

**ENGINEERING SURVEY OF
U.S. NAVY PETROLEUM FACILITIES
AT PEARL HARBOR**



BECHTEL CORPORATION



ENGINEERS - CONSTRUCTORS

TWO TWENTY BUSH STREET • • • SAN FRANCISCO 4, CALIFORNIA

12, May 1949

From: Bechtel Corporation, Contract NCy 16535
To: Officer in Charge, Contract NCy 16535
Subj: Engineering Survey of U. S. Navy Petroleum Facilities
at Pearl Harbor, Report on
Ref: (a) SCinC ltr NT4-9/JJ7 430 CF 13896 to CinC,
NCy 16535 dated 15 Nov 1948
(b) CinC ltr NOy 16535 (80:D) dated 9 March 1949 to
Bechtel Corp
(c) CinC ltr NCy 16535 (80:D) dated 7 Feb 1949 to
Bechtel Corp

1. The Bechtel Corporation, in accordance with Contract NCy 16535 with the Bureau of Yards and Docks, herewith presents engineering report on the results of survey of Navy petroleum facilities at Pearl Harbor.

2. On June 28, 1948, the Bureau of Yards and Docks directed us to proceed with the survey in accordance with our proposal dated June 9, 1948. Time schedule and estimate of man power requirements for the survey were submitted to the Officer in Charge. The field survey started August 16, 1948. Seven Bechtel engineers were engaged. Consulting in electrolysis investigation were Dr. Gordon N. Scott of Los Angeles, and W. R. Schneider of San Francisco, the latter being made available through the kindness of the Pacific Gas and Electric Company.

3. Substantially all the petroleum facilities in and around the Pearl Harbor Navy Base were covered by the inspection. The object of the survey was to determine condition and to make recommendations for improvement to be accomplished by better operation and maintenance; by rehabilitation including the installation of protective measures to guard against corrosion; or by new construction to improve integration or capacity. ✓

4. Survey of the facilities was guided by the provisions of the Contract which outlined the scope and nature of engineering work to be performed. Also, the referenced correspondence was basic to the engineering work. References (a) and (b) stipulated storage and distribution requirements. Reference (c) requested that the report include information as to storage and distribution capacities available after accomplishment of rehabilitation work.

5. Preliminary report of results of field survey with recommendations for rehabilitation was submitted to the Officer in Charge on January 20, 1949.

6. We consider that the report presented herewith, with the minor exception noted below, completes our engineering services under the Contract. Condition of the facilities is described and recommendations made for improvement of the system and its operation. Costs of work recommended or proposed have been estimated based on preliminary design. The capacity of the system, after rehabilitation, has been evaluated. Information presented is sufficient to serve as a basis for decision as to work to be accomplished, for budgeting, and for detail planning.

7. During the course of the investigation existence of harmful stray current effects in the Submarine Base area has been determined. Investigation of possible similar effects in the Shipyard has been inconclusive. Results will be reported by separate correspondence. This will not alter recommendations submitted herewith, although minor additional protective measures for petroleum pipe lines in the immediate vicinity of the source of the stray currents may be forthcoming. ✓

8. We should appreciate advice from the Officer in Charge as to whether this report, as supplemented by the discussion of stray currents to follow, adequately fulfills his requirements under the Contract. ✓

BECHTEL CORPORATION

I. L. Lind

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Project Manager

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**FOR
U. S. NAVY DEPARTMENT
BUREAU OF YARDS AND DOCKS**

NOy 16535

May 1949

**BECHTEL CORPORATION
Engineers - Contractors**

PREFACE

The Bechtel Corporation, in accordance with Contract NOy 16535 with the Bureau of Yards and Docks, herewith presents Engineering Report of the results of Survey of Navy Petroleum Facilities at Pearl Harbor.

Section I is a report of the conditions disclosed in the survey of all the petroleum facilities and includes recommendations for rehabilitation work.

Section II presents recommendations pertaining to the Red Hill underground storage covering operation, maintenance, integration with other facilities, and measures necessary to convert two vaults for storage of gasoline and jet fuel.

Section III presents recommendations pertaining to all other Pearl Harbor petroleum facilities. Recommendations cover operation, maintenance, protective measures for piping subject to aggressive electrolytic corrosion, and integration of the entire system from docks to storage. Capacity of the rehabilitated system is evaluated and compared to stipulated requirements. New facilities beyond rehabilitation necessary to meet such requirements are described.

Section IV presents estimates of labor requirements and costs involved in the rehabilitation measures recommended and the new construction work proposed.

Section V presents order of priority of measures recommended as necessary for rehabilitation and elimination of hazardous operation.

Section VI, an appendix, presents correspondence basic to the engineering work, inspection reports, data sheets, drawings, sketches, and photographs for reference.

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1. Scope and Purpose of Field Report

The Bechtel Corporation has surveyed the petroleum facilities of the U. S. Navy at Pearl Harbor, T. H. and submits herewith report of field results. This supersedes interim field report, dated January 21, 1949.

The purpose of this field report is to:

(a) Report conditions disclosed by physical and electrolytic inspection of the Navy petroleum facilities at Pearl Harbor.

(b) Submit recommendations for immediate repair and rehabilitation.

Work recommended herein as immediate constitutes measures we would initiate to rehabilitate a comparable industrial marine installation and to eliminate hazardous operation. Information is presented to permit, if desired, work to start at any time and without interference with other contemplated improvements.

2. Scope of Navy Petroleum Facilities at Pearl Harbor

The storage system at present includes approximately 6,200,000 barrels of underground storage and 3,600,000 barrels of other storage chiefly in surface tanks presently allocated as follows:

	Fuel Oil Bbl.	Diesel Oil Bbl.	Kerosene Bbl.	Gasoline Bbl.	Lubri- cating Oil Bbl.	Ballast & Slop Bbl.	Total Bbl.
Red Hill Under- ground	5,410,500	571,130					5,981,630
Concrete Under- ground	195,000						195,000
Surface Steel Storage	2,630,000	350,000	100,000		20,000	200,000	3,300,000
Diesel Purifi- cation Plant Concrete U.G.		11,500			1,100	550	13,150
Building 88, Steel					33,600		33,600
Pearl City, Surface, Steel				277,620			277,620
Ewa Junc- tion U.G. Concrete				27,000			27,000
TOTAL	8,235,500	932,630	100,000	304,620	54,700	200,550	9,828,000

There are eight primary pumping stations, as follows: *with total installed pump capacity of 106,770 bbls*

<u>Station</u>	<u>Product</u>	Approximate Installed Pump Capacity <u>bbl/hour</u>
No. 59 Red Hill	Fuel Oil and Diesel Oil	70,000
No. 91	Fuel Oil	11,400
No. 31	Fuel Oil	4,290
No. 77	Fuel Oil	2,860
No. 76	Fuel Oil	5,660
No. 60	Diesel Oil and Lubricating Oil	2,680
No. 88	Lubricating Oil	1,070
Pearl City	Gasoline	8,810

Actual simultaneous capacity to receive and deliver products is a matter of discharge pressures and line sizes as will be fully analyzed in a subsequent section. One fourth of the Red Hill installed capacity represents spares.

The distribution system includes approximately (1) nine miles of exposed fuel oil and diesel pipes in the tunnels of Red Hill system; (2) thirty-two miles of buried and exposed fuel, diesel and lubricating oil lines in the Navy Yard; (3) fourteen miles of mostly buried gasoline lines outside the Navy Yard integrating Barber's Point and the Victor Docks with the Army gasoline distribution system.

Fuel oil and diesel oil are ordinarily received at the fueling piers of the Supply Base and pumped to the Red Hill storage. Distribution is from Red Hill storage tanks to supply or submarine berths, to the surface storage tanks, or to drum and truck filling units.

The fueling facilities in the shipyard are not used and are generally blanked off.

Kerosene is received at the Mike Docks, stored in two nearby surface tanks and distributed by truck,

Lubricating oil is received in partial cargo lots at Mike or Sail docks, stored in surface or underground storage tanks and distributed by pipe lines to docks and drum and truck filling units.

Gasoline is received at the Victor Docks and stored at Pearl City in two surface tanks and in underground Army storage at Kipapa and Waukakalau. A joint Army, Navy distribution system joins Hickam Field, Navy drumming facilities at Ewa, Victor Docks, Pearl City tanks, Marine Corps Air Station, Barber's Point Naval Air Station and the Army storages. There are no gasoline facilities in the Navy Yard except of service station type.

During the latter part of the war and in 1946 a number of oil spillages and oil leakages occurred in the Yard which resulted in the appearance of oil on the surface of the harbor. Some severe fires occurred on the water front. As a result, use of suspected facilities or facilities known to be leaking was generally discontinued without severely handicapping peacetime operations. The required use of the surface tanks for active purposes is greatly curtailed being limited to nine tanks, three in each of the surface tank farms.

3. Methods Used in Survey

Red Hill underground storage Tank 16 was emptied and the bottom cleaned with diesel oil. Tank was visually inspected, sides being inspected from rafts as the tank was filled with water. Tank was leak tested by air pressure between the concrete shell and the steel liner. Bottom plate was drilled in two places. Water leakage rate was determined by standing tests at various levels.

Concrete underground tanks were cleaned and visually inspected.

Surface tanks were emptied and cleaned. Roofs, bottoms and sides were trepanned or drilled to determine loss of metal. Appurtenances and riveting were visually inspected.

Buried lines were exposed in about one hundred locations; these excavations exposed from two to five lines, and their location is shown on Pipe Inspection Sketch 2 in the appendix. The pipe and coating were visually inspected where exposed. At fifty four of these locations as shown on Electrolytic Survey Sketch 1 in the appendix, observations were made with a McCollum earth current meter to determine the magnitude of currents flowing from the bared pipe to the soil, or from the soil to the pipe. In addition, potential measurements were made in several locations to determine the direction of current flow along the pipe lines.

On the long runs of buried gasoline piping the effectiveness of the insulation was determined by noting loss of imposed direct current from pipe to soil at measured stations.

Exposed pipe was inspected visually. Engineering recommendations based on visual inspection were confirmed by leak testing where this procedure was required. For

example, leak tests were made of fuel oil and diesel lines in the Submarine Base area due to unusually unfavorable environment and operating history and to prove or disprove electrolytic action. Certain shipyard fuel oil header sections of cast iron with bell and spigot caulked joints were leak tested as the suitability of this type of joint was questioned.

Records of previous hydrostatic tests were made available and were studied.

4. Conditions Disclosed in Summary

The survey has disclosed that the nature and condition of all of the storage and most of the distribution system is such that it can practically and economically be repaired and rehabilitated, to form an integrated and effective system.

Generally the tankage is in good condition except the roofs of the steel surface tanks. However, Red Hill Tank 16 is subject to leakage which is attributed to defective welds. A careful test of the welds in Tank 16 was made, and no major defects were found, however, several minute leaks were noted. A careful gauging of the tank filled with water indicated a water leak rate of about five barrels per day over most of the test period.

[The surface tanks in the Upper, Middle and Lower Tank Farm are in good condition.] Structure and foundations are good. Bottoms are good, but show occasional deep pits. Shells are good. Roofs require painting and patching. Some fire prevention equipment is obsolete or requires rehabilitation. Due to inadequate drainage, water stands against the base of the tanks.

The Red Hill underground pumping equipment and pipe are in excellent condition. ✓

[The surface system pumps are generally in good mechanical condition and while of older design are still serviceable.] Two of the units in Pump House 76 are of very low head reducing usefulness. The pumps in Pump House 77 are an obsolete design and not well adapted to oil pumping service. ✓

The distribution system, other than Red Hill, has a great deal of deferred maintenance aggravated by lack of original protection. Underground piping is in generally fair to good condition. The gasoline piping which is outside the yard is failing and requires cathodic protection. Buried piping in the yard is

either satisfactory or can be repaired in place with a few exceptions noted below where old age or unfavorable environment make abandonment, rerouting or replacement necessary.

Exposed piping is in generally good basic condition requiring only cleaning, painting and coating, or repair of coating.

Detail results of the electrolytic survey are mentioned elsewhere in the sections of this report concerned with the components of the distribution system. Certain general conclusions are stated here.

Conditions at Pearl Harbor as determined by electrolytic survey do not appear unusually unfavorable from the electrolytic corrosion standpoint except at a few locations such as the approaches to Kuahua Island and the vicinity of the Pearl City gasoline tanks where pipe is buried in moist dredged fill or moist saline sedimental deposits.

Best protection against electrolytic corrosion is to avoid the low spots if practicable, or by insulating the pipe against its environment with adequate coating of mastic or by a coating conforming with Navy specifications for the condition.

Cathodic protection is adapted to long runs of piping in (more or less) open country with a pipe coating which is at least partially effective. Cathodic protection is less well adapted to complicated piping and cable networks such as are found in many parts of the Navy Yard.

A history of rapid failures of piping in the Sub-Base area, and Supply Center indicated that in all probability these failures were electrolytic in nature. Leak tests were made and the leaking lines were exposed along Fierce Street. Examination of the leaks clearly indicated electrolytic corrosion due to stray currents. A survey was made and electrical measurements traced the source of these stray currents to the direct current

generator stations located in this area. A description of the survey methods, the results and recommendations are reported in Section III of this report.

The report of the electrolytic investigation of the buried oil piping within the Navy Yard appears in Section III of this report.

A report of the electrolytic survey of the gasoline lines between Victor Docks and Barber's Point Air Base, with recommendations for cathodic protection was submitted to the Officer in Charge by letter dated December 15, 1948. Subsequently these recommendations were combined with Gordon N. Scott's survey and recommendations covering the gasoline line between Hickam Field and underground storage, under the operating supervision of the Army. This revised report superseded the December 15th report and was submitted to the Officer in Charge, February 18, 1949, and appears in Section III.

5. Summary of Recommendations for Immediate Rehabilitation

Recommendations are stated in the following portion of this section of the report in detail. In summary, recommendations are as follows:

A. Red Hill Tanks

Tanks 14 and 16 - Wash down sides to remove grout. Clean and apply Amercoat to bottom plate only.

Improve operation of level and temperature indicating equipment.

B. Steel Surface Storage and Underground Concrete Tanks

Make minor repairs. Paint and patch roofs; spot weld bottom pits; improve surface drainage.

Repair underground concrete storage tanks.

C. Distribution System

Install cathodic protection on Pearl City - Barber's Point gasoline lines. Rehabilitate petroleum piping in the Navy Yard generally by leak test, and repair in place. Relocate certain lines traversing corrosive areas and under buildings. Paint exposed dock lines. Repair and extend existing cathodic protection in yard. Install drain line seal at Pearl City. Install separator boxes in tank drain line between tanks and harbor.]

Remove 2 1/2" x 3" lines around 490
as alternate in case of break on 20" line
2 1/2" line to Harbor dock

6. Discussion of Conditions Disclosed with
Recommendations for Rehabilitation

A. Red Hill Underground Storage

(1) Tests to date on Tank 16 have disclosed:

The workmanship is good and construction conforms to the design drawings.

Only superficial corrosion was noted, the most severe being on the bottom where salt water collects. Less severe corrosion is general on the walls of the barrel, and is related to the grout deposits or splashes left on the steel.

Leakage test results while erratic indicated minor leakage. The average leak rate observed in the barrel section varied from 9.9 to 2.37 barrels per day during standing tests between the 100 foot and the 198 foot level. In the top access section which due to its smaller area was more sensitive to measurement average leak rates of 37 barrels per day were observed for a period. As the level dropped this decreased to 5.3 barrels per day. A check was tried by refilling and an average of only 0.53 barrels per day was finally observed.

Six seepages of water back into the tank at the 129 foot level were observed, which were due to pinholes in the welding.

Certain complexities are pertinent in considering results and have made the work of inspection time consuming. They are:

Accurate measurements of loss is difficult, and numerous gauge readings at various levels each over an interval of several days must be taken to obtain reliable results. Indicated daily loss was of the order of one fifty thousandth of tank capacity. Even when such a rate of loss was established over a significant period the order of magnitude was still so

small that such factors as minor differences in temperature or movement of the liner plate probably were significant.

The defects or holes through which the loss of water occurred must be comparatively small. A total hole area of the order of one fiftieth of a square inch could have accounted for the average indicated leakage rate whereas the liner area is approximately two acres in extent.

It has been determined that the tell-tale system is not reliable for either testing the welds, or denoting leakage. The automatic level and temperature indicating instruments are not functioning properly.

(2) Immediate Recommendations

Remove loose grout deposits from side walls, with high pressure water streams on Tanks 14 and 16.

Coat bottom plate, with petroleum resistant compound such as Amercoat 23 on Tanks 14 and 16.

Repair points of seepage at the 129 foot level by rewelding when testing is complete on Tank 16.

Correct operation defects, automatic liquid level and temperature indicating equipment.

(3) Recommendations for future installations (of same basic design)

Two proposals are submitted which modify the design and would make possible testing of the welds. This design would also provide a positive drainage system which would, in case of a weld rupture, convey the oil to a central point of drainage and thus prevent leakage into the surrounding earth. These designs should prove of value as applied to any future construction of similar storage.

Proposal (A) shown on accompanying Red Hill Sketch 2 provides a partial metal separator between the concrete and the steel liner. This would be obtained by continuously welding Robertson Q section to the back of the steel sheet, and providing positive drainage of the voids thus formed to a central drain pit or sump. Any leakage could be collected and returned to the tank.

Proposal (B) provides a half round or similar section to be seal welded over all welds on the inner or oil side of the steel liner. This method is shown in detail on Red Hill Sketch 1 in Section II where it is recommended for adapting existing tanks for gasoline storage. It provides a void which could be pressured and the seal welds on the half round positively tested. The void thus formed would in service be at near atmospheric pressure. Any leakage that did occur would be conducted to a central drain sump, and thus could either be returned to the tank or otherwise disposed.

Copper or iron seals should be installed in the cold joints of the concrete shell and every effort should be made to make this shell as nearly as possible oil tight.

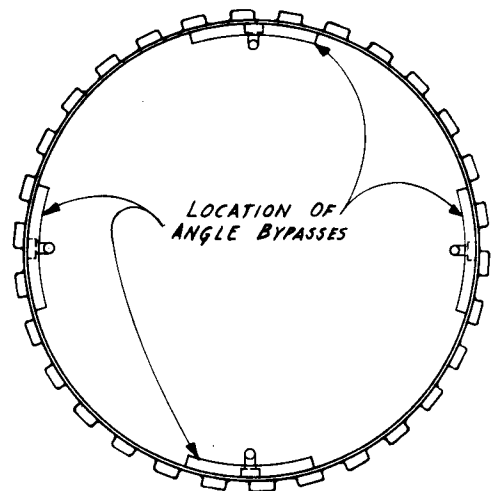
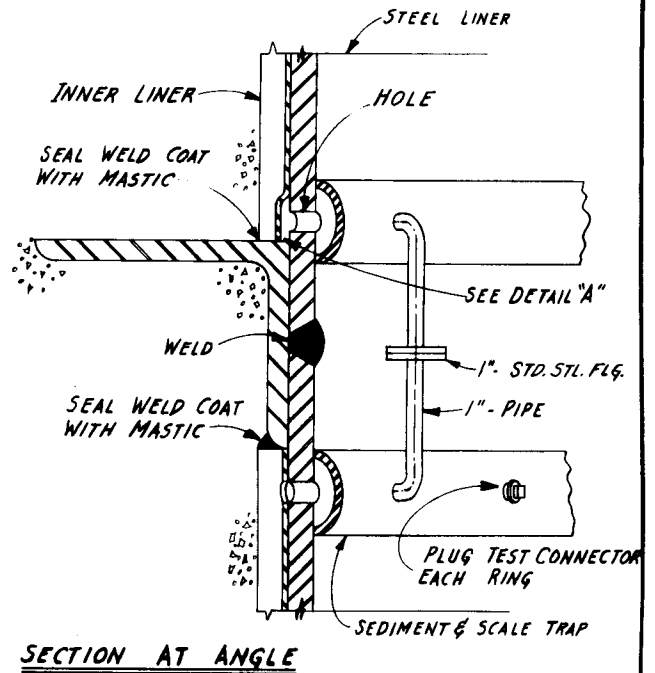
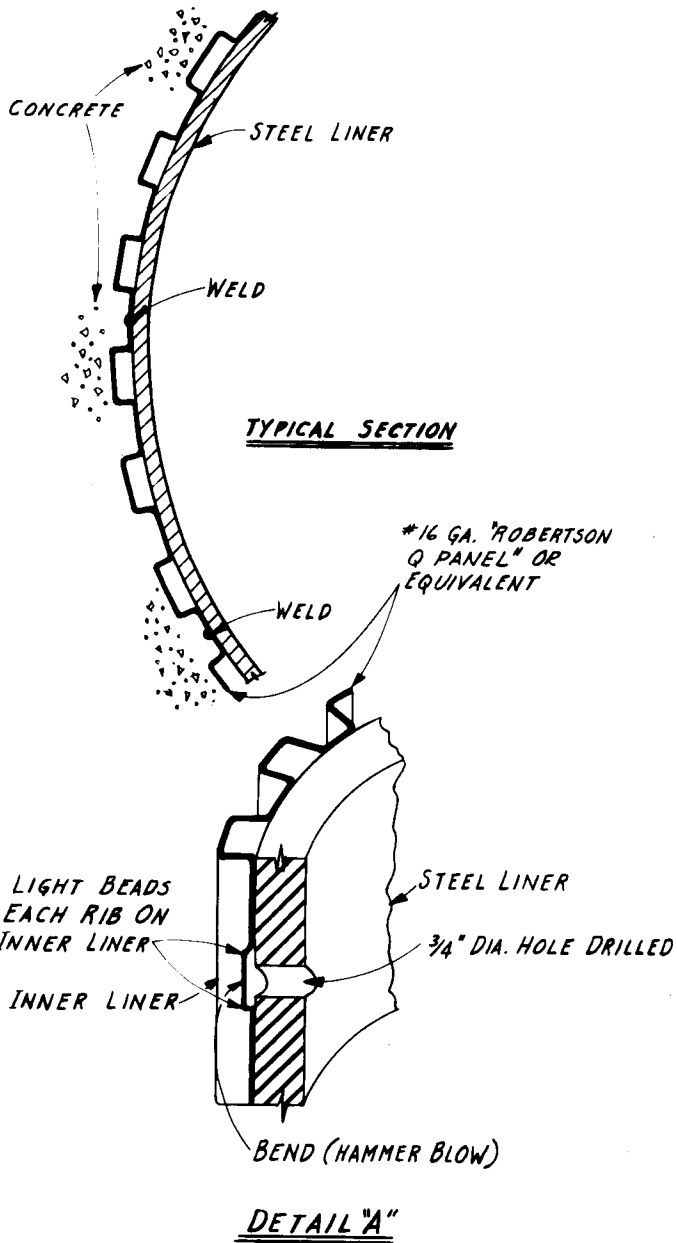
It would be preferable to install the bottom outlet piping in tunnels which would permit inspection and testing at this vital point.

The strain gages as shown on the drawings should be modified on future installations. A better connection should be made to the rock, and the means of transmitting movement to the gage should be improved.

The bottom plate should slope to a center drain.

(4) Continuing Tests Recommended

Tanks 3 and 17 in fuel oil service were completely isolated from the system by disconnecting all piping on December 1, 1948. During the period, December 1, 1948, to



NOTES:
 PRESSURE ANNULAR SPACE WHILE POURING CONCRETE.
 BOTTOM COLLECTOR FULL INNER CIRCUMFERENCE OF BARREL.
 VENT TOP OF ANNULAR SPACE TO ATMOSPHERE.
 ONE LEAKAGE OUTLET FROM BARREL LINER.
 ONE LEAKAGE OUTLET FROM BOTTOM INVERT.

SECT. I-RED HILL-SKETCH 2
 PROPOSED DESIGN FOR
 FUTURE UNDERGROUND TANK



February 9, 1949, careful daily gaging indicated a leakage rate of approximately 60 gallons per day in Tank 3 and 20 gallons per day in Tank 17, or a total loss of 4260 gallons for Tank 3 and 1420 from Tank 17. About March 1, 1949, apparent losses ceased, and as of April 21, no further losses have been recorded. Careful standing tests of this type should also be made on the other tanks and schedule for such testing is included in Section II of this report.

It is recommended that after immediate repairs recommended for Tank 16 have been completed this tank be filled with oil to approximately the 255 foot level and given a 360 day leakage test not to be interrupted unless the indicated leakage rate proves excessive or the tank is urgently required for other service. During this test the tank should be isolated from the system. The oil level should be established by hook gage and the oil temperature be determined daily. It is not exactly known how much this tank leaks or has leaked with oil or with water. Nor on a basis of experience is it considered that such leakage can be accurately established with anything less than a full 360 day test. As an example to indicate the need for a long term test, a temperature change of 1° F. using oil will result in an indicated gain or loss of about 120 barrels or one-third of a barrel a day for a year.

(5) Repair Methods

The loss recorded during the inspection and testing of Tank 16 is probably due to a multiplicity of small holes, which we were unable to locate by visual inspection or with the means of testing provided in the original design. Seven porous welds were located at the 129 foot level through minute water seepages back into the tank.

Based upon the above, consideration has been given to the following methods of repair if complete tightness is required:

Reweld all seams. This would require chipping out all weld metal and rewelding, and as no change in design is provided the new welds could not be positively tested.

Caulk the existing weld with a pneumatic caulking tool. This, if carefully done, would close the small porous areas, and reduce the quantity of leakage. Results by this method would be uncertain and proper testing would not be provided.

Sand blast all welded areas, prime and paint with material insoluble in salt water or petroleum. The material selected would have to have sufficient adhesion to steel to withstand the back pressure possible from underground waters when the tank is empty.

Pump a sealing compound between the steel liner and the concrete. The material used would have to be insoluble in petroleum, and viscous enough to seal off leakage through the concrete shell.

Weld half round or similar sections over all welds as shown on Red Hill Sketch 1, Section II. This method would provide means of testing and is the most positive of any of the methods considered. If it is determined that the tanks must be made completely tight this method appears the best of those considered and it has also been proposed by us as a modification for adapting the tanks to gasoline storage. Estimate of cost of repair by this method is included in Section V.

(6) Discussion

(a) Scope of Storage

Of the twenty 300,000 barrel (nominal capacity) underground storage tanks in the Red Hill system, eighteen are allocated to fuel oil storage and two to diesel storage, with a total actual storage capacity of 5,981,630 barrels. In addition to this there are four surge tanks with a total capacity of 40,200 barrels located adjacent to the underground pump house, three in fuel oil use, and one in diesel service.

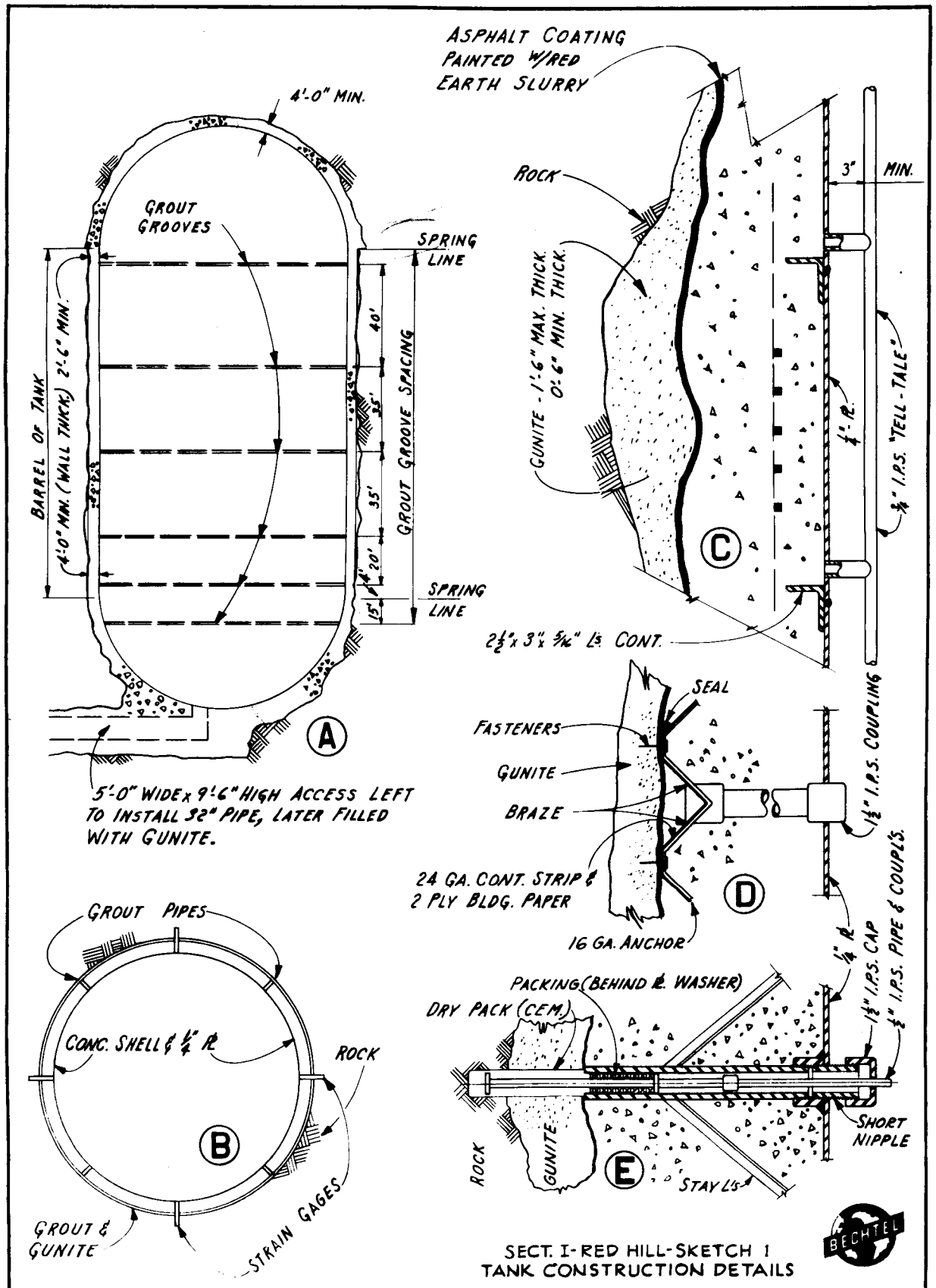
The twenty tanks are vertical, with hemispherical top and bottom heads. They are each 100 feet in diameter, four of them 239 feet in height and the others 251 feet in height.

