

TANK 27 API 653 TANK INSPECTION AND SUITABILITY FOR SERVICE EVALUATION

Thule Air Base, Greenland

July 2008

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EI Project 08-4889



ABSTRACT

Enterprise Engineering, Inc. (EEI) has completed a comprehensive, out-of-service internal and external inspection and suitability for service evaluation of Tank 27 at Thule Air Base, Greenland in accordance with the applicable criteria of API Standard 653, Third Edition, Addendum 3, February 2008 and UFC 3-460-01 (previously 1022A). The API 653 criteria were followed in terms of procedure and evaluation to the greatest extent possible. The inspection was performed on June 8th, 2008.

This report provides inspection findings, tank suitability for service evaluation, conclusions, and recommendations for repair, prior to returning the tank to service. Recommendations for continued long-term service are also provided.

EEI recommends the next API internal out-of-service inspection be scheduled no later than June 2018 (10 years from 2008 inspection), or when a change in condition has occurred.

EEI recommends the next API external inspection be scheduled no later than June 2013 (5 years from 2008 inspection), or when a change in condition has occurred.

In accordance with API Standard 653, this report satisfies the requirement for an out-of-service, integrity inspection and as such, should remain available as a historical record for future reference.

I hereby acknowledge that being familiar with the provisions of API Standard 653, the inspection and evaluation was performed in accordance with the provisions of API Standard 653 and good engineering practices, and with the exercise of usual and customary care.

This tank inspection has determined that mandatory repairs are not required prior to return to service. Tank 27 may be returned to service. Recommended repairs have been identified, and if possible should be completed before returning tank to service.



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July 24, 2008
Date

TABLE OF CONTENTS

	Page
SUMMARY	1
Scope	1
General	1
INSPECTION ASSESSMENT	1
Hydraulic Integrity	1
Structural Integrity	2
Next Inspection	2
REPAIR ITEMS	2
Required Repairs Prior to Return to Service (Mandatory)	2
Recommended Repairs Prior to Return to Service (Non-Mandatory).....	3
Recommended Repairs for Long Term Serviceability.....	4
Coating Requirements	5
SUITABILITY FOR SERVICE EVALUATION	6
Corrosion Rates	6
Tank Floor Corrosion Rates	6
Hydraulic and Structural Integrity	8
ADDITIONAL DISCUSSION ITEMS	9
Gauge Tube (Stilling Well) Requirements.....	9
CLOSURE	11
Conclusions.....	11
Project Team.....	11

APPENDICES

Tank Inspection Data Sheet and Evaluation Items.....	Tab A
Non-Destructive Examination (NDE) and Evaluation Criteria.....	Tab B
Tank Drawings	Tab C
Tank Photographs.....	Tab D
NDE Results.....	Tab E
Calculations.....	Tab F
Field Trip Report	Tab G

TANK 27
API 653 TANK INSPECTION
SUITABILITY FOR SERVICE EVALUATION
Thule Air Base, Greenland

SUMMARY

Scope

Enterprise Engineering Inc. (EEI) has completed a comprehensive, out-of-service inspection and suitability for service evaluation of Tank 27 at Thule Air Base, Greenland. The inspection was performed on June 8th 2008, in accordance with applicable portions of API Standard 653, Third Edition, Addendum 3, February 2008 and UFC 3-460-01 (previously 1022A).

The scope of this project is to determine the structural and hydraulic condition of the tank, determine suitability for service, provide written recommendations for repairs and develop recommendations for long-term service based on visual inspection and non-destructive examination (NDE).

General

Tank 27 is a field erected above ground storage tank. The tank was fabricated and erected in 1951. The tank is 100 feet in diameter and 37 feet 6 inches high and is of welded construction with butt-welded shell plates and lap-welded floor and roof plates. The nominal shell capacity is 49,170 Bbls. Tank 27 is currently in JP-8 service. The tank is not equipped with a floating pan. A new floor was installed in 1999-2000.

INSPECTION ASSESSMENT

The Appendices in this report include a comprehensive table identifying tank features with findings and conclusions as appropriate. The Appendices also contain numerous tables with full reporting of data taken. The following discussion only addresses key integrity issues.

Tank 27 is considered suitable for service as no mandatory repairs were identified. The following are significant findings of the inspection.

Hydraulic Integrity

Hydraulic integrity is the ability of the tank to hold product without compromise to the boundaries of the floor and shell.

Visual inspection of the tank shell found no indications of leakage. A magnetic flux leakage (MFL) scan of the tank floor found no relevant indications of corrosion on the bottom side of the floor requiring repair. A pit survey was conducted for topside corrosion and no pits were identified requiring repair. Based on this inspection and completion of the repairs, Tank 27 is in acceptable hydraulic condition.

Structural Integrity

Structural integrity is the capability of the tank to remain freestanding, with or without product, under the conditions of its design basis. Structural attributes include the floor, shell, roof and their attachments. Ultrasonic inspections of the shell were performed on the first course and on each course up the exterior spiral stair. From interpretation of ultrasonic test (UT) readings recorded, only plate thickness variances were noticed. Based on this inspection of the accessible components, Tank 27 is in acceptable structural condition.

