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RED HILL REPAIR TANKS OPTIONS STUDY

FISC Pearl Harbor, Hawaii

Final Report

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Prepared For:

Naval Facilities Engineering Command
Engineering Service Center
1100 23rd Avenue, Code 232
Port Hueneme, California 93043-4370

Prepared By:

ENTERPRISE ENGINEERING, INC.

Stephen J. DiGregorio, P.E.
Chief Structural Engineer, API 653 Certificate No. 1113

Ray Griffith, P.E.
Structural Engineer/Planner/Cost Estimator

Melvin Yokota, P.E.
Electrical Engineer

Craig Meier
Corrosion Specialist (Cathodic Protection and Coatings)

Submitted By:

Kevin S Murphy, P.E.
Principal
2525 Gambell Street, Suite 200, Anchorage, AK 99503

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ABSTRACT

Enterprise Engineering, Inc. has completed a comprehensive engineering evaluation resulting in the programming of a MILCON project to repair the FISC Pearl Harbor Red Hill tanks. The MILCON project will provide a long term life extension renewal of the tanks (40 year expected tank life), secondary containment, and the capability to detect and locate leaks. Various repair alternatives were evaluated and are discussed in this report. This study also identified new tank repair technologies and evaluated their applicability to the Red Hill tanks.

Two repair alternatives were identified as viable options that meet the criteria in the Project Scope of Work and the criteria discussed at the Kick-Off Meeting. Conceptual designs were developed and cost estimates prepared for each of the two alternatives.

Alternative 1 – Composite Tank: The Composite Tank consists of inspecting and repairing the existing steel liner in each tank, which would become the secondary containment system and then constructing a new liner with a 3 inch wide interstitial space between the new liner and the existing liner. The interstitial space would be filled with grout and have a leak detection system. The Program Amount for this concept is per tank.

Alternative 2 – Tank Within A Tank: The Tank Within A Tank concept consists of inspecting and repairing the existing steel liner in each tank which would become the secondary containment system, and constructing a new tank inside the existing tanks with a 5 feet wide annular space between the new tank and existing tank shell that is accessible for inspection and visual leak detection. The Program Amount for this concept is per tank.

Due to the very unusual nature of the Red Hill complex EEI recommends authorization of a single tank repair project to start the program as a means of proving up the concepts and confirming overall cost validity. Following the first tank repair, execution of repair of three tanks at a time has significant economic benefit. Such an approach can take into account lessons learned from the first tank repair.

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RED HILL TANKS REPAIR OPTIONS STUDY
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1.0 EXECUTIVE SUMMARY

General

Enterprise Engineering Inc. (EEI), under contract to NFESC, was retained to develop concept alternatives and associated planning level cost estimates to repair the 20 underground tanks at FISC Pearl Harbor Red Hill. This document is the Final Submission and presents EEI's recommendations based on the criteria presented in the NFESC Statement of Work and discussions at the kick-off meeting.

The existing Red Hill tanks were constructed during August 1940 to September 1943. Tanks 1 to 4 are REDACTED REDACTED REDACTED REDACTED REDACTED Current and previous inspections have found defects in the tank liner (weld quality and corrosion) that required repair before returning the tanks to service. There is currently a program to clean, inspect and repair all of the tanks with the goal of returning the tanks to service for another 20-year service interval. The current approach consists of performing an out-of service inspection of the tank interior (including scanning the steel liner plates and welds for corrosion and other defects) and repairing defects found during the inspection. Under this approach select defects such as holes and cracks and only those areas having a remaining thickness below a predetermined minimum thickness are repaired (0.170"minimum thickness was used on Tanks 2 and 20). The repair costs are highly variable depending on the condition of the tank and the defects found. Each tank reportedly costs approximately (cost to the government including contractor mark-ups) for just the cleaning and inspection.

The Government has authorized this study to develop tank repair concepts that will provide a long term life extension renewal of the Red Hill tanks. The Government has requested that the repair alternatives meet the following primary objectives:

- Provide a tank life expectancy of 40 years, with reliable inspection intervals of 20 years.
- Minimize risk of a fuel leak.
- Contain leaks that may potentially occur.
- Have the capability to detect and locate potential leaks and repair leaks.

EEI performed a similar study in 1998 (*Repair Tank 19 Red Hill FISC Pearl Harbor, HI DESC Project PRL 98-9)* to develop possible repair options for Tank 19. The 1998 study was performed due to tank integrity issues, environmental concerns, lack of leak detection capability, and lack of secondary containment. This study is discussed further later in this document.

Recommendations and Summary of Concepts

To meet the Government's objectives EEI recommends the following two concepts for consideration.

Alternative 1 - Composite Tank

The Composite Tank alternative consists of providing a new 1/4" thick carbon steel liner on the lower dome and barrel of the existing tank. The new steel liner is separated from the existing steel liner by steel angles or tees welded to the existing steel liner to create an interstitial space filled with grout or concrete. The Composite Tank alternative, in essence, is a double wall tank. Secondary containment is provided by the existing steel liner and a spray applied urethane lining. The interstitial space provides a means for leak detection. Even though Tanks 5 to 20 are taller than Tanks 1 to 4, all tanks will be repaired to the same height (approximately two feet below the expansion joint at the top of the barrel); thus nominal storage capacity of the Composite Tank is the same for all tanks. The Composite Tank concept is presented on sketches SK-1.0 to SK-1.3.

REDACTED

Alternative 2 - Tank Within A Tank

This alternative involves constructing a new tank inside the existing tank. The new tank would be REDACTED and have dome bottom and a fixed roof with a vent pipe connected to the existing tank vent system. The height of the new tank will be the same for all 20 tanks. The top of the new tank will be approximately 2 feet below the expansion joint of the upper dome (below the manhole and walkway of the existing tank). The smaller diameter of the new tank creates a REDACTED around the tank that allows inspection of the exterior of the tank for weeps and leaks. The annular space also allows inspection of the steel liner of the existing tank. Containment of leaks is provided by the steel liner of the existing tank. This concept is presented on sketches SK-2.0 to SK-2.3. The Tank Within A Tank concept with a dome bottom provides a

REDACTED

A variation of a Tank Within A Tank alternative was considered which consists of filling a portion of the lower dome of the existing tank and constructing a new tank with a cone down bottom. This concept involves demolishing the top 35 feet of the lower dome including the REDACTED REDACTED of the dome, excavating the rock behind the dome wall, extending the barrel of the existing tank down to this new elevation, and filling in the remaining portion of the lower dome. This concept is presented on sketches SK-3.0 to SK-3.2. As this concept involves major demolition work and modifications affecting structure of the existing tank, it is not as viable as the new tank with a dome bottom concept, and thus was not further developed.

Opinion of Probable Project Cost

EEI's opinion of probable project construction cost for the two alternatives is presented in the following table.

Opinion of Probable Project Cost

Alternative	Contractor Cost (per tank)	Programmed Cost (per tank)	Total Programmed Cost (20 tanks)
Alternative 1: Composite Tank	REDACTED	REDACTED	REDACTED
Alternative 2: Tank Within A Tank	REDACTED	REDACTED	REDACTED

The cost for the two alternatives is higher than those presented in the Pre-final report and is attributed to the following:

- Revised cost to clean and inspect the existing tanks based on information provided by the government on recent projects to clean, inspect, and repair the Red Hill tanks.
- Cost to remove existing tank coatings. EEI was directed to assume existing tank coatings contain lead.
- Revised field painting costs.
- Revised cost of coating inspection to include inspection by an SSPC QP-5 certified coating inspector.
- Tank elements that were added to the repair alternatives such as a fixed roof and walkways around the new tank in Tank Within A Tank alternative.
- Increased project duration.

The estimates for these two alternatives are based on the following key cost factors:

1. The Programmed Cost includes Contractor Cost plus construction contingency, SIOH and Post Construction Award Services.
2. The cost associated with the design of this MILCON project is not included in the programmed cost.
3. The project pricing is based on 2008 Dollars and does **not** include escalation. This is discussed further later in the document.
4. Steel pricing is based on the July 2008 commodity price for steel; the estimate uses per lb for A36 steel and per lb for high strength steel FOB the mill. The project will require between REDACTED Steel prices are expected to continue to increase and remain at a higher level in the long term. The cost of steel should be monitored and the

Program Amount for this project adjusted accordingly prior to each annual review for MILCON funding.

5. The cost includes shipping of all materials from the mainland to Hawaii.
6. Fuel price is based on 2008 costs.
7. The tanks will be repaired in groups of three tanks and may not be adjacent to each other.
8. Tank cleaning and inspection of the existing internal steel liner prior to construction.
9. Costs to remove existing coatings are based on existing coatings containing lead.
10. The Composite Tank will be 100% internally coated in accordance with UFGS 09 97 13.15 “Epoxy/Fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks”.
11. The Tank Within A Tank will be 100% internally coated in accordance with UFGS 09 97 13.15 “Epoxy/Fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks”. The exterior of the Tank Within A Tank will be 100% coated in accordance with UFGS 09 97 13.27 “Exterior Coating of Steel Structures”. Dehumidification will be used for the coating work. Coating inspection will be performed by an SSPC QP-5 certified inspector.
12. The Composite Tank and Tank Within A Tank will **not** be hydrotested. Hydrotesting is discussed later in this document in the detailed discussion on each alternative.
13. The contractor will be required to provide temporary electrical power during construction.
14. Construction contracting will be via full and open bid process.

If only one tank is initially authorized, as recommended, the cost for the first tank will be higher than the cost per tank if tanks are repaired in groups of three tanks. However the lessons learned during the first tank will likely reduce overall costs as they are applied to the subsequent tanks. Our opinion of probable project construction cost for the Tank Within A Tank alternative if only one tank is initially authorized is presented below:

Contractor Cost: REDACTED (compared to REDACTED per tank if tanks are repaired in groups of three tanks)

Programmed Cost: REDACTED (compared to REDACTED per tank if tanks are repaired in groups of three tanks)

The cost for the Composite Tank alternative if only one tank is authorized has not been estimated but would be comparable to the Tank Within A Tank alternative.

Execution Strategy

EEI recommends authorization of a single tank repair project to start the program, as a means of proving up the concepts and confirming overall cost validity. Following the first tank repair, the lessons learned from this tank can be incorporated into the design and construction of the subsequent tanks. After the first tank is complete, performing the work on three tanks concurrently has significant economic benefits.

We recommend the following project execution strategy:

- Government selection of repair alternative.
- Government authorization of an engineering project to refine the selected alternative and refine/update the project cost estimate, including preparation of a draft DD 1391 for review.
- Preparation of a final DD 1391 to repair all 20 tanks.
- Government authorization of a project to repair a single tank.
- Government authorization of a program to repair three tanks at a time.

Coordination with Other Projects and Activities

Selection of tanks for repair by either the Composite Tank alternative or Tank Within A Tank alternative should be coordinated with the current program to clean, inspect and repair all of the tanks.

