protect the fresh water aquifer would be a series of two inch *(sic)* diameter horizontally drilled holes into the porous rock under each tank to intercept and drain into the lower tunnel leaking fuel which may not have been picked up by the tell- tale system.

4. The above has been discussed with Mr. Miller, NSC PEARL." [B-145]

The fact that water was observed during construction of the USTs makes it apparent that the designers were aware of the real possibility of water intrusion, collection and subsequent corrosion of the backside of the steel liner as a result of contact with water.

EPA and DOH have also recognized the potential for water to come into contact with the backside of the RHBFSF USTs' steel liners as follows: [4]

"The following is an excerpt from 'U.S. Naval Base, Pearl Harbor, Red Hill Underground Fuel Storage System (Red Hill Pumphouse, Tanks, Tunnels, Adits, and Ventilation Structures), HAER No. HI-123' [13]:

'….removal of the tell-tales eliminated a way to drain off any rainwater that percolates down through the lava rock and finds its way into the space between the back side of the steel shell plates and the inner side of the concrete wall. The standing water could cause accelerated corrosion of the back side of the steel shell plate.' [13]

Concrete and loose grout were found at the steel interface behind coupon plate P6 (Figure 10). The description of the initial tank construction, however, describes that grout was injected between the outer Gunite layer and reinforced concrete (p. 2 of reference [14]), but not between the reinforced concrete and tank steel wall:

'If no gross leaks were identified, the barrel was prestressed by injecting grout between the reinforced concrete and Gunite layer. Grout was injected via tubes that penetrated the steel liner and extended through the concrete to the Gunite layer.' [14]

[4] [B-30] - Response to Corrosion and Metal Fatigue Practices, Destructive Testing Results Report, Red Hill Bulk Fuel Storage Facility (Red Hill), Joint Base Pearl Harbor-Hickam, Oahu, Hawaii.

Apparently [15], however, pressurized grout may have also been injected into crevices that formed between the steel plates and the reinforced concrete that shrank during hardening causing the concrete to pull away from the tank walls:

> '- Finally, you had the vault complete - a steel shell as tall as a twenty-five-story building, as large around as a house lot - backed by many feet of solid concrete butting tight against the rock. As the concrete hardened, it shrank slightly away from the steel. Into this space grout under heavy pressure was forced through pipes welded into the plates. This filled in every remaining crevice and pushed inward against the steel with a pressure equal to the outward thrust expected from the oil.' [15]

Since the grout was pressurized to 350 psi, it could have likely found its way to the steel concrete interface from the concrete-Gunite interface through any crevice or crack that may have formed. In one case, grout was found as far as 200 ft away from the tanks in an upper access tunnel [13]. The description of the tell-tale system, also indicates that crevices could exist between the tank wall and concrete layer [13]:

> 'In this way, the tell-tales pipes were designed to collect any fuel that leaked through a hole in a shell plate (or through a hole in a shell-plate weld) into the tiny space between the back side of the steel shell plates and the inner side of the reinforced concrete wall.' [13]

Figure 10: Loose grout behind coupon plate P6. From DT Results Report [1].

During operation, however, the Navy reports that the tell-tale system developed significant issues, including plugging and exterior corrosion induced failure. According to the Navy, the corroded tell-tale piping, in a perforated condition, allowed for fuel to release from the inside of the tank to the monitoring ports, as well as to the external, backside, surface of the tank liner, creating a conduit for fuel releases. The tell-tale system was initially upgraded but then ultimately removed and was never replaced. Therefore, the Navy has, since the removal, eliminated its ability to detect leaks and to drain/manage any water intrusion between the steel liner and the concrete shell of the UST. The removal, without adding an alternative method for addressing the underlying issues, has potentially increased the risk of water being allowed to collect and sit between the steel liner and the concrete shell, particularly given that investigative activities at the RHBFSF have documented that the steel liners, in many locations, are not in intimate contact with the concrete [B-28, B-157]. This has the potential to accelerate the degradation of the concrete shell and exacerbate corrosion on the backside of the steel liner.

2.1 Release History and Facility Investigations

The serious tank integrity issues highlighted in this report are not new. Numerous fuel releases from the USTs at the RHBFSF have been documented and reported by the Navy or other sources. In addition, multiple through-wall holes have been identified during inspections of the RHBFSF USTs. Summaries of the documented fuel releases from the RHBFSF are included in various sources, including a May 1949 report authored by Bechtel Corporation [B-12], a January 2008 Red Hill Bulk Fuel Storage Facility Groundwater Protection Plan prepared by TEC [B-10], a November 2018 Quantitative Risk and Vulnerability Assessment prepared by ABS Consulting [B-15], and various Navy leak histories and confirmed release reports [B-193 - B-196, B-198 - B-232, B-276 - B-296, B-306 - B-307].

In total, at least 72 fuel release incidents at the RHBFSF have occurred, involving more than 175,000 gallons of product. A summary of the releases is provided in Appendix C.

Of the 72 documented fuel releases incidents:

- 30 releases were detected by the tell-tale systems; [5]
- 22 releases were detected by changes in liquid level, inventory changes from mass balances, or visually due to fuel detected external to RHBFSF USTs or fuel/water detected seeping into the RHBFSF USTs;
- 8 releases from through-wall holes documented in connection with inspections; and
- 12 releases were identified as resulting from filling when returning to service from an extended outage.

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[5] At least 1 leak was identified as resulting from seismic activity. The May 1949 Bechtel report notes that there was an "earth disturbance" on June 28th, 1948 and the gaging during the period of June 28 to July 21 indicated a loss of 14 inches or approximately 850 barrels. [B-12]. The "earth disturbance" was described in more detail in a report for the Department of the Interior. 1. Murphy, L.M. and F.P. Ulrich, *U.S. Geological Survey United States Earthquakes*, D.o.t. Interior, Editor. 1948. p. 27.

Available records indicate that fuel releases from the RHBFSF USTs have occurred episodically throughout the history of facility operations, including over the past 40 years. Based on DNV GL's experience in the oil and gas industry, releases from fuel storage infrastructure are likely underreported in the factual record.

It is also clear from the historical documentation that for decades the Navy has been aware of the extensive fuel release history at the RHBFSF caused by the structural and corrosion issues afflicting these USTs. In 1998, Enterprise Engineering, Inc. (EEI) was hired by the Navy to provide a concept design for repair and upgrade for Tank 19, a RHBFSF UST that the Navy has been taken permanently out of service. The EEI report includes the scoping documents as an attachment to their report. The Revised Statement of Architect-Engineer Services indicates that the Navy was well aware of backside corrosion causing fuel releases and sought a solution that addressed that concern.

> "This tank as well as others in the Red Hill Fuel Facility Complex has required **numerous repairs to welds and patching of holes** in the tank shell plates. Locating fuel leaks is extremely difficult, expensive and time consuming. Some of the tanks have shown **evidence of backside corrosion by holes thru the shell plates whereby fuel or water has backseeped into the tank**. Due to increasing concerns for fuel leakage to the environment, **a good solution for the repair of the tank must be effected that can resolve the problem of existing fuel leaks, minimize the occurrence of future leaks and facilitate the detection/location of future leaks.**" [B-268 at RDHLCC0027512]

In its report, EEI repeatedly identified backside corrosion as a primary tank integrity concern.

> "The principle [*sic*] problem manifesting itself now may be corrosion on the exterior of the steel liner, resulting in through plate corrosion. Information on the exterior **condition of the steel liner is unknown and no conclusions can be drawn from the 4 to 5 coupons cut from other Red Hill Tanks**. Water intrusion through the concrete, and collecting behind the steel liner, has been a recognized problem since original construction." [B-267 at RDHLCC0027469]

> "Based on limited evidence, there is a concern that the steel liner at **Red Hill tanks may be entering a period of significantly increased corrosion and through plate holing from backside corrosion**." [B-267 at RDHLCC0027490]

> "**[T]here are multiple pathways for ground water to infiltrate through the massive reinforced concrete walls into the zone between the concrete and the back of the tank's steel liner.** Although this may not happen in most or even a

lot of locations, **all it takes is a few areas on a tank to develop the leak problems that are now being experienced**." [B-267 at RDHLCC0027493]

In 2008, ten years after the study on repair alternatives for Tank 19, EEI was again hired by the Navy, through the Naval Facilities Engineering Service Center (NFESC), this time to evaluate alternatives to repair and upgrade all twenty RHBFSF USTs. This second EEI report likewise acknowledges significant concerns regarding backside corrosion and the potential for releases due to through-wall pitting.

> "Current and previous **inspections have found corroded areas in the steel liner requiring repair such as pitting, holes, plate thinning**, and defective welds (intermittent cracks, lack of fusion, porosity, and slag inclusions).
>
> …
>
> The existing steel liner is subject to external corrosion and **will continue to corrode.** Over time corrosion holes will develop …" [B-170]

In 2010, a Navy audit raised a number of concerns about facility operations, including acknowledging that backside corrosion was caused by groundwater coming into contact with the steel liners of the RHBFSF USTs, and that undetected areas of corrosion could progress to through-wall holes resulting in fuel releases. Based on the results of the audit work, the Navy determined that past fuel releases have resulted in contamination of the rock bed, soil, and groundwater surrounding the RHBFSF USTs and concluded that "**the environment and groundwater sources in the Pearl Harbor area have not been sufficiently protected**." [B-11]

2.2 Administrative Order on Consent (AOC)

In the course of refilling Tank 5 in December 2013 and January 2014 following maintenance and repair work, the U.S. Navy identified an estimated fuel release of approximately 27,000 gallons of Jet Propulsion Fuel No. 8 (JP-8) from the UST and reported the release to the DOH. To ensure that the Navy addresses this and other fuel releases from the RHBFSF and implements infrastructure improvements to prevent future fuel releases, the DOH and the United States Environmental Protection Agency (EPA) entered into an Administrative Order on Consent (AOC) with the Navy and the Defense Logistics Agency – the owner of the fuel at the RHBFSF – in September 2015. The AOC requires that the Navy perform, under the oversight of the regulatory agencies and in consultation with subject matter experts, including the BWS, various investigative actions and technical analyses. The evaluation, testing and analysis completed to date are relevant to a number of the issues in the contested case proceeding. Specifically:

- *Destructive Testing*. Under the AOC, the Navy was required to perform destructive testing on at least one tank (Tank 14) to verify the findings of its Corrosion and Metal Fatigue Practices Report. The EPA and DOH disapproved the Navy's report concerning data from and analyses performed on samples of the steel liner from RHBFSF Tank 14**. Specifically, the regulators rejected the Navy's interpretation that these investigative and testing efforts demonstrated that the Navy's tank inspection practices are sound.** To the contrary, EPA and DOH identified data and interpretation "deficiencies" and raised concerns "over the lack of [non-destructive evaluation] correlation and increasing corrosion rates" that the Navy has yet to address. [B-30]

- *Risk and Vulnerability Assessment*. The AOC requires the Navy to complete a Quantitative Risk and Vulnerability Assessment (QRVA) to provide a comprehensive risk analysis of the RHBFSF. As part of this effort, the Navy hired ABS Consulting to perform Phase 1 of the QRVA. The report prepared by ABS addressing the risks and vulnerabilities at RHBFSF concludes:
    - There is a greater than a 27% probability of an acute, sudden release of between 1000 and 30,000 gallons of fuel from the RHBFSF **each year**;
    - There is a greater than a 34% chance of a sudden release of more than 120,000 gallons of fuel from the RHBFSF in the next 100 years;
    - There is a greater than a 5% chance of a sudden release of more than million gallons of fuel from the RHBFSF in the next 100 years; and
    - The **expected** volume of chronic, undetected fuel releases from the RHBFSF is 5,803 gallons per year. [B-15]

- *Tank Upgrade Alternatives*. The AOC requires the Navy to develop and submit a Tank Upgrade Alternative (TUA) Decision Document that identifies and justifies the Best Available Practicable Technology (BAPT, "defined as the release prevention methods, equipment, repair, maintenance, new construction and operation procedures, or any combination thereof, that offer the best available protection to the environment and is feasible and cost-effective"). The EPA and DOH disapproved the Navy's submittal, which presented a BAPT proposal to upgrade the USTs at the RHBFSF in ways that are similar to the processes and procedures described in the Navy's permit application but also included additional measures not included in the application. **In rejecting the rationale for the Navy's preferred upgrade option, the regulators concluded that the Navy has not demonstrated that the proposed alternative is the most protective of groundwater and drinking water resources, that other options**

are either less protective or impractical, or that the proposed alternative adequately mitigates release risk. [B-28]

Although the AOC process is separate and apart from the DOH's contested case proceeding, this work was designed to inform ongoing and future planning decisions and may be particularly relevant to those decisions related to an evaluation of the Navy's ability or inability to meet UST permit requirements.

3.0 OPINIONS

3.1 The integrity management strategy the Navy is currently conducting will not prevent future releases of the stored regulated substances for the operational life of the tanks.

All available evidence demonstrates that the RHBFSF USTs have a history of leaking and they will continue to leak. The single-wall design of the RHBFSF USTs, where the steel liner with its protective internal polymer coating is the only containment barrier for the fuel stored, coupled with the fact that the concrete shell is only serving as a structural support due to evidence of water ingress to the backside of the steel liner, means that the Navy's ability to prevent releases from the RHBFSF is dependent upon its ability to accurately and reliably identify and repair tank defects in the steel liner and tank system integrity issues before they occur. Existing information, data, and analyses indicate that the Navy cannot accurately or reliably do so. As discussed in detail below, it is well documented that corrosion is progressing through and causing holes in the steel liners of the RHBFSF USTs from the backside, the side that the Navy cannot directly inspect or maintain. This corrosion will only get worse with time, as there is no way to stop or mitigate the corrosion that is occurring on the backside of the tanks. The conditions under which the Navy attempts to address this tank integrity threat are onerous and certainly not conducive to accurate or reliable testing results. Historical and recent tank inspection data and analyses demonstrate that the Navy's current inspection technologies, practices, and procedures cannot accurately detect or characterize the corrosion or other anomalies/defects associated with the RHBFSF USTs' steel liners and, as a result, the Navy cannot operate the RHBFSF USTs in a way that prevents releases.

3.1.1 Inspection Practices

The American Petroleum Institute (API) is a national trade association representing all aspects of America's oil and natural gas industry. The API publishes standards and other documents that provide requirements and guidance to the industry on the construction, maintenance, and repair of equipment and facilities involved in the production, transportation, and storage of petroleum liquid and gas. API Standard 653 addresses the inspection, repair, alteration, and reconstruction of aboveground storage tanks (ASTs). The Navy currently contracts modified API 653 inspections for its USTs at the RHBFSF. API 653 was written for ASTs where the majority of the tank is accessible for visual inspections and direct measurements of potential defects. The only area of an AST that cannot be inspected visually is the bottom side of the tank floor. Thus, indirect inspection methodologies, commonly referred to as non-destructive examinations (NDE), are used to determine the condition of this area. The Navy is utilizing the practices used for the indirect inspection of the bottom side of the floor of ASTs and is applying them to the entirety of the RHBFSF USTs. Each of the RHBFSF USTs is scheduled to be inspected on a rolling 20-year inspection interval, which is the **maximum allowable interval** per API 653. However, the Navy has failed to present API 653 inspection records for Tanks 1, 3, 4, 9, 11, 12, 18, or 19[6] and those records that do exist indicate that the number of years between inspections has often exceeded the 20 year target interval. According to the EPA and DOH, **the current UST inspection interval is averaging 30 years, with the longest duration being 59 years for Tank 18**. [B-30]

The Navy utilizes NDE methodologies to inspect the tanks, Low Frequency Electromagnetic Technique (LFET), Balanced-Field Electromagnetic Testing (BFET), ultrasonic testing (UT), and shear-wave UT, including a variant called phased array ultrasonic testing (PAUT) to "prove-up" the measurements. Each are discussed below. The Navy's inspection techniques are inherently unreliable at the RHBFSF given the scale of the USTs and the conditions under which the inspections occur. The inspections are conducted primarily by manually scanning the interior surface of each UST utilizing a hand-held LFET sensor to detect flaws, which is a variation of eddy current technology. This technique is described in "TO0176-Final API-653 Inspection Report-Tk15.pdf" Appendix C – Test Methods/Procedures and Equipment Description [B-191] as follows:

> "With a low frequency AC driver signal of 3 to 40 Hz for carbon steel, the driver signal fully penetrates the material being tested. When the scanner passes over an area with no defects, the magnetic fields are not distorted.
>
> When the test material has a defect and the sensors are located above that defect, distortions in the magnetic field indicate presence of the flaw. LFET instruments measure this distortion as changes in phase and amplitude. Depth of the flaw is proportional to these phase and amplitude changes. Diameter of the defect is related to the number of sensors affected."

The scanning is performed using a TS-2000 NDT Multichannel System (LFET) for the plates and the Hawkeye 2000 System (point probe - BFET) for the welds. When defects/flaws are identified in the steel plates, then another NDE technique, UT, is used to obtain thickness

[6] DNV GL understands that the BWS requested all inspections records for the RHBFSF USTs but the Navy did not produce any records for those listed.

measurements. If the defect/flaw meets a certain depth criteria, then prove-up measurements are performed using a shear-wave UT or PAUT. If a defect/flaw is identified in the weld, then shear-wave UT or PAUT are used to obtain measurements. The process of scanning is described in the referenced report as follows:

> "Hand held electromagnetic scanners were used to test the steel liner plates of the tank. When defects/flaws were found, then UT measurements were taken to establish actual thicknesses in these areas. Welds were inspected with eddy current probes. When defects/flaws were found, then shear wave (angle beam) ultrasonic testing was performed to establish the remaining thickness at the weld flaw locations."

The inspection relies heavily on the skill of the operator and the accuracy of the hand-held scanners, which at the RHBFSF requires scanning huge areas for days at a time in physically challenging conditions. For example, the surface area scanned in Tank 15 in 2005 was 56,444 square feet; 82.8% of the total surface area of the UST. To put this into perspective this is roughly the size of a football field (57,600 square feet).

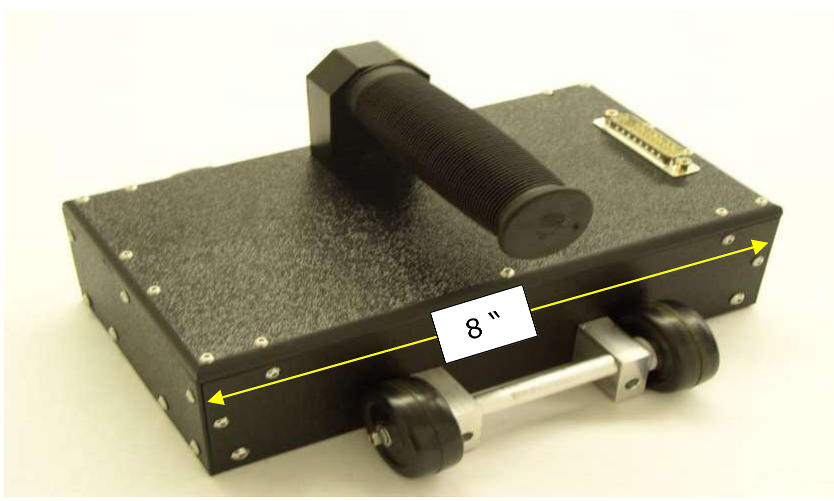


Figure 1. Photograph showing the 8-inch wide hand-held scanner used to perform LFET.

The hand-held LFET scanner used to scan a significant portion of that area is pictured Figure 1 and is described in the report to be 8 inches wide. The system is reported to be capable of detecting backside corrosion pits as small as 0.062 inches in diameter. The inspector is responsible for moving the hand scanner while monitoring the computer screen readout to detect flaws/defects while working off a suspended scaffolding with the work area illuminated by artificial lights. In addition, per the testimony of Navy witness Mr. Frank Kern the inspector must also move the scanner in the "same direction" while performing the inspection in an effort to improve the inspection process. A representative photograph showing the working conditions is presented in Figure 2. This is a laborious task and the inspection of these USTs can take 4 weeks or more to complete. The interior of the tank liner is predominately covered with a coating that precludes the direct contact of the scanner with the steel surface. One of the benefits noted by the inspection contractor in using the LFET for scanning the steel liner is that direct contact with the steel is not required. However, the presence of the internal coating does impede any visual inspection of the steel surface which, if it could be visually inspected, may assist in the detection of any flaws or defects in the steel liner.

Shows LFET scanning under the catwalk.

Figure 2. Photograph showing the application of the hand-held scanner used to perform LFET [B-190].

While API 653 is typically used for aboveground tanks, the Navy has elected to utilize a modified version of the inspection methodology and repair requirements within the API standard for the USTs at RHBFSF. The high-risk area for the development of potential leaks in an above-ground tank is the bottom side of the tank floor since that represents the only area on an above-ground tank that cannot be visually inspected. Typically, this area is inspected utilizing methodologies similar to the methodology used by the inspection contractor for the RHBFSF USTs. However, as noted previously, the specific size and conditions at the tank at RHBFSF are vastly different from those found at ASTs (or even typical USTs) and render the methods used highly inaccurate and unreliable. As a frame of reference, for a typical above-ground storage tank that would be capable of holding a similar volume as the RHBFSF USTs (12,600,000 gallons, 196 feet diameter x 56 feet high), the bottom area of the tank would be approximately 30,200 square feet. The surface area of a single RHBFSF

UST requiring inspection is approximately 68,200 square feet. Further underscoring the difference, the top side of the bottom of an AST is typically sand blasted and can be visually inspected so only the exterior of the AST tank bottom is not visible and is being scanned. Additionally, the equipment is typically partially automated in that the scanning device detects the flaws and is not completely person dependent (i.e., does not require the operator of the scanner to simultaneously watch where they are scanning and read the monitor to catch potential flaws).

Regulations for the oil and gas industry require an operator to perform preventive and mitigative actions for known threats to the integrity (ability to operate without leakage) of a system that contains fuel. The preventive and mitigation actions are designed to eliminate or reduce the risk that a known threat would have to the integrity of the system. A preventative action reduces the probability of a loss of integrity (leak). A mitigative action reduces the consequence of a loss of integrity. A typical preventive action for external backside corrosion is the application of cathodic protection. The USTs at the RHBFSF currently do not have a cathodic protection system and by their design one may not be feasible to install.

One mitigation strategy is to have the ability to detect and contain leakage. **The Navy eliminated its ability to detect fuel leakage (removal of the tell-tale system without installing an alternative method for addressing the problem) and the current design of the RHBFSF USTs does not include secondary containment.** For reference, all new USTs and piping, including small commercial gas stations must implement secondary containment and interstitial monitoring. The Navy has explored the potential of installing secondary containment as detailed in its TUA report dated December 2017 (tank within a tank concept). While the report concluded that building a tank within a tank can be accomplished, the Navy does not appear to be pursuing this option. [B-27]

While monitoring the level of liquid will allow for the eventual detection of large leaks, it is highly unlikely to detect a release quickly due to the large size of the USTs and long periods of tank inactivity (i.e., no fuel movement) that are necessary to accurately measure leaks at the required minimum leak detection level. The only preventive action the Navy implements at the RHBFSF appears to be the use of tank inspections and repairs. Reliable inspection and subsequent repair of the RHBFSF USTs thus are critical, but even the Navy's own API inspectors have acknowledged that

> "The overall difficulty of the task of completing the repairs does not lend itself to regularly achieving exceptional workmanship results." [B-192]

The manual nature of the inspection, the sole dependence upon the ability/competence of the individual inspectors, the presence of an internal coating on the steel liner, the difficult working conditions, and the sheer amount of steel to be inspected are all detrimental to being able to produce consistent and reliable inspection results, which are ***required*** in order to prevent releases from the USTs.

3.1.2 Inspection Data

Modified API inspections, as-described above, have been performed only on Tanks 2, 5, 6, 13, 14, 15, 16, 17, and 20 (less comprehensive inspections were conducted on Tanks 7, 8, and 10 and are discussed below). Therefore, a significant number of the USTs still in operation, six (6) of the 18 tanks or 33%, have not undergone complete API inspections. Given the amount of corrosion and number of through-wall holes that have been identified during these inspections, there is significant concern that through-wall perforations (conduits for fuel to leak into the environment) likely exist on those tanks that have not yet been inspected. A summary of the API tank inspections is shown in Table 1. The inspections in 2005 and 2006 "focused on selected areas of the lower dome and upper dome and 100% testing on the barrel, extension, and expansion areas" [B-190, B-191, B-192], and the inspections in 2008 and 2010 reportedly inspected 100% of the Upper Dome, Lower Dome, and Barrel [B-237 - B-240, B-242].[7] The nominal wall thicknesses (NWT) for the upper dome, lower dome, and barrel are 0.250 inches, while the NWT for the floor is 0.500 inches. A summary of the anomalies identified for each inspection is provided in Table 2. In general, the inspections identified underside or backside corrosion, topside anomalies (pits, gouges, dents, tack welds, bulges), weld anomalies (cracks, lack of fusion [LOF], lack of penetration [LOP], incomplete penetration [IP], undercut, porosity, etc.), and through holes. The distribution of these anomalies is represented graphically in the chart in Figure 3.

[7] 97% of the surface area of the Upper Dome for Tank #2 was inspected.

Table 1. Summary of API inspections conducted on the USTs at RHBFSF.

Tank	Inspection Start Date	Report Date
1		
2	Apr-08	Oct-08
3		
4		
5	Nov-10/Oct-17	Nov-10/Aug-20
6	Mar-06	Jan-07
7	1998	1998
8	1998	1998
9		
10	1998	1998
11		
12		
13	Oct-17	May-20
14	Jul-17	Aug-20
15	Jan-05	Jan-07
16	Dec-05	Jan-07
17	Aug-17	Aug-20
18		
19		
20	Sep-08	Dec-08

Table 2. Summary of the number of anomalies identified from the API 653 inspections performed on Tanks 2, 5 (2010), 6, 15, 16, and 20.

Feature Type	Tank 2	Tank 5 (2010)	Tank 6	Tank 15	Tank 16	Tank 20	Total
Underside Corrosion	48	249	181	94	138	71	781
Through Holes	2	2	0	11	6	1	22
Topside (pits, gouges, tack welds, dents, bulges)	52	56	99	4	55	35	301
Weld Cracking	12	1	0	2	0	1	16
Weld (IP, LOF, LOP, porosity, undercutting, etc.)	59	40	398	65	310	137	1009

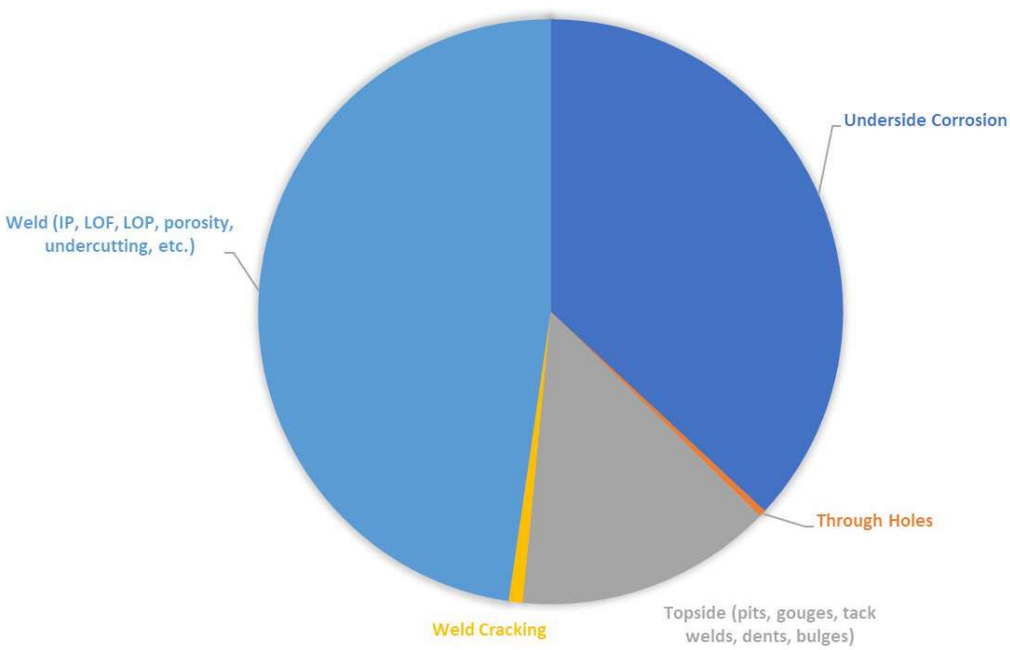


Figure 3. Chart showing the anomaly distribution identified during the API 653 inspections for Tanks 2, 5 (2010), 6, 15, 16, and 20.

Anomalies, and the threats associated with each can be classified as Time Dependent, Resident, Random or Time Independent. *Time-dependent threats* include external corrosion, internal corrosion, and stress corrosion cracking; *Resident threats* include manufacturing, welding/fabrication, and equipment-related anomalies; and *Random/Time-Independent threats* include third-party/mechanical damage, incorrect operation, and weather-related outside force damage. [2] Based on the distribution of anomalies identified on the USTs at RHBFSF both time-dependent and resident threats were observed. Of significant concern are time-dependent threats that manifest and grow in a manner whereby the growth mechanism cannot be slowed or mitigated. In the case of the RHBFSF USTs, this is underside or backside corrosion. For reasons discussed below and in Section 3.2, the corrosion process that is occurring on the outside surfaces of the steel liners on the USTs cannot be slowed or mitigated and it is expected to get worse with time.

Figure 4 is a histogram showing the remaining wall thickness measured during the API 653 inspections for anomalies associated with backside corrosion on the barrel, upper and lower domes, and expansion/extension. Twenty-two (22) through-hole anomalies were identified, two on Tank 2, two on Tank 5, eleven on Tank 15, six on Tank 16, and one on Tank 20, and are included within the plot. Vertical lines have been added to the plot to indicate the repair thresholds that the Navy has used for the API inspections. There are multiple lines included because the Navy has been reducing its repair threshold (i.e., allowing the steel liners to get thinner and thinner before requiring repairs) over time. In 2005/2006, the Navy reported that it repaired everything less than 0.190 inches in remaining wall thickness. Currently, Navy processes call for repairs of everything less than 0.160 inches, excluding the bottom of the tank. Applying the 2005/2006 repair criteria to the total population of identified corrosion anomalies (663) results in 244 corrosion anomalies that would have been repaired, or 36.8% of total population. Applying the 2017/2018 (current) repair criteria results in 80 corrosion anomalies that would have been repaired or 12.1% of the total population.

Figure 5 and Figure 6 are photographs documenting instances of through-hole anomalies. The morphology appears consistent with backside corrosion perforations.

