ENTERPRISE

ENGINEERING, INC.

REPAIR TANK 19, RED HILL

FISC PEARL HARBOR, HAWAII

DESC PROJECT PRL 98-9

Under Contract to:
Pacific Division
Naval Facilities Engineering Command
Honolulu, Hawaii

A/E Contract N62724-98-C-0002
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PREPARED BY:

Stephen J. DiGregorio, P.E.

Kathleen L. Gardner, P.E.

Stephen S. Brooks, P.E.

SUBMITTED BY:

Stephen S. Brooks, P.E.

STATE OF ALASKA
49TH
STEPHEN S. BROOKS
No. ME-8473
REGISTERED PROFESSIONAL ENGINEER

Yarmouth, ME 04096 • 172 Main Street, P.O. Box 550 • (207) 846-3900 • Fax (207) 846-1115
Anchorage, AK 99503 • 3335 Arctic Blvd., Suite 100 • (907) 563-3835 • Fax (907) 563-3817

ABSTRACT

Tank 19 is one of 20 underground fuel storage tanks at the Red Hill facility. The tank is 53.34 M (175 ft) below the ground surface, 76.32 M (251 ft) tall x 30.48 M (100 ft) in diameter, with a dome bottom and top. Tank 19 as well as the other Red Hill tanks is excavated from lava rock and lined with 0.610 M (2 ft) to 1.22 M (4 ft) of concrete and a 6.35 mm (1/4 inch) thick steel plate interior liner. The nominal storage capacity of Tank 19 is 300,000 Bbl.

The overall goal of this project is to determine an appropriate and cost effective solution to repair Tank 19 that provides long term life extension renewal of the tank, minimizes the risk of fuel leakage, contains leaks that may develop, facilitates the capability to detect and locate leaks more readily than the current leak detection system, and provides future maintainability.

The Concept Design to repair Tank 19 was prepared on site during May 4, 1998 through May 12, 1998, using a modified Functional Analysis Concept Development (FACD) process. FISC Pearl (Customer and User), PACDIV (Design Agent), and the A/E team participated as a team to define major project requirements and develop possible solutions.

Three viable repair concepts were developed, and cost estimates prepared. Cost estimates for additive options to provide under tank leak detection and extend the tell tale piping to the upper dome were also prepared.

	Base Cost	**Total Additive Cost** (includes CP System)	**Maximum Total Cost**
Composite Tank with secondary containment	$5,298,000	$1,306,000*	$6,604,000*
Internal Bladder type lining with secondary containment	$2,339,000	$747,000	$3,086,000
Life extension repair of the existing tank steel lining.	$4,610,000	$747,000	$5,357,000

*Includes $539,000 to coat tank barrel

All of the above concepts have merit. The final selection of a concept should be based on the life expectancy of Red Hill, available funds, and importance placed on secondary containment.

A fourth project, to cathodically protect the exterior of the existing steel liner of the tank, was estimated at $551,000.

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1.0 EXECUTIVE SUMMARY

OVERALL PROJECT SCOPE AND GOALS

Enterprise Engineering, Inc., under contract N62742-98-C-0002 with PACDIV, NAVFAC, was commissioned to provide a 10% Concept Design solution to repair Red Hill Tank 19, Special Project PRL 98-9. The Concept Design was prepared on site during May 4, 1998 through May 12, 1998, using a modified FACD process to maximize user involvement in the development of the solution.

The overall goals of the project include:

- Long term life extension renewal of the tank, rather than a 10 year or less fix
- Minimize risk of fuel leakage
- Contain leaks that may develop
- Detection of leaks and leak locations more readily than current configuration
- Provide for future maintainability
- Provide a constructable, cost effective solution
- Accurate prediction of project cost

FUNCTIONAL ANALYSIS CONCEPT DEVELOPMENT (FACD) PROCESS

The modified FACD process used in the development of the Concept Design is based on defining major project elements and goals, brainstorming possible solutions to meet identified goals, and refinement of individual project elements that have the greatest likelihood of cost effectively meeting the overall goals.

FACD FINDINGS RECOMMENDATIONS

The FACD team developed the following major tank repair concepts, which received further evaluation, refinement and cost estimating:

- Providing a free standing API 650 type tank within the existing tank
- Providing a composite tank consisting of a new 6.35 mm steel liner welded to the interior of the existing tank with 100 mm concrete grout between the new and existing steel liner
- Providing an internal bladder type liner inside the existing tank
- Repair the existing tank after rigorous inspection for possible corrosion holes and plate thinning and lining the interior of the tank with a spray-applied flexible liquid membrane such as polysulfide or flexibilized novalac epoxy

After initial evaluation of the above concepts, it was agreed by the FACD team that none of the concepts would include repair of the upper dome for fuel storage, as the incremental capacity of 37,000 Bbl of the upper dome is not justified due to the high expense of repair.

It was also agreed by the FACD team that the free standing tank in a tank concept would not be further evaluated or developed as the cost of the steel tank alone was estimated at four times the cost of the composite tank concept. To resist internal pressure from fuel storage and water hydrostatic test, the shell of the tank would need to be 38 to 50 mm thick at the bottom of the barrel. A 38 to 50 mm is four times the thickness of a new steel liner for the composite tank concept and therefore approximately four times the cost of a 6.35 mm steel liner.

After the FACD brainstorming session, the design team prepared cost estimates for the following concepts, which were presented during the conclusion of the FACD and final outbrief meeting with government stakeholders:

- A composite tank consisting of a new 6.35 mm steel liner welded to the interior of the existing tank with 100 mm concrete grout between the new and existing steel liner
- Internal bladder type liner inside the existing tank
- Repair of the existing tank including rigorous inspection for possible corrosion holes and plate thinning and lining the interior of the tank with a spray-applied flexible liquid membrane

SUMMARY OF CONCEPT PROJECT COSTS

The estimated base construction cost for each of the concepts are:

• Composite Tank	$5,298,000
• Internal Bladder Type Liner	$2,339,000
• Repair and Recoat Existing Tank	$4,610,000

Additive bid items that may be considered for each concept include:

• Extend tell tale piping to upper dome for cleaning	$111,000
• Under tank leak detection	$85,000
• Cathodic Protection System (Tank 19 only)	$551,000
• Coat tank barrel (Composite Tank Concept only)	$559,000

EEI RECOMMENDATIONS

The three concepts to repair Tank 19 (Composite Tank, Bladder Type Liner, and Repair Existing Tank) are all viable options. The measure of success of any option is the degree of confidence in the repair and its attainment of the project goals noted earlier.

The Composite Tank concept has a high degree of confidence in meeting the stated goals. The New steel liner, with attention to QA/QC during construction and if properly maintained over the years, should have a service life in excess of 25 years. The present tanks have survived for 55 years. The interstitial space and existing steel liner provide secondary containment. Isolated interstitial spaces with tell tale piping provide leak detection and leak location.

The Bladder type liner concept should last in excess of 10 years, but we recommend a bladder changeout in 10 years. The bladder serves as primary containment and therefore provides increased confidence in minimizing the risk of fuel leakage. The interstitial space between the bladder and the existing steel liner provides secondary containment and leak detection. Determination of leak location, however, is less effective than the composite tank as there are no isolated interstitial spaces.

The Repair and Recoat Existing Tank concept relies heavily on the extensive inspection of the existing tank to identify and locate problem areas in the existing steel liner. The liquid applied membrane liner, however, compensates for the difficulty in locating problem areas in the existing steel liner as it provides added protection to minimize fuel leakage. The liner should last 20 years or more. The Repair and Recoat concept does not have an interstitial space or secondary containment. Determination of leak locations is difficult and must rely on visual inspection of the tank interior, and isolation with the tell tale system.

There are many ways to select one of the above repair concepts for implementation. One method is to consider the expected long term need for fuel storage at Red Hill.

If the life of the facility is less than 5 years, repair the tank following current practice.

If the life of the facility is between 5 and 15 to 20 years, the bladder option offers the most cost effective solution, even with a scheduled 10 year bladder replacement.

If the life of the facility is unknown, but expected to be at least 15 years, the composite tank offers long term life extension with secondary containment and the capability to detect and locate leaks more readily than the current leak detection system.

The repair and recoat option, is also a viable alternative, but does not have secondary containment. The degree of confidence in either concept depends on the condition of the existing steel liner and the extent to which it is relied upon for primary or secondary containment.

ACTIONS/DECISIONS REQUIRED

1. Upon receiving direction as to project configuration, EEI will develop a draft DD 1391 for review.
2. The Government review comments on the formal FACD report and cost estimates will be addressed at a project review meeting, as yet unscheduled.
3. At the conclusion of the project review meeting, adjustments will be made to the cost estimate if necessary and a final DD 1391 will be prepared.

2.0 FACD CONCEPT DEVELOPMENT

INTRODUCTION

The modified Functional Analysis Concept Development (FACD) conference was assembled to involve customer, user, design agent and A/E participation on a team basis to better define the scope of project requirements, develop substantially different approaches for comparative evaluation, and minimize concept design changes. The modified approach is based on the A/E performing the facilitator role, and expediting the process to minimize time demands on government and A/E personnel.

The EEI team assembled on May 4, 1998 for the initial briefing, historical construction presentation, and tank visit, followed by the formal FACD on May 5 and 6, 1998 to define requirements, brainstorm concepts, and assemble a coordinated package of concepts into functional packages for cost estimating. The EEI team spent the following 4 days refining the concepts and preparing cost estimates for each of the concepts.

Refined concepts and cost estimates were presented on May 11, 1998 to government stakeholders. Additive bid items of each concept were discussed, resulting in the Government indicating that cost associated with lining the existing tank piping be included in the base cost for each concept project. The Government also indicated that selection of a concept(s) for DD 1391 preparation would be identified after review of the information presented.