Alternative 1 - Composite Tank

As the Composite Tank alternative relies on the integrity of the existing steel liner for secondary containment, the steel liner and welds of the barrel and lower dome of the existing tank need to be 100% scanned for thinning due to corrosion and weld defects and repaired. If a tank was inspected within the past 5 years that included scanning of the steel liner and welds and repair of thin areas and weld defects, the existing steel liner does not need to be re-inspected. If the steel liner has never been scanned, 100% scanning of the steel liner and welds of the barrel and lower dome of the existing tank must be included in Composite Tank alternative.

Alternative 2 – Tank Within A Tank

Similarly, the Tank Within A Tank alternative with a dome bottom relies on the integrity of the steel liner in the lower dome and barrel of the existing tank for secondary containment. If a tank was inspected within the past 5 years that included scanning of the steel liner and welds and repair of thin areas and weld defects, the existing steel liner does not need to be re-inspected. If the steel liner has never been scanned, 100% scanning of the steel liner and welds of the lower dome and barrel of the existing tank must be included in this alternative.

The logistics of hydrotesting the new Tank Within A Tank are complex. Given the unique conditions of hydrotesting the new tanks at Red Hill, EEI has assessed the risks of not hydrotesting the tank and what measures could be done if a hydrotest is not performed. Our assessment is that the hydrotest can be waived; however, additional non-destructive testing of the shell is recommended. Another recommendation is to perform an initial fill test with fuel and then operate the tank at a lower fill height. Repairing tanks in groups of three tanks and performing an initial fill test with fuel will require using fuel from a fourth tank to perform the initial fill test.

Decisions/Actions Made

Based on government review comments on the Pre-final report and discussions during the project review meeting, EEI has made the following revisions to the recommended alternatives and opinions of project cost presented in this final report:

1. Revised the cost to clean and inspect the existing tanks.

2. EEI was directed to assume existing tank coatings contain lead. Coating removal cost was revised and is now based on existing tank coatings containing lead.

3. Coating inspection by a NACE coating inspector was changed to SSPC QP-5 certified inspector.

4. Revised the leak detection piping of the Composite Tank alternative so that the piping is within the interstitial space, not inside the tank.

5. Provided discussion that hydrostatic testing of the structural integrity the Composite Tank alternative is not necessary as the new steel liner is a non-structural element supported by grout in the interstitial space and the existing tank and that a hydrotest would not provide a reliable leak test as leak detection time is not immediate.

6. Revised the Tank Within a Tank alternative to include a fixed roof and a vent pipe connected to the existing tank vent in the upper dome so that personnel could access the annular space around the tank and added walkways around the exterior of the new tank at three levels.

7. Assessed the risks of not performing a hydrostatic test of the new tank in the Tank Within A Tank alternative and recommended that the new tank be constructed without performing a hydrotest. Revised the project cost to delete hydrotesting and added additional non-destructive examination of the tank shell.

2.0 PROJECT SCOPE AND HISTORY

Project Scope and Goals

The overall scope and goals of this study as stated in the NFESC Statement of Work include:

- Maintain a total usable capacity in Red Hill of REDACTED of product storage. (This criteria was discussed at the kick-off meeting and is under Government review.)
- Tank life expectancy of 40 years.
- Minimize risk of a fuel leak.
- Contain leaks that may potentially occur.
- Capability to detect and locate potential leaks and repair leaks.
- Provide suggested grouping for simultaneous tank work with construction sequencing of each group.
- Prepare an estimated timeline indicating major milestones and phases of construction.
- Prepare a written life maintenance plan.
- Develop constructible repair options utilizing the most current available technologies.
- Prepare project cost estimates.

The project scope was further refined at the kick-off meeting held on June 18, 2008 at FISC Pearl Harbor. During the meeting FISC personnel reiterated the goal that the repair should be based on a 40 year life extension of the tanks. Additionally, as the Government is currently evaluating fuel storage needs at FISC Pearl Harbor Red Hill complex and future storage capacity requirements are not known and may change, direction was given to not attempt to develop concept repair alternatives based on meeting a target storage capacity.

History

The FISC Pearl Harbor Red Hill complex was constructed during August 1940 to September 1943 and consists of twenty underground vertical cylindrical reinforced concrete fuel storage tanks (Tanks 1 - 20) with a dome top and bottom and internal steel liner, fuel piping, mechanical and ventilation systems, electrical systems, REDACTED and associated infrastructure.

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REDACTED The primary structure of the tanks consists of an upper dome, barrel, and lower dome. The upper dome was constructed first. Rock was excavated to create a cavity for the upper dome. Steel framing and liner plates were then installed, followed by filling the cavity with reinforced concrete, REDACTED After the upper dome was constructed the barrel and lower dome were excavated and the rock face was sealed with gunite. The wall of the barrel was constructed of reinforced concrete REDACTED and lined with REDACTED After the barrel was constructed, it was pre-stressed by injecting grout between the reinforced concrete and lava rock. The lower dome was constructed of reinforced concrete and lined with REDACTED . The floor of the lower dome is flat and consists of REDACTED

Each tank has a steel framed tower in the center of the tank extending from the floor of the lower dome to the top of the upper dome and a walkway from the manhole at the Upper Tunnel level to the tower. The center tower was used during original construction to construct the tanks.

Eighteen tanks are currently in service and presently used to store JP-5, JP-8 and F-76 fuel as follows:

- Tanks 2 to 6: JP-8
- Tanks 7 to 12: JP-5
- Tanks 13 to 16: F-76
- Tanks 17, 18, 20: JP-5

Tank 1 and Tank 19 are considered permanently out of service. Tank 19 was taken out of service circa 1986 for gauging repairs. The tank was not placed back in service as "weeping" was observed from some of the channel doublers in the upper dome.

Tank repairs and modifications have been provided over the years that include:

- Removal of leak detection piping inside some of the tanks.
- Repair of defective welds in the upper dome. Some tanks were repaired by welding channels over defective welds. Other tanks were repaired by welding batten plates over defective welds. And some tanks were repaired by repairing only the defective welds.
- Repair of defective welds in the barrel and lower dome.
- Repair of pitting, holes, and thin areas in the steel liner.
- Removal of grout tube couplings in the steel liner. The couplings were removed during original construction and the openings in the liner repaired with welded patch plates.
- Repairs to the center tower.
- Removal of steam heating coils.

- Full coating of the tanks (including aluminum metalizing of the floors) circa late 1960s, early 1970s, using the earliest versions of the NRL polyurethane coating systems.

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). There is currently a program to clean, inspect and repair all of the tanks with goal of retuning the tanks to service for another 20-year cycle. The current round of inspections (Tanks 2, 6, 15, 16 and 20) was the first time a tank ever received 100% scanning of the steel liner plates and welds.

3.0 PREVIOUS TANK 19 REPAIR STUDY

Summary of 1998 Study

EEI completed a Functional Analysis Concept Design (FACD) study in 1998, *Repair Tank 19, Red Hill, FISC Pearl Harbor, Hawaii, DESC Project PRL 98-9 Contract N624724-98-C-0002* to consider possible repair options for Tank 19. Several concepts were brainstormed by the team. The 1998 study selected following concepts for cost estimating:

- Repair and Recoat Existing Steel Liner
- Internal Bladder Type Liner
- Composite Tank

A free standing tank inside the existing tank concept was also considered but was not further evaluated or developed as the cost of the tank alone was believed to be four times the cost of the Composite Tank concept. The 1998 study recommended the following:

1. If the life of the Red Hill facility is less than 5 years, the repair and recoat option is a viable alternative but does not provide secondary containment or leak detection.

2. If the life of the facility is between 5 and 15 to 20 years, the internal bladder offers a cost effective solution, even if the bladder is replaced in 10 years.

3. If the life of the facility is expected to be at least 15 years, the Composite Tank option offers long term life extension, secondary containment, and capability to detect and locate leaks.

Applicability of 1998 Study to Current Study

The repair and recoating approach does not improve the service interval of the tanks beyond 20 years at which point another cycle of clean, inspect, and repair is required, nor does it meet the stated goals of the Statement of Work to provide containment of leaks and leak detection.

The internal bladder type liner alternative is not a viable alternative as it was estimated that the bladder liner would need replacement in 10 years and thus does not meet the goal of a 40-year life extension.

The Composite Tank alternative is a viable option for a long term life extension renewal of the Red Hill tanks and is further developed in this Repair Options Study report.

The Tank Within A Tank alternative also has merit in that it provides a long term life extension, secondary containment, and the capability to detect and locate leaks. Thus, we have also chosen to further develop this alternative in this Repair Options Study report.

4.0 DEVELOPMENT OF REPAIR OPTION PARAMETERS

A project kick-off meeting was held on June 18, 2008 at FISC Pearl Harbor to discuss project scope and goals, parameters for tank repair options including fuel storage requirements, operational considerations, environmental items, leak detection and tank availability. The following parameters were discussed during the project kick-off meeting. These parameters have been considered in developing concept repair alternatives for this study.

Tank Capacity

Tanks 1 to 4 are presently filled to an average useable capacity of REDACTED each at an approximate REDACTED REDACTED REDACTED Per discussions during the project kick-off meeting, the Government is currently evaluating fuel storage needs for Red Hill. At this time, future storage capacity requirements are not known and may change. Comments were made that the overall storage capacity requirements could decrease or increase and that storage capacity requirements for specific fuels (JP-5, JP-8, and F-76) could also change. Direction was given during the project kick-off meeting not to attempt to develop concept repair alternatives based on meeting a target storage capacity.

Tank Life Expectancy

One of the goals of this study, as stated in the Statement of Work, is to develop repair alternatives that provide a tank life expectancy of 40 years. The repair alternatives presented in this study are based on providing a life expectancy of 40 years or more with normal and usual inspection and maintenance.

Secondary Containment and Leak Detection

In considering secondary containment and leak detection, it is important to note that tanks generally weep before leaking. It is not intended that a secondary containment system contain weeps or leaks indefinitely. Once a leak is detected, it is expected that action will be taken to stop the leak (such as lowering the product level or emptying the tank), providing repairs, and cleaning up the fuel in the secondary containment system. Visual detection of a leak is the fastest way to detect leaks. Detection by electronic leak detection systems may have a significant time delay before a leak is detected.

Thus, in developing repair concepts, we have considered alternatives and new technologies that provide containment of leaks that may potentially occur, including leak detection and location of leaks. These alternatives and technologies are discussed later in this report.

Grouping of Tanks for Simultaneous Construction

The Statement of Work states to provide suggested grouping of tanks for simultaneous work with construction sequencing of each group. Currently five tanks are used for JP-8 service (Tanks 2 to 6), four tank are used for F-76 service (Tanks 13 to 16), and 9 tanks are used for JP-5 service (Tanks 7 to 12 and Tanks 17, 18, and 20). Tanks 1 and 19 are considered out of service. Our study assumes all 20 twenty tanks will be repaired.

During the project kick-off meeting, EEI was informed that 3 to 4 tanks could be made available at a time for tank repairs. The Government may initially make tanks available based on type of fuel service (i.e. one JP-5 tank, one JP-8 Tank, and one F-76 tank); later groups may have two or more tanks of the same product service.