Next Inspection

API 653 recommends the interval to the next internal inspection be determined based on known corrosion rates, but in no case shall the interval exceed 20 years from time of inspection. When corrosion rates are not known or well established, API 653 recommends that the tank be inspected within 10 years. A maximum interval between inspections of 10 years is also commonly used in many government and commercial facilities.

The corrosion calculations presented in API 653 suggest floor backside corrosion may exist that magnetic flux leakage scanning methods will not find as it is below a “threshold” used for scanning. The calculations for this tank assumed backside corrosion equal to 20% metal loss may not have been located. When applying a 20% metal loss over a short period of time, such as eight years as is the case with this relatively new floor, the linear corrosion rate appears excessive.

The calculated corrosion rates using the suggested approach discussed above indicate that the next API internal inspection should be scheduled no later than 6.5 years from the inspection date. EEI advises that the 6.5 years calculated indicates that there is not enough historical information to establish a reliable corrosion rate and the 10 year interval commonly used by the government and by API for tanks of unknown corrosion rates should be followed. The dry climate and lack of observed deficiencies support the increase in the inspection interval. In the interim, a limited out-of-service inspection of the coating should be performed during any maintenance cleanings.

An external in-service inspection should be conducted in accordance with API 653 requirements no later than June 2013, or sooner if change in condition has occurred.

REPAIR ITEMS

Based upon the API field inspection, engineering judgment and knowledge of funding practices, recommendations developed are listed below as required (mandatory) and recommended (non-mandatory) and recommended for long term serviceability.

Required Repairs Prior to Return to Service (Mandatory)

Mandatory refers to those API 653 items that are considered critical to the hydraulic or structural integrity of the tank or are required to meet code prior to placing Tank 27 back into service.

- The inspection of Tank 18 found no mandatory repairs that would prevent the tank from returning to service.

Recommended Repairs Prior to Return to Service (Non-Mandatory)

The repairs listed below are not mandatory per API 653 or for structural and hydraulic integrity of the tank. EEI highly recommends these repairs for long-term preservation and integrity of the tank, and believes that the repairs should be performed concurrently with required repairs noted above.

1. Line relieving / differential thermal relief (LR/DTR) at the 10 inch Issue nozzle is set at 25 psi while the thermal relief loop piping is set at 200 psi. The following repair is recommended:
 - Remove the LR/DTR piping.
2. A double block and bleed (DB&B) plug valve is present on the Low Fuel Piping to isolate it from the Issue Piping. The LR/DTR piping relieves into the pipeline rather than into the tank. The following repair is recommended:
 - Remove the LR/DTR on the Low Fuel Piping.
3. Body cavity relief (BCR) is present on the valves at the Issue and Fill nozzles. The BCR currently relieves into the tank rather than into the pipeline. The following repair is recommended:
 - Revise the BCR to relieve into the pipeline.
4. The float for the Shand & Jurs tape gauge is not functional. The following repair is recommended:
 - Provide a new tape gauge head, float, tape and springs.
5. Tank 27 has been equipped with two 10 inch pressure/vacuum vents. The following repair is recommended:
 - Disassemble and clean the pressure/vacuum vents.
6. Tank 27 is equipped with two 2 inch ¼-turn ball valves in the dead shell that provide a means of leak detection. The flanges have been blinded. The following repair is recommended:
 - Remove the blind flanges to allow monitoring of the interstitial space.
7. Localized coating failures and corrosion were observed on the exterior shell, floor extension, shell appurtenances, stairs, roof and roof appurtenances. The following repair is recommended:
 - Remove the coating from the affected areas, clean and recoat to prevent further degradation.
8. Replace the gasket for the manway prior to reinstalling the manway cover plate.
9. Provide surface preparation and recoat all interior and exterior repair areas, new materials and areas damaged as a result of repairs in accordance with Coating Requirements.

Recommended Repairs per Current Military Criteria: The following recommended repairs are in accordance with UFC 3-460-1 (formerly MIL-HDBK-1022A):

1. The 12 inch Fill Piping includes a diffuser with a 12 inch x 19 inch opening and appears to be undersized. Section 8.3.9 of UFC 3-460-01 limits the velocity to 12 ft/s at maximum flow and 3 ft/s until the fill piping is submerged. The following repair is recommended:
 - This item withdrawn after discussion with operations personnel.
2. The floor and lower 4 feet of the interior tank shell and columns of Tank 27 are coated. Section 8.3.7 of UFC 3-460-01 states that vertical tanks storing aviation fuel should be 100% coated, including floor, shell and underside of roof. Rust was observed falling from the underside of the roof during the inspection. The following repair is recommended:
 - Coat the remaining interior surfaces of the tank.
 - Note: The decision to proceed with this recommendation requires consideration of multiple variables such as the difficulty of applying coatings at low temperatures and the low corrosion rate of uncoated plate steel in the ambient dry air.
3. Tank 27 is not equipped with a product recovery system per Section 8.3.12 of UFC 3-460-01. The following repair is recommended:
 - This item withdrawn after discussions with operations personnel.
4. Table 2 of UFC 3-460-01 describes appurtenances for atmospheric storage tanks. Tank 27 is not equipped item (dd) striker plates under all openings used for manual gauging. The following repair is recommended:
 - Provide a ¼ inch thick x 12 inch diameter round striker plate.
 - Seal weld the reinforcing plate to the shell. The completed repair shall have no cracks and shall have complete penetration and complete fusion with the shell plate.
 - Provide visual examination, vacuum box testing (BT) and either liquid penetrant testing (PT) or magnetic particle testing (MT) of the completed repair.
 - (Note: It was reported that POL use the same gauge hatch as the ATG where a datum plate is present and would act as a striker plate. Although this is acceptable in the short term, the installation of a new striker plate on the floor may be required when the next generation ATG system with gauge tubes is executed.)