HISTORY AND BACKGROUND

The FACD kicked-off with a government presentation on Red Hill historical information, tank construction, and certain historical information on past tank problems and procedures used to repair problems throughout the Red Hill complex. The majority of the problems encountered to date can be traced back to the unique design and construction of the facility.

The original construction of the tanks at Red Hill consisted of excavating the lava rock formation of Red Hill, sealing the rock face with approximately 150 mm (6 inch) of gunite, followed by constructing the upper dome, barrel and lower dome of the tank. The upper dome was constructed first followed by the barrel and lower dome. The walls of the barrel are constructed of reinforced concrete, 1.219 m (four feet) thick at the lower dome, and lined with an internal steel liner, 150 mm (1/4 inch) thick.

Over the years, many original construction defects in the tanks, including original poor weld quality and design defects with the upper dome construction.

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

Due to the lack of sufficient data, no conclusions can be drawn as to the specific causes and mechanisms creating the backside corrosion. Nor can it be generalized yet if the backside corrosion experienced to date is an isolated condition, or if there is widespread backside corrosion at a near hole through level.

The extreme difficulty of locating and fixing leaks, is a key element in this project evaluation to develop a long term life extension repair to the tank.

PROJECT ELEMENT BRAINSTORMING

Infrastructure

The FACD started with examining infrastructure requirements associated with tank repairs. and identifying what infrastructure items are important (Gauging, ATG, ladder, elevator, venting, etc.).

- Tank Gauging and Automatic Tank Gauging

  FISC indicated that the present tank gauging should be changed. A variety of types of systems were identified. However, as the FISC Red Hill tanks are undergoing several test setups it was agreed that this project will take advantage of work of others, and no additional effort was required as a part of the FACD.

- Access Ladder to Lower Dome

  FISC indicated that the present ladder is adequate and no efforts are required as a part of the design

- Elevator Requirements

  FISC indicated that elevators are no longer being installed in the tanks, as maintenance is usually with outside contractors. Thus, no elevator will be included in this project.

- Tank Venting

  FISC indicated that the present tank venting system is adequate and does not need to be changed.

- Fire Suppression and Detection

  FISC indicated that the entire Red Hill complex is being evaluated by others, thus no work in this area is required at this time.

Leak Detection or Prevention and Leak Containment

The FACD team brainstormed how tank leak prevention and/or leak detection and leak containment could be provided. The following concepts were expressed by the team:

* indicates selected for further discussion during the FACD

1. Interstitial tank in tank concept *
2. Continued use of the tell tale system *
3. Improved tell tale system *
4. Drilling monitoring wells below the tank *
5. Internal Bladder system *
6. "Cladding" the existing steel liner with thin steel plate (carbon or stainless)
7. Free standing API 650 tank inside the existing tank *
8. Inventory leak detection system
9. Periodic tank tightness testing (tracer or helium)
10. Acoustic leak detection
11. Prevent further backside corrosion with a cathodic protection system *
12. Repair cracks and voids in the concrete behind the steel liner
13. Provide thicker shell plates
14. Cap the top of Red Hill to prevent rainwater intrusion and divert streams on side of Red Hill
15. Inject a corrosion prevention compound behind the existing shell

Tank in a Tank

The following concepts to provide a tank in a tank were expressed by the team:

* indicates selected for further discussion during the FACD

Interstitial tank in tank concept *

1. Internal bladder type liner *

2. "Cladding" the existing steel liner with thin steel (carbon or stainless)
3. Free standing API 650 tank inside existing tank *
4. To prevent continued problems, must keep groundwater out
5. Inject bentonite as a water/liquid plug between the new and original tank shells
6. Provide an airspace between the new and original tank shells to drain liquid for tank leak detection
7. Weld plates to the existing steel liner (i.e. cladding)
8. Provide a steel spacer between the existing steel liner and new liner (i.e. a rolled steel shape)
9. Do not repair the upper dome (capacity reduction)

Repair Existing Tank

The following "requirements" to repair the existing tank to meet user goals were developed:

1. Must not leak
2. Confirm condition of shell before repairs to determine near future leaks and possible current leaks
3. Will not be secondarily contained
4. Provide a good tell tale system or inventory leak detection system
5. Arrest backside corrosion, if found to be prevalent
6. Prevent inside bottom corrosion
7. Repair must be forgiving to compensate for or "neutralize" occurring in other tanks.
8. Must be testable

The following concepts were expressed by the team:

* indicates selected for further discussion during the FACD

1. Provide enhanced inspection followed by applying a spray-on liner *
2. Use NRL coating system, with zinc chromate primer
3. Use a polysulfide or flexibilized novalac epoxy coating *
4. Provide a cathodic protection system to neutralize backside corrosion *

Piping

1. The following concepts to assure piping integrity were presented:
2. Place the DN 450 (18 inch) line, now in bottom slop service, back to fuel fill/issue service
3. Provide a new fill diffuser
4. Determine the integrity of existing fuel lines as they have been out of service as long as the tank has been out of service and possibly subject to internal corrosion
5. Consider internally lining the piping as a means of extending piping life
6. Remove the water line connection and covert the line back to original slop service
7. No new nozzle valves required. New valves are not included in this project as they are being automated by a separate project.

PROJECT ELEMENT REFINEMENT

Once the numerous ideas were collected, selected concepts were further discussed to refine approaches and clarify methods of implementation.

Free Standing (API 650 Tank) Tank in a Tank

1. Pressure at lower dome spring line is about 65 Psig. EEI advised that preliminary calculations indicate that a shell plate thickness of 38 mm (1.5 inch) to 50 mm (2 inch) at the lower dome spring line is required.

Composite Tank

1. The composite tank will have a liquid tight inner liner and an interstitial space between the existing steel liner and the new inner liner
2. If the inner liner cannot resist liquid pressures it must be supported against the existing shell or supported by a filler material
3. Any materials within the interstitial space must be resistant to welding process

Further development of the secondary space concept resulted in the following:

1. The existing steel liner will be secondary containment for the tank, therefore,
   - Apply 40-60 mil thick film liner to existing steel liner, or
   - Arrest backside corrosion with a cathodic system
2. The composite system must be developed with a leak detection system capable of locating leaks.
3. Must be constructable and repairable.

4. The secondary space must provide structural support for inner liner. Possible options may include:
   - Sand
   - Pea gravel
   - Grout
   - Concrete
   - Bentonite

Tell Tale Leak Detection System

* Items considered very important for inclusion in final concept

1. Use larger diameter piping that is less likely to become plugged, with heavy wall thickness for a greater corrosion allowance.*
2. Must have backside connection at each horizontal imbedded angle at each shell course in barrel. Connect just above angle, to prevent creating a water pocket*.
3. Extend tell tale risers up to Gauging Gallery so they can be blown out if ever plugged.
4. Drill new casing through the wall of the lower dome into Lower Tunnel for leak detection pipes, so that the leak detection pipes are raised out the water zone of the lower dome.*
5. Improve leak detection below the lower dome floor*.
6. Cathodically protect pipes if in water bottom zone.
7. 100% welded construction.
8. Allow for periodic testing.
9. Use stainless steel tubing.
10. Seal cracks in concrete.
11. Provide a pressure or vacuum pad.
12. Isolate as many sections as possible to improve ability to isolate search for leaks*.

PROJECT SELECTION FOR COST ESTIMATING

After brainstorming and discussing various tank repair concepts, the following was determined:

1. EEI will prepare a base project cost estimate for the following project configurations:

   Tank in Tank Concepts

   - Repair tank using a composite inner steel liner and grout fill between the existing steel liner and new liner

- Repair tank using an "internal bladder" liner as a tank in tank.

Repair Existing Tank Concepts

- Repair tank with rigorous consideration for a long term life extension.

Elements Common to all Concepts

- Cathodic protection system for the existing steel liner using a deep anode groundbed, impressed current system

2. The FACD team agreed that the freestanding tank in tank concept was too expensive, far more than other viable concepts, thus no estimate is warranted for this option.
3. All concepts are based on not fixing the upper dome. However, an order of magnitude cost to repair the upper dome will be developed to confirm it is not cost effective.
4. A separate cost estimate will be developed for an undertank leak detection system, consisting of micro directional drilling below the tank from the lower tunnel.

The following matrix identifies possible projects identified for costing.

RED HILL TANK 19 FACD - TANK REPAIR CONCEPTS

TANK IN TANK CONCEPTS		REPAIR EXISTING TANK
Composite (1/4" steel shell, grout fill, telltale system)	**Bladder System** (As primary containment vessel)	**Internal Lining** (Complete rehab after thorough inspection)
Condition Assessment: structural metal thickness - condition	Condition Assessment: structural metal thickness - condition	Condition Assessment: complete scan, and gas leak testing (100%)
Provide "As needed" repairs to existing shell (structural and liquid tight)	Provide "As needed" repairs to existing shell (structural and liquid tight)	Provide "As needed" repairs
Do not re-coat existing plate, patch only	Do not re-coat existing plate, patch only	Internal lining (Flexible liquid membrane, such as Polysulfide)
New 1/4" interior plate with structural steel vertical Tees **(shop precoat?)** Grout Fill in interstitial.	Bladder with 10 year life (single vertical sheet on barrel)	Zinc chromate primer?
Coat 100% tank bottom		
Optional interior shell coating		
Open top, or cone up roof		
Tell tale system for leak detection	Tell tale system for leak detection	Tell tale system for leak detection
Cathodic protection to arrest corrosion on backside of existing shell	Cathodic protection to arrest corrosion on backside of existing shell	Cathodic protection to arrest corrosion on backside of existing shell
Elements common to all concepts		
Tank Gauging (ATG)	Will be determined based on current ongoing FISC pH evaluation and testing program (FAS compliant)	
Repair tower, tie to roof	Allows eliminating some cable ties	
Upgrade hoists as needed	Contractor responsibility, based on his methods and means	
Repair fill, issue and sludge piping	As needed for process, and upgrade integrity	
New platform at top of tower	Enhanced ability to maintain new tank gauging systems	

3.0 DETAILED DISCUSSION OF CONCEPTS EVALUATED FOR COST

The following information is presented to better describe the overall concept solutions and engineering considerations, and to identify the items included in the project cost estimates. During the design of the selected concept, all assumptions will be re-validated for acceptability, constructibility, and meeting user needs.