It was decided that this study would consider tanks being available in groups of three and that specific tanks in each group need not be determined. Additionally, the estimate of project costs would be based on repairing three tanks at a time. In preparing the cost estimates, we have assumed that the three tanks would be different product service and thus not adjacent to each other. This scenario considers the additional cost of working on tanks that are at opposite ends of the Upper Tunnel, which requires work to be staged at Adit 4 and Adit 5. A cost reduction is possible if two tanks are adjacent to each other.

As discussed previously, EEI is recommending repair of only one tank at first as a test case to refine the approach from both a design and construction perspective. While this approach may increase the cost of the first tank, EEI feels that there is the potential for later benefits in that pricing and design concepts can be confirmed and lessons learned can be applied to the follow-up groups of tanks.

5.0 LONG TERM LIFE EXTENSION RENEWAL ALTERNATIVES CONSIDERED

The following alternatives were evaluated for this study.

- Composite Tank
- Permutations of the Composite Tank
- Tank Within A Tank
- Other New Technology

Alternative 1 - Composite Tank

The Composite Tank alternative consists of providing a new steel liner inside the existing tank. The new steel liner would extend up to and be sealed approximately 2 feet below the expansion joint of the upper dome (below the manhole and walkway of the existing tank). The new steel liner is supported and separated from the existing steel liner by structural steel angles or tees welded to the existing steel liner to create an interstitial space for leak detection. To resist fluid pressure from tank contents, the interstitial space will be filled with grout or self-leveling concrete. Secondary containment is provided by the existing steel liner. As the existing steel liner will continue to corrode over time, the interior surface will be coated with a spray applied urethane lining to provide a release prevention barrier.

EEI considers the Composite Tank alternative a viable option and has prepared a project cost estimate. This alternative is further discussed in the sections that follow.

Composite Tank Permutations

The following permutations of the Composite Tank alternative were considered but later dismissed as not being viable:

New Steel Liner Plates Welded to Existing Steel Liner

This permutation of a Composite Tank eliminates the structural steel angles (or tees) and grout/concrete supporting the new liner. The existing steel liner will be inspected and repaired to provide secondary containment. The new liner plates will be welded directly to and supported by the existing steel liner. The "interstitial space" (i.e. interface) between the new liner and existing liner provides means for leak detection. Leaks in the new liner will be contained by the existing liner and detected by leak detection piping. This alternative was dismissed because:

1. Placing new steel against old steel sets up a galvanic corrosion mechanism between the new steel and existing steel causing the new steel to act as an anode and corrode.
2. The existing steel liner is subject to external corrosion and will continue to corrode. Over time corrosion holes will develop resulting in loss of secondary containment. Current repairs are based on a remaining thickness of 0.100 inches after 20 years and repairing only corroded areas that have a remaining metal thickness below a predetermined threshold thickness.

3. Even if the existing steel liner is coated with a urethane lining to provide a release prevention barrier, the urethane lining would be damaged by welding the new steel liner plates to the existing steel liner.

New Steel Liner Plates with Metal Mesh

In this permutation metal mesh is provided between the new liner plates and existing steel liner. The metal mesh creates a wider interstitial space and thus better leak detection. This permutation was dismissed for the same reasons stated above.

New Steel Liner Plates with Fiberglass Mesh and Urethane Lining

In this permutation fiberglass mesh isolates the new steel liner from the existing liner, thus eliminating the corrosion mechanism between new and old steel and creates an interstitial space for leak detection. Additionally, existing steel liner will be coated with a urethane lining to provide a secondary containment release prevention barrier. This permutation was dismissed because the urethane lining and fiberglass mesh would be damaged by welding the new steel liner plates to the existing steel liner.

Alternative 2 - Tank Within A Tank

This alternative involves constructing a new tank within the existing tank. The new tank would be REDACTED and have either a dome or flat bottom and a fixed roof. The top of the new tank will be approximately REDACTED below the expansion joint of the upper dome (below the manhole and walkway of the existing tank). The smaller diameter of the new tank provides REDACTED REDACTED annular space around the tank that allows inspection of the exterior of the tank and the steel liner of the existing tank. Containment of leaks is provided by the steel liner of the existing tank.

EEI considers the Tank Within A Tank alternative a viable option and has prepared a project cost estimate. This alternative is further discussed in the sections that follow.

Other Technologies

Other technology considered in this study includes tank linings. Developments in tank linings are available that provide secondary containment and leak detection. These lining systems have been used on new tanks and to retrofit existing tanks.

Tankbau

One European manufacturer (Tankbau) has developed a "double skin" lining which has an interstitial space for leak detection. The lining consists of a double polyester resin coating with textile glass mats applied in layers to the tank structure and an interstitial space of metal foil or spacer fabric. Detection of leaks into the interstitial space is provided by monitoring the interstitial space with a vacuum leak detector. Manufacturer literature states the lining can be applied to existing aboveground and underground steel tanks and concrete tanks and has been used in over 400 tanks. Our concerns with this product are:

- The system has only been applied to tanks that are far less than the REDACTED of the Red Hill tanks, which have much higher operating pressures at the bottom of the shell.
- The Red Hill tanks have an expansion joint between the barrel and upper dome. Differences in thermal expansion between the lining and existing steel lining could cause the lining to disbond.
- Long term adhesion to the existing steel liner.
- Susceptibility to mechanical damage.
- Ability to monitor the interstitial space with a vacuum leak detector on large tanks such as the Red Hill tanks.
- Difficult to locate leaks in the lining.
- Ability to remove any detected fuel that breaches the inner skin.
- Long term maintenance and inspection of the lining integrity.

Nedeljkovic

Another European lining manufacturer (Nedeljkovic) uses a lining of PVC foil. The foil lining is applied to the tank wall and provides an interstitial space to monitor for leaks. According to manufacturer literature the custom made lining is inserted into the tank and air between the lining and tank is then pumped out to create a vacuum so that the lining adheres to the tank. The manufacture's literature does not state whether a vacuum alone is used to adhere the lining or if an adhesive is also used. One drawback to this system is adhesion of the lining to the tank wall. If the tank wall corrodes, corrosion holes will cause loss of vacuum between the lining and tank wall and the lining would no longer adhere to the tank. Additionally, if there are pinholes in the existing steel liner it may not even be possible to create a vacuum to adhere the lining. Another concern is that this system appears to have been developed and used only on small underground tanks.

Tank Tech

Other companies also offer tank linings with an interstitial space. Tank Tech, Inc. offers a fiberglass lining system that consists of a 100% solids epoxy and a 3-D glass fabric (PARABEAM) that is bonded to the tank wall. The 3-D glass fabric consists of two parallel fabric layers interwoven together with vertical pile threads to create an interstitial space between the fabric layers. The tank surface is first cleaned and prepared to receive the lining. Epoxy is then applied to the tank surface at 20 to 30 mils wet film thickness. The 3-D glass fabric is then placed on the wetted area and the epoxy is worked into the fabric causing the fabric to expand. As the epoxy cures a cavity or interstitial space is formed between the upper and lower fabric layers by the vertical pile threads. The upper layer is then sealed with epoxy. The fabric is placed in parallel courses. The edges are butted together in order to have a continuous interstitial space between adjacent courses and sealed with seam material tape. The surface is then sealed with a topcoat of epoxy. The lining is tested by pressurizing the interstitial space with air and checking for leaks using the soap bubble method. Our concerns with this product include:

- Differences in thermal expansion between the lining and existing steel lining which could cause the lining to disbond.
- Long term adhesion to the existing steel liner.
- Susceptibility to mechanical damage.
- Difficult to locate leaks in the lining.
- Ability to remove any detected fuel that breaches the inner fabric layer.
- Long term maintenance and inspection of the lining integrity.

Conclusions

Based on our review of tank lining technology we conclude that these alternatives are not long term viable options for the Red Hill Tanks due to their susceptibility to mechanical damage and lack of ability to locate leaks. Additionally, these linings do not stop corrosion on exterior of the tank. As the existing steel liner in the Red Hill tanks will continue to corrode, the lining which relies on the tank wall for structural support could eventually fail.

The Composite Tank and the Tank Within A Tank alternatives are EEI's recommended alternatives and are further discussed in the Detailed Discussion of Recommended Alternatives.

6.0 ALTERNATIVE 1 - COMPOSITE TANK DETAILED DISCUSSION

General Discussion

The overall concept for the Composite Tank alternative consists of a new steel liner inside the tank supported by structural steel angles or tees welded to the existing steel liner. The new steel liner is separated from the existing steel liner by the angle or tees to create a 3" to 4" interstitial space for leak detection. The existing steel liner will be coated with a urethane lining to provide containment of leaks. To resist fluid pressure from tank contents, the interstitial space will be filled with grout or self-leveling concrete. The product side of the liner will be coated with a MIL-DTL-24441 epoxy polyamide primer and intermediate coat and a fluoropolyurethane topcoat in accordance with UFGS 09 97 13.15 "Epoxy/Fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks".

In developing the Composite Tank alternative, we have not included lining the upper dome, due to the very high incremental cost compared to the increase in storage capacity of approximately REDACTED . The new composite liner will terminate and be sealed approximately REDACTED the expansion joint of the upper dome. The upper dome will be inspected and repaired only to prevent infiltration of ground water.

In our 1998 Repair Tank 19 study, we considered a barrel lining concept of horizontal courses with rolled sheets and horizontal tee supports welded to the existing steel liner, and a concept of vertical courses with flat sheets and vertical tee supports. We have chosen the vertical course concept with vertical support angles in this study for the following reasons:

1. Steel angles are less expensive than tees.

2. Vertical courses supported by vertical angles welded to the existing steel liner allow isolation of the barrel into vertical zones for improved leak detection and leak location. REDACTED liner plates with vertical angles spaced at REDACTED extending from the lower dome spring line to just below the expansion joint between the barrel and upper dome will compartmentalize the interstitial space of the barrel into REDACTED The width of the liner plates and spacing of the angles at REDACTED is based on the maximum width of the new liner plate that can be through the existing isolation doors in the Upper Tunnel to Tanks 17, 18, 19, and 20. Slightly wider sheets could be used for Tanks 1 to 16; however, the sheets would still need to fit through the REDACTED of the tanks. We recommend REDACTED for all tanks.

3. Horizontal support angle or tees would act as a barrier in the leak detection system and isolate the interstitial space of the barrel into horizontal spaces. This would considerably increase the complexity and cost of the leak detection system.

4. If the courses are horizontal and the support angles are arranged vertically, the new liner plates would span over several support angles and can only be attached to the interior supports with plug welds.

5. Horizontal courses would be only REDACTED based on the maximum plate width. This increases the number of horizontal joints in the barrel compared to REDACTED vertical courses.

The lower dome will be lined similar to the barrel except that the support angles will extend radially from the center of the bottom of the dome up to the spring line. The new liner plates will be custom cut to fit the shape of the dome and radial spacing of the support angles.