(b) Construction Information

The tanks have reinforced concrete walls which are 2'-6" thick at the top and 4'-0" at the bottom spring lines. The upper dome concrete is 8'-0" thick at the spring line and 4'-0" at the top. The lower dome rests on a mass of concrete which is about 20 feet deep under the bottom. The concrete shell is lined with 1/4" steel plate (butt welded), which was used as a form to pour the concrete against. The design premise was, "The basic structure is the rock consolidated by grouting, not the concrete or the steel incorporated in it".

These tanks are located in a rocky ridge, its rocks being several types of basalt originating from the volcano Koolau. The lava flows are in sheets from 3 to 50 feet thick and contain numerous small lava tubes. Some large ones were encountered during the excavation for the tanks. All flows are broken with vertical joints which divide them into a large number of separate blocks. These joints are from 6 to 10 feet apart in the thicker flows. At the top, and often at the base of the flows is a layer of fragmental material known as clinkers and cinders. This material is sometimes cemented, and other times the cementing materials have been leached out, by water, thus leaving bodies of loose material. No flows of underground waters were encountered during the excavation for the tanks. There was, however, some seepage due to rainfall penetrating the rocky structure.

Construction information was taken from the Technical Report of the project made by the Navy.



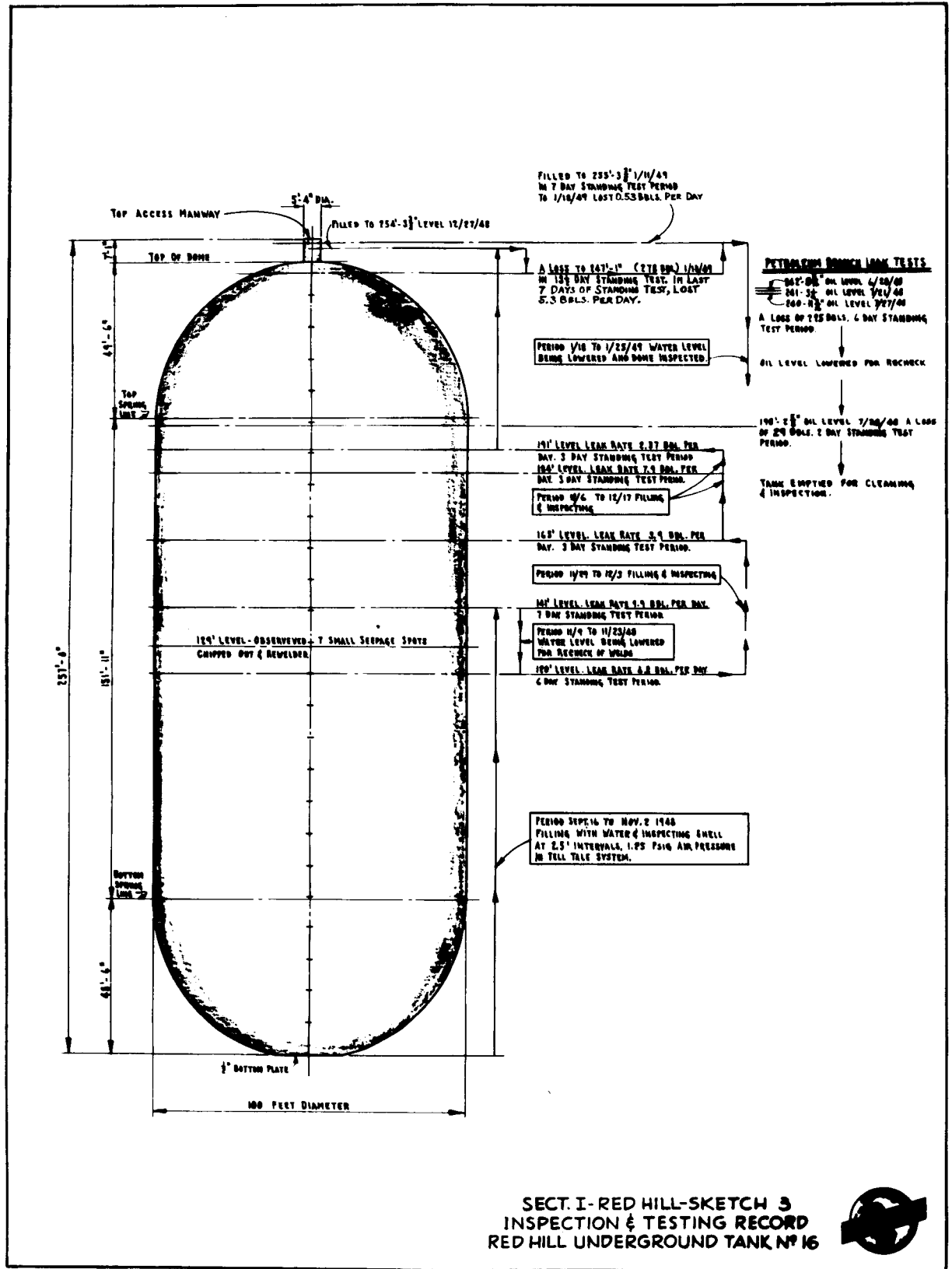
(c) Tests on Tank 16

After an earth disturbance on June 28, 1948, and previous to our inspection, gaging during the period June 28 to July 21, indicated a loss of 14 inches, or approximately 850 barrels. The suction and discharge valves were blanked off with the oil level standing at 241' - 3-1/4" and a six day test conducted over the period July 21 to July 27. Careful hand gaging during this test indicated a loss of 37.4 barrels per day. The level was then lowered to 198' - 2-5/8" and a two day test was conducted. This indicated a loss of 14.5 barrels per day at this level. The tank was then emptied. The total leakage indicated during the entire period was in the order of 1100 barrels. Results of this and subsequent tests are indicated in accompanying Red Hill Sketch 3.

To det. if leakage was in down as not in down a through tell-tale (see diag)

Our first inspection of the tank was made on August 30, 1948, and after a study of the design and construction a test procedure was formulated and agreed upon. This was discussed in letters to the Officer in Charge of Construction, dated September 10 and September 29, 1948, which are included in the appendix to this report.

A series of tests were made to determine the effectiveness of the tell-tale systems, both as to leak indication and testing of welds in the steel liner. The results indicated that the design will neither serve as a means of indicating leakage nor permit proper testing of the welds. After testing the bottom plate and the piping connections from the bottom, filling the tank with water was started, and the sides and welds were inspected at two foot intervals. A two pound air test was first applied to the tell-tale system for two periods of short duration in order to spring the steel liner away from the concrete if possible. During the remainder of the testing periods the pressure was maintained at 1.25 psig. This testing continued until the 140 foot level was reached, where a seven day standing test was made.



SECT. I - RED HILL - SKETCH 3
 INSPECTION & TESTING RECORD
 RED HILL UNDERGROUND TANK NO 16



The water was lowered to the 120 foot level, and the welds and walls were again examined both during lowering and raising of the water level. At the 129 foot level six points of water seepages through welds were noted. These were around patches which were used to cover the bolt holes where attachments for the waler forms were made. During the process of raising and lowering the water level, the welded seams which had been wire brushed became covered with a coating of hydrated ferric oxide.

The water level was raised to the 191 foot level. The inspection at two foot intervals was continued, and no points of leakage other than that noted at the 129 foot level were observed. The manway was closed, and the water level was raised to about the 256 foot level, which is in the entrance section of the top dome. This cylindrical section is approximately 5'-4" diameter. Standing tests during the period of December 27, 1948, to January 10, 1949, revealed the water level falling at the average rate of 37 barrels per day for 6-1/2 days. This leakage decreased to an average of 5.3 barrels per day during the last seven days of the period, with the water level standing at about the 247 foot level. The water level was raised to 255'-3" on January 11, and a seven day test indicated a leak rate averaging only 0.53 barrels per day. *original rate*

The exact amount of leakage is difficult to determine when testing with water due primarily to the fact that the leakage rate is very small compared to the tank capacity, and such factors as evaporation and temperature change and possible effects of rusting become significant and may cause day to day indicated fluctuations in leakage rate. There also may be some movement of the steel liner which would influence the liquid level in the tank. However, it is believed that an actual small leakage of the order of 5 barrels per day may exist.

The data collected are not consistent and contain many variables which are difficult to correlate. The fact that the reported rate of leakage in the barrel of the tank was independent of head may be accounted for by accepting the theory that

there is a multiplicity of extremely small holes or porosities in the welds, and that rate of permeation of the weld, concrete, and rock exists regardless of pressure, and that the varying or constant leak rates at different heads is due to a temporary plugging or opening of some of the holes by sediment in the water or fine rust from the tank steel or by delayed wetting action. This porosity theory would also account for the fact that no oil leaked back into the tank when empty, which would be due to absence of the head required to force oil back through the holes. When the tank is empty there may be practically no oil pressure behind the liner because, due to individual slow leak rates, the oil has then had time to permeate the surrounding structure, thus dividing itself into a number of minute streams which may or may not join after a time. The structure outside of the concrete is a vesicular basalt and probably would, under a slow distributed leakage, absorb a large quantity of oil which it would not release.

(d) Tests on Tank 14

At Tank 14 oil seepages appeared near and on the face of the lateral tunnel under the tank. These were minor and appeared in the cold joints. It was decided to empty this tank and thoroughly inspect the bottom. Some traces of oil were observed under the steel liner, but it was not possible to find a defective weld or to locate the source of any leak. The bottom plate was in good condition. There were some minor pits which it was believed were caused by the corrosive action of salt water which settles out of the oil. A standing water test with the level at the bottom spring gave no indication of leakage.

B. Surface Storage Tanks

The surface storage tanks are located in three areas known as the Lower, Middle and Upper Tank Farms. The following tabulation indicates the scope of this storage:

<u>Farm Area</u>	<u>Number Of Tanks</u>	<u>Capacity Barrels</u>	<u>Total Storage Barrels</u>
Lower	15	50,000	750,000
Middle	9 1	50,000) 80,000)	530,000
Middle	Underground Reservoir	195,000	195,000
Upper	13	150,000	1,950,000

Eighteen of these tanks were inspected, the sidewalls and roofs were generally drilled and samples were trepanned from the bottom plates. The tanks were found in good condition with no appreciable loss on the shell courses and an average loss on the bottom plates of, say, 0.025". The roofs are generally in poor condition and require patching.

The tanks were erected on oiled sand padded grades, and the foundations are in good condition. A conservatively estimated probable additional life of 20 to 30 years can be expected if the tanks are maintained as in the past, and are used for the handling of the same quality of products.

Reports of tank inspection were covered in letters to Officer in Charge dated September 29, 1948, December 3, 1948, and January 12, 1949. These letters and a data sheet for all surface tank inspections are included in Section VI.

The underground 195,000 barrel reinforced reservoir located in the Middle Tank Farm was constructed about 1920. Inspection revealed that the concrete was cracked in numerous places, and when empty the leakage rate back into the reservoir from the oil soaked ground was several barrels per day. This unit appears to be one of the major sources contributing to the oil underlying the Merry Point area of the Navy Yard.

It is recommended that this reservoir be repaired as follows:

Chip out all cracks, cut off protruding reinforcing bars, thoroughly clean, sand blast, apply expanded metal, and gunite interior surface of sides and floor. Report of inspection and sketch showing repair method are included in Section VI.

The required immediate repairs to rehabilitate the steel surface storage tanks is dependent upon the type of petroleum products to be handled. The following recommendations for immediate repairs are based on the storage of heavy oils with a flash point above 120 degrees F.

Spot weld deeper pits on bottom plates. There are few places requiring repair, and this is a minor item.

Repair roofs by patching with one eighth inch plate welded over bad areas.

Wire brush roofs and paint with two coats of primer and one finish coat.

Chip, brush, clean and paint bottom angle as above specified.

Restore any removed sections of retaining levees.

Install concrete boxes around the revised drain connections on Tanks 33 and 35.

The following are optional recommendations and are not necessary to slow up the present rate of deterioration:

Improve drainage around tanks. Starting level with tank bottom, slope area adjacent to tank down $1/2''$ per foot for a minimum of ten feet away from the tank. These slopes are approximate and can be rough graded. The first two feet of sloped area at the tank should be sand mixed with $1/4''$ rock and compacted with oil.

Remove fire alarm system, which is inoperative.

Remove water sprays and deflector plates.

Check volume in tank levees in Lower Tank Farm and Tanks 33 and 35 in Middle Tank Farm.

Install oil water separators in oil drain lines from tanks to pump houses as indicated in accompanying Sketch 4. One separator only is required for Upper, one for Middle, and one for Lower Tank Farm.

C. Pumping Stations

In this section, for handy reference, all pumping stations for whatever use are listed and discussed.

There are eight primary pumping stations located in the Shipyard area and Pearl City. The following tabulation shows the building number, type of pumps and the approximate capacity under individual and widely varying head conditions.

<u>Products Handled</u>	<u>Building Number and Location</u>	<u>Make and Type of Pump</u>	<u>No. of Pumps</u>	<u>Approximate Capacity bbl/hr</u>
Fuel Oil	76 Lower Tank	Alberger Turbine	2	2860
	Farm	Worthington Gear	1	2860
Fuel Oil	77 Near Main	Worthington	2	2860
	Gate	Centrifugal		
Fuel Oil	31 Middle Tank	Kinney Rotary	3	4290 ? <i>approx 2500 gal</i>
	Farm	Piston		
Fuel Oil	91 Upper Tank	Kinney Rotary	5	11400
	Farm	Piston		
Fuel Oil & Diesel	59 Red Hill	Byron Jackson	11	70000
	Underground	Centrifugal		
Gasoline	Pearl City	Dayton Dowd	1	285
		Centrifugal		
		Worthington	1	700
		Centrifugal		
		Byron Jackson	2	5545
		Centrifugal		
		Gould Centrifugal	2	2280
Lube Oil	88 Merry Point	Granberg Rotary	6	566
		Worthington Gear	2	500
Diesel & Lube Oil	60 Purification	Worthington Gear	2	430
	Plant	Worthington	2	1900
		Centrifugal		
		Warren	2	280
		Centrifugal		
		Gould Rotary	1	70

There are four pumpout or residue units and one transfer pump as follows:

<u>Building Number and Location</u>	<u>Make and Type of Pump</u>	<u>Number of Pumps</u>	<u>Approximate Capacity bbl/hr</u>
Bldg. 386, Halawa Gate	Kinney Heliquad	1	1000
Bldg. 649, Kuahua (1)	Worthington Gear	1	500
Bldg. 696, Kuahua (2)	Kinney Heliquad	2	700
Bldg. 25, Shipyard	Kinney Rotary Piston	1	60
Bldg. 162, Transfer located in pipeway below Tank 35	Worthington Centrifugal	1	1000

These pumping stations are generally in good condition.

The two Alberger turbine pumps in Building 76 are low head. Pump House 77 is poorly located and the two Centrifugal Pumps located in this building have an unsatisfactory operation history. Analysis of the service requirements, piping condition, and operating efficiency has resulted in recommendation to abandon this facility. Pump House 649, Kuahua residue pump, has settled to such an extent that the suction and discharge lines have been freed from the manifold to prevent breakage due to the strain.

*Accomp. photo
survey*

Recommendations for immediate work on the pumping stations are as follows:

Abandon Pump House 77.

Revise the piping in pumpout Pump House 649 to relieve the strain and reconnect to make this unit available.

Recommendations for the Pearl City pumping unit are included in the section devoted to gasoline.

D. Fuel Oil Piping System

(1) Red Hill Tunnel Piping

Red Hill tunnel piping consists of approximately three miles each of 32" and 18" pipe, and about one half mile of 8" drain pipe. This pipe is all exposed in the Red Hill tunnel system, being strung on steel supports in a manner easily accessible for inspection and maintenance. The 8" drain discharges to two drainage tanks installed on the surface and side of Red Hill.

The Red Hill tunnel piping is in an excellent condition. Water drips from the tunnel roof leave deposits on the lines. The deposits on the lines should be cleaned off regularly and the pipe paint restored where required.

(2) Piping from Red Hill Tunnel Outlet to How Docks

The following buried fuel oil lines extend from the Red Hill tunnel outlet to the How Docks via the Halawa Pumping Station.

One 32" welded steel fuel oil line, with double wrapped bituminous coating.

One 18" welded steel fuel oil line, with double wrapped bituminous coating.

Lying with the two above pipes and running between the Ballast Tanks and the How Docks are:

One 12" welded steel ballast line, with single wrapped bituminous coating.

One uncoated 6" drain line from the How Docks to the Halawa pumpout Pump House with 4" discharge to the ballast tanks.

These lines are of vital importance in the operation of the fuel oil system as they constitute the life line between the major point of storage of Red Hill and the principal points of oil receipt and delivery.

The 32" and 18" fuel oil piping is in good condition. It is adequately coated and is receiving protection from the cathodic protection system installed near the Halawa Pumping Station. The anode bed of this system was exposed and found about 50% expended. One cable connection is broken.

The 12" ballast line and the 4" and 6" drain lines are not adequately coated and are not directly protected by the cathodic protection system. However, these pipes were in good condition when inspected.

The 24" water main along the railroad tracks in this area is within the range of the cathodic protection unit and is picking up current, thereby potentially discharging to earth elsewhere and corroding at that point.

Recommendations for immediate work on this section of fuel oil piping are as follows:

The 32" and 18" pipe are in daily use at working pressures up to 200 pounds. No hydrostatic testing is presently required.

Include 12" ballast line in cathodic protection by bonding with 4/0 cable to the same cable as connects 32" and 18" lines to negative terminal of the cathodic protection rectifier. ✓

Improve cathodic protection of the 32", 18" and 12" lines by bonding across flanges or other fittings causing high electric resistance.

Avoid damage to the 24" water main by bonding to negative terminal of cathodic protection rectifier and adjusting bond resistance to reduce current flow along pipe line to zero.

Review made by

Repair broken cable connection to one anode bed pipe.

(3) Main Feeders to King Docks and Sail Docks 19, 20, 21

The feeders consist of 18" and 16" steel welded and double wrapped bituminous coated piping connecting the King Docks and Sail Docks 19, 20 and 21, with the Red Hill tunnel outlet and the head end of the How Docks, the former section being the more important.

These lines were examined and found to be in good condition. In the past, leaks have been reported. The section of 18" line under Building 490 has been blanked and a portion removed. Cause of failure was reported as electrolytic. This buried pipe is in an unfavorable environment from the standpoint of electrolytic corrosion, being buried deep in dredge fill which was used to form the land approach to Kuahua Island. The soil around the pipe is moist with brackish water. This section of piping is not receiving electrolytic protection from the cathodic protection unit at Halawa Pump House, although it should be within operating range.

Recommendations for immediate work on the main feeder to King Docks and Sail Docks 19, 20 and 21 are as follows:

Abandon the 18" pipe under Building 490 and replace it, rerouting to avoid the building. This new pipe should be laid as close to the surface as practicable and be given an adequate coating, using mastic or coating conforming with the Navy specification for the service condition.

Beginning at the How Docks, this section traverses an area in the Supply Center, finally returning to a point near the Red Hill Tunnel Outlet, where it joins the 32" line which is cathodically protected. High resistance joints such as flanges, gate valves or expansion joints in this line should be bonded with 4/0 cable jumpers and thus allow positive cathodic protection.

(4) Main Feeder from Red Hill Outlet to Sail Docks, Mike Docks and Lower Tank Farm

This welded steel line starts near the Red Hill Tunnel entrance and continues south near Pierce Street, reducing in size from 22" to 18" to 16" and finally to 12" near the head of Merry Loch. The 22", 18" and 16" section through the Submarine Base Area was installed in 1943 and is coated with grease, covered with cellophane and a light coat of bituminous material. From near the head of Merry Loch to a point about 200 feet north of Pump House 77, the line is welded steel pipe, bituminous coated. From that point on, it continues as a 12" screw connected, mostly bituminous painted line, along South Avenue to fuel oil Pump House 76. This line is now of importance as a direct connection between the Red Hill outlet and the Sail Docks and Mike Docks, and as a distributional fuel oil outlet for the Middle and Lower Tank Farms. The 12" section from a point near the head of Baker Docks is presently being used to fill the two 50,000 barrel tanks in the Lower Tank Farm which are used to supply fuel oil for power plants, Building 8, 149, 177, through the 14" line from Pump House 76 to the shipyard.

This section of line was first examined at a number of points in the vicinity of Sail and Mike Docks and was found to be in apparently good condition up to the termination of the welded steel section about 100 feet south of Bell Hole 52. The line had been cut and blanked off on Shane Street south of Beeman Center because of leakage in the past under Beeman Center which appeared through the pavement on Shane Street. Recent hydrostatic tests indicated leakage north under Beeman Center but no leakage south to the first valve pit. Subsequently, this latter section of the line was repressured to 300 psig. and was found to be tight although the parallel diesel line was corroded and leaking. One hundred and fifty feet of the line excavated and inspected along Pierce Street however revealed the pipe coating to be totally failed due to the solvent action of the oil from the leaking 12" diesel line.

Pictures in Section VI show typical soil conditions, coating condition, oil saturated ground and type of corrosion of these lines.

Electrolytic tests indicated a tendency to discharge under Beeman Center. This section of the line through the Submarine Base along the line of the former railroad tracks is generally covered with paving or building. The pipe passes through a variety of soils varying from dry volcanic tuff to wet dredged fill under Beeman Center. Conditions favorable to corrosion are thus present and inspection and maintenance is made difficult. The cause of the past failure under Beeman Center may be electrolytic or physical due to the settling of new fill, or possible a combination of the two.

Electrical measurements were made between the buried oil lines and the neutral D.C. distribution bus in Substation Building 626 in which is located direct current rectifiers. These observations indicate that stray currents exist in this vicinity and are affecting the diesel and lubricating oil lines. It is believed that these currents are caused by open circuit or high resistance connections in the bare neutral common to the A.C. and D.C. systems between Building 626 and the docks and by the bare neutral being in contact with cable sheath between the rectifiers and the neutral bus at the distribution cubicles.

There is thus a strong probability that the 18" fuel oil and 12" diesel oil lines on Pierce Street are affected by both stray current and galvanic action.

From near Bell Hole 52 to Pump House 76 the 12" line is mostly of screwed steel and is about 24 years old. The coating is an ineffective bituminous paint. This section of line is generally and severely corroded and deeply pitted along most of its length. Condition of the pipe is attributed primarily to age and inadequate coating.

Electrolytic tests indicated a general pickup of current along this section except in the vicinity of the Lower Tank Farm

where the earth cover is substantially increased by the tank berms. The soil varies from volcanic tuff to a mixture of tuff and coral fill and was found generally to be dry with a fairly high electrical resistance.

The recommendations for immediate work on this feeder from the Red Hill outlet to Sail Docks, Mike Docks and Lower Tank Farm are as follows:

Since the fuel oil line that arcs through the Submarine Base is now in oil soaked soil and a general bad environment, subject to stray currents and galvanic action, and partly located under buildings, we do not recommend attempting to repair and recoat in place. It is recommended that this portion of line be relocated from the pipe tunnel at the Diesel Purification Plant to a point where the line returns to North Street near the head of Quarry Loch. The portion of the line from the valve pit near Red Hill outlet to the Purification Plant tunnel is to remain in service. As much as practicable of the abandoned pipe is to be reclaimed, and reinstalled above ground with new line as required to run parallel to the railroad from a point near the ballast handling facilities to the previously mentioned point near the head of Quarry Loch.

Leak test line to 250 psig and repair in place except sections relocated or abandoned. The pressure of 250 psig applies to all subsequent references to leak test unless exception is made.

The 12" oil line through Pump House 77 to the Lower Tank Farm and Pump House 76 will not be required, and it is recommended that it be abandoned from the cross, where it now connects with the 12" line serving the Mike Docks, to Pump House 76. See letter from Officer in Charge of Construction, Contract NOy 16535 to Bechtel Corporation dated 9 March, 1949. The tanks set aside for power plant use can be filled through the main feeder which runs through the shipyard area. The abandonment of the Lower Tank Farm, except for fuel storage and supply to the power plants, will also

make possible the abandonment of Pump House 77. This will require connection of the 12" line serving Tanks 29, 30, and 31, in the Middle Tank Farm to the 12" line leading to Pump House 31 requiring about 200 feet of 12" pipe. The present lines from these tanks to Pump House 77 are in poor condition, buried at a depth of 13 feet, and would require extensive repairs.

(5) Feeder from Red Hill Outlet to Upper Tank Farm,
Merry Point and the Navy Shipyard

This line leaves Red Hill tunnel outlet as 18" welded steel, increasing at nearby valve chamber "E" to 24". It rises to a deep open trench generally parallel to the railroad tracks, then runs again underground for about 600 feet to enter Pump House 91. Leaving Pump House 91 it continues mostly above ground as 18" welded steel parallel to the railroad tracks to near the head of Merry Loch. From this point the line runs near parallel and well back of Shipyard Berth B-24.

Beyond Bell Hole 21, the line continues as 18" cast iron bell and spigot to near Bell Hole 95 from where it continues as a 16" cast iron line with a stuffing box and packing type connection. This 16" line is exposed in a tunnel as it parallels Avenue C along the head end of the repair basins. Leaving the tunnel the line changes to 14" cast iron bell and spigot and continues along Seventh Street to Central Avenue. At about this point the line changes to 14" welded steel continuing along Central Avenue to Sixth Street and thence to Pump House 76 at the Lower Tank Farm.

This line is a vital link connecting Red Hill with Pump House 91, the distributional outlet for the Upper Tank Farm and the most important pumping plant other than Red Hill. The line is the major feeder for the Merry Point docks and the only effective feeder for the shipyard docks. Power Houses 8, 149 and 177 are supplied by this line from supply tanks located in the Lower Tank Farm. This feeder, with the feeder described above forms a loop essential for integrated operation of the Red Hill system,

the surface tankage and the dock lines. If the 12" line between Pump Houses 77 and 76 is abandoned as recommended above this feeder will become the only supply for the Lower Tank Farm and the power houses.

This line has been blanked off and out of service from the head end of Merry Loch to near the intersection of Avenue B and Seventh Street.

The steel section of this line extending from the Red Hill tunnel outlet to near Bell Hole 21 is in good condition. A portion of this section where the line is exposed along the railroad track between Pump House 91 and the head of Merry Loch has developed failure at some welded joints. These defects have been repaired by welded patches.

The 18" cast iron bell and spigot section is in good condition, as is the 16" cast iron packed joint section. However the effectiveness of the bell and spigot caulked joint to remain tight in oil service was questioned. Hydrostatic test of 250 psig was applied and only slight leakage was measured.

The 14" bell and spigot section along Seventh Street was found in good condition and somewhat graphitized at Bell Hole 65.

The 14" steel section terminating in Pump House 76 was examined in one location and found in good condition. This line has been in continuous service to supply the power houses and as such has been given periodic testing and maintenance.

Recommendation for immediate work on the feeder line from Red Hill Outlet to Upper Tank Farm, Merry Point and the Navy Shipyard is as follows:

Hydrostatic test and repair in place steel and cast iron sections of this line.

(6) Dock Lines

There are about five miles of exposed dock lines of various sizes, as follows:

<u>Docks</u>	<u>Size</u>
How	22", 12", 8"
King	16", 8"
Sail	12"
Mike	18", 12"
Baker	14", 12", 10", 8", 6"

The dock lines are welded steel pipe. Generally the dock lines are coated with bituminous material with felt and kraft paper wrapping. Pipe risers for hose connections are spaced about 75 to 100 feet. The risers are not generally coated.

On How Docks 7 and 8, the lines are supported inboard of the working platform on extensions of the bent caps. The lines are partly coated and partly bare. Coating is bituminous with single felt wrapping. Lines are in good condition. On the fuel pier, How Docks 1 to 4, the lines are installed in concrete pipeways built along the side of the dock. Pipe is coated with bituminous material with single felt wrapping.

On the King Docks, the dock lines are generally in good condition with some points of failure of the coating. Risers are uniformly corroded. On the Sail Docks, the dock lines are in good condition with intermittent coating failures. Risers are uniformly and extensively corroded, with a considerable number of bolts which need replacement.

On the Mike Docks the fuel oil line and risers are bare and show incipient corrosion. On the Baker Docks, 6 to 25, the lines are generally in good condition, except for occasional coating failure. A section of line is missing at Baker 22 and 23. Risers are bare and show corrosion. On the Baker Docks 1 to

4, inclusive, the dock line is bare and periodically wetted. Dock lines and risers are extensively corroded.

Piping is generally supported directly by the pier structure or suspended on metal hangers, many of which are in badly corroded condition. Where support is directly from the structure use of intermediate pipe supports would be preferable to permit access for maintenance.