The discussion is broken down into the following major categories:

- Mobilization associated with Red Hill Construction
- Repairs common to all concept projects
- Composite tank in tank repair
- Bladder type tank in tank repair
- Repair and recoat existing tank
- Impressed current cathodic protection
- Under tank leak detection

PROJECT MOBILIZATION SPECIAL TO RED HILL

On conventional projects, there is little need as a designer to elaborate on mobilization and setup issues associated with the project. Red Hill Tanks, being difficult to access, require some considerations in the design to adequately identify contractor work, as well as determining accurate costs. The following items are presented, and reflect the types of contractor efforts required for tank repairs over the last 20 years.

Contractor Offices and Staging Area

It is expected the contractor will utilize the area near Adit 4 or 5 for offices and minor staging. Adit 5 will be the principal access point for movement of materials into the tank. The vent shaft located directly above Tank 19 also may be used for some utility access into the tank.

Tank Cleaning

As Tank 19 is already cleaned, the cost of cleaning the tank is not included the cost estimate. However, a water wash to remove accumulated dust is included.

Ventilation System Modifications

Mechanical ventilation of the tank will be needed for general ventilation during construction, as well as for welding operations. The existing supply air fan at the surface above Tank 19 has been exposed to the elements since its installation in the early 1990's and is in deteriorated condition.

The fan will be removed and a new supply air fan with a capacity of 9.500 L/s will be installed. The supply air fan will connect to the existing tank vent pipe. An exhaust fan will be provided in the Lower Tunnel with a capacity of 9,500 L/s. The exhaust fan will be ducted to the outlet of the existing DN 800 fuel pipe. Inside the tank, flexible ducts will be used to collect fumes from welding and dust from construction.

An air dehumidification system with a capacity of 9,500 L/s of outside air will also be provided in order to prevent high humidity, condensation and flash corrosion in the tank during sandblasting and coating operations.

When large scale painting of the tank surfaces is performed, the capacities of the supply and exhaust fans will be increased to 19,000 L/s each.

If open abrasive blasting of the tank surfaces is performed, a dust collection system will be provided in the Lower Tunnel. The dust collection system will consist of a dust collector (bag house), exhaust fan with a capacity of 9,500 L/s, ductwork and accessories. The dust collection system will filter the tank air before discharge into the Lower Tunnel or Lower Tunnel exhaust system. The dust collection system will not be used for containment of hazardous waste or grit resulting from the abrasive blasting, only fugitive dust.

Compressed Air System

Compressed air will be required for construction operations. The contractor supplied air compressor will be located outside the entrance to Adit 5. Approximately 500 meters of DN 100 piping will be needed between the air compressor and Tank 19. The actual size of the line will be the contractor's responsibility. Air drops and other branch connections will be provided as necessary. It was the experience of the last project that the existing DN 50 airline was not large enough.

Construction Electrical Support Requirements

Power supply (480V, 3Ph) for contractor trailers and construction work will be obtained from the existing substation R20 in the lower tunnel, adjacent to the Gauging Station. The size of the feeder will depend somewhat on the contractor's requirements for electrical power and dehumidification. At this time, a 70 amp branch circuit has been included. Local transformers will provide service to the contractor's facility.

All electrical and lighting equipment in the tunnels and tank will be Class 1, Division 2, Group D hazardous rated.

Additional lighting will be required in the tank, consisting of 400 watt metal halide floodlights (Nema 7x6 beamspread). Seven fixtures will be provided at the 15 M, 30 M, 45 M and 60 M levels inside the tank, 28 fixtures total, attached to the center tower. Power (277 volt) will be obtained from Panel P1 and a new 480 V panel in the lower access tunnel.

Power for small hand tools and equipment will be obtained from spare breakers in panel P-2 in the Tank 19 upper gallery and a new 208Y/120V panel in the lower access tunnel.

Power for welding machines is required in both the upper and lower tunnels. Two 300 amp arc welders in the upper tunnel can be supplied from panel P-1, with additional 60 amp, 480 volt molded case circuit breakers and welding receptacles. A single 300 amp arc welder in the lower tunnel can be supplied from an existing 200 A receptacle using a temporary equipment rack with breakers and receptacles.

Boom, Monorail and Hoisting Systems

Tank 19 contains two booms with baskets, plus a jib crane, these items are left over from past repairs. It is the practice at Red Hill to allow the contractor to use these government furnished equipment (GFE) items, but no assurances are provided as to suitability of the equipment for the contractors needs. The contractor has the option of re-certifying the equipment, or providing new equipment. For the purposes of cost estimating for this project, we have included certification of the present booms and jib, plus replacement of the air motor driven lifts and man baskets. Reportedly, newer equipment that operates faster, is available.

We have also included the contractor providing a monorail system, supported from the upper dome just above the spring line adjustment plate. This monorail, and two accompanying platforms, are crucial to cost effective construction.

BASIC REPAIRS COMMON TO ALL PROJECTS

To a considerable degree, all of the tank repair concepts developed during the FACD share common elements of basic work. The following describes these common elements, plus minor differences associated with each concept.

Fuel Pipe Modifications

The existing piping at the bottom of the tank will be modified as necessary to meet the user's requirements. These pipes include the DN 800 (32 inch) fill/issue pipe, DN 450 (18 inch) slop pipe and DN 200 (8 inch) water pipe.

The DN 800 fill/issue pipe will continue to be used for primary fuel transfers. Inside the tank, the existing piping and gooseneck will be removed and replaced with new piping and an anti-vortex fitting. In the Lower Tunnel, the pipe will connect to the existing skin valve. The test spool section between two valves will be maintained for valve leak testing. New valves are not included in this project as they are being automated by a separate project.

The DN 450 slop pipe currently is also used as a conduit for the tell tale piping. After removal of the existing tell tale piping, the slop pipe will be converted for use as a second fill/issue pipe as a backup to the DN 800 fill/issue pipe. Inside the tank, new piping and an anti-vortex fitting will be provided. In the Lower Tunnel, new piping and valves will be provided to connect the DN 400 pipe to existing fuel piping.

Water piping to the tank is no longer needed. The DN 200 water pipe will be converted for use as a slop pipe, which was its original function prior to conversion to use as a water pipe. Inside the tank, the existing water piping and valve will be removed. In the Lower Tunnel, the existing water piping will be removed and new DN 200 piping and valves will be provided to connect to existing slop piping. This pipe also serves the purpose for a low level draindown line.

The current condition of the DN 800, DN 450 and DN 200 piping, embedded in concrete between the Lower Tunnel and the bottom of the tank, is not known. However, the pipes are over 50 years old, the DN 800 pipe has been used as a ventilation duct for the last several years, the DN 450 pipe has been used as a slop line for fuel and water, and the DN 200 pipe has also been used for water service.

It is possible that these pipes have deteriorated and require reconditioning or replacement. During the design process, additional investigation and possible testing will be conducted to confirm condition. Proposed testing would include visual inspection of the larger pipe, plus some ultrasonic (UT) thickness evaluation, and possibly TV observation of the smaller lines. In the event pipe wall corrosion, thinning or other problems are discovered, life extension repairs are in order.

The proposed method for rehabilitation of the piping consists of cleaning the interior surfaces of the pipes and installing a cured-in-place pipe liner. The liner will slightly reduce the interior diameter of the piping in this section, but the smoother surface usually compensates for the reduction. The more costly removal of existing concrete and piping and installation of new piping will not be necessary. After pipe repairs, the lines will be hydrostatically tested to confirm integrity.

Tell Tale System - Composite Tank Repair

Over the years, the value of a well thought out tell tale system has been proven. The FACD conference confirmed that the Tank 19 repairs will include a new system for several options, incorporating concepts that have been proven in the past.

The tell tale system will be used for visual detection of leaks in the inner liner from the interior of the tank to the interstitial space between the new inner liner and the existing steel liner. The system can also be used for monitoring of any water that may breach the outer (original) steel lining into the leak detection interstitial space.

The existing tell tale piping is approximately 28 to 55 years old and will be removed. The work includes removal of the tell tale piping for the upper dome and barrel, removal of the jumper pipes and ring header in the lower dome, removal of the tell tale piping in the existing DN 450 slop pipe and removal of the valve manifold in the Lower Tunnel.

The new tell tale system will consist of leak detection piping for the tank barrel and lower dome. Piping will be DN 40, extra strong, 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 piping will be connected to the inner liner near the bottom of the barrel at the lower dome spring line. As the composite tank will have 52 interstitial spaces, 1.820 M wide each, vertically up the barrel, there will be 52 leak detection connections to the inner liner. The 52 connections will be headered together in 13 zones of 4 pipe connections per zone. Thus, if a leak is detected, an area of the tank 7.3 M wide, from the lower dome spring line, to the upper dome spring line can be isolated for the leak search. The leak detection system also can be used for injection of a detectable gas in the interstitial space, for leak site determination.

Each of the 13 zones will have a single pipe will be routed through a new DN 450 penetration in the lower dome to the Lower Tunnel. The penetration in the lower dome will be located above the tank water level.

In addition to the 13 zones for the tank barrel, one zone will be provided for the entire lower dome. The lower dome tell tale pipe will be routed from a new sump at the center of the flat part of the tank bottom to the Lower Tunnel. The pipes from the 14 zones will be grouped into a manifold in the Lower Tunnel. Drilling or coring of the concrete between the lower dome and the Lower Tunnel will be required in order to provide a path for the tell tale piping.

As an Additive Bid Item, the tell tale piping for the 13 zones around the barrel could be extended from the bottom of the barrel up to the gauging gallery at the top of the upper dome. This would allow for clearing of the piping with compressed air or some other means.