Materials

The new liner could be constructed with either ASTM A 36 carbon steel plates or ASTM A 240 stainless steel plates. A carbon steel liner is a lower material cost. Additionally the cost for welding carbon steel is approximately 25% less than welding stainless steel. A stainless steel liner, however, provides greater resistance to corrosion and thus would not need to be coated but is a much greater cost. Because of its resistance to corrosion, REDACTED thick stainless steel plates could be used instead of REDACTED thick carbon steel plates. If a stainless steel liner is provided, the angles supporting the new liner plates would also be stainless steel. Using stainless steel angles eliminates the corrosion potential between the new liner plates and angles. The corrosion potential between dissimilar metals of the stainless steel tees and the existing carbon steel liner is not a concern as the interface will be coated with a urethane lining. A REDACTED thick stainless steel liner with stainless steel support angles would be approximately additional cost per tank compared to a carbon steel liner with coating.

The project cost estimate is based on using a carbon steel liner.

Secondary Containment

The existing steel liner is subject to external corrosion in the form of pitting, thin areas of general metal loss, holes, and localized corrosion in the form of small "worm-like" corrosion trails. In order for the existing steel liner to provide containment of a leak, the liner plates and welds will need to be inspected and thin areas, holes, and weld defects (cracks, lack of fusion, and porosity) will need to be repaired.

EEI recently performed an assessment of the existing steel liner in Tanks 2 and 20 in support of a project to clean, inspect, and repair the tanks. The assessment consisted of calculating an external corrosion rate and a minimum required thickness of the REDACTED thick steel liner plates. This minimum thickness served as the screening criteria for determining whether to repair thin areas and pits in the steel liner plates for another 20-year interval until the next inspection. EEI calculated an external corrosion rate of 0.001744 inches/year using the linear method of API 653 and a remaining thickness of REDACTED at the end of a 20-year service interval in 2028. Recognizing that the external corrosion is a theoretical rate, twice the corrosion rate (i.e. 0.003488 inches/year) was used following the guidance of API 570 to calculate a minimum thickness for repair screening criteria. EEI recommended a minimum thickness of REDACTED as the screening criteria for determining whether thin and pitted areas in the REDACTED inch thick steel liner plates require repair. This recommendation was reviewed and accepted by the Government. At twice the calculated corrosion rate of 0.001744 in/yr (i.e. 0.003488 inches/year), the steel liner will reach a minimum thickness of REDACTED in 20 years and is predicted to hole through in REDACTED years.

As the existing steel liner will continue to corrode from the exterior, repair of thin areas less than REDACTED thick only provides an estimated 20-year maximum service interval until a minimum thickness of REDACTED is reached and corrosion holes begin to develop. Even if all corroded areas are repaired to restore the steel liner to its original REDACTED thickness, corrosion holes will develop. As the existing steel liner will not be accessible to inspection and repair after the new steel liner is installed, other measures are therefore needed to provide a 40-year life expectancy of the containment system.

EEI's 1998 Repair Tank 19 study considered the installation of a cathodic protection system to reduce exterior corrosion of the existing liner. The 1998 study concluded that the application of cathodic protection for the existing steel liner could be accomplished by installing deep impressed current anodes. For such a cathodic protection system to prove effective, a continuous media must exist between the anodes and the steel liner. There also cannot be any other structures that would block the protective current. The media on the exterior of the tanks, however, is not continuous. Gaps and voids have been found between the steel liner and concrete when the Red Hill tanks have been taken out of service for inspection. Additionally it is likely that gaps and cracks have formed between the concrete and pre-stressing grout, between the grout and gunite, and between the gunite and rock due to thermal expansion and shrinkage. Documentation from original construction also noted that large voids were encountered in the lava rock when the tanks were excavated. The voids in the rock are vent holes that were formed when the lava solidified. More than likely, the corrosion observed on the existing steel liner follows the gaps and cracks, giving the impression of "worm lines". The voids and gaps pose a problem to installing any deep anodes as current from the anodes would be hindered by voids in the rock, and gaps between the rock/gunite interface, gunite/pre-stressing grout interface, grout/concrete interface, and concrete/steel liner interface, leaving areas of the steel liner without effective protection.

Another concern with providing cathodic protection is the effect of the reinforcing steel in the concrete surrounding the lower dome, barrel, and upper dome. Record drawings show the concrete around the barrel ranges from REDACTED feet thick and contains REDACTED REDACTED The concrete on the outside of the lower dome is a minimum of REDACTED and reinforced. The reinforcing steel would intercept a significant amount of the protective current. If the reinforcing steel is electrically grounded to the steel liner, it will benefit from the current, but will shield the existing steel liner from protection. If the reinforcing steel is not electrically grounded to the steel liner, it will be subject to stray current corrosion. This occurs when the current picked-up by the reinforcing steel jumps through the concrete to the steel liner. Where the current jumps off, the reinforcing steel will be subject to severe corrosion and will be destroyed.

There is little confidence that the application of cathodic protection could effectively control corrosion of the existing steel liner, and its application could damage the reinforcing steel in the supporting concrete. The application of cathodic protection to control corrosion is therefore not viable.

Recognizing that cathodic protection would not be effective and that corrosion holes will eventually develop in the existing steel liner, we recommend a spray-applied urethane lining on the interior surface of the existing steel liner. The urethane lining will be approximately REDACTED thick and have the capability to bridge and seal corrosion holes that develop in the existing steel liner and thus would be the secondary containment release prevention barrier. The urethane lining will also prevent moisture migration into the interstitial space from outside the tank and thus minimize the potential for corrosion of the interstitial side of the new liner plates. The lining material will be comparable to that used in the construction of UL 1746-Part 4 listed underground fuel storage tanks. This product is marketed by the Steel Tank Institute, under the trade name ACT-100-U. The UL 1746-Part 4 coating systems for tanks complies with the Federal EPA requirements for effective corrosion prevention and containment, eliminating the need for cathodic protection on storage tanks. UL 1746-Part 4 tanks are commonly used within DESC facilities for product recovery tanks, oil-water separators, and at military service stations. The ACT-100-U coating has a proven track record, and a projected service life in excess of 50 years.

Interstitial Space

We have selected REDACTED interstitial space. The interstitial space can be any width; however, increasing the width only results in a greater reduction in storage capacity. Our concern with a narrower width is that the urethane lining could be damaged during welding of the new liner plates.

To prevent buckling of the new steel liner from fluid pressure from tank contents, the interstitial space will be filled with grout or self-leveling concrete. Filling the interstitial space with non-shrink grout or self-leveling concrete provides support of the new liner plates. Fluid pressure on the new liner from tank contents is transferred to the existing tank structure via the grout (or concrete) fill. This allows the use of REDACTED thick liner plates.

Of most importance is the structural quality of the grout or concrete between the existing steel liner and new liner. The grout or concrete must also have chemical properties that will not promote corrosion. Consideration should be given to introducing additives in the grout or concrete mix that will reduce moisture and/or maintain elevated pH levels, while increasing strength. A hydrophilic chemical grout was considered but dismissed. Hydrophilic grouts are a polyurethane grout that reacts with water and expands into a flexible foam seal and are typically used to seal leaks. Hydrophilic grouts; however, have no structural strength and thus are not be capable of supporting fluid pressure acting on the new steel liner.

If the interstitial space is not-filled, the thickness of the new liner plates would need to be REDACTED at the bottom of the barrel and REDACTED the bottom of the lower dome to resist fluid pressure from tank contents and the spacing of the supports would need to be reduced.

We recommend the interstitial space be filled with non-shrink grout or self-leveling concrete having a minimum compressive strength of REDACTED To resist fluid pressure in the interstitial space from the grout or concrete without excessive bulging, the grout or self leveling concrete must be placed in lifts not exceeding in 5 feet and the liner plates need to be supported continuously at REDACTED .

To meet the support requirements, the edges of the new vertical liner plates on the barrel will be supported with a continuous vertical angle welded continuously on both sides to the existing steel liner. Additionally, two vertical angles arranged in the shape of a tube will be provided in the interstitial space at the center of the plate to support the plate and form a drainage path for leak detection. To prevent compartmentalizing the interstitial spaces into REDACTED wide spaces the two support angles at the center of the liner plate which form a tube shape will be welded to the existing liner with intermittent fillet welds and will have drainage holes so that fuel that leaks into the interstitial space can drain into the "tube" space to the leak detection pipes.

The new steel liner plates in the lower dome will be supported similar to the liner plates on the barrel except the support angles will be will extend radially from the center of the bottom of the dome up to the spring line.

Leak Detection

Leak detection is provided by the interstitial spaces in the barrel and lower dome with leak detection piping connected to the interstitial spaces.

As previously stated, the Composite Tank will have REDACTED wide interstitial spaces, vertically up the barrel. Each interstitial space will have two vertical angles arranged in the shape of a tube at the center of the interstitial space to support the liner plate and form a vertical drainage path for leak detection. The two center support angles will also have drainage holes so that fuel in the interstitial space can drain into the "tube" space.

We considered providing leak detection piping on the interior of the tank which would be connected to the steel liner near the bottom of the barrel at each drainage "tube" space to detect leaks in the barrel. This concept consisted of the following:

- Leak detection piping on the interior of the tank connected to the steel liner near the bottom of the barrel. The piping would be connected to the vertical drainage "tube" space in each interstitial space. As there are REDACTED interstitial spaces in the barrel, there would be REDACTED leak detection piping connections to the steel liner near the bottom of the barrel.
- The REDACTED piping connections would be headered together inside the tank into REDACTED pipe connections per zone.
- Each of the REDACTED will be routed through a new REDACTED penetration in the lower dome to the Lower Tunnel.
- In addition to the REDACTED for the tank barrel, one zone will be provided for the entire lower dome. The lower dome leak detection piping will be routed from a new sump below the center of the lower dome floor to the Lower Tunnel.

The above concept of leak detection piping was revised due to concerns that piping inside the tank could corrode and result in a leak path into the interstitial space and because the concept is similar to the existing leak detection piping inside the tanks which is being removed due to leak problems.

The concept for leak detection was revised as follows:

- A horizontal drainage "tube" space will be provided in the interstitial space at the bottom of the barrel. This horizontal "tube" space will be continuous around the tank and be compartmentalized into REDACTED
- The vertical drainage "tube" space in each REDACTED interstitial spaces in the barrel will tie into the horizontal tube space. As the horizontal tube space is compartmentalized to into REDACTED REDACTED interstitial spaces are headered together per zone.
- Leak detection piping will be provided in the interstitial space of the lower dome and connect to REDACTED compartments of the horizontal tube space. Thus, there will be REDACTED leak detection pipes, each pipe serving REDACTED interstitial spaces of the barrel.
- Piping will be REDACTED diameter, extra strong pipe to reduce possibility of pipe blockage and to increase service life. All leak detection piping will be fully welded. No threaded fittings will be permitted. The REDACTED leak detection pipes will be routed through a new REDACTED diameter penetration in the lower dome to the Lower Tunnel. Drilling or coring of the concrete between the existing lower dome and the Lower Tunnel will be required in order to provide a path for the leak detection piping.
- In addition to REDACTED zones for the tank barrel, one zone will be provided for the entire lower dome. The leak detection piping for the lower dome will be routed from a new sump below the center of the lower dome floor to the Lower Tunnel.
- The leak detection pipes from REDACTED zones of the barrel and the one zone of the lower dome will be grouped into a manifold in the Lower Tunnel.