Access to lines for inspection and maintenance is difficult in some docks, notably Sail 1, 10 to 14, and the shipyard berths, especially Baker Docks 1 to 4.

Recommendations for immediate work on the dock lines are as follows:

Hydrostatically test and repair dock lines in place.

a. Clean, paint and coat risers.

b. Clean, paint and coat bare dock lines.

c. Repair any defective coating on dock lines. Coating should include protection of flanges and valves.

d. Coating as applied to exposed dock lines is covered by Bureau of Yards and Docks Specification No. 34Yb dated April 1943, in which coal tar base coatings applied cold above the tidal range and hot below it are recommended. In this specification, we concur.

e. Wrapped dock lines should be repaired on the same basis and not include rewinding.

f. Minor failures to wrapping which leave the under coating in good condition may be disregarded.

Improve access to all pipe lines for inspection and maintenance where other conditions permit this to be done economically.

(7) Laterals Between Main Feeders and Dock Lines

There are a number of buried laterals between the main feeder and the dock lines in sizes as follows:

How (7 and 8)	16"
King	16"
Sail	12"
Mike	18", 12"
Baker	16", 14", 12", 8"

It is recommended that they be hydrostatically tested and repaired in place.

(8) Distribution System in Upper, Middle and Lower Tank Farms,

The distribution piping in the tank farms consists of the following:

In the Upper Tank Farm the suction and discharge lines are 24", 18", 14" and 12" welded steel. Drain lines are 8" and 6" cast iron bell and spigot.

In the Middle Tank Farm the suction and discharge lines are 12" welded steel and cast iron bell and spigot. Drain lines are 8" and 6" cast iron bell and spigot.

In the Lower Tank Farm, suction and discharge lines are 12", 8" and 6" screwed steel; 24" and 12" welded steel. Drain lines are 12" and 8" and 6" cast iron bell and spigot.

Upper Tank Farm

Distribution and suction lines in the Upper Tank Farm are generally in good condition. Suction lines are partly above ground. Pipe coating consists of a single application of bituminous material. Corrosion of these lines is negligible.

Drain lines are generally buried and are in good condition. Some seepage has been found around bell and spigot joints.

Middle Tank Farm

Distribution and suction lines within the Middle Tank Farm proper are partly above ground. Piping coating consists of a single application of bituminous material. Corrosion of these lines is negligible. Eight inch drain lines are buried and in generally fair condition.

In attempting to hydrostatic test the 12" steel and cast iron lines between the tank farm and Pump House 77, the lines were leaking so badly that no pressure could be built up. It is believed that these lines were a contributing factor to the past heavy oil leakage into Merry Loch.

Lower Tank Farm

The 24" and the 12" welded steel suction and discharge lines serving Tanks 10, 11, 12, 13, 14, 17 and 18 are mostly above ground and in good condition. Some corrosion has been found on portions of the 24" line under the fire dykes. Pipe coating on above ground piping consists of a single application of bituminous material. Under the fire dykes protection consists of ineffective bituminous and single felt coating.

The 12" and 8" screwed steel distribution and suction lines are in fair to poor condition. Considerable general corrosion and pitting has been found on these lines. Only slight traces of bituminous coating remain. The 12" and 8" cast iron

bell and spigot drain lines are in fair condition. The 12" screwed steel main drain line is in poor condition, showing general corrosion, pitting and evidence of leakage. However, there is considerable life left in these lines.

Recommendations for immediate work on the Upper, Middle and Lower Tank Farms are as follows:

Hydrostatically test suction and discharge lines in the Upper Tank Farm, and repair in place.

In the Middle Tank Farm hydrostatically test suction and discharge lines in tank farm proper and repair in place. The 12" steel and 12" cast iron lines between Pump House 77 and the tank farm will no longer be required and abandonment is recommended. This will require the installation of about 200 feet of new 12" pipe to connect Tanks 29, 30 and 31 with Pump House 31. ✓

In the Lower Tank Farm, hydrostatically test suction and discharge lines, and repair in place.

Test and repair of drain lines is not required where oil water separators are installed as recommended above.

E. Ballast Handling and Oil Separators

This facility is composed of two 10,000 barrel tanks, a pump house, and an oil separator. The separator unit consists of a reinforced concrete sump 14' x 14' and 9'-8" deep. Connected to this are two concrete structures 3'-0" deep, 5'-4" wide, and 67'-10" long which serve as a final means of separating the oil and water.

The facility is in good condition and, while connected to the ballast line, is not of sufficient size to handle a large cargo of ballast. Large quantities of ballast are presently discharged to a 150,000 barrel tank, where most of the separation between oil and water takes place.

F. Diesel Oil Storage

There is presently allocated to diesel oil handling and storage the following tankage:

Red Hill, two tanks	571,130 barrels
Upper Tank Farm, two tanks	300,000 barrels
Middle Tank Farm, one tank	50,000 barrels
Underground Purification Plant, five tanks	11,500 barrels
<hr/>	
Total	932,630 barrels

NOT TO BE USED FOR FUEL OIL
COULD BE USED FOR FUEL OIL

These capacities do not allow for any operating outage.

The Red Hill underground tanks and the large surface tanks are discussed above.

The diesel purification plant is an underground installation erected in 1943 consisting of eight prestressed concrete tanks, five of which are in diesel service, two in lubricating oil service, one in slop service, and pump room, pumps and manifolds, filters and centrifuges. This unit is used for reclaiming diesel oil which has been contaminated with water, and is arranged to receive from or discharge to submarines at the Sail and Mike Docks.

The purification plant equipment is in good condition, this unit being particularly well maintained. Two of the concrete tanks were inspected and found to be in good condition except for some minor cracks and partial failures of the Amercoat lining. These failures, while numerous, are of a minor nature except on the side walls near the bottom, where an extensive area has failed. This condition is believed representative. Cleaning and recoating of failed areas is recommended.

The other six tanks in this group should be cleaned and inspected and similarly repaired.

G. Diesel Oil Distribution System

(1) Diesel line from Red Hill Tanks to How and King Docks and Sail Docks 19, 20 and 21

The line from the first two Red Hill tanks to the How Docks is 16" welded steel. The feeder to the How and King Docks and Sail Docks 19, 20 and 21 is 10" welded steel. These lines are protected with double bituminous and felt coating.

The above lines lie with the corresponding fuel oil lines previously described as serving the same area, and they are in similar condition. The diesel line under Building 490 has failed and has been replaced, but it is not connected for use, a short spool being omitted at the valve chamber east of Building 490.

The following are recommendations for immediate work on this section of the diesel oil distribution system:

Improve bonding on the 16" line between Red Hill tunnel outlet and How Docks to improve results of cathodic protection.

Abandon the diesel line under Building 490, and replace with a new line routed around building. After this, hydrostatically test the feeder lines and repair in place if required. The work on adjacent fuel oil and diesel lines should be done at the same time.

Bond the 10" diesel oil line from the head end of the How Docks through the Kuahua pump house to the valve pit at the Red Hill tunnel outlet by 4/0 cable brazed to the pipe across all flanges or other appurtenances offering high electrical resistance. Connect this section electrically to the 16" diesel oil line, thereby extending to the 10" pipe cathodic protection already afforded to the 16" line.

(2) Diesel Line from Red Hill Pump House to Merry Loch
Pump House 162 via Underground Pump House 60

This diesel feeder line consists of a welded steel line beginning at the diesel oil manifold in the Red Hill pump house and extending to a point near Pump House 162. Coating for this line consists mostly of grease, cellophane wrapped, and covered with bituminous material.

Beginning at the Red Hill pump house as a 16" line, the feeder continues to a valve pit near the portal of the Red Hill tunnel, where the size changes to 12" and continues through Pipe Tunnel 1, and thence under Beeman Center through the Submarine Base to a valve pit at the head of Quarry Loch, where the size changes to 8". The 8" line continues along North Road changing to 6" to terminate in a blank at the 8" kerosene line to Mike Docks from former diesel Pump House 162.

This section of line was first exposed and examined at a number of points in the vicinity of Sail and Mike Docks and was then observed to be in good condition up to the termination at the feeder line leading to the Mike Docks. However, the line had been cut and blanked on Shane Street south of Beeman Center. Oil leaks have appeared in the past on the surface of Shane Street, and hydrostatic tests then indicated that the leakage was occurring under Beeman Center. The section of line south between Beeman Center and the first valve pit was tested to about 85 psig, and a leak rate of 52 gallons a minute was recorded. One hundred and fifty feet of the line was excavated along Pierce Street, and two one eighth inch holes and one five eighth inch hole were located. Areas of eighteen square inches around the failures were badly corroded. The remainder of this line to the Mike Dock feeder proved to be tight by test. The pipe wrapping had failed completely due to the solvent action of the diesel oil.

This line here parallels the fuel oil line and is subject to the same unfavorable conditions as described in the discussion of the fuel oil header through the Submarine Base Area.

Pictures in Section VI show typical soil conditions, coating conditions, oil saturated ground and type of corrosion of these lines.

Recommendations for immediate work are as follows:

Since the diesel oil line that arcs through the Submarine Base is now in oil soaked soil and generally bad environment, subject to stray currents and galvanic action, and partly located under buildings, we do not recommend attempting to repair and recoat in place. It is recommended that this portion of line be relocated from the pipe tunnel at the Diesel Purification Plant to a point where the line returns to North Street near the head of Quarry Loch. The portion of the line from the valve pit near Red Hill outlet to the Purification Plant tunnel is to remain in service. As much as practicable of the abandoned pipe is to be reclaimed, and reinstalled above ground with new line as required to run parallel to the railroad from a point near the ballast handling facilities to the previously mentioned point near the head of Quarry Loch.

Hydrostatic test and repair in place the sections of this header to 250 psig except sections relocated or abandoned.

This work is to be coordinated with similar work recommended for parallel fuel oil lines.

(3) Diesel Dock Lines

There are about three miles of dock lines of various sizes as follows:

<u>Docks</u>	<u>Sizes</u>
How 1 through 4	12"
How 7 and 8	12", 8"
King	10", 8", 6"
Sail	6"
Mike	8"

Dock lines are welded steel pipe, generally coated with bituminous and felt wrapping. Pipe risers are uncoated 6" and 4" size on about 75 to 100 foot centers.

Lines are in excellent condition at How Docks 1 through 4 and in good condition at How Docks 7 and 8. Valves and hoses on How Docks 7 and 8 show deterioration. Lines on How Docks 1 through 4 are coated with double bituminous and felt wrapping. Lines on How Docks 7 and 8 are partly coated with single bituminous and felt wrapping.

Lines on the King Docks are generally in good condition with some points of failure in the coating of single bituminous and felt wrapping.

Lines on the Sail Docks are generally in fair condition, but subject to corrosion due to ineffective protective coating.

Lines on the Mike Docks are generally in good condition with some points of failure in the bituminous coating.

It is recommended the following immediate work be done:

Hydrostatically test and make necessary repairs to all dock lines.

Clean and apply protective coating to all bare dock lines and risers.

Inspect, repair and paint pipe hangers.

Repair all defective portions of protective coating.

H. Kerosene Facilities

Kerosene can be received from tankers in cargo lots through a portion of the diesel system which has been rearranged to permit this operation. Tanks 33 and 35 in the Middle Tank Farm are used for storage purposes. Cargo is received at the Mike Docks and discharged to the tanks through a new 8" welded steel painted line largely in a tunnel. From these tanks the product is loaded into trucks via an 8" and 10" buried welded steel line to the nearby truck loaded rack and transported to a 1,000 barrel tank located in the Halawa Filling Plant area; this tank is the supply for the drum fillers.

The condition of the storage facilities and line from tanks to Pump House 162 are discussed above with the other surface tanks and their piping.

It is recommended that the 8" and 10" line to the truck loading stand be kerosene pressure tested and repaired in place.

I. Lubricating Oil System

(1) Storage

The lubricating oil storage is located in three different yard areas as follows:

Building 88 houses fifty six 600 barrel riveted cylindrical horizontal tanks with dished heads. They are installed on concrete foundations and steel cradles, two high and in two parallel rows. Between the two groups of tanks are located rotary pumps, suction, discharge lines, and manifolding.

Located adjacent to this building are four operative truck loading stands, pumps, meters, and fillers for drumming of lubricating oil.

At the Diesel Purification Plant two of the 550 barrel concrete tanks are used for lubricating oil.

Near Halawa Filling Plant are two 10,000 barrel bolted steel lubricating oil storage tanks.

Summary of Lubricating Oil Storage

Building 88	33,600 barrels
Purification Plant	1,100 barrels
Halawa Filling Plant	20,000 barrels
<hr/>	
Total	54,700 barrels

Building 88 facilities are carefully maintained. No evidence of corrosion or deterioration was observed.

The purification plant is discussed under diesel storage.

The 10,000 barrel tanks near Halawa filling plant are heavy specially reinforced bolted tanks. Inspection revealed no corrosion or leakage.

(2) Lubricating Oil Distribution

The lubricating oil distribution system consists of about six miles of piping connecting storage in Building 88 with the Mike and Sail Docks, the two 10,000 barrel storage tanks, the diesel purification plant, and the truck loading rack. About one and one-half miles of this piping is buried as follows:

(a) Building 88 to docks, (b) across the head of Quarry Loch, (c) across the Submarine Base point, (d) from the Sail Docks to the 10,000 barrel storage tanks, (e) from the diesel purification plant to the truck loading rack. The 6" lines connecting the Sail Docks and the tanks and the 4" lines from the purification plant to the truck loading rack are welded steel. These lines were installed without coating, being painted only. In addition to buried piping, there are approximately four and one-half miles of exposed 3", 4" and 6" welded steel lines most of which are located on the Sail and Mike Docks. Operating diagram of the system is included in Section VI.

Ref. 1948
The six inch lines to the storage tanks and the four inch lines to the truck rack have failed in the past in the vicinity of Substation 626 and between North Road and the railroad tracks. Lines have been repaired in place. The lines from Building 88 to the Mike Docks were replaced in 1936. Some are now leaking. Sail and Mike dock lines are in fair condition, showing corrosion of pipe and flange bolts where lines are not adequately protected.

The following are recommendations for immediate rehabilitation:

Lubricating oil pressure test all buried lines, and repair in place if tests indicate limited or local leakage.

Replace with adequately coated pipe if tests indicate extensive or general leakage. Lines from Building 88 are under pavement and, in view of inaccessibility, it would be most economical to replace these lines with mastic coated pipe.

Lubricating oil pressure test and make necessary repairs in place to dock lines.

Clean and apply adequate coating to dock lines and risers.

J. Gasoline Receiving and Distribution System

This installation consists of new and modern docking facilities, at which both incoming and outgoing cargoes are handled. The shore tanks consisting of two 150,000 barrel tanks which were removed from the Navy Yard area and re-erected at some 4,500 feet from the docks have an operating capacity of 138,813 barrels each. One tank is used for motor and one for aviation gasoline. They are presently equipped with modified breather roofs. The dock area is connected to the pump house and manifold pit by two 10" welded steel lines. Cargoes can either be pumped into the tanks or the Army Waiawa booster pumps located adjacent to the main

highway near Ewa Junction, which pumps discharge to Army storage. In the Pearl City pump house are located six centrifugal transfer pumps of varying capacities. There is also a small truck loading rack located on the property and most of the local Army and Navy demands are supplied by truck from this point. The Pearl City installation is protected with a new well designed foamite system using dry powder. The general purpose is to receive all motor and aviation gasoline to distribute to Navy facilities at Ewa Junction and Barber's Point, to act as a transfer point for incoming Army cargoes, and to load cargoes for distribution. The installation was placed in operation in 1945.

The equipment is in good condition. These tanks were removed from the Upper Tank Farm and re-erected at Pearl City. Inspection, February 25, 1949, revealed only very minor corrosion. The roofs were generally good. However, drilling indicated a thin area. The shell indicated some loss on the top course, but this loss was minor. The bottoms were trepanned, and these samples indicated no loss of metal. All tank appurtenances were in good condition.

Leakage due to electrolytic corrosion has frequently occurred on the buried lines in the pump house area, most of which was on the lines to the truck loading rack.

There are several design features that are worthy of discussion because they do not conform to oil industry practice, and we believe they should be avoided.

The drains leaving the tank areas are not protected against flash back.

The gasoline leakage from the pump glands and bleeders flows to a sump from which it is discharged into a slough or drainage ditch outside the station area.

The pump house floor is located several feet below ground level which creates a drainage and ventilation problem,

and also a hazardous working condition. Good design would dictate that the pump house floor be located just above ground level and that the manifold piping be installed in a pit outside the pump house.

The pump house manifolding is irregular and does not permit readjustment often found necessary due to operational changes without major revision. A good design of this type of installation is to have the discharge lines passing over the suction lines with sufficient clearance to permit the installation of valves.

The following recommendations are made for immediate rehabilitation:

Install cathodic protection to piping as recommended in letter to Officer in Charge of Construction dated February 18, 1949. Copy of this letter is included in Section VI. The lines in this area are in a corrosive soil, and failure history indicates that protection should be provided at once to save replacement.

The lines are regularly pressure tested with water, and this procedure should be continued. It is recommended that the frequency of testing be increased and a pressure recorder be installed to assist in determining the leak rate pending and after cathodic protection installation.

Install drainage collection system on pump glands and bleeders, as shown by accompanying Sketch 5.

Install flash back prevention on drain lines from levee area and on main drain from pump house building as shown also on accompanying Sketch 5.

K. Drumming and Truck Filling Units

(1) Halawa Drum Filling Plant

This drum filling unit consists of six well equipped filling stands housed in a wood frame building covered with galvanized iron. The fillers are supplied by pumps taking suction from two 1,000 barrel and two 10,000 barrel tanks. The following products can be handled: two grades of lubricating oil, diesel oil, and kerosene. The capacity is 550 drums per hour of any one of the above products.

The equipment is modern, well maintained and in good condition.

The filled lubricating oil containers are stacked horizontally in piles from four to six high with wooden separators between the rows. These storage piles are in the open and subject to the action of the sun and weather. It is industrial practice to store such drums under open side roof shelters in steel racks so that the weight will not rest on the other drums in the stack and that individual drums can be readily removed. Such an installation is recommended for filled lubricating oil containers in the storage area adjacent to the Halawa Filling plant. Lubricating oil has a high flash point and no special fire protection is recommended. ✓

The possibility of obtaining sufficient returnable welded drums to take care of normal requirement, and locally filling the more rapidly moving grades as required should be investigated.

(2) Truck Filling, Navy Yard

The main Navy Yard truck filling rack is located near Building 490. It is of excellent design, and it is equipped to handle the following products: Lubricating oil, diesel oil, fuel and waste oil.

There are also truck filling facilities located adjacent to Building 88 which are equipped to handle kerosene and lubricating oils.

The equipment is in good condition.

(3) Drum Conditioning Plant

The unit is located on the main highway toward Ewa and consists of cleaning units, boilers, painting equipment, buildings and a large storage area.

The equipment is in good condition.

There is an apparent surplus of both high pressure cylinders and single trip oil drums. These containers are exposed to the weather and are deteriorating, and many are now beyond economic repair. It appears desirable to dispose of surpluses and paint and properly protect containers required, especially the pressure cylinders, which cannot stand a severe loss of metal and pass ICC tests.

*Material
Camp*

(4) Drum Filling and Truck Loading, Ewa Junction

This drum filling unit is housed in a wood frame galvanized iron covered building and consists of ten meter equipped filling stands. A capacity of 500 barrels per hour is understood to have been reached. Motor or aviation gasoline can be filled and is supplied by centrifugal pumps from two 13,500 barrel prestressed concrete underground tanks which were constructed in 1942.

There is also a small truck loading rack located in this area which is served from the same underground tanks.

The Amercoat lining of the 13,500 barrel motor gasoline tank has failed locally. On the bottom are numerous points where the lining has peeled off, and on the side walls there are a number of blisters, some of which are broken, and a number

of which are filled with water. The concrete is porous, and probably the tank will leak in gasoline service.

It is believed that the aviation gasoline tank condition is similar as type and age are the same and service is similar.

Dry wells were installed adjacent to these tanks and are connected to the stripping pump discharge, presumably to receive water drainage. There is no provision made to readily determine whether or not gasoline is being pumped, and the use of this equipment in the future should be discontinued.

The following recommendations are made for repair of tanks:

Sand blast shell and bottom and then apply reinforced gunite lining and coat with Amercoat 23 or equivalent.

As an alternate, if tanks can be repaired in dry season and the walls thoroughly dried, then patch present lining.

Inspect aviation gasoline tank and, if similarly deteriorated, apply same repair.

SECTION II--RECOMMENDATIONS PERTAINING TO THE
RED HILL UNDERGROUND STORAGE AND
DISTRIBUTION SYSTEM

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1. Recommendations for Improved Operating Techniques at Red Hill Storage and Distribution System

In general, the operation of Red Hill underground storage and distribution facilities is good. The operators are well qualified and trained, and no recommendations are offered concerning personnel.

Certain improvements in technique have been considered, however. The automatic liquid level indicators for the tanks operate accurately, but they are too sluggish for good operation. One indicator is in the pump house and one is in the gager's station. Switches on the panel board cut in the selsyn circuit to any one of the twenty tanks. The response is slow, and considerable time is required for the dial pointer to come to rest at the level indication. Alterations can be made to this system to speed up the response and simplify the taking of tank gagings. Temperatures in the tanks are indicated by resistance thermometers which are located in thermowells projecting into the tanks at various levels. These units have failed frequently, and they should have much longer life. It is recommended that the cause of failure be investigated and that the trouble be corrected.

2. Recommendations as to the Scope, Character and Frequency of Regular Navy Inspections of Red Hill System

In addition to daily routine inspections of Red Hill facilities that are normally made by well trained operators, the following schedule of periodic maintenance inspections is recommended:

The tanks should be visually inspected at intervals tentatively established at five years. First inspection is thus now due. Findings of these inspections will determine the long range maintenance program and minimum interval of inspection

required. The inspection at the first and second five year intervals should consist of filling the tank with oil up into the 5'-4" diameter manway access section and gaging the oil with a hook gage for a minimum of 120 days to determine if any leakage exists. Should leakage be determined by careful gaging, it is our recommendation that the oil level be dropped slowly in short intervals until this leakage is no longer apparent. This we believe to be the best method of establishing the zone of leakage. Finally the tank should be emptied and all weld and plate areas visually inspected for corrosion. This inspection should be accomplished by slowly filling the tank with water and inspecting the entire liner area from rafts. In any leakage zone the welds can be magnafluxed, tested with a vacuum box or given other special inspection to locate the defect.

Instruments and electrical equipment should be inspected monthly.

Pumps should have a regular monthly inspection.

Pipe lines and valves should be pressure tested and inspected yearly.

The ventilation system for the Red Hill tunnels and pump house should be tested and inspected monthly.

Condition of the tunnels, surface vents, and provisions for fire protection require a monthly check.

Reference is made to "Navy Handbook of Operating Procedures for Handling Fuel Oil and Diesel Fuel Oil at Naval Supply and Fuel Depots, Section IV". This manual affords excellent information as to inspection and testing procedures.

3. Recommendations for the Integration of Red Hill Storage and Distribution System with that of the Entire Area

Complete integration of all Navy Yard facilities requires that the Red Hill storage and distribution system be unified and in balance with the surface storage and yard distribution system, including the dock lines. The Red Hill system itself is well integrated and balanced. A limiting factor is the piping between the underground vaults and the pump station. If it were desired to issue oil at maximum rates by utilizing pumping facilities and ultimate distribution line capacities, the suction lines to the pumps would limit output to about 34,000 bbl/hr while the pumps as arranged are capable of 55,000 bbl/hr. For fueling rates considered herein as required these lines are adequate.

There are deficiencies in the yard distribution system connected with the Red Hill system. As discussed in Section III these deficiencies will be largely corrected by rehabilitation.

4. Recommendations for the Measures Necessary to Convert One or Two Storage Vaults to Use for Gasoline and Jet Fuel Storage ✓

A. General

The problem of storing light petroleum products in underground storage such as constructed at Red Hill presents many difficulties. The design of the tanks such as size, appurtenances, and even the detail methods of construction do not lend themselves to the storage of light products with their explosive vapors. We believe that, even with the most carefully designed protective measures practicable, adaptation of the existing storage for light oil use involves some degree of risk.

We have analyzed the problems in a preliminary way but without the exhaustive engineering study necessary to final solution of a problem of this magnitude. In the discussion presented below we recommend measures we believe necessary in order to convert one or more tanks in the Red Hill storage for use in aviation gasoline or jet fuels storage. We have based these recommendations upon using Tanks 1 and 2 which are the tanks at the lower elevation and nearest to the harbor area.

B. Vent and Ventilation Systems

(1) The vent system of Tanks 1 and 2 is now completely separated from Tanks 3 to 20, inclusive. Tanks 1 and 2, however, are interconnected by a common vent system. Because of possible contamination of a large quantity of miscible fluids by backflooding thru the vent piping, this common vent system should be rearranged for storing such dissimilar fuels as aviation gasoline and jet fuels. Tank 1 should be completely blanked off from Tank 2. A new separate 24" vent pipe and bombproof vent should be provided for Tank 1.

(2) The receiving rate and issuing rate would be 2,280 barrels per hour, corresponding to a displacement of 12,800 cubic feet per hour. The rate is determined by capacity of Pearl City pumps. Two dual pressure and vacuum vent valves with entrainment separator flame arrestor, each capable of handling 25,600 cubic feet per hour, or twice the displacement rate, should be installed in the gaging chamber of Tanks 1 and 2.

(3) Relocated diesel oil in Tanks 3 and 4 will require separate venting. Diesel oil and fuel oil have the same allowable flash point limit and are classed together as relatively nonhazardous from the standpoint of the amount of vapor they release. However in view of the greater inflammability of the diesel oil and possibility of contamination by backflooding of fuel oil through vent piping, a new and separate vent system would be required for Tanks 3 and 4 similar to that now used for Tanks 1 and 2.

(4) A new explosion-proof ventilating fan with operating switch at the upper access tunnel should be installed in each gaging chamber of Tanks 1 and 2, and the exhaust should be piped into each respective 24" vent line to atmosphere per accompanying Sketch 2 to insure that inflammable mixtures do not form in this working area. A metal partition and swing door would be installed at entrance to gaging chamber of Tanks 1 and 2. The present 10" ventilation pipes from each gaging chamber to Fan 7A in the upper access tunnel would be blanked off.

(5) Fan 1 in the upper access tunnel might handle vapors within the inflammable range. Explosion-proof motor, non-sparking fan blades and adequate grounding should be installed.

(6) To maintain maximum safety in the upper access tunnel, bulkhead doors must be normally closed so that air movement would always be toward the exhaust portal.

C. Fire Protection

(1) To extinguish a possible fire, a dry Foamite system, consisting of separate A and B powder storage and foam generator, should be installed.

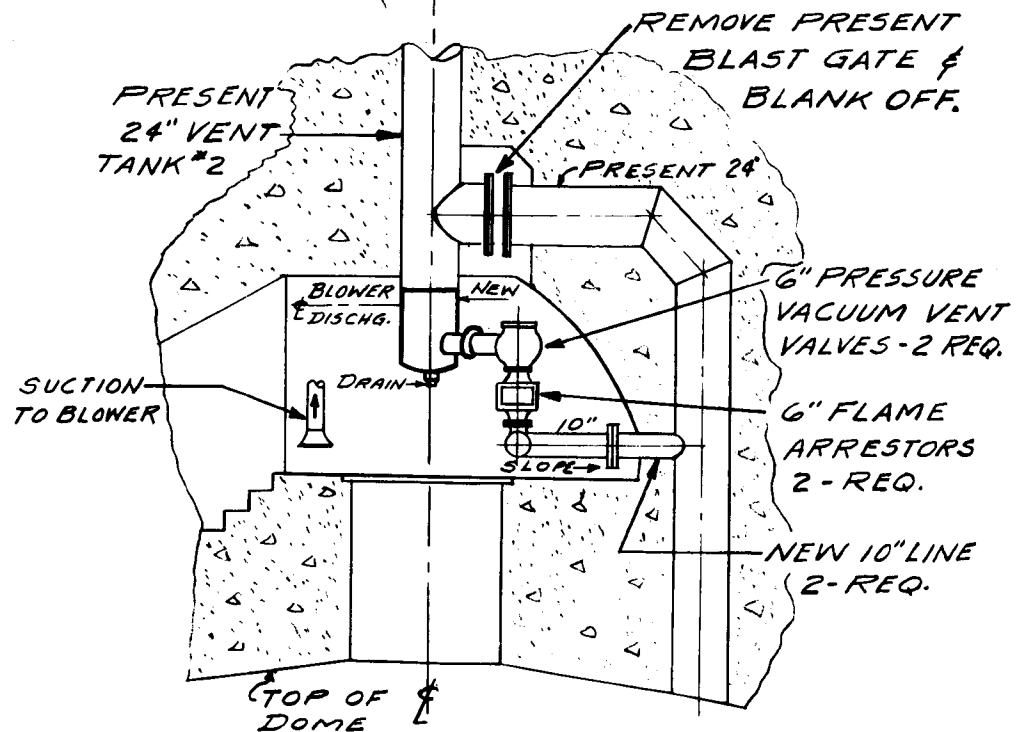
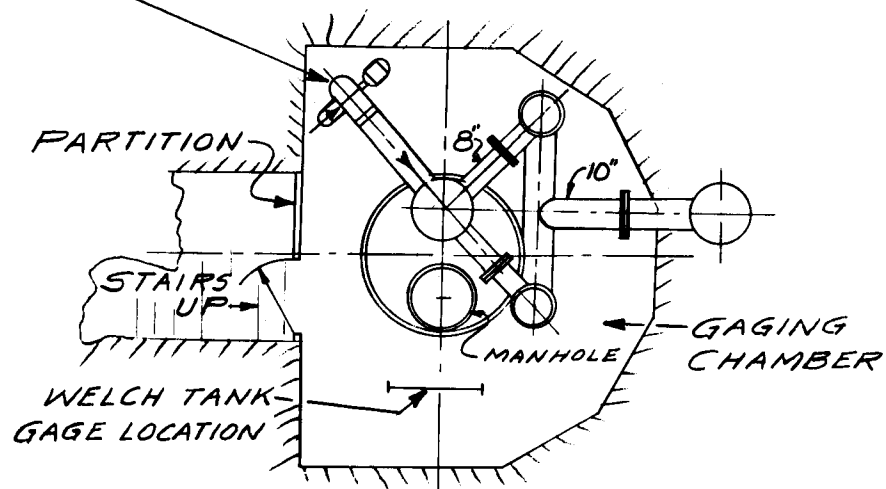
(2) All tank appurtenances, such as Welch Automatic Gauge, should be explosion-proof.