Tell Tale System - Bladder Tank Repair

The tell tale system proposed for the Bladder system will be quite similar to that envisioned for the Composite Tank concept. The bladder sheets on the barrel will be attached to a ring type lower support channel, with segmentation for vertical zoning. One key difference is that the entire bladder in the barrel will be one continuous interstitial space. However, segmenting the collection header will allow some degree of leak site determination.

Tell Tale System - Life Extension Tank Repair

In the event life extension repairs are made to the existing tank, the existing tell tale system above the lower dome will be tested, and only repaired as needed. The entire lower dome system, plus the pipes from the tank to the Lower Tunnel, will be replaced, following a concept similar to that presented for the Composite Tank.

Tank Gauging, or Automatic Gauging (ATG)

The present gauging system for Tank 19 consists of a float and tape system, with a transmitter for remote readout at the Gauging Station. Throughout the Red Hill complex, the tank gauging system is being updated to meet the upcoming FAS system requirements. An additional goal of the FISC is that any new ATG system shall also be capable of tank leak detection through inventory management, or static testing.

Several initiatives are on-going at the FISC to install and evaluate different concepts. At this time, it was agreed this project will take advantage of the findings from the other initiatives, and not propose any new concepts.

Thus, a line item is included in the estimate for an ATG system, without being specific as to type of system. The primary ATG devices will be located in the Gauging Gallery with conduits extending down into the Upper Tunnel, near the tank manhole. Local readout and control functions will be panel mounted. Additional wire and conduits will extend to The Gauging Station, located in the Lower Tunnel.

Tank Hi Level Alarm System

Although any new ATG system could include software based Hi/Hi-Hi level alarm functions, EEI recommends installation of an independent, self checking system for Hi/Hi-Hi level detection and alarming. This is also a part of "criteria" presented in Mil HDBK 1022.

We have included a "Scully" system in the project, with thermistor style sensors extending into the tank from the Gauging Gallery, and the control panel located in the Upper Tunnel, adjacent to the manhole door. A conduit will be run to the Gaugers Room in the Lower Tunnel, and a remote alarm panel will be installed.

Center Tower Modifications

Recent and past projects have included the construction of a platform at the top of the tower, accessible from the Gauging Gallery, that is used for some of the ATG hardware mounting and servicing. Also, it is our understanding that the top of the towers can be braced and tied in to the upper dome, allowing some of the support cables to be removed.

While details of these items are somewhat sketchy, we have included an allowance in the cost estimates for tower modifications and a gauging platform. During design, these items will be further evaluated.

Tank Venting

Primary tank venting is considered adequate, and no repairs have been included in any of the concept cost estimates.

Fire Detection and Suppression

The FISC currently has an overall fire system study underway. The Repair Tank 19 project does not include repairs to any of the associated systems.

COMPOSITE TANK IN TANK CONCEPT

Engineering Considerations

The overall concept for the Composite Tank in a Tank system consists of a new 6.35 mm (1/4 inch) thick steel liner support by structural steel tees welded to the existing steel liner vertically at 1.829 m on center, creating an interstitial space between the existing steel liner and the new liner with the interstitial space between being filled with concrete grout. The internal pressures due to fuel are transferred to the existing tank structure by the grout fill. The new interior liner, similar to the existing liner, only serves as a means of making the tank liquid tight. The lower dome would be treated similar to the barrel.

It is assumed that the existing steel liner, and concrete outside the liner, is in a condition suitable to continue as the primary structural element of the tank. This is a reasonable assumption, as there was no evidence of any structural failure during our brief inspection of the tank.

We have considered a barrel lining concept of both horizontal coursing, with rolled sheets, and vertical coursing with flat sheets. We have chosen the vertical concept for the following reasons:

1. Vertical courses supported by vertical tees welded to the existing steel liner will allow isolation of the barrel into vertical zones for improved leak detection and leak location. Vertical tees spaced at 1.829 M on center, running from the lower dome spring line to the upper dome spring line will isolate the barrel into 52 vertical elements. Spacing of the tees at 1.829 M on center is based on the maximum width of the new liner plate that can be transported in the tunnels and through the existing isolation doors in the Upper Tunnel.

2. Vertical plates can be brought into the tank as long flat sheets. If a horizontal configuration is used, the plates would have to be rolled to shape, or rolled in the tank during erection.
3. If the courses are horizontal, the tees for plate support would have to be rolled. This would present considerable problem as it is unlikely the tank is perfectly.
4. If the courses were horizontal, the horizontal tees would act as a barrier in the leak detection system, considerably increasing the complexity and cost of the tell tale system.

The existing steel liner is assumed to have sufficient thickness remaining for welding the tees. The thickness of the steel liner needs to be confirmed during design by performing ultrasonic scanning of vertical sections of the barrel at each tee location to determine to determine metal thickness, thin areas, and plate lamination.

The present coating system in general appears in excellent condition, and is to be reused as is. However, it must be removed at the locations where the vertical tees will be welded to the existing steel liner.

A plate thickness of 6.34 mm (0.25 inch) has been selected, as it matches the present liner thickness. It is possible that a 4.76 mm (3/16 inch plate may be used , at a steel weight savings of 25%. However, there would not be any substantive savings in erection or welding, only in the cost of the material. The disadvantages with the thinner plate include less corrosion allowance, greater burn-through during welding.

The steel plates and tees will be specified with at a mill sandblast or pickling to remove slag. Prior to bringing the plates and tees into the tank, a full water wash will be specified to remove any chlorides that may be on the steel from transportation, or on-site storage.

The lower dome would be treated similar to the barrel except that the tees would be welded radial from the bottom of the dome up to the spring line and the new liner plates would have to be custom cut to fit the shape of the dome and radial spacing of the tees.

The present project does not include repairing the upper dome, due to the expected very high incremental cost compared to the increase in storage of 35,000 Bbls. The new composite liner will terminate and be sealed just below the adjustment plate of the upper dome.

A variety of materials has been considered for filling the interstitial space between the existing steel liner and new liner. The most important characteristics required include:

- Non corrosive by nature
- Flowable, self leveling
- Will not settle or shrink
- Sufficient strength to transfer liquid pressures to the existing tank structure

After considering a variety of materials, we have included non shrink grout in our cost estimate for the interstitial space fill.

We have considered the possibility of casting some type of a channel or slot in the grout, just behind the new liner, to enhance leak detection. We have rejected this concept due to construction difficulties, and more importantly, as it sets up a possible corrosion point at the air/grout interface. The absence of a channel or slot in the grout will not prevent leak detection or vertical flow of liquid.

Corrosion mechanisms, and need for coatings in the interstitial space, has been considered. The grout will naturally passivate any uncoated steel, minimizing corrosion. As the entire basis of this concept is built on the assumption that the existing steel liner is totally or nearly liquid tight, the possibility of water intrusion is considered low. Thus, we suggest that the tees, and backside of the new steel liner, do not need to be coated.

The need to provide a water hydrotest after completion of the work has been considered. If this tank was built to API 650 standards, a water hydrotest would be mandatory. However, the primary reason for a hydrotest is to prove the structural integrity of the tank. A water hydrotest has limited benefit in leak testing a new tank. Considering the fact that all welds in the new liner will be vacuum box tested, and the tank will have a tell tale system, we suggest a hydrotest is not warranted.

Composite Tank Useful Life Considerations

The overall features incorporated in the Composite Tank Repair concept all are similar to any new tank construction. Thus, the functional life of the facility will be renewed for a considerably longer period. Considering the present facility is over 55 years old, this life extension project may have a similar life. The only major maintenance required will be coatings, and if properly applied, would be on a 20 to 25 year cycle.

Composite Tank Goal Attainment

The following assessment compares this project to the original goals established during the FACD and on Government requirements.

Original Goal	Goal Attainment
Long term life extension renewal of the tank, rather than a 10 year or less fix	The new liner, properly maintained, should have a life in excess of 25 years
Minimize risk of fuel leakage	New steel liner, with considerable attention given to specified QA/QC and Government surveillance
Contain leaks that may develop	The interstitial space will isolate a leak to a 1.83 M wide panel, with leak detection tell tale for determination of leaking. This system provides secondary containment.
Allow location of leaks more readily than current configuration	Concept tell tales consolidate 4 panels together, limiting leak search to areas 7.3 M wide X barrel height. Also, injection of a detection gas is possible through tell tale system
Provide for future maintainability	Standard Red Hill maintenance practices can be followed
Provide a constructable, cost effective solution	Concept design considers many aspects to make it a constructable solution
Accurate prediction of project cost	Time will tell..........

Composite Tank System Description and Execution

The existing steel liner will be water washed to remove the lightly adhered dirt and dust. All locations where tees 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.

Miscellaneous existing problems will also be repaired. This will include repairing any identified thin spots or holes by welding patch plates and removing grout tubes, clip, and attachments projecting in the tank that would interfere with the interstitial lining concept.

The existing coating will be removed 150 mm (6 inch) wide at each tee location using enclosed grit or high pressure water blasting equipment. The WT 100 (4 inches deep) vertical tees will be welded in place with continuous fillet welds both sides for compartmentalizing and structural strength. The welds will be visually inspected using AWS criteria. Spot QA/QC with magnetic particle or dye penetrate testing will also be required.

Starting at the bottom of the barrel, steel plates up to 9 M long will be tack welded in place using the contractor built monorail. After tacking two adjacent plates in place, a complete penetration butt weld will be made, including complete penetration weld into the support tee. We suggest the contractor be prohibited from using SMAW welding procedure. An automated welding machine is much more likely to make reliable full penetration welds. Horizontal joints will also be made using a butt weld procedure, most likely with an automated welder. A backing bar will be welded to the upper sheet prior to its being hung in place, to assure obtaining a complete penetration weld.