Recommended Repairs for Long Term Serviceability

1. Table 2 of UFC 3-460-01 describes appurtenances for atmospheric storage tanks. Tank 27 is not equipped with item (j) an automatic level alarm system independent of the gauging system. The following repair is recommended:
 - Provide an independent level alarm for the HI, HI-HI and Low levels.
 - Note: The nozzles and fittings may be installed while the tank is out of service. The alarm system may be installed at a future date.

2. The portion of the shell below the new floor is commonly referred to as the “dead shell”. The new floor has been continuously welded to the dead shell. Although not clearly prohibited by 653 to our knowledge, the welding of the deadshell to the underside of the floor is not considered an acceptable engineering practice when a full strength fillet weld is provided. The floor, welded top and bottom, can no longer act as a hinge, permitting rotation of the shell above the floor when the tank is emptied and filled. Many tank engineers are concerned that laminar tearing of the floor plate can occur with full strength welds to shell above and dead shell below. API 650 Appendix I does however address this condition, and requires an engineering analysis of the condition if a full strength weld is to be used. A decision is required by the government as to the long term acceptability of this condition. The anticipated repair includes grinding out the excessive weld on the underside of the new floor (floor to dead shell weld). Alternative means to prevent water introduction below the tank by using a sealant is required.
3. Program the tank for an API external in-service inspection in 5 years, and an API out-of-service internal inspection no later June 2018.
4. Test all level alarms and switches as part of on-going maintenance.

Coating Requirements

All repairs involving steel surface grinding, cutting, and welding shall be preceded by proper coating removal. At this time it is not known if any of the existing coating layers have significant lead or chromate components. The contractor shall be responsible for testing coating systems for lead and chromate levels, and develop engineered controls to prevent worker safety hazards, and spread of contaminated dusts. Coating removal method shall be contractor determined, to suit contamination levels and follow-up steps.

Coating System at Localized Repair Locations Only (Interior and Exterior)

Provide repair of localized areas of failed and damaged coatings on the interior and exterior of the tank and areas affected by the repair work. Provide a coating system that complies with MIL-PRF-4556F (superseding MIL-C-4556), two-coat application, 4 to 8 mils DFT per coat. Provide surface preparation in accordance with the coating manufacturer’s recommendations to ensure adhesion of the coating system. For tank interior coating, provide surface preparation in accordance with the coating manufacturer’s recommendations for immersion service. Provide 2 to 3 mil surface profile unless recommended otherwise by the coating manufacturer. Prior to surface preparation, test surfaces for soluble salts, oil, and grease and clean as required to remove contaminants. Tank interior coatings shall cure for not less than 14 days prior to introducing fuel into the tank. Provide longer cure time when recommended by manufacturer.

MIL-PRF-4556F (superseding MIL-C-4556) is an epoxy polyamide coating system that was used for coating the interior of storage tanks prior to the development of the MIL-DTL-24441 epoxy polyamide coating system and is still used on the interior of filter separators and other process vessels.

SUITABILITY FOR SERVICE EVALUATION

Corrosion Rates

Corrosion rates for the tank shell and roof were calculated using assumed nominal metal thicknesses when the tank was constructed in 1951. The corrosion rate for the floor was calculated using an assumed nominal metal thickness when the floor was installed in 2000. The corrosion calculations are also based upon the plate thicknesses obtained from UT thickness measurements at the time of the inspection. The corrosion rates are summarized as follows:

Floor: 0.00675 inches per year (See Table 1 below)

Shell: 0.00072 inches per year

Roof: Negligible – Plate thickness is within mill tolerance

Tank Floor Corrosion Rates

Bottom side corrosion with small volumetric metal loss may be present and not detected by MFL scanning. The metal loss used to establish the bottom side corrosion rate was conservatively calculated using the average thickness of the floor minus a 20% threshold value for undetected bottom side pits per API. The MFL floor scanner is not setup to indicate (alarm) for minor metal loss.

The minimum remaining floor thickness (MRT) used in the calculations is based on API 653 Section 4.4.7 and Table 6-1. The assessment of the floor found that the tank floor coating, with an average thickness of 10.7 mils, is a lining as defined in API RP 652. The tank has the means to provide detection and containment of a bottom leak. Based on this information, the MRT used in the calculations is 0.050 inch.