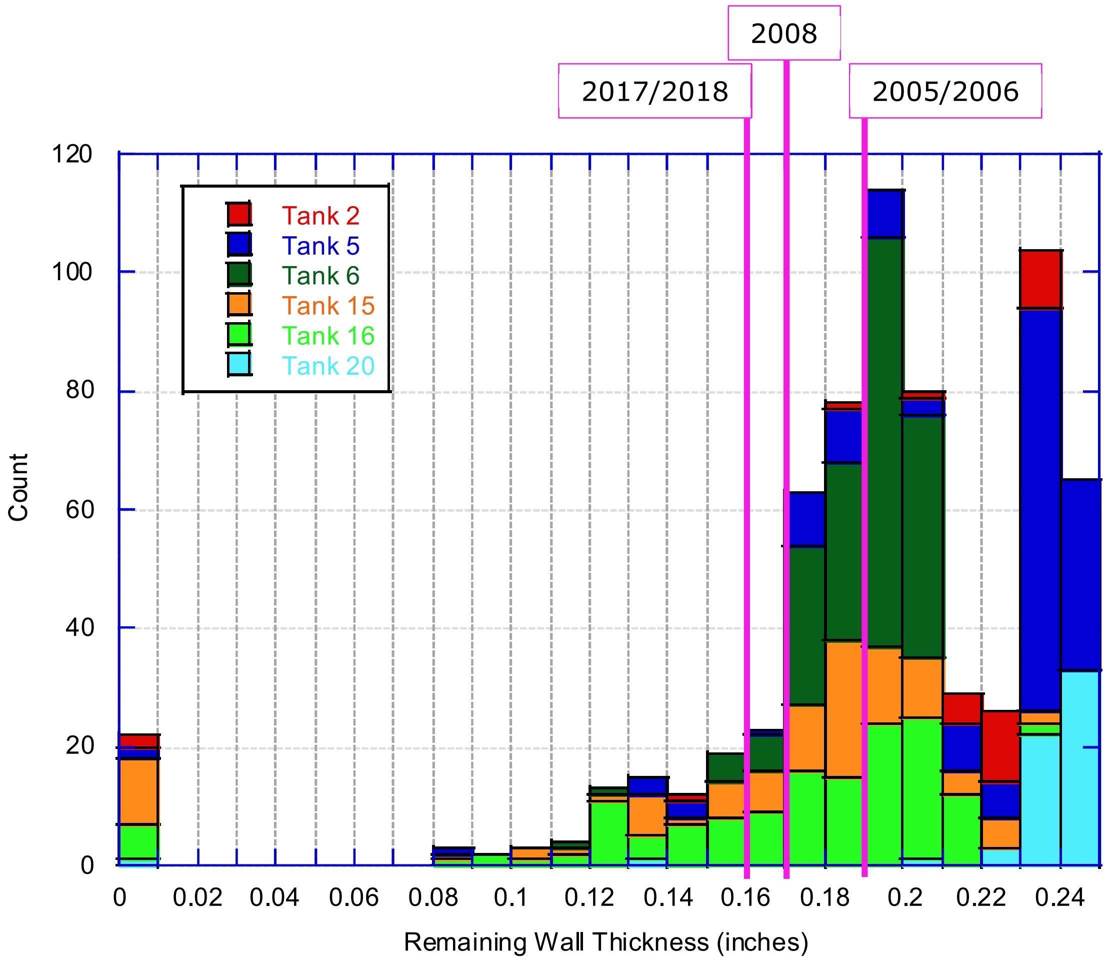


Figure 4. Histogram showing the distribution of remaining wall thickness for anomalies classified as backside corrosion (and through wall) for the Barrel, Upper & Lower Domes, Expansion, and Extension. Pink lines correspond to the Repair Threshold in 2005/2006, 2008, and 2017/2018; i.e. everything to the left of these lines would have been repaired.

Figure 5. Photographs extracted from the API Tank 16 Inspection Report (Photograph 8) showing "holes at the top of course F of the upper dome".

Flaw 347 through hole in strap

Figure 6. Photograph extracted from the API Tank 20 Inspection Report showing a through-wall hole.

Figure 7 is a chart showing the vertical distribution of backside corrosion anomalies within the tanks for the barrel (Rows 1-28), upper and lower domes, and expansion/extension (Rows E1-E4). Backside corrosion anomalies persist along all vertical locations associated with the USTs. This is highlighted by examining the largest vertical section of the tank, the barrel; refer to Figure 8. The figure shows numerous backside corrosion anomalies present at all vertical locations, many of which are very deep. In fact, looking at anomalies with a reported remaining wall thicknesses of <0.125 inches (<50% NWT; corresponding to a corrosion depth of >50%) illustrates that significant corrosion is occurring and can occur at all vertical locations throughout the USTs, refer to Figure 9. Therefore, all liner surfaces associated with the USTs require extensive inspection to detect and accurately size the areas of corrosion.

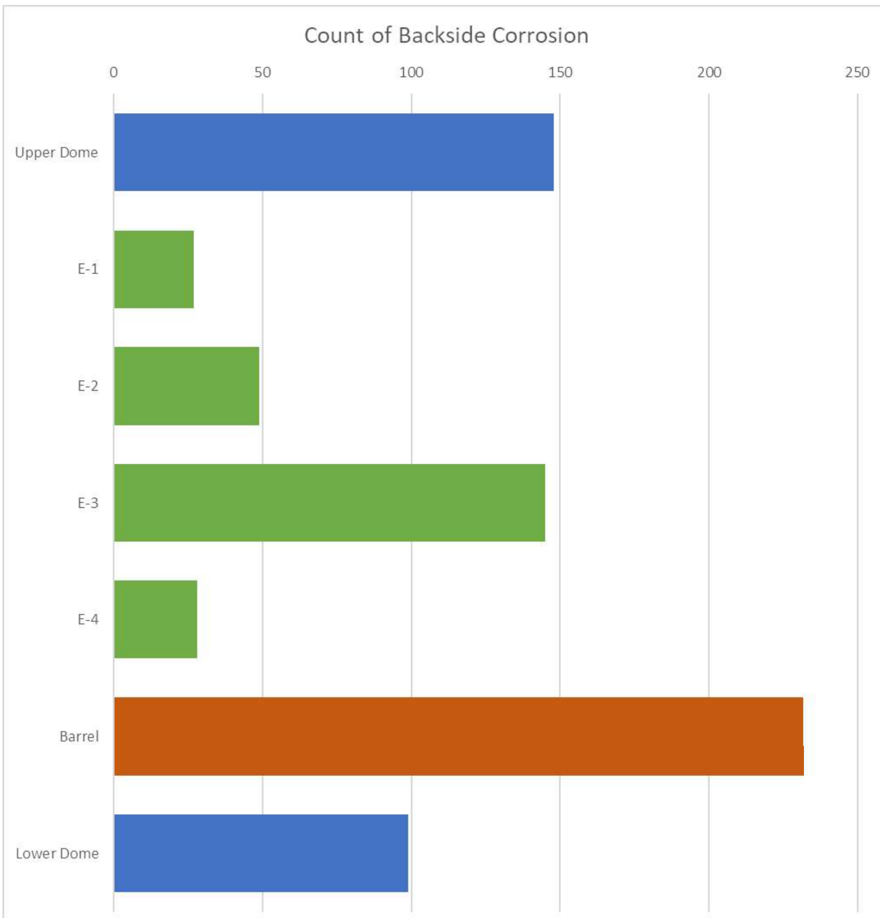


Figure 7. Chart showing the vertical distribution of backside corrosion anomalies within the upper dome, extension/expansion (E1, E2, E3, E4), barrel, and lower dome identified during the API 653 inspections.

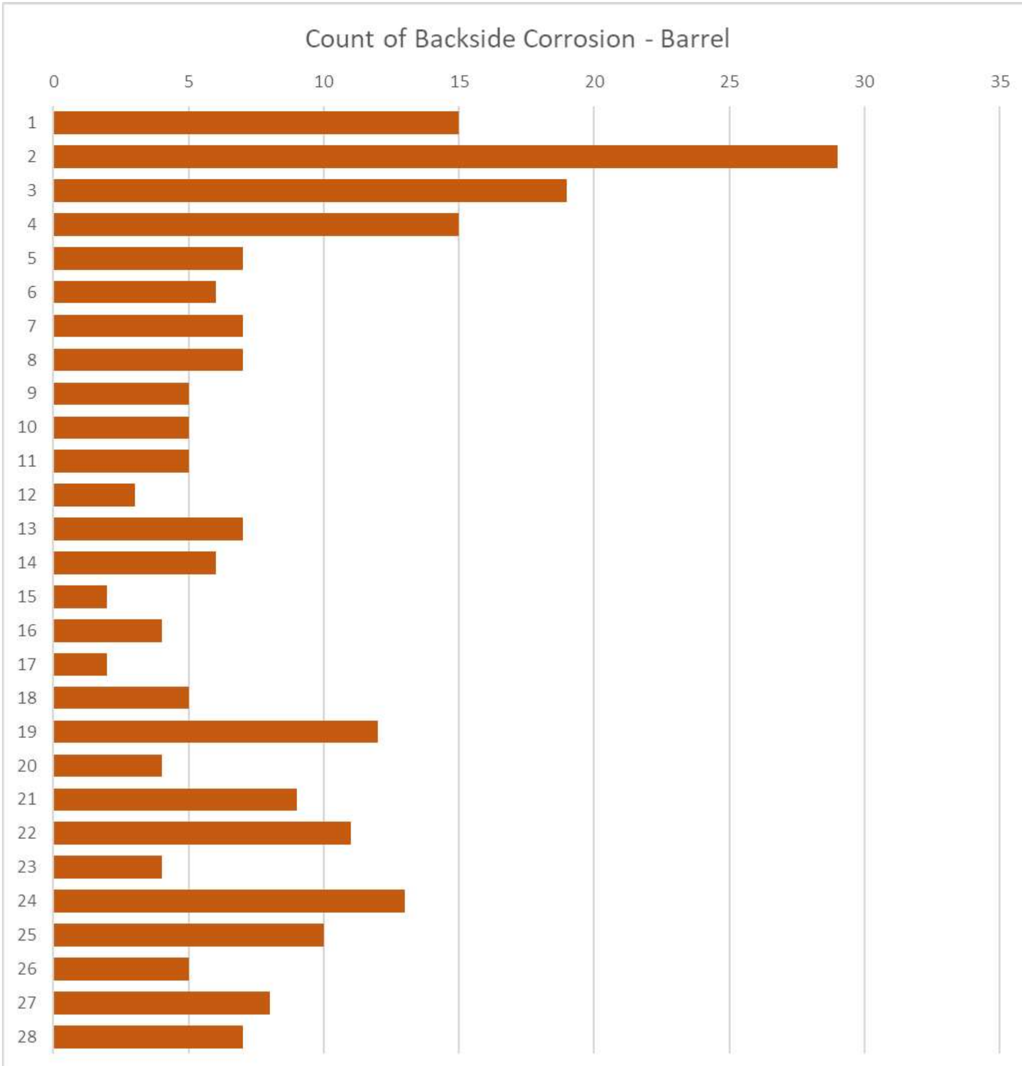


Figure 8. Chart showing the vertical distribution of backside corrosion anomalies within the barrel section identified during the API 653 inspections.

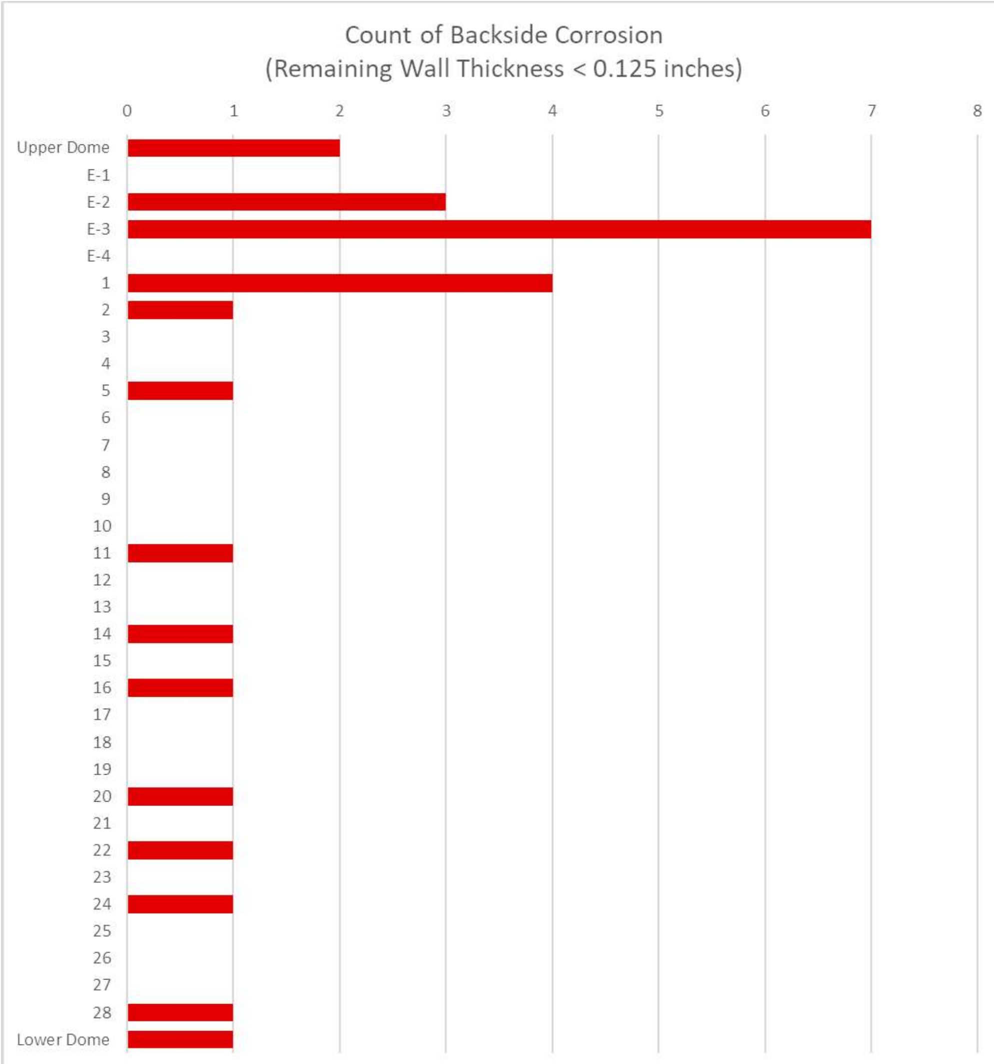


Figure 9. Chart showing the vertical distribution of backside corrosion anomalies with remaining wall thickness <0.125 inches (<50% NWT) identified during the API 653 inspections.

Although much less comprehensive, inspections were performed on Tanks 7, 8, and 10 in 1998 (about 22 years ago). [B-176 - B-189] In general, the inspections consisted of visually inspecting the internal surfaces of the USTs for coating damage, pitting, and through holes. In addition, the 0.500-inch thick bottom and the 0.250-inch thick first and second ascending plates of the lower dome of Tanks 8 and 10 were spot checked with a UT thickness gauge. Approximately 70 bottom and 220 to 330 ascending plate UT thickness readings were obtained in Tanks 8 and 10. In Tank 7, only the 0.500-inch bottom plate was spot checked with UT. Approximately 77 bottom UT thickness readings were obtained in Tank 7. The barrel and upper dome areas of the USTs were only visually inspected, and no UT thickness readings were recorded. Repair records from Tanks 7, 8, and 10 provided indicate there was one (1) through wall backside corrosion repair in Tank 7 and twelve (12) through wall backside corrosion repairs in Tank 10.

In all of the API 653 Tank Inspection reports provided by the Navy (Tanks 2, 5, 6, 7, 8, 10, 13, 14, 15, 16, 17, and 20), backside corrosion was identified and is present. In Tanks 2, 5, 7, 10, 13, 16, and 20, the corrosion had manifested into through-wall defects that, at least at the time of inspection, provide pathways for product to leak into the surrounding environment.

3.1.3 Destructive Testing and Analysis

In 2018, at the request of the EPA and DOH, the Navy conducted metallurgical and corrosion analyses on steel liner samples, commonly referred to as "coupons," removed from Tank 14 to:

- "Validate the results of NDE inspection technologies used at Red Hill.
- Characterize the metallurgy of the steel material used in the tank liner.
- Record observations and chemical characteristics of the concrete behind the liner.
- Assess the procedures for calculating corrosion rates and recommend improvements as warranted.
- Evaluate results against current corrosion-mitigation practices and recommendations." [B-160]

Upon completion of this destructive testing, the Navy presented its interpretation of the results in a July 2019 Corrosion and Metal Fatigue Practices, Destructive Testing Results Report. [B-160] The Navy interpreted the destructive testing results as indicative of sound tank inspection practices. The EPA and DOH, in consultation with their own subject matter experts in fuel storage management and corrosion, disagreed with the Navy and disapproved the report. In a March 2020 letter, EPA and DOH made clear that they "do not concur" with the Navy "that the 'NDE results are validated, both by Destructive Testing and thorough, case-by-case analysis.'" Instead, given recognized concerns "over the lack of NDE correlation and increasing corrosion rates," the regulators required the Navy to further evaluate and improve its tank inspection, repair, and maintenance process. Specifically, the EPA and DOH recommended that the Navy:

a. Evaluate technology and develop processes to improve the Navy's NDE procedures. This new process should then be assessed for its effectiveness, which should be done with another destructive test.
b. Conduct additional analyses on the condition of the concrete structure and imbedded reinforcing steel.

c. Evaluate potential causes for corrosion and possible actions to reduce corrosion rates, if possible.
d. Immediately reevaluate the repair threshold and associated factor of safety to account for inaccuracies in NDE, corrosion rates, and possible delays in repair cycles. [B-30]

DNV GL agrees with the EPA and DOH's concerns. Our independent analysis of the destructive testing confirms that the Navy cannot rely upon its existing tank inspection, repair, and maintenance practices to identify and repair the RHBFSF USTs before corrosion defects breach the internal surface of the steel liner and, as a result, the Navy cannot prevent fuel releases from the RHBFSF USTs for their operational life.

3.1.3.1 Corrosion Analysis

A summary of the coupons removed for the study is shown in Table 3. In all, 10 coupons were removed from the following areas: Upper dome – 1, Extension – 2, Barrel – 6, Lower Dome – 1. The locations of these coupons were identified following LFET inspection and prove-up inspection, as necessary, per the normal tank inspection procedures discussed in Section 3.1.1. The coupons (12-inch x 12-inch) were removed, photographed, radiographed (CT-scan), and cross-sections were removed for metallographic analysis. Additional analyses were performed to assess the chemical constituents and mechanical properties.

The coupons all exhibited some amount of backside corrosion. Figure 10 contains photographs of the backsides of each coupon removed. Dark and light brown corrosion products can be seen on all samples, with Coupons A1 and 3 having the most significant amounts of corrosion; depths of 51.2% of NWT and 47.6% of NWT, respectively. Cross-sections showing the measured depths of corrosion are provided in Figure 11. An undercut pit appears to be present within the cross-section for Coupon 3. Pits within pits and undercutting are morphologies commonly associated with microbiological influenced corrosion (MIC)[8]. Notably absent from the analyses conducted as part of the metallurgical and corrosion analyses are tests to determine whether MIC may be contributing to the corrosion process. It is well documented within the literature and oil and gas industry that rates of MIC can be much higher than rates of general corrosion [3]. This is an important factor for any operator to evaluate when considering a threat assessment and corresponding corrosion growth rate to determine a suitable reinspection interval. However, it appears to be absent from the Navy's risk assessment.

[8] "Microbiologically influenced corrosion (MIC) refers to corrosion caused by the presence and activities of microorganisms. While microalgae, bacteria, and fungi do not produce unique types of corrosion, they can accelerate corrosion reactions or shift corrosion mechanisms. Microbial action has been identified as a contributor to rapid corrosion of metals and alloys exposed to soils; seawater, distilled water, and freshwater; crude oil, hydrocarbon fuels, and process chemicals; and sewage." [NACE International - https://www.nace.org/resources/industries-nace-serves/microbiologically-influenced-corrosion-industry]

Coupon 1	Coupon 2	Coupon 3	Coupon 5	Coupon 6
				
Coupon 7	Coupon 8	Coupon 10	Coupon A1	Coupon A2
				

Figure 10. Photographs showing the undersides / backsides of the coupons removed from Tank 14 as part of the destructive analyses.

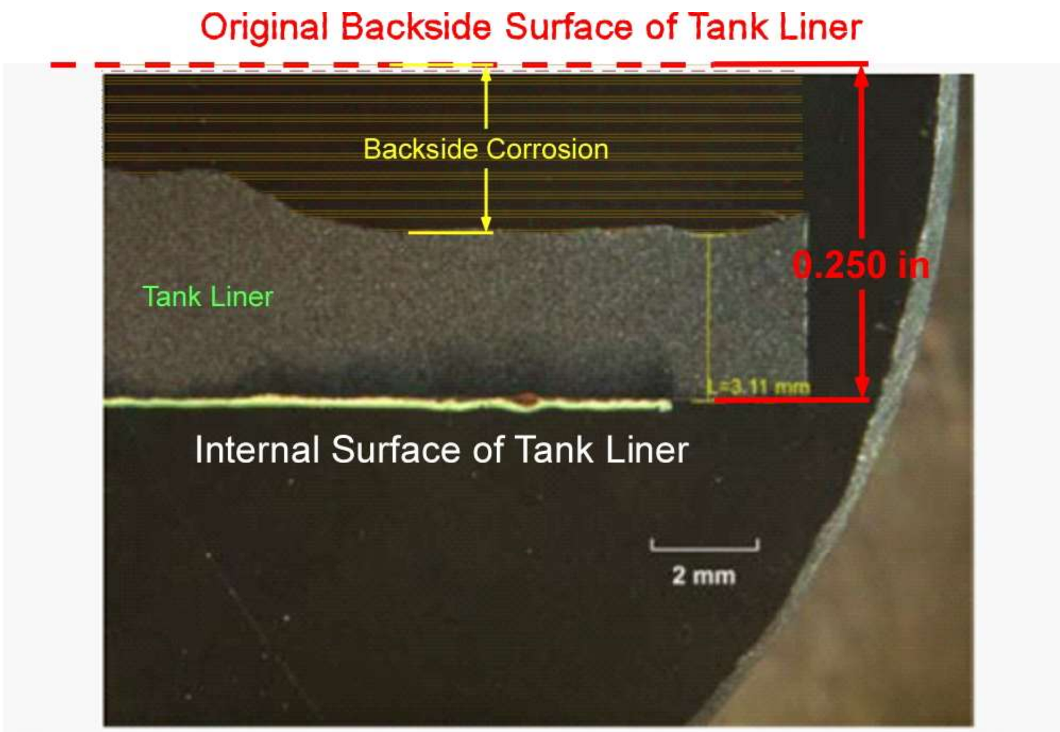


Figure 3-10 Cross Section of Coupon A1 at Area of Maximum Wall Loss

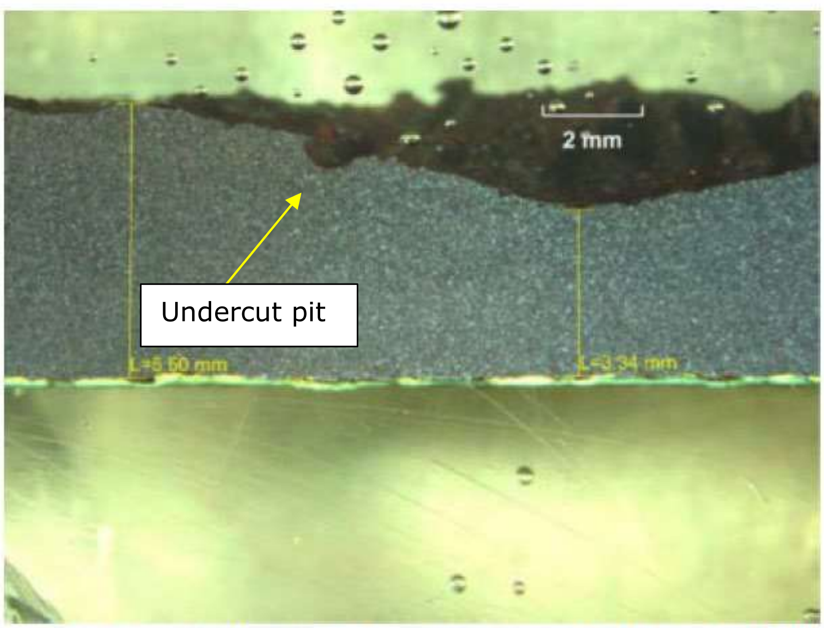


Figure 3-4 Cross Section of Coupon 3 at Area of Maximum Wall Loss

Figure 11. Photographs showing the metallographic cross-sections removed from Coupons A1 and 3. Annotations have been added to the original figures.

The results from the testing indicate that there is a potential for increasing corrosion rates with time.[9] This is based on the results that identified the presence of varying pH levels in the concrete behind where the coupons were removed, as well as the presence of chlorides identified within the corrosion products of the steel. Carbon steel passivates in the presence of electrolytes of high pH levels; however, if the pH drops below around 10-11, then the carbon steel can begin to corrode.[4] Concrete typically has high pH levels and, when in intimate contact with steel, can provide protection to the steel by creating a local environment that exhibits a high pH. However, if the steel is not in intimate contact with the concrete, then the steel may not benefit from the high pH of the concrete to facilitate passivation. This is important because it is well documented that there are gaps or voids between the steel liner and the concrete for the USTs. [B-30] In addition, the pH can decrease over time if the concrete degrades, and therefore, making the steel susceptible to corrosion. The results of the destructive testing suggest that the concrete is degrading, such that the pH levels in close proximity to the USTs external surface are decreasing. Accordingly, it is likely that the corrosion rates at these locations have increased.

EPA and DOH have also recognized that the destructive testing indicates the potential for increasing corrosion rates:[9]

> "Passivation can be lost when the pH of the concrete drops below approximately pH 11 [7], or chloride (Cl) ions are present in sufficient concentration [4, 7]. The NACE Standard Practice SP0308-2008 [9] indicates that acid-soluble chlorides in excess of approximately 0.2 % (by weight of cement) can initiate corrosion of steel in concrete. The ion chromatography analyses of the concrete powder samples showed that the chloride concentration in the concrete ranged from 50 ppm (0.005 % by weight of cement) to 171 ppm (0.017 wt%), which is much lower than the threshold. The concentration of chlorides detected in the corrosion products using energy dispersive X-ray analyses (EDXA), however, was significantly higher…maximum value of 1.7 wt%...The maximum concentration of the chlorides in the corrosion products were approximately 100 times higher than the maximum concentration in the concrete. Chlorides at these levels as well as the drop in concrete alkalinity below approximately pH 11 are likely to breakdown passivation and cause increasing corrosion rates of the steel." [B-30]

Although the source of the deleterious chlorides has not been determined by the Navy, there are two likely sources; the surrounding soil or chloride-laden constituents used to fabricate the concrete (water and/or sand). The Navy's witness, Dr. Johnson, suggests that the chloride levels within the concrete are "below the threshold levels that would suggest chloride-induced

[9] Response to Corrosion and Metal Fatigue Practices, Destructive Testing Results Report, RHBFSF, USEPA and State of Hawaii DOH, March 16, 2020.

corrosion of reinforcement is a concern." Similarly, another Navy witness, Mr. Robert Jamond, appears to share Dr. Johnson's theory, stating that the chloride levels measured in the concrete were less than a threshold of 0.2 weight percent, which he claims indicates that "neither chloride-induced corrosion on the liner nor on the concrete reinforcing is to be expected." These posits are flawed because Dr. Johnson and Mr. Jamond ignore evidence from the analysis of the corrosion products (conducted as part of the same study) that identified chlorine concentrations that are one hundred times (100x) higher than the results from the concrete. In fact, seven (7) of the ten (10) coupons exhibited chlorine levels of 0.3 weight percent and greater, up to 1.7 weight percent. These concentrations are in excess of the 0.2 weight percent "threshold" cited by Mr. Jamond. The concentration of aggressive species, such as chlorides, is a common facilitator of corrosion of carbon steel. For example, bridge decking and surrounding infrastructure is notorious for exhibiting accelerated corrosion resulting from yearly road salt application that consequently increases the local chloride concentration.

Similarly, Dr. Johnson posits that "the chloride deposition rate is likely very small" given the distance of the USTs from the coastline. Although he offers no evidence to support the "very small" conclusion, even if the deposition rate is small, millennia of small amounts can concentrate to appreciable levels. Simple soil analyses, commonly conducted as part of an external corrosion investigation, should be performed to better understand the source of the chlorides. Regardless, the fact remains that high chloride levels were found in the corrosion products on the external surfaces of the coupons removed from Tank 14. The presence of increased levels of chlorides within the corrosion products indicates that the chlorides are concentrating over time, which will increase the likelihood of severe corrosion. Chlorides are known to promote localized corrosion of carbon steels by breaking down protective layers on carbon steels in aqueous environments. [4-7]

It is important to note that the extent of the corrosion, both in terms of number and size, will get worse with time. During the corrosion process, the steel transforms into corrosion products that are larger in volume than the steel. In other words, the corrosion products take up more space. The corrosion products will generate significant forces between the steel liner and the concrete, effectively prying the steel liner from the concrete at locations that are in intimate contact. This process will further expose the surrounding steel to the corrosive environment and reduce any protective benefit from the concrete where it actually still is in contact with the steel. These areas will then begin to corrode, as many other areas already are, continually perpetuating and expanding the corroded areas.

3.1.3.2 Fatigue Analysis

The stated purpose of conducting the Destructive Testing was to "verify the findings of the Corrosion and Metal Fatigue Practice Report." [B-159] Within the Corrosion and Metal Fatigue

Practice Report, the Navy states that "there has been no inspection data that suggests any metal fatigue issues in the tanks." And if present, "would be expected to culminate in cracks in the tank steel plate welds." [B-173] Several of the API inspections identified cracks within and associated with welds; however, assessments were not performed to determine if fatigue was associated with any of these defects. Nor were currently used NDE techniques properly evaluated for their ability to accurately and reliably detect and size weld or fatigue cracks. This is a particular concern for the RHBFSF USTs as repair weld defects have been identified as the cause of the Tank 5 fuel release reported in 2014.

Fatigue is defined as the "phenomenon leading to fracture under the repeated or fluctuating stresses having a maximum value less than the tensile strength of the material."[8] The cyclic stresses with tanks can be exacerbated by areas that do not provide sufficient back support, such as voids within the concrete. This was recognized during an engineering review for Tank 20 conducted in 2009, which identified voids in the lower dome. The report noted "flexing of the liner plate may cause the welds to crack, [and recommended] repair[ing] the three voids by injecting grout to fill the void." [B-264]

Non-destructive inspection methods cannot be used to determine whether defects have grown via a fatigue mechanism. Fractographic features that are characteristic of fatigue, such as beach marks and fatigue striations, can only be observed by inspecting the fracture surface. This would require removing a coupon containing the defect, breaking open the defect to expose the fracture surface, and then examining the fracture surface at high magnifications using an optical stereo microscope and a scanning electron microscope. This analysis was not conducted or even proposed as part of the Destructive Testing Scope of Work. [B-159] Thus, in the testimony of Mr. Jamond, it is not clear how he arrived at the opinion that "NDE weld examination results for the entirety of Tank 14 showed that no linear indication of fatigue were found." This is simply not possible to determine without additional destructive testing. This conclusion is supported by the defect classification (Indication Type) utilized by the inspection company for Tank 14 that has "fatigue" notably absent from the list. [B-298] Several weld indications (WI) and linear indications (L, Linear) were identified during the Tank 14 inspection, but were not targeted for destructive testing.

3.1.3.3 Inaccuracy of the NDE Measurements

The results of the destructive testing study identified significant concerns, demonstrating that the equipment and practices that the Navy is currently utilizing cannot accurately detect and size backside corrosion and pitting. The intent of the study was to "Validate the results of NDE inspection technologies used at Red Hill." The expected accuracy of the results were:

- Backside pitting – Prove-up measurement (pit depth) within 20 one-thousandths of an inch (mils) of actual laboratory results. (Note: this corresponds to ±8 % of the NWT for the upper dome, lower dome, and barrel.)

- Wall thinning – Prove-up measurements within 5% of actual laboratory results.

These requirements are in alignment with the specifications for Qualification Test Acceptance Standards contained within API 653. The results of this validation study as summarized by the Navy is shown in Table 3. The table represents that prove-up (phased array UT [PAUT]) was only performed on 5 of the 13 coupons, as 8 of the coupons state "No prove-up," which is not accurate. PAUT measurements were conducted on all coupons; however, if the results of the PAUT identified a result that was outside of the measurement capability, less than 0.160 inches or greater than 0.200 inches, then the value was not reported in the table. In fact, PAUT was performed on Coupon 3 and only identified a non-actionable lamination that would not require repair. Following destructive testing of Coupon 3, backside corrosion was identified and exhibited a maximum depth of 0.119 inches (47.6% of the NWT).

A more accurate representation of the NDE results is presented in Table 4. Comparing the results to the expected accuracy shown in Columns 12-15, it is apparent that the vast majority of the NDE results do not meet the accuracy requirements; five (5) of the ten (10) coupons, 50%, definitively did not meet the prove-up requirements for backside pitting. In other words, **the odds of the tool meeting the performance metric is the same as flipping a coin**.