NDE inspection of the complete penetration weld presents some problems. Use of radiography is not possible, as the backside is not accessible. Grinding the weld and using a UT shear wave method, on a 100% basis, is not practical, nor reliable. We suggest the primary NDE be visual, plus random use of the ultrasonic shear wave method. All welds will be vacuum box tested to 10-12 Psig, providing further quality assurance in the work completed.

After one course of plates are welded in place, the interstitial space can be filled with grout. To prevent bowing of the new liner from the plastic grout, the grout should be place in lifts up to the top on the vertical course. Once the grout has set, the next course of plates can be erected. Erection of the composite floor will be similar to the barrel.

Installation of the new tell tale system, and fuel piping modifications will be on-going during the barrel work.

After all of the lower dome and barrel work is complete, application of coatings can commence. As a minimum, the lower dome will receive a white metal blast and NRL coating system. The current NRL system utilized calls for a prime and intermediate coat using a Mil C 24441 epoxy polyamide system and a topcoat of the WC-5 formulation. This NRL system meets the most stringent California VOC rules, thus should be acceptable in HI. All piping within the tank will be coated at the same time.

Coating of the barrel is considered a desirable option, but not a mandatory feature to obtain a useable facility. However, one of the main advantages of coating the barrel, other than corrosion protection, is that tank cleaning will be more efficient and thus less costly.

The first filling of the tank with fuel will follow traditional Red Hill practices to identify any possible loss of product.

BLADDER TYPE LINER SYSTEM

Engineering Considerations

The overall concept for the Internal Bladder Tank in a Tank system consists of a fuel resistant sheet membrane liner attached to the existing steel lining as an internal bladder. A cushion material will be provided between the liner and the existing steel liner to protect and cushion the liner and protect it from any small protrusions and abrasion during filling/issuing fuel. Internal pressure from the fuel is transferred to the existing tank structure as the bladder and cushion are in direct contact with steel liner. The membrane liner, similar to the existing steel liner, only serves as a means of making the tank liquid tight.

It is assumed that the existing steel liner and concrete outside the liner, are in a condition suitable to continue as the primary structural element of the tank. This is a reasonable assumption, as there was no evidence of any structural failure during our brief inspection of the tank.

The present coating system in general appears in excellent condition, and is to be reused as is. However, it must be removed at the locations where liner attachments will be welded to the existing steel liner. All locations of existing coating damage will be repaired. All protrusions, grout tubes, brackets, etc. must be removed prior to installing the membrane.

The membrane concept consists of a single sheet "draped" from the upper dome spring line, down to the spring line of the lower dome. No horizontal field seams will be permitted. The width of the membrane sheet will be the contractor/vendor responsibility as the width is dependent upon vender factory seam capabilities and contractor ability to transport the liner through the tunnel and install it inside the tank. The goal however is to minimize vertical seaming.

The liner material will be hung just below the upper dome adjustment plate, using a carefully designed batten strip concept. We envision attaching the liner at the lower barrel alignment plate using a batten strip on top of a fabricated leak detection collector ring. The collector ring would be isolated in segments to limit the extent of searching for leaks.

Leak detection pipes would extend from this collector ring to the Lower Tunnel, through a newly drilled boring in the lower dome, similar in concept to the Composite Tank Repair.

The liner on the bottom dome would be installed in segments with field seaming, to match the shape of the cone. Due to number of pipes and tower columns on the flat center plate of the lower dome, consideration could be given to not covering this section with the membrane. This is further justified as the bottom plate is 12.7 mm (1/2 inch) thick.

We have researched materials available for the bladder membrane. Several liner manufacturers are currently making materials suitable for this application. Although their primary market is lining dikes, several of the materials are currently being used in the fabrication of temporary "bladder tanks", up to 50,000 gallons and larger in size. Several manufacturers have on-going immersion tests programs, and are in their 6th year of testing. Manufacturers are willing to provide warranties of up to 10 years for use of their products in fuel immersion service. Thus we have no concerns in considering a sheet membrane liner for this application, with the provision that the liner be replaced at the end of 10 years use.

The product closely evaluated is Petro Gard 10 supplied by MPC Containment Systems. It is a high strength reinforcing fabric coated with a urethane aromatic resistance polymer. Over all thickness of the material is 40 mils. The method of seaming provides joints stronger than the parent material Suitable, but less recommended products are Petro Gard 6 or Seaman

Corporation XR-5. XR-5 is a polyester reinforced, 30 mils thick minimum (40 mils nominal) material, weighing 1.02 kg/m^2 (30 oz/ sq. yd). Petro Gard 6 is similar to XR-5. Both products meet compatibility requirements, but are not as strong or thick and do not have the urethane polymer for greater resistance to fuel.

Similar products are manufactured by Cooley Engineered Membranes Inc., another major supplier of membrane liners.

Several manufacturers can supply a cushion material suitable for this application. Generally, it is similar to a geotechnical filter membrane, made from non-woven polypropylene material. Consideration will be given in the design to the attachment of the cushion to the existing steel liner, to prevent the cushion form slipping and "bunching" up at the bottom of the barrel. Possibly, flat plate clips, similar to those used in lining of ductwork, could be spot welded to the steel liner.

A concept was suggested to use stainless steel plate coils as an internal liner and hang the plates from the upper dome spring line, just below the adjustment plate. EEI does not recommend this concept for the following reasons:

1. The potential for galvanic corrosion of the existing steel liner and new stainless steel liner from dissimilar metals in contact is difficult to prevent, even if a cushion material is sandwiched between the stainless steel sheet and the existing steel liner.
2. If 26 gage sheet is used, welding without burning through the sheet is more difficult to control. Additionally, as 26 gage sheet are very thin, the sheets will need to be joints with lap welded joints which have much lower strength than butt welded joints.
3. Stainless steel is highly susceptible to corrosion pitting from chloride attack. Chlorides may be introduced into tank as seawater from a tanker delivery. Chloride pitting in thin gage plate can easily result in a through plate hole.
4. The price per pound of stainless steel plate coil is approximately 2 to 3 times the cost of carbon steel plate and is highly variable.

Bladder Concept Useful Life Considerations

The basic premises of the Bladder Repair Concept are a useful life of about 10 years and the recommendation to plan on changing the liner at the end of 10 years service. Liner attachments, leak detection piping, and basic tank repairs will have a much longer life expectancy.

Bladder Concept Goal Attainment

The following assessment compares this project to the original goals established the FACD and on Government requirements.

Original Goal	Goal Attainment
Long term life extension renewal of the tank, rather than a 10 year or less fix	The bladder system should last 10 years. Other repairs have a longer life
Minimize risk of fuel leakage	New membrane liner over existing steel shell. This system provides secondary containment.
Contain leaks that may develop	The interstitial space will isolate a leak between the present steel shell and new membrane
Allow location of leaks more readily than current configuration	The entire barrel liner is one section. However the collection ring will be isolated to assist in reducing leak site determination.
Provide for future maintainability	The liner will need replacement at the next scheduled 10 year inspection interval
Provide a constructable, cost effective solution	Concept design considers many aspects to make it a constructable solution

Bladder System Description and Execution

The existing steel liner will be water washed to remove the lightly adhered dirt and dust. All locations where liner attachments will be welded to the existing steel liner will be scanned for metal thickness, thin areas and plate laminations, to assure a solid structural attachment point.

Miscellaneous problems in the existing steel liner will also be repaired. This will include repairing any identified thin spots or holes by welding patch plates and removing grout tubes, clip, and attachments projecting into the tank that could possibly perforate the bladder liner.

An attachment arrangement will be welded to the barrel, just under the upper dome alignment plate. A "jumper shield" will be welded over the expansion joint and adjustment plate to protect the membrane liner from damage. The lower barrel attachment system will have a leak detection collection header and will be welded to the existing steel liner at the lower dome spring line.

The cushion material will be draped and attached to the barrel using a system developed during design. The liner will be draped from the upper barrel attachment to the lower dome attachment, and bolted in place. Once two vertical sheets are draped, the joint between will be seamed. This joint will be vacuum box and air lance tested for integrity. We suggest that a factory technician participate in the initial seaming, as well as provide a final inspection of the bladder liner. Once the liner segments are seamed, the liner will be attached to the lower dome batten strip and bolted in place.

Once the barrel portion of the liner is installed, the liner in the lower dome will be attached and tested.

REPAIR AND RECOAT EXISTING TANK CONCEPT

Engineering Considerations

The overall concept for the Repair and Recoat system consists of performing a 100% shell scan for thin spots and corrosion, and a helium test for holes in welds and in the plates, followed by application of a liquid, spray applied liner

It is assumed that the existing shell and concrete outside the liner, are in a condition suitable to continue as the primary structural element of the tank. This is a reasonable assumption, as there was no evidence of any structural failure during our brief inspection of the tank.

Based on limited evidence, there is a concern that the steel liner at Red Hill tanks may be entering a period of significantly increased corrosion and through plate holing from backside corrosion. In order to fully assure integrity of the existing steel liner, we suggest, prior to application of the coating, a rigorous testing program to identify all thin spots, general corrosion, and pinhole leaks. Once found, these defects can be repaired. Either MFE or UT scanning techniques can be used to determine general plate corrosion and thinning. However, both systems have limitations that indicate the need for additional testing using a detectable gas.

Because the tank is constructed with steel angles that serve as backing bars at welded joints in the steel liner and are cast into the concrete wall of the tank, we suggest that the detectable gas testing program be approached very thoroughly to assure gas dispersion and draining of any trapped water behind the existing steel liner. Each course should be drilled at the top and bottom for gas injection and dispersion testing.

Once defects discovered by testing are repaired, the existing NRL coating system would have to be removed to a white metal condition. As the existing coating system is in excellent condition and well adhered, the existing coating could be removed using a high pressure water spray in an enclosed chamber, with vacuum removal of water and coating material. The original "tooth profile" of the plate surface would then be preserved, and suitable for the follow on coating application.