Table 1 – Tank 27 Floor	
Age of Floor	8 years based on installation in 2000.
Original thickness	Annular Ring 7 mm (0.276") General Floor Plate 6 mm (0.236")
Average Thickness of General Plate	Tave = 0.228" based on 2 thickness measurements per plate
Average Thickness of Annular Ring	Tave = 0.268" based on 2 thickness measurements per plate
Floor Product Side Corrosion	
Maximum Depth of Product Side Pitting	0.000" (No pits were identified.)
Minimum Remaining Thickness	RTip = 0.228" – 0.000" = 0.228" (general plate) RTip = 0.268" – 0.000" = 0.268" (annular ring)
Product Side Corrosion Rate	StPr = Pit Depth / year = 0.000" / 8 yr = 0.00 in/yr Corrosion rate is justified given that the floor is adequately coated and the coating has a remaining life of 20+ years.
Floor Bottom Side Corrosion	
Minimum Remaining Thickness at Areas of Bottom Side Corrosion Detected by MFL Scanning	RTbc = 0.217" (general plate) RTbc = 0.251" (annular ring)

Table 1 – Tank 27 Floor

Depth of Bottom Side Pitting Not Detected by MFL Scanning (Assumption)	MFL = 20% of Tave RTbc = 0.228” – 0.20 x 0.228” = 0.182” (general plate) RTbc = 0.268” – 0.20 x 0.268” = 0.214” (annular ring) Governs for RTbc
Bottom Side Corrosion Rate	UPr = (Tave – RTbc) / years UPr = (0.228” – 0.182”) / 8 = 0.00575 in/yr (general plate) UPr = (0.268” – 0.214”) / 8 = 0.00675 in/yr (annular ring)
Minimum Thickness Required at Next Inspection	
Floor – General	0.050” for tank bottom/foundation design with means for detection and containment of a bottom leak.
Floor at Annular Ring	Per API 653 Table 4-4 the minimum thickness is 0.170” for bottom shell course < 0.750” and stress < 24,300 psi.
Floor at Critical Zone	Per API 653 the minimum thickness is the smaller of 50% of tmin of the bottom shell course (0.50 x 0.591” = 0.296”), 1/2 of the original thickness of the floor (1/2 x 0.276” = 0.138”), but not less than 0.100”. For the critical zone, 0.138” controls.
Minimum Remaining Thickness (Based on an In-Service Interval Or = 20 yrs) Floor – General	MRT = (Minimum of RTbc or RTip) – Or x (StPr + UPr) MRT = (0.182” or 0.228”) – 20 x (0.00 + 0.00575) MRT = 0.182 – 20 x 0.00575 = 0.067” > 0.050” OK The general tank floor plate thickness will not be reduced below the limiting MRT at a 20-year inspection interval.
Minimum Remaining Thickness (Based on an In-Service Interval Or = 20 yrs) Floor at Annular Ring	MRT = (Minimum of RTbc or RTip) – Or x (StPr + UPr) MRT = (0.214” or 0.268”) – 20 x (0.00 + 0.00675) MRT = 0.214 – 20 x 0.00675 = 0.079” < 0.170” NG The annular ring thickness will be reduced below the limiting MRT at a 20-year inspection interval.
Minimum Remaining Thickness (Based on an In-Service Interval Or = 20 yrs) Floor at Critical Zone	MRT = (Minimum of RTbc or RTip) – Or x (StPr + UPr) MRT = (0.214” or 0.268”) – 20 x (0.00 + 0.00675) MRT = 0.214 – 20 x 0.00675 = 0.079” < 0.138” NG The tank floor plate thickness at the critical zone will be reduced below the limiting MRT at a 20-year inspection interval.
In-Service Interval (Or) Floor at Annular Ring	Or = (RTbc – MRT) / UPr Or = (0.214” – 0.170”) / 0.00675 in/yr Or = 6.5 years The service interval is limited to 6.5 years based on the assumed corrosion rate applied to the annular ring.
In-Service Interval (Or) Floor at Critical Zone	Or = (RTbc – MRT) / UPr Or = (0.214” – 0.138”) / 0.00675 in/yr Or = 11.3 years The service interval is limited to 11.3 years based on the assumed corrosion rate applied to the critical zone.

Hydraulic and Structural Integrity

The following table summarizes the hydraulic and structural integrity of Tank 27:

HYDRAULIC AND STRUCTURAL INTEGRITY		
Evaluation Item	Findings	Comments
Foundation	Tank 27 rests on a gravel mound. The tank passes API 653 criteria for levelness and differential settlement.	Acceptable
Floor	<p>Visual inspection of the floor joints found no relevant indications. MFL scanning of the tank floor found no relevant indications of corrosion on the bottom side of the floor. A pit survey was conducted for topside corrosion and no pits were identified requiring repair.</p> <p>No localized bulges or depressions of the floor were found during the inspection</p> <p>Based upon the calculated corrosion rate, the annular floor plate thickness will be reduced below the requirements for minimum floor plate thickness of 0.170 inch at a 20-year inspection interval.</p>	Refer to “Inspection Assessment – Next Inspection” for further discussion.
Shell	Inspection found no indications of damage or deterioration to the shell.	Acceptable
Roof	Inspection found no indication of damage or deterioration of the roof.	Acceptable
Internal Fluid Pressure	Hoop stresses caused by internal fluid pressure passes API 653 criteria.	Acceptable
Hydrostatic Test	Shell is adequate to resist the internal fluid pressure caused by a full height hydrostatic test with water.	Acceptable
Brittle Fracture	<p>The API 653, Section 5, Figure 5-2, Brittle Fracture Considerations has been evaluated with the following findings:</p> <ol style="list-style-type: none"> 1. Does the tank meet API 650(7th edition or later, 1980): No, built in 1951. 2. Has a prior hydrotest been performed demonstrating fitness: Yes. 3. Is the tank shell thickness < 0.5 inch: No. 4. Does the tank operate at metal temperature above 60 deg F?: No. 5. Is the tank membrane stress below 7 ksi?: No. 6. Tank steel exempt per API 650, Figure 4-1 or API 653 Figure 5-2: No. 7. Tank full at lowest one day temperature per API 650 Figure 2.2: Yes. 	The tank, having been hydrotested after the installation of the new floor, does not fit the API 653 at-risk profile for brittle fracture failure.