The correlation between the NDE results and actual depth measurements can be visualized using a unity plot, refer to Figure 12, where the x-axis represents the NDE measured corrosion depths and the y-axis represents the actual (verified) corrosion depths from destructive testing. The LFET (◆), PAUT (■), and aggregated best estimate (○) are presented in the plot. If the NDE results were perfect, the data points would all fall on the center-dashed line labeled "unity". Tolerance bands, represented as ±5% and ±8% on the plot, correspond to the acceptance criteria of the techniques to detect wall thinning and backside pitting, respectively. The results indicate that most of the data points fall outside of these tolerance bands. Some of the NDE measurements were conservative, where the actual depth was less than the NDE reported depth. However, there is not a strong correlation between the NDE reported depths and the actual depths and the majority of the results are outside of the acceptance criteria for the techniques. Furthermore, results for two of the coupons were both nonconservative (false negatives) and outside of the acceptance criteria. **The presence of nonconservative and false negative results indicate the susceptibility for actionable corrosion anomalies to be left within the USTs unrepaired, resulting in an increased likelihood for anomalies reaching a through-wall hole and resulting in a leak prior**

to the next tank inspection (currently scheduled, but not historically performed, at 20 year intervals).

The inaccuracy of the NDE results in comparison to reality were highlighted by the regulatory agencies in a March 16, 2020 letter to the Navy stating:

> "The Regulatory Agencies believe that there lacks sufficient correlation between NDE and the laboratory measurements, therefore further evaluation of NDE procedures should be pursued." [B-30]

Table 3. Navy summary of the coupons removed as part of the metallurgical and corrosion analysis. [B-160]

Table 2-1 Tank 14 Coupon Locations

#	Row in Master Table	Overall ID	Contractor Repair No.	Region	Course	Plate	X-Coord	Y-Coord	Ind Type	Screening Measurement (in)	Prove-up Measurement (in)	Actual Minimum Thickness (in)
1	2282	14-UD-A-42-45-107	14-UD-A-42-45-107-3	UD	A	42	45	107	BC	0.147	0.112	0.208
2	2892	14-ER-E3-12-33-40	14-ER-E3-12-34-44-5	ER	E3	12	33	40	BC	0.157	0.150	0.152
3	2903	14-ER-E3-13-9-18	14-ER-E3-13-7-5-2	ER	E3	13	0-18	18	BC	0.033	No prove-up	0.131
4	2959	14-ER-E2-3-32-232	14-ER-E2-3-32-232-5	ER	E2	3	32	232	BC	0.110	No prove-up	Not used
5	3706	14-BA-26-15-15-8	14-BA-26-15-28-3-1	BA	26	15	27	8	BC	0.047	No prove-up	0.224
6	N/A	N/A	N/A	BA	24	8	N/A	N/A	N/A	N/A	No prove-up	0.158
7	3944	14-BA-23-7-38-49	14-BA-23-7-32-36-1	BA	23	7	38	49	BC	0.157	0.135	0.164
8	4300	14-BA-20-13-236-43	(No Repair)	BA	20	13	236	43	BC	0.069	0.200	0.206
9	4625	14-BA-17-13-4-41	14-BA-17-13-4-41-1	BA	17	13	4	41	BC	0.037	No prove-up	Not used
10	6492	14-LD-3-9-24-215	(No Repair)	LD	3	9	24	215	BC	0.198	0.200	0.242
A1	3962	14-BA-23-9-95-50	14-BA-23-9-94-53-2	BA	23	9	87-103	45-55	BC	0.134	No prove-up. Weld repair	0.122
A2	5176	14-BA-11-4-226-50	(No Repair)	BA	11	4	226	50	BC	0.161	No prove-up	0.248
A3	N/A	N/A	N/A	BA	3	3	N/A	N/A	N/A	N/A	No prove-up	Not used

Note: Coupons 4 and 9 were not used due to anticipated difficulties in removing them, as explained in the text of Section 2.0, so Coupons A1 and A2 were substituted for them. Coupon A3 was an alternate coupon that was not used.

Table 4. Summary of the results of the NDE and destructive testing, incorporating NDE (LFET and PAUT) results not presented in Table 3.[10] [B-160]

Coupon #	Expected Features from NDE	Actual Features from Visual Inspection	LFTE Screening Measurement (in)	PAUT Prove-up Measurement (in)	Best Estimated Minimum Thickness (in)	Actual Minimum Thickness (in)	Actual Minimum Thickness **-20 mils** (in)	Actual Minimum Thickness **+20 mils** (in)	Actual Minimum Thickness **-5%** (in)	Actual Minimum Thickness **+5%** (in)	**LFTE Screening within 20 mils**	**LFTE Screening within 5%**	**PAUT within 20 mils**	**PAUT within 5%**
1	One or more backside-corrosion (BC) pits in central part of coupon	Corrosion on many parts of coupon, mostly on right half. Pitting present	0.147	0.112	0.112	0.208	0.188	0.228	0.198	0.218	No	No	No	No
2	One or more BC pits in most of top half of coupon	Corrosion mostly concentrated in a 2" horizontal band. Pitting present. Portions adhered to concrete.	0.157	0.150	0.150	0.152	0.132	0.172	0.144	0.160	Yes	Yes	Yes	Yes
3	Horizontal plate manufacturing flaw† running through middle of coupon, but no backside corrosion	Visible backside corrosion scattered throughout coupon. Pitting present.	0.033	>0.200	>0.200	0.131	0.111	0.151	0.124	0.138	No	No	No	No
5	Horizontal laminar-type manufacturing flaw† all over coupon, but no BC pits expected	Slight corrosion on several isolated parts of coupon surface. Most of coupon was adhered to concrete.	0.047	<0.160	<0.160	0.224	0.204	0.244	0.213	0.235	No	No	No	No
6	No indications, including BC pits thinner than 200 mils, expected	Slight corrosion on several isolated parts of coupon surface. Most of coupon was adhered to concrete. Pitting present.	>0.200	>0.200	>0.200	0.158	0.138	0.178	0.150	0.166	No	No	No	No
7	One or more BC pits expected throughout coupon	Thick corrosion product on about 90% of coupon. Pitting present	0.157	0.135	0.135	0.164	0.144	0.184	0.156	0.172	Yes	Yes	No	No
8	At center, an inclusion, or an original manufacturing flaw†, expected, with a minimum thickness of 69 mils	Slight corrosion on about 40% of coupon surface. Pitting present	0.069	>0.200	0.200	0.206	0.186	0.226	0.196	0.216	No	No	Maybe	Maybe
10	No indications, including BC pits thinner than 200 mils, expected. If any BC is present, it would be general metal loss	No significant metal loss found. Black surface throughout coupon area.	0.198	>0.200	0.200	0.242	0.222	0.262	0.230	0.254	No	No	Maybe	Maybe
A1	One or more BC pits expected throughout whole coupon, except for left-most 1"	Concrete adhesion on top 2/3 of coupon; concrete on about 60% of bottom 1/3 of coupon. Pitting present	0.134	<0.160	0.134	0.122	0.102	0.142	0.116	0.128	Yes	No	Maybe	Maybe
A2	At center, a thickness greater than 160 mils expected, otherwise, no indications. If any BC is present, it would be general metal loss	On most of coupon, from 1" from the top all the way down, slight corrosion scattered throughout surface, with concrete adhesion as well.	0.161	>0.160	<0.160	0.248	0.228	0.268	0.236	0.260	No	No	Maybe	Maybe

[10] "Maybe" denotes prove-up measurements that were performed, but the actual measured values were not noted; falling outside of the evaluation window of 0.160 and 0.200 inches.

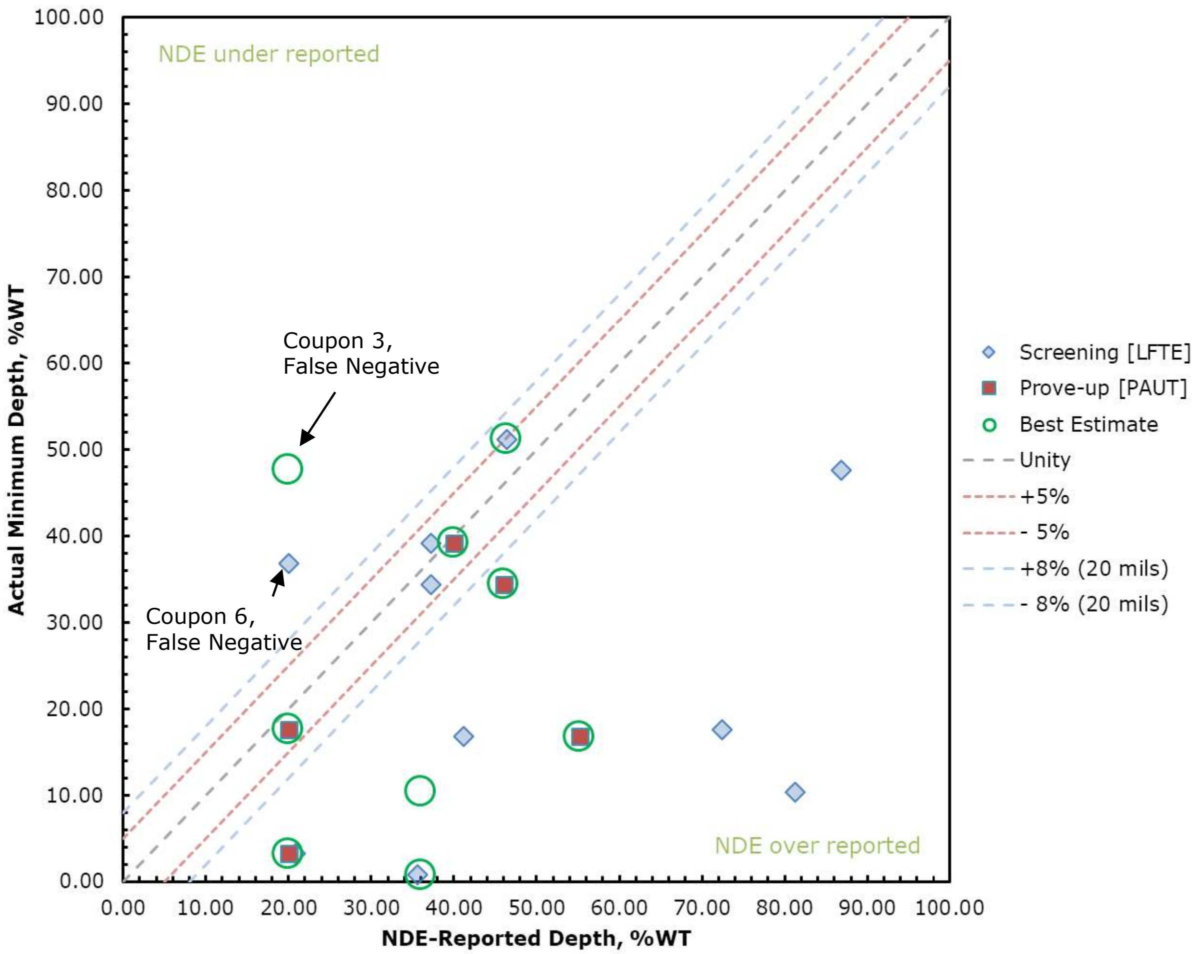


Figure 12. Unity plot comparing the results from the NDE to the actual measured corrosion depths, assuming a nominal wall thickness of 0.250 inches.

3.1.3.4 Statistical Analysis of NDE Results

It is important to validate the accuracy of the inspection tools that are responsible for maintaining the integrity of a particular asset or system. Statistical approaches offer a means to evaluate the data against performance criteria and determine if there are inherent biases with a tool and/or method.

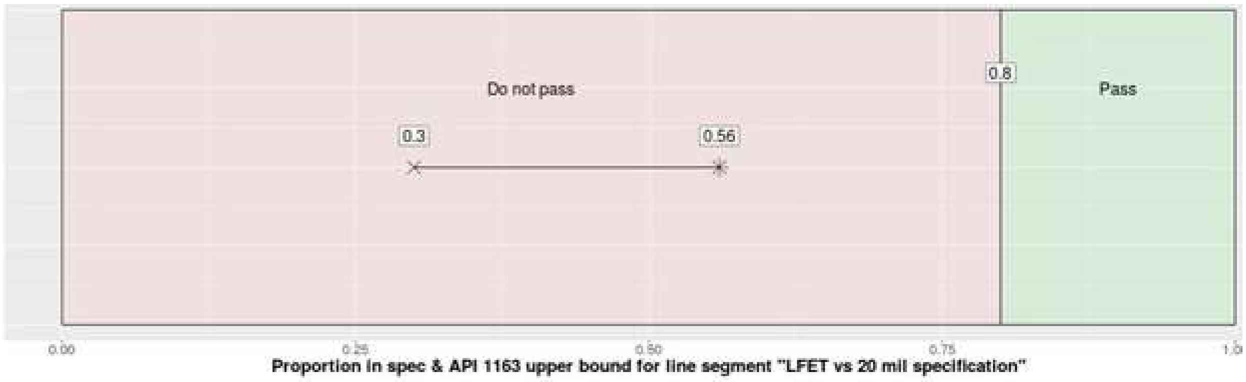
Evaluating the correlation between the measured NDE depth and "true" or actual anomaly depths is not a process unique to storage tanks and can be evaluated using other standards within the oil and gas industry. For instance, the 2013 second edition of the API 1163 "In-line Inspection Systems Qualification" is the pipeline industry standard for comparing NDE and actual corrosion depths. API 1163 Appendix C "Estimating the Performance Specifications from a Comparison of Individual Validation Measurements" details the statistical methodology used to assess if a given NDE tool is possibly meeting the promised vendor specification.

The API 1163 statistical approach is based on assessing each matched pair of the tool estimated corrosion depth with its corresponding actual direct value accepted as being true. Many NDE measurements are made by the tool, but only a small subset is measured directly. Consistent with the destructive testing performed on Tank 14, whereby hundreds or thousands of NDE measurements were made; however, only 10 coupons were selected for destructive analysis. Each matched pair of NDE and direct results are treated as binary, either within specification or not. The total number of in-specification matches is converted to a proportion of the total number of matched pairs that are found to be within specification. This is handled using a form of the binomial confidence interval with the mathematics found in Appendix C of the API 1163 standard. From a statistical perspective, what is called the null hypothesis (Ho) states that the population proportion of NDE within specification meets or exceeds the vendor claimed tool performance. The alternative hypothesis (Ha) states that Ho is not true.

The API 1163 standard develops what is termed a one-tailed confidence interval for the population binomial proportion. With generally a small quantity of samples, the upper bound of this interval is often higher than the sample proportion found to be successes (within specification). If this upper bound of a 95% one-tailed confidence interval meets or exceeds the vendor promised performance, then Ho is not rejected. This implies the NDE tool may be meeting the promised goal. Only if this upper bound is below the promised performance is the null hypothesis rejected with 95% confidence. Typical performance specifications are that the tool will agree (within specification) with the direct actual matched value 80% of the time.

Table 4 summarizes the results of the destructive testing performed on the ten coupons removed from Tank 14, incorporating comparisons between the NDE methods (LFET, PAUT) and the actual corrosion depth measurements determined from destructive testing. As seen in this table, the specification limit is 20 mils for backside pitting. A LFET or PAUT measurement would be a success (within specification) if its value is within ± 20 mils of the actual matching destructive testing depth.

Of the ten match pairs, three of the LFET measurements are within the specification of 20 mils. For PAUT, one of six measurements are within 20 mils with four as "maybe". The four "maybe" designations are a result if prove-up measurements that were performed, but the actual values were not noted. Two of the four "maybe" values were below the repair threshold of 0.160 inches and no measurement was noted. The remaining two "maybe" values were either greater than 0.200 inches or no wall-loss features were identified. In the below API 1163 analysis, the "maybe" values will be counted as successes of being within 20 mils giving the PAUT tool the benefit of doubt.

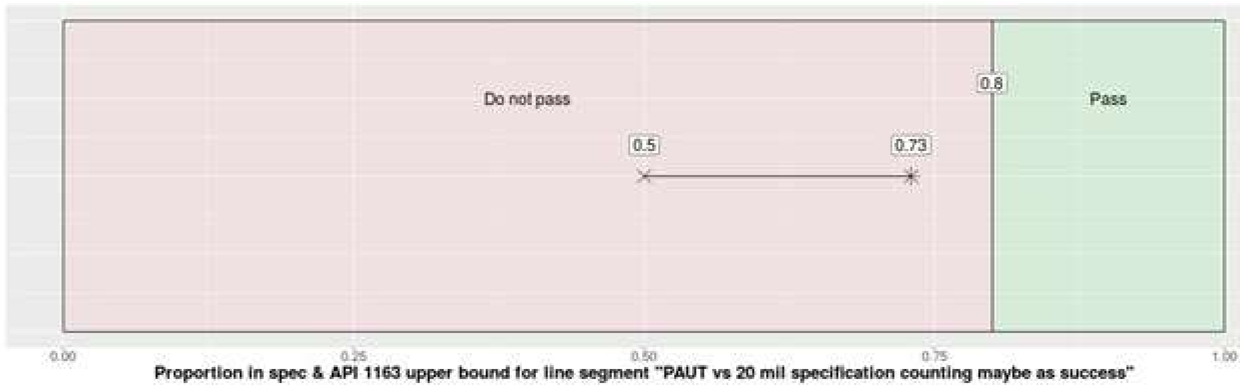


In Spec	Matched Pairs	Proportion	Confidence Interval	API 1163 Upper Bound	Vendor Spec	Pass / Fail
3	10	0.30	0.95	0.56	0.80	Fail

Figure 13. API 1163 assessment of the performance of LFET.

With three of ten within the threshold of 20 mils, the sample proportion within specification is 3/10 = 0.3 as seen in Figure 13 depicted by an "×" and called "Proportion" in the table. For the relatively small sample size of ten matched pairs, the one-tailed 95% confidence interval is wide with the upper bound at 0.56 that is labeled "API_1163_upper_bound" below the plot. Since 0.56 is less than the specification limit of 0.80 (80% in specification), the portion of the measurements within specification fails and therefore, API 1163 is not passed. Graphically this is seen with the upper confidence interval bound 0.56 in the pink "Do not pass" part of the output.

With the four "maybe" PAUT values in Table 4 considered to be within +/- 20 mils, five of ten are then within the 20 mils. The sample proportion within specification is 5/10 = 0.5 as seen in Figure 13 depicted by an "×" and called "Proportion" in the table below the plot. For the relatively small sample size of ten matched pairs, the one-tailed 95% confidence interval is wide with the upper bound at 0.73 that is labeled "API_1163_upper_bound" below the plot. Since 0.73 is less than the specification limit of 0.80 (80% in specification), the portion of the measurements within specification fails and therefore, API 1163 is not passed. Graphically this is seen with the upper confidence interval bound 0.73 in the pink "Do not pass" part of the output.



In Spec	Matched Pairs	Proportion	Confidence Interval	API 1163 Upper Bound	Vendor Spec	Pass / Fail
5	10	0.50	0.95	0.73	0.80	Fail

Figure 14. API 1163 assessment of the performance of PAUT.

API 1163 is an important standard in the oil and gas industry that is key to quantifying NDE tool performance relative to meeting vendor specifications. With its use of the upper tail of a one-side 95% confidence interval, considerable caution is provided before rejecting a given tool assessment. Even given this considerable caution, the results fail the API 1163 analysis for the performance metric, ±8% (20 mils), or tool tolerance of ± 5%. Thus, it is difficult to have faith in either tool (LFET or PAUT) being able to provide accurate assessments of steel liner thickness and thus corrosion depths. An analysis was performed to determine the tool tolerance whereby the current LFET NDE results would pass the API 1163 criteria. It was determined that the tool tolerance must be extended from ± 5% to ± 24.4% to meet this standard.

It is clear that the technology, practices, and procedures that the Navy is currently using to assess corrosion damage are inadequate to identify and accurately size the wall loss anomalies. This sentiment is echoed in the EPA and DOH letters to the Navy rejecting the Navy's unsupported position that the "NDE results are validated, both by destructive testing and thorough case-by-case analysis." [B-160, B-32]

3.1.4 Corrosion Growth Rate

Internal inspection is one of the primary methods by which to evaluate an underground fuel storage tank's integrity and minimize the potential for corrosion impacts to lead to leaks and/or releases into the environment. Tank operators are required to establish a corrosion growth rate in order to determine and justify the intervals between internal inspections. API Standard 653 – Tank Inspection, Repair, Alteration, and Reconstruction states the following:

> "Section 6.4.2.1 Intervals between internal inspections shall be determined by the corrosion rates measured during previous inspections or anticipated based on experience with tanks in similar service. Normally, bottom corrosion rates will control and the inspection interval will be governed by the measured or anticipated corrosion rates and the calculations for minimum required thickness of tank bottoms (see 4.4.7). The actual inspection interval shall be set to ensure that the bottom plate minimum thicknesses at the next inspection are not less than the values listed in Table 6-1. **In no case, however, shall the internal inspection interval exceed 20 years."**

As stated earlier, API 653 is primarily used for ASTs. Its inspection methodologies and repair requirements for above ground tank bottoms are being applied by the Navy to the RHBFSF USTs. In this case, the "bottom" for the RHBFSF USTs is the entire steel liner and is the sole means for preventing a release of the contents to the environment from the tanks. For the USTs at the RHBFSF, the "bottom plate minimum [remaining wall] thickness at the next inspection" is 0.100 inches. This thickness value is set by API 653 for ASTs with no means for detection and containment of a bottom (liner) leak.

Establishing an accurate corrosion growth rate (CGR) is critical in determining the repair threshold for areas of reduced wall thickness resulting from corrosion, such that a suitable reinspection interval can be achieved. If a CGR is selected that is **less** than the actual CGR of the corrosion, then this would result in fewer required repairs, allowing those features not repaired to corrode to depths that result in remaining wall thickness less than the thickness minimum before the next tank inspection. Thus, resulting in an unconservative approach and increasing the likelihood of future fuel leaks. Recall that the thinnest the liner plate can be for an above ground tank per API 653 at any time in the tank's life is 0.100 inches.

The Navy's approach to determining the CGR for its USTs has varied. Counter to industry standards and principles of sound science, the Navy's approach is not consistently based on the actual conditions found in the tanks nor conservative. For Tanks 6, 15, and 16 inspected in 2005 and 2006, the CGR was set using the NDE measured depths of corrosion on the backside of the liner for the tank being inspected. This resulted in a CGR of 0.0045 inches per year (4.5 mils per year [mpy]). For Tanks 2 and 20 in 2008, the Navy did not take into account the NDE corrosion depths actually identified in the tank and instead calculated a CGR that would result in the liner reaching a minimum thickness (T_{min}) of 0.100 inches at a future next inspection date. This resulted in a CGR of 1.747 mpy. For Tanks 13, 14, and 17 in 2017, the Navy set a CGR of 3 mpy even though they found areas of corrosion inside Tank 13 that exceeded 3 mpy resulting in through-wall holes in the tank. Thus, the rate was again not related to the measured conditions found in the tank. For Tank 5, which was inspected twice, first in 2010 and again in 2017, it appears that the Navy used the 3 mpy CGR, but established two different minimum thicknesses for the liner. In 2010 the minimum thickness of the liner was set at 0.140 inches, while in 2017 the minimum thickness was set to 0.100 inches. There were two through-wall holes discovered in Tank 5 during the 2010 inspection, which means the CGR was more than 3 mils per year in those areas. Again, the Navy is not using actual measurement data from the tank to establish a CGR.

Per the different CGRs established, the repair threshold would have been 0.190 inches for tanks 6, 15, and 16; 0.135 inches for Tanks 2 and 20 (although the Navy did decide to double the CGR for establishing the repair threshold for these two tanks and set it at 0.170 inches); 0.160 inches for Tanks 13, 14, and 17; and for Tank 5 a repair threshold of 0.200 inches in 2010 and 0.160 inches in 2017.

The Navy is aware of the difficulty in determining one overall corrosion growth for an entire facility as it was detailed in EEI's report. [B-238]

> "1. It is not possible to calculate an actual corrosion rate for the Red Hill Tanks because the time interval during which corrosion occurred is unknown and cannot be determined.
>
> 2. Selecting areas of the steel liner and measuring the remaining thickness to determine actual corrosion rates would not necessarily be representative of external corrosion conditions throughout the tank because the rock stratum surrounding the Red Hill tanks varies in type and porosity."

The fact that they have decided to implement a single repair threshold in their most recent tank inspection reports, which is not even consistent with highest rate determined based on field observations, may result in areas where more aggressive corrosion is occurring developing through-wall holes in the liner within the planned 20-year service life between inspections. Such a risk would be amplified if the Navy continues to defer some of its UST inspections beyond the specified 20-year inspection interval.

Figure 15 is a plot showing the historic corrosion growth rates and the Navy-defined acceptable corrosion depths for the USTs at the RHBFSF. It is clear that by selecting lower growth rates and higher acceptable corrosion depths, the Navy is allowing for an increased (longer) reinspection interval, and moving in a less-conservative direction, which is counter intuitive and goes against all industry norms for managing high risk, aging assets.

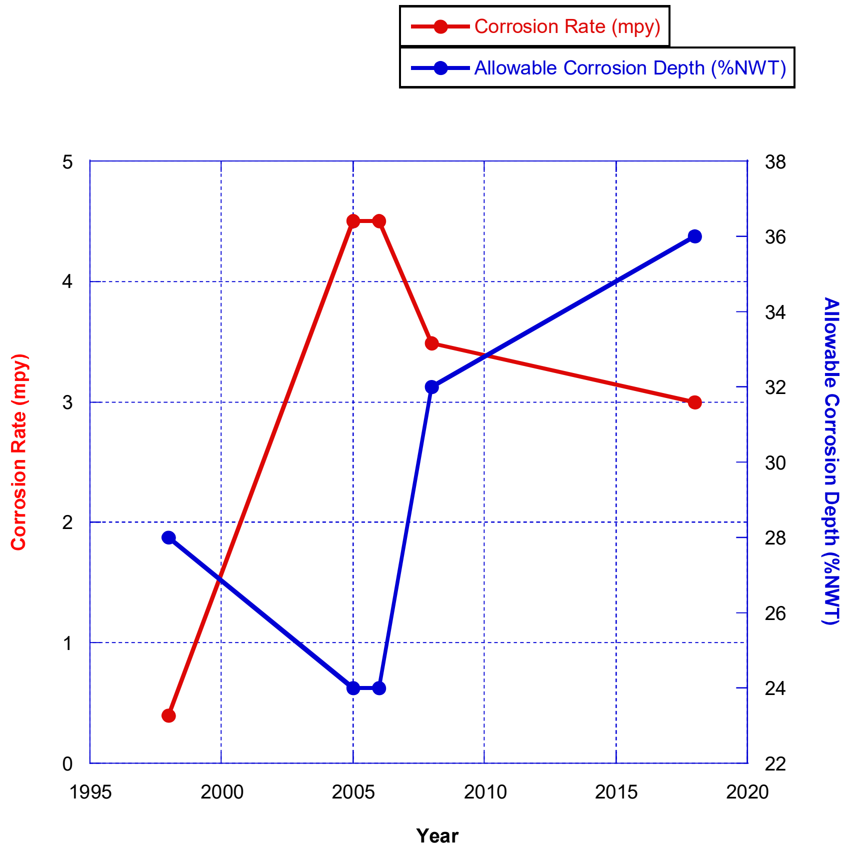


Figure 15. Plot showing the historic corrosion growth rates and allowable corrosion depths selected by the Navy for the USTs at the RHBFSF.

In the response by the EPA and DOH to the Navy's Corrosion and Metal Fatigue Practices, Destructive Testing Results Report, Red Hill Bulk Fuel Storage Facility, the regulatory agencies note on page 5 Section 4 Potential for Increasing Corrosion Rates that

> "The Regulatory Agencies believe the Navy is underestimating corrosion rates for Tank 14 and should reassess corrosion rates as used in calculating repair thresholds under TIRM." [B-30]

The report notes that the Navy is not using the thinnest reading within the tank to determine the corrosion growth rate, are not accounting for the reduction in pH levels of the concrete shell which can accelerate corrosion growth rates, and the potential the USTs are experiencing rainfall infiltration. [B-30] Our opinion supports the statements made by the regulatory agencies. In addition, the Navy's reduction (using lower rates) in the corrosion growth rates it is using in establishing the repair criteria for the tanks at the RHBFSF are, in our opinion, not what a prudent operator would do in the case of increasing uncertainty. The conditions that currently exist behind the steel liner are indicative of aggressive corrosion growth rates and therefore require a much more conservative approach when calculating repair thresholds and reinspection intervals.

The NDE inspection methodology the Navy is using has not been shown to produce consistent, reliable, and accurate results. What is known is that backside corrosion is occurring. When confronted by an increase in uncertainty, prudent operators increase their conservatism. In this case that would be to increase the estimated corrosion growth rate, increase remaining thickness repair thresholds, and implement additional inspection measures/procedures. The Navy should be seeking more details (i.e. conducting additional destructive testing) about the conditions on the backside of the steel liner and the concrete shell. They should be acting to increase their knowledge of the conditions on the backside of the steel liner and altering their plan of action accordingly. Contrary to sound environmental precautions and industry standards, however, the Navy is not taking any of these actions. Instead, over time, the Navy has decreased the estimated corrosion growth rate and decreased the remaining repair threshold; it appears that the Navy is rationalizing the limited sampling done to date in order to support planned operations.

3.1.5 Repair Strategy

The Navy relies on the results of API 653 inspections and methods developed for ASTs to identify, size, and determine the repairs necessary to prevent leaks. It is important to note that ASTs have dikes to capture any fuel that may be released before it enters the environment and that the side walls of ASTs can be inspected from both sides. Neither of these release capture or inspection features are available for the RHBFSF USTs. Compounding this inability to detect fuel releases as soon as they happen, the Navy's destructive testing has demonstrated that it does not have the ability to detect with any accuracy or reliability areas of the steel liner that need to be repaired before leaks occur. Table 5 is a list of typical repair procedures and specifications for anomalies identified during the API 653 inspections. The list was included as part of the tank inspection reports conducted on Tanks 7, 8, and 10 in 1998. Many of the procedures utilize the application of steel patch plates that are welded to the internal tank surface over the identified areas of damage, including pitting and backside corrosion. Similar repair procedures/specifications were not included in the tank inspection reports for Tanks 2, 5, 6, 13, 15, 16, 17, 19, or 20; however, as the Navy utilizes the patch plates as the typical repair method for corrosion-related damage at RHBFSF, it appears that similar processes are utilized. [B-190 - B-192, B-237 - B-240, B-242]

Table 5. Table showing the typical repair procedures/specifications for anomalies identified during API 653 tank inspections performed in 1998. [B-176]

ER-PEARL-TK10

8.0 REPAIR SPECIFICATIONS

8.1 Typical Repair Procedures:

REPAIR TYPE #	TYPE OF DAMAGE	REPAIR PROCEDURE (SEE NOTE 4)	APPROX. SIZE
1	RUSTED AREA, PITTING	REMOVE RUST AND ADJACENT COATING. MEASURE & RECORD DEPTH OF PITS. CLEAN TO BARE METAL, RECOAT.	0.25 SQ. M.
2	DEEP GOUGE IN LINER PLATE	MEASURE & RECORD DEPTH OF GOUGE. CHECK WITH UT FLAW DETECTOR FOR CRACKS. RESURFACE WITH WELD, GRIND SMOOTH, RECOAT.	0.1 SQ. M.
3	LEAK - POROUS/DEFECTIVE WELD	CLEAN SURFACE, VACUUM TEST FOR LEAK, WELD PATCH PLATE OVE R LEAK, CLEAN TO BARE METAL, RETEST WITH VACUUM BOX, RECOAT	0.1 SQ. M.
4	LEAK - DOUBLER PLATE	CLEAN SURFACE, VACUUM TEST FOR LEAK REMOVE DOUBLER PLATE, CLEAN SURFACE AND GRIND, WELD PATCH PLATE OVER LEAK, CLEAN TO BARE METAL, RETEST WITH VACUUM BOX, RECOAT.	0.25 SQ. M.
5	LEAK - BLISTER/RUST THROUGH FROM BACK SIDE	REMOVE RUST AND ADJACENT COATING, MEASURE & RECORD THICKNESS. WELD PATCH PLATE OVER LEAK. CLEAN TO BARE METAL. RETEST WITH VACUUM BOX, RECOAT	0.2 SQ. M.
6	LEAK - HOLE	CLEAN SURFACE, VACUUM TEST FOR LEAK. WELD PATCH PLATE OVER LEAK. CLEAN TO BARE METAL, INCLUDING WELD. RETEST WITH VACUUM BOX, RECOAT	0.1 SQ. M.
7	BLISTER/DENT	REMOVE COATING TO BARE METAL. MEASURE & RECORD THICKNESS, RECOAT.	0.1 SQ. M.
8	COATING FAILURE	REMOVE COATING TO BARE METAL, RECOAT.	1.0 SQ. M.
9	BUTT WELD FAILURE BETWEEN LINER PLATES	DRILL HOLES IN LINER PLATE AT BOTH SIDES OF THE DAMAGE. PURGE WITH NITROGEN DURING HOTWORK. REMOVE WELD, REWELD, INSTALL THREADED PLUGS IN HOLES AND SEALWELD. CLEAN TO BARE METAL, INCLUDING WELD. RETEST WITH VACUUM BOX, RECOAT.	300mm
10	FILLET-WELD FAILURE BETWEEN BACKER STRIPS IN UPPER DOME AND LINER PLATES	REMOVE DEFECTIVE WELD AND REWELD. CLEAN TO BARE META, INCLUDING WELD. RETEST WITH VACUUM BOX, RECOAT.	300 mm
11	FILLET-WELD FAILURE BETWEEN 3.5 MM STEEL COVER PLATE AND LINER PLATES IN UPPER DOME	DRILL HOLES IN STEEL COVERS AND PURGE WITH NITROGEN DURING HOT WORK. REMOVE DEFECTIVE WELD AND REWELD. INSTALL THREADED PLUGS IN HOLES AND SEALWELD. CLEAN TO BARE METAL, INCLUDING WELD, RETEST WITH VACUUM BOX, RECOAT	300 mm

GENERAL NOTES:

1. PATCH PLATES FOR UPPER DOME, DOME EXTENSION, BARREL OF TANK AND LOWER DOME TO BE 6mm THICK. PATCH PLATES FOR BOTTOM PLATE TO BE 11mm THICK.
2. ALL WELDS TO BE CONTINUOUS.
3. SANDBLAST PATCH PLATES BEFORE WELDING IN PLACE AND BREAK EXPOSED EDGE BY GRINDING CHAMFER OF 1.5 mm MINIMUM.
4. THE REPAIR PROCEDURE IS THE SAME, REGARDLESS OF THE LOCATION OF THE DAMAGE IN THE UPPER DOME, TANK BARREL, OR LOWER DOME.