If a leak is detected in the barrel, the search for the leak can be narrowed to REDACTED wide area of the barrel consisting REDACTED interstitial spaces extending vertically from the lower dome spring line to top of the composite tank. The leak detection system also can be used for injection of a detectable gas in the interstitial space to locate the leak. As the entire lower dome is one zone for leak detection, a leak detected in the lower dome would involve inspecting the entire lower dome to locate and repair the leak.

Tank Venting

Our understanding is the existing tank venting system is adequate but upgrades have been recommended. No repairs have been included in the project cost estimate.

Hydrostatic Testing

A hydrotest is a test to demonstrate fitness for service and is primarily a test of the structural integrity of a tank. The new steel liner, however, is not a primary structural element as it relies on the grout in the interstitial space and on the existing tank to resist internal pressure from tank contents. A hydrotest, therefore, would not provide a test of the structural integrity of the new steel liner; nor is a structural integrity test of liner necessary as non-destructive examination will be performed on the welds of the new liner.

A hydrotest also does not provide a reliable leak test as leak detection time is not immediate. It will take time for weeps and small leaks to migrate through the grout/steel liner interface in the interstitial spaces and collect in the leak detection pipes. It is possible that a hydrotest could be completed before a leak is detected in the leak detection pipes. A more reliable method of finding leaks in the new liner welds is to vacuum box test the welds.

For these reasons, a hydrotest is not warranted and is not included in the Composite Tank alternative.

Attainment of Goals

The Composite Tank alternative meets the following project goals:

- Provides a 40+ year tank life extension.
- Minimizes the risk of a fuel leak.
- Provides containments of leaks that may potentially occur.
- Provides the capability to detect and locate leaks. Leak detection time, however, is not immediate as it will take time for weeps and small leaks to migrate through the grout/steel liner interface in the interstitial spaces and collect in the leak detection pipes. Leak location is also limited to REDACTED zones in the barrel and one zone in the lower dome.

Construction

After the tank is drained and taken out of service for repairs, the interior will be cleaned with a high pressure water wash.

The interior coating will be removed by enclosed abrasive blasting or high pressure water blasting. As existing tank coatings contain lead, the interior coating will need to be removed, handled, and disposed in accordance with UFGS 02 82 33.13 20 "Removal/Control and Disposal of Paint with Lead".

The existing steel liner plates will be inspected for pitting, thinning, and holes. Areas having a remaining thickness less than REDACTED inches and holes will be repaired by welding patch plates over the area. Liner plate welds will be inspected for cracks, lack of fusion, and porosity and repaired. Miscellaneous existing problems will also be repaired. This will include removing clips and attachments projecting into the tank that would interfere with the urethane lining and new liner plates. All locations where liner support angles will be welded to the existing steel liner will be scanned to determine metal thickness, thin areas, and plate laminations, to assure a solid structural attachment point.

Angles that support the vertical edges of the new liner plates will be welded to the existing steel liner with continuous fillet welds on both sides to provide REDACTED wide interstitial spaces in the barrel. The angles that support the center of the liner plates which form the "tube" section for leak detection will be welded intermittently. The welds will be visually inspected in accordance with AWS criteria. Spot magnetic particle or liquid penetrant inspection will also be required.

After the support angles are installed, the existing steel liner and support angles will be coated with a urethane lining. The surface of the existing liner plates and support angles will be cleaned to remove oil, grease, and soluble salt contamination and abrasive blasted to near white metal in accordance with SSPC SP-10. It is critical that abrasive-blasted surfaces remain dry and free of contaminates. The contractor will be required to provide dehumidification during abrasive blasting to prevent prepared steel surfaces from corroding. Due to the amount of surface area involved, application of the urethane lining will require considerable coordination. It may be necessary to clean and coat the existing steel liner and angles in sections. The prepared steel surfaces and primed surfaces will need to be monitored for contamination. Recoat times must also be closely monitored. The entire lining process will need to be inspected by an SSPC QP-5 certified inspector. Records of the entire process must be maintained, including post application dry film thickness, adhesion tests, and results of holiday testing.

Starting at the bottom of the barrel REDACTED long steel plates will be tack welded in place to the support angles. After tack welding two adjacent plates in place, the vertical edges of the plates will be butt welded to each other, including complete penetration weld to the support angle. The center of the plates will be welded with plug welds spaced vertically at REDACTED feet on center to the intermediate support angles which form the tube section for leak detection. The horizontal weld between courses will also be welded with a complete penetration butt weld. A backing bar will be welded to the upper plate prior to being hung in place to assure obtaining a complete penetration weld with the lower plate.

Non destructive examination (NDE) of the complete penetration butt welds presents some problems. Use of radiography is not possible, as the backside of the weld is not accessible. We recommend 100% of the welds be inspected for cracks, lack of fusion, lack of penetration, porosity, and slag inclusions using Balanced Field Electromagnetic Technique (B.F.E.T) or ultrasonic shear wave inspection. All welds will be vacuum box tested to 10-12 Psig to provide further quality assurance in the work completed.

After one course of plates are welded in place and the welds inspected, the interstitial space can be filled with grout or self-leveling concrete. To prevent bowing of the new liner plates from the plastic grout (or self-leveling concrete), the grout (or self-leveling concrete) should be placed in lifts not exceeding REDACTED in height. Once the grout (or self-leveling concrete) has set, the next course of plates can be erected.

After the new liner plates are installed the product-side of the plates will be cleaned to remove oil and salt contamination, abrasive blasted to near white metal in accordance with SSPC SP-10, and coated with a MIL-DTL-24441 epoxy polyamide primer and intermediate coat and a fluoropolyurethane topcoat in accordance with UFGS 09 97 13.15 “Epoxy/Fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks”. Similar to the application of the urethane lining, the contractor will be required to provide dehumidification. Due to the amount of surface area involved, it may be necessary to prepare and coat the new steel liner in sections. The entire coating process will need to be inspected by an SSPC QP-5 certified inspector. Records of the entire process must be maintained, including post application dry film thickness, adhesion tests, and results of holiday testing.

Construction of the liner in the lower dome will be similar to the barrel.

Installation of the leak detection piping and fuel piping modifications will be performed during the course of the work.

Inspection and Testing During Construction

The following inspections will be required:

- As the Composite Tank alternative relies on the integrity of the existing steel liner for secondary containment, the steel liner and welds of the barrel and lower dome of the existing tank need to be 100% scanned for thinning due to corrosion and weld defects and repaired. If a tank was inspected within the past 5 years that included scanning of the steel liner and welds and repair of thin areas and weld defects, the existing steel liner does not need to be re-inspected. If the steel liner has never been scanned, 100% scanning of the steel liner and welds of the barrel and lower dome of the existing tank must be included in Composite Tank alternative.
- The existing steel liner will be inspected for cleanliness and surface profile prior to applying the urethane lining.
- The product side of the new liner plates will be inspected for cleanliness and profile prior to applying the coating system.
- The urethane lining on the existing steel liner and coating on the new steel liner will be holiday tested.
- The urethane lining on the existing steel liner and coating on the new steel liner plates will be inspected by an SSPC QP-5 certified coating inspector. The coating inspector will be present during pre-preparation testing, surface preparation, lining and coating application, initial cure of the lining and coating, and coating repair work. The inspector must be independent from the coating contractor, and must have experience with this type of lining and coating and their application. The inspector's authority must be clearly established in the contract documents.
- Welds of the new liner on the lower dome and barrel will be visually inspected and vacuum box tested at REDACTED psig for leaks. The welds will also be 100% inspected for cracks, lack of fusion, lack of penetration, porosity, and slag inclusions using Balanced Field Electromagnetic Technique (B.F.E.T.) or ultrasonic shear wave inspection.
- Welds around pipe penetrations will be visually inspected and inspected by either magnetic particle or liquid penetrant inspection. The welds will also be 100% inspected for cracks, lack of fusion, lack of penetration, porosity, and slag inclusions using Balanced Field Electromagnetic Technique (B.F.E.T.) or ultrasonic shear wave inspection.

Life Maintenance Plan

It is expected that Composite Tank alternative will have a 40+ year life if maintained. The only major maintenance required will be the internal coating, and if properly applied, would be on a 15 to 20 year cycle.

For long term serviceability, we recommend the following maintenance plan:

1. Monthly: Visually check the leak detection piping for product. The presence of product is an indication of a possible leak in the new liner. If product is detected, record which leak detection pipe(s) contained fuel. This will help to identify the zone where the leak is believed to be located. Repair of leaks in the steel liner will involve draining and cleaning the tank, locating the leak, and welding a patch plate over the leak area. If water is present, this suggests that there is water intrusion from outside the tank into the interstitial space. Record which leak detection pipe(s) contained water. This will help to identify the zone where the leak is believed to be located. It is important to note, however, that as the existing steel liner and urethane lining is covered by grout in the interstitial space and the new steel liner plate, it is not possible to find a leak in the urethane lining to repair it.

2. 10 Years after Return to Service: Perform a baseline internal out-of-service inspection. The internal inspection will include:

    a. Visual inspection of the liner plates and welds in the barrel and lower dome.

    b. 100% scanning of the liner plates using Low Frequency Electromagnetic Technique (L.F.E.T.) or other nondestructive examination scanning methods capable of detecting metal loss on the interstitial side of the liner plates.

    c. Inspection of 100% of the liner welds for cracks using Balanced Field Electromagnetic Technique (B.F.E.T), ultrasonic shear wave inspection, or other non-destructive examination methods.

    d. Inspection of the interior coating by a NACE coating inspector.

    e. Based on the findings of the out-of-service inspection establish the interval until the next internal inspection. It is recommended that the interval not exceed 20 years.

3. Program the tank for re-coating in 15 to 20 years, depending on coating conditions.

7.0 ALTERNATIVE 2 – TANK WITHIN A TANK DETAIL DISCUSSION

General Discussion

This alternative involves constructing a new tank within the existing tank. The new tank will be REDACTED diameter. The top of the new tank will be approximat REDACTED feet below the expansion joint of the upper dome (below the manhole and walkway of the existing tank). The smaller diameter of the new tank provides REDACTED wide annular space around the tank that allows inspection of the exterior of the new tank shell and the steel liner on the barrel and upper dome of the existing tank.

New Tank

The new tank will be welded steel construction and will be designed in accordance with the applicable sections of API 650. As fluid pressure at the bottom of the shell is quite high (approximatel REDACTED the shell may need to be reinforced with external stiffeners to keep the bottom shell courses to a reasonable thickness. The tank will be braced laterally with struts to the existing tank to resist rocking from seismic ground motions.

The tank exterior will be coated with a MIL-DTL-24441 epoxy polyamide primer and intermediate coat and a polyurethane topcoat in accordance with UFGS 09 97 13.27 “Exterior Coating of Steel Structures”. The interior of the tank will be coated with a MIL-DTL-24441 epoxy polyamide primer and intermediate coat and a fluoropolyurethane topcoat in accordance with UFGS 09 97 13.15 “Epoxy/Fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks”.