HYDRAULIC AND STRUCTURAL INTEGRITY		
Evaluation Item	Findings	Comments
Seismic	<p>Seismic calculations were performed in accordance with API 650 Appendix E.</p> <p>The calculations indicate that the tank is considered to be stable against overturning and that the longitudinal stresses are acceptable.</p> <p>Calculations were performed utilizing the specific gravity for JP-8, an earth foundation, seismic parameters $S_s = 0.37$, $S_1 = 0.15$ and an importance factor of 1.0.</p>	No exception taken.
Wind Evaluation	<p>A wind analysis was performed per API 650, Section 3.11. Calculations were performed using an importance factor of 1.1 and a wind velocity of 135 mph.</p> <p>The tank is not anchored. The evaluation determined that an empty unanchored tank is at risk of overturning.</p> <p>Evaluation of the shell buckling determined that shell stiffeners are required for the design wind speed.</p>	<p>There is no requirement to upgrade the tank to current API 650 standards for anchorage.</p> <p>Damaged shell plate was replaced and shell stiffeners were installed as part of the 1999-2000 repair project.</p>

ADDITIONAL DISCUSSION ITEMS

Gauge Tube (Stilling Well) Requirements

Overall Requirements and Decisions Required

Although gauge tubes were not included in the scope of work, the findings are presented herein as an aide to those who may execute the work in future. The requirements for stilling wells have been reviewed. These requirements are based on our latest understanding for the upcoming SPAWAR executed ATG system, as issued by PMO of DESC and other agencies. There have been ongoing discussions with respect to modifications to the current published requirements. At this time, the criteria are still under refinement and formal direction has not been published. The comments below represent concept solutions for this tank and we believe are consistent with the latest DESC direction (June 30, 2008). We recommend the concept be submitted to DESC for ratification or redirection at the time a need to execute is identified.

This facility is a prime candidate for the next generation ATG system as the present is an ITT Barton system. The next ATG system will likely be a system manufactured by MTS or ENRAF. The decision between the two systems should be based upon successful service in the Arctic with temperatures to -65 deg F. As these tanks do not, and we understand, will not ever get floating pans, the need for gauge tubes must be verified at the time of execution. We understand the current thinking is any location of displacer type level measurement must have a gauge tube for repeatable, accurate measurement. For discussion we will address gauge tube needs based on worse case, that of a tank needing full gauge tube application. One of the differences between each system is that two gauge tubes would be required for MTS while three are required for ENRAF. Although the number of gauge tubes for ENRAF could be reduced with the use of the 10”/2” combo gauge tube, DESC appears to be moving away from this recommendation.

Site Specific Tank Parameters Affecting Gauging and Stilling Wells

The Tank is a typical aboveground tank with a cone-down floor, one center low point sump and no floating pan. The sump is 4 feet in diameter and 18 inches deep. Within the sump is the 2" Water Draw-Off Piping, 3" Diameter Low Fuel Piping and a 6" Roof Support Pipe Column. The roof rafters are supported on a plate welded to the top of the center pipe column. The diameter of the support plate appears to be less than the diameter of the sump. There are currently no means to gauge water in the sump.

Current Requirements: SK-1, SK-2 and SK-3

Strict adherence to SK-1, SK-2 and SK-3 as provided by the government may not be practical or possible due to the configuration of the tank structure and lack of a floating pan. It is our understanding that they are no longer appropriate and should not be followed.

Manual Gauging

Manual gauging is currently performed at the ATG thief hatch. The tank is equipped with a separate 8 inch thief hatch, with no gauge tube, approximately 10 feet from the center sump.

It is our understanding that a gauge tube is desirable, but not a mandatory requirement for manual gauging and sampling in a tank lacking a floating pan. Therefore, the present thief hatch for manual gauging should be acceptable for use as is. In the event a gauge tube is required, it should be constructed as noted for the ATG gauge tube.

Combination Water/Temperature Probe Location

The current ITT Barton temperature sensor and the ATG level sensor probe are both located within an 8 inch thief hatch near the tank shell. An 8 inch gauge tube with a datum plate is present on the tank floor. The datum plate is at the same elevation as the chine. However, the gauge tube is only 4 feet tall and is not equipped with slots. This location is undesirable for water probe sensing, but is acceptable for the level sensor. There appears to be adequate space available to locate a water/temperature probe directly over the sump. The probe must be located with a minimum clearance of 2 inches to any steel object, such as the sump wall and the piping. To install the probe, it will be necessary to cut a hole in the steel roof and position it between roof rafters. The center compression plate must not be altered. Nozzle and gauge tube requirements follow.