As discussed above, the threshold of corrosion damage requiring a repair patch plate has been modified by the Navy to be less and less conservative. Additionally, the minimum thickness allowed to remain in service after inspection (T_{min} or T-min thickness threshold) has become less conservative (i.e. thinner) over time, as Table 6 shows.

Table 6. Summary of the repair threshold (T_{min}) for API 653 inspections conducted on the USTs according to year. [B-160]

Year	Repair Threshold (inch)	References
2007	0.190	B-190, B-191, B-192
2008	0.170	B-237, B-238
2017/2018	0.160	B-297, B-298, B-299

The allowable corrosion damage (depth) on the barrel has been increased from 24% to 36% (i.e. 0.190 inches of remaining wall thickness to 0.160 inches of remaining wall thickness). Once a feature with a depth greater than the corrosion damage threshold is identified, a repair is detailed based on the geometry and other damage identified in the area. The repair patch plate is then welded onto the internal surface of the tank covering the corrosion damage. **This repair method effectively increases the local wall thickness in the area of corrosion damage but reduces the effectiveness of subsequent inspections.** This is due to the presence of the welds that join the patch plates to the tank. The welds create local geometric discontinuities that make identification of flaws very difficult using the Navy's current inspection methods. This concern was highlighted by one of the API 653 inspectors pertaining to "undetected thinned locations adjacent to the prior repairs" who stated,

> "The close proximity of the prior repairs and the seam welds made the detection of these flaws unlikely and they were not detected by the scanning effort." [B-192]

As described above, backside corrosion is a threat that cannot be mitigated or reduced due to the geometry, construction and subsurface location of the USTs. Once corrosion has started, it will continue to occur, even with an additional patch plate placed on the internal surface. In the case of many other assets, such as other USTs and ASTs, mitigation strategies can be implemented, such as modifying the level of cathodic protection, or reapplying coating to the surface. The nature of the USTs at the RHBFSF precludes such mitigating strategies.

As previously discussed, backside corrosion will continue to get worse, both in the number of locations and size of the corrosion features. This is verified by the most recent API inspections performed in 2017 and 2018 on Tanks 5, 13, and 14 requiring several repairs:

"greater than 2 square feet in area for each location. Several of these repairs are full plate replacement repairs.

These repairs will be unlike any previous repairs done at the Red Hill Facility and will require extensive design and construction considerations. Repairs could include the removal of existing shell plates and inserting new plate or welding patch plates to cover the affected areas."

As a result of the Tank 5 fuel release in 2013 and 2014, multiple API 653 inspections have been performed within the last 11 years. Tank 5 was removed from service in 2010 for inspection and repair that occurred between August and September of 2010. [B-242] Following repair, the tank was in the process of being refilled and placed back into service when the leak was identified. As a result of that leak, the tank was again removed from service and a subsequent API 653 inspection was performed in October 2017 to January 2018, approximately 7 years later from the 2010 inspection.[11] Tank 5 is the only tank to undergo multiple modern API 653 inspections. This offers a unique opportunity for the Navy to evaluate the backside corrosion that is occurring and check that the processes and procedures are appropriate for preventing future leaks. In 2010, Willbros Government Services, LLC (Willbros) issued the Tank 5 Final Tank Inspection & Integrity Report. [B-242] Detailed within the report were the results of NDE and the corresponding repairs that were classified as "Mandatory" - Immediate repairs required before returning tank to service, "Short-term" - Repair indications or flaws found that have the criteria which exceeds the intended (10 yr) service[12] and operational interval, and "Long-term" - Repair indications or flaws found that have the criteria which exceeds the intended (20 yr) service and operational interval.

Specifically related to the 20-year intended service, backside corrosion features resulting in remaining wall thicknesses of 0.198 inches and less were identified as Long-term repairs. This suggests that the Navy utilized a repair threshold of 0.200 inches for this inspection, which for a Tmin of 0.140, correlates to a corrosion growth rate of 0.003 inches (3 mils) per year; in alignment with what the Navy is currently utilizing.

Given this repair threshold, one can compare the measured wall thicknesses from NDE that was performed in 2017 to estimate the corrosion growth rates (CGRs):

$$CGR\left(\frac{in}{year}\right) = \frac{0.200\,(in) - Measured\ Wall\ Thickness\ (in)}{6.74\ (years)}$$

[11] The 2010 and 2017 API inspection reports identify service lives of 68.26 and 75 years respectively, such that the interval is 6.74 years.

[12] Willbros report provided the Navy an option of using a 10-year operational life vs the typical 20-year operational life if the Navy's plans for the tank needed only 10 more years of service.

Essentially measuring the corrosion growth that has occurred over the 6.74 years between the measurements. Figure 16 is a plot of the calculated corrosion growth rates for the backside corrosion anomalies identified during the 2017 API inspection. The data show CGRs between 0 and 13.4 mpy, with an average of 5.1 mpy. The results indicate that the CGRs for the tank may be much higher than anticipated by the Navy (3 mpy) and/or illustrate the inaccuracies of the methods and practices the Navy is utilizing to assess backside corrosion on the USTs.

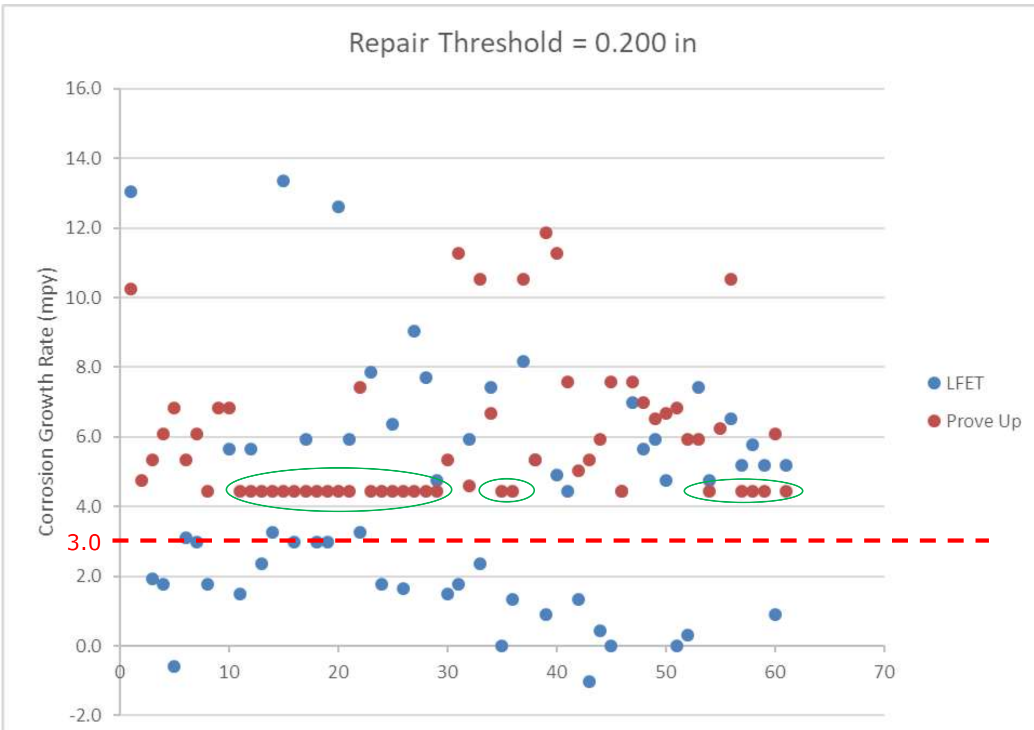


Figure 16. Plot showing the calculated corrosion growth rates for backside corrosion anomalies identified during the 2017 API 653 inspection for Tank 5. Navy's adopted corrosion growth rate tied to reinspection intervals. Note – Data circled in green correspond to measurements that were only reported as "<0.160", such that the data are lower bounds.

Another example illustrating the pervasive nature of unmitigated backside corrosion is shown in a photograph taken during the most recent (2017) inspection of Tank 5. The photograph shows a location of backside corrosion requiring repair that is directly adjacent to a previously repaired location. For all of the reasons highlighted in prior sections, corrosion will continue to occur, exposing additional areas that will eventually corrode and require repairs (if detected in time). The patch plates on top of patch plates will make detection and sizing of these corrosion features more difficult. Based on the Navy's recent NDE results from the destructive testing, more difficulty (less accuracy) will only lead to more leaks.

Photo 29: Backside Corrosion around existing patch plates

Figure 17. Photograph from the API inspection conducted on Tank 5 in 2017 showing backside corrosion (BC) below the repair threshold of 0.160 (requiring repair) adjacent to an area that was previously repaired with a patch plate.

3.1.6 Risk Analysis

Given the findings from the prior API 653 inspections, metallurgical and corrosion analyses, and NDE verification work, as well as the previously discussed release history of the RHBFSF USTs, there is significant concern and risk that the tanks are currently leaking and that future leaks will continue to occur.

An independent contractor for the Navy, ABS Consulting, issued Phase 1 of a planned, multiphase QRVA evaluating the likelihood for future leaks, both acute and chronic. [B-15] An acute leak is one characterized by a larger hole that releases product relatively quickly and is easier to identify – most commonly by the tank level monitoring system, referred to as the Automated Fuel Handling Equipment (AFHE), but also by soil vapor and groundwater wells environmental monitoring. A chronic leak occurs from smaller holes that leak slowly over a longer period of time and can be harder to identify – most commonly by tank tightness testing or by environmental monitoring as above. DNV GL reviewed the QRVA report and found it was professionally executed using recognized risk assessment software. ABS followed a sound risk assessment methodology based on nuclear industry guidance. [9, 10] The Navy's own contractor concluded:

- There is a greater than a 27% probability of an acute, sudden release of between 1000 and 30,000 gallons of fuel from the RHBFSF each year <u>(Note - this correlates well with the leak history of at least 72 reported release incidents over more than 75 years with an estimated total fuel leakage of 175,000 gallons of product and a large recent acute leak of 27,000 gallons in 2013/14 - see Section 2.1);</u>
- There is a greater than a 34% chance of a sudden release of more than 120,000 gallons of fuel from the RHBFSF in the next 100 years;
- There is a greater than a 5% chance of a sudden release of more than million gallons of fuel from the RHBFSF in the next 100 years; and
- The expected volume of chronic, undetected fuel releases from the RHBFSF is 5,803 gallons per year. [B-15]

DNV GL agrees with ABS that the likelihood of both sudden and chronic releases from the RHBFSF USTs are high. However, as discussed below ABS' calculations likely underestimate the overall risk of future releases from the RHBFSF because certain risks were not even considered in Phase 1 of the QVRA and some assumptions underlying ABS' analysis effectively ignored or minimized actual RHBFSF release frequencies.

Contrary to the claims of Navy witness Mr. Curtis Stanley, ABS actually underestimates, rather than overestimates, the overall risk and likelihood of future fuel releases from the RHBFSF USTs. While ABS' overall methodological approach is generally sound, its risk calculations understate this risk primarily as a result of deficiencies in the historical data upon which ABS relied, selective use of that data that improperly discounted reported release events, flaws in the implementation of the Bayesian updating methodology, and prescribed limitations on the scope of the assessment. When considered together, the only reasonable conclusion is that the unacceptably high risks identified by ABS are in all likelihood even higher.

Several specific deficiencies and limitations likely contribute significantly to ABS' underestimation of risk, including: (1) reliance on incomplete historical release data from the RHBFSF; (2) reliance on an unwarranted assumption that UST leak rates are constant over time, disregarding physical failure mechanisms, like corrosion, that correspond with an increasing rate over time as a true renewal process is not occurring; (3) discounting releases identified by the tell-tale leak detection and collection system without sufficient due diligence;

(4) calculation of leak frequency distributions for individual RHBFSF USTs using Navy leak data from dissimilar (smaller) tanks at distant locations, while excluding leak data from neighboring RHBFSF USTs; and (5) exclusion from the initial (Phase 1) QVRA the consideration of risks from such external sources such as fire, flood, and earthquake.

Most of the historical RHBFSF leak event data is ignored

The treatment of historical release data in the QVRA performed by ABS report merits particular attention. First, relying primarily on Navy-supplied data, ABS only identified 65 leak events occurring at the RHBFSF where, as noted above, there are at least 72 fuel release incidents from the RHBFSF documented in Navy records. Using only reported fuel release incidents as a starting point is already an underestimation as releases from fuel storage infrastructure are often underreported. From this incomplete initial count of 65 leaks, ABS then excludes 10 based on Navy representations that the incidents involved water, not fuel. However, neither the Navy nor ABS provides sufficient justification for excluding these 10 releases as a loss of tank integrity occurred. Leaks from and seepage back into the RHBFSF USTs, whether of fuel or water, indicate a pathway for releases into the environment that should not be ignored absent clear and convincing evidence that fuel could not make its way out of the UST. ABS then excluded wholesale another 25 leak incidents that were detected by the tell-tale leak detection and collection system without confirming whether the reported releases were the result of malfunctions associated with the tell-tales themselves or were indicative of fuel releases to the environment. Without this additional verification, it is not conservative to exclude these known leak incidents from the risk analysis, as they may be actual detections of fuel releases during which the tell-tales performed their intended function. The cumulative effect of these omissions and exclusions is that ABS' risk calculations are based on a count of, at most, 30 historical leak events at the RHBFSF, where a more accurate, prudent, and defensible count of total fuel release incidents is 72.

ABS' Bayesian update analysis significantly underestimates RHBFSF leak frequencies

Furthermore, some elements of the Bayesian update analysis as performed by ABS are not conservative. Specifically, ABS used a two-stage Bayesian update methodology to estimate the small leak frequency during operation for each of the 20 individual RHBFSF tanks (Table 5-14, B-15).

In performing these calculations, ABS used empirical evidence of small leaks[13] from six Navy UST locations (Table 5-11, B-15) to define a starting distribution (NGRID prior) applied for each RHBFSF UST. These Navy UST data comprise just 10 small leak events over a long

[13] Note that a leak of 1.5 GPM (which is 90 GPH) is considered by ABS as a small leak. Such a leak would release over 2,100 gallons in a single day!

period of operation amounting collectively to 7,050 tank years. These data pertain to much smaller tanks at distant locations and are not as pertinent in assessing risk as the extensive leak history data directly available from the Red Hill site. As noted earlier there have been 72 reported leaks at the RHBFSF over a population of 1316 tank-years.

The Bayesian update is intended to improve the estimated likelihood by combining the starting distribution with actual local leak data, and the more local data available the less the starting distribution impacts the final result. To update the NGRID prior distribution with the Red Hill specific data, ABS selected only 18 leak events from its adjusted count of 30 leaks, excluding 12 events (like the recent Tank 5 release) that occurred during return-to-service operations.

Moreover, in performing a separate two-stage update for each of the 20 RHBFSF tanks individually, ABS used only the RHBFSF leak data for each UST. Thus, the resulting estimate of leak frequency for an individual RHBFSF UST is based on data from smaller tanks at distant locations but ignores entirely the extremely relevant failure data from 19 other near-identical RHBFSF USTs of the same vintage and in the same location and service. Such an approach to estimation is not conservative and underestimates the risk of future fuel releases.

Even more significant is the lack of conservatism in ABS' estimation of large leak frequencies, which stems from two deficiencies noted above: a reliance in the Bayesian update analysis on operating data from much smaller tanks at distant locations; and, more importantly, the omission of relevant data from the RHBFSF operating history.

Similar to the treatment of small leaks, ABS used a two-stage Bayesian update methodology to estimate the frequency of large leaks in RHBFSF tanks. In performing these calculations, ABS defined a starting prior distribution using data from six Navy UST locations comprising zero (0) large leak events over 7,050 tank-years (Table 5-20, B-15).

ABS then proceeded to update the prior distribution with the claimed RHBFSF experience of zero (0) large leak events over 1316 tank-years. This claim derives from a statement in the ABS report: "No RHBFST fuel incidents with leakage rates greater than 1.8 gpm have historically been observed at Red Hill facility." (p. 5-113)

This statement is contradicted by specific evidence that at least one RHBFST (Tank 16) did experience a leak rate of 3.1 gpm. Tank 16 was refilled and the level decreased 3.63-inches in about four days, indicating a loss of about 18,000 gallons. No information was given as to when the leakage was stopped. [B-10] In addition, there are other leak events where the release volume (or leak rate) has not been documented. For example, in one leak event, Tank 15 is judged to be "leaking badly", but no leak rate has been provided. The tank was removed from service from Aug. to Oct. 1981. Following repair, the tank was refilled to the 185-foot level and showed leakage. [B-199] Although the incidents involving Tank 16 and

Tank 15 occurred during return to service, rather than normal operation, this distinction may pertain more to when the leak was discovered rather than when the condition first occurred. Furthermore, the separate analysis performed by ABS concerning leaks during a return to service event inaccurately characterizes all 12 such incidents as small leaks.

Thus, the ABS risk analyses failed to acknowledge and use historical data indicating at least one large leak—and possibly more—has occurred at the RHBFSF. This failure has led to underestimation of the frequency of large leaks and associated fuel release volumes. Depending on the choice of prior distribution, the ABS analysis based on zero large leaks results in an estimated recurrence interval for large leaks of one incident in approximately 15,000 to 17,000 years (Tables 5-22 and 5-27, B-15). The occurrence of one large leak (or more) at Red Hill in 1,316 tank years suggests the QRVA may have underestimated the frequency of large leaks by at least an order of magnitude.

Renewal Process is not True Renewal

The QRVA performed by ABS Consulting identifies the repair process that the Navy is utilizing as a "renewal" process. **DNV GL's opinion is that the tanks are in an end-of-life phase and that a true renewal process is not occurring**. This means that ABS' use of constant failure rates is optimistic because failure rates are increasing with age as the tanks are in end-of-life stage. As previously mentioned, the Navy has adopted a modified API 653 inspection for the tanks, which applies the inspection methodologies for an AST bottom, where the backside cannot be directly inspected, to all surfaces of the USTs. Consequently, the Navy also recognizes that there is a useful life to the bottom of an AST, at which time backside corrosion has reached a level necessitating replacement of the tank floor.

Page 5-175 of the QRVA has the following assertion.

> We [ABS] feel that a strong reason for why we do not see evidence of corrosion rate acceleration at the RHBFSF is that there is an effective continuous "renewal" process in place for the tanks and supporting flow path components. This renewal process occurs via the regular tank inspection and repair processes in practice at the facility, specifically the commitment that all tanks will be inspected with 100% area coverage at least once every 20 years, and that as a result of these inspections there is a process in place for replacement of tank liner sections or plates where actual breeches in continuity are discovered or where impending breeches are predicted to cause through-wall leakage prior to the next inspection. [B-15]

A renewal would be a point in time in which a given tank and its environment would be returned to new or pristine condition. While periodic, roughly twenty-year, inspection and remediation is planned, these will not restore a tank to its initial pristine condition with no anomalies. The surrounding concrete will also not be returned to its initial condition. This is just a partial renewal at best given the results from the Section 5 AOC requirements that demonstrate that the areas that need repair cannot be accurately identified. Additionally, it is not a continuous time process in which renewal might occur at any point in time. Instead, at best, it is discrete and based on a roughly twenty-year time interval, which in practice is often not met.

Due to the fact that there is not a true renewal process, the USTs will continually degrade to an end-of-life asset. This is demonstrated by the fact that Tanks 1 and 19 have been taken out of service. The use of constant failure rates is common in risk assessments but would not apply to an end-of-life situation. Generally, once the corrosion allowance of an item is exhausted, then that component has reached its end of life and it is replaced. If it is not inspected or if left in service without repair, a higher failure rate reflecting the potentially greater contribution of corrosion to its failure is justified. Also, the thinner wall reduces its mechanical strength and hence would potentially increase failures related to reduced strength. The prior discussion, which showed the repair strategy, does not fully match the term renewal and would not support the use of a constant failure rate for these nearly 80-year old USTs that experience unmitigated backside corrosion, near end of life.

3.1.6.1 Acute Leaks

ABS estimated the risk of acute leaks, which are sudden releases of fuel. These calculations underestimate acute leak frequencies. Perhaps most importantly, the risk estimates for acute leaks provided by ABS do not even consider all potential scenarios by fuel releases from the RHBFSF that might occur as later phase risks were excluded from Phase 1. This first phase of what was initially planned as a four-phase quantitative risk assessment only considered certain internal events. Release initiating events such as fire, flood, and earthquakes, just to name a few, were not considered in ABS' Phase 1 analyses. Thus, the actual expected likelihood of future fuel releases is necessarily higher than initially reported by ABS. DNV GL demonstrates later in this section that the leak frequencies used by ABS for acute pipe leaks are well below currently accepted values in the oil and gas industry and thus predictions of leaks from pipe sources are also underestimates.

Various places within the QRVA and other documents refer to a 34% chance of an acute leak (≥ 120,000 gallons) in 100 years. In particular, the excerpt below is from Page ES-4 of the executive summary of the QRVA.

> "Given these risk thresholds of interest, the Phase 1 QRVA shows that the best point estimate cumulative frequency of event sequences leading to 120,000 gallons or greater of fuel release to the environment (outside the control and physical boundaries of the RHBFSF) that could potentially impact water table safety is 0.00417 events per

year (or about one event every 240 years). This yields an annual probability of occurrence of 0.00416 and a probability of occurrence over 100 years of 0.342 (or about a 34% chance of occurrence sometime during the next 100 years). Another way to think of this risk is that there is about a 66% likelihood that such an event will not occur over the next 100 years of facility operation." [B-15]

Reading such wording may lead one to believe that this implies the probability of a single acute leak in 100 years is 34.2%. This is misleading as this is really the probability of <u>at least one acute leak</u> during this time period. In the table below, Table 7, it is seen that 0.342 is the probability of one or more acute leaks in the number of years shown. In addition to the 100 years, a time frame of 20 years is also shown as this is approximately the tank maintenance interval utilized by the Navy. **As calculated by ABS, there is an 8% probability of having a 120,000 gallons leak within the inspection interval of the USTs.**

Table 7. Probability of having an acute leak (≥ 120,000 gallons) of the time periods of 20 and 100 years.

# Years	Probability of Acute Leak			
	≥ 1	1	2	3
20	0.080	0.077	0.003	<0.001
100	0.342	0.276	0.057	0.008

The above probabilities are based on the binomial distribution with the probability of an acute leak per year of 0.00417 as stated in the QRVA. A similar result to the 0.342 is 0.341 if a Poisson distribution is used as an approximation to the binomial that is often done in practice.

The key point of the above analysis is that 0.342 is not the probability of a single acute leak. Instead, the acute leak probabilities for 100 years are 0.276, 0.057, and 0.008 for exactly 1, 2, and 3 leaks, respectively. Thus, 0.342 and 0.080 are the probabilities of having 1, 2, or 3 leaks within 100 and 20 years, respectively.

The ABS report also provides predictions for other large acute events. The leak frequency for an acute leak event (120,000 gallons or greater) is reported as one event per 240 yrs. The Navy appears to take issue with its own consultants' conclusions as somehow too high or unrealistic, but reported leaks allow for direct comparison of ABS predictions with the actual historical record. The ABS analysis (Fig 12-2) shows that an acute release of between 1,000-30,000 gallons released is predicted to occur about 0.3/year or once per 3 years and a release between 30,000-60,000 gallons is predicted to be about 0.015/year or once per 70 years. There was a release of 27,000 gallons from Tank 5 in Dec 2013, which the Navy characterized as a 1 in 35-year event. [B-34] The value of 27,000 gallons is close to the upper limit of the first band (1,000-30,000 gallons) and also close to the lower limit of the second band (30,000-60,000 gallons). So, an estimate of predicted likelihood might be the average of those two estimates – once per 3 years and once per 70 years. This is once per 37 years, almost exactly what was observed. This does not support the Navy's contention that the ABS results are an overprediction.

Similarly, experience in the oil and gas industry shows leaks are not rare events. Unlike at the RHBFSF, however, fuel storage tanks in industry have secondary containment and other processes are in place to prevent leaks from entering the environment. Good leak statistics for process equipment are not readily available, but an exception is the UK Sector of the North Sea where a leak database has been developed after the Piper Alpha disaster in 1988 where a major leak event ignited and killed 167 workers – the worst offshore disaster in history. This data set over the period of 1992 to 2012 has 4283 leak events of all sizes recorded from 350+ installations [11]. This equates to 0.61 reported leaks per installation per year. While each offshore installation is more complex than the RHBFSF, they are easier to inspect and leaks are more obvious. Also, small leaks, which can be significant for the RHBFSF, may not be fully reported in the North Sea dataset. Given that an offshore installation is effectively one process unit and a refinery might be 20+ process units, the experience of leaks onshore and offshore is comparable. This is as would be expected as all the equipment is built to similar engineering codes with similar safety factors incorporated.

DNV GL has not been provided the opportunity to verify all the frequencies employed by ABS but a simple test was possible to compare pipework leak frequencies. ABS (p-5-134) used an average rate over several pipe diameters of 4.14×10^{-12} events/ft-hr (events per foot per hour) for small leaks and 6.75×10^{-13} events/ft-hr for large leaks. The International Association of Oil & Gas Producers (IOGP) has published its pipework failure rate based on data from the North Sea dataset covering 2006-2015 [12]. The tabulation of data for steel pipes is shown in Table 8. For a small leak, this might be equivalent to 1-3 mm in the tabulation and a large hole, 50-150 mm. As ABS considered 8", 18" and 36" pipes, it is sensible to use the 18" pipe data column. This provides a leak frequency of 7.8×10^{-6} events/m-yr (events per meter per year) for small holes and 9.4×10^{-7} events/m-yr for large holes. Converting ABS data in ft and hr into meters and years to allow direct comparison, the ABS values become 1.2×10^{-7} and 1.9×10^{-8} events/m-yr respectively. A comparison is shown in Table 9. ABS pipe leak events are much less than the IOGP values by 65x and 49x for small and large leaks, respectively. Therefore, ABS is significantly underestimating the risk from pipe leaks. IOGP also notes that leak rates in the offshore industry are declining with time as process installations fabrication and their inspection and maintenance improve. As the RHBFSF facility is over 75 years old, it may not have benefited from all the improvements seen in the oil and gas industry.

ABS failure rates for pipe leaks are underestimates and this may also be true for tank leaks – but this could not be verified. ABS Phase 1 QRVA also does not address risks to be addressed in Phase 2 (fire, flood, and earthquake risks). Thus, the ABS overall risk estimates are not likely to be overestimates of risk but may underestimate acute leak frequencies.

Table 8. Table extracted from IOGP showing the pipe leak events/m-year.[11]

HOLE DIA RANGE (mm)	2" DIA (50 mm)	6" DIA (150 mm)	12" DIA (300 mm)	18" DIA (450 mm)	24" DIA (600 mm)	36" DIA (900 mm)
1 to 3	3.6E-05	1.6E-05	1.1E-05	7.8E-06	6.9E-06	6.9E-06
3 to 10	1.5E-05	6.7E-06	5.1E-06	4.6E-06	4.4E-06	4.4E-06
10 to 50	6.6E-06	2.7E-06	2.5E-06	2.9E-06	3.0E-06	3.0E-06
50 to 150	2.4E-06	5.6E-07	6.4E-07	9.4E-07	1.0E-06	1.0E-06
>150	---	3.5E-07	5.6E-07	1.2E-06	1.6E-06	1.6E-06
TOTAL	6.0E-05	2.7E-05	1.9E-05	1.7E-05	1.7E-05	1.7E-05

Table 9. Comparison of IOGP and ABS pipe leak frequencies for an 18" pipe.

Leak size in 18" pipe	**IOGP events/m-yr**	**ABS events/m-yr**	**Difference ABS below IOGP by factor**
Small (1-3mm)	7.8×10^{-6}	1.2×10^{-7}	65x
Large (50-150mm)	9.4×10^{-7}	1.9×10^{-8}	49x

3.1.6.2 Chronic Leaks

ABS predicted a significant expected volume associated with slow chronic fuel releases from the RHBFSF, but their assessment likely underestimates the volume of chronic leaks. ABS documented the chronic leak criterion for 18 active tanks at the facility (the configuration of the facility at the time of their assessment). This was 41,400 gallons or greater per year for the entire facility. The QRVA report highlights possible leak rates that would be undetectable. ABS' analysis shows that the expected chronic release rate is 5803 gallons per year (gpy). The value includes assumptions for the quantity of the leak until it is detected plus the amount that continues to leak until the tank can be emptied. This estimate is also based on assumptions related to corrosion growth rates, as well as an assumption significantly weighting a lower leak value. [B-15 at 5-165] This assumption was not adequately justified. Thus, the ABS chronic leak prediction is based on multiple assumptions and may be significantly underestimated. Figure 18

Certain chronic leaks could be detected by the currently installed continuous AFHE level monitoring system [B-15 at 5-157], which will alarm at a level decline of 0.5 inches and 0.75 inches. The first alarm corresponds to a leak of 2,456 gallons and the latter to 3,684 gallons. This leak detection is only feasible if the tank level is constant and no fuel is added or removed. An assessment of the AFHE system response for the Tank 5 release shows that the AFHE system required one month to identify the leak of 27,000 gallons (but potentially up to 39,312 gallons). [B-276] ABS did not use the predicted chronic leak rate from Fig 5-17 [B-15] as it is assumed they believe the AFHE system will trigger a Navy response, but the QRVA report is lacking documentation in this regard. ABS discussed this on p5-157 but also noted that, even if the tank level is not changed over several months, other tank activities, such as fuel sampling or water drainage would occur, and this would complicate detection by the AFHE system. The logic used by ABS in rejecting its own calculations (shown in ABS Fig 5-17 and reproduced in Figure 18) has not been adequately justified. Their analysis shows that exceeding a chronic leak threshold of 41,400 gpy has a probability of 0.07/year or once in 14 years.