A spiral stair will be provided on the exterior of the tank to access to bottom of the annular space. A walkway will be provided around the entire tank at three elevations approximately ever REDACTED feet up the shell to provide access to the exterior of the tank for inspection and repair.

The upper dome of the existing tank will be inspected and repaired only to prevent infiltration of ground water.

Tank Roof

The tank can be either open-top or have a fixed roof. An open top tank allows booms to be mounted on the center tower for construction and for future inspection and maintenance of the tank. An open top tank, however, prevents ventilating the annular space for personnel access. The tank would need to have a fixed roof and be vented to the existing tank vent pipe at the top of the upper dome or the annular space would need a roof and ventilation. We recommend a fixed roof tank with a vent pipe connected to the existing tank vent pipe at the top of the upper dome. The roof will also have a hatch for entry into the tank. Several options for a fixed roof were considered.

- Rafter-Supported Roof supported from the Center Tower: In this option roof plates would be supported on structural steel rafters spanning REDACTED from the tank shell to the center tower. Roof plates would b REDACTED thick minimum (REDACTED plates are recommended).

The center tower will need to be evaluated to support additional load and most likely strengthened to support of the weight of the fixed roof.

- Truss-Supported Roof: In this option the roof would not be supported from the center tower. Roof plates would be supported on long trusses supported from shell. This option, however, presents challenges in fabricating the trusses in short lengths so that they can be brought through the Upper Tunnel into the tank and temporarily supported in place until field splices are completed.
- Self-Supported Dome Roof: This option is similar to the truss-support roof option except that structural steel framing is used. Steel framing has the advantage over trusses in that it is easier to coat.
- Fixed Roof with External Framing: This concept consists of a primary steel framing system above the roof plates from which a secondary system of steel framing and rafters are hung. The primary framing system would supported from either the new tank shell or the existing tank shell and have a compression ring around the existing tower, thus no additional loads would be supported from the tower. The benefit of this concept is that the primary steel framing is above the roof; thus there is no restriction on the depth of the framing. Additionally, as the primary framing is above the roof, it is easier to maintain and coat. The secondary framing inside the tank, being shallower depth, allows more usable storage capacity.

EEI recommends a fixed roof concept with external framing.

Tank Bottom

Two options were considered for the tank bottom:

- Dome Bottom
- Cone-Down "Flat" Bottom

Dome Bottom: A dome bottom would consist of REDACTED thick steel plates supported on reinforced concrete fill on top of the existing steel liner in the lower dome. The existing steel liner will be inspected, repaired, and coated with a urethane lining to prove secondary containment. Reinforced concrete fill will then be placed on top of the existing steel liner to support the new dome bottom plates. Shear studs will be provided to anchor the concrete fill to the existing steel liner. The concrete fill will be REDACTED thick below the floor of the new dome bottom. The concrete fill will increase in thickness up the sides of the lower dome to REDACTED thick at the top of the lower dome and extend under the shell of the new tank to support the new tank. The floor of new dome bottom will be flat and constructed of REDACTED thick plates for additional strength and corrosion allowance. A dome bottom concept relies on the reinforced concrete fill acting as an inverted dome in compression to support the entire weight of the tank.

Cone Down Bottom: A cone down bottom consists of REDACTED thick steel plates, a sand cushion layer below the steel plates, and a flexible membrane liner below the sand cushion. The floor would have REDACTED slope to a sump at the center of the tank. The entire lower dome of the existing tank will be filled with structural fill or lean concrete to create a flat surface for the new floor. A flexible membrane liner will be placed on top of the structural fill or lean concrete, followed by the sand cushion and floor plates. This option does not rely on the existing steel liner or a urethane lining for secondary containment because the flexible membrane liner provides secondary containment. Another benefit of this option is that an impressed current cathodic protection system can be provided in the sand cushion filled interstitial space between the tank floor and membrane liner. Filling the lower dome of the existing tank to construct a cone bottom, however, results in a significant reduction in storage capacity. One way to provide more storage capacity is to remove the top REDACTED feet of the lower dome and extend the barrel of the existing tank down to this lower elevation. This will involve removing the top REDACTED feet of the existing steel liner in the lower dome and the REDACTED feet of reinforced concrete on the outside of the liner.

As the cone down bottom concept involves major demolition work and modifications affecting structure of the existing tank, it is not as viable as the new tank with a dome bottom concept, and thus is not further developed. Only a dome bottom is further developed and discussed in this report.

Materials

ASTM A 573 grade 70 material was selected to resist internal pressure form tank contents and keep the thickness of the bottom shell courses REDACTED thick.

Secondary Containment

Containment of leaks is provided by the existing tank; specifically the steel liner on the tank barrel and lower dome. Prior to tank construction, the steel liner on the barrel and lower dome will be inspected and repaired. As the steel liner of the lower dome will be covered by the new tank bottom and thus not accessible for future inspection or repair, it will be coated with a urethane lining to provide a release prevention barrier. The urethane lining material and application will be the same as for the Composite Tank alternative.

The steel liner on the existing tank barrel will be visible from the annular space and accessible for repair; thus it is not necessary to provide a urethane lining on the barrel.

Leak Detection

As the exterior of the new tank is visible, leaks in the shell can be readily located and repaired. Additionally, the floor of the annular space between the tank and existing barrel will have a trench to collect and contain leaks. The trench will be continuous around the tank and drain to four equally spaced sumps. The sumps could be equipped with a level float and alarm equipment when liquid collects in the sumps.

The interstitial space of the dome bottom will have two leak detection pipes. Piping will be REDACTED diameter, extra strong pipe to reduce possibility of pipe blockage and to increase service life. All leak detection piping will be fully welded. No threaded fittings will be permitted. The leak detection piping will be routed from a new sump below the center of the new tank floor to the Lower Tunnel; thus the entire interstitial space of the dome bottom will be one zone for leak detection purposes. Two pipes are recommended for redundancy. Drilling or coring of the concrete between the existing lower dome and the Lower Tunnel will be required in order to provide a path for the leak detection piping.

Tank Venting

The new tank will have a vent pipe extending up to the upper dome of the existing tank and connect to the existing tank venting system. Our understanding is the existing tank venting system is adequate but upgrades have been recommended. No repairs have been included in the project cost estimate.

To prevent the tank from venting to the annular space, it will not have overflow ports.

Hydrostatic Testing

API 650 requires new tank be hydrotested with water. Only when water is not available does API 650 allow testing of the shell by a penetrating oil test of all of the shell welds for leakage or by vacuum box testing or by a combination of a penetrating oil test and vacuum box testing.

Water may be available at Red Hill; however, the logistics of obtaining the water, filling the tank, and disposing of the test water are complex. The only pipeline that could be used to fill a tank iREDACTEDop line and would several weeks to fill a tank. There is also no place to dispose of the test water. Trucking the water offsite is not feasible. It was suggested that a temporary lagoon could be excavated to allow the water to filter into the ground. This, however, is also probably not feasible as an environmental discharge permit would be extremely difficult if not impossible to obtain as the area is over an aquifer.

Given the unique conditions of hydrotesting the new tanks at Red Hill, EEI has assessed the risks of not hydrotesting the tank and what measures could be done if a hydrotest is not performed. Our assessment is as follows:

- The risk that the tank could fail catastrophically is low. The new tank will be designed, fabricated, and constructed in accordance with API 650. Careful detailing and construction of the tank following the requirements of API 650 and quality control, inspection, and testing during construction will be required.
- As ambient air temperature inside the Red Hill complex is generally constant and not expected to fall below 60 degrees F the risk of brittle fracture failure is considered to be low.
- Should a tank leak or fail, it will be contained by the existing tank.

Based on our assessment of the above risk factors, it is our recommendation that the new tanks could be constructed without performing a hydrotest with water.

EEI recommends the following if a hydrotest is **not** performed:

- Perform radiography of shell welds in accordance with API 650.
- Perform a penetrating oil or vacuum box test of 100% of the shell welds.
- Perform Balanced Field Electromagnetic Technique (B.F.E.T.), or ultrasonic shear wave inspection of 100% of the shell welds. Inspect for cracks, lack of fusion, lack of penetration, porosity, and other rejectable defects. Repair all rejectable defects. This additional inspection is recommended as API 650 does not require 100% of shells welds be radiographed. Additionally, B.F.E.T. and ultrasonic shear wave can potentially detect weld defects that are not readily detectable by radiography.
- Initially fill the tank will full (to the rim angle) with fuel and hold for 24 hours.
- Operate the tank at a reduced fill height below the rim angle and roof framing (this ensures that tank operates at a lower stress level than initial filling).
- Should the new tank leak or fail during initial filling with fuel, the fuel will be contained within the existing tank. EEI recommends that the contained fuel be pumped back into the existing tank from which it was taken, not into one of the new tanks, until the cause of the leak is determined and corrected.

Repairing tanks in groups of three tanks and performing an initial fill test with fuel will require using the fuel from a fourth tank to perform the initial fill test of the new tanks.

Tank Fill Height

Although the tank will be initially tested with fuel to the rim angle, EEI recommends the 100% full level be lower to ensure that tank operates at a lower stress level than initial filling. This 100% level should also be below the roof framing inside the tank. As the framing has not been designed, we suggest the 100% level be at least REDACTED below the top of the rim angle. This height can be refined during the project design phase. The REDACTED height provides space for the roofing so it is not submerged, and a safety margin against overfilling the tank.

REDACTED

If the tank is filled at a rate of REDACTED, the reaction time between Hi-level alarm and Hi-Hi level alarm is REDACTED minutes and the reaction time between Hi-HI level alarm and 100% level is REDACTED minutes.

Attainment of Goals

The Tank Within A Tank alternative meets the following project goals:

- Provides a 40+ year tank life expectancy.
- Minimizes the risk of a fuel leak.

- Provides containments of leaks that may potentially occur.
- Provides the capability to detect and locate leaks.

Construction

As it is possible that materials and equipment may be lowered into the existing tank using contractor-provided booms mounted on the center tower, we have chosen to keep the central tower. The center tower and walkway will remain after construction for future use to access the new tank and annular space.

Inspection and Testing During Construction

The following inspections will be required:

- As the Tank Within A Tank alternative with a dome bottom relies on the integrity of the existing steel liner in the lower dome and barrel for secondary containment, the steel liner and welds of the lower dome and barrel need to be 100% scanned for thinning due to corrosion and weld defects and repaired. If a tank was inspected within the past 5 years that included scanning of the steel liner and welds and repair of thin areas and weld defects, the existing steel liner does not need to be re-inspected. If the steel liner has never been scanned, 100% scanning of the steel liner and welds of the lower dome and barrel of the existing tank must be included in this alternative.
- Welds in the new dome bottom will be visually inspected and vacuum box tested aREDACTED REDACTED or leaks. The welds will also be 100% inspected for cracks and rejectable defects using Balanced Field Electromagnetic Technique (B.F.E.T), ultrasonic shear wave inspection, or other non-destructive examination methods.
- The shell to lower dome weld will be inspected in accordance with API 650.
- Shell welds will be visually inspected and radiographed in accordance with API 650. Additionally, as the tank will not be hydrotested, 100% of the shell welds will be tested for leaks by penetrating oil or vacuum box testing and 100% of the shell welds will be inspected for cracks and rejectable defects using Balanced Field Electromagnetic Technique (B.F.E.T), or ultrasonic shear wave inspection.
- Welds around pipe penetrations will be visually inspected and inspected by either magnetic particle or liquid penetrant inspection. The welds will also be 100% inspected for cracks, lack of fusion, lack of penetration, porosity, and slag inclusions using Balanced Field Electromagnetic Technique (B.F.E.T.) or ultrasonic shear wave inspection.
- The existing steel liner in the lower dome will be inspected for cleanliness and surface profile prior to applying the urethane lining.
- The urethane lining will be holiday tested.
- Tank interior and exterior coatings will be inspected by an SSPC QP-5 certified coating inspector and holiday tested.