Hand needle gun and/or open sandblasting would be required at structural elements, expansion joint, and other locations not accessible to coating removal by the water spray system.

The proposed concept of using a liquid spray applied membrane, 40 to 60 mil thick, is to compensate for (i.e. "neutralize") backside corrosion and difficult to find pin hole leaks from through plate corrosion. The general product type being considered for the application is polysulfide coating or a flexibilized novalac epoxy coating. These types of coatings have been successfully applied to military cut and cover fuel tanks as a means of assuring a liquid tight condition, even with cracked concrete. These coatings have also been occasionally applied to military steel tanks.

Repair and Recoat System Useful Life Considerations

The type of system proposed generally is considered to have a useful life of 20 to 25 years when properly applied. Periodic inspection and minor repairs can be expected, particularly at the 10 year interval.

Repair and Recoat System Goal Attainment

The following assessment compares this project to the original goals established during the FACD and on Government requirements.

Original Goal	Goal Attainment
Long term life extension renewal of the tank, rather than a 10 year or less fix	The liquid applied membrane liner system should last 20 years or more. The degree of inspection will discover other problems for a long term repair.
Minimize risk of fuel leakage	The lining system has a good track record of compensating for or "neutralizing" any substrate problems
Contain leaks that may develop	This system does not have an interstitial space. The present system of tell tales to the space between the shell and concrete is only partially effective in containing leaks.
Allow location of leaks more readily than current configuration	No change from existing conditions. Leak location will be difficult and must rely primarily on visual surface inspection
Provide for future maintainability	The liner will need periodic inspection plus replacement in 20-25 years
Provide a constructable, cost effective solution	Concept design considers many aspects to make it a constructable solution
Accurate prediction of project cost	Time will tell..........

CATHODIC PROTECTION SYSTEM

Engineering Considerations

Considerable thought has been given to the determination of why the steel liner on many of the Red Hill tanks is exhibiting backside corrosion. The overall concern is that all of the repair options presented depend on the existing steel liner in one form or another to remain as a part of the new system. This has led us to conclude that arresting the backside corrosion, by installing an impressed current cathodic system, is important to the overall life extension of the facility.

Furthermore, establishing the causes for the backside corrosion will assist in the life extension of all of the tanks, irrespective if they are repaired the same as Tank 19.

From the 4 or 5 coupons cut from Red Hill tanks other than Tank 19, it appears that the backside of the steel liners are suffering from two types of corrosion:

- The first type is a generalized corrosion attack that has resulted in broad areas of metal loss. These areas have corrosion pits of 12.7 mm to 38 mm (1/2 to 1 1/2 inches) in diameter.

- The second type of corrosion evident on the coupons is a very localized pitting with holes as small as the diameter of a paper clip, up to 3 mm (1/8 inch) in diameter, that had fully penetrated the 6.35 mm (1/4 inch) thick steel liner. The neighboring steel on the latter samples was virtually fully intact.

Since the original construction of the Red Hill tanks incorporated a concrete wall, minimum 0.609 M to 1.21 M (2 to 4 feet) thick behind the steel liner, the high pH of a quality concrete would normally provide an effective means of passivating the steel. This passivation of the steel would continue for an indefinite amount of time as long as the integrity of the concrete at the steel/concrete interface remained intact and dry.

Several mechanisms could be contributing to the corrosion on the backside of the steel liners. The original concrete may have been mixed with seawater instead of fresh water. Beach sand may have been used in the concrete mix. Either of these items or any other mechanism that would allow chlorides into the concrete, would result in several types of destructive processes.

The reinforcing steel in the concrete, the hangers (tie backs) that fully penetrate the concrete, the strain gauge tubes, and the grout tubes would corrode. The corrosion products expand to several times the original volume of the steel. This expansion process creates high tensile forces within the concrete and easily splits and cracks the concrete. Once the concrete has cracked, it would allow ground water to infiltrate to the interface between the concrete and steel liner. Also the presence of any significant chlorides in the concrete would act directly on the back side of the steel liner to form corrosion.

Another corrosion mechanism that is possible is that the steel liner is not in contact with the concrete in all places. If water or high humidity were present in these voids it would set up a differential corrosion cell between the steel exposed to the humid air (anodic zone) and the steel covered by concrete. This type of process can be easily demonstrated by the way a steel bollard set in a concrete footing will corrode at the interface unless the concrete is crowned to facilitate quick water drainage away from the steel bollard.

A review of the 1949 Bechtel report on the NSC Fuel System clearly reveals that even as early as September, 1948 (See Appendices 1C, 1D, and 2A of the 1949 report), the integrity of the concrete behind the steel liner was broken. The Bechtel report describes how when compressed air was used to attempt to pressurize the tell tale piping system, very little or no back pressure could be achieved. They concluded "we believe that the most probable location of a leak not indicated by the tell tale system would be through the strain gage installation, because at this point, both the concrete and most of the gunite is penetrated by a 1/2 inch pipe that extends through the 1 1/4 inch pipe to the outer face of the 1/4 inch plate liner, detail "E". A leak occurring in or around any one of these 24 strain gage connections could easily find its way through a porous or broken section of the gunite."

This quite clearly demonstrates that there are multiple pathways for ground water to infiltrate through the massive reinforced concrete walls into the zone between the concrete and the back of the tank's steel liner. Although this may not happen in most or even a lot of locations, all it takes is a few areas on a tank to develop the leak problems that are now being experienced.

Much of these conclusions have to be made based on review of old reports and "as-built" drawings, and a very small sampling of tank coupons taken out of different tanks. A survey using ultrasonic scanning equipment that is able to provide complete coverage of an area (B-Scan or C-Scan) is needed for at least representative sections of the tank before any more reliable conclusions can be made. To date, the only backside corrosion evaluation for any of the Red Hill tanks has been done by personnel visually inspecting the internal side of the tank walls; looking for through wall corrosion penetrations or by very limited point to point ultrasonic testing (A-Scan).

Therefore nobody knows as a fact whether the external skin of Tank 19's 6.35 mm (1/4 inch) thick steel tank liner is corroded 90% of the way through at 1, 10, 100, or 1,000 locations.

Proposed Cathodic Protection System

Although the Red Hill tanks are located in a so called "rock" excavation, the possibility of providing an effective cathodic protection system is not as unlikely as first thought. The existing network of cathodic protection (CP) systems at Pearl Harbor was designed by PSG Corrosion Engineering (PSG) San Diego, California under contract N62755-87-C-0923.

One of the 24 deep anode CP systems for this project is located only 200 feet from Red Hill's ADIT 6 next to the Tank 355. This CP systems protects the 16 inch fuel line from ADIT 6 to Pearl City Tank Farm. Although this area appears to be the same rocky formations that the Red Hill tanks were excavated in, the operating resistance of this CP system is only 1.2 Ohms (8.0 Volts/6.6 Amps).

Similar fractured rock formations exist at the Pearl Harbor Upper Tank Farm and Middle Tank Farm where a similar system of 8 deep anode groundbeds was installed. The only logical conclusion is that although the local geology is "rocky", it is fractured rock that is very permeable. The permeability must be allowing water to migrate through and thus electrical current is able to be efficiently distributed to these tanks and pipelines.

A possible impressed current cathodic system would consist of 4 anode groundbeds for Tank 19; located at 90 degree radial positions. These deep anode groundbeds would be similar to the 24 other ones at FISC fuel pipelines and tanks. The major construction difference is that since the Red Hill tanks are so deep in the mountain, the holes have to be much deeper. An active anode length of 91.44 M (300 feet) and an inactive length of 53.34 M (175 feet) would be required for a total hole depth of 144.78 M (475 feet). Each anode groundbed would have 12 mixed metal oxide anodes similar to the anodes already in use in the other CP systems.

For Tank 19 only, a total of 4 anode groundbeds are required. If this CP concept for Tank 19 is later expanded to include Tank 20, then only 6 anode groundbeds (two more) would be required instead of 8. For Tanks 17, 18, 19, and 20, a total of 9 anode groundbeds would be required instead of 16. The point is that the first CP installation for a single tank is the greatest per unit cost. As more tanks are included in the CP system, less anode groundbeds are required.

An important factor used in designing a cathodic protection system is the current density, expressed in mAmps per square meter or square foot. Although for steel pipelines in soil or water this criteria is typically 2 mA/Ft^2, for steel in concrete this value ranges by a factor of 10 depending on chloride concentration in the concrete, ambient oxygen, and amount of moisture present. For new concrete coated steel pipelines, design values as low as 0.2 mA/Ft2 are used. For reinforcing steel in bridge and pier decks that are contaminated with heavy chlorides, this value approaches 3 mA/Ft^2.

If this project were to proceed to a design, it would be very helpful to obtain representative samples of the concrete behind tank's steel liner. These concrete samples would be crushed into a powder and tested for total chloride concentration. This information would be used to adjust the cathodic protection system basis of design calculations.

The rectifier would be placed inside the Upper Tunnel instead of on top of Red Hill in order to avoid exposure to the elements, eliminate vandalism and allow more frequent monitoring.

The CP system must be designed with the ability to monitor its effectiveness. This is done by measuring DC Voltages (CP Potentials) between the steel liner and the concrete environment using reference electrodes that would be embedded in the concrete at the areas that would most likely be the most difficult to provide corrosion control. These areas would be the furthermost away from the anode groundbeds. These reference electrodes would be placed in position by micro directional drilling from inside the Upper and Lower Tunnels.

UNDER TANK LEAK DETECTION SYSTEM

One of the intriguing concepts presented at the FACD is to provide a network of leak detection borings below the bottom of the tank. An investigation into available equipment in Hawaii finds that several contractors have micro boring rigs that can be used for the directional drilling of 50 mm (2 inch) diameter holes. Drilling through the concrete plug below the tank is not a problem, and is actually easier than drilling through basalt formations. It appears sufficient space exists to gain access to the concrete face for drilling.