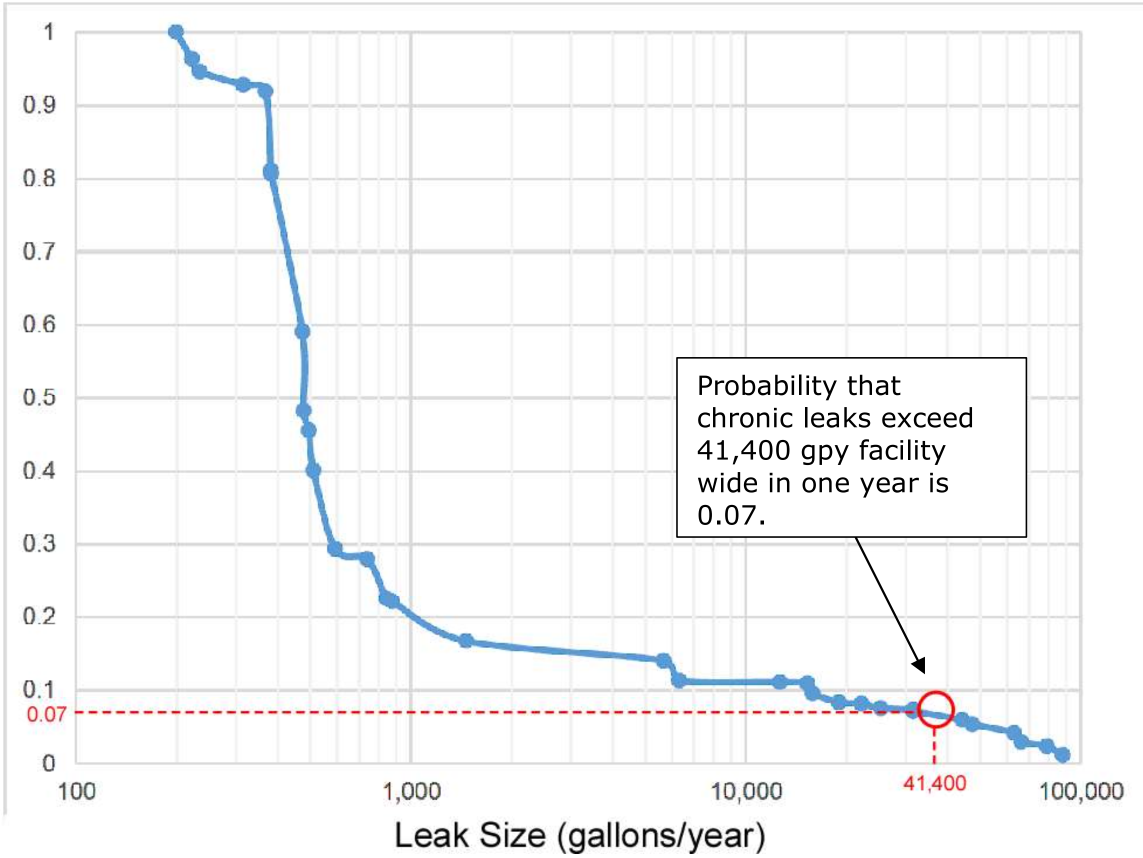


Figure 18. Plot extracted from ABS Report showing the cumulative leak probability per year (y-axis) vs chronic leak size (x-axis).

3.1.7 Summary

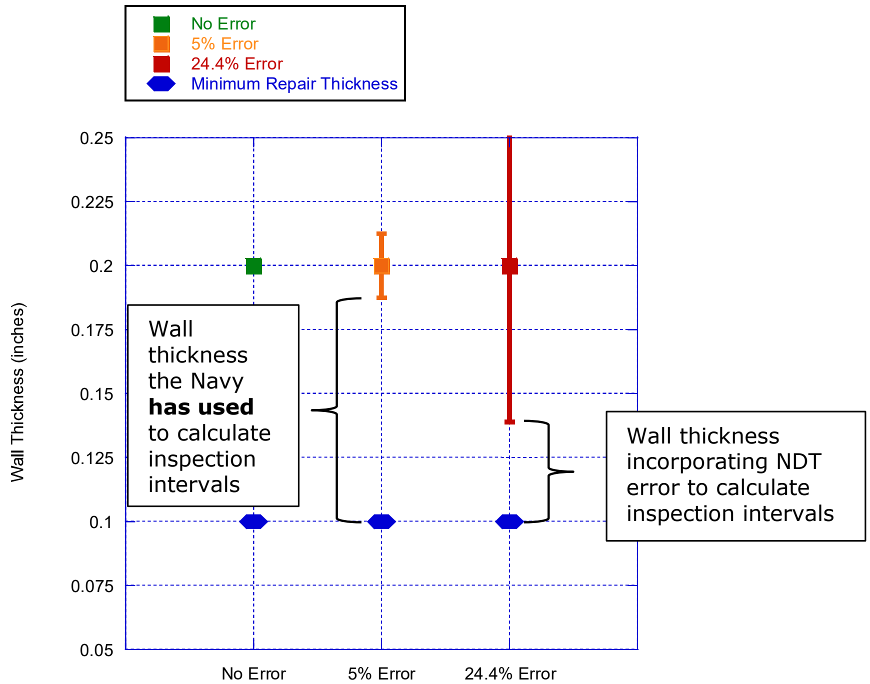
At least 72 fuel release incidents associated with the USTs at the RHBFSF, correlating to nearly one leak per year, have occurred. As demonstrated by the API 653 inspections and the destructive testing that has been conducted on steel liner samples removed from Tank 14, the current inspection technologies, practices, and procedures cannot accurately detect, identify, or size the corrosion and fabrication anomalies/defects associated with the steel liner in each Red Hill tank.

Despite not being able to accurately detect, identify, or size corrosion anomalies, the Navy has elected to move to both a less conservative corrosion growth rate and a less conservative acceptable corrosion depth for the operation of these assets. This is counterintuitive and goes against all industry norms for managing aging assets, particularly high risks assets. In fact, in a letter to the Navy rejecting the justification for its proposed TUA decision the EPA/DOH states that the Navy "should explain:

- How the risk due to limitations of the NDE process to detect back side corrosion and weld flaws that could develop into a leak through the steel lining will be addressed; and
- How risk from potential back side corrosion of the steel liner, which may be due to lower pH and concrete passivation loss (indicative of a corrosive environment) will be mitigated."

As shown and discussed above, the NDE practices failed to meet the performance metric, ±8% (20 mils), or tool tolerance of ± 5%. An analysis was performed to determine the tool tolerance whereby the current LFET NDE results would pass the API 1163 criteria. It was determined that the tool tolerance must be extended from ± 5% to ± 24.4% to meet this standard. LFET methodology is used to scan 100% of the liner plates and find areas that do not meet a set thickness criterion for follow up PAUT prove up measurements. If the accuracy of the LFET methodology is much less than stated – which is apparent based on the destructive testing conducted to date - then there is a probability that areas of the liner with less than the target remediation thickness are left unmitigated in the tank. This is represented graphically in Figure 19. To account for the large potential errors in the NDE technique, the actual reinspection interval must be reduced dramatically to prevent areas from corroding below the minimum thickness level required and potentially developing through wall defects. For example, using the parameters from the 2017/2018 Tank 14 inspection, a 20-year reinspection interval is reduced to 3.8 years; less than $1/5^{th}$ of the current planned reinspection interval of 20 years.

In summary, the Navy continues to reduce the repair threshold for its USTs even though they have demonstrated the inaccuracies of their inspection methodology. These inaccuracies combined with the resulted thinner wall left unrepaired increase the risk of unmitigated underside corrosion resulting in a through-wall defect and a release of stored materials to the environment. Thus, the Navy has not and cannot demonstrate that it can safely operate the RHBFSF USTs without fuel releases for the operational life of the tank system, a requirement not only in the State of Hawaii but for all other operators in the oil and gas industry.



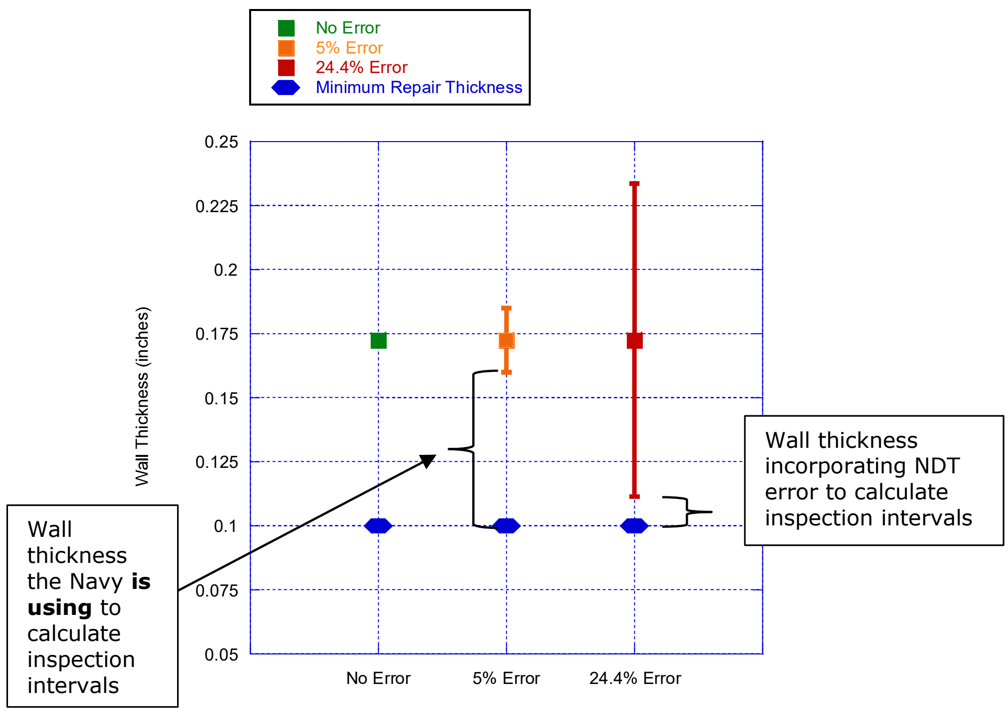


Figure 19. Plots showing API Inspection repair thresholds from 2005/2006 (top) and 2017/2018 (bottom) incorporating error associated with the NDE measurements from Tank 14 destructive testing results.

3.2 The Navy cannot mitigate the primary integrity threat to the USTs at the RHBFSF, underside corrosion.

The RHBFSF USTs are not adequately protected from corrosion. The USTs at the RHBFSF are fabricated using a carbon steel liner for product containment and carbon steel framing and reinforced concrete for structure support. This is highlighted in the discussion presented in Section 1.0. Carbon steel will degrade (corrode) in the presence of an aqueous environment if left unmitigated. This is evidenced by the number of reported leaks that have already occurred at RHBFSF, the results of prior API 653 inspections, and the observations and findings from the Destructive Analysis and Testing performed on the coupons removed from Tank 14. Corrosion is occurring on the underside of the USTs and will continue to occur in the future.

Corrosion is an irreversible deterioration process of a material resulting from a chemical or electrochemical reaction with its local environment. At temperatures near ambient, the corrosion process is almost always electrochemical in nature. In carbon steels, the corrosion process can be illustrated as shown in Figure 20. This process requires an electrolyte (such as water [H_2O] as illustrated), a cathodic reaction such as water reduction (in neutral pH deaerated water) or oxygen (O_2) reduction (in aerated water), and transfer of current (electrons) between the anodic (-) to the cathodic (+) reactions. The process for corrosion of iron (Fe) can be summarized as the combination of two electrochemical reactions, one anodic and one cathodic.

Anodic Reaction	$Fe \rightarrow Fe^{2+} + 2e^-$
Cathodic Reaction (deaerated conditions)	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$
Cathodic Reaction (aerated conditions)	$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

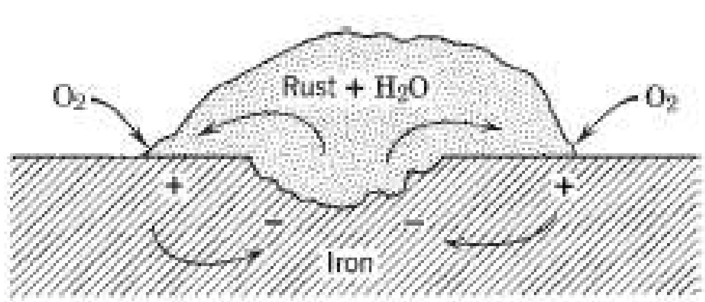


Figure 20. Illustration showing the corrosion process on carbon steel. [Uhlig Corrosion and Corrosion Control, Fourth Edition, 2008].

Eliminating water or any one of the species associated with the electrochemical reactions effectively mitigates the corrosion process. Alternatively, the corrosion process can be mitigated by electrically interfering with (cathodically polarizing) the electrochemical reactions. This is commonly referred to as cathodic protection (CP) within the tank and pipeline industry.

For the USTs at the RHBFSF, the water or electrolyte that is in contact with the carbon steel liners and facilitating the corrosion reactions is likely rainwater that has permeated through the soil and concrete tank shell, picking up ionic species and other constituents. The chemical composition of this electrolyte is likely much different from the nascent chemistry of rainwater.

Based on the fundamental science of the corrosion process, the Navy has three options to mitigate the primary threat to the leak integrity of the USTs:

- Remove the water;
- Remove the oxygen; or
- Apply cathodic protection to the steel liner.

Removal of water and oxygen in underground environments is unrealistic and cannot be achieved and has thus driven an emphasis and requirements within the tank and pipeline industry for the application of cathodic protection. For example, Title 40 of the Code of Federal Regulations (CFR) Part 280 pertaining to UST systems and Hawaii UST rules (HAR Chapter 11-280.1) require that USTs that "routinely contains product must be protected from corrosion" by means of one of the following:

1. The tank is constructed of fiberglass-reinforced plastic;
2. The tank is constructed of steel and cathodically protected;
3. The tank is constructed of steel and clad or jacketed with a non-corrodible material;
4. The tank is constructed of metal without additional corrosion measures provided that the tank is installed at a site that is determined by a corrosion expert not to be corrosive enough to cause it to have a release due to corrosion during its operational life; or
5. The tank construction and corrosion protection are determined by the department to be designed to prevent a release.

The USTs at RHBFSF were not constructed of fiberglass-reinforced plastic. Nor were the RHBFSF designed or constructed in a manner conducive to the application of cathodic protection. The condition of the concrete structural support does not serve as a barrier to water ingress, and therefore is not a barrier to corrosion, such as cladding or jacketing. This is verified by the presence of backside corrosion that has been identified through multiple API 653 inspections and destructive testing, as well as evidence (discussed in Section 3.1.3) that indicates the concrete is deteriorating with time.

The RHBFSF USTs cannot be considered clad or jacketed as such terms are defined by or understood in industry practice. Federal regulations, 40 CFR Part 280, identify technical guidance and codes of practice, that "may be used to comply" as clad or jacketed systems, refer to Figure 21. [13-16]

(3) The tank is constructed of steel and clad or jacketed with a non-corrodible material; or

Note to paragraph (a)(3).
The following codes of practice may be used to comply with paragraph (a)(3) of this section:

(A) Underwriters Laboratories Standard 1746, "External Corrosion Protection Systems for Steel Underground Storage Tanks";

(B) Steel Tank Institute ACT-100® Specification F894, "Specification for External Corrosion Protection of FRP Composite Steel Underground Storage Tanks";

(C) Steel Tank Institute ACT-100-U® Specification F961, "Specification for External Corrosion Protection of Composite Steel Underground Storage Tanks"; or

(D) Steel Tank Institute Specification F922, "Steel Tank Institute Specification for Permatank®".

Figure 21. Excerpt from CFR 40 Part 280.

These codes of practice pertain to clad or jacketed systems that are fabricated using fiberglass reinforced plastic (FRP) and/or resin-based products. Furthermore, these standards define ***cladding*** as "a resin, laminate or coating that is tightly adhered to the tank forming a significant dielectric barrier between the tank and its environment…," and provide "approved resin systems" and corresponding manufacturers [13, 15]. There is no ambiguity as to what constitutes a cladding. The RHBFSF USTs do not exhibit a tightly adhered or bonded barrier to the environment. ASTM E2681, Standard Guide for Environmental Management of Underground Storage Tank Systems Storing Hazardous Substances or Petroleum, defines Composite Clad Steel Tanks as a "steel tank with a nonmetallic laminate such as fiberglass or urethane applied to the tank exterior which provides a significant dielectric barrier between the steel tank and … the electrolyte [17]." The USTs at the RHBFSF just do not meet the minimum definition of a clad system.

The Steel Tank Institute Standard F922 pertains to a jacketed UST system, Permatank®, "that combines a steel inner tank within a fiberglass reinforced outer containment" [14]. The standard further defines the term ***jacketed tank*** as "A single or double walled steel tank, manufactured in accordance with UL 58 and is allowed by this specification, with FRP wrap applied upon its exterior which provides either secondary or tertiary containment. The jacket surrounds the steel tank creates an annular space between the jacket and the steel. The annular space is to be vacuum testing for tank tightness of the outer containment FRP to ensure that there are no breaches in the jacket. ASTM E2681 also defines jacketed steel tanks as tanks utilizing a “nonmetallic jacket (such as FRP)” and a “factory installed vacuum gauge to monitor the interstitial space between the tanks” [17]. Similar to the definition of cladding, there is no ambiguity as to what constitutes a jacketed tank. The construction of the USTs at the RHBFSF are not clad or jacketed systems. In both cases, the concrete supporting the carbon steel liner does not meet the established criteria or definitions of a clad or jacket.

The concrete shells of the RHBFSF are cracked and/or perforated, and deteriorating, resulting in pathways for water to contact the steel liner. **The Navy is aware of the presence of backside corrosion that continues to occur on all of the USTs that have undergone API inspections at the RHBFSF.** There is no reason to believe that backside corrosion is not occurring on any of the tanks that have not yet undergone an API inspection. Based on this documented backside corrosion and the science of the corrosion process, no expert could credibly determine that the RHBFSF site is not corrosive enough to cause a corrosion-induced release during the operational life of the USTs. Finally, with their antiquated tank construction practices and lack of corrosion protection, the RHBFSF USTs are not designed to prevent releases in a manner that is equally protective of human health and the environment as fiberglass construction, cathodic protection, or proper cladding or jacketing. Simply put, the Navy does not employ any of the necessary UST corrosion protection alternatives at the RHBFSF.

Testimony by Navy witness Ms. Danae Smith states that “The EPA guidance for UST regulations at 80 FR 41566 (Navy Exhibit 81), page 41595, states that “[m]etal tanks and piping which are encased or surrounded by concrete **have no metal in contact with the ground** and are not subject to the corrosion protection requirements.” See also Navy Exhibit 80, the Requirements for Field-Constructed Tanks and Airport Hydrant Systems, October 2017, which describes the following method of construction to protect tanks from corrosion: “[t]ank is made of steel and **completely isolated from contact with the surrounding soil** by being enclosed or jacketed in noncorrodible material, such as concrete.” The tanks at Red Hill have no metal in contact with the ground because they are separated from the ground on all sides by a layer of concrete.” The Navy references EPA guidance; however, due to construction practices and likely deterioration of the concrete, the concrete does not eliminate or **completely isolate** the metal liner from contact with water that is coming from the surrounding soil. In fact, moisture and corresponding corrosion were identified on several of the coupons removed as part of the destructive testing. Testimony provided by Mr. Jamond states “The presence of moisture indicated there is potential for corrosion to occur or continue. The presence of corrosion product indicated that some corrosion had occurred.”

The corrosive properties associated with soil are not inherently associated with the particulates that comprise the soil, but rather the ionic species and compounds that are soluble in an electrolyte, such as water. It is for this reason that the corrosion community commonly performs laboratory corrosion studies and research programs using simulated soil solutions (simulants) that do not contain any particulates. Although the concrete may separate the steel liner of the USTs from the particulates in the soil, the concrete does not **completely isolate** the liner from the corrosive electrolyte (moisture) that has been visually verified at multiple locations and indirectly verified at each and every backside corrosion anomaly.

The concrete surrounding the tanks does not meet the design or regulatory intent to isolate the steel liner from the corrosive species and electrolytes found in the ground and cannot be reasonably considered as corrosion protection in its current condition. This is supported by the recent API inspections of Tanks 5, 13, and 14, which identified backside corrosion requiring repairs that:

> “will be unlike any previous repairs done at the Red Hill Facility and will require extensive design and construction considerations. Repairs could include the removal of existing shell plates and inserting new plate or welding patch plates to cover the affected areas.” [B-297, B-298, B-300]

3.3 There is insufficient information to determine whether or not the Navy can meet release detection requirements.

The Navy has not established that it can meet applicable release detection requirements. The Navy states in its permit application that the release detection technology applied to the RHBFSF USTs, a differential pressure system produced by Mass Technology Corporation, is capable of detecting a leak rate of at least 0.5 gallon per hour (gph). It is not clear, however, that the Navy is actually able to detect a leak rate of 0.5 gph.

Leak detection is a critical means to minimize the environmental damage caused by releases of fuel as no mitigation actions can be taken until the leak is detected. Currently leak detection at the RHBFSF primarily relies on annual or semi-annual tank tightness testing and the installed AFHE level monitoring system. Tank tightness is a level detection method based on a Mass Technology Corporation tool that measures the pressure at the bottom and the surface of the tank to determine tank level and whether a leak is occurring. In order to be accurate, the fuel level must not be added to or reduced during the test, so the tank is taken out of service for a full 5 days (i.e., for the duration of the test). The test has been represented as being capable of detecting leak rates of 0.5 gph. Currently tank tightness tests are carried out semi-annually and leaks that start shortly after a test can persist for 6 months before a follow-up tank tightness test can determine the leak. The AFHE level monitoring system can detect leaks but as discussed earlier, the 27,000 gallon leak from Tank 5 took one month to detect due to simultaneous operational activities.

Navy has provided limited materials in support of its position. The Final 2018 Annual Leak Detection Testing Report of 17 Bulk Field-Constructed Underground Storage Tanks at the Red Hill Fuel Storage Complex of January 2019, is redacted and the data referenced in the report has not been produced. Based on the information that has been provided in this report, ten (10) of the 18 operational USTs were tested per the test requirements. Four (4) tanks were not tested due to being out of service at the time of the testing. An additional four (4) tanks were tested but not per the full test liquid height requirements. It is unknown if the Navy is currently restricting the fill height in those tanks; otherwise, they could be using portions of these tanks to store fuel that were above the testing height (i.e., locations that have not been tested).

The Mass Technology test reports attached as Appendix B include linear regression plots and certain statements that indicate the recorded data resulted in a change rate detected below the minimum detection level of 0.5 gph. While the methodology used has been represented as certified by the National Work Group on Leak Detection Evaluations (NWGLDE), these claims cannot be independently verified (i.e., that the methodology produces the necessary results) without the underlying data. Although a comprehensive technical analysis of the Navy's release detection technology is not possible without the missing data, the known limitations of the tool and the information available in the leak detection report raise concerns about the potential utility of the tool and/or the Navy's interpretation of the testing results. Specifically, the leak detection technology exhibits the same limitations as a tank tightness test. That is, the method requires that the tank be isolated from filling or emptying activities and to stay static for several days. Historically tank tightness testing was only performed annually or semi-annually. Thus, chronic leaks could persist for many months before a subsequent tightness test.

In addition, Figure 22 and Figure 23 are plots from the Navy's leak detection report that represent testing performed in 2018 for Tanks 10 and 11, respectively. The linear regression plots show the mass measurement (ft H_20) on the y-axis and time (hours) on the x-axis. Horizontal lines have been added to the plots. Comparing the deviations of the mass measurement to the horizontal lines, it is clear that there is a more pronounced "drift" of the measured values for Tank 11. A trend of this type of drift can be indicative of a leak in a tank. Given the redacted nature of the Navy's leak detection report, including the absence of the data itself, DNV GL is unable to conclusively determine the actual cause of the drift that appears to be depicted in this report. In fact, it is difficult to draw any conclusions without additional information, including contemporaneous temperature, pressure, and density monitoring data and the calculations, if any, used by Mass Technology to compensate for variations throughout the test. It is clear, however, that additional documentation is necessary to fully understand whether the Navy is able to detect a leak rate of 0.5 gph, and the Navy has not provided sufficient information in its permit application to do so.

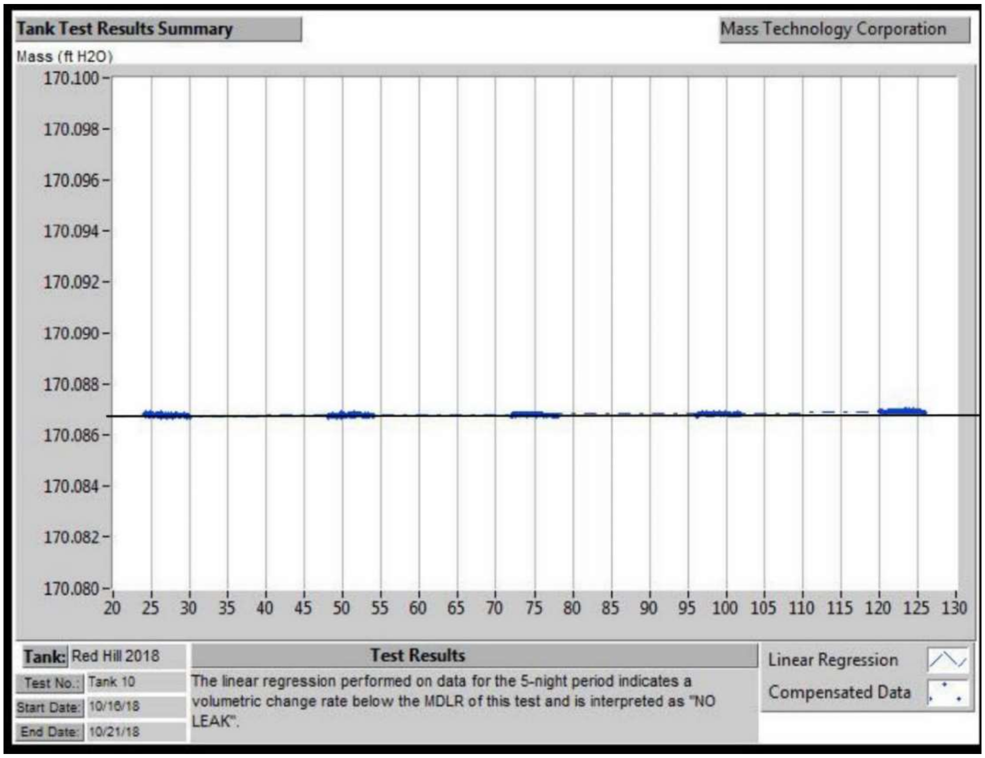


Figure 22. Plot produced from tank tightness testing performed on Tank 10 in 2018.

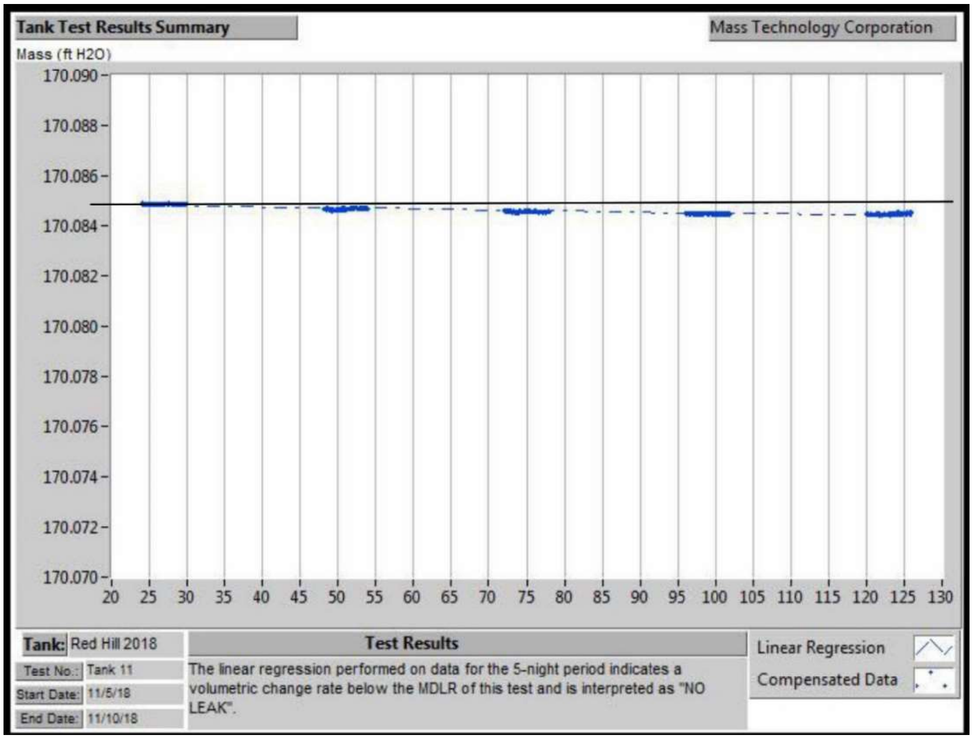


Figure 23. Plot produced from tank tightness testing performed on Tank 11 in 2018.

3.4 Conclusion

For all of the reasons and concerns discuss above, it is the opinion of DNV GL that fuel releases from the Navy's USTs will continue to occur at the RHBFSF. The Navy has not adequately demonstrated that it can manage the integrity of the RHBFSF USTs such that future releases will not occur, nor has it implemented any structural improvements to prevent these releases from entering the surrounding environment. Without a means to properly mitigate corrosion, accurately detect leaks, or sufficiently prevent environmental impacts, it is DNV GL's opinion that the USTs at RHBFSF and corresponding infrastructure should be relocated to an area that does not have the potential to adversely impact drinking water resources. If this is untenable, the Navy should provide adequate reasoning to justify this opinion, and move expeditiously to modify the existing USTs to ensure tank-with-a-tank secondary containment with a sufficient annular space to enable inspection, maintenance, testing, and repair of the external surfaces of the new inner tank and internal surfaces of the existing external tank (liner in their current configuration).

4.0 TECHNICAL REFERENCES

1. Murphy, L.M. and F.P. Ulrich, *U.S. Geological Survey United States Earthquakes*, D.o.t. Interior, Editor. 1948. p. 27.
2. ASME, *B31.8S: Managing System Integrity of Gas Pipelines*. 2018, The Americal Society of Mechanical Engineers.
3. Usher, K.M., et al., *Critical review: Microbially influenced corrosion of buried carbon steel pipes.* International Biodeterioration & Biodegradation, 2014. 93: p. 84-106.
4. Panarese, W.C., *Environmental Performance of Concrete*, in *Corrosion: Materials*, S.D. Cramer and B.S. Covino, Editors. 2005. p. 579-588.
5. Bertolini, L., et al., *Corrosion of Steel in Concrete*. 2nd Edition ed. Vol. 392. 2013: Wiley Online Library.
6. Kodama, T., *Corrosion of Wrought Carbon Steels*, in *Corrosion: Materials*, S.D. Cramer and B.S. Covino, Editors. 2005, ASM. p. 5-10.
7. Tinnea, J., et al., *Corrosion in Bridges and Highways*, in *Corrosion: Materials*, S.D. Cramer and B.S. Covino, Editors. 2006.
8. Wulpi, D.J., *Understanding how components fail*. 2013: ASM international.
9. Papazoglou, I.A., et al., *NUREG/CR-2815 Probabilistic Safety Analysis Procedures Guide*, O.o.N.R. Research, Editor.
10. Society, T.A.N., *NUREG/CR-2300 PRA Procedures Guide: A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Plants*, D.o.N. Energy, Editor.
11. Bolsover, A., A. Falck, and R. Pitblado, *A Public Leak Frequency Dataset for Upstream and Downstream Quantitative Risk Assessment*. 2013: AIChE Global Conference on Process Safety, San Antonio.
12. Producers, I.A.o.O.G., *Risk Assessment Data Directory Process Release Frequencies*. 2019, International Association of Oil & Gas Producers.
13. Institute, S.T., *ACT-100-U® SPECIFICATION FOR EXTERNAL CORROSION PROTECTION OF COMPOSITE STEEL UNDERGROUND STORAGE TANKS - F961*. 2017.
14. Institute, S.T., *Permatank®: F922 - Specification for Permatank®*. 2017.
15. Institute, S.T., *ACT-100® SPECIFICATION FOR EXTERNAL CORROSION PROTECTION OF FRP COMPOSITE STEEL UNDERGROUND STORAGE TANKS - F894*. 2018.
16. Laboratories, U., *UL Standard 1746 - External Corrosion Protection Systems for Steel Underground Storage Tanks*. 2007.
17. ASTM, *E2681 - Standard Guide for Environmental Management of Underground Storage Tank Systems Storing Hazardous Substances or Petroleum*. 2013.

APPENDIX A

CV's

David M. Norfleet, Ph.D., P.E.