- The new urethane lining on the existing steel liner plates in the lower dome will be inspected by a SSPC QP-5 certified coating inspector.

Life Maintenance Plan

The Tank Within A Tank alternative is essentially construction of a new tank plus repair and upgrade of the existing steel liner for secondary containment. It is expected that this repair alternative will have a 40 to 50 year life or longer if maintained. The only major maintenance required will be coatings, and if properly applied, would be on a 15 to 20 year cycle. In-service external inspection and out-of-service internal inspection of the new tank should be performed following the guidance of API 653 and as recommended herein.

For long term serviceability, we recommend the following maintenance plan:

1. Monthly:

    a. Visually check the leak detection piping of the dome bottom for product. The presence of product is an indication of a possible leak in the tank bottom. If water is present, this suggests that there is water intrusion into the existing lower dome from outside the tank.

    b. Test the level float and alarm equipment in the containment trench for proper operation.

2. Routine In-Service Inspections: Perform an inspection of the exterior of the tank on a routine basis. The inspection can be performed by owner/operator personnel. API 653 does not define the frequency of routine in-service inspections. EEI suggests routine inspections be performed at least once every six months.

3. Formal In-Service Inspections: Perform a formal in-service inspection every 5 years by an API 653 certified inspector. The inspection should include visual inspection and ultrasonic thickness measurements of the shell and visual inspection of the steel liner on the existing tank barrel for leaks.

4. 10 Years after Return to Service: Perform an API 653 baseline internal out-of-service inspection. The internal inspection will include:

    a. Visual inspection of the plates and welds in the dome bottom.

    b. 100% scanning of the plates in the dome bottom using Low Frequency Electromagnetic Technique (L.F.E.T.) or other nondestructive examination scanning methods capable of detecting metal loss on the interstitial side of the dome bottom plates.

    c. Inspection of 100% of the welds in the dome bottom for cracks using Balanced Field Electromagnetic Technique (B.F.E.T), ultrasonic shear wave inspection, or other non-destructive examination methods.

    d. Visual inspection of the interior of the shell.

    e. Inspection of the interior and exterior coating by a NACE coating inspector.

f. Based on the findings of the out-of-service inspection establish the interval until the next internal inspection. (It is recommended that the interval not exceed 20 years).

g. Visual inspection of the steel liner and coating of the existing tank.

5. Program the new tank and existing tank liner for re-coating in 15 to 20 years, depending on coating conditions.

8.0 COMPARISON OF COMPOSITE TANK VS. TANK WITHIN A TANK

The following table summarizes and provides a comparison between Alternative 1 - Composite Tank and Alternative 2 - Tank Within A Tank in respect to the project goals.

Comparison of Composite Tank vs. Tank Within A Tank		
Item	**Composite Tank**	**Tank Within A Tank**
40-year life renewal extension	Provides a 40+ year life extension.	Provides a 40+ year life extension.
Secondary containment	REDACTED	REDACTED
Type/System	Secondary containment provided by the steel liner of the existing tank and a urethane lining.	Secondary containment provided by the steel liner of the existing tank. Secondary containment of the dome bottom is provided by the existing steel liner plates and a urethane lining.
Leak Detection/Location	REDACTED	REDACTED
Barrel	Steel liner plates arranged vertically supported by vertical angles welded to the existing steel liner isolate the barrel into 52 interstitial spaces. Piping connected to the interstitial spaces is headered to provide 13 vertical zones for leak detection and leak location. Leak detection time is not immediate as it will take time for weeps and small leaks to migrate through the grout/steel liner interface in the interstitial space and collect in the leak detection pipes. Leak location is limited to 13 zones in the barrel.	Annular space around the new tank allows immediate visual inspection of the exterior of the tank shell for leaks.
Lower Dome	Piping connected to the interstitial space of the lower dome provides leak detection.	Piping connected to the interstitial space of the dome bottom provides leak detection.

Comparison of Composite Tank vs. Tank Within A Tank

Item	Composite Tank	Tank Within A Tank
Maintainability (Capability to Inspect/Repair)	REDACTED	REDACTED
Barrel	REDACTED	REDACTED
Primary Shell	Requires draining and cleaning the tank to inspect the steel liner. Inspection of barrel will require cable supported personnel platforms and booms from the center tower.	Annular space around the new tank provides access to the tank exterior for inspection and repair.
Secondary Containment	Existing steel liner and urethane lining are not accessible for inspection and repair after the new liner plates are installed.	Barrel: Existing steel liner is accessible for inspection and repair Lower Dome: Existing steel liner and urethane lining in the lower dome are not accessible for inspection and repair after the tank is constructed, t
Lower Dome	REDACTED	REDACTED
Primary Shell/Floor	Requires draining and cleaning the tank to inspect the steel liner.	Requires draining and cleaning the tank to inspect the tank interior and dome bottom.
Secondary Containment	Once the new liner plates are installed, the existing steel liner and urethane lining are not accessible to inspection and repair.	Once the new liner plates are installed, the existing steel liner and urethane lining are not accessible to inspection and repair.
Nominal Storage Capacity	REDACTED	REDACTED
Existing	Tanks 1 to 4: tank Tanks 5 to 20: REDACTED tank Total capacity: Nominal capacities include the capacity of the upper dome	Tanks 1 to 4: REDACTED per tank Tanks 5 to 20: per tank Total capacity: REDACTED Nominal capacities include the capacity of the upper dome
After Repair	Tanks 1 to 20: REDACTED tank Total capacity: Nominal capacity does not include the upper dome and is based o REDACTED intestinal space and only barrel and lower dome being repaired.	Tanks 1 to 20: REDACTED tank Total capacity:

9.0 REPAIRS COMMON TO BOTH REPAIR ALTERNATIVES

Both alternatives share common elements of basic work. The following describes these common elements, plus minor differences associated with each alternative.

Tank Cleaning

In both the Composite Tank alternative and Tank Within A Tank alternative, the tank will need to be drained and cleaned.

Existing Steel Liner Inspection and Repair

As the Composite Tank alternative relies on the integrity of the existing steel liner for secondary containment, the steel liner and welds of the barrel and lower dome of the existing tank needs to be 100% scanned for thinning due to corrosion and weld defects and repaired. If a tank was inspected within the past 5 years that included scanning of the steel liner and welds and repair of thin areas and weld defects, the existing steel liner does not need to be re-inspected. If the steel liner has never been scanned, 100% scanning of the steel liner and welds of the barrel and lower dome of the existing tank must be included in Composite Tank alternative.

Similarly, the Tank Within A Tank alternative with a dome bottom relies on the integrity of the steel liner in the lower dome of the existing tank for secondary containment. If a tank was inspected within the past 5 years that included scanning of the steel liner and welds and repair of thin areas and weld defects, the existing steel liner does not need to be re-inspected. If the steel liner has never been scanned, 100% scanning of the steel liner and welds of the lower dome and barrel of the existing tank must be included in the Tank Within A Tank alternative.

Coating Removal

The coatings on the existing tank will need to be removed and the existing steel surface prepared (SP-10) for the application of the urethane liner. In the case of Alternative 1 – Composite Tank this will require the blasting and removal of the coating from the barrel and the lower dome. Alternative 2 – Tank Within A Tank will require the blasting and removal of the coating from the lower dome only.

Testing of the existing coating inside Tank 2 and other tanks determined the existing tank coatings contain lead. Existing coatings will therefore need to be removed, handled, and disposed in accordance with UFGS 02 82 33.13 20 "Removal/Control and Disposal of Paint with Lead".

Center Tower and Walkway

The center tower in each tank originally had two booms for hoisting personnel platform and materials, and equipments. The government has been reported that the booms have since been removed from all of the tanks. The contractor, therefore, will need to provide booms or a monorail system for tank cleaning and inspection and construction work. Prior to erecting booms, the central tower should be inspected by a structural engineer and any deficiencies and deterioration repaired. Additionally, the elevated platform walkway to the tower should also be inspected and repaired as necessary.

Record drawings indicate the center tower is braced at four elevations with REDACTED diameter cable to each of the four legs of the tower. EEI's site visit to Tank 2 and Tank 19 found Tank 2 does not have cable bracing, or it was removed. Tank 19, however, has cable bracing. In the Composite Tank alternative and the Tank Within A Tank alternative, the cables will need to be relocated or the tower strengthened to allow removal of the cables. Strengthening the tower can be quite extensive, we have chosen in this study to relocate the cable bracing. In the Composite Tank alternative the cable bracing will be relocated and attached to the new steel liner. In the Tank Within A Tank alternative, the cable bracing will be relocated and attached to the inside of the new tank shell.

Fuel Piping Modifications

Fuel piping for each tank consists of REDACTED diameter pipe which transitions to REDACTED diameter pipe in side the tank and REDACTED diameter pipe. Both pipes penetrate through the floor of the lower dome and extend up into the tank. As part of tank repairs, the piping will be pressure tested to determine the integrity of existing fuel lines. Additionally, EEI recommends the existing piping between the tank and first valve outside the tank in the Lower Tunnel be internally lined as a mean of extending piping life.

As the Tank Within A Tank alternative will have REDACTED of reinforced concrete on top of the existing dome bottom, the fuel pipes will need to be modified to extend up into the tank.

Sample lines

FISC personnel indicated that sample lines are required. Sample lines will be provided for the new tanks. The existing sample lines will be removed and new sample lines will be routed from the Lower Tunnel, through the same pipe casing used for the existing lines, and into the tanks.

Level Alarms

Level alarms will be provided to avoid overfilling the tanks.

10.0 CONSTRUCTION RELATED ITEMS

Tank Access

REDACTED

REDACTED
REDACTED

REDACTED

REDACTED

REDACTED

Contractor Laydown/Storage Area

REDACTED

Ventilation

REDACTED

Compressed Air

Compressed air will be required for construction operations. The contractor supplied air compressor will be located REDACTED depending on which tanks are being repaired. Approximately REDACTED piping will be needed between the air compressor and the tank being worked on. The actual size of the line will be the contractor's responsibility. Air drops and other branch connections will be provided as necessary.

Electrical Power

REDACTED

REDACTED The contractor will need to provide temporary electrical power using portable diesel or propane engine generator sets REDACTED REDACTED during construction.