Temperature/water probe Option 1 – No Gauge Tube

Option 1 consists of cutting a hole in the steel roof plate and installing an 8 inch flanged spool above the opening. The hole must be located between roof rafters and over the sump.

Temperature/water probe Option 2 – Gauge Tube Below Roof

Option 2 includes a 10 inch roof nozzle with an 8 inch aluminum gauge tube supported from the roof or floor. It is our understanding that the DESC preference is 8 inches to permit greater flexibility in the future with a variety of manufacturers. There appears to be sufficient clearance for a gauge tube to line up over the sump. But if not, it can be located within several feet of the sump, which is also acceptable to DESC. The preference is to support the tube from the floor and guide with a slip-collar to a riser in the roof. The bottom of the tube must be installed a

minimum of 24 inches above the floor. If lateral bracing is required to stabilize the tube, it can be attached to the center roof support pipe column.

As the tank is 37 feet 6 inches tall, the installation of a single pre-assembled gauge tube would require a crane. It would likely be more practical to fabricate the gauge tube in multiple flanged sections for assembly within the tank. The length of tubes could suit shipment to the site via the military air freight system. Since the tank is not equipped with a floating pan, flanges would not be an issue.

ATG Servo Float Stilling Well Requirements

The current ATG level sensor and temperature sensor are located within an 8 inch thief hatch near the tank shell. An 8 inch gauge tube with a datum plate is present on the tank floor. However, the gauge tube is only 4 feet tall and is not equipped with slots. This location is acceptable for the level sensor. . It is not clear why the tank is equipped with such a short tube, and in fact it was found in-effective as in one case, the gauge sensor was landed outside of this tube.

The Tank is equipped with two spare flanged roof nozzles; a 10 inch near-shell and an 8 inch near-center nozzle. Neither is equipped with a gauge tube. It is recommended to use the 10 inch near-shell nozzle since it is located farther from fill piping diffuser and any swirl effects.

The ATG level sensor gauge tube may have a diameter of 4, 6 or 8 inches. It is our understanding that the DESC preference is an 8 inch aluminum tube to permit greater flexibility in the future with a variety of manufacturers. The preference is to support the tube from the floor and guide with a slip-collar to a riser in the roof as noted above for the temperature/water probe gauge tube.

CLOSURE

Conclusions

Based on the extent of this inspection, Tank 27 is considered suitable for service.

Project Team

Site Team

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Support Team

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APPENDIX A

Tank Inspection Data Sheet and Evaluation Items



AST TANK INSPECTION DATA SHEET

Tank No. 27
Owner/Operator: U.S. Air Force
Location Thule Air Base, Greenland

API 653 INSPECTION

Type: Internal & External w/ Suitability for Service
Date: June 8th, 2008
By: Enterprise Engineering, Inc.
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(907) 563-3835

EI Project No: 08-4889

TANK DATA

API 653 Inspector: David A. Stchyrba
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Type: Vertical AST
Diameter: 100' – 0"
Shell Height: 37' – 6"
Configuration: Butt Welded Shell w/ 5 courses
Foundation: Gravel Pad
Leak Detection: Two detection ports in interstitial space
Date Erected: 1951, New floor installed 1999-2000
API Standard: New floor to API 650, 9th Ed. Addendum 2 1995
Original construction assumed 12C 9th Ed. 1950

Designed By: Unknown
Manufacturer: Unknown
Erector: Unknown
Fuel Stored: JP-8
Design Specific Gravity: 0.82
Operating Fill Height: 34' – 0" (From facility)
Max Fill Height: 36' – 9" (Name plate)
Nominal Capacity: 49,170 Bbls (Name plate)
Strapped Capacity: 53,510 Bbls (Strapping chart)
Change In Service: None
Current Tank Cleaner: Shaw subcontractor
Date Last Strapped: Strapped after installation of new floor
Date of Last Inspection: Unknown
Date of Previous Cleaning: Unknown
As-Built Drawings, Specifications: Design drawings for new floor available

EVALUATION CRITERIA

API Standards: API 650, 11th Edition, June 2007
API 653, 3rd Edition, Addendum 3, Feb 2008

Ground Snow: 25 psf (UFC 3-310-01)
Wind Speed: 135 mph (UFC 3-310-01)
Seismic: $S_s = 0.37$, $S_1 = 0.15$ (UFC 3-310-01)