(3) All electrical equipment not meeting the Underwriters' requirement for Class 1 Group D installation would be replaced.

(4) A pneumatic spark free locomotive would be required for the train in the lower access tunnel.

(5) A continuous gas sampling system would be required to automatically determine whether an explosive mixture exists in the atmosphere in the gaging chamber of Tanks 1 and 2 and at bottom valve chamber area in the lower tunnel.

1500 CFM BLOWER &
EXPLOSION PROOF MOTOR
INSTALL AS HIGH AS POSSIBLE.



REVISION OF TANK VENTS

TANK NO 2 SHOWN

TANK NO 1 TO BE SIMILAR

REF. DWG. 9UF M-3

SECT. II - RED HILL SKETCH 2
ALTERATIONS TO TANKS 1 & 2
PROPOSED METHOD OF VENTING TANKS



D. Booster Pumps and Pipe Line

It is impractical to use the existing pipe lines which carry fuel and diesel oil for aviation gasoline and jet fuels. A new 10" line should be installed from Tanks 1 and 2 out the lower access tunnel and down the hillside, connecting to the existing 10" gasoline line along Kamehameha Highway (and to a new jet fuel line if one is to be installed). A booster pump station manifolded for pumping either direction would be required. This would consist of three pumps of 2280 bbl/hr for series or parallel operation with one spare. Accompanying Sketch 3 shows diagrammatic layout.

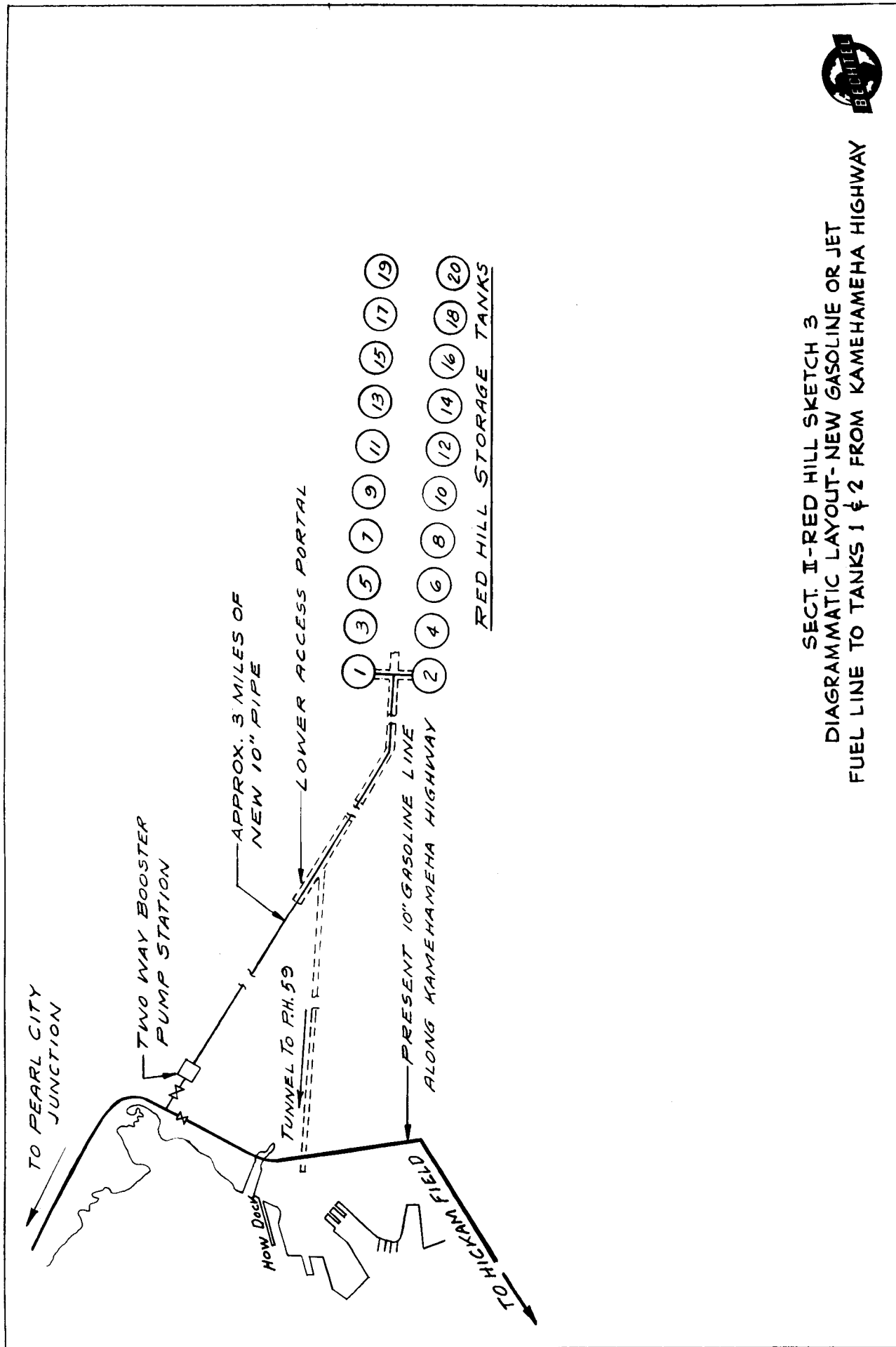
It is proposed to use the single 10" line between the booster pumps and tanks for the two clean products. Its use would result in degrading some aviation to jet fuel, and would require water washes.

E. Alteration to Insure Tank Tightness

Tanks 1 and 2, if used for storage of such light products as aviation gasoline and jet fuels, must be maintained tight, and an effective method of detecting leakage is required. Testing of Tank 16 has indicated minor leaks probably exist which the tell-tale system did not reveal. Leakage would be at a greater rate and more hazardous in light oil service.

It is proposed that half round sections be welded over all welds, which will (a) permit testing the seal welds, (b) reduce the service pressure on the tank liner butt welds to substantially atmospheric, (c) provide a means of draining any possible leakage to a central point. The present tell-tale system would be removed and the holes plug welded and covered. The accompanying Sketch 1 shows in detail this proposal.

These half rounds or similar enclosures would cover every portion of the present welds. The system so formed could be regularly tested for absolute tightness by a time test of air pressure retention or by visual inspection from a float-



SECT. II-RED HILL SKETCH 3
 DIAGRAMMATIC LAYOUT-NEW GASOLINE OR JET
 FUEL LINE TO TANKS 1 & 2 FROM KAMEHAMEHA HIGHWAY



ing raft within the tank. The system thus permits provision against leakage but if any leakage does occur it will drain into the collection system rather than permeate into the concrete and rock structure.

A preliminary estimate of the cost of work to carry out the above recommendations is included in Section IV.

SECTION III--RECOMMENDATIONS PERTAINING TO
NAVY YARD AND PEARL CITY
PETROLEUM FACILITIES

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1. Recommendations for Integration of the Entire System
for Each Type of Fuel from Docks to Storage

As noted in the discussion of the Red Hill system, integration is considered to require that all the facilities for any of the petroleum products used shall be in balance and operable as an effective unit. Deficiencies in the storage and distribution system, exclusive of Red Hill, resulting from deferred maintenance and some obsolescence have reduced capacity, and some connecting links between Red Hill Storage, surface storage, and the docks have become ineffective.

The vital step toward integration of the entire system is rehabilitation of the yard distribution system. As formerly operated, the system was well integrated, and as soon as the essential parts of the distribution system are restored to service, it will again be integrated.

The petroleum facilities at the Pearl Harbor Naval Base consist of large capacity storage interconnected with liberally sized pipe lines, as shown on the operating diagrams included in Section VI. These diagrams show storage, pump houses, line sizes and other pertinent information. A study of these diagrams indicated the scope and flexibility of the installations, and the ability with minor changes or alterations to perform any desirable operation. Changes of surface tank service from one product to another can easily be made with little readjustment of piping, and several products can be handled.

No recommendations for new or relocated pumping, piping, or other facilities to accomplish integration are made.

Individual petroleum product systems are discussed below.

A. Fuel Oil System

The fuel oil system as it exists is well integrated in respect to the storage and pumping facilities and the docks which they serve. Rehabilitation work as recommended will correct the deficiencies now present in the system which impair its maximum utility.

B. Diesel Oil System

Integration of the diesel oil system is quite complete except for inoperable sections resulting from line failures or other deterioration. Rehabilitation work will restore this system to its original scope. The diesel oil system has almost its entire pumping capacity in the Red Hill pumps and thereby must rely primarily on Red Hill facilities for issuing oil. Pumps in the Purification Plant can pump to the Sail Docks from underground storage, but their capacity is low. The lack of sizeable diesel oil pumps in the yard limits the usefulness of surface tanks as working storage to the diesel fueling rate available by gravity flow, for example, 2500 barrels per hour to the Mike Docks.

To utilize the Mike Docks facilities for diesel oil the main distribution line from Red Hill will have to be connected into the 8" line now in kerosene service.^{N0} Switch of service can easily be made as and when required to receive kerosene.^{N0}

C. Lubricating Oil System

The lubricating oil system provides storage, pumps, lines, and purification equipment for the bulk handling of various grades of lubricating oils. Pumps and tanks in Building 88 and lines on the Mike Docks permit handling of four grades simultaneously. Facilities in the Underground Purification Plant and at the Sail Docks are in duplicate, permitting flow of two grades of oil. These two systems are interconnected, and both are integrated with the Halawa drumming plant, tankage, and loading rack by double lines.

This system appears to be well integrated for performing lubricating oil operations such as receiving, blending, drumming, bulk loading, and bulk storage. Rehabilitation work will restore deteriorated parts of the system to full workability.

D. Kerosene Facilities

This system is integrated for present operations. If substantial or continuous flow of kerosene to the drumming plant were to be desired, a line of about three or four inches diameter could be used to supplant the trucking. If the pump in Pump House 162 is to remain disconnected from the diesel oil system, as appears probable, it would be suitable for pumping several hundred barrels of kerosene per hour to the Halawa plant.

E. Gasoline System

The intent has been to keep all gasoline facilities other than motor vehicle service stations out of the Navy Yard. Therefore, this system is not integrated with any other yard petroleum facilities.

Gasoline facilities belonging to the Navy which have Pearl City as their apex, are well integrated both for Navy use and for receiving and distributing Army gasoline to Army facilities. The Pearl City system is modern, and except for maintenance and rehabilitation work discussed elsewhere in this report, nothing is to be recommended concerning integration of the gasoline system.

F. Defueling System

There are no special defueling facilities installed in the Navy Yard other than those in connection with the defueling of submarines in the Submarine Area. Defueling is generally accomplished on the other dock areas by pumping the oil directly into the oil distribution system, that is if the product is on specification. If the product in the vessel being repaired is not on

specification the oil is pumped off into tank trucks and moved to the ballast ground facilities where it is processed. This arrangement appears satisfactory.

G. Use of Burning Pits for Disposal of Waste Products

There are several thousand barrels of oil emulsions stored at Pearl Harbor and in the past the disposal of this material has been accomplished in two ways. One was to accumulate cargo and ship by Navy tanker to the mainland where the emulsions were reprocessed in one of the coastal refineries, and the second means that was used for some time was burning in open pits. Some of these emulsions were processed locally and burned in Power Plant 8. It appears that probably the most economical method is shipping back to the mainland for reprocessing. Generally the type of emulsion existing at Pearl Harbor cannot easily be broken without proper equipment. The means and equipment required is quite thoroughly discussed in the Navy Fuel Oil Depot Manual.

Should it become desirable to erect separate equipment that would dispose of these emulsions by burning, obtaining almost complete combustion, it would be necessary to erect a brick furnace similar to a boiler furnace and with about the same ratio of combustion volume dictated by good power plant practice. In that these oil emulsions contain approximately 50% water a dry fuel will have to be utilized to heat up the furnace and assist in obtaining complete combustion after the injection of the emulsions is started. Due to the large amount of water in the emulsions and the quantity of heat that will have to be supplied to vaporize this water this practice is costly. Further, the entire amount of heat in the fuel is wasted. Such an installation is not recommended. This discussion covers any type of oily emulsions or solids which might be found at Pearl Harbor and accordingly we do not consider the installation of burning pits necessary or practicable.

Disposal of any occasional limited amounts of semi solid sludge by burial at a suitable remote location is preferable to burning.

2. Recommendations for Improved Operating Techniques and Type, Character and Frequency of Regular Navy Inspections

Operating techniques involved in the storage and movement of the various petroleum products used by the Navy with the facilities in the Navy Yard and its environs include the following operations to be discussed.

The principal operations, those of receiving oil cargo from tankers and disbursement from storage, appear to be well handled, and no recommendations are contemplated. Qualifications and training of the personnel are good and require no discussion. Certain improvements can be recommended in the handling of oil products. Methods of keeping product inventories and transfer records could be improved to aid operating control such as detection of oil leaks and losses and determination of handling capacities and rates. Escape of oil to harbor waters represents a loss of valuable product, a fire hazard, and an unpleasant nuisance. Installation and use of effective oil-water separators for the effluent of all sea drains as recommended in Section I would reduce this problem. Some seepage from oil soaked ground areas may exist. Collection pits dug in such areas would not only aid in draining this oil from the ground but would also represent recovery of a valuable product for reclaiming and use. In the drumming of oil products a large number of single trip steel barrels are used. Filled drums should be stored only for short intervals, and drums should be adequately protected against physical damage and corrosion.

Inspection and testing of facilities should be maintained on a well planned and definite schedule. There should be both day by day routine inspections by operators in connection with their regular duties in addition to regularly scheduled tests and inspections. For details and descriptions of such procedures, reference is made to "Navy Handbook of Operating Procedures for Handling Fuel Oil and Diesel Fuel Oil at Naval

Supply and Fuel Depots, Section IV". The following summary is an example of a reasonable test schedule for the facilities:

Tanks	Yearly
Appurtenances	Monthly
Pumps	Monthly
Instruments	Monthly
Electrical Equipment	Monthly
Pipe Lines	Yearly, to 1-1/2 times working pressure
Cargo Hoses	Monthly
Cathodic Protection Equipment	Monthly
Fire Protection Equipment	Monthly

Certain items of maintenance work should receive regular periodic attention similarly, and are also discussed in the above reference. Examples would be yearly touch up painting on surface tanks and exposed lines.

3. Recommendations Concerning Adequacy of Pumping Installations, Fueling Rates, Valve Controls, Ship to Shore Connections, Etc.

A. Basis of Calculation of Fuel Oil and Diesel Oil Distribution Capacities

The capacity of fuel and diesel oil distribution facilities is presented in summary in accompanying Table 1. The fueling rates attainable at the different docks and individual berths have been calculated and represent the capacity of the present facilities after rehabilitation in accordance with our recommendations. Maximum rates stipulated as required are tabulated for main feeder lines to docks and for individual loading berths. Information as to requirements was obtained from letter from Supply Officer in Command to Officer in Charge dated November 15, 1948, which is included in the appendix. Corresponding rates computed for the existing facilities after rehabilitation are also shown in three categories:

1. Distribution lines too small to meet new requirements.
2. Distribution lines sufficient size to meet new requirements.
3. Distribution surplus capacity for new requirements.

In each of the above categories the berth capacity is expressed comparative to the new requirement, i.e. in category (1) the capacity is expressed as the maximum that can be supplied to one berth, in category (2) this capacity is expressed as the maximum that can be supplied to a group of berths and in category (3) the capacity is shown as the amount that could be supplied to an individual berth.

Many combinations of simultaneous operation are possible other than those considered in this tabulation. Points of limitation by line size or location are included, however.

Calculations for the fuel oil line capacity were based on Navy Special Fuel Oil with an API gravity of 17 degrees and a viscosity of 800 SSU at an 80 degrees F. flow temperature from Red Hill. If a more viscous grade of fuel oil is being used, or if the Navy Special is being pumped from a tanker or surface tanks at a temperature lower than 80 degrees F., computed rates shown in Table 1 would be too liberal. However, most of the flow rates encountered in this study indicate turbulent flow, wherein viscosity differences result in less proportional difference in line capacity than is the case in the region of viscous flow. Line pressure losses are based on the best available data for discharge pressures of existing pumps, and allowance is made for loading hose friction by allowing for dock connection pressures of about 30 psig. ✓

Diesel oil, being of low viscosity, is not subject to any substantial difference in flow due to moderate temperature change or variation in viscosity. Computations are based on 37 degrees API gravity and 45 SSU viscosity. Conditions of pressure for fueling are assumed as in the fuel oil study.

Distribution lines and connections at Baker Docks in the shipyard area are presently disconnected. In view of the decision against fueling in the shipyard, as outlined in letter from the Officer in Charge dated March 9, 1949, no discussion on adequacy of these facilities is presented here. Calculations of the capacity of the shipyard system after rehabilitation are presented in Table 2. This system, if repaired, would represent a substantial fueling capacity.

B. Fuel Oil and Diesel Oil Distribution Capacity

How Docks

Fuel oil and diesel oil rates to H-1-2-3-4 on the fuel pier as computed check well with operating experience. The rates meet those as stipulated for fuel oil, but they are limited by the Red Hill lines while issuing and by pump capacity when receiving, particularly when the tanks become nearly full. It will be noted that diesel capacity is somewhat below the stipulated requirements.

Lines to berths H-7-8 beyond the fleet landing area permit adequate flow for fuel oil, but the diesel oil line is too small for the stipulated rate.

King Docks

The existing fuel oil system should be capable of issuing the required rates simultaneously to K-7-8-10-11 from Red Hill. The 8" header to K-7-8 limits cargo receiving to about 3400 bbl/hr.

When issuing diesel oil from Red Hill, each berth can receive its required 2000 bbl/hr., but the berths can receive simultaneously only a total of about 6500 bbl/hr. The computed receiving rates are much less than stipulated, even when using only one berth at a time.

Sail Docks

Fuel oil feeder lines to Sail berths include three routes to reach the different areas. The 12" line to S-19-20-21 via Kuahua Pump House can carry 8000 bbl/hr. as far as the junction at the pump house. The line from there to S-20 being smaller can carry only 4000 bbl/hr. to supply S-20-21 with 2000 bbl/hr. each. Berths S-10 to 13 can issue a total of 8000 bbl/hr. as required through the 12" line coming from the

22" feeder. The third route feeds only the berth S-1, where the maximum berth capacity is 6700 bbl/hr. when supplied from Pump House 91.

When issuing diesel oil, required rates can be met at all berths individually. However, total rates in any of the three feeder systems outlined above fall somewhat short of the stipulated 8000 bbl/hr.

For defueling of diesel oil, two gear pumps in Pump House 696 at Sail Docks are used and are rated at 350 bbl/hr. each. They can take suction on any of the defueling lines from the four berths so provided and pump the oil through the purification system. Aside from the booster pumps, defueling of diesel oil from submarines is limited with existing lines to about 1000 bbl/hr. by the pressure which submarine fuel tanks will stand because the oil is discharged by displacing it with water. For this operation, a pressure at the dock connection of 15 psig. is assumed available.

Mike Docks

When issuing fuel oil at 16,000 bbl/hr. as stipulated, the maximum output of Pump House 91 can be utilized, augmented by 6000 bbl/hr. from Red Hill. Both the 16 inch and 18 inch feeder lines would be used. Thereby, any two of the four berths can operate simultaneously at 8000 bbl/hr. The same rates can be attained when receiving oil into tankage.

Diesel oil facilities issuing and receiving rates at the Mike Docks are limited by the long 8 inch header to values considerably below those stipulated.

Thus at the Mike Dock, the fuel oil capacity is adequate, and the diesel oil capacity is inadequate with respect to the requirements stipulated. The 12" diesel and 16" fuel supply lines have been recommended for relocation incident to rehabilitation. If it is desired to improve the capacity of the sys-

tem in the direction of the requirements as stipulated, consideration might be given to the following:

In relocating the 16" fuel oil and 12" diesel lines, manifolding at each end may be installed to permit these lines to be used interchangeably. If, for example, the 16" line were in diesel service and the 12" line in fuel service, the diesel distribution deficiencies at the Mike Docks would be largely eliminated. This exchange would still permit meeting stipulated fuel oil requirements.

C. Lubricating Oil Distribution Capacity

With the issuing rates of lube oils being necessarily low as compared to petroleum fuels, and considering that a large portion of the oil is issued in drums, the adequacy of distribution facilities is determined chiefly by the quantity and rate that can be handled when receiving lube oil cargo from tankers. The Officer in Charge has stipulated by letter dated March 9, 1949, included in Section VI, that a lube oil cargo should be discharge during a total dock daytime of 24 hours from T-2 type tankers under normal operating conditions where the split in cargo follows past experience. A maximum of 10,000 barrels has been reported as the quantity of a lube oil shipment.

Lube oil shipments are received at Building 88 from the Mike Docks. Calculated receiving capacities for the four grades of oil from each of the berths are tabulated below. The rates represent use of the four lines simultaneously. One fourth of each rate indicates the capacity of a single line.

<u>Grade</u>	<u>Assumed Pumping Viscosity</u>	<u>Bbl/Hr. at Berth</u>			
	<u>SSU</u>	<u>M-1</u>	<u>M-2</u>	<u>M-3</u>	<u>M-4</u>
2190-T	1000	460	580	1060	1060
9250	1500	304	380	700	700
9370	3000	152	188	352	352
1120	3000	152	188	352	352

The above rates can be subject to considerable variations, depending on pumping temperature and on actual viscosity of a particular shipment. Although a maximum cargo of the two most viscous grades could not be pumped out at the two farthest berths, M-1-2, in the time indicated, the near berths, M-3-4, are adequate. In view of the above tabulation, no recommendation beyond rehabilitation is offered because the facilities appear to be fully adequate.

D. Kerosene Distribution Capacity

Facilities for bulk handling of kerosene are described above in this section of the report. Issuing requirements and transfer rates are indefinite, but here again the adequacy of the system is related to the receiving rate from tankers. The stated rate is 5000 bbl/hr., which can be met by the ships' pumps. With the existing system for receiving kerosene cargo, calculations indicate that tanker pumps could adequately put 5000 bbl/hr. of kerosene into the farther storage, Tank 33, against the full level. Gravity flow from the kerosene tanks to the nearby truck loading rack via 10" line is adequate.

E. Gasoline Distribution Capacity

The required receiving and issuing rates for Victor Docks and Pearl City pump station are 2800 bbl/hr. for either motor or aviation gasoline. Both pumping and line facilities are adequate for this rate.

F. Capacity of Pumping Installations

A wide variety of pump makes and types are installed in the various pump houses. For the most part they are Kinney rotary piston and gear pumps and Byron Jackson centrifugals. The rest consist of other types of displacement and centrifugal pumps. The accompanying Table 3 presents pertinent data on each pump.

The principal pumps, and the newest, are the gasoline pumps at Pearl City and the fuel oil and diesel oil pumps in the Underground Receiving Pump House which serves Red Hill. As previously indicated, the gasoline pumps are adequate in number, capacity, and pressure for their required service.

The Red Hill pumps consist of two sizes totalling eleven pumps. These are installed so that there is at least one spare for each of three groups. Therefore, in the group of the five largest fuel oil pumps, P-1-2-3-4-5, the capacity is that of four, and they can be operated either parallel, separately, or two in series, or two pairs in series parallel. Of the smaller group of three fuel oil pumps, P-6-7-8, the capacity is that of two, operable singly, parallel, or in series. Likewise, the three similar diesel oil pumps, P-9-10-11, are installed in a similar manner. None of these pumps are connected for operating more than two in series. Capacities are adequate to meet the maximum requirements of How Docks, or alternately, other dock requirements as indicated.

Surface storage tanks in the Upper Tank Farm can be served adequately with the pumps in Pump House 91. Five positive displacement pumps have a total rated capacity of 11,400 bbl/hr. They augment the fuel oil capacity of the Red Hill system, and they are suitably situated to feed the Mike Docks and Sail Dock S-1.

Situated in the Middle Tank Farm, Pump House 31 contains three displacement pumps with a total capacity of about 4200 bbl/hr. Two of these pumps have steam turbine drivers.

They can take suction from adjacent surface tanks and underground reservoir. In addition to fueling at Mike Docks, these pumps can be used for oil transfers between tanks.

The condition of and recommendations for abandonment of Pump House 77 have been covered in Section I of this report.

With the decision against fueling at docks in the lower end of the shipyard, the pumping facilities in Pump House 76 are required only for supplying fuel to the power plant from two tanks in the Lower Tank Farm and for handling waste oils. For this service, the pumps are adequate.

The eight lube oil pumps in Building 88 have a total capacity of about 1000 bbl/hr. This capacity is adequate for the desired bulk transfers of lube oil to and from the tanks in this building.

The underground pump house at the purification plant contains seven pumps which are adequate for the service. Two are gear pumps for lube oil service with a capacity of 430 bbl/hr. They are used for supplying lube oil to submarines at Sail Docks from this underground storage. Four centrifugal pumps are used for pumping diesel oil from the underground storage primarily for fueling. Their total capacity is about 2200 bbl/hr. A small rotary pump is used in defueling operations.

In addition to these principal pump stations, there are five auxiliary ones. At the Middle Tank Farm, Building 162 contains a centrifugal transfer pump which has been in diesel oil service. It is now connected with the kerosene system, and it would be useful for transfer of kerosene to Halawa drumming plant if a line were to be installed. The remaining four pump stations are for pump out and defueling purposes. They are located one on the How Dock lines near Halawa gate, one at Kuahua Island near King Docks, one for defueling at the submarine base near Sail Docks, and one for pump out in the shipyard area at Baker Docks. The latter would be inadequate if

Baker Docks were to be used for fueling. The urgently needed rehabilitation work on Pump House 649 at Kuahua Island is discussed in Section I of this report. ?

G. Valve Controls

The petroleum system contains no automatically operated control valves other than pressure relief valves on pump discharge lines and pressure control to truck loading rack. Operating valves in the Red Hill underground system are electric motor operated from central control rooms. Hand operated gate valves comprise most of the valves in the entire system. They are located wherever required for isolating equipment or directing of flow. In general, valve controls are adequate. There are many cast iron valves in petroleum system service, mostly in the older installation. Care should be taken at high fueling rates that none of these valves become dangerously overpressured beyond their rating. Also, care should be exercised to avoid mechanical shock to these cast iron valves.

H. Dock Connections

The number of outlet connections on the docks is quite ample. In most cases the size is adequate for the particular service and is in proportion to the size of the supply headers.

I. Storage Capacity After Rehabilitation

The system storage except for roofs of surface tanks and the leaky concrete underground reservoir is useable now. Rehabilitation of these tanks has been recommended. Capacity is tabulated on Page 2 of Section I, and is in summary as follows:

	<u>Total Storage Capacity Bbl.</u>
Fuel Oil	8,235,500
Diesel Oil	932,630
Kerosene	100,000
Gasoline	304,620
Lubricating Oil	54,700
Ballast and Slop	200,550
	<hr/>
Total	9,828,000

Should it be decided as indicated by letter from Officer in Charge, dated March 9th, not to use 13 tanks in the Lower Tank Farm, storage capacity will be reduced by 650,000 barrels. If the 195,000 barrel reservoir in the Middle Tank Farm is also not repaired, the total reduction in fuel oil storage capacity will be 845,000 barrels thereby reducing total fuel oil storage capacity to 7,390,500 barrels.

J. Additional Facilities Required to Meet Indicated Deficiencies from Stipulated Requirements

The above discussion indicates that deficiencies in capacity of the rehabilitated system are limited to the fuel or diesel oil services to and from the How, King, Sail, and Mike Docks. Additional facilities beyond rehabilitation calculated to be required in order to meet stipulated requirements are as follows:

How Docks

Diesel Oil:

- (1) 2400 ft. of 12" feeder line from Halawa Pump Out Pump House to the barge wharf, H-7-8
- (2) 700 ft. of 8" dock header to serve H-7-8

King Docks

Fuel Oil:

- (1) 1800 ft. of 16" line to King 1-3-5 from dock valve chamber
- (2) 500 ft. of 16" line to King 7-8 from dock valve chamber

Diesel Oil:

- (1) 500 ft. of 10" line from Kuahua valve chamber to King 11 header
- (2) 500 ft. of 10" line to King 7-8 from King valve chamber
- (3) 1800 ft. of 14" line to King 1-3 and serving King 5

Sail Docks

Diesel Oil:

- (1) 400 ft. of 10" line from new 14" feeder, required for Mike Docks, to shore end of S-1
- (2) 1100 ft. of 8" line along S-1 to Pier 1
- (3) 400 ft. of 6" line from Pier 1 to Pier 4
- (4) 1400 ft. of 6" line from Tunnel 1 to S-10
- (5) 1800 ft. of 6" line from S-19 to S-21

Diesel Defueling:

- (1) 1400 ft. of 8" line from S-21 to existing 6" line at S-19
- (2) 2600 ft. of 8" line from S-1 to S-14
- (3) 75 hp booster pump at S-19
- (4) 50 hp booster pump at Pier 3
- (5) 50 hp booster pump at S-14

Mike Docks

Diesel Oil:

- (1) 2600 ft. of 14" line from Pump House 91 and around Merry Point. If the operational interchange of the relocated 16" fuel and 12" diesel oil lines proposed above is accepted, this construction item can be eliminated. The exchange of lines if permanent would reduce the potential usefulness of the shipyard fueling facilities and the Lower Tank Farm
- (2) 500 hp of new pumping facilities at Pump House 91

4. Recommendations Concerning Protective Measures for Sub-Surface Piping which has been Subject to Aggressive Attack of Either Galvanic or Electrolytic Nature

A. Summary

Our recommendations are:

(1) Immediately install cathodic protection on the Pearl City and Ewa Junction to Barber's Point gasoline lines before the inadequate coating fails.