Head of Section, Incident Investigation

Curriculum Vitae

DNV GL USA, INC.
Pipeline Services Department
5777 Frantz Road
Dublin, OH 43017-1386
Tel: (614) 761-1214
Fax: (614) 761-1633
www.dnvgl.com
www.dnvusa.com

Dr. Norfleet is the Head of Section for the Incident Investigation Group within the Pipeline Services Department at DNV GL USA, Inc. (formerly CC Technologies). Dr. Norfleet is a graduate of The Ohio State University, where he received his Ph.D. in Materials Science and Engineering. Technological interests, experience, and research have provided him with an advanced understanding of the mechanical behavior and failure mechanisms associated with many different material systems.

Dr. Norfleet consults on multidisciplinary failure investigations for a variety of industries, including Oil and Gas and consumer products. His background and experience in metallurgy, corrosion, microscopy, and fatigue and fracture have provided him with the knowledge and skill sets necessary to consult and advise on projects pertaining to a variety of materials and manufacturing processes. Dr. Norfleet has consulted on matters presiding before both State and Federal Courts.

Areas of specialization include: Engineering Failure Analysis, Metallurgy, Corrosion, Mechanical Behavior, Fatigue and Fracture, Fractography, and Materials Characterization (Scanning Electron Microscopy (SEM), Focused Ion Beam (FIB), Transmission Electron Microscopy (TEM), Energy Dispersive Spectroscopy (EDS/EDX).

Education

Ph.D., Materials Science and Engineering, The Ohio State University
M.S., Materials Science and Engineering, The Ohio State University
B.S., Materials Science and Engineering, The Ohio State University

Professional Registration

Dr. Norfleet is a Licensed Professional Engineer (P.E.) in the state of Illinois.

Experience

Principal Engineer	DNV GL USA, Inc. Dublin, Ohio	2014 – Present
Senior Engineer	Det Norske Veritas (U.S.A.), Inc. (formerly CC Technologies)	2011 – 2013
Senior Staff Consultant	Engineering Systems Inc. (ESI) Aurora, IL	2011
Staff Consultant	Engineering Systems Inc. (ESI) Aurora, IL	2007 – 2010
Graduate Research Associate	The Ohio State University Materials Science and Engineering	2002 – 2007

Professional Activities

American Society for Materials (ASM International)

Member
Editorial Board Member, *Journal of Failure Analysis and Prevention*
ASM Failure Analysis Committee Member (2008-Present)
ASM Emerging Professionals Committee Member (2009-2012)
ASM Chicago Regional Chapter Board Member (2010)
Chair, "Failure Analysis: Fatigue and Fracture," MS&T 2012
Chair, "Failure Analysis: Tools and Techniques," MS&T 2009
Chair, "Failure Analysis: Tools and Techniques," MS&T 2008

American Society for Mechanical Engineers (ASME)

Member

International Pipeline Conference (IPC)

Chair, "In-Line Inspection – Technology Advancements," IPC 2014

National Association of Corrosion Engineers (NACE)

Member

American Society for Testing and Materials (ASTM)

ASTM E58: Forensic Engineering Committee Member

International Metallographic Society (IMS)

Member
Chair, "Failure Analysis: Applications of Electron Microscopy," M&M 2011
Chair, "Failure Analysis: Practical Metallography/Fractography in Case Studies," M&M 2009
Chair, "Three-Dimensional Imaging in the Biological and Materials Sciences: Bridging Nano and Micron Scales," M&M 2009

Midwest Microscopy and Microanalysis Society

Member (2007-2010)

Professional Recognition

Alpha Sigma Mu Member, Materials Science and Engineering Honor Society

International Metallographic Society (IMS)
1st Place Award in Artistic Electron Microscopy (2007)
1st Place Award in Digital Analyses Technology, Metallography Category (with F.E. Schmidt, 2009)

Additional Education

Principles of Failure Analysis, ASM International World Headquarters, 2007.

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Books Chapters

1. **D. M. Norfleet** and J. A. Beavers, Chapter 13 – Aqueous Corrosion Failures, Understanding How Components Fail, Third Edition, 2013.

2. **D. M. Norfleet** and J. A. Beavers, Chapter 2 – Stress-Corrosion Cracking of Carbon and Low-Alloy Steels (Yield Strength Less Than 1241 MPa), Stress Corrosion Cracking, Materials Performance and Evaluation, Second Edition, 2017.

3. **D. M. Norfleet** and J. A. Beavers, Chapter 2 – Stress-Corrosion Cracking of Copper Alloys, Stress Corrosion Cracking, Materials Performance and Evaluation, Second Edition, 2017.

Publications and Presentations

1. Ralston, K. D., Padgett, B. N., Beavers, J. A., **Norfleet, D. M.**, Delanty, B. S., Klages, M. B. Prewitt, T. J. (2019, May 15). Laboratory Testing in Leachate Environments to Understand Stress Corrosion Cracking on an Insulated Above-Ground Pipeline. NACE International.

2. Ralston, Kevin D., Padgett, Barbara N., **Norfleet, David M.**, Cao, Liu, Delanty, Burke S., Klages, Mark B., Beavers, John A., and Prewitt, Thomas J.. "Root Cause Analysis of an Above-Ground Pipeline With Stress Corrosion Cracking." Proceedings of the 2018 12th International Pipeline Conference. Volume 1: Pipeline and Facilities Integrity. Calgary, Alberta, Canada. September 24–28, 2018.

3. Narasi Sridhar, John A. Beavers, Feng Gui, Liu Cao, Greg Quickel, Barbara Padgett, and **D. M. Norfleet**, "Materials Compatibility Issues with Ethanol Storage and Transportation – A Review," NACE Corrosion 2017 Conference and EXPO, New Orleans, Louisiana, March 26 – 30, 2017, Paper Number 10039.

4. **D. M. Norfleet**, J. A. Beavers, "Corrosion-Related Threats to Oil and Gas Pipelines," NACE Corrosion Risk Management Conference, 2016.

5. **D. M. Norfleet**, G. T. Quickel, J. A. Beavers, and H. Deeb, "Pump Stations and Terminal Facilities – Material Compatibility with Ethanol," NACE Corrosion 2015 Conference, 2015, Paper Number C2015-6104.

6. M. R. Chebaro, N. Yoosef-Ghodsi, **D. M. Norfleet**, J. H. Berman, A. C. Sutton, "Experimental and Analytical Leak Characterization for Axial Through-wall Cracks in a Liquids Pipeline," IPC2014-33037, 10th International Pipeline Conference, Calgary, Alberta, Canada, September 29 – October 2, 2014.

7. B. N. Padgett, M. R. Chebaro, **D. M. Norfleet**, J. A. Beavers, and S. D. Ironside, "Methanol-Induced Axial Stress Corrosion Cracking in a Northern Canadian Liquids Pipeline," IPC2014-33033, 10th International Pipeline Conference, Calgary, Alberta, Canada, September 29 – October 2, 2014.

8. Chebaro, M. R., Padgett, B. N., Beavers, J. A., **Norfleet, D. M.**, Ironside, S. D., "Methanol-Induced Internal Stress Corrosion Cracking In A Northern Petroleum Pipeline, NACE Corrosion 2014 Conference and EXPO, San Antonio, Texas, March 9 – 13, 2014, Paper Number C2014-3985.

9. Dimiduk, D. M., Uchic, M. D., Rao, S. I., Shade, P. A., Woodward, C., Viswanathan, G. B., Nadgorny, E. M., Palasik, S., **Norfleet, D. M.**, Mills, M. J., “Strengthening and Plastic Flow of Ni3Al Alloy Microcrystals,” (2013) Philosophical Magazine, 93 (1-3), pp. 96-120.

10. **David Norfleet**, Matt Kenner, John Wilkinson, “Failure Analysis of a Motorcycle Footrest,” Materials Science & Technology 2013, October 27 – 31, 2013, Montreal, Québec, Canada.

11. **D. M. Norfleet**, G. T. Quickel, and J. A. Beavers, “Determining the Effects of Ethanol on Pump Stations and Terminal Facilities – Guidelines Document, PR-186-12204-R02, 2013.

12. **D. M. Norfleet**, M. E. Stevenson, J. A. Wilkinson, M. T. Kenner, and D. B. Brickman, “Failure Analysis of a Commercial Brush Chipper Hood,” Case History in Journal of Failure Analysis and Prevention, Volume 11, No. 6, 2011.

13. **D. M. Norfleet**, Emerging Professionals Corner, Advanced Materials and Processing, Volume 168, No. 8, Issue 8, 2010.

14. F. E. Schmidt and **D. M. Norfleet**, “Impact Fatigue Failure of Ordnance Components,” Microscopy and Microanalysis Proceedings, Richmond, VA, July 2009.

15. **D. M. Norfleet**, P. M. Sarosi, S. Manchiraju, M. F.-X. Wagoner, M. D. Uchic, P. M. Anderson, and M. J. Mills, “Transformation-induced Plasticity during Pseudoelastic Deformation in Ni-Ti Microcrystals,” Acta Materialia, Volume 56, Issue 13, 2008.

16. F. E. Schmidt, **D. M. Norfleet**, and K. L. Johnson, “Improper Weld Repair of a CF8M Cast Stainless Steel Impeller,” Microscopy and Microanalysis, Volume 14, Supp. 2, 2008.

17. A. L. Pilchak, **D. M. Norfleet**, M. C. Juhas, and J. C. Williams, “Friction Stir Processing of Investment Cast Ti-6Al-4V: Microstructure and Properties,” Metallurgical Transactions A, Volume 39, No. 7, 2008.

18. **D. M. Norfleet**, J. C. Williams, S. Ghosh, M. J. Mills, and S. Rokhlin, “The Use of Modeling and Experiment to Understand “Dwell Fatigue” in Ti Alloys,” The 11th World Conference on Titanium 2007 Symposium Proceedings.

19. D. A. Turnquist and **D. M. Norfleet**, “Investigation of Wheel Bolt Failures,” Materials Science and Technology Conference, Fatigue and Fracture Session in the Failure Analysis Symposium, Houston, TX, October 21, 2010.

20. M. A. Hineman, **D. M. Norfleet**, and J. L. McDougal, “Best Practices for Scanning Electron Microscopy and Energy Dispersive Spectroscopy in Forensic Examinations,” Materials Science and Technology Conference, Pittsburgh, PA, October 2009.

21. F. E. Schmidt and **D. M. Norfleet**, “Digital Radiography in Failure Analysis: X-ray vs. Neutron,” ASNT Chicago Section, March 2009.

22. **D. M. Norfleet**, D. E. Alexander, J. Gauthier, and C. Cherry, “Radiography in Failure Analysis: X-ray vs. Neutron,” Materials Science and Technology Conference, Pittsburgh, PA, October 2008.

23. **D. M. Norfleet**, M. J. Mills, D. M. Dimiduk, M. D. Uchic, and S. J. Polasik, "Correlating Changes in Dislocation Substructures to Plasticity Size-Effects in Nickel and Titanium Alloys," TMS Annual Meeting and Exhibition, San Antonio, TX, 2006.

24. **D. M. Norfleet**, M. J. Mills, J. C. Williams, and M.D. Uchic "Anisotropy and Size Effects in the Plastic Deformation of Ti-6242 Single Colonies," Materials Science and Technology Conference, New Orleans, LA, November 2004.

25. **D. M. Norfleet**, M. J. Mills, J. C. Williams, and M. D. Uchic "Mechanical Property Measurements of a Near Alpha Titanium Alloy at the Micron-Size Scale," Poster Presentation at Gordon Research Conference: Physical Metallurgy, July 2004.

26. **D. M. Norfleet**, M. J. Mills and J. C. Williams, "Use of a FIB as a micro-machining tool: Study of local mechanical properties and deformation mechanisms during dwell fatigue in Ti-6242," TMS Annual Meeting and Exhibition, Charlotte, NC, 2004.

27. **D. M. Norfleet**, M. J. Mills and J. C. Williams, "Tension/Compression Asymmetry, Anisotropy and Size Effects in the Plastic Deformation of Ti-6242 Single Colonies," Materials Science and Technology Conference, Chicago, IL, 2003.

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CURRICULUM VITAE

(CV generation date: 2019-07-14)

Robert Barbeauld

Principal Engineer

Education

Field of expertise	University/School	Year
Bachelor of Science, Mechanical Engineering	Georgia Institute of Technology	Dec 1985

Employment

Colonial Pipeline Company **Jun 2008 - Sep 2018**

Position:	VP Technical Services
Description:	My primary responsibility was to lead a department to provide technical support for Colonial operations. That support included engineering (civil, mechanical, electrical, hydraulic, controls); regulatory compliance (Integrity Management Program); supervisory, communications, and data acquisition (SCADA) for the pipeline control center; centralized one call center for pipeline locate requests; and management and maintenance of company pipeline easements, fee properties, and permit locations. Secondary departmental responsibility was to provide engineering support for the Project Management and Implementation department. This department managed all large and complex projects. My organization provided all Engineering Standards and Construction and Material Specifications. My responsibility was to ensure those standards and specifications were met or approve any deviations. Served as Deputy Crisis Management Team Leader. In this role was primary contact point between Crisis Management Team and the Incident Command Team deployed to the site of an incident. Was responsible for providing technical support for the response. Performed in the role during 5 actual incidents.

Colonial Pipeline Company **Aug 2006 - Jun 2008**

Position:	Gulf Coast District Leader
Description:	Responsible for all pipeline operations, maintenance, and projects in Colonial's Gulf Coast District including all company assets located in Texas, Louisiana, and Mississippi. Served as Incident Commander for an unannounced full deployment response drill that included participants from Federal, State, and Local agencies.

Colonial Pipeline Company **Jun 2005 - Aug 2006**

Position:	Engineering Manager - Project Clear Skies
Description:	Responsible for all engineering and design of facility modifications and five new tanks required to allow Colonial to transport ultra low sulphur diesel (ULSD) without significant contamination from refinery origin to customer delivery tankage. Project impacted 14 facilities at a cost of $65 million.

Colonial Pipeline Company **Aug 2002 - May 2005**

Position:	Engineering Team Leader
Description:	Responsible for engineering department. Provided technical support to operations and project management departments.

Colonial Pipeline Company **Jul 2000 - Jul 2002**

Position:	Operations Manager - Mississippi
Description:	Responsible for all operations in the State of Mississippi. Integrated pipeline acquisition into Colonial operations during this time – 147 mile 20" pipe from Belle Chasse, Louisiana to Collins, Mississippi. Served as initial on scene commander during responses for variety of incidents.

Colonial Pipeline Company **Feb 1999 - Jun 2000**

Position:	Project Engineer - AL/TN Expansion Project
Description:	Responsible for overseeing engineering on proposed new pipeline from near Talladega, Alabama to Murfreesboro, Tennessee including new tank farms near Talladega and Murfreesboro, a terminal facility near Huntsville, Alabama, and an origin and midpoint pumping stations. Project was cancelled and never built.

Colonial Pipeline Company **Sep 1994 - Jan 1999**

Position:	Gulf Coast District Project Team Leader
Description:	Responsible for overseeing all Colonial pipeline and storage tank integrity, maintenance and construction projects in the Gulf Coast District (Texas, Louisiana, and Mississippi).

Served as Operations Section Chief in the Incident Command System for two large scale pipeline incident responses.

Colonial Pipeline Company **Feb 1988 - Aug 1994**

Position:	Various Roles - Engineering Department
Description:	Associate Engineer to Staff Engineer. Was responsible for providing support to operations. Highlights include equipment modifications, equipment failure analysis, replacement of 40" pipeline crossing of the Atchafalaya River by directional drilling, replacement of external floating roofs with internal floating decks and geodesic domes on selected breakout tanks at 14 tank farms, and being a certified API 653 tank inspector for company.

Boeing Military Aircraft Corporation **Jan 1986 - Feb 1988**

Position:	Tool Designer
Description:	Designed and modified existing tools for assembling and constructing of engine nacelles for KC-135, 737, 747, 757, and 767 aircraft.

Other information

Litigation Experience:

Served as Company Representative in lawsuit brought against Company and others in State Court involving a right of way dispute. Following deposition Company was removed from the lawsuit. Case occurred around 1997.

Served as a witness for Company in a lawsuit involving joint venture partner that was decided by a three judge arbitration panel. Was deposed and testified before three judge arbitration panel. Case occurred around 2005.

Served as Company Representative in lawsuit brought against company in Federal Court. Was deposed twice during the lawsuit. Case was settled through arbitration before trial. Dispute began in 2008 and was settled in 2012/2013 timeframe.

Robin Pitblado

Senior Vice President

Curriculum Vitae:

Personal Statistics:

(Last revision: 2020-12-20)

Citizenship : United Kingdom (Permanent Resident: USA)
Date of Birth : Non disclosable

Language Capabilities:

Language	Level
English	Native

Academic and Professional Attainment:

Doctor of Philosophy, University of Sydney, Chemical Engineering, 1977
Bachelor of Engineering, McGill University, Chemical Engineering, 1970
Brennan Medal (Institution of Chemical Engineers)
Harry West Memorial Service Award (Mary Kay O'Connor Process Safety Center, Texas A&M University)

Summary of Professional Experience:

Responsibilities and Experience
Dr Robin Pitblado is a Senior Vice President working in Risk Management Solutions in Houston.

He is one of DNV GL's more senior and experienced safety management, safety case, risk assessment and environmental engineers. He is expert in safety and environment risk assessment technology, PSM assessment, consequence modelling, safety management system audits, and government compliance reviews. He has spent periods managing risk teams and offices in both the UK and the USA. Dr. Pitblado has worked on professional assignments in the UK, USA, Europe, Australia, and the Far East for a variety of industrial, professional body, and government clients. He has published widely, including being lead or joint author / editer of three textbooks.

He acted for 2 years as the DNV Risk Fellow and for 4 years as the Risk Service Lead. He was awarded the Brennan Medal from the IChemE and the Harry West award by Texas A&M University for contributions to safety. He has sat on various industry committees representing DNV GL.

Major assignments at DNV GL have included:

Accident Investigation:
He has managed/coordinated Investigations of several major accidents, including several deepwater events including the BW Offshore CDSM FPSO explosion event (9 fatalities), the Petrobras P-36 FPU accident (11 fatalities), and other accidents involving an FPSO, a Katrina hurricane damaged facility, an onshore gas plant, two jack-up drilling vessel collapses (at sea and at a Singapore yard), an electrical substation fire, and a train derailment (8 fatalities). He also investigated a serious DNV wind tower accident (1 fatality). He helped in the development of the BSCAT barrier-based accident investigation method and has applied this in several investigations. Accidents investigated include those which were dominated by human error or safety culture, and those dominated by technical failures or software errors. The FPSO investigation was dominated by safety culture as the company had excellent safety programs and safety studies but the crew did not always follow defined procedures. The recent jack-up accident in Singapore was due to a software error that showed itself during commissioning – and resulted in a major fall event in the yard. Dr Pitblado applied the BSCAT approach to both incidents successfully.

Dr Pitblado has developed several powerful investigation tools, including the Accident HAZOP approach, that provides a powerful means to select between alternative incident scenarios and to reject those that do not fit the evidence – but in a manner that is traceable and transparent.

He helped develop the BSCAT method that merges modern safety barrier thinking with well-established root cause methods. He coordinated with the software development company in creating the BSCAT software tool.

LNG:
He led a Joint Industry Project (JIP) involving most of the major LNG companies in North America in 2004 and a follow-up JIP in 2007. This reviewed the potential consequences of a range of accidental and intentional (terrorism) releases of LNG from LNG vessels in USA waters. These results have been widely published and were a factor in his invitation to join the US Government GAO LNG Panel. He has participated in several LNG hazard identifications and risk assessments.

Upstream Safety
He was closely involved in the development of DNV GL's new offshore risk tool – Safeti Offshore and with use of newer bow tie based barrier risk assessments for offshore applications. He was heavily involved in the Macondo (Deepwater Horizon) response – carrying out safety assessments for the responding fleet and procedural HAZOPs for various well intervention activities.

Risk Assessment
He has participated in or managed several large scale risk assessment projects – onshore and offshore. He has been involved in recent USA facility siting projects, developed guidelines for applying the TNO multi-energy method, and carried out large scale refinery expansion project (consequnces and fire hazard assessments). He has carried out QRA's for a large number of single facility projects, as well as entire petrochemical complex areas (Altona, Kwinana, and Hong Kong LPG).

OSHA PSM
He was active working with refineries in California to implement the OSHA PSM 1910.119 standard. He has led safety management system assessments and creation of management systems for Kuwait National Petroleum Company, Saudi Aramco, and others. In total, he has undertaken over 100 safety management system assessments globally for oil and chemical companies, rail operations and electrical power distributors.

General Safety
He has been involved in several reliability and mechanical integrity reviews. He led a major review of reliability and mechanical integrity systems for a large refining company. He has led a review of pipeline stress corrosion cracking for a major gas distribution system.

He has carried out Bow Tie barrier diagram based risk assessments of rail hazards for a major rail operator for a period of 18 months and more recently for a large onshore upstream oil facility. This included developing hazard and risk registers, reviewing, valuing and assigning to owners to all of the identified controls.

He developed the original DNV GL risk assessment guidelines and technical instructions system, allowing DNV GL to deploy risk services globally with comon and repeatable methods, this system is now supported on the DNV GL Intranet - RiskNet.

Robin Pitblado

Senior Vice President

Curriculum Vitae:

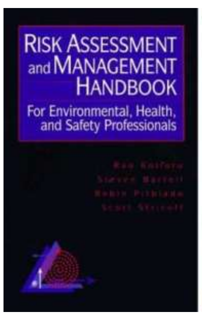
Present Position:

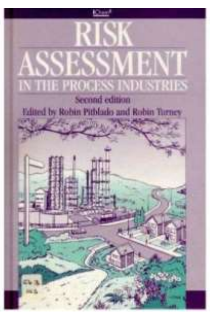
Dr Robin Pitblado has the grade of Senior Vice President in the Oil & Gas Division.

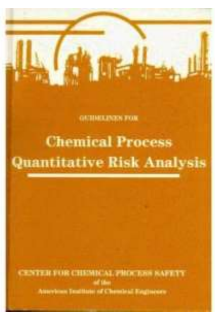
Publications and Papers:

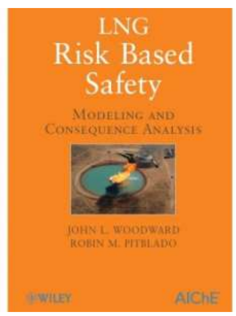
Dr Pitblado is author or co-author of 7 textbooks:

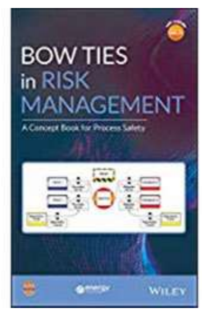
1) Process Safety in Upstream Oil & Gas, A CCPS Concept Book, AIChE/Wiley, in press.
2) Bows Ties in Risk Management a CCPS/EI Concept Book, AIChE / Wiley, 2018
3) LNG Risk Based Safety, J Woodward and R M Pitblado, Wiley Interscience, 2011.
4) Risk assessment in the process industries (2nd ed.), Turney R.; Pitblado R. (Eds.), Institution of Chemical Engineers (IChemE), Rugby: IChemE, 1996.
5) Risk assessment and management handbook for environmental, health and safety professionals, Kolluru R.; Bartell S.; Pitblado R.; Stricoff S. New York: McGraw-Hill, 1996.
6) Guidelines for Chemical Process Quantitative Risk Assessment, Centre for Chemical Process Safety, A.I.Ch.E., 1989 (Dr Pitblado lead author).
7) Quantitative assessment of major hazard installations, Pitblado R.M.; Nalpanis P., Safety cases within the Control of Major Accident Hazards (CIMAH) Regulations 1984. Lees F.P. and Ang M.L. (Eds.) London: Butterworths, 1989, p. 179-196.











Technical Papers:

Dr Pitblado has authored around 100 technical papers on safety, risk assessment, accident investigation, management system, and most recently 5 papers each on LNG consequence analysis, bow tie and barrier methods, and papers on Operations Safety. He is around 10 peer reviewed journal papers. He participated in the development of the DNV GL Position paper on enhanced offshore safety and lessons from the Macondo accident.

Professional Training

2013: Actively Caring about SHE
2013: DwD – Dealing with Dilemmas, web
2012: Introduction to Drilling and Well
2007: DNV Energy Portal Introduction
2006: Introduction to DNV
2002: DNV Consulting Course
2001: USA Harassment Awareness
2001: Employment Law for Mgrs & Supv
1998: BARNUM-SEMINAR
1995: TQM Course DNV
1993: ORGANISATION LEVEL 3
1993: Management Development Program
1993: Total Quality Management

Other Information:

Chartered Engineer
Fellow of the Institution of Chemical Engineers
Registered Safety Professional
Member American Institute of Chemical Engineers

Awarded the Brennan Medal by IChemE
Awarded the Harry West Medal by Texas A&M University Process Safety Center

APPENDIX B

Documents Relied Upon

Note: Documents listed in *italics* were produced by the Navy in connection with this proceeding with the referenced file name and numeric identifier.

Exhibit No.	Citation
B-2	Section 8.2: Risk/Vulnerability Assessment Scope of Work, Red Hill Bulk Fuel Storage Facility NAVSUP FLC, Pearl Harbor, HI (PRL), Joint Base Pearl Harbor-Hickam, Administrative Order on Consent In the matter of Red Hill Bulk Fuel Storage Facility EPA Docket No. RCRA 7003-R9-2015-0l, DOH Docket No. 15-UST-EA-01, April 13, 2017 (https://www.epa.gov/sites/production/files/2017-04/documents/red hill risk assessment scope of work.pdf)
B-6	NAVFAC Naval Facilities Engineering Command Engineering and Expeditionary Warfare Center. SITE SPECIFIC REPORT, SSR-NAVFAC EXWC-Cl-1655, 11 October 2016, Red Hill Facility, Tank Inspection, Repair, and Maintenance Report, Administrative Order on Consent (AOC) Statement of Work (SOW), Section 2.2. Prepared by Ms. Terri Regin, PE, Mr. Frank Kem, PE, Mr. James Gammon, and Mr. Lean-Miquel Sanpedro (https://www.epa.gov/sites/production/ files /2016-1O/documents/red-hill-aoc-section-2-2-tirm-report-2016 - 10 - 11.pdf)
B-10	Red Hill Bulk Fuel Storage Facility Final Groundwater Protection Plan, Pearl Harbor, Hawaii, Prepared for: Department of the Navy, Commander Naval Facilities Engineering Command, Pacific Pearl Harbor, HI 96860-3134, January 2008 https://health.hawaii.gov/shwb/files/2014/08/2008-Final-Groundwater-Protection-Plan.pdf
B-11	Naval Audit Service, 2010, Audit Report: Department of the Navy Red Hill and Upper Tank Farm Fuel Storage Facilities, Report Number N20I0-0049, August 16, 2010
B-12	Engineering Survey of U.S. Navy Petroleum Facilities at Pearl Harbor for U.S. Navy Bureau of Yards and Docks, May 1949, Bechtel Corporation.
B-15	2018. Quantitative Risk and Vulnerability Assessment Phase 1 (Internal Events without Fire and Flooding). Red Hill Bulk Fuel Storage Facility NAVSUP FLC Pearl Harbor, HI (PRL). Administrative Order on Consent in the matter of Red Hill Bulk Fuel Storage Facility EPA Docket No. RCRA 7003-R9-2015_01, DOH Docket No. 15-UST-EA-01. Prepared by ABS Consulting. November 12.
B-24	NAVFAC Naval Facilities Engineering Command Engineering and Expeditionary Warfare Center. SITE SPECIFIC REPORT, SSR-NAVFAC EXWC-Cl-1745, 24 April 2017, Red Hill Facility, Tank Inspection, Repair, and Maintenance Procedure Decision Document, Administrative Order on Consent (AOC) Statement of Work (SOW), Section 2.4. Prepared by Ms. Terri Regin, PE, Mr. Frank Kem, PE, Mr. James Gammon, and Mr. Lean-Miquel Sanpedro (https://www.epa.gov/sites/production/files/2017-09/documents/red_hill_aoc_tirm_decision_document.pdf)

Exhibit No.	Citation
B-25	2017. Underground Storage Tank System Evaluation Report. Red Hill Bulk Fuel Storage Facility. Joint Base Pearl Harbor-Hickam. Submitted to the Environmental Protection Agency (EPA). Submitted by: Atlas Geotechnical, Eastern Research Group, Inc., PEMY Consulting, and Powers Engineering and Inspection, Inc. June 13 (https://www.epa.gov/sites/production/files/2017-06/documents/red_hill_facility_compliance_evaluation_report_june_2017.pdf)
B-26	2017. United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH). Approval of Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW") Section 2.4-Tank Inspection, Repair, and Maintenance ("TIRM") Procedures Decision Document and Clarifications. Letter to Captain Richard D. Hayes, III from Mr. Bob Pallarino, Project Coordinator, EPA Region 9 Land Division and Mr. Steven Chang, Project Coordinator, DOH Solid and Hazardous Waste Branch. September 5. (https://www.epa.gov/sites/production/files/2017-09/documents/epa_and_doh_approval_of_tirm_decision_document.pdf)
B-27	2019. Department of the Navy. Tank Upgrade Alternatives ("TUA") and Release Detection Decision Document for the Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW") Sections 3 and 4. September 9. (https://www.epa.gov/sites/production/files/2019-09/documents/red_hill_aoc_tua_proposal_decision_document_20190919.pdf)
B-28	2020. United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH). Notice of Deficiency for the Tank Upgrade Alternatives Decision Document and New Release Detection Alternatives Decision Document, for Red Hill Administrative Order on Consent Statement of Work Sections 3.5 and 4.8. Letter to Captain Gordie Meyer, Commander Navy Region Hawaii from Mr. Steve Linder, P.E., Red Hill Project Coordinator, EPA Region 9 and Ms. Roxanne Kwan, Interim Red Hill Project Coordinator, DOH. October 26. (https://www.epa.gov/sites/production/files/2020-10/documents/red-hill-tua_proposal_final_combined_response-2020-10-26.pdf)
B-29	2018. Department of the Navy. Administrative Order on Consent Statement of Work Section 4.6 New Release Detection Alternative Report, Red Hill Bulk Fuel Storage Facility (Red Hill), Joint Base Pearl Harbor-Hickam, Oahu, Hawaii. July 26. (https://www.epa.gov/sites/production/files/2018-08/documents/red-hill-aoc-4.5-relase_detection_alternatives_report-2018-07-26.pdf)

Exhibit No.	Citation
B-30	2020. United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH). Response to Corrosion and Metal Fatigue Practices, Destructive Testing Results Report, Red Hill Bulk Fuel Storage Facility (Red Hill), Joint Base Pearl Harbor-Hickam, Oahu, Hawaii. Letter to Captain Marc Delao, Commander Navy Region Hawaii from Mr. Steve Linder, P.E., Red Hill Project Coordinator, EPA Region 9 and Ms. Roxanne Kwan, Interim Red Hill Project Coordinator, DOH. March 16. (https://www.epa.gov/sites/production/files/2020-03/documents/joint-response-red-hill-corrosion_metal_fatigue_practices_destructive_testing_results-signed-2020-03-16.pdf)
B-31	2020. Department of the Navy. Administrative Order on Consent Statement of Work, Section 5.3.3 Corrosion and Metal Fatigue Practices, Destructive Testing Results Report, Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, Hawaii. Letter to Mr. Steve Linder, USEPA, and Ms. Rozanne Kwan, DOH, from Captain Marc Delao, Navy. June 2. (https://www.epa.gov/sites/production/files/2020-07/documents/red_hill_dtrr_aoc_sow_sec_5_2jun.pdf)
B-32	2020. United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH). Response to Navy Letter Acknowledging Agency Disapproval of the Navy's Corrosion and Metal Fatigue Practices, Destructive Testing Results Report, Red Hill Bulk Fuel Storage Facility (Red Hill), Joint Base Pearl Harbor-Hickam, Oahu, Hawaii. Letter to Captain Marc Delao, Commander Navy Region Hawaii from Mr. Steve Linder, P.E., Red Hill Project Coordinator, EPA Region 9 and Ms. Roxanne Kwan, Interim Red Hill Project Coordinator, DOH. July 7. (https://www.epa.gov/sites/production/files/2020-07/documents/red_hill_joint_regulatory_agency_response_2020-07-07.pdf)
B-33	2018. NAVFAC Naval Facilities Engineering Command. Red Hill Alternative Location Study. Submitted by Austin Brockenbrough Engineering Consulting. Revision 03. February 5. (https://www.epa.gov/sites/production/files/2018-03/documents/red_hill_alternative_location_study_5_february_2018_redacted.pdf)
B-34	2019. Department of the Navy (Navy). Risk and Vulnerability Assessment for the Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW") Section 8. Letter to Mr. Omer Shalev, USEPA, and Ms. Rozanne Kwan, DOH, from Captain Marc Delao, Navy. May 29. (https://www.epa.gov/sites/production/files/2019-06/documents/risk_assessment_letter_and_summary.pdf)

Exhibit No.	Citation
B-35	2019. United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH). Section 8 of the Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW") Approval of Section 8.3 and Requirement to Complete Additional Work. Letter to Mr. Captain Marc Delao Regional Engineer, Navy Region Hawaii, from Mr. Omer Shalev, Project Coordinator, EPA Region 9 Land Division and Ms. Roxanne Kwan, Interim Project Coordinator, DOH Solid and Hazardous Waste Branch. September 23. (https://www.epa.gov/sites/production/files/2019-10/documents/red-hill-risk_assessment_approval_and_additional_work_requirement_2019-10-28.pdf)
B-36	2019. Department of the Navy (Navy). Risk and Vulnerability Assessment ("RVA") Phase 2 for the Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW") Section 8. Letter to Mr. Omer Shalev, USEPA, and Ms. Rozanne Kwan, DOH, from Captain Marc Delao, Navy. November 19. (https://www.epa.gov/sites/production/files/2019-12/documents/red_hill_aoc_8.3_phase_2-2019-11-19.pdf)
B-37	2020. United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH). Risk and Vulnerability Assessment ("RVA") Phase 2 Proposed Scope of Work for the Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW") Section 8, Notice of Deficiency and Opportunity to Cure. Letter to Captain Gordie Meyer, Commander Navy Region Hawaii, from Mr. Steve Linder, P.E., Red Hill Project Coordinator, EPA Region 9 and Ms. Roxanne Kwan, Interim Red Hill Project Coordinator, DOH. October 23. (https://www.epa.gov/sites/production/files/2020-10/documents/red_hill_aoc_8-notice_of_deficiency_and_opportunity_to_cure-2020-10-26.pdf)
B-38	2017. United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH). Conditional Approval of Red Hill Administrative Order on Consent Statement of Work ("AOC SOW") Section 8.2 Scope of Work – Risk/Vulnerability Assessment Letter to Captain Richard D. Hayes III, Regional Engineer, Navy Region Hawaii, from Mr. Bob Pallarino, Project Coordinator, EPA Region 9 Land Division and Mr. Steven Chang, Project Coordinator, DOH. May 16 (https://www.epa.gov/sites/production/files/2017-06/documents/regulatory_agency_conditional_approval_of_risk_scope_of_work.pdf)
B-39	Board of Water Supply (BWS). 2015a. Subject: August 7, 2015 Meeting Between the Board of Water Supply (BWS), United States Environmental Protection Agency (EPA), and Hawaii Department of Health (DOH) to Discuss BWS Comments to the Proposed Administrative Order on Consent (AOC) and Statement of Work (SOW) on the Red Hill Bulk Fuel Storage Facility. Pages 2 and 3. August 17.
B-40	Board of Water Supply (BWS). 2015c. Subject: Board of Water Supply Recommendations to Consider in the Development of the Red Hill Administrative Order on Consent (AOC) Work Plans. December 3.