AST EVALUATION ITEMS

TABLE OF CONTENTS

	PAGE
FOUNDATION	1
FLOOR	2
SHELL	4
ROOF	8
COATINGS	10
APPURTENANCES	12
PIPING.....	13

FOUNDATION		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
FOUNDATION		
Type	The tank sits on a gravel mound.	
Levelness	The maximum differential between max and min elevations is 0.17 feet (2.04 inch).	Tank 27 passes API 653 criteria for shell levelness and differential settlement.
Rigid Body Tilt	Tank 27 has small amount of tilt. The amount of tilt is 0.06 feet (0.77 inch).	Calculations of data acquired at the shell determine that the tank is slightly tilted but within acceptable limits.
Height Above Dike Floor	The new floor is 29 inches above the gravel base.	
Material Below Tank Floor	The material below the tank floor could not be inspected. Design drawings indicate that the interstitial space is filled with concrete.	
Drainage Around Tank	Drainage around the tank is adequate.	
Tank Anchors	Tank 27 is not equipped with anchors.	
Containment Dike	Tank 27 sits within a lined containment dike. The liner batten strips are attached to an angle and plate welded to the old floor.	
Secondary Containment	Tank 27 has a double bottom.	
Settlement	Calculations indicate that Tank 27 passes API 653 criteria for settlement.	
Erosion/Washouts	No indications of washouts or erosion were observed.	
Sealed at Foundation	The tank rests on a gravel pad. It is not sealed.	No further action recommended.
Additional Foundation Items, Comments or Notes:		
None.		

FLOOR		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
TANK FLOOR		
Type	The tank has a double bottom. The new floor configuration is cone down with an annular ring and lap welded steel plates.	
Nominal Thickness	The floor consists of 7 mm (0.276 inch) thick annular floor plates and 6 mm (0.236 inch) thick floor plates.	
Annular Ring Plates	Tank 27 has been provided with a butt-welded annular ring.	
Thickness	The average thickness of the annular ring plates is 0.268 inches. The average thickness of the interior floor plates based on 5 UT readings per floor plate is 0.228 inch. The exterior floor extension (chine) has an average thickness of 0.265 inch based on twelve locations.	
Interior Width	The average floor plate width is 8 feet.	
Floor seam welds	No relevant indications were found on the floor plate seam welds.	
MFL Floor Scan	MFL of the accessible areas of the floor found no indications requiring an ultrasonic test (UT) prove-up.	
Bottom Side Floor Pitting/Corrosion	Based on MFL and UT examination, bottom side pitting/corrosion is not prevalent.	
Top Side Floor Pitting/Corrosion	No pits were identified requiring repair.	
Patch Plates	No patch plates were observed on the floor.	
Doubler/Support Plates	The interior piping supports for the Fill, Issue, Low Fuel and Water Draw-Off lines have support plates that have been seal welded to the floor.	
Plug Welds	No plug welds were observed.	
Weld Artifacts	No significant weld artifacts were noted.	
Vacuum Box Testing	The floor-welded seams are coated. A vacuum box test was not performed.	
Helium Leak Testing	HLT was not performed.	

FLOOR		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
Floor Bulges, Depressions	No significant bulges or depressions were noted.	
Oil Canning/Flexing	No significant flexing of floor plates was observed.	
Edge Settlement	Edge settlement was not noted.	Measurements taken for edge settlement at eleven equidistant locations pass API 653, Appendix B criteria.
Floor Critical Zone	No significant corrosion or deflection was observed within the critical zone.	
Floor Profile	The floor is cone down. The average differential height from the shell to the center of the tank is 2.19 feet. The tank floor has a 4.35% slope to the center sump.	
Sumps	Tank 27 is equipped with a 46 inch diameter center sump.	
Secondary Liner Below Floor	There is no secondary liner below the original tank floor.	See "Foundation – Secondary Containment"
Leak Detection Below Floor	There are two ¼ turn ball valves with blind flanges within the dead shell. The extent of piping below the floor is unknown.	Recommend removing the blind flanges to allow monitoring of the interstitial space.
Cathodic Protection Below Floor	Tank 27 is not equipped with cathodic protection.	
Additional Floor Items, Comments, Notes: None.		

SHELL		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
TANK SHELL		
Nominal Thickness	UT Thickness Coating	See Exterior Coatings section.
1 st Course	0.591 inch 11.0 mils	
2 nd Course	0.459 inch 11.0 mils	
3 rd Course	0.344 inch 11.1 mils	
4 th Course	0.242 inch 10.7 mils	
5 th Course	0.249 inch 12.1 mils	
Rim Angle	Unable to access.	
Plumbness	Visual observations found no noticeable out-of-plumbness.	
Roundness	The tank was measured across two diagonal locations with no out-of-roundness noted.	
Dents/Buckles	No significant dents or buckles requiring repairs were observed. It was reported that plate was previously damaged. The 1999-2000 repair work included replacing the damaged shell plates and installing wind girders.	
Banding/Peaking	No significant banding or peaking was observed.	
Interior Shell pitting/corrosion	No pits or corrosion were observed on the interior 1 st course. The upper courses of the interior shell were not accessible.	
Exterior Shell pitting/corrosion	No significant pits were observed on the exterior shell as viewed from the ground elevation.	
Insert plates	Two 12 inch diameter insert plates were observed in the dead shell.	
Welded Patch Plates	No welded patch plates were observed on the exterior or interior shell surfaces.	
Floor Extension	The floor extension (chine) extends an average of 2 inches out from shell.	
Interior Shell Welds	Visual inspection of accessible interior shell welds found no indications for further inspections or examinations.	