(2) Improve scope and effectiveness of existing cathodic protection of Red Hill outlet lines.

(3) Eliminate harmful stray current effects on Navy Base pipe lines.

(4) Apply coating on all new buried steel pipe lines and repair sections in accordance with Bureau of Yards and Docks Specification 34Yb.

B. Discussion

(1) Electrolysis Survey of Pearl City and Ewa Junction to Barber's Point Gasoline Lines

The insulation value of the line coating was checked and an electrolysis survey consisting of McCollum meter readings was made. Cathodic protection was recommended and because of the condition of the pipe coating immediate installation was urged. Detail of the pipe inspection and McCollum meter readings are presented in Section VI. Recommendations for cathodic protection and drawings showing details are presented in "C" below.

(2) Electrolysis Survey of Petroleum Facilities within Pearl Harbor Naval Base

Earth-Line Currents

McCollum meter readings were made at a number of excavations for the purpose of inspecting the pipe lines. The record of these readings are in Section VI. These earth current readings and soil resistance measurements in general indicate the corrosive soils to be limited to certain yard areas. The consultant's report of this work is presented in "D" below.

Recommendations for improving and extending cathodic protection on fuel and diesel piping from Red Hill outlet to How Docks and main feeder to King Docks and Sail Docks 19, 20 and 21 are included in Section I.

Stray Currents

The rapid failures of buried oil lines experienced in the Submarine Base area indicated that these may be affected by electrical currents from a foreign source. Electrical measurements were made between the buried oil lines and the neutral D.C. distribution bus in Substation Building 626 in which is located the direct current rectifiers. These observations indicate that stray currents exist in this vicinity and are affecting the diesel and lubricating oil lines. It is believed that these currents are caused by open circuit or high resistance connections in the bare neutral common to the A.C. and D.C. systems between Building 626 and the docks and by the bare neutral being in contact with cable sheath between the rectifiers and the neutral bus at the distribution cubicles.

This investigation of stray currents is at the date of this report still continuing and will be reported later. However, it now appears that the 18"-16" fuel oil and 12" diesel oil lines along Pierce Street have been affected by both stray currents and local galvanic action. The buried lubricating oil lines near

Substation Building 626 have had a very short service life, and this aggressive attack is quite probably due to stray currents.

There is also a definite possibility that stray currents exist in the shipyard area. Some evidence has been obtained by ammeter readings between the ground bed and ground bus at Substation 99. However no directional or quantitative analysis of this current has been made.

(3) Pipe Coating

In general the steel pipe in the vicinity of Pearl Harbor and in the Navy Yard has been installed with coatings of low insulation value. The lines from the Red Hill tunnel portal to the How Docks are an exception, the coating on these lines meets Bureau of Yards and Docks Specification 34Yb, and where inspected was found to be in excellent condition.

The soil in the Navy Yard consists broadly of lava, coral and materials dredged from the harbor, and lines buried in such materials should be carefully installed. Specification 34Yb properly covers the above condition, and specifically points out that lines buried in very bad soil conditions should have the coatings reinforced with gunite.

Our recommendation is that all new steel pipe lines and repair sections should be coated as specified by Bureau of Yards and Docks Specification 34Yb, and in no case should an exception be made.

In several of the yard areas, particularly in the area near Pump House 91 and the head of the 1010 Docks in the shipyard, excavations during the past several years have revealed rather large quantities of oil underlying the surface. In the 1010 area near the power plant a French drain has been installed. This is a tile pipe with uncemented joint surrounded by rock and about at the water level. This method is a very effective means of recovering oil from these underground areas and

is one to be recommended. It would be necessary to install a skimmer, pump and tank at each location as has been done at the power plant. A program of this type is rather important because this underlying oil acts as a solvent on coating of the buried lines in the various areas and the bare metal will be subject to electrolytic or galvanic attack.

C. Cathodic Protection of Navy Gasoline Line, Pearl City and Ewa Junction to Barber's Point

Electrolysis measurements were made on the Ewa Junction Barber's Point gasoline line, and on the lines in the vicinity of Pearl City pump house and the Victor Docks. These measurements and their interpretation were under the direction of William R. Schneider consulting with Gordon N. Scott. The purpose of this electrolysis testing was to locate the sections of these lines where electrolysis would ultimately cause failure, and to design a cathodic installation that would provide the required amount of electrical protection.

A preliminary inspection of the line was made to determine the condition of the coating, observe low marshy sections, dry areas and interfering structures. Based upon these observations electrolysis measurements were made at one-half mile intervals, and additional tests were made where these tests indicated the necessity.

The electrolysis measurements were made with a McCollum earth current meter, shepard rods to determine soil resistance, and a Weston Electrolysis volt-ammeter. A record of these data are included in Section VI, McCollum Meter Readings.

From the results of these measurements the electrical characteristics of the coating used on the line was determined, and the length of pipe line to which a single rectifier and anode bed would give protection. These data were subsequently combined with those obtained by Gordon N. Scott for the Army's distribution system which is directly connected to and a part of

the Navy system. The recommendations for cathodic protection of the entire system are shown on the accompanying Sketch 1.

Briefly the recommendations are for the installation of three rectifiers on the portion of the line under operation by the Navy, and four units in the portion of the line operated by the Army. These units are designed with three types of anode beds:

- (a) Type A comprising 8 - 6" x 80" Graphite Anodes laid vertically on 15 foot centers, paralleled by insulated 4/0 conductor center tapped for lead to rectifier. Type A Anode to be installed at Victor Docks, also recommended for Aiea and Hickam Rectifier Stations.
- (b) Type B comprising 500 lineal feet of scrap 8-inch pipe or other steel sections weighing approximately 7 tons for use with two rectifier stations between Ewa Junction and MCAS, to Barber's Point.
- (c) Type C comprising 350 lineal feet of eight inch scrap pipe or other steel sections weighing approximately 5 tons for use with two rectifier stations between Ewa Junction and Wākakalaua Tank Farm.

Distance from anode to pipe line should not be less than 350 feet and preferably 500 feet. This separation also applies to location of anode with respect to adjacent underground structures. (The requirement is waived for the Victor Dock installation.) The accompanying Sketch 2 shows the proper layout for all types of anodes. Their location and other details are shown on Sketch 1. ✓

The soil characteristics are such that the size and type of the corrosion eliminators and carbon anodes for Rectifier Stations 1, 2 and 3 can be specified and purchased. The specifications for the eliminators are included herewith.

Before the pipe lines can be placed under cathodic protection it will be necessary (a) to render the pipe lines electrically continuous (b) to insulate all lateral connections to tanks, loading racks and other structures (c) to cross-bond parallel lines at appropriate intervals.

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In general the insulation flanges and bonding are shown on Sketch 1, however the installation will have to be thoroughly checked to make certain that all valves, flanges, etc., are bonded, and that all insulation flanges are removed.

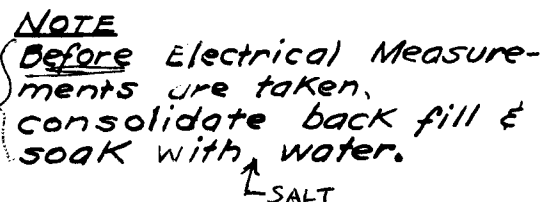
It will also be necessary to locate and identify all neighboring underground structures before placing the cathodic protection units in service.

After the type B and C anodes Nos. 4, 5, 6, and 7 are installed the overall resistance of the anode, pipe line and connecting cables on each is to be measured. This can be done by connecting the anode lead to the positive terminal of an ordinary fully charged 6 volt storage battery. The lead from the pipe line is connected to one cell, two cells and three cells, and the current output and battery terminal voltage is measured for two, four and six volts, respectively. Accompanying Sketch 3 shows diagrammatically the method and readings required. We recommend that these data for anodes, 4, 5, 6, and 7 in high resistance soil be submitted to Gordon N. Scott for analysis before final rectifier recommendations are made. This conforms with the arrangement previously made between Dr. Scott and the Army, and consolidates the rectifier specifications.

We recommend that an engineer experienced in cathodic protection place the installation in service and perform the necessary follow-up work to determine its affect on other structures and install proper bonding to eliminate possible damage to any found to be affected.

Should cathodic protection be applied to these gasoline lines, the following instruction should be issued to all mainte-

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SECT III-CATHODIC PROTECTION-SKETCH 3

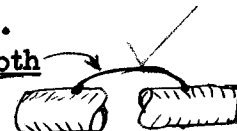
BECHTEL CORPORATION

CATHODIC PROTECTION - OVERALL
RESISTANCE - OIL HANDLING FACILITIES
PEARL HARBOR

JOB NO.	DRWG. NO.	REV.
1426	E-P-2	0

nance crews that before a valve is removed, the line cut, or the continuity of the pipe line otherwise interrupted?

- (a) All rectifiers are to be ^{turned off-} ~~rendered inoperative.~~
- (b) A conductor is to be shorted to the pipe on both sides of the proposed work.



The direct-current ^{Rectifier} voltmeter and the ammeter readings should be recorded monthly. These readings may show an output decrease as the dry season advances, and an increase of output during the rainy season. These changes are normal and no readjustment of the rectifier is required. However a sudden decrease or complete stoppage of the rectifier output either indicates a broken or corroded anode cable, or an extreme deterioration or loss of anode material, and should be immediately investigated.

We express preference for the Type C. B. Rexselen Rectifier manufactured by the Electrical Facilities, Inc., 4224 Holden Street, Oakland 8, California, because of the many successful operation installations in the Coastal Areas of California, wherein the atmospheric conditions are quite similar to the Pearl Harbor area. On the other hand, rectifiers purchased from either the Federal Telephone and Radio Corporation, Newark 1, New Jersey, or General Electric Company, Bridgeport, Connecticut, should give good service. These instruments are generally ordered by Type Number, phase, cycle and input, and D.C. output and require no detailed specification. The following description of the three rectifiers, which can be ordered at once, we believe is sufficient to obtain a satisfactory unit:

Rectifier Station No. 1 (Hickam)

One Type C. B. Rexselen Corrosion Eliminator Single Phase
110 Volt 60 Cycle A.C. Input 8 - 10 Volt 50 Ampere
D.C. Output

Rectifier Station No. 2 (Aiea)

One Type C.B. Rextselen Corrosion Eliminator Single Phase
110 Volt 60 Cycle A.C. Input 8 - 10 Volt 50 Ampere
D.C. Output

Rectifier Station No. 3 (Victor Docks)

One Type C.B. Rextselen Corrosion Eliminator Single Phase
110 Volt 60 Cycle A.C. Input 8 - 10 Volt 50 Ampere
D. C. Output

Required

3 - Corrosion Eliminators as above specified.

D. Consultant's Report of Electrolytic Survey of Petroleum
Facilities Within Pearl Harbor Naval Base

Pearl Harbor, T. H.
December 27, 1948

Bechtel Corporation
U. S. Post Office Box 94
U. S. Naval Base
Pearl Harbor, T. H.

Subject: Electrolytic Inspection of Petroleum
Facilities at Pearl Harbor

Gentlemen:

In the following report the electrolytic inspection of the petroleum facilities at Pearl Harbor is discussed in detail.

This discussion pertains to distribution facilities within the Naval Base. The gasoline distribution system, which is outside the Naval Base, is discussed in a separate report.

Red Hill Outlet and How Dock Lines:

From the Red Hill Outlet Tunnel north to the Halawa Pumping Station there are five lines:

- One 32" steel, welded and double wrapped, bituminous coating fuel oil line
- One 18" steel, welded and double wrapped, bituminous coating fuel oil line
- One 16" steel, welded and double wrapped, bituminous coating diesel line
- One 12" steel, welded and single wrapped, asphaltic coating ballast line
- One 4" drain line,

All of these lines are intended to receive electrical protection from the cathodic corrosion eliminator installed in the pump house, and tests made in these lines at Bell Holes 24, 25 and 26, as far as 1700 feet south of the pumping station showed that the pipe is picking up current from the soil at the rate of 0.3 milliampere and up, per square foot of surface and therefore not corroding.

To insure the uninterrupted continuation of this protection, the negative cable from the cathodic corrosion eliminator should be extended to the 12" ballast line and the cable to the 16" Diesel line should be reconnected, this connection having broken away from the clip.

The ballast and diesel lines are now receiving protection indirectly from the protected lines through the valve and pump connections.

From the pump house west to the How Docks there are five pump lines as follows:

- One 32" steel, welded and double wrapped, bituminous coating fuel oil line
- One 18" steel, welded and double wrapped, bituminous coating fuel oil line
- One 16" steel, welded and double wrapped, bituminous coating diesel line
- One 12" steel, welded and single wrapped, asphaltic coating ballast line
- One 6" drain line.

These lines are fully or partially protected by the cathodic corrosion eliminator in the Halawa pumping station, picking up 19 milliamperes from the soil at a point 800 feet west of the station.

The two foregoing groups of lines were examined at three points, 1400 and 600 feet south of the pumping station toward the Red Hill tunnel and 800 feet west of this station

toward the How Dock, Bell Holes 24, 25 and 26. The short lengths exposed for inspection showed no signs of corrosion, thus confirming the information given by the electrolysis test.

The "anode" or "ground bed" installed about 1942 at the Halawa Pump House consists of a bed of nine 40' lengths of 8" bare pipe placed in moist salt marsh soil on the south bank of Halawa Creek, 12" below the surface, at the tide level. This bed has been 50% expended during its six years of service.

Tests made on the interconnected 16" fuel oil and 8" diesel oil lines on the north bank of Halawa Creek, and near the How Docks 7 and 8, showed that these lines were also receiving protection from the cathodic corrosion eliminator, picking up from 3.8 to 14.6 milliamperes per square foot of pipe surface. A visual inspection of the short lengths uncovered for the test revealed no corrosion.

The 18" welded steel and wrapped fuel oil line, and the 10" welded steel and wrapped diesel oil line, Bell Hole 62, showed a heavy discharge of current to the soil, of 11 and 9 milliamperes per square foot respectively.

} BAD
CORROSION
OCCURRING!
HERE!

This potentially corrosive condition can be mitigated by bonding the 18" to the 32" fuel oil line at the head end of the How Dock and the 10" diesel oil line to the 16" diesel oil line at the same location. The Halawa pumping plant cathodic corrosion eliminator, when turned on and off, showed very little effect at this location, which is within 2000 feet and therefore within working range of the unit, thus showing the need for such bonding. These pipes at this point are at a depth of seven feet in soil of naturally low resistance and unevenly permeated with oil, a condition which is favorable to corrosion.

DONE?

The twenty-five year old cast iron water line to Aiea was tested on the south bank of Halawa Creek, and found to be picking up 6 milliamperes per square foot of surface. Fifty per cent of this was found to be due to the nearby cathodic corrosion eliminator in the Halawa Pump House. Possible damage

by above cathodic protection unit can be mitigated by bonding 24" water line to negative terminal of corrosion eliminator, adjust bond resistance to reduce current flow along pipe lines, to zero.

Lower Tank Farm Feeder:

This welded steel and asphalt coated fuel oil line, installed in 1942, starts at the Red Hill tunnel entrance on North Street and continues south near Pierce Street, reducing in size in three steps from 22" to 12" at a point about 200 feet north of Fuel Oil Pump House No. 77. From that point on it continues as a 12" screw connected, mostly bituminous painted line, along South Avenue to the Fuel Oil Pump House 76.

Electrical tests were made along this line with the earth current meter and by the drop of potential method, with the following results:

A test made at the intersection of North and Pierce Streets, Bell Hole 85 showed that the 22" pipe was discharging into the soil at the rate of 5 milliamperes per square foot of pipe surface, which is in the potentially corrosive range. Potential drop tests show that this corrosive area is centered under Beeman Center, a concrete floored area directly over the pipe.

On Shane Street south of Beeman Center, Bell Hole 58, the line has been cut and blanked. For testing purposes this cut was temporarily reclosed by bonding over with a copper cable. The pipe was then found to be discharging at the rate of .7 milliampere per square foot, although before bonding a small pick up was observed. This change indicated a tendency to discharge under Beeman Center. The resistance of the soil is low, 300 ohms.

An oil leak under 65 pounds pressure test has been reported between Bell Hole 58 and Beeman Center and subsequent leak tests with water indicated leakage under the Beeman

Center at the end toward Bell Hole 58. Substantially the same conditions, but possibly more **severe**, were found in the parallel 12" diesel oil line.

This failure may be due to either of two causes, or their combined action:

(1) A pipe installed in a saline and low resistance soil, under a concrete (or other air tight) cover is generally found to be in a very corrosive environment which appears to be confirmed in this case, by the electrical tests. } ☆

(2) A second probable cause of the pipe failure is the settling of the ground in this locality, which occurred after the pipe was installed. The surface has since that time been regraded, but the soil subsidence may have broken a welded connection or caused failure of the pipe covering or highly stressed the pipe locally, a condition favorable to corrosion. } ☆

(3) The failure may have been due to a combination of the two effects, the soil pressure breaking the pipe at a point weakened by corrosion, a combination that has occurred elsewhere on a number of occasions. } Most Recently 12 July 1963 at junction of Ft. Weaver Rd. and Cane Row Rd. at Ewa Plantation Hospital

The portion of the fuel oil and diesel line which is under Beeman Center is no longer considered serviceable and has been blanked off.

Continuing south from Shane Street, along Pierce Avenue and North Road the electrical tests showed no current discharge on the fuel oil lines, Bell Holes 57, 55, 56, 52.

The parallel diesel oil line in this vicinity however, showed an appreciable discharge of 2.8 milliamperes at Bell Hole 57.

About 100' south of Bell Hole 52 the fuel oil line changes from 12" welded steel to 12" screwed connection steel pipe, continuing to Pump Houses 76 and 10.

Bell Holes 84A, 84, 83, 82A, 82 covering this screwed section to the start of the Lower Tank Farm showed moderate pick up. At this point the soil cover on the pipe increases to about 12', due to the tank farm berm, and discharges are noted at Bell Holes 18 and 2, the latter amounting to 6.1 milliamperes per square foot. Such discharge under increased ground cover is characteristic.

This screwed pipe is about 24 years old. The cover is an ineffective bituminous paint. Many failures have occurred, most of which were patched. A section along the Marine Corps area appears to have been replaced.

Oil was observed at Bell Holes 84, 18 and 2.

The line is generally and severely corroded and deeply pitted along most of its length. Aside from the variation in ground cover no unusually severe conditions from the standpoint of electrolytic corrosion were observed, although these may have been present in the past. Condition of the pipe is attributed to age and lack of adequate covering.

Shipyard Feeder:

The 24" line from the Red Hill tunnel outlet south to the pumping plant No. 91 is generally above ground, and, not being subjected to soil corrosion, is in good shape. This line is buried from a point about 600 feet north of Pump House 91, to 300 feet south. Line size changes at Pump House 91 to 18". The buried sections have a light bituminous coating. No electrolysis tests were made at these buried sections. The lowest area near Pump House 91 is the most likely point of discharge.

The feeder from Pump House 91 continues back of Merry Point, parallel to, and well back of, Baker Docks, 22, 23, 24, 25, along and back of the headwall of the Repair Basins, and through the shipyard along Seventh Streets and Central Avenue to tie in with Pump House 76. Size decreases from 18" to 16", 14" and finally 12". This feeder supplies the ship-

yard berths and the shipyard power plant via short stub feeders and waterfront lines.

Electrolytic tests were made back of Baker Dock 25. Bell Holes 21 and 22, and Bell Hole 23 on a nearby stub feeder, showing pickup of 2.2 and 8. and 3 milliamperes respectively. Another test was made at Bell Hole 69 showing a pickup of 30 milliamperes.

The stub feeder to the power plant Bell Hole 64 showed a discharge of 6.4 milliamperes.

The line observed, where of steel, was in good condition with a felt wrapping and a double bituminous coating at Bell Holes 21 and 22 and unprotected at Bell Hole 69. The line along Seventh Street includes a cast iron section from about the power plant stub feeder to Central Avenue. This shows graphitized cast iron at Bell Hole 65. This feeder is blanked off between the head of Merry Loch and stub feeder to the power plant.

Upper Tank Farm:

The Upper Tank Farm consists of thirteen 150,000 barrel tanks. Working lines in the Upper Tank Farm include 8", 12", 14" 16" and 24" steel filling lines, and 8" cast iron drain lines. Filling lines are generally above ground except under berms. Drain lines are generally buried. Tests were made at Bell Hole 41 on the 24" filling line and a pick up of one milli-ampere noted. Soil resistivity was 1500 ohms. At Bell Hole 28 the 18" fuel oil filling line showing a pick up of .6 milliampere and 2000 ohm soil. Lines were coated with bituminous paint. The soil resistivity was high for its moisture content indicating low salt content and natural freedom from electrolytic attack.

For Zinc Anodes, Use	Mg m ₂ put	USE MG ANODES OF WEIGHT	SOIL CORROSION VALUES	MEASURED SOIL RESISTIVITY VALUES	SOIL RESISTIVITY VALUES (OR ADJECTIVES TO USE)
23 lb	300	50 lb.	HIGHLY CORROSIVE	Below 1000 ohm-cm	VERY LOW SOIL RESISTANCE
23 lb	200-220	32 + 17	VERY	1000 to 3000	LOW (Pear Harbor SOIL AVERAGES) ✓
14	50	9 lb	MODERATELY	3000 to 5000	MEDIUM ✓
	50 to 100	9 lb	MILDLY	5000 to 10,000	HIGH ✓
	0	nil	RARELY	Above 10,000 ohm-cm	VERY HIGH ✓

Use Zn on bare pipe up to 1500 ohm-cm & coated up to 2500.

Use Mg on bare pipe up to 5000 ohm-cm & coated up to 10,000.

-94-

THIS IS A PRACTICAL CORROSION SCALE TO USE

Middle Tank Farm:

The Middle Tank Farm consists of ten 50,000 barrel tanks, connected by a system of 12" fuel oil lines and 8" cast iron drain lines.

The fuel oil lines are welded steel, coated with a heavy bituminous dip, and the cast iron drain lines have bell and spigot caulked joints. Filling lines are above ground except under berms. Drain lines are buried.

Earth current meter tests were made in this yard at Bell Holes 78, 79, 81, 75, 77, 73, 74, 49, 48, 46, 47, 45 and 51 showing that with the exception of very small discharges at Bell Holes 79 and 47, the underground pipes were picking up current from the surrounding soil. They may therefore be considered as being free of electrolytic corrosion.

Where the filling and drain lines leave the tank farm and proceed to Pump House 77, which is 900 feet distant, they pass across a low filled area naturally draining into the head of Merry Loch. Here conditions favorable to electrolytic corrosion are to be found and evidence reported but measurements were not taken at Bell Hole 51 where the pipes were exposed due to oil soaked soil.

Lower Tank Farm:

The fuel oil lines connecting the thirteen 50,000 barrel tanks in the Lower Tank Farm are 8" and 12" screw connected, and 24" welded steel lines protected by a dip or brush coat of bituminous material.

Tests were made at Bell Holes 1, 3, 4, 4A, 5, 6, 9, 11, 12, 13, 14, 15, 17A and 17. Small pick up or insignificant discharges were noted except in Bell Holes 9, 17A and 12, which were as follows:

Bell Hole	Discharge	Soil Resistance
9	2.9 m.a.	800
12	20.0 "	1200
17A	2.7 "	500

Bell Holes 9 and 17A were under berms and possibly the extra soil cover accounts for the moderate discharge. Bell Hole 12 is in a line extending under the railroad tracks to supply oil to Building 58. It is not now required. Cause of the high discharge is not known, but represents some unusual condition.

Very truly yours,

Wm. R. Schneider

SECTION IV--ESTIMATES OF COSTS

	<u>Page</u>
1. Discussion	96
2. Estimated Cost of Rehabilitation of Petroleum Facilities as Recommended in Section I	97
3. Estimated Cost of New Facilities to Meet Navy Requirements as Stipulated in Letter Dated November 15, 1948, and Revised by Letter Dated March 9, 1949	101
4. Estimated Cost of Recommended Alterations and Additions to Red Hill Underground Tanks 1, 2, 3, 4, to Provide Storage for Aviation Gasoline and Jet Fuel in Tanks 1 and 2	103

1. Discussion

There are presented herewith estimates of costs as follows:

(a) Estimated cost of rehabilitation of petroleum facilities as recommended in Section I.

(b) Estimated cost of new facilities to meet Navy requirements as stipulated in letter dated November 15, 1948, and revised by letter dated March 9, 1949.

(c) Estimated cost of recommended alterations and additions to Red Hill underground Tanks 1, 2, 3 and 4 as necessary to provide storage for aviation gasoline and jet fuel in Tanks 1 and 2.

Estimates of costs involving construction work were based on preliminary design only and without the preparation of detailed engineering plans. The cost of installing transformers and electric distribution lines for the pumping units has not been included.

The cost of rehabilitation, particularly of buried piping, cannot be accurately estimated nor the scope of the work accurately predicted in advance. Our estimates of such costs are based on field observations, information gained in piping and tank repair work to date, and beyond that upon assumption and other experience.

Major items of rehabilitation or new construction work which can be accomplished separately are estimated separately for convenience in planning.

Estimates include man hours of labor as well as total costs. In estimating labor costs the rates in effect in Honolulu, March 15, 1949, were used.

The estimates of costs, as presented, are sufficiently accurate for use in planning such as budgeting the cost of the work and decision as to feasibility and desirability of improvements.

2. Estimated Cost of Rehabilitation of Petroleum Facilities as Recommended in Section I

This work is described in detail in Section I and is presented in the order of priority recommended in Section V.

	<u>Estimated Man Hours of Labor</u>	<u>Estimated Cost</u>
A. Work Classified as Priority One		
(1) Cathodic protection Pearl City and Ewa Junction to Barber's Point gasoline lines	3,400	30,900
(2) Abandon 18" fuel and 10" diesel oil lines under Building 490 and reroute to avoid building, etc.	3,100	16,300
(3) Improve and extend cathodic protection on fuel and diesel oil piping from Red Hill outlet to How and King Docks and Sail Docks 19, 20 and 21	500	2,300
(4) Abandon 18" - 16" fuel and 12" diesel route in Submarine Base Area, and relocate above ground parallel to railroad track	5,000	30,100

	<u>Estimated Man Hours of Labor</u>	<u>Estimated Cost</u>
(5) Test and repair main fuel oil line through shipyard to Lower Tank Farm	4,500	\$ 15,100
(6) Test and repair lubricating oil lines Building 88 to Mike Docks	4,400	15,200
(7) Remove loose grout from walls and Amercoat bottom only of Red Hill Tanks 14 - 16	900	3,500

B. Work Classified as Priority Two

(1) Repair surface storage tanks in the following order:		
(a) Power plant fuel supply		
Lower Tank Farm (2 tanks)	7,400	24,200
(b) Upper Tank Farm (13 tanks)	64,000	212,500
(c) Middle Tank Farm (9 tanks)	37,500	123,300
(2) Install recording pressure gage seal in drain line, and collection system for bleeder and pump gland leakage Pearl City pump house	1,100	5,100
(3) Test and repair all dock piping and all laterals from headers to docks, except shipyard	40,500	139,800

	<u>Estimated Man Hours of Labor</u>	<u>Estimated Cost</u>
(4) Test and repair tank farm piping and install separator boxes in drain line, Upper and Middle Tank Farms (2 boxes only). Lower Tank Farm piping to Power Plant fuel supply tanks only to be repaired	4,000	16,300
(5) Test and repair lubricating oil distribution system pipe lines	3,400	11,300
C. Work Classified as Priority Three		
(1) Test and repair kerosene lines Tanks 33 - 35 to docks	400	1,700
(2) Recondition two 13,500 barrel concrete underground tanks Ewa Junction Alternate--reinforced gunite coating; Man Hours 3,400 *; Cost \$56,700	7,500	20,000
(3) Repair lining eight underground concrete tanks, Diesel Purification Plant	1,000	3,400
(4) Repair 195,000 barrel underground concrete reservoir in Middle Tank Farm	5,900*	162,400

* Subcontract Basis

	<u>Estimated Man Hours of Labor</u>	<u>Estimated Cost</u>
D. Work to Rehabilitate Petroleum Facilities in Shipyard Area		
(1) Repair 13 surface storage tanks Lower Tank Farm. Test and repair piping and install separa- rator box (1 only)	40,700	\$ 132,800
(2) Test and repair shipyard dock lines and laterals thereto	17,900	59,600
E. Summary		
Priority One Work	21,800	113,400
Priority Two Work	157,900	532,500
Priority Three Work	14,800	187,500
	<hr/>	<hr/>
Sub-Total	194,500	\$ 833,400
Facilities Not Used--Shipyard Area	58,600	192,500
	<hr/>	<hr/>
Grand Total	253,100	\$1,025,800

Amended by [signature]

3. Estimated Cost of New Facilities to Meet Navy Requirements as Stipulated in Letter Dated November 15, 1948, and Revised by Letter Dated March 9, 1949

The work estimated below is described in detail in Section III, 3, J.