Exhibit No.	Citation
B-41	Board of Water Supply (BWS). 2016a. Subject: Board of Water Supply (BWS) Recommendations for Inclusion into the Red Hill Bulk Fuel Facility Administrative Order on Consent (AOC) Work Plans. April 25
B-42	Board of Water Supply (BWS). 2016b. Subject: Board of Water Supply (BWS) Comments to the Work Plans Being Developed Under the Red Hill Bulk Fuel Storage Facility Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 2 through 5 and 8. May 27.
B-43	Board of Water Supply (BWS). 2016c. Subject: Board of Water Supply (BWS) Comments to the Work Plans Being Developed Under the Red Hill Bulk Fuel Storage Facility Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 3, Tank Upgrade Alternatives. September 30.
B-44	Board of Water Supply (BWS). 2016d. Subject: Board of Water Supply (BWS) Comments Discussed with the United State Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH) at the October 4 and 5, 2016 meeting to discuss the Work Plans Developed Under Sections 2, 3, 4, and 8 of the Red Hill Fuel Facility Administrative Order on Consent (AOC) Statement of Work. November 4.
B-45	Board of Water Supply (BWS). 2016e. Subject: Board of Water Supply Comments to the Tank Inspection, Repair and Maintenance (TIRM) Report Being Developed Under the Red Hill Bulk Fuel Storage Facility (RHBFSF) Administrative Order on Consent (AOC) Statement of Work (SOW) Section 2. November 21.
B-46	Board of Water Supply (BWS). 2017a. Subject: Board of Water Supply (BWS) Comments to the Work Plan Being Developed Under the Red Hill Bulk Fuel Storage Facility Sections 2, 3, 4, and 8 of the Red Hill Field Facility Administrative Order on Consent (AOC) Statement of Work Section 5.3. February 13.
B-47	Board of Water Supply (BWS). 2017b. Subject: Board of Water Supply (BWS) Comments Pertaining to the Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH) February 15, 2017 Administrative Order on Consent (AOC) Sections 2, 3, 4, 5 and 8 Meeting. March 9.
B-48	Board of Water Supply (BWS). 2017c. Subject: Letter Dated April 25, 2017 From Read Admiral J.V. Fuller Regarding the Board of Water Supply (BWS) Website Frequently Asked Questions (FAQ) on the Red Hill Bulk Fuel Facility. Memorandum from Ernet Y.W. Lau, PE, Manager and Chief Engineer, BWS to Mr. Roy K., Amemiya, Managing Direction, City and County of Honolulu. May 4. Attachment - Naval Audit Service, 2010. Audit Report N2010-0049, Department of the Navy Red Hill and Upper Tank Farm Fuel Storage Facilities, August 16 (redacted).
B-49	Board of Water Supply (BWS). 2017d. Subject: Board of Water Supply (BWS) Comments to the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Tank Inspection, Repair, and Maintenance (TIRM) Procedure Decision Document Section 2.4 Dated April 24, 2017. June 1.

Exhibit No.	Citation
B-50	Board of Water Supply (BWS). 2017e. Subject: Board of Water Supply (BWS) Comments to the Conditional Approval Scope of Work for Destructive Testing Dated May 30, 2017 submitted to the Regulatory Agencies Pursuant to Section 5.3.2 of the Red Hill Administrative Order on Consent, dated July 7, 2017. July 14.
B-51	Board of Water Supply (BWS). 2017f. Subject: Board of Water Supply (BWS) Comments to the Conditional Approval of Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Deliverable-3.2 Tank Upgrade Alternatives Scope of Work, Red Hill Bulk Fuel Storage Facility (RHBFSF) dated December 8, 2016. August 7.
B-52	Board of Water Supply (BWS). 2018a. Subject: Board of Water Supply (BWS) Comments on the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Section 3 Tank Upgrade Alternatives (TUA) Report dated December 8, 2017. February 12.
B-53	Board of Water Supply (BWS). 2018b. Subject: Comments on the Michael Baker International's Report: Test Plan for Evaluating Leak Detection Methods at the Red Hill Bulk Fuel Storage Facility (RHBFSF), Joint Base Pearl Harbor-Hickam, Oahu, Hawaii in support of Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 4.5: New Release Detection Alternatives and 4.6: New Release Detection Alternatives Report. March 23.
B-54	Board of Water Supply (BWS). 2018c. Subject: Comments on the Department of the Navy (Navy) Report: Seismic Profiling to Map Hydrostratigraphy in the Red Hill Area, Red Hill Bulk Fuel Storage Facility (RHBFSF) Joint Base Pearl Harbor-Hickam, Oahu, Hawaii, March 30, 2018. Completed under Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 6 and 7. April 20.
B-55	Board of Water Supply (BWS). 2018d. Subject: Board of Water Supply Comments on the Hawaii Department of Health Proposed Underground Storage Tank Regulations (Proposed Repeal of Chapter 11-281 and Adoption of Chapter 11-280.1 Hawaii Administrative Rules, Updated April 26, 2018). June 1.
B-56	Board of Water Supply (BWS). 2018e. Subject: Honolulu Board of Water Supply (BWS) Comments on the Red Hill Bulk Fuel Storage Facility (RHBFSF), New Release Detection Alternatives Report, Administrative Order on Consent (AOC) – Section 4.6, dated July 25, 2018, and the Navy's presentation of this topic at the August 14 and 15, 2018 AOC Meetings in Honolulu. September 17.
B-57	Board of Water Supply (BWS). 2018f. Subject: Board of Water Supply (BWS) Comments on the Groundwater Protection and Evaluation Considerations for the Red Hill Bulk Fuel Storage Facility (RHBFSF) Report, dated July 27, 2018. October 2.

Exhibit No.	Citation
B-58	Board of Water Supply (BWS). 2018g. Subject: Honolulu Board of Water Supply (BWS) Comments on draft "Report to the Thirtieth Legislature, State of Hawaii, 2019, Pursuant to Section 342L-62 Hawaii Revised Statutes, The Third Annual Fuel Tank Advisory Committee Meeting to Study the Issues Related to Leaks of Field-Constructed Underground Storage Tanks at Red Hill Bulk Fuel Storage Facility and Four Other DOD Facilities", Prepared By: State of Hawaii, Department of Health (DOH), Underground Storage Tank Section, dated December 2018. December 24.
B-59	Board of Water Supply (BWS). 2019a. Subject: Honolulu Board of Water Supply (BWS) Comments to IMR Test Labs Destructive Analysis of 10 Steel Coupons Removed from Red Hill Fuel Storage Tank #14, REPORT No. 201801967, Dated December 17, 2018. March 5.
B-60	Board of Water Supply (BWS). 2019c. Subject: Underground Storage Tank (UST) Permit Application for Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor Hickam (JBPHH), Oahu, DOH Facility ID NO. 9-102271. March 28.
B-61	Board of Water Supply (BWS). 2019e. Subject: Honolulu Board of Water Supply (BWS) Comments on the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Sections 6 and 7 Groundwater Modeling Working Group Meeting No. 14 Held on March 15, 2019. April 12
B-62	Board of Water Supply (BWS). 2019f. Subject: Underground Storage Tank (UST) Permit Application for Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor Hickam (JBPHH), Oahu, DOH Facility ID No. 9-102271. May 17.
B-63	Board of Water Supply (BWS). 2019g. Subject: Honolulu Board of Water Supply (BWS) Comments on ABS Consulting (ABS) Report "Quantitative Risk and Vulnerability Assessment Phase 1 (Internal Events without Fire and Flooding) dated November 12, 2018" and "Navy's Risk and Vulnerability Assessment Summary" and Cover Letter dated May 29, 2019 as per Red Hill Bulk Fuel Storage Facility (RHBFSF) Administrative Order on Consent (AOC) Statement of Work (SOW) Section 8. September 5.
B-64	Board of Water Supply (BWS). 2019h. Subject: Honolulu Board of Water Supply Comments on Navy's "AOC SOW Section 5 Corrosion and Metal Fatigue Practices, Destructive Testing Results Report" dated July 7, 2019 and IMR's Report "Destructive Analysis of 10 Steel Coupons Removed Red Hill Fuel Storage Tank #14" dated December 17, 2019. October 7.
B-65	Board of Water Supply (BWS). 2019i. Subject: Honolulu Board of Water Supply (BWS) Comments on Navy's Conceptual Site Model (CSM), Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility (RHBFSF) Revision 1 dated June 30, 2019. October 7.

Exhibit No.	Citation
B-66	Board of Water Supply (BWS). 2019j. Subject: Comments of the Honolulu Board of Water Supply on United States Department of the Navy's "Red Hill Bulk Fuel Storage Facility Administrative Order on Consent Tank Upgrade Alternatives and Release Detection Decision Document" dated September 2019 as per Red Hill Bulk Fuel Storage Facility Administrative Order on Consent Statement of Work Sections 3 and 4. October 22.
B-67	Board of Water Supply (BWS). 2020a. Subject: Honolulu Board of Water Supply (BWS) Comments on ABS Consulting (ABS) document "8.2 Risk/Vulnerability Assessment Phase 2 Scope of Work" dated September 6, 2019 and associated Navy's Cover Letter "Risk and Vulnerability Assessment (RVA) Phase 2 for the Red Hill Administrative Order on Consent (AOC) Statement of Work (SOW) Section 8" dated November 19, 2019. January 23.
B-68	Board of Water Supply (BWS). 2020c. Subject: Honolulu Board of Water Supply (BWS) Comments on the Navy's Investigation and Remediation of Releases (IRR) Report, Red Hill Bulk Fuel Storage Facility (RHBFSF) Revision 00 dated March 25, 2020. August 1.
B-69	Board of Water Supply (BWS). 2020d. Subject: Honolulu Board of Water Supply (BWS) Comments on the Navy's Groundwater Flow Model Report, Red Hill Bulk Fuel Storage Facility (RHBFSF) Revision 00 dated March 25, 2020. September 25.
B-70	Department of Health (DOH). 2019. Application for an Underground Storage Tank Permit, Red Hill Bulk Fuel Storage Facility, Facility ID No. 9-102271. Letter from Ms. Lene Ichinotubo, PE, Acting Chief, Solid Hazardous Waste Branch, DOH to Ms. Raelynn Kishba, Commander, Navy Region Hawaii. April 12. https://health.hawaii.gov/shwb/files/2019/05/Red-Hill-U0416HM-9-102271.pdf
B-71	Department of Health (DOH) and Environmental Protection Agency (EPA). 2017a. Conditional Approval of Scope of Work for Destructive Testing Dated May 30, 2017 submitted to the Regulatory Agencies Pursuant to Section 5.3.2 of the Red Hill Administrative Order on Consent. Page 1, Paragraphs 1 and 2. July 7. https://www.epa.gov/sites/production/files/2017-07/documents/conditional_approval_of_destructive_testing_sow_7_july_2017.pdf
B-72	Department of Health (DOH) and Environmental Protection Agency (EPA). 2017b. Red Hill Administrative Order on Consent Statement of Work ("AOC SOW")- Conditional Approval of Section 4.5 New Release Detection Alternatives of Scope of Work dated June 19, 2017. Page 2, Paragraph 3. July 26. https://www.epa.gov/sites/production/files/2017-08/documents/final_epa_and_doh_cond_appr_w_enclosure-release_detect_sow_2014-07-26.pdf

Exhibit No.	Citation
B-73	Department of the Navy (Navy). 2019. UST Permit Application for Red Hill Bulk Fuel Storage Facility, JBPHH, Oahu, DOH Facility ID NO. 9-102271. Submitted to State of Hawaii Department of Health on March 13, 2019, signed by Captain, M.R. Delao, with enclosure DOH Form No. 2, Application for an Underground Storage Tank Permit for Red Hill Bulk Fuel Storage Facility, DOH Facility ID No. 9-102271. https://health.hawaii.gov/shwb/files/2019/03/redhillpermitapplication.pdf
B-74	Department of the Navy (Navy). 2019. Response to DOH Letter. UST Permit Application for Red Hill Bulk Fuel Storage Facility, JBPHH, Oahu, DOH Facility ID NO. 9-102271. Submitted to State of Hawaii Department of Health on May 15, 2019, signed by Captain, M.R. Delao, with enclosure Revised DOH Form No. 2, Application for an Underground Storage Tank Permit for Red Hill Bulk Fuel Storage Facility, DOH Facility ID No. 9-102271. https://health.hawaii.gov/shwb/files/2019/05/Navy-Region-Hawaii-Response-to-DOH-letter-U0416HM-May-23-2019-OCR-scan.pdf
B-75	Environmental Protection Agency (EPA). EPA UST regs CFR Title 40, Chapter I, Parts 280 and 281 https://www.ecfr.gov/cgi-bin/text-idx?SID=121ab75da7d3f71d24fd5426266d365c&mc=true&node=pt40.29.280&rgn=div5 https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=686342a687bb63b2d302e75bb0e5ebf2&mc=true&r=PART&n=pt40.29.281
B-76	Permit No. P-2019-XXX, Dated July XX, 2019, Expiration July XX, 2024, Permittees: Owner Name and Address: US Navy – COMNAVREG HI, 850 Ticonderoga Street, Suite 100, JBPHH, HI 96860 and Operator Name and Address: Naval Supply Systems Command Fleet Logistics Center Pearl Harbor, 1942 Gaffney Street, Suite 100, JBPHH, HI 96860. https://health.hawaii.gov/shwb/files/2019/06/Red-Hill-and-Hickam-AHS-UST-Operation-Permit-draft-corrected.pdf
B-77	Department of the Navy (Navy). 2019. June 12, 2019 Permit Application Corrections. https://health.hawaii.gov/shwb/files/2019/06/UST-permit-application-for-Red-Hill-Bulk-Fuel-Storage-Facility-JBPHH-June-12-2019-corrections.pdf
B-78	Department of the Navy (Navy). 2019. June 12, 2019 Permit Application Draft Permit Application with Corrections. https://health.hawaii.gov/shwb/ust-rh-permit-application/
B-79	2019. Hawaii Department of Health. Public Comments on Draft Permit Application. October 22. https://health.hawaii.gov/shwb/files/2019/10/Comments-received-RH-draft-permit.pdf

Exhibit No.	Citation
B-80	Department of the Navy (Navy). 2019. UST Permit Application for Red Hill Bulk Fuel Storage Facility, JBPHH, Oahu, DOH Facility ID NO. 9-102271. Submitted to State of Hawaii Department of Health on May 15, 2019, signed by Captain, M.R. Delao, with enclosure Revised DOH Form No. 2, Application for an Underground Storage Tank Permit for Red Hill Bulk Fuel Storage Facility, DOH Facility ID No. 9-102271. https://health.hawaii.gov/shwb/files/2019/05/UST-permit-application-for-Red-Hill-Bulk-Fuel-Storage-Facility-JBPHH-May-23-2019-OCR-scan.pdf
B-81	2015. Department of Health (DOH) and Environmental Protection Agency (EPA). Administrative Order on Consent. In the Matter of Red Hill Bulk Fuel Storage Facility. EPA Docket No. RCRA 7003-R9-2015-01 and DOH Docket No. 15-UST-EA-01. September 29. https://health.hawaii.gov/shwb/files/2015/09/Red-Hill-AOC_Final_29SEP151.pdf
B-82	2015. Department of Health (DOH) and Environmental Protection Agency (EPA). Administrative Order on Consent. In the Matter of Red Hill Bulk Fuel Storage Facility. EPA Docket No. RCRA 7003-R9-2015-01 and DOH Docket No. 15-UST-EA-01. Attachment A. Statement of Work. September 29. https://health.hawaii.gov/shwb/files/2015/09/Red-Hill-SOW__11SEP15.pdf
B-83	2020. Department of the Navy (Navy). Red Hill Bulk Fuel Storage Facility. Second Quarter 2020 – Quarterly Groundwater Monitoring Report. DOH Facility ID No. 9-102271. DOH Release ID Nos. 990051, 010011, 020028, and 140010. July 24. (4 parts listed as 136a, b, c, and d). https://health.hawaii.gov/shwb/files/2020/10/2020-07-24-2nd-qtr-gw-monitoring-rept-cover-ltr.pdf and https://health.hawaii.gov/shwb/files/2020/10/2020-07-2nd-qtr-gw-monitoring-rept-part-1.pdf and https://health.hawaii.gov/shwb/files/2020/10/2020-07-2nd-qtr-gw-monitoring-rept-part-2.pdf and https://health.hawaii.gov/shwb/files/2020/10/2020-07-2nd-qtr-gw-monitoring-rept-part-3.pdf
B-84	Red Hill Bulk Fuel Storage Facility Revisions to the Groundwater Protection Plan, Pearl Harbor, Hawaii. Prepared for: Department of the Navy, Commander Naval Facilities Engineering Command, Pacific Pearl Harbor, HI 96860-3134. December 2009. (https://health.hawaii.gov/shwb/files/2014/12/990051-1209Groundwater_revisions.pdf)
B-85	Department of the Navy (Navy). Underground Fuel Storage, Log of Formations In Tank Excavation ("Tank Barrell Logs"). Fourteenth Naval District, Pearl Harbor, Hawaii. May 23, 1943.
B-86	Department of the Navy (Navy). 120 Day Short-Long Term Release Response Report: Tank 16 Release. February 23, 1999.
B-87	TIRM Report Appendix – List of Appendices https://www.epa.gov/sites/production/files/2016-10/documents/red_hill_tirm_report_list_of_appendices.pdf
B-88	TIRM Report Appendix A - Telltale Piping Holes
B-89	TIRM Report Appendix B- Red Hill Dome Truss Scaffold

Exhibit No.	Citation
B-90	TIRM Report Appendix C Red Hill Monorail Scaffold
B-91	TIRM Report Appendix D Boom and Basket System
B-92	TIRM Report Appendix E API 653 Inspection Report Tank 13 July 1995
B-93	TIRM Report Appendix F API 653 Inspection Report Tank 10 1998
B-94	TIRM Report Appendix G API 653 Report Tank 7 1998
B-95	TIRM Report Appendix H API 653 Report Tank 8 1998
B-96	TIRM Report Appendix I Contract Number FA8903-04-D-8681-0176-All https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendices-a-i-redacted.pdf
B-97	TIRM Report Appendix J Tank 16 API 653 Final Inspection Report 2007 https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendix-j-redacted-optimized.pdf
B-98	TIRM Report Appendix K API 653 Inspection Tank 6 2007 https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendix-k-redacted-optimized.pdf
B-99	TIRM Report Appendix L API 653 Inspection Tank 15 2007 https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendix-l-redacted-optimized.pdf
B-100	TIRM Report Appendix M Contract Number N47408-04-D-8503-0031-All
B-101	TIRM Report Appendix N API 653 Inspection Tank 2 2008
B-102	TIRM Report Appendix O API 653 Inspection Tank 20 2008
B-103	TIRM Report Appendix P Contract Number N62583-09-D-0132-0003-All
B-104	TIRM Report Appendix Q WGS Daily Production Report Tanks 5 and 17 https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendices-m-q-redacted-optimized.pdf
B-105	TIRM Report Appendix R WGS Tanks 5 and 17 Work Plan (rev0 24 May 2010) https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendix-r-redacted-optimized.pdf
B-106	TIRM Report Appendix S WGS RFI6 Pressure Washing https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendix-s-redacted.pdf

Exhibit No.	Citation
B-107	TIRM Report Appendix T WGS Inspection Report Rev E https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendix-t-redacted-optimized.pdf
B-108	TIRM Report Appendix U CSI Services – Daily Coating Inspection Report
B-109	TIRM Report Appendix V WGS Work Plan – Abrasive Blasting and Surface Preparation 2012
B-110	TIRM Report Appendix W WGS Warranty Work Plan
B-111	TIRM Report Appendix X NAVFAC Drawing No. 7019545 MILCON P-060 coating details https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendices-u-x-redacted.pdf
B-112	TIRM Report Appendix Y Not Used
B-113	TIRM Report Appendix Z Not Used
B-114	TIRM Report Appendix AA WGS Analysis Hydro Report
B-115	TIRM Report Appendix AB WGS Redhill Complex TK 5 Project – Pressure Test Log
B-116	TIRM Report Appendix AC Willbros D0132 DO 3 Red Hill mod 9
B-117	TIRM Report Appendix AD WGS ASNT Records
B-118	TIRM Report Appendix AE Tank 5 Inspection Checklist
B-119	TIRM Report Appendix AF FY-78 MILCON P-060 Scope of Work
B-120	TIRM Report Appendix AG WGS Weld WPS and PQR https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendices-aa-ag-redacted.pdf
B-121	TIRM Report Appendix AH WGS WPQ Records
B-122	TIRM Report Appendix AI WGS Daily Report 01-16-13 Rev 0
B-123	TIRM Report Appendix AJ Tank 5 Warranty notice
B-124	TIRM Report Appendix AK Notice to Proceed Oct 2014
B-125	TIRM Report Appendix AL TK 5 Visual Inspection Report Signed
B-126	TIRM Report Appendix AM TK 5 MT-LT Inspection Report
B-127	TIRM Report Appendix AN WGS Tank 5 Work Plan Appendix M
B-128	TIRM Report Appendix AO WGS Free Product Report
B-129	TIRM Report Appendix AP WGS Tank 5 Pressure Testing Procedure Jun 2014
B-130	TIRM Report Appendix AQ WGS Tank 5 Pressure Testing Report Jun 2014
B-131	TIRM Report Appendix AR QASP RHT5 Warranty Rework

Exhibit No.	Citation
B-132	TIRM Report Appendix AS WGS Tank 5 Suitability For Service Statement; https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendices-ah-as-redacted-optimized.pdf
B-133	TIRM Report Appendix AT WGS Repair Work Plan Red Hill Tank 5 https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendix-at-redacted-optimized.pdf
B-134	TIRM Report Appendix AU WGS D-0132 Basic Award
B-135	TIRM Report Appendix AV WGS Sample and Drain Line Drawings
B-136	TIRM Report Appendix AW WGS Tank 5 Repairs – Repair NDE QC Data
B-137	TIRM Report Appendix AX List of Welder PQR
B-138	TIRM Report Appendix AY API Inspector Qualifications
B-139	TIRM Report Appendix AZ NAVSUP GLS Instruction 10345.1 – Fuel Tank Return to Service
B-140	TIRM Report Appendix BA Contract Number N62742-03-C-1402-All
B-141	TIRM Report Appendix BB Red Hill Tank 5 Inspection SOW
B-142	TIRM Report Appendix BC Generic 653 SOW April2010
B-143	TIRM Report Appendix BD UFGS Section 33 56 17.00 20
B-144	TIRM Report Appendix BE UFGS Section 33 56 18.00 20
B-145	TIRM Report Appendix BF Telltale Leak Detection System
B-146	TIRM Report Appendix BG DLA ATG Policy Letter 2009
B-147	TIRM Report Appendix BH NAVSEA 5104 14 August 2011 RSO Application
B-148	TIRM Report Appendix BI NAVFACINST 5104 1
B-149	TIRM Report Appendix BJ Report on the Trip to Pacific Division Naval Facilities Command
B-150	TIRM Report Appendix BK Acquisition Schedule Red Hill CIR
B-151	TIRM Report Appendix BL Overall CIR Schedule without modification
B-152	TIRM Report Appendix BM Red Hill Tank CIR Contract Sequencing
B-153	TIRM Report Appendix BN Contract Number N39430-15-D-1632-0005 Tanks 14, 17, 18
B-154	TIRM Report Appendix BO Contract Number N39430-15-D-1632-0004 Tanks 4, 13
B-155	TIRM Report Appendix BP NAVFAC Drawing No. 7019544 MILCON P-060 https://www.epa.gov/sites/production/files/2020-07/documents/red-hill-tirm-report-appendices-au-bp-redacted-optimized.pdf

Exhibit No.	Citation
B-156	Honolulu Board of Water Supply (BWS). Comments on the Red Hill Bulk Fuel Storage Facility (RHBFSF), Scope of Work for Destructive Testing Supplement - Destructive Testing Plan, Supplement to Administrative Order on Consent (AOC) and Statement of Work (SOW) Section 5.3.2, dated June 1, 2018 and Our Inspection on June 25, 2018 of Coupons Removed from Tank 14.
B-157	Destructive Analysis Of 10 Steel Coupons Removed From Red Hill Fuel Storage Tank No. 14, Pursuant To Section 5.3 Of The Administrative Order On Consent Statement Of Work. Red Hill Bulk Fuel Storage Facility, Joint Base Pearl Harbor-Hickam, Oahu, Hawaii.
B-158	Field Notes: Tank 14 Coupon Removal.
B-159	Red Hill Bulk Fuel Storage Facility - Scope Of Work For Destructive Testing Supplement Destructive Testing Plan: Supplement To Administrative Order On Consent (AOC) And Statement Of Work (SOW) Section 5.3.2, 1. June 2018.
B-160	Administrative Order On Consent (AOC Statement Of Work (SOW) Section 5 Corrosion And Metal Fatigue Practices, Destructive Testing Results Report). Red Hill Bulk Fuel Storage Facility (Red Hill), Joint Base Pearl Harbor-Hickam, Oahu, Hawaii.
B-161	Administrative Order On Consent (AOC) Statement Of Work (SOW) Section 5 Corrosion And Metal Fatigue Practices, Destructive Testing Plan. Red Hill Bulk Fuel Storage Facility (Red Hill), Joint Base Pearl Harbor-Hickam, Oahu, Hawaii.
B-162	Status of Application for an Underground Storage Tank Permit Red Hill Bulk Fuel Storage Facility. Red Hill, Aiea Facility ID No. 9-102271.
B-164	Approval of Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW") Section 2.4-Tank Inspection, Repair and Maintenance ("TIRM") Procedures Decision Document and Clarifications. September 5, 2017
B-165	Response to August 17, 2015 Letter re: Red Hill Bulk Fuel Storage Facility.
B-166	Meeting Between the Board of Water Supply (BWS), United States Environmental Protection Agency (EPA), and Hawaii Department of Health (DOH) to Discuss BWS Comments to the Proposed Administrative Order on Consent (AOC) and Statement of Work (SOW) on the Red Hill Bulk Fuel Storage Facility. August 7, 2015.
B-167	Honolulu Board of Water Supply (BWS) Request for a Copy of the Red Hill Bulk Fuel Storage Facility (RHBFSF) Tank 14 Steel Liner Destructive Testing Laboratory Results pursuant to the Destructive Testing Plan, Supplement to Administrative Order on Consent (AOC) and Statement of Work (SOW) Section 5.3.2. June 1, 2018.