We have included an Additive Bid item for implementation of this concept.

4.0 FIELD VISIT TO TANK 19

GENERAL

A field visit was made to Tank 19 by the design team and government representatives on Monday, May 4, 1998. The tank was checked for oxygen and petroleum vapors by EEI. No hazardous conditions were found.

FIELD OBSERVATIONS

Tank lighting was adequate for general observation of conditions and safety.

Coating samples were taken of the shell and floor for follow-up chemical testing for lead and chromium.

The following summarizes observations made by the team while inside the tank:

1. The original 1960-63 applied NRL coating system (green surface color) was evident throughout the tank. The observable condition on the shell was excellent, with no particular areas exhibiting failure. The coating on the flat floor was failing in most areas. There was no metalizing below the coating. The barrel portion of the tank, and lower dome exhibited a sediment (dirt) surface on the coating that easily came off by wiping with a rag. The coating thickness averaged 10 to 12 mils thick.
2. The tank had two booms on the center tower. One boom had a "power climber" basket. An additional jib boom was adjacent to the entrance manhole.
3. The tower did not have an elevator to the floor. Access to the lower dome is via a ladder with cage and platforms.
4. The batten plates on the upper dome were previously repaired (1960-63) by rewelding on all sides. Only a few "weeps" were observed, based on staining. No staining noticed exceeded 300 mm (12 inch) long, indicating most likely it may have been small pockets of trapped product behind the batten plate or may have travel down the exterior of the tank.
5. The original grout tubes were evident throughout the tank. The tubes consisted of a 76.2 mm (3 inch) pipe protruding 50 mm (2 inch) into the tank, with a flat welded cover plate.
6. Original scaffold beam clips are still present above the expansion joint.
7. The tell tale system installed in 1960-63 was still in place, and consisted of 6 vertical risers, 38 mm (1.5 inch) diameter, around the tank, and taps into each course. A single "ring" telltale was present in the lower dome.
8. Two "static ground" pipes were found, extending from the lower dome, to the upper dome.

9. Tunnel access doors were measured. The blast door has a clear opening of 889 mm X 2133 mm (2'-11" x 7'). The isolation doors have a clear opening of 1168 mm X 1981 mm (3'-10" x 6"-6").

10. The DN 800 (32 inch) fill pipe extends 3 to 3.7 M (10 to 12 ft.) above the floor and has a gooseneck installed in 1990 for ventilation.

11. All twelve tell tale pipes exit the tank through a DN 400 (16 inch) line. The annular space around the tell tale lines is flush with the floor of the tank and serves as a bottom withdrawal line. A follow-up check in the lower tunnel confirmed this line was connected to the facilities bottom sludge and water system.

12. A DN 200 (8 inch) pipe extends into the tank and is capped off. A DN 50 (2 inch) valved water line was connected to the DN 200 line.

13. A DN 200 capped pipe extended above the floor. A DN 100 capped nipple was on the DN 200 pipe.

14. A DN 150 (6 inch) capped pipe extends above the floor. A DN 50 (2 inch) plugged nipple was on the DN 150 pipe.

15. Laboratory results of coating samples from the tank barrel and lower dome are summarized as follows:

Sample Location	Laboratory Reference No.	Chromium Content mg/kg	Lead Content mg/kg
Barrel Wall (near manhole)	982157001	20900	49.7
Barrel Wall (near upper dome spring line)	982157002	4920	140
Lower Dome	982157003	7150	102

Analytical testing for chromium was performed using EPA method SW846-7191. Analytical testing for lead was performed using EPA methoc SW846-7421.

5.0 HISTORICAL INFORMATION GATHERED

The following general information was obtained by reviewing as built record drawings, as well as oral history from individuals knowledgeable in the long term history of Red Hill. No attempt has been made to document the many small projects and repairs completed, or work not related to repair of Tank 19.

ORIGINAL CONSTRUCTION AND OPERATION

The Red Hill fuel storage complex was constructed between 1941 and 1943, as a part of the War mobilization effort.

The facility originally stored diesel and NSFO (heavy oil). It is not believed Tank 19 was ever in NSFO service. The Tank 17-20 section was converted to store aviation gasoline in the early 60's. All active tanks currently store JP-5 or DFM (F76).

TANK 19 FINDINGS

Tank 19 received its first major overhaul between 1960 and 1963 (based on as builts dated 11/63). The work completed included:

- Repairing the upper dome batten plates, by welding all sides
- Removing the original tell tale piping system, and installing a new tell tale system with fewer, but larger diameter pipe (1-1/2" schedule 80).
- Sandblasting and application of an NRL coating system on entire steel liner (no metalizing was applied to the flat section of the lower dome)

Around 1986, the tank was taken out of service for gauging repairs. The tank was not placed back in service as "weeping" was observed from some of the batten plate plates in the upper dome.

In 1990, a repair project was started to begin Phase 1 repairs to the tank. This project was to have included installation of hoisting equipment and a tower elevator. The project also included ventilation system improvements. The project was canceled before it was finished due to contractor problems.

The EEI field effort on May 4, 1998, confirmed that most of the 1960 work completed remains today.

OTHER TANK PROJECTS

1949 Tank 16 Problems

Tank 16 was taken out of service due to possible leaking. An extensive evaluation was conducted by Bechtel Corp. to determine the location of the leak. Interesting findings of Bechtel's evaluation are:

- Water was encountered in the tell tale system at the 178 foot level. Bechtel Corp. concluded from qualitative chemical analysis that the water was from a source external to the tank and that water can accumulate between the concrete and steel lining.

- There is a possibility that not all voids were filled with grout, thus enabling a leak to occur and not be indicated in the tell tales. Bechtel suspected that the most probable location of a leak that is not indicated in the tell tales would be through the strain gauge installation, because both the concrete and the gunite is penetrated by a 25 mm (1/2 inch) pipe that extends through the 32 mm (1 1/4 inch) strain gauge sleeve to the gunite layer.

1960 Repairs to Tank 17, 18, 19, 20

See discussion on Tank 19 above

Late 60's Repair of Tank 5, 6, and 12

Work reportedly included modification to the tell tale systems as follows:

- Existing tell tale system was removed

- New tell tale piping was installed (larger, schedule 80 pipes)

- A new tell tale conduit pipe was drilled into the Lower Tunnel. The exit point in the tank was above the water line in the lower dome, thus solving previous corrosion problems in the tell tale piping.

- The tell tale piping included pipes extending into the Gauging Gallery, thus the lines could be "blown out" if blocked.

The tell tale systems were removed as a part of the 1978-1984 tank repairs.

1978-1984 Repairs Tank 1 to Tank 16

A comprehensive life extension project was completed to these tanks over a six year period. The work generally consisted of:

- Removal of all tell tale systems.
- Repair of all upper dome batten plates. Some tanks received full welding of the plates. Some tanks were fixed by welding "U" shaped enclosures over the batten plates.
- All butt welds, and batten plate welds in the lower dome, barrel, and upper dome were sandblasted, visually inspected and vacuum box tested. Considerable lengths of welds were repaired by rewelding.
- The grout tubes were cut off and a patch plate was welded over the penetration.
- Booms and lift systems were installed.
- The tower was repaired and braced
- The tank interior received a 100% NRL coating system. The flat center floor in the lower dome was metalized prior to coating.

LESSONS LEARNED

The following summarizes "lessons learned" over the years from the many types of failures repaired, and difficulty in making repairs.

Tank Coatings

1. The NRL coating systems used have generally provided good service on the barrel and upper dome. The 36 year old coating in Tank 19 is still well adhered and not showing any signs of failure, except on the flat floor of the lower dome.
2. The NRL coating systems used in the lower dome have had many problems. The use of metalizing was a failure, causing premature coating loss, blisters and peeling.
3. Water in the lower dome has aggressively attacked the coatings.
4. Patching the NRL coating system has not been entirely successful. New coatings do not adhere to old coatings. Currently, patching is being accomplished by a "butt joint" scheme, with no overlap of new and old coatings.
5. The tank walls, and particularly the towers and platforms must be carefully water washed to remove all dust prior to coatings. If not done, considerable dust and grit ends up in the coating systems.

Tank Tell Tale System

1. The original tell tale system of DN 19 (3/4 inch) pipes did not work well as they were standard wall and too small, resulting in becoming plugged.
2. The tell tale system installed in tanks 17-20 was an improvement, as they used DN 38 (1-1/2 inch) heavy wall (sched 80) pipes. However, the tell tales reduced to DN 19 and were routed through the former DN 450 (18 inch) fill/issue line which was converted to a bottom slop line. The tell tale pipes were subject to aggressive corrosion. Another problem is the lower dome tell tale system had a single ring collector, well above the bottom of the tank. Considerable water build up was allowed.
3. The third generation tell tale system was very successful, as it used DN 38 (1-1/2 inch) heavy wall pipes that were routed to the Lower Tunnel through a new DN 450 conduit, installed above the normal water line. These tell tales also extended up into the Gauging Gallery and could be blown out with compressed air.
4. All systems have an inherent defect, in that they are attached to the shell well above the embedded horizontal angles, thus allowing water build up behind the plates.
5. None of the systems were very accurate in identifying the location of the leak. Frequently the leak would migrate partially around the tank and not exit at the nearest tell tale.

Tank Upper Dome Construction

1. The upper dome was constructed with a backer bar on the interior side of the tank. Welding of the dome plates was conducted on the exterior side of the tank, before the concrete was poured. This backer bar, or batten plate, has been a problem since original construction.

2. Early attempts at repairing the batten plates by welding on all four sides was only marginally successful. The biggest problem was trapped product catching fire during welding.

3. A second method of batten plate repair consisted of welding formed "U" shaped channels over the batten plate. The original repair was not difficult. However, some of these "U" channels welds have begun to fail, resulting in the collection of fuel in the channels. It also seems that many channels are connected both horizontally and vertically, creating a very large interstitial space. Recent attempts at pressurizing the space with water and air were unsuccessful.