	<u>Estimated Man Hours of Labor</u>	<u>Estimated Cost</u>
A. Fuel Oil System		
(1) King Docks, 2300 ft. of 16" lines for dock headers	26,000	\$ 136,000
B. Diesel Oil System		
(1) How Docks, 2400 ft. of new 12" feeder and 700 ft. of 8" dock piping	16,000	87,000
(2) King Docks, new feeder and dock piping consisting of 1000 ft. of 10" and 1800 ft. of 14" lines	18,000	102,000
(3) Sail Docks, new feeder and dock piping as follows: 400 ft. of 10" 1100 ft. of 8" 3600 ft. of 6"	20,000	126,000
(4) Sail Docks defueling piping, 4000 ft. of 8"	18,000	104,000

	<u>Estimated Man Hours of Labor</u>	<u>Estimated Cost</u>
(5) Sail Docks defueling pumps, three, totalling 175 H.P.	2,000	25,000
(6) Mike Docks, 2600 ft. of 14" feeder and dock piping	18,000	100,000
(7) Mike Docks, new 500 H.P. pump at Building 91	6,000	46,000
	<hr/>	<hr/>
Total Diesel	98,000	\$ 590,000
Total Estimated Cost Fuel and Diesel	124,000	\$ 726,000

4. Estimated Cost of Recommended Alterations and Additions to Red Hill Underground Tanks 1, 2, 3, 4, to Provide Storage for Aviation Gasoline and Jet Fuel in Tanks 1 and 2

The work calculated below is described in detail in Section II, 4, and the corresponding reference paragraphs are indicated.

<u>Description</u>	<u>Estimated Man Hours of Labor</u>	<u>Estimated Cost</u>
(1) Prepare tanks 3 and 4 for diesel oil service (B-3)	11,000	\$ 73,200
(2) Vent piping, ventilation system, vacuum pressure valves, miscellaneous piping Tanks 1 and 2 (B-1,2,4)	13,000	72,200
(3) Replacing existing electrical and other equipment not meeting underwriters' requirement for the service condition (B-5, C-2, 3, 4)	2,000	30,000
(4) Fire protection (C-1)	1,500	25,800
(5) Continuous automatic gas sampling equipment four areas adjacent Tanks 1 and 2 (C-5)	500	4,500
(6) Alterations to insure tank tightness Sketch Red Hill 1 Section I (E)	19,200	83,600

<u>Description</u>	<u>Estimated Man Hours of Labor</u>	<u>Estimated Cost</u>
(7) Light oil distribution facilities: (D)		
10" pipe line	35,000	236,000
Pump station	4,100	59,000
	<hr/>	<hr/>
Total	86,300	\$ 584,300

SECTION V--ORDER OF PRECEDENCE OF REHABILITATION WORK

1. Discussion

There is submitted herewith recommendations as to the order of precedence of accomplishment of the rehabilitation work on Navy petroleum facilities at Pearl Harbor recommended in Section I.

Recommendation as to relative priority of rehabilitation measures is a matter involving operating practicability, funds available, costs, and most importantly the major objectives in rehabilitation.

Recommendations below are framed on the basis of considering the petroleum facilities at Pearl Harbor as an industrial marine terminal, where much deferred maintenance and some obsolescence has brought the facility to a point where it can not now meet its former capacity in performance.

Within the above generally defined objective and considering the condition of the facilities as disclosed by survey we conclude:

(a) Much of the Plant distribution system is blanked off and out of service due to deferred maintenance and to such an extent that capacity is importantly restricted. However, this system is generally in such condition that it can be economically repaired and rehabilitated and this can be done now in most cases consistent with any improvements and increases that appear probable on information available to us. Rehabilitation of important parts of the distribution system is therefore assigned priority one.

(b) The plant storage except for roofs of surface tanks and the leaky concrete underground reservoir is useable as is and its condition does not handicap operations, nor is it known to be deteriorating at a rapid rate. The removal of grout splashes from the steel liners of the Red Hill underground tanks is essential to preserve this facility and is of the highest priority. Otherwise work on storage is, in general, priority two.

2. Order of Precedence

In accordance with the above, and referring to the recommendations for rehabilitation as presented in Section I, we recommend priority as follows:

A. Work classified as Priority One:

(1) Install cathodic protection on gasoline distribution system piping.

(2) Abandon 18" fuel oil and 10" diesel oil under Building 490 and reroute to avoid building. The new pipes should be laid with minimum cover and should be coated with either mastic or coating conforming with a Navy specification for the service condition. After this complete test and repair the remaining part of the old pipe.

(3) Improve cathodic protection on fuel and diesel piping from Red Hill outlet to How Docks and main feeder to King Docks and Sail Docks 19, 20 and 21.

Include 12" ballast line in cathodic protection by connecting with 4/0 cable to the cable which now connects the other lines to negative terminal of the rectifier.

Improve cathodic protection on the 32", 18", 16", and 12" lines from Red Hill outlet to How Docks by bonding across flanges, or other fittings causing high electric resistance with 4/0 cable.

Avoid damage to the 24" water main by bonding to oil lines connected to the negative terminal of the rectifier. A resistance installed in this bond should be adjusted to reduce the current flowing along the water line to a valve approaching zero.

Bond the 18" and 10" lines from How Docks through the Kuahua pump house to the valve pit near Red Hill Outlet with 4/0 cable.

Repair broken connection to ground bed member and cover anode.

(4) Relocate the 18" fuel oil and 12" diesel oil lines now routed through the Submarine Base Area. Test and repair sections of these lines between Red Hill outlet valve pit and the Diesel Purification Plant and other sections not relocated or abandoned. Abandon Pump House 77 and 12" fuel oil line to the Lower Tank Farm.

(5) Test and repair the main fuel oil feeder from Red Hill outlet through Pump House 91, through Shipyard to Lower Tank Farm.

(6) Test, repair and recoat buried lubricating oil lines under pavement from Building 88 to Mike Docks. Should lines be generally corroded they should be replaced with pipe, factory coated with mastic or equivalent.

(7) Remove loose grout from walls and Amercoat bottom 1/2" plate only of Red Hill Tanks 14 and 16. This work is recommended for all Red Hill tanks which upon inspection are found in a comparable condition. ✓

B. Work classified as Priority Two:

(1) Repair surface storage tanks progressing through the tank farms in the following order: Upper (13 tanks), Middle (9 tanks), Lower (2 tanks) only.

(2) Pearl City pump house area.

Provide pressure recording gage for leak testing gasoline lines to docks.

Install seal in tank drainage line.

Install equipment for separating gasoline leakage from pump glands from existing sump.

(3) Test and repair all dock lines and lateral feeders thereto, except shipyard area.

(4) Tank farm piping:

Test and repair oil distribution piping in the tank farms in the following order: Upper, Middle, Lower (lines to and from Power Plant fuel supply tanks only).

Disconnect oil drains from surface storage tanks to harbor drains at Pump Houses 76, 77 and 91 and install one separator box at Pump House 91, and one at junction of 8" drain lines near Tank 29.

(5) Lubricating oil distribution lines:

Test and repair lubricating oil lines in the following order:

Around point of Submarine Base
Across head of Merry Loch
From Diesel Purification Plant to truck rack
From Sail Docks to 10,000 barrel tanks at Halawa

C. Work classified as Priority Three:

(1) Test and repair kerosene piping from Tanks 33 and 35 to Mike Docks and truck filling stand.

(2) Repair 13,500 barrel aviation and motor gasoline tanks at Ewa Junction.

(3) Clean and repair lining failures in eight concrete tanks at the Diesel Purification Plant.

(4) Repair 195,000 barrel underground concrete reservoir in Middle Tank Farm.

D. Work to rehabilitate petroleum facilities in Shipyard:

- (1) Repair 13 surface storage tanks in Lower Tank Farm, test and repair piping and install one separator box (only).**
- (2) Test and repair shipyard dock lines and laterals thereto.**

SECTION VI--APPENDIX

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- A. McCollum Meter Readings--Navy Yard
Fuel Oil and Diesel Oil Lines
(2 sheets)
- B. Bell Hole Inspection Data--Navy Yard
Fuel Oil and Diesel Oil Lines
(2 sheets)
- C. Bell Hole Locations--Gasoline Lines
- D. Surface Tank Inspection Data
- E. Repairs to Reinforced Concrete Underground
Reservoir--Middle Tank Farm
- F. Development of Barrel Section Showing
Tell Tales, Tank No. 16
- G. Fuel and Diesel Oil System--Distribution
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- H. Lubricating Oil System--Distribution
and Storage
- I. McCollum Meter Readings--Gasoline Line
Pearl City to Barber's Point

4. Photographs

- A. Typical Tank Roof Corrosion Surface
Storage Tanks
- B. Typical Corrosion of Buried Fuel and
Diesel Oil Lines in Submarine Base
Area
- C. Excavation of Oil Lines in Submarine
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- D. Repair of Weld Failure, Merry Point
Area
- E. Anode Bed at Halawa Stream Showing
Loss of Metal After Five Years
Operation

NAVAL SUPPLY CENTER
Pearl Harbor, T.H.
Navy 128, c/o F.P.Q.
San Francisco

Address Reply to
SUPPLY OFFICER IN
COMMAND and refer to:

NT4-9/JJ7
430

CF 13896

15 Nov 1948

From: Supply Officer in Command
To: Officer in Charge of Construction, NOy-16535

Subj: Contract NOy-16535 - Survey of Fuel and Lubricant
Storage and Distribution Facilities, Pearl Harbor.

Refs: (a) Com14 ltr NOy-16535 (80:D) to SOinC, NSC dtd
17 Sep 48.

(b) NSC Pearl ltr ser 10826 to SecNav dtd 7 Nov 47
and seven endorsements thereto

(c) BuDocks disp 292145 to Com14 dtd 29 April 48.

Encls: (A) thru (E) Bulk Storage and Distribution Requirements.

1. Reference (a) requests information on types and quantities of products to be stored, and number of berthing spaces for receipt and issue of these products.
2. Reference (b) requests authority to effect certain changes in the petroleum distribution system operated by the Naval Supply Center, Pearl Harbor.

3. Reference (c) advises that informal information from CNO indicates approval of reference (b) is doubtful and that it is questionable whether requirements of the fuel system can be established firmly at this time.

4. Enclosures (A) through (E) outline the bulk storage and distribution requirements. Distribution requirements are based on experience during the years 1942-1945.

5. Jet fuel distribution system requirements are not known at this time.

W. V. FOX

BULK STORAGE REQUIREMENTS					
PRODUCT	SPECIFICATION	MAX. STORAGE ABOVE GROUND	MAX. STORAGE UNDERGROUND	AVG. WORKING STORAGE ABOVE GROUND	AVG. WORKING STORAGE UNDERGROUND
Oil, Fuel, Boiler (Special)	7-0-1f 2 Oct 1944	2,615,000	5,607,200	299,400	5,412,200
Oil, Fuel, Diesel	7-0-2e 15 May 1945	350,225	588,320**	300,625	588,320**
Motor Fuel	VV-M-561 14 March 1946	138,800	26,000	138,800	26,000
Grade 115/145, Air. Recip. Eng. Fuel	AN-F-48a Amend 3 20 July 1948	138,000	0	138,800	0
Grade JP-1, Air. Engine Fuel	AN-F-32a* 10 July 1947	296,000	0	296,000	0
Kerosene	VV-K-211a 9 April 1941	99,925	0	50,425	0
Grade 1120 Aircraft Engine Lubricating Oil	AN-O-8 25 Jan 1946	16,800	0	11,400	0
Symbol 9250 Lubricating Oil	14-0-13a 1 Dec 1944	15,900	550	12,900	550
Symbol 9370 Lubricating Oil	14-0-13a 1 Dec 1944	18,860	560	15,860	560
Symbol 2190-T Lub. Oil, Turbine	14-0-15 15 Aug 1945	2,400	0	2,400	0
Slop Oil		168,360	0	168,360	0

* Not confirmed

** Revised

5,860,270

6,222,630

ENCLOSURE (A)

DISTRIBUTION SYSTEM REQUIREMENTS

FUEL OIL

DESIRED OPERATION - BBLs/HR

BERTHS	MAIN FEEDER* LINE TO BERTHS	CAPACITY PER RECEIPT	CAPACITY PER BERTH ISSUE	REMARKS
H-1-2-3-4	30,000	10,000	10,000	Size of present lines is adequate
H-7-8	12,000	0	6,000	Feeder to H-7-8 can be taken off main feeder to H-1-2-3-4
K-1-3-5-7-8-10-11	8,000	8,000	2,000	Facilities do not exist presently at K-1-3-5
S-1-10-11-12-13-14- 19-20-21	8,000	0	2,000	If desirable from planning stand- point, S-19-20-21 can be serviced from main feeder to K berths
M-1-2-3-4	16,000	8,000	8,000	
B-1-2-3-12-13-15- 16-17-18-20-21-22- 23-24-25	12,000	8,000	8,000	
B-4-6-7-8-10-11	12,000	3,000	3,000	
A-11-12-13-14 DE-1-2-3-4-5-6	12,000	0	2,000	Facilities do not exist presently
O-1	3,000	0	3,000	Feeder to O-1 can be taken off main feeder to Able and DE berths

* Total pumping requirements - 50,000 bbls. per hour

ENCLOSURE (B)

DISTRIBUTION SYSTEM REQUIREMENTS

DIESEL OIL

DESIRED OPERATION - BBLS/HR

BERTHS	MAIN FEEDER LINE TO BERTHS*	CAPACITY PER BERTH RECEIPT	ISSUE	REMARKS
H-1-2-3-4	12,000	12,000	12,000	
H-7-8	10,000	0	5,000	Feeder to H-7-8 can be taken of main feeder to H-1-2-3-4
K-1-3-5-7-8-10-11	8,000	8,000	2,000	Facilities do not exist presently at K-1-3
S-2-3-4-5-6-7- 8-9-15-16-17-18-19	8,000	0	1,000	
S-1-10-11-12-13-14- 20-21	8,000	0	3,000	
M-1-2-3-4	12,000	12,000	12,000	Should have sufficient pumping capacity to transfer diesel oil receipts to underground at same rate
A-11-12-13-14 DE-1-2-3-4-5-6 0-1	10,000	0	2,000	Facilities do not exist presently
S-1-21, incl.	1,800	1,800	0	Defuel lines presently at S-14-15-16-19 Provision should be made to permit any number of ships to defuel up to total of 1,800 bbls. 1 hr. with sufficiently low pressure drop to prevent transfer between ships defueling into same line.

* Total pumping requirements - 24,000 bbls. per hr.

ENCLOSURE (C)

DISTRIBUTION SYSTEM REQUIREMENTS

LUBRICATING OILS

DESIRED OPERATION - G.P.M.

BERTHS	MAIN FEEDER LINE TO BERTHS	CAPACITY PER BERTH RECEIPT	ISSUE	REMARKS
SYMBOLS 9250-9370				
S-1-21, incl. M-1-2-3-4	1,000 *	0 *	100 0	
SYMBOL 1120				
M-1-2-3-4	*	*	0	
SYMBOL 2190T				
M-1-2-3-4	*	*	0	*There should be sufficient large lines to handle average pumping capacity of a tanker from M-1-2-3 or 4 to Bldg. 88 for symbols 9250, 9370, 1120 and 2190-T, and from Bldg. 88 to Halawa tanks for Symbols 9250 and 9370.

DISTRIBUTION SYSTEM REQUIREMENTS

GRADE 115/145 AVGAS

DESIRED OPERATION - BBLs/HR

BERTHS	MAIN FEEDER LINE TO BERTHS	CAPACITY PER RECEIPT	BERTH ISSUE	REMARKS
V-1-2-3-4	2,800	2,800	2,800	Present system is adequate
		MOTOR GRADE GASOLINE		
V-3-4	2,800	2,800	2,800	Present system is adequate
		KEROSENE		
N-3	5,000	5,000	0	Present system is adequate

KEROSENE

ENCLOSURE (E)

Public Works Office
COMMANDANT 14TH NAVAL DISTRICT
Pearl Harbor, T.H.
Navy No. 128 c/o F.P.O.
San Francisco, California

NOy-16535 (80:D)

1202

9 Mar 1949

From: Officer in Charge of Construction, Contract
NOy-16535
To: Bechtel Corporation, San Francisco, California
Subject: Contract NOy-16535, Rehabilitation of POL
System - Capacities Required
Reference: (a) SOinC ltr NT4-9/JJ7 430 CF 13896 to OinCC
dtd 15 Nov 48

1. For the purposes of planning the final Bechtel report as required by Contract NOy-16535, the following information is submitted:

- (a) Upper and Middle Tank Farms will be made suitable for use if economically feasible. Lower Tank Farm will not be used except to meet Shipyard requirements. It has been proposed by the Naval Supply Center that two tanks be retained by the Shipyard to store boiler fuel. It is understood that a request will be initiated for two more tanks; one to be used for slop oil and one to be used as a standby tank for cleaning operations.
- (b) Laterals and dock distribution lines in the Shipyard will not be used. The facility will be drained and blanked off but will not be removed

except where it interferes with other Shipyard facilities. However, the main feeders to the Lower Tank Farm will probably be used about once a week for transfer of fuel to the tanks to be retained in this farm.

- (c) The capacities of black and diesel oil during the period 1942-45 are considered adequate. Since the Shipyard dock facilities are to be eliminated, the quantities given by Enclosures (A) through (E) of reference (a) are applicable only insofar as they apply to facilities other than those existing in the Shipyard.
- (d) It is desired that kerosene and lube oil systems be so designed that it will not be necessary to exceed 24 hour total dock daytime for T-2 type tankers under normal operating conditions where the split in cargo follows past experience. It is estimated that a capacity of 5,000 barrels per hour per berth must be provided for kerosene. The following listed capacities may be provided for lube oil.

<u>Berth</u>	<u>Grade 2190-T</u>	<u>Grade 9250</u>	<u>Grades 9370 & 1120</u>
M-1	460 B/H	304 B/H	152 B/H
M-2	580 B/H	380 B/H	188 B/H
M-3	1060 B/H	700 B/H	352 B/H
M-4	1060 B/H	700 B/H	352 B/H

s/ C. W. PORTER

September 10, 1948

Officer in Charge of Construction, NOy-16535
Public Works Office
Fourteenth Naval District
Pearl Harbor, T. H.

Subject: Red Hill Underground
Tank No. 16

Dear Sir:

Forwarded, attached, is the procedure proposed by us for determining the nature and location of the leak in Red Hill Underground Tank No. 16.

In conference with Navy representatives August 31, C. E. Frishholz, our chief project engineer on NOy-16535, outlined this proposal and we understand steps taken so far are in accord with it.

Very truly yours,

BECHTEL CORPORATION

I. L. Lind

MEMORANDUM:

Subject: Inspection of Red Hill Tank No. 16

Summary

Careful gaging had developed that tank no. 16 was leaking at the rate of approximately 13 barrels per day. A study indicates that the most probable reason is a construction fault, which most likely will be in areas adjacent to the grout pipes or those pipes installed for the movement gages. The plan of testing to locate the leak is described, step by step, for the areas to be covered. Design details of the Red Hill tanks are briefly discussed.

Recommendations

None until the inspection is complete.

Discussion

A. Procedure of test

The Petroleum Operations Group had formulated a plan for testing tank 16 which we have thoroughly discussed with them, and with which we are in agreement. We have made certain suggestions which have been accepted and incorporated in their plans.

Visual inspection will be made of the side walls from the elevator with spot lights. The purpose of this is to try to locate any leakage of oil or water back into the tank, and to also locate any defect or construction oversight that may be readily seen.

The plan is to first test the piping connections out of the bottom of the tank, these are a 32" and 16" suction and discharge line, and eight inch drain line and two 6" connections installed for a future steam coil. This test is to be made by

blinding off these lines and pressuring each to 100 pounds per square inch hydrostatic, and observing any decrease in pressure that would indicate a leak. If the leak is not found in these lines, the bottom sheet is next to be tested. This is to be done by applying air pressure, 1-1/2" to 2" of water, under the plate and soap testing the welds. Next, the bottom inverted dome section is to be tested in the same manner. The next step is to start filling the tank with water, starting air thru the tell tale connections, and endeavor to build up air pressure behind the steel liner, this pressure not to exceed 2" of water. The sides will be carefully inspected from rafts as the water is increased at intervals until the top of the tank barrel is reached or the leak is found.

B. Pertinent Construction Details

The construction of the tanks has been studied to determine the most probable points where leakage would occur and not be indicated in the tell tale system. We will briefly review the construction details. After excavation, the walls were gunited, the specification calling for a minimum thickness of 6" and a maximum thickness of 1'-6". This gunite surface was coated with asphalt which was then painted with a red earth slurry. Where due to over-breakage, the gunite would exceed 1'-6", concrete was poured. The 1/4" steel plate shell was placed and welded against the 2-1/2" x 3" x 5/16" angles with the 3" leg inward. These angles are in five foot intervals. The concrete was poured in 5 foot lifts using this steel as a form. The wall of the barrel is 4'-0" thick at the bottom spring line, tapering to 2'-6" thick at the top of the barrel. The inner side is reinforced with hoops and verticals of 1" square reinforcing steel. A typical wall detail is shown "C" on attached sketch. Six grout grooves were provided as shown in the attached sketch, detail "A" and "B", each having four grout pipes, detail "D", at quarter points. In each groove, four strain gages, detail "E", were also installed midway between the grout pipes. The grouting was done on the side walls in accordance with the following procedure: "Fourteen days or later, after the completion of the last pour of the concrete wall, pump water into

opening between gunite lining and concrete wall, water pressure to exceed by 20 pounds that anticipated from a full tank of oil, if no serious leaks occur, proceed to fill the opening with grout. Grout to progress upward from grout groove 15 feet above base of barrel, and thence to top of barrel". The grout used was thin and it has been stated to be a mixture of 40 gallons of water to one sack of cement. In cases where this mixture flowed too readily, the mixture was thickened by the addition of cement.

During this grouting procedure, pressure was in some cases exerted against the $1/4$ " steel lining, this is shown in construction pictures, and probably occurred due to voids in the wall. The most likely place for such voids would be adjacent to the $1-1/4$ " pipes used for grout and strain gages, 48 of which were installed in each tank. If this was the case, there would be a possibility that all such voids did not become filled with grout, thus enabling a leak to occur and not be indicated in the tell tales.

However, 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 $1/2$ " pipe that extends thru the $1-1/4$ " pipe to the outer face of the $1/4$ " plate liner, detail "E". A leak occurring in or around any one of these 24 strain gage connections could easily find its way thru a porous or broken section of the gunite. The pipe caps covering these openings were specified to be cut off and a plate welded over the opening. We have noted that in tank no. 16, the closure was not made as specified. These points will be closely inspected and reported on in detail in the near future.

September 29, 1948

Officer-in-Charge of Construction, NOy-16535
Public Works Officer
Fourteenth Naval District
Pearl Harbor, T. H.

Subject: Tests on Red Hill Underground Fuel
Oil Tank No. 16.

Dear Sir:

By letter dated September 10 and by Memorandum dated September 16, 1948, we have recommended a test procedure for determining the location and nature of the reported leak in Underground Fuel Oil Tank No. 16.

This procedure as modified is as follows:

- (1) Pressure on tell tale (maximum pressure 2 psi.) regulated by a mercury column. Provide means of determining if air flows from remaining tell tales.
- (2) Fill to bottom grout groove with water. This groove is 15' / below bottom spring line. Clean and inspect area above groove.
- (3) Inspect grout and strain gauge connections. Suggest that caps be drilled to explore for oil.
- (4) Inspect liner areas with slowly rising water level.
- (5) Inspect area carefully at junction of bottom sheets and barrel, especially all overhead welding.

Concurrently with the preparation for leak testing the liner as outlined, which preparation involved the building of suit-

able floats, we have performed experiments to determine if the entire steel liner could be pressured with air.

Briefly this was done by providing a mercury manometer and mercury seal pot with which we could pressure the tell tales to approximately 1 psi. We then pressured individual tell tales and found that this could be done in about one second using about 1 c.f.m. of air. We then measured the freedom of flow between individual tell tales while maintaining 1 psi. at the outlet valve of one of them, by connecting each of the other tell tales to a bottle of water and checking the water head. With this test we found that when we pressured one tell tale to 1 psi. at the outlet valve, we could expect a pressure varying from 1" to 0" of water on the other tell tales.

Subsequently we applied about 5 c.f.m. of air to all the tell tales in parallel and developed a maximum pressure of about 1/8 psi.

The above simple initial tests are not a basis for any final conclusions but the inferences are:

- (1) There is not a free flow circumferentially around the tank between tell tale openings, in the space between the liner and the concrete. Otherwise the tell tale pressure would have equalized.
- (2) Resistance from the tell tale outlet valve to the space between the liner and the concrete is unduly high. Otherwise the small volume of air used would not have raised the pressure so quickly.
- (3) There is little resistance to the escape of air from the space between the liner and the concrete either to the inside of the tank or else to the rock behind the concrete. Presumably the escape is to the rock, since otherwise oil should have leaked into the tell tales in operation.

If these inferences prove correct the effectiveness of the tell tale system to detect a leak while in operation is in question and usefulness of the tell tale system in testing the tank for leakage by using air pressure is limited. Reliable performance of the above functions depends upon a positive void between the liner and the concrete, which apparently does not uniformly exist.

In spite of any limitations of the tell tales we plan to continue along the lines of the program outlined above. A larger capacity compressor has been made available and the test pressure at the outlet valve will be carefully raised to 2 psi. in the reasonable assurance that no such pressure can be developed behind the liner. Test pressure at these tell tale outlets used in construction was said to have been 2.5 psi.

Since the pressure developed behind the liner can be expected to be non-uniform and substantially below the pressure at the tell tale outlet valve the matter of locating the cause of the reported leakage by this procedure becomes one of chance. Since the oil has apparently escaped without being indicated by the tell tale system the chance of building up pressure at the point of the leak via the tell tales is correspondingly reduced, since some ready escape to the rock must be presumed to exist in the vicinity.

Following completion of the proposed test procedure the tank will be full of water. If the leak is still undetected we plan to confirm the existence of the leak and its quantity by very careful gaging at two or more levels. By analysis of the amount lost at different levels we hope to calculate the location, in depth, of the leak and its approximate total size. The area suspected will then be carefully re-examined.

Very truly yours,

BECHTEL CORPORATION

I. L. Lind

September 29, 1948

Officer in Charge of Construction, NOy-16535
Public Works Office
Fourteenth Naval District
Pearl Harbor, T. H.

Subject: Inspection of 50,000 Bbl. Fuel Oil
Tanks in Lower Tank Farm, Pearl
Harbor Naval Base

Dear Sir:

Forwarded herewith is a status report on inspection of
50,000 barrel Fuel Oil Tanks in the Lower Tank Farm at the
U. S. Naval Base, Pearl Harbor.

	<u>No. of Tanks</u>	<u>Plant Serial Number of Tanks</u>
Tanks inspected to date	3	Nos. 21-22-23
Tanks drilled ready for inspection	3	Nos. 24-18-19
Tanks cleaned ready for inspection	2	Nos. 13-14
	—	
Total tanks in process	8	
Tanks remaining lower tank farm	7	Nos. 10-11-12- 15-16-17- 20
	—	
Total lower tank farm	15	

A detailed report of the inspection of Tank No. 21 is
attached. The tank is in good condition after twenty-four years
of service and requires only nominal repair.

The condition of Tanks Nos. 22 and 23 is comparable to that of No. 21.

Results of inspection so far indicate that we can reasonably assume Tanks Nos. 17 and 20, now used to store power house fuel, and Tanks Nos. 11 and 12, used to store recovered oil are in about the same condition as those inspected. Accordingly, we recommend that these tanks be given only a limited inspection, without cleaning.

Very truly yours,

BECHTEL CORPORATION

I. L. Lind

MEMORANDUM:

Subject: Inspection of Lower Tank Farm 50,000 Bbl.
Fuel Tank No. 21.

1. Bottom Sheets

Thirty-six trepan samples, 1-1/2" diameter were taken, indicating an average loss of .024" or about 7% of the original plate thickness of 11/32". (This and other original plate thicknesses were assumed as drawings of the plating were not available.)

2. Side Sheets (Shell)

The shell indicates negligible corrosion. Eight trepans 1-1/2" diameter were taken and sixteen 1/2" holes were drilled. The results of these measurements of plate thickness follow:

<u>Course</u> Number	<u>Assumed original</u> <u>Thickness</u> Inches	<u>Measured</u> <u>Thickness</u> Inches	<u>Loss</u> Inches
1	.250	.250	.0
2	.250	.250	.0
3	.3437	.320	.0237
4	.4375	.396	.0415
5	.500	.500	.0
6	.625	.618	.007

3. Roof Sheets

The roof indicates considerable corrosion and numerous holes are observed. Most of the corrosion was external and due to testing the salt water sprays. The sketch sheets near the edge of the tank are badly corroded and require extensive patching.

Twenty-five trepan samples, 1-1/2" diameter, were taken and twenty-five 1/2" holes were drilled. These measurements indicated that there was an average loss of .0525" or 28% of the assumed thickness of .1875.