Exhibit No.	Citation
B-168	IMR Test Labs Destructive Analysis of ten (10) Steel Coupons Removed from Red Hill Fuel Storage Tank #14, Report No. 201801967, pursuant to Section 5.3 of the Red Hill Bulk Fuel Storage Facility (RHBFSF) Administrative Order on Consent (AOC) Statement of Work (SOW). December 17, 2018.
B-169	U.S. Navy. Red Hill Bulk Fuel Storage Facility Quantitative Risk and Vulnerability Assessment Work Plan.
B-170	Red Hill Repair Tanks Options Study.
B-171	Quantitative Risk and Vulnerability Assessment Proposed Scope of Work - APPENDICES.
B-172	Revision to Conditional Approval of Scope of Work for Destructive Testing. Submitted to the Regulatory Agencies Pursuant to Section 5.3.2 of the Red Hill Administrative Order on Consent. May 30, 2017.
B-173	Red Hill Bulk Fuel Storage Facility Scope Of Work For Destructive Testing.
B-174	Administrative Order On Consent Statement Of Work Section 3.3 Tank Upgrade Alternatives Report. Red Hill Bulk Fuel Storage Facility (Red Hill), Joint Base Pearl Harbor-Hickam, Oahu, Hawaii.
B-175	Email re: Whitacre; Red Hill Document Production; EPA/DOH Requests 1.b. and 2.b. I; Navy Questions# 6, 7 and 18; Dates and Estimates of Historical Releases I; and Fuel Observations - Tanks 19 and 20.
B-176	*Tk 10 '98 api 653 part 1.pdf* [RDHLCC0001128]
B-177	*Tk 10 '98 api 653 part 2.pdf* [RDHLCC0001160]
B-178	*Tk 10 '98 api 653 part 3.pdf* [RDHLCC0001199]
B-179	*Tk 10 '98 api 653 part 4.pdf* [RDHLCC0001237]
B-180	*Tk 10 '98 api 653 part 5.pdf* [RDHLCC0001270]
B-181	*TK 8 '98 API 653 PART 1.PDF* [RDHLCC0004715]
B-182	*TK8 '98 API 653 PART 2.PDF* [RDHLCC0004765]
B-183	*TK 8 '98 API 653 PART 3.PDF* [RDHLCC0004742]
B-184	*TK7 '98 API 653 PART 1.PDF* [RDHLCC0004566]
B-185	*TK7 '98 API 653 PART 2.PDF* [RDHLCC0004592]
B-186	*TK7 '98 API 653 PART 3.PDF* [RDHLCC0004624]
B-187	*TK7 '98 API 653 PART 4.PDF* [RDHLCC0004655]
B-188	*TK7 '98 API 653 PART 5.PDF* [RDHLCC0004685]
B-189	*TK 7 '98 API 653 PART 6.PDF* [RDHLCC0004552]
B-190	*Tank 6 Final API 653 Inspection Report-Tk 6_2007.pdf* [RDHLCC0003796]
B-191	*TO0176-Final API-653 Inspection Report-Tk15_2007.pdf* [RDHLCC0001513]
B-192	*Tank 16 API 653 Final Inspection Report_2007.pdf* [RDHLCC0002009]

Exhibit No.	Citation
B-193	*2002 07 CRN.pdf* [RDHLCC0000565]
B-194	*RH HIST Tank 16_1.pdf* [RDHLCC0000821]
B-195	*RH HIST Tank 1_2.pdf* [RDHLCC0000854]
B-196	*RH HIST Tank 6 and 7_1.pdf* [RDHLCC0000899]
B-197	*2008-Final-Groundwater-Protection-Plan.pdf* [RDHLCC0000001]
B-198	*Gabbard 26 Sep RFI.docx* [RDHLCC0000360]
B-199	*redacted-original tank records.pdf* [RDHLCC0000365]
B-200	*1998 04 CoverLetter.pdf* [RDHLCC0000408]
B-201	*1998 10 CRN.pdf* [RDHLCC0000410]
B-202	*1999 02 iReleaseResponse.pdf* [RDHLCC0000411]
B-203	*Site Characterization_CTO_0228_FISC.pdf* [RDHLCC0000412]
B-204	*2000 12 CRN.pdf* [RDHLCC0000561]
B-205	*2000 12 Response Letter.pdf* [RDHLCC0000563]
B-206	*2003 04 Response Letter.pdf* [RDHLCC0000569]
B-207	*2002 04 17 CRN.PDF* [RDHLCC0000572]
B-208	*2009 Biennial Tank Integrity Test Report.pdf* [RDHLCC0000574]
B-209	*Final API 653 Report-Tank 6.pdf* [RDHLCC0000586]
B-210	*Tank 6 98 API 653.pdf* [RDHLCC0000600]
B-211	*CRN 23Jan14.PDF* [RDHLCC0000637]
B-212	*Release_1070983 Red Hill 13 Jan 14.pdf* [RDHLCC0000640]
B-213	*History of Estimated Releases.pdf* [RDHLCC0000642]
B-214	*RH_CompUnverLeakHistories_DEC17.xlsx* [RDHLCC0000646]
B-215	*RH_UnverifiedHistoriesExsum_FEB18.docx* [RDHLCC0000654]
B-216	*RedHill_Releases(Initiators)_080318.xlsx* [RDHLCC0000657]
B-217	*RedHill_Releases(Initiators)_20171117.xlsx* [RDHLCC0000736]
B-218	*RH_CompUnverLeakHistories_DEC17-NAVFACcomments.xlsx* [RDHLCC0000814]
B-219	*Red Hill Document Production - EPADOH Request 1.b. Navy Questins # 6 ... (1.69 MB).msg* [RDHLCC0000820]
B-220	*Red Hill Document Production - EPADOH Request 1.b. Navy Questions # 6... (1.04 MB).msg* [RDHLCC0000834]
B-221	*RH HIST Tank 17 and 18_1.pdf* [RDHLCC0000835]

Exhibit No.	Citation
B-222	*Red Hill Document Production - EPADOH Request 1.b. Navy Questions # 6... (1.22 MB).msg* [RDHLCC0000842]
B-223	*RH HIST Tank 14 and 15_1.pdf* [RDHLCC0000843]
B-224	*Red Hill Document Production - EPADOH Request 1.b. Navy Questions # 6... (1.66 MB).msg* [RDHLCC0000853]
B-225	*Red Hill Document Production - EPADOH Request 1.b. Navy Questions # 6... (1.77 MB).msg* [RDHLCC0000870]
B-226	*RH HIST Tank 11 to 13_1.pdf* [RDHLCC0000871]
B-227	*Red Hill Document Production - EPADOH Request 1.b. Navy Questions # 6... (1.90 MB).msg* [RDHLCC0000884]
B-228	*RH HIST Tank 8 and 10_1.pdf* [RDHLCC0000885]
B-229	*Red Hill Document Production - EPADOH Request 1.b. Navy Questions # 6... (2.24 MB).msg* [RDHLCC0000898]
B-230	*Red Hill Document Production - EPADOH Request 1.b. Navy Questions# 6... (1.25 MB).msg* [RDHLCC0000916]
B-231	*RH HIST Tank 2 to 5_1.pdf* [RDHLCC0000917]
B-232	*RH HIST Tank 19 and 20_1.pdf* [RDHLCC0000928]
B-233	*CLEAN 9 RED HILL TANKS, PCM MODIFICATIONS_000192EE.pdf* [RDHLCC0000936]
B-234	*INSPECT RH TANK 12 N62755-94-D-2802_000192F0.pdf* [RDHLCC0001311]
B-235	*CLEAN 9 TANKS _00019218.pdf* [RDHLCC0001315]
B-236	*INSPECT RH TANK 13_000192F1.pdf* [RDHLCC0001506]
B-237	*5.98 RedHill_API653Report_Tank20_05DEC08.pdf* [RDHLCC0002668]
B-238	*Red Hill Tank 2 final 9-29-2008_Part1.pdf* [RDHLCC0002979]
B-239	*Red Hill Tank 2 final 9-29-2008_Part2.pdf* [RDHLCC0003043]
B-240	*Red Hill Tank 2 final 9-29-2008_Part3.pdf* [RDHLCC0003107]
B-241	*Tank 2 Engineering Review - Final Report 10-13-08.pdf* [RDHLCC0003171]
B-242	*54118 Final Inspection Report r0 Transmitted by WGS 08 Aug 2016.pdf* [RDHLCC0003192]
B-243	*TK6 '98 API 653.PDF* [RDHLCC0004515]
B-244	*6-Email Chow to Liming 2018 07 27 with followup email string.pdf* [RDHLCC0004792]
B-245	*6-Email Chow to Liming 2018 07 27.pdf* [RDHLCC0004794]
B-246	*Red Hill Application for UST Permit 2018 - Enclosure 06* [RDHLCC0024721]
B-247	*Red Hill Application for UST Permit 2018 - Enclosure 07* [RDHLCC0024733]

Exhibit No.	Citation
B-248	*Red Hill Application for UST Permit 2018 - Enclosure 08* [RDHLCC0024742]
B-249	*Red Hill Application for UST Permit 2018 - Enclosure 09* [RDHLCC0024765]
B-250	*Red Hill Application for UST Permit 2018 - Enclosure 10* [RDHLCC0024793]
B-251	*Red Hill Application for UST Permit 2018* [RDHLCC0024797]
B-252	*Red Hill Application for UST Permit 2018 - Enclosure 01* [RDHLCC0024802]
B-253	*Detailed Status Responses to Willbros Engineers, Inc., 1998 Report* [RDHLCC0024832]
B-254	*Appendix A (Site Investigation Notes) to Red Hill Complex Fire, Life Safety, and Environmental Risk Assessment/Analysis* [RDHLCC0024860]
B-255	*Appendix B (Site Investigation Photographs) to Red Hill Complex Fire, Life Safety, and Environmental Risk Assessment/Analysis* [RDHLCC0024921]
B-256	*Appendix C (Cost Estimate Backup) to Red Hill Complex Fire, Life Safety, and Environmental Risk Assessment/Analysis* [RDHLCC0024964]
B-257	*Appendix D (Structural Analysis - Tunnel Bulkheads and Oil-Tight Doors) to Red Hill Complex Fire, Life Safety, and Environmental Risk Assessment/Analysis* [RDHLCC0024975]
B-258	*Appendix E (PACDIV Comments and WILLBROS Responses) to Red Hill Complex Fire, Life Safety, and Environmental Risk Assessment/Analysis* [RDHLCC0024976]
B-259	*Red Hill Complex Fire, Life Safety, and Environmental Risk Assessment/Analysis Vol II of II - Final Submittal* [RDHLCC0025058]
B-260	*Red Hill Complex Fire, Life Safety, and Environmental Risk Assessment/Analysis Vol I of II - Final Submittal* [RDHLCC0025363]
B-261	*2018 Annual Leak Detection Testing Report of 17 Bulk Field-Constructed Underground Storage Tanks at Red Hill Fuel Storage Complex* [RDHLCC0027241]
B-262	*1. Red Hill Catastrophic Release Final 20150915.pdf* [RDHLCC0027316]
B-263	*4. Red Hill Hypothetical Release Rates 3.0.pdf* [RDHLCC0027328]
B-264	*5. SUMMARY Tank 20 Engineering Review - Final Report 01-27-09.pdf* [RDHLCC0027330]
B-265	*6a. Tank 15 Phase 2 Report.pdf* [RDHLCC0027352]
B-266	*7a. Tank 19 Rpr.pdf* [RDHLCC0027416]
B-267	*7b. Tank 19 Rpr1.pdf* [RDHLCC0027459]
B-268	*7c. Tank 19 Rpr2.pdf* [RDHLCC0027511]
B-269	*7d. Tank 19 Rpr3.pdf* [RDHLCC0027521]
B-270	*7e. Tank 19 Rpr4.pdf* [RDHLCC0027557]
B-271	*7f. Tank 19 Rpr5.pdf* [RDHLCC0027588]

Exhibit No.	Citation
B-272	*7g. Tank 19 Rpr6.pdf* [RDHLCC0027621]
B-273	*7h. Tank 19 Rpr7.pdf* [RDHLCC0027623]
B-274	*7i. Tank 19 Rpr8.pdf* [RDHLCC0027653]
B-275	*7j. Tank 19 Rpr9.pdf* [RDHLCC0027685]
B-276	*8. Pearl Harbor Tank 0105 AFHE Findings_02_6_2014.pdf* [RDHLCC0027721]
B-277	*9. RH_Tank01_UnverifiedHistory.PDF* [RDHLCC0027731]
B-278	*10. RH_Tank02_UnverifiedHistory.PDF* [RDHLCC0027741]
B-279	*11. RH_Tank03_UnverifiedHistory.PDF* [RDHLCC0027743]
B-280	*12. RH_Tank04_UnverifiedHistory.PDF* [RDHLCC0027745]
B-281	*13. RH_Tank05_UnverifiedHistory.PDF* [RDHLCC0027746]
B-282	*14. RH_Tank06_UnverifiedHistory.pdf* [RDHLCC0027748]
B-283	*15. RH_Tank07_UnverifiedHistory.pdf* [RDHLCC0027752]
B-284	*16. RH_Tank08_UnverifiedHistory.pdf* [RDHLCC0027754]
B-285	*17. RH_Tank09_UnverifiedHistory.pdf* [RDHLCC0027755]
B-286	*18. RH_Tank10_UnverifiedHistory.pdf* [RDHLCC0027757]
B-287	*19. RH_Tank11_UnverifiedHistory.pdf* [RDHLCC0027760]
B-288	*20. RH_Tank12_UnverifiedHistory.pdf* [RDHLCC0027762]
B-289	*21. RH_Tank13_UnverifiedHistory.pdf* [RDHLCC0027764]
B-290	*22. RH_Tank14_UnverifiedHistory.pdf* [RDHLCC0027766]
B-291	*23. RH_Tank15_UnverifiedHistory.pdf* [RDHLCC0027768]
B-292	*24. RH_Tank16_UnverifiedHistory.pdf* [RDHLCC0027769]
B-293	*25. RH_Tank17_UnverifiedHistory.pdf* [RDHLCC0027774]
B-294	*26. RH_Tank18_UnverifiedHistory.pdf* [RDHLCC0027777]
B-295	*27. RH_Tank19_UnverifiedHistory.pdf* [RDHLCC0027779]
B-296	*28. RH_Tank20_UnverifiedHistory.pdf* [RDHLCC0027781]
B-297	*Red Hill Tank 13 OOS Pre-Repair Inspection Report.pdf* [RDHLCC0027792]
B-298	*Red Hill Tank 14 OOS Pre-Repair Inspection Report.pdf* [RDHLCC0028009]
B-299	*Red Hill Tank 17 OOS Pre-Repair Inspection Report.pdf* [RDHLCC0028323]
B-300	*Tank 5 Final API 653 Inspection Report REV 1 (sent) SIGNED.pdf* [RDHLCC0028613]
B-301	*Red Hill Application for UST Permit 2018 - Enclosure 05* [RDHLCC0024719]
B-302	*Red Hill Application for UST Permit 2018 - Enclosure 02* [RDHLCC0024829]
B-303	*Red Hill Application for UST Permit 2018 - Enclosure 03* [RDHLCC0024830]

Exhibit No.	Citation
B-304	*Red Hill Application for UST Permit 2018 - Enclosure 04* [RDHLCC0024831]
B-305	*6b. Tank 15 Repair As Built Jun05.pdf* [RDHLCC0027372]
B-306	*37. Whitacre 2014i.pdf.msg* [RDHLCC0027783]
B-307	*RH HIST Tank 19 and 20_1.pdf* [RDHLCC0027784]
B-308	Board of Water Supply (BWS) comments on the Red Hill Administrative Order of Consent (AOC) Statement of Work (SOW) Sections 6 and 7 Meeting Held November 16, 2017 and the Groundwater Modelling Working Group Meeting No. 5 Held on November 17, 2017. Letter to Mr. Bob Pallarino and Ms. Roxanne Kwan. December 19, 2017.
B-310	Tank Upgrade Alternatives
B-311	Appendix I - Notification for Underground Storage Tanks Form No. I (6/99)
B-312	Navy Production of Documents in Response to Discovery Request Items 4 and 5 Vaughn Index
B-313	Historic American Engineering Record - U.S. NAVAL BASE, PEARL HARBOR, RED HILL UNDERGROUND FUEL STORAGE SYSTEM
B-314	Board of Water Supply (BWS). 2019b. Subject: IMR Test Labs Destructive Analysis of ten (10) Steel Coupons Removed from Red Hill Fuel Storage Tank #14, Report No. 201801967, dated December 17, 2018 pursuant to Section 5.3 of the Red Hill Bulk Fuel Storage Facility (RHBFSF) Administrative Order on Consent (AOC) Statement of Work. March 6.
B-315	Board of Water Supply (BWS). 2017g. Subject: Red Hill Bulk Fuel Facility Administrative Order on Consent (AOC) – Board of Water Supply (BWS) Comments Regarding the 31 August 2017 AOC Meeting Regarding Tank Upgrade Alternatives, and Quantitative Risk and Vulnerability Assessment. September 12.
B-316	Board of Water Supply (BWS). 2017h. Subject: EPA Letter Regarding: Revision to the Conditional Approval of Scope of Work for Destructive Testing Dated May 30, 2017 Submitted to the Regulatory Agencies Pursuant to Section 5.3.2 of the Red Hill Administrative Order on Consent. October 16.
B-317	Board of Water Supply (BWS). 2017i. Subject: Approval of Red Hill Administrative Order on Consent ("AOC") Statement of Work ("SOW") Section 2.4- Tank Inspection, Repair, and Maintenance ("TIRM") Procedures Decision Document and Clarifications dated September 5, 2017. October 18.
B-318	Board of Water Supply (BWS). 2017j. Subject: Red Hill Bulk Fuel Storage Facility – Tank Upgrade Alternative Decision Process Document Dated September 29, 2017. October 19.
B-319	Board of Water Supply (BWS). 2017k. Subject: Red Hill Bulk Fuel Storage Facility – Red Hill Tanks 14, 17, and 18 Non-Destructive Examination Plan Document Dated October 2017. November 9.

Exhibit No.	Citation
B-320	Board of Water Supply (BWS). 2015b. Subject: September 28, 2015 United States Environmental Protection Agency (EPA) and Hawaii Department of Health (DOH) Response to Comments (RtC). December 3.
B-321	Board of Water Supply (BWS). 2020b. Subject: Request for Update on United States Department of the Navy's "AOC SOW Section 5 Corrosion and Metal Fatigue Practices, Destructive Testing Results Report" dated July 7, 2019. March 5.
B-322	Board of Water Supply (BWS). 2016. Subject: Honolulu Board of Water Supply (BWS) Recommendations to the United States Environmental Protection Agency (EPA) for Characterization Activities While the Navy Red Hill Shaft is Pumping at Low Volumes. October 24.
B-323	*3. NavyBulkTank_SpillReleaseData.pdf* [RDHLCC0027324]

APPENDIX C

Release History

Release	Tank	Date	Volume (gallons)	Reference
1	1	1947	5	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000857
2		1953	UK	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000858; B-197 at RDHLCC0000042
3		1964	UK	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000859; B-197 at RDHLCC0000042
4		1964		B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000859; B-197 at RDHLCC0000042
5		1964		B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000859; B-197 at RDHLCC0000042
6		1965	UK	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000861; B-197 at RDHLCC0000042
7		1965	UK	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000861; B-197 at RDHLCC0000042
8		1966	UK	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000861; B-197 at RDHLCC0000042
9		1967	UK	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000861; B-197 at RDHLCC0000042

Release	Tank	Date	Volume (gallons)	Reference
10	1	1970	4623	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000862; B-197 at RDHLCC0000042
11		1971	16830	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000862; B-197 at RDHLCC0000042
12		1971	5031	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000862; B-197 at RDHLCC0000042
13		1972	4810	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000862; B-197 at RDHLCC0000042
14		1975	10671	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000864; B-197 at RDHLCC0000042
15		1977	999	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000864, B-197 at RDHLCC0000042
16		1978	7874	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000864; B-197 at RDHLCC0000042
17		1978	13221	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000865; B-197 at RDHLCC0000042
18		1982	2417	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000866; B-197 at RDHLCC0000042

Release	Tank	Date	Volume (gallons)	Reference
19	1	1982	871	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000867; B-197 at RDHLCC0000042
20		1983	2229	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000868; B-197 at RDHLCC0000042
21		1983	-1090	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000869
22		1983	-1004	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000869
23		1999	UK	B-15 at RDHLCC0025723; B-216; B-214; B-195 at RDHLCC0000869
24	2	1947	UK	B-15 at RDHLCC0025723; B-216; B-214; B-231; B-197 at RDHLCC0000042
25		1954	0.375	B-15 at RDHLCC0025723; B-216; B-214; B-231 at RDHLCC0000918
26		1954	10	B-15 at RDHLCC0025723; B-216; B-214; B-231 at RDHLCC0000918
27		2008		B-15 at RDHLCC0025723; B-216; RDHLCC0002979 at RDHLCC0003013
28		2008		B-15 at RDHLCC0025723; B-216; RDHLCC0002979 at RDHLCC0003013

Release	**Tank**	**Date**	**Volume (gallons)**	**Reference**
29	**3**	1949	4260	B-15 at RDHLCC0025723; B-216; B-214
30	**5**	1964	1	B-15 at RDHLCC0025723; B-216; B-214; B-231 at RDHLCC0000924
31		1965	1	B-15 at RDHLCC0025723, B-216; B-214; B-231 at RDHLCC0000924; B-197 at RDHLCC0000043
32		1972	0.5	B-15 at RDHLCC0025723; B-216; B-214; B-231 at RDHLCC0000925; B-197 at RDHLCC0000043
33		2010	UK	B-15 at RDHLCC0025723; B-216; B-214; B-242 at RDHLCC0003672
34		2014	27000	B-15 at RDHLCC0025723; B-216; B-214
35	**6**	1952	UK	B-15 at RDHLCC0025723; B-216; B-190 at RDHLCC0003808
36		2002	UK	B-15 at RDHLCC0025723; B-216
37	**7**	1973	UK	B-15 at RDHLCC0025723; B-216;B-196 at RDHLCC0000908; B-197 at RDHLCC0000043; B-184 at RDHLCC0004577
38		1978	UK	B-15 at RDHLCC0025723; B-216; B-214; B-197 at RDHLCC0000043; B-184 at RDHLCC0004577

Release	Tank	Date	Volume (gallons)	Reference
39	**7**	1980/81	6505	B-15 at RDHLCC0025723; B-216; B-214; B-197 at RDHLCC0000043; B-184 at RDHLCC0004578
40		1998	UK	B-187 at RDHLCC0004659
41	**9**	1958	1500	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000648; B-197 at RDHLCC0000043; B-285
42		1978		B-15 at RDHLCC0025723; B-216; B-197 at RDHLCC0000043
43		1980	1900	B-15 at RDHLCC0025723, B-216; B-214 at RDHLCC0000648; B-197 at RDHLCC0000043; B-285
44		1996	UK	B-197 at RDHLCC0000043; B-233 at RDHLCC0000962
45	**10**	1973	UK	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000648; B-197 at RDHLCC0000043; B-176 at RDHLCC0001140
46		1976	UK	B-15 at RDHLCC0025723; B-216; B-196 at RDHLCC0000909; B-176 at RDHLCC0001140
47		1980	3123	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000648; B-176 at RDHLCC0001141
48		1981	5097	B-15 at RDHLCC0025723; B-216; B-197 at RDHLCC0000043; B-176 at RDHLCC0001141

Release	Tank	Date	Volume (gallons)	Reference
49	**10**	1996	UK	B-228 at RDHLCC0000894; B-233 at RDHLCC0000974
50		1998	UK	B-180 at RDHLCC0001290
51	**11**	1980	25,628	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000648; B-197 at RDHLCC0000044; B-226 at RDHLCC0000873
52	**12**	1964	UK	B-15 at RDHLCC0025723; B-216; B-197 at RDHLCC0000044; B-226 at RDHLCC0000875
53		1973	UK	B-15 at RDHLCC0025723; B-216; B-197 at RDHLCC0000044; B-226 at RDHLCC0000875
54		1981	4280	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000648, B-197 at RDHLCC0000044; B-226 at RDHLCC0000874
55	**13**	1976	UK	B-15 at RDHLCC0025723; B-216; B-197 at RDHLCC0000044, B-226 at B-226 at RDHLCC0000879
56		1981	UK	B-15 at RDHLCC0025723; B-216; B-197 at RDHLCC0000044; B-226 at B-226 at RDHLCC0000879
57	**14**	1982	UK	B-15 at RDHLCC0025723; B-216
58		1995	UK	B-223 at RDHLCC0000845; B-233 at RDHLCC0001062

Release	Tank	Date	Volume (gallons)	Reference
59	**15**	1981	UK	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000648; B-197 at RDHLCC0000044; B-223 at RDHLCC0000851
60	**16**	1948/49	11009	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-197 at RDHLCC0000044; B-194
61		1949	17737	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-197 at RDHLCC0000044; B-194
62		1973	UK	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-197 at RDHLCC0000044; B-194 at RDHLCC0000822
63		1981	UK	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-194 at RDHLCC0000824
64		1981	UK	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-197 at RDHLCC0000045; B-194 at RDHLCC0000824
65		1998	1469	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-194 at RDHLCC0000832; B-194 at RDHLCC0000833
66	**17**	1949	1420	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650
67		1969	1	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-197 at RDHLCC0000045; B-221 at RDHLCC0000837

Release	Tank	Date	Volume (gallons)	Reference
68	**17**	1975	UK	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-197 at RDHLCC0000045; B-221 at RDHLCC0000838
69	**19**	1964	UK	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-197 at RDHLCC0000045; B-191 at RDHLCC0001644; RDHLCC0000928
70		2000	UK	B-204
71		1998	UK	B-15 at RDHLCC0025723; B-216; B-214 at RDHLCC0000650; B-197 at RDHLCC0000045
72	**UK**	2012	6	B-198 at RDHLCC0000361

ABOUT DNV GL

DNV GL is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property, and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software, and independent expert advisory services to the maritime, oil and gas, power, and renewables industries. We also provide certification, supply chain, and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter, and greener.

EXHIBIT B

APPENDIX C

Release History

(Updated 12/18/2021)

Release	Tank/Asset	Date	Volume [1] (gallons)	Reference
1	1	1947	5	B-15 at BWS005166; B-195 at BWS027743; B-214; B-216
2		1953	UK	B-15 at BWS005166; B-195 at BWS027744; B-197 at BWS027814; B-214; B-216
3		1964	UK	B-15 at BWS005166; B-195; B-197 at BWS027814; B-214; B-216
4		1964		B-15 at BWS005166; B-195 at BWS027745; B-197 at BWS027814; B-214; B-216
5		1964		B-15 at BWS005166; B-195 at BWS027745; B-197 at BWS027814; B-214; B-216
6		1965	UK	B-15 at BWS005166; B-195 at BWS027747; B-197 at BWS027814; B-214; B-216
7		1965	UK	B-15 at BWS005166; B-195 at BWS027747; B-197 at BWS027814; B-214; B-216
8		1966	UK	B-15 at BWS005166; B-195 at BWS027747; B-197 at BWS027814; B-214; B-216
9		1967	UK	B-15 at BWS005166; B-195 at BWS027747; B-197 at BWS027814; B-214; B-216

Release	Tank/Asset	Date	Volume [1] (gallons)	Reference
10	**1**	1970	4623	B-15 at BWS005166; B-216; B-214; B-195 at BWS027748; B-197 at BWS027814
11		1971	16830	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216
12		1971	5031	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216
13		1972	4810	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216
14		1975	10671	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216
15		1977	999	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216
16		1978	7874	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216
17		1978	13221	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216
18		1982	2417	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216

Release	Tank/Asset	Date	Volume [1] (gallons)	Reference
19	**1**	1982	871	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216
20		1983	2229	B-15 at BWS005166; B-195 at BWS027748; B-197 at BWS027814; B-214; B-216
21		1983	-1090	B-15 at BWS005166; B-195 at BWS027755; B-214; B-216
22		1983	-1004	B-15 at BWS005166; B-195 at BWS027755; B-214; B-216
23		1999	UK	B-15 at BWS005166; B-195 at BWS027755; B-214; B-216
24	**2**	1947	UK	B-15 at BWS005166; B-197 at BWS027814; B-214; B-216; B-231
25		1954	0.375	B-15 at BWS005166; B-214; B-216; B-231 at BWS028473
26		1954	10	B-15 at BWS005166; B-214; B-216; B-231 at BWS028473
27		2008		B-15 at BWS005166; B-216; B-238 at BWS029230
28		2008		B-15 at BWS005166; B-216; B-238 at BWS029230

Release	Tank/Asset	Date	Volume [1] (gallons)	Reference
29	**3**	1949	4260	B-15 at BWS005166; B-216; B-214
30	**5**	1964	1	B-15 at BWS005166; B-214; B-216; B-231 at BWS028479
31		1965	1	B-15 at BWS005166; B-197 at BWS027815; B-214; B-216; B-231 at BWS028479
32		1972	0.5	B-15 at BWS005166; B-197 at BWS027815; B-214; B-216; B-231 at BWS028480
33		2010	UK	B-15 at BWS005166; B-214; B-216; B-242 at BWS029889
34		2014	27000	B-15 at BWS005166; B-214; B-216
35	**6**	1952	UK	B-15 at BWS005166; B-190 at BWS025861; B-216
36		2002	UK	B-15 at BWS005166; B-216
37	**7**	1973	UK	B-15 at BWS005166; B-184 at BWS025697; B-196 at BWS027765; B-197 at BWS027815; B-216
38		1978	UK	B-15 at BWS005166; B-184 at BWS025697; B-197 at BWS027815; B-214; B-216

Release	Tank/Asset	Date	Volume [1] (gallons)	Reference
39	**7**	1980/81	6505	B-15 at BWS005166; B-184 at BWS025698; B-197 at BWS027815; B-214; B-216
40		1998	UK	B-187 at BWS025779
41	**9**	1958	1500	B-15 at BWS005166; B-197 at BWS027815; B-214 at BWS028414; B-216; B-285
42		1978		B-15 at BWS005166; B-197 at BWS027815; B-216
43		1980	1900	B-15 at BWS005166; B-197 at BWS027815; B-214 at BWS028414; B-216; B-285
44		1996	UK	B-197 at BWS027815; B-233 at BWS028517
45	**10**	1973	UK	B-15 at BWS005166; B-176 at BWS025438; B-197 at BWS027815; B-214 at BWS028414; B-216
46		1976	UK	B-15 at BWS005166; B-176 at BWS025438; B-196 at BWS027766; B-216
47		1980	3123	B-15 at BWS005166; B-176 at BWS025439; B-214 at BWS028414; B-216

Release	Tank/Asset	Date	Volume [1] (gallons)	Reference
48	**10**	1981	5097	B-15 at BWS005166; B-176 at BWS025439; B-197 at BWS027815; B-216
49		1996	UK	B-228 at BWS028466; B-233 at BWS028529
50		1998	UK	B-180 at BWS025588
51	**11**	1980	25,628	B-15 at BWS005166; B-197 at BWS027816; B-214 at BWS028414; B-216; B-226 at BWS028445
52	**12**	1964	UK	B-15 at BWS005166; B-197 at BWS027816; B-216; B-226 at BWS028447
53		1973	UK	B-15 at BWS005166; B-197 at BWS027816; B-216; B-226 at BWS028447
54		1981	4280	B-15 at BWS005166; B-197 at BWS027816; B-214 at BWS028414; B-216; B-226 at BWS028446
55	**13**	1976	UK	B-15 at BWS005166; B-197 at BWS027816, B-216; B-226 at BWS028443, BWS028451
56		1981	UK	B-15 at BWS005166; B-197 at BWS027816, B-216; B-226 at BWS028443, BWS028451

Release	Tank/Asset	Date	Volume [1] (gallons)	Reference
57	**14**	1982	UK	B-15 at BWS005166; B-216
58		1995	UK	B-223 at BWS028433; B-233 at BWS028617
59	**15**	1981	UK	B-15 at BWS005166; B-197 at BWS027816; B-214 at BWS028414; B-216; B-223 at BWS028439
60	**16**	1948/49	11009	B-15 at BWS005166; B-194; B-197 at BWS027816; B-214 at BWS028414; B-216
61		1949	17737	B-15 at BWS005166; B-194; B-197 at BWS027816; B-214 at BWS028414; B-216
62		1973	UK	B-15 at BWS005166; B-194 at BWS027728; B-197 at BWS027816; B-214 at BWS028414; B-216
63		1981	UK	B-15 at BWS005166; B-194 at BWS027730; B-214 at BWS028414; B-216
64		1981	UK	B-15 at BWS005166; B-194 at BWS027730; B-197 at BWS027817; B-214 at BWS028414; B-216
65		1998	1469	B-15 at BWS005166; B-194 at BWS027738, BWS027739; B-214 at BWS028414; B-216

Release	Tank/Asset	Date	Volume [1] (gallons)	Reference
66	**17**	1949	1420	B-15 at BWS005166; B-214 at BWS028414; B-216
67		1969	1	B-15 at BWS005166; B-197 at BWS027817; B-214 at BWS028414; B-216; B-221 at BWS028425
68		1975	UK	B-15 at BWS005166; B-197 at BWS027817; B-214 at BWS028414; B-216; B-221 at BWS028426
69	**19**	1964	UK	B-15 at BWS005166; B-191 atBWS026699; B-197 at BWS027817; B-214 at BWS028414; B-216; B-232
70		2000	UK	B-204 at BWS028333
71		1998	UK	B-15 at BWS005166; B-197 at BWS027817; B-214 at BWS028414; B-216
72	**UK**	2012	6	B-198 at BWS028133
73	**6-inch Multi-Product Defuel Pipeline (Hotel Pier)**	Identified via Pressure test failure on 1/20/2021	UK	B-410

Release	Tank/Asset	Date	Volume [1] (gallons)	Reference
	6-inch Multi-Product Defuel Pipeline (Hotel Pier)	Identified via Pressure test failure on 1/23/2021	UK	B-410
74	**Piping near 20**	5/6/2021	1618	B-411, B-412, B-413
75	**Pipeline Kilo Pier**	7/16/2021	150	B-414
76	**Fire Suppression Piping**	11/20/2021	>14,000	B-415

1 – Volume is based on values reported by the Navy or disclosed within documents. DNV has not independently verified the release volumes.

DEPARTMENT OF HEALTH

STATE OF HAWAII

In the Matter of the Emergency Order to UNITED STATES NAVY For Emergency Change-In-Service and Defueling of 20 Underground Storage Tanks, Red Hill Bulk Fuel Storage Facility	DOCKET NO. 21-UST-EA-02 CERTIFICATE OF SERVICE

CERTIFICATE OF SERVICE

I HEREBY CERTIFY that a copy of the foregoing documents were served upon the following, via email, to their last known email address on December 18, 2021:

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