Minor contractor loads such as small ventilation fans up to one 5.6 kW (7.5 hp) per tank, and power for lighting, small tools, and possibly for auxiliary power for automatic horizontal and vertical tank welders (not including welding machine power) may be obtained from the stationary power distribution system within the Red Hill facility.

Major contractor loads such as for tank ventilation REDACTED REDACTED and welding machines will have to be powered from the contractor's portable diesel or propane engine generator sets.

Welding machine requirements for repair and construction work for each tank have been estimated as follows:

- Liner repair phase: One six-pack of Miller XMT 304 welding machines

- Tank construction phase: Two 600A, 100 percent duty cycle welding machines for use with horizontal and vertical automatic tank welding machines (Miller Dimension 652), two Miller XMT 456 welding machines, and one six-pack of Miller XMT 304 welding machines.

It is recommended that the tank construction be sequenced in such a way that major welding operations are limited to one tank per generator. With that in mind, the preferred sequence would be to start with the first tank in the back section (Tanks 9-20), the second tank in the forward section (Tanks 1-8), and the third tank in the back section (Tanks 9-20). That way, the Contractor will only require two 450 kW diesel engine generator sets.

The temporary electrical system does not include allowance for electric air compressors. In order to prevent having air compressor motor start and loading inrush currents adversely impact the input voltage to welding machines, it is recommended that engine driven air compressors be located outside the tunnels and temporary piping or hoses be run in to the tanks. If loads are low, air dryers may be powered either from the tunnel distribution system or from the contractor's portable diesel engine-generator system.

Construction Duration

Estimated construction durations for the Alternative 1 - Composite Tank and Alternative 2 - Tank Within A Tank alternative are provided below. The durations are based on repairing tank in groups of three tanks at a time and assumptions on crew size and production, equipment and material procurement lead time, fabrication time, and shipping time.

- Alternative – 1: Composite Tank: 3.31 years (172 weeks)
- Alternative – 2 Tank Within A Tank: 3.27 Years (170 weeks)

To meet this schedule will require working double shifts during the blasting and coating process. This will minimize the time required for dehumidification. An estimated timeline indicating major milestones and phases of construction for each alternative is provided in the appendices.

11.0 OPINION OF PROBABLE PROJECT COST

Introduction

The opinion of probable project cost was prepared based on cost data obtained from past projects supplemented by actual quotations from vendors for major items including steel, coatings abrasive blasting, dehumidification, steel fabrication costs, and erection costs. The estimated labor requirements using current labor rates expected in Hawaii are based on a large US based international contractor using imported labor.

Programmed Cost

The programmed cost per tank for this MILCON project ranges between REDACTED (Alternative 1 – Composite Tank) and REDACTED (Alternative 2 – Tank With A Tank) depending on the alternative selected. Programmed costs include a construction contingency of REDACTED Supervision, Inspection & Overhead (SIOH) of REDACTED and Post Construction Award Services of REDACTED The cost associated with the design of this MILCON project is not included in the programmed cost.

Construction Cost (Contingency and Escalation)

The contractor cost per tank for the project ranges between REDACTED (Alternative 1 – Composite Tank) and REDACTED (Alternative 2 – Tank Within A Tank) depending on the alternative selected. Contractor (construction) costs include both subcontractor and prime contractor overhead and profit. Construction costs also include an estimating contingency of Escalation is **not** included in the estimate due to the extreme volatility of commodities at this time. Escalation well in excess of past typical yearly escalation should be anticipated.

The cost estimate breakdown for each alternative is included in the appendices.

Cost Estimating Assumptions

The following assumptions were used in the preparation of this opinion of probable project cost.

Overall Assumptions

- The project pricing is based on 2008 Dollars and does not include escalation. (Refer to discussion on Steel Prices and Market Volatility.)
- Steel pricing is based on the July 2008 commodity price for steel; the estimate uses per lb for A36 steel and REDACTED per lb for high strength steel FOB the mill. The project will require between REDACTED tons of steel.
- The cost includes shipping from of all materials from the mainland to Hawaii.
- Fuel price is based on 2008 costs.
- Existing tank coatings contain lead.
- The tanks will be repaired in groups of three and may not be adjacent to each other.

- The cost includes cleaning and inspection of the existing tank liner prior to construction.
- The Composite Tank and Tank Within A Tank will **not** be hydrotested.
- The contractor will be required to provide temporary electrical power during construction.
- Construction contracting will be via full and open bid process.

Alternative – 1 Composite Tank

The project cost for the Composite Tank alternative is based on the following:

- Removal of the existing coating on barrel and lower dome.
- Inspecting the existing steel liner on the barrel and lower dome (100% scan of the liner plates and welds).
- Spray-applied urethane lining on the existing steel liner on the barrel and lower dome (including cleaning and surface preparation of the existing steel liner).
- REDACTED thick carbon steel liner plates on the lower dome and barrel of the existing tank supported on vertical steel angles welded to the existing steel liner.
- REDACTED interstitial space filled with grout or self-leveling concrete.
- The product side of the liner 100% coated with a MIL-DTL-24441 epoxy polyamide primer and intermediate coat and a fluoropolyurethane topcoat in accordance with UFGS 09 97 13.15 "Epoxy/Fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks".
- Leak detection for the barrel and lower dome.

Alternative 2 - Tank Within A Tank

The project cost for the new tank in existing alternative is based on the following:

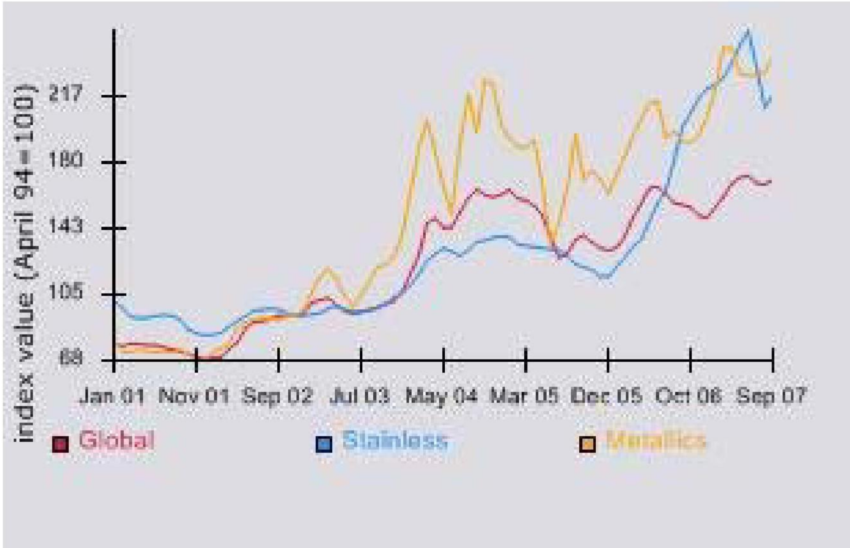
- REDACTED new tank with a dome bottom.
- Self-supported fixed roof with structural steel framing.
- Tank exterior 100% coated with a MIL-DTL-24441 epoxy polyamide primer and intermediate coat and a polyurethane topcoat in accordance with UFGS 09 97 13.27 "Exterior Coating of Steel Structures". Tank interior 100% coated with a MIL-DTL-24441 epoxy polyamide primer and intermediate coat and a fluoropolyurethane topcoat in accordance with UFGS 09 97 13.15 "Epoxy/Fluoropolyurethane Interior Coating of Welded Steel Petroleum Fuel Tanks".
- Removal of existing coating on lower dome.
- Inspecting the existing steel liner in the lower dome (100% scan of the liner plates and welds).
- Spray-applied urethane lining on the existing steel liner of the lower dome (including cleaning and surface preparation of the existing steel liner).

- Reinforced concrete dome foundation
- Leak detection piping for dome bottom

Steel Prices and Market Volatility

The project cost may vary based on the cost of steel and fuel in the world marketplace. Several indices clearly demonstrate that the rise and trends of the steel market far exceed escalation as identified above.

CRU data indicates an increase of over 300% in steel prices from 2001 to 2007.



A recent Wall Street Journal article dated July 16, 2007 states "The price of a ton of hot-rolled steel, a benchmark base product used in most finished steel, currently stands at around $575 on the spot market--well above the $175 the same ton of steel cost on the spot market back in 2001." This equates to approximately 325% cost increase in six years.

There are a number of factors affecting the volatility of the steel market and high cost of steel including: rapid growth of steel production and demand in China, consolidation of the steel industry, and rising cost of transportation caused by increased energy costs and limited supply.

Steel prices are expected to continue to increase in 2008 and remain at a higher level in the long term. The cost of steel should be monitored and the Program Amount for this project adjusted accordingly prior to each annual review for MILCON funding.

12.0 OTHER TANK-RELATED PROJECTS

The following are recent and on-going studies affecting the Red Hill tanks and facility.

Leak Detection

DESC HQ (Environmental) has recently retained Michael Baker Jr., Inc. to evaluate leak detection systems for the Red Hill Tanks. This study, *Market Survey of Leak Detection Systems for Red Hill Fuel Storage Facility, Fleet Industrial Supply Center, Pearl Harbor, March 31, 2008* has been published in draft format. EEI's understanding of the study is that it conducted a market survey of available leak detection systems for very large tanks. The study identified seven candidates capable of providing "In-Tank" highly accurate leak detection for very large tanks. The seven candidates were evaluated and ranked as to the system that would provide the best option for leak detection.

The Composite Tank alternative incorporates an external visual leak detection piping system in barrel and lower dome of the tank. Alternative 2 – Tank Within A Tank has leak detection piping for the dome bottom and also provides the ability to inspect the shell of the tank while the tank is in service. The ability to visually detect leaks will augment an "In-Tank" Leak Detection system.

Based on EEI's understanding of the leak detections systems evaluated, neither of the two recommended tank repair alternatives will adversely impact the installation of an "In-Tank" highly accurate leak detection system. In the case of Alternative 2, where the exterior of the tank shell can be inspected, the "In-Tank" leak detection system is less important but is still a useful tool and provides an additional level of detection.

Electrical Classification Study

A study was performed by EDG in 2001 to develop a standard electrical area classification for all of the FISC Fuel Department facilities at Pearl Harbor. The study included an analysis of ventilation rates for various fuel vapor concentrations.

Ventilation Study

A ventilation study was performed by MWH in 2005. The study reviewed the results of a 1999 ventilation study performed by Thermal Engineering and the 2001 Electrical Classifications Study. The 2005 Ventilation Study provided options for improving the ventilation system at Red Hill.

13.0 PROJECT TEAM

Enterprise Engineering, Inc.

Kevin S. Murphy, P.E.	Principal In-Charge
Stephen J. DiGregorio, P.E.	Project Manager and Lead Structural Engineer
Ray Griffith, P.E.	Structural Engineer/Planner/Cost Estimator
Melvin Yokota, P.E. (HHMI Inc.)	Electrical Engineer
Craig Meier (Corrosion Control Inc.)	Corrosion Specialist (cathodic protection and coatings)
Stephen S. Brooks, P.E.	Project QA Review