The roofs have considerable life and justify repair if used in the present tank location. However, if the tanks were dismantled and re-erected the roofs would require replacement.

4. Appurtenances and internal members

All appurtenances and internal members are in good condition.

5. Painting

The paint, except for the roof, is in good condition.

6. Riveting

Tank is riveted throughout. All rivets show limited general corrosion with no excessive conditions or active leakage.

7. General Statement

The tank is in good condition after twenty-four years of service and requires only nominal repair.

C. E. Frishholz
Project Engineer

Appendix 1F

U. S. Post Office Box 94
U. S. Naval Base
Pearl Harbor, T. H.
December 3, 1948

Officer in Charge of Construction,
Contract NOy 16535
Public Works Office
Fourteenth Naval District,
Pearl Harbor, T. H.

Subject: Recommendations for Immediate Repair
of 50,000 Barrel Fuel Oil Tanks in Lower
Tank Farm, Pearl Harbor Naval Base

Reference: Letters to Officer in Charge of Construction
(a) dated September 29, 1948, subject:
"Inspection Lower Tank Farm"; (b) dated
September 24 and November 17, subject:
"Fire Protection Lower Tank Farm."

Dear Sir:

The tank inspection in the Lower Tank Farm has been completed with the exception of Tanks 11 and 12 which are in slop oil service, and Tanks 17 and 19 which are in power plant fuel oil service. We do not consider it necessary to empty, clean and internally inspect these operating tanks. This conclusion appears sound because all tanks inspected in this area were found to be in approximately the same physical condition. Therefore, it is safe to assume that about the same repair work will be required, as we recommended on the tanks we are covering in this report.

The tanks are approximately 106 feet in diameter, 33 feet high, and have a capacity of 50,000 barrels. They are riveted construction, built in 1924, and erected on well oiled sand padded grades which we consider to be excellent practice.

The riveting and caulking exhibit a very good quality of workmanship and only minor leaks in the seams and rivet heads have occurred. The tanks are in good condition except the roofs, which show corrosion and failure principally in the area adjacent to the top angle iron. This condition can be economically repaired by welding patches over the bad areas. Roof corrosion is largely the result of testing and maintaining the water sprays, which are obsolete equipment and serve no useful purpose especially on heavy oil tanks.

The bottom plates show corrosion on the interior surfaces, but practically none on the underside of the bottom plates which rest on the oiled grade. The internal pitting is not serious, and, prorated based upon similar service conditions an additional 20 years of life could be expected.

The attached report discloses the physical inspection methods and findings in more detail.

In this and other tank areas, the eight inch cast iron drain connections to the bottom of the tanks should be disconnected from the pump house manifold and an oil separator box installed which would separate the water and oil and permit discharging relatively clean water into the harbor. At the same time this oil separator would make the system fool proof and faulty operation could not result in the discharge of oil into the harbor waters. This arrangement as now existing, we consider to be a hazardous condition requiring immediate correction.

The immediate work required to rehabilitate this facility depends upon the type of petroleum products that are to be handled. We are basing the following recommendations for immediate repairs upon the storage of heavy oils with a flash point above 120 degrees F:

1. On tank bottoms, spot weld severe pits (1/16" or more).
2. Repair roof by welding 1/8" plate over bad areas.

3. Remove fire alarm system, and weld cover patches over the holes left in upper course of the tank shell.
4. Remove deflector plate around edge of tanks.
5. Remove water spray system.
6. Clean and paint tank roofs, with two coats of heavy red lead (30# per gal) and one approved surface coat.
7. Wire brush and prime two coats as above and one surface coat all rusted spots on sides.
8. Chip brush and clean bottom angle and paint as above specified.
9. Starting level with tank bottoms, slope area adjacent to tank down 1/2" per foot for a minimum of ten feet away from the tank. The first two feet from the tank of sloped area should be sand mixed with 1/4" rock and compacted with oil.
10. Check volume within tank levees. This should equal a minimum of 1-1/4 times tank capacity.

To assist in planning, we are including the following supplemental recommendations for use in event storage of light oils with a low flash point, such as gasoline and kerosene, is contemplated:

1. For gasoline service only, replace roofs (in lieu of item 2 above)
2. Install sufficient number of vacuum pressure vents.
3. Install gaging hatches near ladder.
4. Remove present drain connections and install standard API drain nozzle with 4" steel valve in the concrete box to which the present 8" drain is connected with cast iron valve.
5. Replace cast iron valves on tank nozzles with steel valves.
6. Revise foam system, install new suitable mixing chambers and applicators.

Very truly yours,
BECHTEL CORPORATION

I. L. Lind

MEMORANDUM:

Bechtel Survey Navy Fuel Facilities
Pearl Harbor

Inspection of Lower Tank Farm

This survey covers eleven 50,000 barrel fuel oil storage tanks Nos. 10, 13, 14, 15, 16, 18, 19, 21, 22, 23 and 24 in the Lower Tank Farm.

A close physical inspection of tanks, appurtenances, grades, pipe lines and fire protection facilities was made. Inspection procedure was described in detail in a previous report which covered the inspection of Tank No. 21. Individual reports have been prepared for all the above tanks, which information is summarized below:

1. Tanks

(a) Roofs:

All roofs have the same general corroded conditions. The edges or eaves are in most cases badly corroded. Many corroded places have occurred at riveted joints. The peaks have holes through the metal in many cases. Roof corrosion is attributed to drippings from salt water spray nozzles installed for fire protection. Such drippings have collected in low spots. The inside roof surface is uniformly corroded to a limited and unimportant extent. The paint has failed on all roofs.

(b) Shell:

All shells were found in good condition and showed corrosion but little below rolling tolerances. Few rivet leaks were found and rivet heads were in excellent condition, both inside and out. Inside corrosion was uniform and did not exceed .020 inch in any tank.

(c) Bottoms

The tank bottoms are considered to be in good condition. Considerable corrosion was found with some pitting and scars but in no case except in Tank No. 10 were pits of appreciable depth found. In this tank pits measuring approximately 1/10" were found on plates adjacent to tank's sump. Certain areas which are depressed showed scale due to standing bilge water. Bottom angles are in good condition and rivets shown only the average loss of plates. Metal loss average may be considered to be approximately .025 - .030 inch.

(d) Structural Members

Roof supporting columns are I beams measuring 9" x 4-1/2" x 3/8". No great scaling is evident and metal loss is superficial. Cross members are 3" angle iron and 3" x 3/8" straps. Roof rafters are 6" I beams which show little corrosion. All ladders, both internal and external, are good.

(e) Appurtenances

All hatches, winches, cables and swing pipes are in satisfactory condition. However, in Tank No. 10 the swing joint has a piece broken out which would preclude emptying this tank below the level of this break. Manholes are good with cast iron cover plates. Vents are galvanized 3" 180 degree bends, two in each tank.

(f) Paint

As noted before, roof paint is scaled away. This is probably due to the water spray system. Shell paint is in fair shape and was applied during 1936. However, during war camouflage paint was superimposed so that general condition of former tank paint is not known. In most cases where paint was chipped off, metal surfaces were clean and showed no corrosion. No paint or red lead had been applied to outside bottom of tank.

Pipe lines above ground are in need of paint but are tar coated where buried. Cyclone fence, otherwise in good condition, requires painting.

(g) General

The tanks are in generally good condition considering their age and the degree of maintenance received. Type of materials stored has resulted in uniform but limited interior corrosion.

2. Grades

The tanks are well spaced. The area is clear of brush and weeds. Fire walls or berms are in good condition considering that they have not been oiled. They should be checked for capacity.

Tank foundations are of oiled sand. There appear to be no gravel bases or concrete edge rings.

Ground areas adjacent to tanks are not in good condition and in every case slope toward the tanks. Many of the tanks are actually below grade and this has permitted water to drain under the bottom plates and angles, with resulting corrosion. No drains or drainage trenches exist within tank rings so that water has no means of escape except by means of seepage through berms or into ground.

3. Connecting Pipe Lines

Fuel oil suction and discharge lines are mostly below ground or, where above ground, pass occasionally through berms. Where below ground all show corrosion. Drain lines are cast iron and in good condition. Salt water spray lines to tanks are galvanized. Condition of pipe lines will be covered in separate report including electrolytic survey.

4. Valve and Valve Pits

All valves are cast iron, 125#, faced and drilled, flanged brass inserts, rising stem. Most appear to be in excellent condition, but a few have been found to leak. Concrete valve pits and housing over same are in fair condition.

5. Fire Protection

There is an above ground foam system originating in a main pump house. The foam pumping equipment is placed at adequate distance from the tank farm. It consists of two motor driven reciprocating pumps, one acid solution and one soda solution, taking suction from solution tanks. There are auxiliary powder generators to augment liquid storage, which is not adequate. Foam solution and powder is stale and should be replaced if system is made operative. The condition of this equipment is satisfactory. The lines completely circumvent the tank farm branching off to each tank. The connecting lines to the foam pump house have been cut during removal of some tanks. Recommendations for immediate rehabilitation of this piping have been covered by previous report. The lines above ground are in good condition, as are the quick closing valves. The lines enter the tanks at the bottom of lower tank rings, passing to the center of tank where they are flanged to vertical cylindrical internal mixing chambers. The chambers are of plate construction and rise to within approximately 2' of roof peaks, above highest oil level. Most have been found to leak at bottom flange.

The Gamewell fire alarm system is out of service and in most cases inoperative. This system consists of electrical warning devices originating in fusible points, two places at top of shell rings. These are connected to alarm box placed near bottom of shells by wiring in standard conduit. The alarm boxes are in turn connected to central fire station. The conduit and wiring has been damaged by corrosion in many cases.

A salt water spray is installed on top of each tank. Water from these sprays is diverted by means of plates placed at an angle around tank periphery, so as to curtain the sides of tanks. Many of these diversion plates have been corroded away in spots.

The saltwater fire main is buried with frequent two outlet hydrants. All hydrants are in bad condition. The hydrants are well distributed around tank farm. Some are being conditioned at the present time.

Appendix 1G

Contract NOy 16535

U. S. Post Office Box 94
U. S. Naval Base
Pearl Harbor, T. H.
January 12, 1949

From: Bechtel Corporation, Contract NOy 16535
To: Officer in Charge of Construction,
Contract NOy 16535

Subject: Recommendation for Immediate Repair of Tanks
in Middle and Upper Tank Farms, Pearl Harbor
Naval Base.

Reference: Letter to Officer in Charge of Construction
dated December 3, 1948, subject: Recommenda-
tion for Immediate Repair of 50,000 Barrel Fuel
Oil Tanks in Lower Tank Farm, Pearl Harbor
Naval Base.

1. The inspection of tanks in the Middle and Upper
Tank Farms has been completed, and summary inspection
report and recommendations for immediate repair are submit-
ted herewith. In general these tanks are in good condition and
with proper maintenance an additional life of from twenty to
thirty years can be expected, with the similar product storage.

2. Middle Tank Farm

(a) This group of tanks is numbered 29 to 38
inclusive, and all tanks except 37 and 38 were cleaned, drilled
and otherwise inspected. In order to reduce expenditures and
expedite the work it was decided not to enter these tanks
because we have sufficient evidence that their physical condi-
tion will closely approximate that of the tanks which were
inspected in this area. The attached inspection report covers
the tanks and appurtenances in detail.

There is located in the Middle Tank Farm a 195,000 barrel (fuel oil) underground reinforced concrete reservoir which was constructed about 1920. This reservoir is now being cleaned preparatory to inspection.

(b) There are ten tanks in this area, nine of which are approximately 106 feet in diameter and 33 feet high and have a capacity of 50,000 barrels each. One tank is 120 feet in diameter and 40 feet high with 80,000 barrel capacity. They are riveted construction and erected on oiled sand padded grades. The same high quality of workmanship exists as noted in the Lower Tank Farm, and only minor leaks have occurred in the caulked seams and rivet heads. The tanks erected during the period 1920-1925 are in good condition, and no measurable loss has occurred in the shell courses. The roofs, however, are generally corroded on the outer surface, but appreciably less than the Lower area tanks. This corrosion is attributable to the testing of the water sprays which should be discontinued. The roofs can be economically repaired by patching and painting.

(c) The bottom plates are corroded on the interior surfaces, but practically no corrosion was disclosed on the underside of the plates which rest on the oiled grades. The interior corrosion is uniform over the whole bottom and is between 0.025" and 0.035". There are some local pitted areas.

(d) The eight inch cast iron drain from this area is directly connected to the harbor through Pump House 77 where it is valved off. This line should enter an oil separator as previously recommended for the Lower Tank Farm, and further the line should not be used for pressure service.

3. Upper Tank Farm

(a) There are thirteen 150,000 barrel tanks in this area, and based upon our inspection of other and older storage tanks in the same usage, we deemed it unnecessary to inspect more than two tanks. The tanks selected were 51 and 52 and the cleaning and inspection has been completed.

(b) The tanks are approximately 160 feet in diameter and 40 feet high. These riveted tanks erected during the period 1920 to 1926 were found to be in good condition and exhibited high degree of workmanship. No measurable metal loss was noted on the shells and a uniform corrosion loss of about 0.020 was found on the bottom plates. Rusted areas with some small holes were observed on the roofs.

(c) The same design of tank drainage system exists in this area, as described above, and the line has been directly connected to the Harbor through Pump House 91, but it is presently disconnected. This system should be revised and a separator box installed, further these drains should not be used for oil transfer or pressure service.

4. The immediate repairs to rehabilitate the equipment in the Middle and Upper Tank Farm areas is dependent upon the type of petroleum products to be handled. We are basing the following recommendations for immediate repair on the storage of heavy oils with a minimum flash point of 120 degrees F:

(a) Spot weld deeper pits on bottom plates. There are few requiring repair and this is a minor item.

(b) Repair roofs by patching with one eighth inch plate, welded over bad areas.

(c) Wire brush roofs and paint with two coats of primer and one finish coat.

(d) Chip, brush, clean and paint bottom angle as above specified.

(e) Wire brush and paint small rusted areas on shells as above specified.

(f) Replace retaining levees around tanks.

(g) Install concrete boxes around the revised drain connections on Tanks 33 and 35.

5. The following are optional recommendations and are not necessary to preserve the tanks, or slow up the present rate of deterioration:

- (a) Remove fire alarm system which is inoperative.
- (b) Remove water sprays and deflector plates.
- (c) Check volume in kerosene tank berms. This should be a minimum of 1-1/2 times tank capacity.

6. The recommendations for the storage of low flash oils as set forth for the Lower Tank Area also apply to these tanks should the permanent storage of light oils be considered.

BECHTEL CORPORATION

I. L. Lind

MEMORANDUM:

Bechtel Survey Navy Fuel Facilities
Pearl Harbor

Inspection of Middle and Upper Tank Farms

This inspection covers eight 50,000 barrel and two 150,000 barrel riveted steel oil storage tanks. The 50,000 barrel tanks Nos. 29, 30, 31, 32, 33, 34, 35 and 36 are located in the Middle Tank Farm and the 150,000 barrel tanks Nos. 51 and 52 are located in the Upper Tank Farm. Two tanks in the Middle Tank Farm and eleven tanks in the Upper Tank Farm were not inspected because we have sufficient evidence to indicate that their physical condition will closely approximate that of similar tanks inspected. Individual inspection reports have been prepared for each tank inspection; which information and other pertinent facts are summarized below:

1. Tanks

(a) Roofs

All roofs have the same general corroded condition, which is attributed to the testing of the salt spray. The corrosion is largely external, only a small loss being found on the interior surface. The paint in all cases can be considered as a complete failure.

(b) Shell

All sheets in the shell courses were found to be in excellent condition, and corrosion was within the rolling tolerance. Some leaking rivets and caulked seams showed leakage. This can readily be stopped by caulking. The tanks were last painted (not considering camouflage) in 1939 and require only touching up of small rusted areas.

(c) Bottoms

The tank bottoms which were placed on an oiled sand grade are considered to be in good condition. The inner surface of the sheets show general corrosion, with local pitted areas where pits do not exceed an average of .020". The bottom angles are only slightly corroded. Some corrosion was observed on the underside of the bottom plates on tanks in the Middle Tank Farm and the presence of water was observed, which is believed due to a poor drainage condition.

(d) Structural Members

The roof is supported by 9" x 4-1/2" x 3/8" I beam columns, and 6" I beam rafters. These members show no evidence of corrosion and are in good condition.

(e) Appurtenances

Winches and cables, hatches, vents, ladders, manways and nozzles are in good condition. The foamite mixing chamber and solution lines inside the tanks are in good condition, although there is evidence of some oil leakage back into the foam lines.

(f) The tanks are in good condition with a uniform and limited interior corrosion. The tanks in these areas are in better condition than those in the Lower Tank Farm and can be put in good condition at relatively low cost.

2. Grades

The layout of the tanks in these areas is good and tanks are well spaced. The sand padded grades in the Middle Tank Farm were not well oiled, and the underlying foundation soils are not well drained. This combined with the lack of drainage from the areas and poorly graded areas around the tanks has resulted in seepage of water under the bottom plates which has caused some corrosion. The retaining levees around the tanks

are in good condition except where they have been removed for yard extension, particularly in the Upper Tank Farm. These levees should be replaced in order to preserve the safety of surrounding property in case of fire or tank failure.

3. Connecting Pipe Lines

Most of the pipe lines in the areas are below ground. Two kinds of pipe have been used, steel and cast iron bell and spigot. Some of the steel pipe used was galvanized. The condition of this piping will be reported on under pipe inspection.

4. Valves and Valve Pits

Oil valves are 250 pound flanged cast iron bronze trimmed rising stem. The drain valves are 125 pound flanged cast iron bronze trimmed, rising stem. The valve pits are in serviceable condition.

5. Fire Protection Facilities

Both tank areas are protected with a foam system which originates in two stations, one in Building 23 and one in Building 91A. They are interconnected so either one or both can serve either tank area. The system is composed of a small amount of liquid A and B solution stored in tanks, and applied by motor driven reciprocating pumps, and dry powder storage and generators. The equipment is in good condition and has been well maintained.

April 29, 1949

Survey of Navy Petroleum Facilities
Red Hill - Pearl Harbor, T.H.
Inspection Tanks 14 and 16

1. Physical Scope and Description of Facilities

Facilities consist of twenty steel lined concrete underground storage vaults, 100 feet in diameter and 250 feet high, the bottom and top domes being one-half regular polyhedrons connected by a right circular cylinder. Each tank is equipped with a tell tale system designed to indicate the presence of any leakage between the concrete shell and the steel lining by conveying any infiltration at the interface to an external observation point. Likewise, it was intended that this system serve as a testing device whereby air pressure could be introduced between the concrete and the lining, and any voids in the lining be detected by the escape of pressure. Each tank holds approximately 302,000 barrels, and Tanks 14 and 16 have been in fuel oil service since placed in operation.

2. Survey Method Used

Tanks were prepared for inspection by emptying and cleaning the interior surfaces. Methods of cleaning included hosing with water, wiping with diesel oil, rinsing with solvent, wiping down, wire brushing and soap washing.

When the tank bottoms and the first bottom dome course were under examination, inspection was made with the tank dry and ladders to reach as high as the seam between the first and second course. As the search continued upwards, tanks were flooded to the desired levels and inspection conducted from rafts rowed around the shell.

Based upon the supposition that placing a head of air on the tell tale system would produce a positive pressure between the steel liner and the concrete shell, and that any voids in the liner would exhaust air, flaws in the steel liner were sought by the bubble test.

On the bottom and the first course the welds were cleaned and, with air pressure on the tell tale, the seams brushed with soap solution. As the tank was flooded to higher levels, the dry seams were wire brushed, questionable areas chalked and upon the next flooding re-examined when submerged. At all levels all protrusions, patches, tell tales and sheets were hammer tested for soundness. When the tanks were flooded and periods of quiescence were sufficiently long to permit accurate measurements, standing tests were made to determine any variation in liquid level.

Surface inspection was made by cleaning areas as best suited, the removal of the particular type of deposits and depth of pitting measured.

The migration of air, oil and water, as detectable under the sheets, was traced by drilling two test holes in the bottom of Tank 16 and twenty in Tank 14 and removing such screwed plugs or fittings as were available in the liner.

Hydrostatic tests were placed on all the major lines to determine their condition between the tank bottom and their exit point in the gallery in the lower tunnel.

Compressed air, controlled by a mercury overpressure regulating device, was introduced into the tell tales in the gallery and used to establish what communication existed between the tell tales themselves and the miscellaneous other cooling, steam heating sleeves and spare lines extending into the gallery. Bubble jars were utilized for this purpose during the pressure trials, which were converted to sample collection receptacles when the pressure was released.

Tests were made to determine if there was a free annular space between the steel liner and the concrete. This was done by applying 2 psig. air pressure to a single tell tale and measuring the pressure indicated on the remaining tell tales. Sketch 6 shows the development of the barrel section of Tank 16, the location of the tell tales, and connections to the liner. When applying 55 inches of water pressure to tell tale No. 6 the following pressures were measured in the other tell tales:

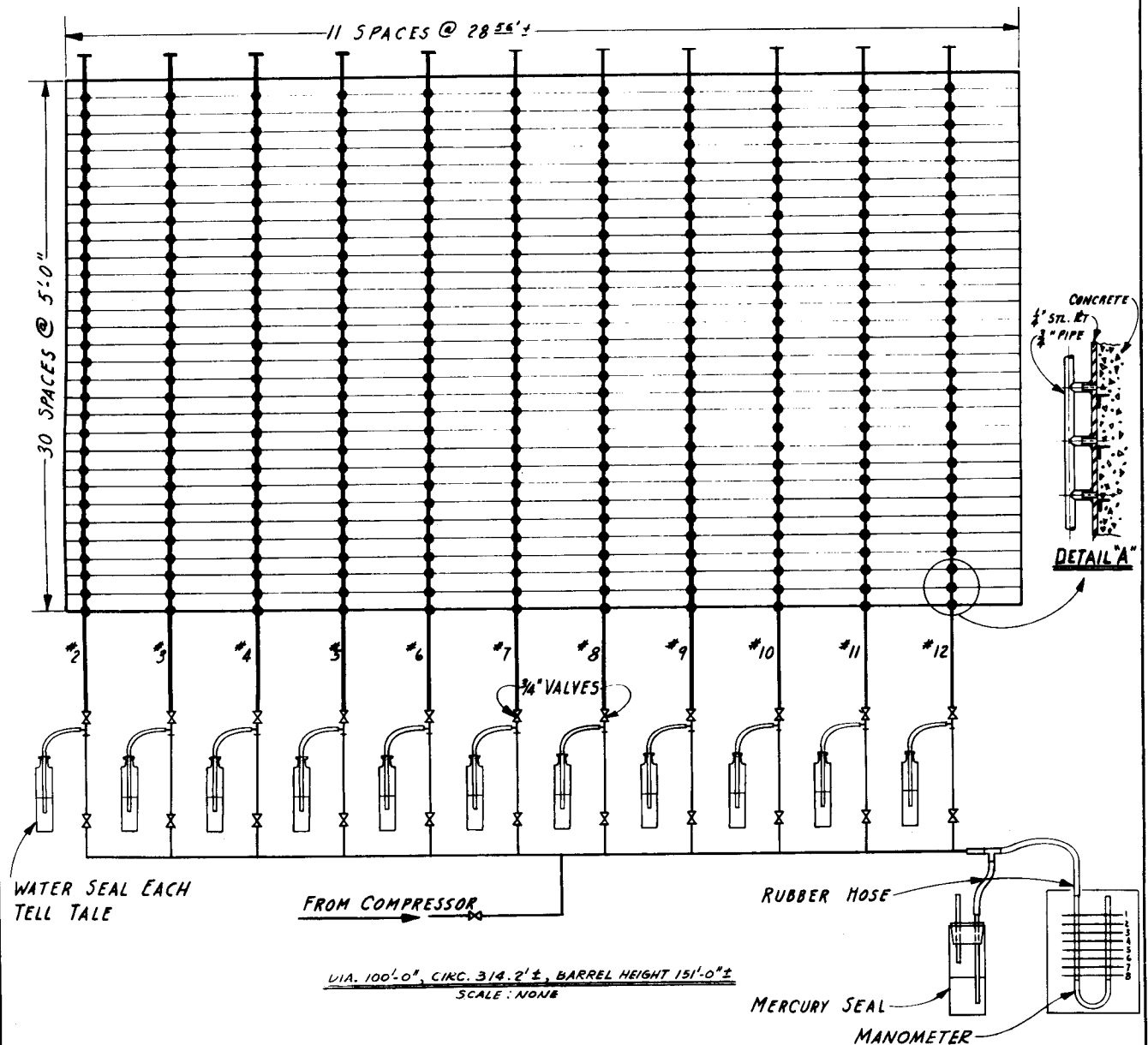
<u>Tell Tale Number</u>	2	3	4	5	6	7	8	9
Inches of Water	$1\frac{1}{4}"$	$1\frac{3}{4}"$	$1\frac{3}{4}"$	$1\frac{1}{2}"$	55"	$1\frac{3}{4}"$	$1\frac{1}{4}"$	$1\frac{3}{4}"$
<u>Tell Tale Number</u>	10	11	12					
Inches of Water	1"	$1\frac{1}{2}"$	$1\frac{1}{2}"$					

3. Condition of the Facilities

Tank 14

This vessel was suspected of leaking in the bottom dome because of oil seepage spots on the face in the lower gallery. Test holes were driven into the gunite at this location without materially affecting the flow which was continuous at approximately 4 oz. per day.

Inspection of the interface between the sheets in the bottom and first course and the concrete indicated minor quantities of oil at several locations. No defects were found in the sheets or welds up to the half way mark, where a standing test verified the examination by showing no drop in water level during a test period of five days.



SECT. VI-RED HILL-SKETCH 6
DEVELOPMENT OF BARREL SECTION
SHOWING TELL TALES TANK NO 16



Approximately 50 percent of the sheet area in this zone was covered with cement adhesions ranging from 1/32 to 2" in thickness and tightly adherent. Beneath this coating the sheets were as installed and the blue mill finish intact. Where the seams had been buffed at the time of construction and the mill finish damaged, superficial rusting had occurred.

On the bottom plate and under cement spatter which was not firmly affixed, pitting was apparent to a maximum depth of 0.05 inches. Corrosion products from these localities were high in sulphides and suggestive of anaerobic activity.

Tank 16

This vessel had a confirmed leak rate of .080 inches per day at the 134 foot level which decreased to .020 inches per day although the tank had been filled progressively to the 191 foot level. No defects in the welds or sheets giving positive results with the bubble test was found. Seven bleed spots at the 129 foot level were noted in welds on the occasions when the water level was dropped back for a recheck.

The only tell tale indication began at the 178 foot level when No. 5 began to drip water at a rate of approximately 1 quart per day. Qualitative chemical analysis of the flow and tank water indicated the source to be external to the vessel. This demonstrates that surface water can lay between the concrete and the steel liner.

Examination of the sheets in this tank showed that the majority have sustained surface deterioration. The portion arising from mechanical damage caused by the buffing away of the mill finish surrounding the welds during construction, or where cutting slag from torches impinged upon the sheet was covered with a red to black film. The balance, approximately 31 percent of the total area, showed pits in various stages of activity ranging to a maximum depth of 0.10 inches in a few isolated cases. This corrosion is not as yet serious however it stresses the necessity of cleaning the deposits off the steel.

Observation tended to establish that pitting had originated beneath loose attachments of concrete in the presence of oil and water and progressed inward from the margins towards a central depression or groove. Where inactive the entire area was covered with red rust with occasional central spots or grooves ranging from black to grey black. Where active the point of attack was generally oil saturated and small bright flecks indicated localities of metallic migration. Samples from these areas gave positive tests for H_2S and anaerobic conditions were probably present.

4. Discussion

Observations in both vessels indicate that no cracks or voids are present in the lining or welds and that the water loss in No. 16 is probably due to numerous pin holes in the weld metal. The decreasing leak rate of water is believed indicative of their tendency to seal themselves as natural rusting proceeds, and that the fuel oil losses as logged are traceable to inaccuracies inherent with measurement over too short periods of time.

The condition of the tell tale system and the concrete shell cannot be determined due to inaccessibility, but the following deductions are made from observation of their behavior.

In pressuring the tell tale system, air was fed at a continuous rate which did not appear to decrease as the system came to pressure. This was first attributed to leaks in the steel liner, but when none were discovered was interpreted to mean that the interface between the concrete shell and the steel liner was in communication with the outside ground.

On the straight side of the shell 143 tell tale connections between the liner and vertical collector pipe were hammer tested at the sheet to determine if there was any space between the liner and concrete shell. The majority sounded solid but 34.6 percent of the connections in scattered locations indicated that there was some space at the interface. When none of these

supposedly open tell tales ever gave indication of leakage and No. 5 flowed a small amount of water identified as from a source other than the tank, the theory of communication with the outside ground again followed.

The remote reading thermometer system should be examined for cause of thermocouple failure and restored to working condition. Their present location adjacent to the tank wall may be responsible for the erratic results reported to be the previous experience. Consideration should be given to relocating these elements at a point more centrally located in the vessel toward more reliable readings.

P. H. Coleman

Appendix 2B

April 29, 1949

Inspection and Recommended Repair
195,000 Barrel Concrete Reservoir
Middle Tank Farm

This underground reinforced concrete structure of approximately 195,000 barrel capacity situated in the Middle Tank Farm was built in 1920 and originally served as a fuel oil reservoir. Through Pump House 31 fuel oil is distributed to Mike, Sail and Baker Docks. In the past this reservoir has been the suspected source of oil leakage entering the harbor and its use has been abandoned except for slop.