Tank Barrel Construction

1. The method of anchoring the shell plates to the concrete consisted of embedded horizontal rolled angles at every shell course with the embedded leg horizontal. This creates a water pocket behind the steel line plate, and significantly complicates the installation of any effective tell tale system.

2. A leak in one tank liner plate was attributed to a piece of wood left in the concrete, against the steel. No other similar incidents are known.

Contractor Requirements Working on Tanks

1. Some past projects have indicated to the contractors the size of utilities (compressed air lines, electricity) that must be installed for temporary use. Significant problems resulted when the contractor's methods required more utilities than specified. Currently, all utility sizing is the responsibility of the contractor.

2. All weight handling equipment is considered "available GFE equipment" for the contractor's use, without any assurances placed on its suitability for use. It is up to the contractor to repair, replace, and re-certify in order to utilize the equipment.

Tank Leaks and Backside Corrosion

1. Currently, the only method used to identify through corrosion is close visual inspection of the tank surface for "coating blisters". When a hole exists, usually water bleeds through, causing the blister.

2. Evaluation of the tank for unknown backside corrosion has not been attempted.

3. Due to the limited number of coupon cut form the existing steel liner when repairing leaks, no conclusions can be made as to the mechanism causing the pin hole through plate corrosion.

6.0 COST ESTIMATE

SUMMARY OF CONCEPTS

The table at end of this section summarizes the cost of the three concept projects to repair Tank 19 developed during the FACD:

- Composite Tank
- Internal Bladder Type Liner
- Repair Existing Tank

The summary provides a breakdown of costs into major elements and funding types, and a comparative cost per barrel of capacity. Included are additive bid items that may be considered for each concept.

All concepts are based on not fixing the upper dome. However, an order of magnitude cost to repair the upper dome for fuel storage has been included.

COST COMPARISON: COMPOSITE TANK VS INTERNAL BLADDER

The Composite Tank concept consisting of a new steel liner should have a service life in excess of 25 years, if properly maintained over the years. The Bladder liner should last in excess of 10 years, but we recommend changing the bladder in 10 years. Estimated costs to inspect, maintain, and repair the Composite Tank after 20 years compared to changing the Bladder liner every 10 years are as follows:

	Estimated Cost per Occurrence	**Cumulative Estimated Maintenance/Repair Cost at 20 years**
Composite Tank		
Set-up/mobilization	$382,000	$382,000
Ventilation	$258,000	$258,000
Inspect interior steel Liner	$40,000	$40,000
Barrel Repairs	$200,000	$200,000
Lower Dome Repairs	$100,000	$100,000
Estimated Total Cost (Composite Tank)		**$980,000**

Internal Bladder Type Liner

Set-up/mobilization	$331,000	$662,000
Ventilation	$233,000	$466,000
Change Bladder	$512,000	$1,024,000
	Estimated Total Cost (Bladder System)	**$2,152,000**

RED HILL TANK 19 FACD - SUMMARY OF COSTS

	TANK IN TANK CONCEPTS		REPAIR EXISTING TANK
Cost Element	**Composite** (1/4" steel shell, grout fill, telltale system)	**Bladder System** (As primary containment vessel)	**Internal Lining** (Complete rehab after thorough inspection)
Base estimated cost	$5,298,000	$2,339,000	$4,610,000
Cost/Barrel Shell Capacity	$19.99	$8.83	$17.40
Additive Bid Items (or options)			
Extend tell tale to upper dome for cleaning	$111,000	$111,000	$111,000
Coating of the Barrel	$559,000	Included in Base Bid (membrane)	Included in Base Bid (lining system)
Under Tank Leak Detection (Directional drilling)	$85,000	$85,000	$85,000
Cathodic Protection System - Tank 19 only	$551,000	$551,000	$551,000
Total, Base + Additives	$6,604,000	$3,086,000	$5,357,000
Fix upper Dome for Fuel Storage	$1,351,000	Not possible with bladder system	$816,000

RED HILL TANK 19 FACD - COST ELEMENTS

	TANK IN TANK CONCEPTS		REPAIR EXISTING TANK
Cost Element	**Composite** (1/4" steel shell, grout fill, telltale system)	**Bladder System** (As primary containment vessel)	**Internal Lining** (Complete rehab after thorough inspection)
Total Cost	$5,298,000	$2,339,000	$4,610,000
Distributed overhead GC items	$529,416	$208,620	$423,740
Construction Duration in Field (Months)	12	5	10
Cost Elements including distributed costs			
Prepare site for work (power, ventilation, lift equipment)	$1,022,994	$629,458	$979,995
Existing Tank Investigation	$40,081	$16,203	$471,565
Common tank repairs (piping, shell repairs, etc.)	$527,526	$536,018	$545,795
Barrel work (except coating)	$2,129,648	$402,871	$859,323
Lower Dome work (except coating)	$718,821	$115,653	$386,338
Repair and Recoat Tank Barrel	Not in base bid	N/A (membrane)	$605,633
Repair and Recoat Tank Floor	$219,192	N/A (membrane)	$193,562
Tell Tale System	$299,561	$305,951	$232,628
Line existing fuel piping if required	$226,105	$225,340	$226,153
Upper Dome Repairs (minimal, preservation)	$113,648	$107,163	$109,282

RED HILL TANK 19 FACD - Summary of Cost by Funding Category

	TANK IN TANK CONCEPTS		REPAIR EXISTING TANK
	Composite Tank (1/4" steel shell, grout fill, telltale system)	**Bladder System** (As primary containment vessel)	**Internal Lining** (Complete rehab after thorough inspection)
Total Base Estimated Cost	**$5,298,000**	**$2,339,000**	**$4,610,000**
Maintenance	**$1,825,000**	**$1,191,000**	**$4,055,000**
Set-up, Prep, Demolition	$959,519	$563,432	$925,040
Basic Tank Repairs & Appurtenances (Remove grout tubes & misc. clips)	$265,935	$278,179	$278,080
Repair Existing Tank Lower Dome			$386,338
Repair Existing Tank Barrel			$859,323
Upper Dome Repairs	$113,648	$107,163	$109,282
Inspect Existing Tank	$40,081	$16,203	$471,565
Lower Dome Coating	$219,192		$193,562
Barrel Coating			$605,633
Tank Piping - Lining	$226,105	$225,340	$226,153
Repair	**$3,434,000**	**$1,108,000**	**$515,000**
Set-up, Prep, Demolition	$63,475	$66,026	$54,954
Basic Tank Repairs & Appurtenances (Tank piping, Tower Mods, Tank ATG)	$222,556	$217,491	$227,274
Barrel Repairs	$2,129,648	$402,871	
Lower Dome Repairs	$718,821	$115,653	
Tell tale System	$299,561	$305,951	$232,628
Minor Construction	**$39,000**	**$40,000**	**$40,000**
Basic Tank Repairs & Appurtenances (Hi level control and alarms)	$39,035	$40,348	$40,441

RED HILL TANK 19 FACD - Summary of Cost by Funding Category

	TANK IN TANK CONCEPTS		REPAIR EXISTING TANK
	Composite Tank (1/4" steel shell, grout fill, telltale system)	**Bladder System** (As primary containment vessel)	**Internal Lining** (Complete rehab after thorough inspection)
Total Base Estimated Cost	**$5,298,000**	**$2,339,000**	**$4,610,000**
Additive Bid Items (or options)			
Maintenance	**$1,110,000**	**$551,000**	**$551,000**
Tank Cathodic Protection (Tank 19 only)	$550,955	$550,955	$550,955
Coat Barrel	$558,512		
Repair	**$111,000**	**$111,000**	**$111,000**
Extend tell tale piping to upper dome for cleaning	$111,089	$111,089	$111,089
Minor Construction	**$85,000**	**$85,000**	**$85,000**
Under Tank Leak Detection	$85,312	$85,312	$85,312
Total Cost: Base + Additives	**$6,604,000**	**$3,086,000**	**$5,357,000**
Total Cost (Base + Additives) By Funding Category			
Maintenance	**$2,934,000**	**$1,742,000**	**$4,606,000**
Repair	**$3,545,000**	**$1,219,000**	**$626,000**
Minor Construction	**$124,000**	**$125,000**	**$126,000**

7.0 FACD TEAM

PACDIV

Ron Tanaka - PDE/NTR

FISC Pearl Harbor

Jim Gammon - Operations

Glen Engle - Planning

Mike Gladson - Planning

Enterprise Engineering, Inc.

Stephen S. Brooks, P.E. - Overall FACD Facilitator and Technical Contributor

> Steve is a Mechanical Engineer experienced in all aspects of specialized tank repairs and construction and is an API 653 certified tank inspector.

Stephen J. DiGregorio, P.E. - Project Manager, Lead Engineer

> Steve is a Structural Engineer with extensive experience in detailed repair and construction in a wide variety of tanks and pressure vessels.

Kathleen L. Gardner, P.E. - Design Manager and Cost Estimator

> Kathy is experienced in the use of the "Success Estimating & Cost Management System" computer program.

Larry Goodwin - Red Hill Construction and Hoisting Equipment Specialist

Thermal Engineering Corporation

Peter K. Schubert - On-Island Design Team host and Technical Contributor

Peter has in depth knowledge of the Red Hill tanks, including logistics, tank ventilation and adit system design.

David Niino - Mechanical Engineer

David contributes to the project his knowledge of the Red Hill facility and tank ventilation.

PSG Corrosion Engineering, Inc.

Brendan Sheehan - Cathodic Protection and Corrosion Evaluation Specialist

Brendan's cathodic protection experience in Hawaii extends through military installations, including Red Hill piping.

Harold H. Miura, Inc.

Melvin Yokota - Electrical Engineer

Melvin contributes to the project his knowledge of the Red Hill Facility and electrical issues at Red Hill.

HMS, Inc.

Ehsan Mugal - Cost Estimating Engineer