Inspection indicates that the concrete is in good condition and that the piping and internal appurtenances are not excessively corroded. Vent caps in the roof require cleaning and painting.

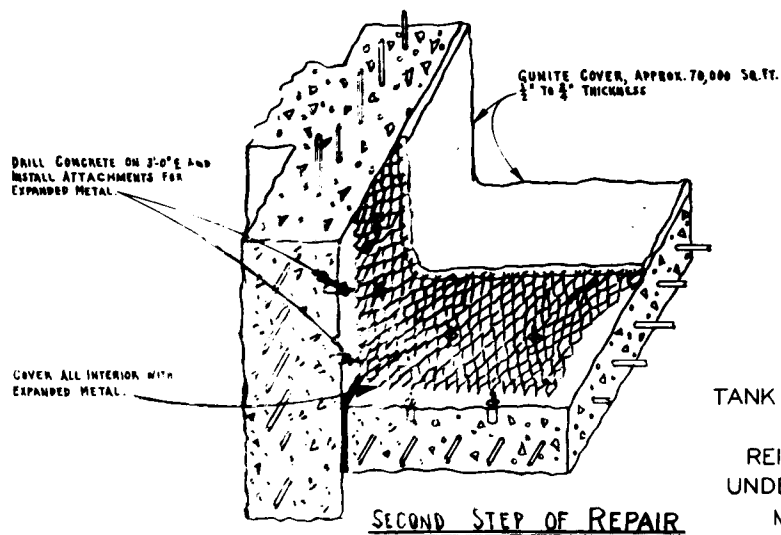
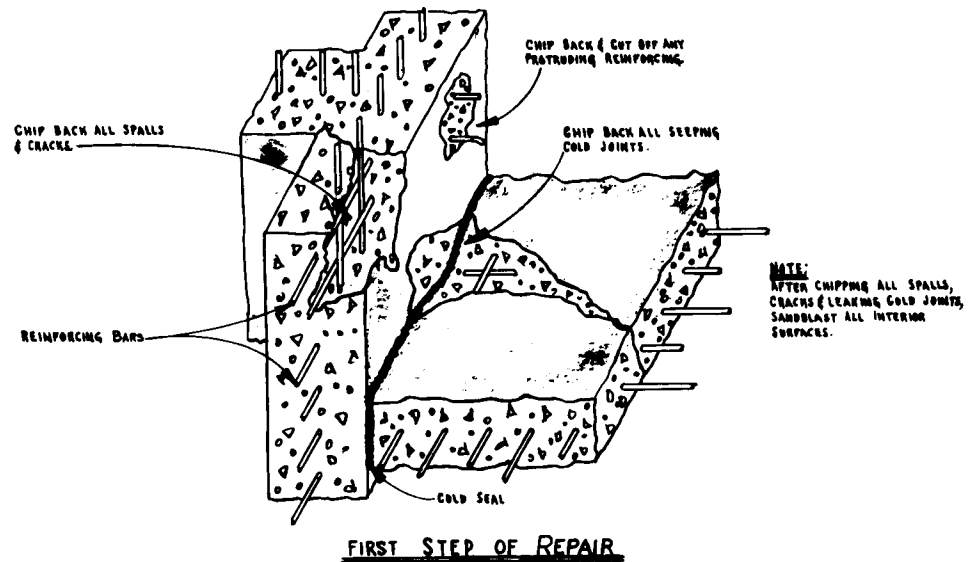
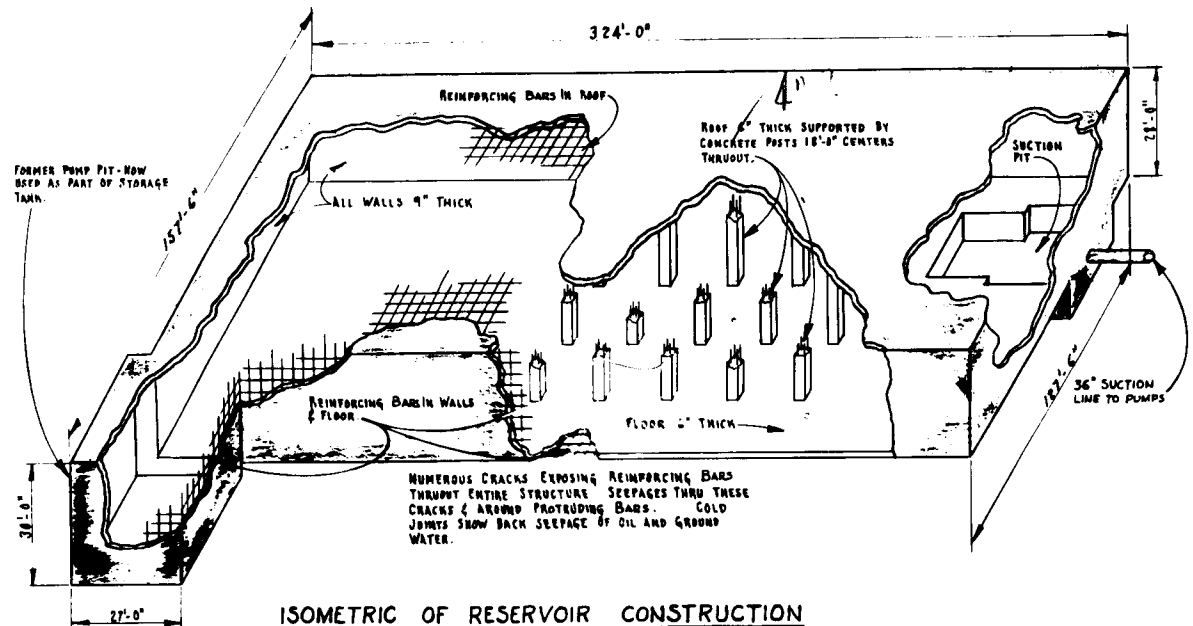
However, numerous cracks in the concrete and extensive leakage back into the reservoir were observed, particularly in the sump section on the south end of the structure.

The accompanying sketch shows the recommended method of repair of floor and sides. This consists of chipping all cracks, spalls and pour joints back to good material and cutting off any protruding reinforcing, followed by sand blasting all side and bottom surface to afford good adhesion of the gunite. Attachments should then be set into the walls and floors, expanded metal attached and the prepared surfaces, about 70,000 square feet, covered with gunite 1/2 to 3/4 inch in thickness.

Estimated cost of repair is presented in Section IV.

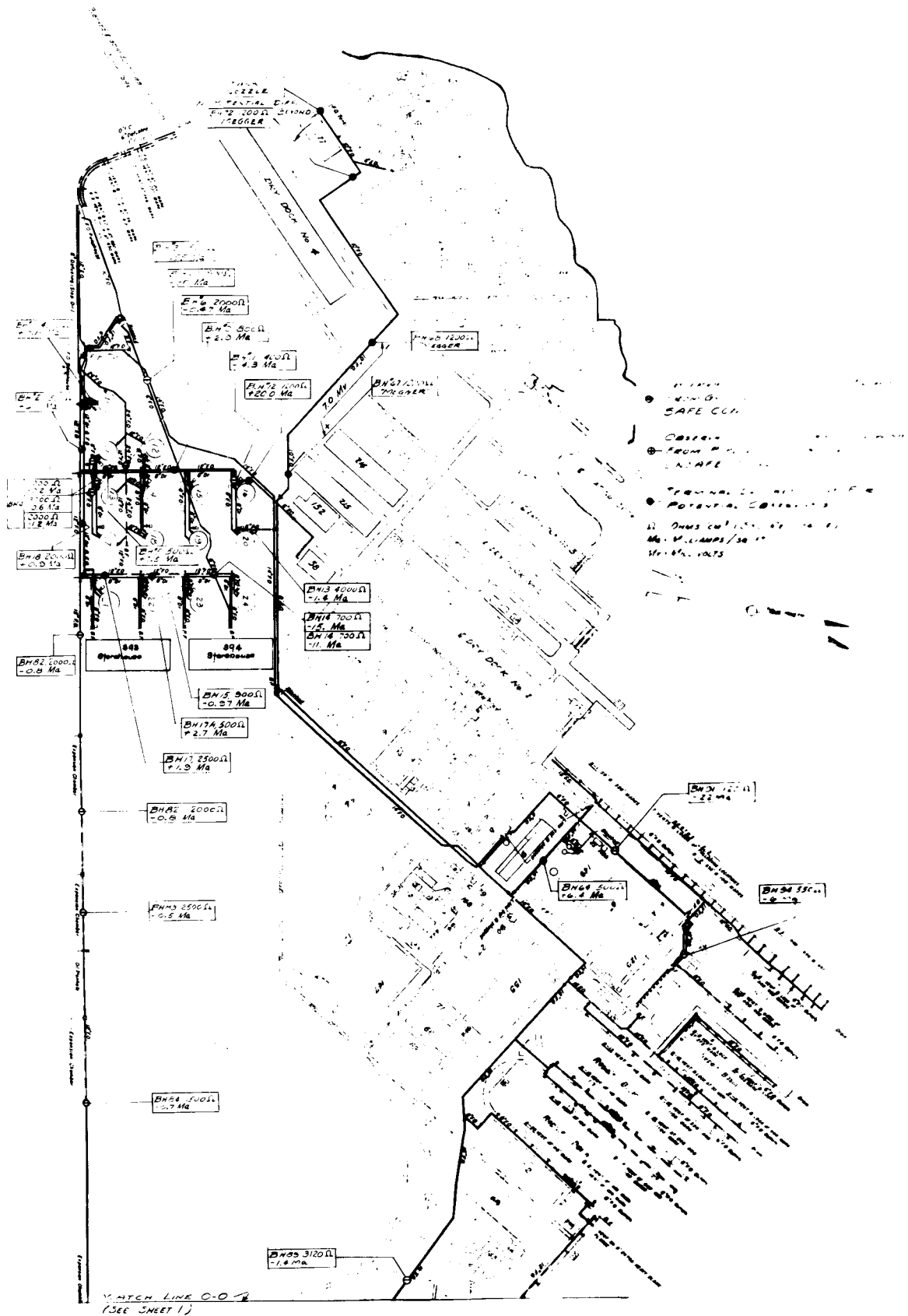
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J. L. Bensinger



SECT. VI
TANK INSPECTION SKETCH 5
REPAIRS TO
REINFORCED CONCRETE
UNDERGROUND RESERVOIR
MIDDLE TANK FARM





SECT. VI-ELECTROLYTIC SURVEY-SKETCH
 McCOLLUM METER READING
 NAVY YARD F.O. & D.O. LINES
 SHEET 2 OF 2



BELL HOLE
NUMBER

FIELD INSPECTION RECORD
CONDITION OF PIPE LINES AT
VARIOUS BELL HOLES

21.	18" F.O. Steel Wrapping - Two Layers Tar & Felt in Good Condition. Gen. Corrosion 15 Mills Depth of Cover 7 Ft. Sand & Volcanic Ash - Damp	25. (e) 4" Drain Cast Iron Some Corrosion Fair Condition	30.	12" D.O. Steel Near Tank 47 Inspection Made Berm With 4' of Cover Wrapping - Tar & Felt - Good No Corrosion Pipe in Open. Not in Berm in Good Cond.	35.	8" Drain Cast Iron From Tank 54 Gen. Corrosion 4 Mills Depth of Cover 5 Ft.	41. (a) 24" F.O. Steel Suction to TK51 Coating - Tar Spotty & Poor Gen. Corrosion 7 Mills No Pitting Depth of Cover 6 Ft. Volcanic Ash - Dry
22.	18" F.O. Steel Wrapping - Two Layers of Tar & Felt in Good Condition. Gen. Corrosion 11 Mills Depth of Cover 7 Ft.	26. (a) 32" F.O. Steel Same as 25a Except Flanges Are Shown in This Hole. Flanges Have Tar - No Corrosion. Salt Water in Hole b,c,d & e Same as in #25	31.	12" F.O. Steel Blanked Suction Line To Tank 47. Inspection made in Berm. Condition Similar to #30	36.	8" F.O. Steel To Tank 48 Inspection Made in Berm with 2' Cover Aluminum Painted Gen. Corrosion 2 Mills	(b) 8" Drain Cast Iron Gen. Corrosion 15 Mills Pitts Many at 50 Mills Depth of Cover 13 Ft. Brown Dirt & Sea Shells-Damp
23.	12" F.O. Steel Wrapping - Asphalt & Felt Thin but in Fair Condition Gen. Corrosion 5 Mills Depth of Cover 7 Ft. Volcanic Ash Gravel - Damp	27. (a) 8" F.O. Steel Suction Line to TK55 No Coating or Wrapping Gen. Corrosion 22 Mills Depth of Cover 2 Ft.	32. (a) 8" F.O. Steel No Wrapping Coating of Red Lead and Aluminum Paint. Several Pitts Present. Several Pitts at 54 Mills Corrosion 19 Mills Obviously Pitting Has Been Checked by the Painting. Pipe in Good Condition. Depth of Cover 1 Ft.	37.	8" Drain Cast Iron From Tank 53 Gen. Corrosion 25 Mills Depth of Cover 3 Ft. Volcanic Ash - Dry	(c) Besides the Above Mentioned Pipes, The Following Were Found in the Same Bellhole in Poor Condition 1 - 12" at 12 Ft. 2 - 8" at 12 Ft. 2 - 6" at 13 Ft.	
24. (a) 32" F.O. Steel Near Bldg. 480 Wrapping - Tar & Felt in Good Condition. No Corrosion or Pitts Depth of Cover 4 Ft. Rocks & Gravel Salt Water in Hole	28. (a) 8" F.O. Steel Suction Line to TK55 No Coating or Wrapping Gen. Corrosion 43 Mills -Scaling Depth of Cover 18" Lava & Sand - Dry	(b) 8" Drain Cast Iron No Coating or Wrapping Gen. Corrosion 17 Mills Few Pitts at 48 Mills Bell Joint in Hole Lead Packing Good Depth of Cover 2 Ft.	38.	14" F.O. Steel Near Tank 52 Inspection Made in Berm with Depth of Cover 3 Ft. Wrapping Tar & Felt - In Poor Condition No Corrosion or Pitts Wrapping on Pipe Above Ground in Poor Condition No Corrosion or Pitts	42.	12" F.O. Steel Suction to TK45 Wrapping Tar & Felt Peels Off Very Easily Gen. Corrosion 67 Mills No Pitting Depth of Cover 4 Ft.	
(b) 18" F.O. Steel Condition Same As "a"	(b) 8" Drain Cast Iron No Coating or Wrapping Gen. Corrosion 17 Mills Few Pitts at 48 Mills Bell Joint in Hole Lead Packing Good Depth of Cover 2 Ft.	(b) 8" Drain Cast Iron No Wrapping Painted Black No Corrosion or Pitts Bell Joint Well Leaded Depth of Cover 3 Ft.	39.	12" & 14" F.O. Steel Near Tank 52 Inspection Made in Berm with 4 Ft. Cover Wrapping Tar & Felt - In poor Condition. No Corro. or Pitts Wrapping on Pipes Above Ground In Poor Condition. No Corrosion or Pitts	43. (a) 8" F.O. Steel Suction to Tank 45 Coating Red Lead Black Paint & Aluminum on Top Layer. Sealing off No Corrosion or Pitts Depth of Cover 2 Ft.	(b) 8" Drain Cast Iron Gen. Corrosion 22 Mills No Pitts Depth of Cover 4 Ft.	
(c) 12" Ballast Steel Condition Same As "a"	(b) 8" Drain Cast Iron Good Condition	33.	12" F.O. Steel Suction to TK46 Inspection Made in Berm Wrapping - Heavy Tar - Good No Corrosion or Pitts Pipe in Above Ground Area Needs Painting No Corrosion	40.	24" F.O. Steel Near Pumphouse 91 Heavy Tar Coating - Good No Gen. Corrosion Pitts Several at 93 & 100 Mills Depth of Cover 7 Ft. Volcanic Rock & Red Soil at Pipe Depth Ground Saturated with Oil	44.	8" F.O. Steel Suction Line to TK54 Coating Black Paint & Aluminum - Chipping off Gen. Corrosion 5 Mills Pitts Several at Bottom 15 Mills Depth of Cover 2 Ft.
25. (a) 32" F.O. Steel Near Bldg. 530 Wrapping 2 Layers of Tar & Felt - Good Condition No Corrosion or Pitts Depth of Cover 9 Ft. Gravel & Lava Rocks - Moist	29.	14" F.O. Steel Near Tank 48 No Coating or Wrapping Inspection Made in Berm Several Pitts at 27 Mills Exposed Portion of Pipe Outside of Berm not Corroding Paint Peeling off.	34.	8" F.O. Steel Suction Line to TK53 No Wrapping. Aluminum Coating Scaling Gen. Corrosion 9 Mills Depth of Cover 2 Ft. Volcanic Ash - Dry			
(b) 18" F.O. Steel							
(c) 12" Ballast Steel							
(d) 16" D.O. Steel b,c & d same as "a"							

**FIELD INSPECTION RECORD
CONDITION OF PIPE LINES AT
VARIOUS BELL HOLES**

**BELL HOLE
NUMBER**

45. (a) 8" F.O. Steel (Shown 12" F.O. on Dwg.) At Tank 37 Wrapping - Tar & Burlap Gen. Corrosion 22 Mills No Pits Moisture Between Wrapping & Pipe Depth of Cover 3 Ft.	55. (a) 12" F.O. Steel Edge Sub Baseball Field Wrapping Asphalt & Felt - Good No Corrosion or Pits Depth of Cover 6 Ft. Coral, Sand	58. (b) 12" D.O. Steel Coating Red Lead & Black Paint. No Corrosion or Pits Depth of Cover 7 Ft.	62. (c) 10" D.O. Steel Wrapping Tar & Felt No Corrosion or Pits Sand & Coral - Damp Depth of Cover 2 Ft.
(b) 8" Drain Cast Iron Shown as 8" Drain on Dwg. Gen. Corrosion 5 Mills No Pits	(b) 16" F.O. Steel Wrapping Tar & Cellophane-Good No Corrosion or Pits Depth of Cover 5 Ft.	NOTE: - Both of These Lines Were Found Cut and Blanked. Inspection was made 3 Ft. from each of the Blanked Ends. At the Bottom of the Hole There was Salt Water with a Layer of Oil on Top.	
46. (a) 8" F.O. Steel Suction to TK36 Coating - Tar - Peeling off Moisture Between Pipe & Tar Gen. Corrosion 20 Mills Pits Several at 70 Mills Depth of Cover 2 Ft. Volcanic Rocks - Dry	(c) 12" D.O. Steel Wrapping Tar & Cellophane-Good No Corrosion or Pits Depth of Cover 6 Ft.	59. 22" F.O. Steel Near Bldg. 626 Coating - Heavy Tar No Corrosion or Pits Gravel, Sand Volcanic Ash Depth of Cover 6 Ft.	74. 12" F.O. Steel To Tank 34 Coating Tar No Corrosion or Pits Depth of Cover 2 Ft. Red Dirt & Rocks
(b) 8" Drain Cast Iron Gen. Corrosion 23 Mills No Pits	(b) 12" D.O. Steel Wrapping Tar & Cellophane No Corrosion or Pits Depth of Cover 4 Ft. Coral, Sand & Brown Dirt	60. 18" F.O. Steel Near Bldg. 490 Coating Heavy Tar No Corrosion or Pits Depth of Cover 5-1/2 Ft. Oil & Water in Hole	75. (a) 12" F.O. Steel No Coating or Wrapping Gen. Corrosion 37 Mills Pits Several at 75 Mills Depth of Cover 7 Ft.
47. 12" F.O. Steel Wrapping Tar & Burlap Gen. Corrosion 25 Mills Pits Few at 60 Mills Depth of Cover 3 Ft.	(c) 12" D.O. Steel Wrapping Tar & Cellophane No Corrosion or Pits Depth of Cover 4 Ft. Coral, Sand & Brown Dirt - Damp	61. (a) 18" F.O. Steel Opposite Bldg. 647 Wrapping Tar & Felt No Corrosion or Pits Depth of Cover 6 Ft. Water in Hole	76. 8" Drain Cast Iron Gen. Corrosion 25 Mills Pits Several at 88 Mills Depth of Cover 2 Ft.
48. 12" F.O. Steel No Coating or Wrapping Gen. Corrosion 25 Mills Pits Several at 60, 67 & 73 Mills Depth of Cover 20 Ft. Black Dirt Volcanic Rocks	(b) 12" D.O. Steel Wrapping Tar & Cellophane No Corrosion or Pits Depth of Cover 7 Ft.	(b) 10" D.O. Steel Wrapping Tar & Felt No Corrosion or Pits Depth of Cover 6 Ft.	77. 12" F.O. Steel Coating - Tar Peeling Off Gen. Corrosion 8 Mills No Pitting. Inspection Made in Berm. Pipe Above Ground Looks Good Needs Maintenance
49. 8" Drain Cast Iron Gen. Corrosion 8 Mills Pits Several at 86 Mills Depth of Cover 3 Ft.	56. (a) 18" F.O. Steel Near Bldg. 678 Wrapping Tar & Cellophane No Corrosion or Pits Depth of Cover 4 Ft. Coral, Sand & Brown Dirt	62. (a) 18" F.O. Steel Near Bldg. 482 Wrapping Tar & Felt No Corrosion or Pits Depth of Cover 5-1/2 Ft. Soil at Bottom of Pipe Saturated with Oil	78. 8" Drain Steel Near Tank 29 No Coating or Wrapping Gen. Corrosion 46 Mills No Pitting Depth of Cover 2'-6"
	57. (a) 18" F.O. Steel Near Bldg. 687 Wrapping Tar & Cellophane Pipe Coated With Red No Corrosion or Pits Depth of Cover 7 Ft. Coral & Seashells Sand Oil in Hole	63. (a) 18" F.O. Steel Near Bldg. 689 Coating, Red Lead and Black Paint. No Corrosion or Pits Depth of Cover 7 Ft.	
	58. (a) 18" F.O. Steel Near Bldg. 689 Coating, Red Lead and Black Paint. No Corrosion or Pits Depth of Cover 7 Ft.		

**FIELD INSPECTION RECORD
CONDITIONS OF PIPE LINES AT
VARIOUS BELL HOLES**

**BELL HOLE
NUMBER**

1. (a) 8" F.O. Steel Tar Coating Pitting - 37 Mills On Side of Pipe Depth of Cover 4 Ft. Coral & Sand - Dry	6. (a) 24" F.O. Steel Asphalt Coating - Fair Pipe Examined in Berm With 3 Ft. of Cover Pipe outside of Berm above Ground, No Corro. Needs Maintenance	11. (a) 2 - 8" F.O. Lines Steel No Coating or Wrapping Pitting on Both Pipes Several Pits at 41 Mills Depth of Cover 1 Ft. Coral & Brown Dirt - Damp	16. (a) 2 - 8" F.O. Lines Steel No Coating or Wrapping Several Pits at 85 Mills Depth of Cover 3 Ft. Coral & Volcanic Ash - Damp	64. 14" F.O. Steel Near Bldg. 9 No Coating or Wrapping Gen. Corrosion 20 Mills Several Pits at 35 Mills Depth of Cover 7 Ft. Coral, Lava Ash & Sand - Damp
(b) 8" Drain Cast Iron Gen. Corrosion 12 Mills	(b) 12" F.O. Steel No Coating General Corrosion Some Pits - 20 Mills	(b) 1 - 8" Drain Cast Iron Depth of Cover 2 Ft. Good Condition	(b) 8" Drain Cast Iron Gen. Corrosion 5 Mills	65. 14" F.O. Cast Iron Bell Jts. Opposite Bldg. 13 No Coating or Wrapping Few Pits at 105 Mills Depth of Cover 7 Ft. Lava & Volcanic Ash - Dry
2. (a) 12" Dr. & F.O. Steel No Coating or Wrapping No Corro. or Pits Depth of Cover 14 Ft. Gravel & Brown Dirt, Moist	(c) 8" Drain Cast Iron Good Condition	12. 6" F.O. Steel Wrapping - Tar, No Oxide Good Condition No Corrosion or Pits Depth of Cover 2 Ft. Coral & Sand - Moist	17. (a) 12" F.O. Steel No Coating or Wrapping Several Pits at 85 Mills Depth of Cover 7 Ft. Coral & Lava Rock - Dry Ground Around Pipe Saturated With Oil	67. 10" F.O. Steel Near Bldg. 215 Wrapping - Asphalt & Felt Wrapping Starting to Peel Off at Pipe Bottom No Corrosion or Pits Depth of Cover 3 Ft. Brown Dirt & Gravel - Dry
(b) 12" F.O. Steel No Coating or Wrapping Badly Pitted In Poor Condition Depth of Cover 14 Ft. Gravel & Brown Dirt, Moist	7. 8" F.O. Steel No Coating Gen. Corrosion 25 Mills Several Pits at 35 Mills Depth of Cover 4 Ft. Clay, Lava & Coral - Damp	13. 6" F.O. Steel No Coating or Wrapping Gen. Corrosion 25 Mills No Pits Depth of Cover 2 Ft. Coral & Sand - Damp	(b) 8" Drain Cast Iron Gen. Corrosion 20 Mills Depth of Cover 7 Ft. Ground Around Pipe Saturated With Oil	
3. 8" F.O. Steel No Coating or Wrapping Gen. Corrosion. No Pitting - Fair Condition Depth of Cover 4 Ft. Coral, Gravel, Sand - Dry	8. (a) 8" F.O. Steel No Coating Gen. Corrosion 25 Mills No Pitting Depth of Cover 5 Ft. Brown Dirt & Coral - Dry	14. (a) 12" F.O. Steel No Coating or Wrapping Gen. Corrosion 25 Mills Several Pits at 75 Mills Depth of Cover 6 Ft. Oil Saturated in Ground No Apparent Leaks	18. (a) 12" F.O. Steel No Coating or Wrapping Several Pits at 67 Mills Depth of Cover 15 Ft. Oil in Hole Near Pipe Ground Saturated With Oil	68. 10" F.O. Steel Near Dry Dock No. 4 Wrapping - Asphalt & Felt Wrapping in Good Condition No Corrosion or Pits Depth of Cover 4 Ft. Coral & Sand - Damp
4. (a) 2 - F.O. Lines - Steel No Coating General Corrosion Depth of Cover 5 Ft. Coral, Gravel & Sand - Dry Pipes in Fair Condition	(b) 8" Drain Cast Iron Good Condition	(b) 8" Drain Cast Iron Gen. Corrosion 20 Mills No Pits. 911 Saturated in Ground. Depth of Cover 5 Ft.	(b) 12" F.O. & Drain Steel No Coating or Wrapping Gen. Corrosion 38 Mills Several Pits at 115 Mills Depth of Cover 15 Ft. Oil in Hole Near Pipe Ground Saturated With Oil	69. (a) 14" F.O. Cast Iron Near Bldg. 97 No Wrapping Black Paint on Pipe No Corrosion or Pits Depth of Cover 9 Ft. Coral, Lava Rock, Gravel - Damp
(b) 1 - 8" Drain Cast Iron Depth of Cover 5 Ft. Pipe in Good Condition	(b) 8" Drain Cast Iron Good Condition	(c) 6" F.O. Cast Iron No Corrosion Depth of Cover 5 Ft. Good Condition	19. 6" F.O. Steel Tar Coating in Good Condition No Corrosion or Pits Depth of Cover 3 Ft.	(b) 6" F.O. Cast Iron No Coating or Wrapping No Corrosion or Pits Depth of Cover 4 Ft.
5. (a) 12" F.O. Steel No Coating General Corrosion Several Pits - 100 Mills Depth of Cover 5 Ft. Coral, Gravel & Sand - Dry	10. (a) 8" F.O. Steel No Coating Gen Corrosion 25 Mills No Pits Depth of Cover 2 Ft. Clay, Rocks & Gravel - Damp	15. (a) 2 - 8" F.O. Lines Steel No Coating or Wrapping Gen. Corrosion 30 Mills Several Pits at 77 Mills Depth of Cover 3 Ft. Coral & Volcanic Ash - Damp	20. 8" F.O. Steel No Coating or Wrapping Gen. Corrosion 23 Mills Several Pits at 41 Mills Depth of Cover 5 Ft. Coral & Lava Ash - Dry	70. 10" F.O. Cast Iron Near Bldg. 872 No Coating or Wrapping Several Pits at 12 Mills Depth of Cover 4 Ft. Coral & Sand - Damp
(b) 8" Drain Cast Iron Depth of Cover 3 Ft. Gen. Corrosion 20 Mills	(b) 8" Drain Cast Iron Good Condition	(b) 8" Drain Cast Iron General Corrosion 8 Mills		



VI - I

TYPICAL TANK ROOF CORROSION
SURFACE STORAGE TANKS
PEARL HARBOR NAVAL SHIPYARD



VI - 2

TYPICAL CORROSION OF BURIED FUEL AND
DIESEL OIL LINES IN SUBMARINE BASE AREA
COATING FAILURE, OIL SATURATED SOIL AND
ENVIRONMENT OF LINES ARE CLEARLY INDICATED



VI - 3

EXCAVATION OF OIL LINES
IN SUBMARINE BASE AREA.
SHOWING SOIL CONDITIONS
AND COATING FAILURE



VI - 4

REPAIR OF WELD FAILURE
MERRY POINT AREA.
SHOWS SOIL CONDITIONS
AND COATING FAILURE.



VI - 5

ANODE BED AT HALAWA STREAM SHOWING LOSS
OF METAL AFTER FIVE YEARS OPERATION.
CATHODIC PROTECTION PROVIDED OIL LINES
SUPPLY CENTER AREA.