SHELL		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
Exterior Shell Welds	Visual inspection of accessible exterior shell welds found no indications for further inspections or examinations. Original weld seams were inspected by trepanning.	
Door sheet	No door sheets were observed. However, full course height sections were likely removed for the installation of the new floor.	
Shell-to-Floor Weld – Interior	Visual inspection of the interior shell-to-bottom welds found no indications for further inspections or examinations.	
Shell-to-Floor Weld – Exterior	Visual inspection of the exterior shell-to-floor welds found no indications for further inspections or examinations.	
Floor-to-Dead Shell - Exterior	The new floor is welded to the dead shell.	No remedial work is recommended at this time.
Shell Manways	Two 36 inch diameter round manways located in the 1 st shell course.	
Flush Cleanouts	Tank 27 is not equipped with a flush cleanout.	
Shell Reinforcing Plates		
Manway (Size, Thickness, Telltale Hole)	<u>Manway #1</u> 36 inch diameter, 0.640 inch thick neck (UT). Diamond reinforcing plate 90 inch wide x 76 inch high x 0.643 inch thick (UT). A telltale hole is not present.	The reinforcing plate does not meet current API 650 criteria for open telltale holes. However, it is not recommended to install one at this time.
	<u>Manway #2</u> 36 inch diameter, 0.642 inch thick neck (UT). Diamond reinforcing plate 90 inch wide x 76 inch high x 0.652 inch thick (UT). A telltale hole is not present.	The reinforcing plate does not meet current API 650 criteria for open telltale holes. However, it is not recommended to install one at this time.
Receipt/Fill (Size, Thickness, Telltale Hole)	12 inch diameter nozzle, 0.538 inch thick neck (UT). Diamond reinforcing plate 32 inches wide x 26 inch high x 0.653 inch thick (UT). A telltale hole is not present.	The reinforcing plate does not meet current API 650 criteria for open telltale holes. However, it is not recommended to install one at this time.

SHELL		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
Pressure Relief for Fill (Size, Thickness, Telltale Hole)	1 inch diameter nozzle, 0.184 inch thick neck (UT). A reinforcing plate is not present.	A reinforcing plate is not required.
Issue (Size, Thickness, Telltale Hole)	10 inch diameter nozzle, 0.497 inch thick neck (UT). Diamond reinforcing plate 28 inches wide x 22½ inch high x 0.643 inch thick (UT). A telltale hole is not present.	The reinforcing plate does not meet current API 650 criteria for open telltale holes. However, it is not recommended to install one at this time.
Pressure Relief for Fill (Size, Thickness, Telltale Hole)	1 inch diameter nozzle, 0.178 inch thick neck (UT). A reinforcing plate is not present.	A reinforcing plate is not required.
Low Fuel/Drain (Size, Thickness, Telltale Hole)	3 inch diameter nozzle, 0.292 inch thick neck (UT). Diamond reinforcing plate 13½ inches wide x 10½ inch high x 0.638 inch thick (UT). A telltale hole is not present.	The reinforcing plate does not meet current API 650 criteria for open telltale holes. However, it is not recommended to install one at this time.
Water Draw-Off (Size, Thickness, Telltale Hole)	2 inch diameter nozzle, 0.220 inch thick neck (UT). A telltale hole is not present.	A reinforcing plate is not required.
Fire (Size, Thickness, Telltale Hole)	Two 3 inch diameter nozzles with injection ports at top of 5 th course.	
Shell Vents	Tank 27 is not equipped with shell vents.	
Overflow Ports	Tank 27 does not have any overflow ports.	
Wind Girders and Shell Stiffeners (Size & Elevation)	Tank 27 is equipped with two internal shell stiffeners located in the 4 th and 5 th shell courses.	

SHELL		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
<p>Tank Nameplate Data (Complete as Possible):</p> <p>Repaired/Altered to API 653 Edition 2nd Dec 1995</p> <p>Reconstructed by Jens Pilegaard WS A/S Contract No. F61101-99-C0010</p> <p>Date Completed 2000.07.07</p> <p>Original Standard API Tank No. 27 Tank Dia. 100' Height 40' Specific Gravity 0.85</p> <p>Design Pressure -5/+8 psf Original Construction Date 1951 Year Reconstructed 1999-2000</p> <p>Liquid Level Max 36'9" Capacity 49170 BBL Maximum Operating Temperature 100 Deg F</p> <p>Shell Course</p> <p>2 x ¼"</p> <p>1 x 11/32"</p> <p>1 x ½"</p> <p>1 x 5/8"</p>		
<p>Additional Shell Items, Comments or Notes:</p> <p>Stenciled on shell:</p> <p style="padding-left: 20px;">Tank 27</p> <p style="padding-left: 20px;">JP-8</p>		

ROOF		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
TANK ROOF		
Type	Fixed cone-up with 16 pipe columns.	
Roof Plate Thickness (Outer/Mid/Inner)	The roof consists of 3/16 inch (0.188 inch) thick roof plates. Average thickness for the plates is 0.184 inch.	
Roof Topside pitting/corrosion	No significant pitting or corrosion was identified on the topside of the roof.	See "Roof Exterior" under Coatings section.
Roof Bulges/Depressions	No significant bulges or depressions were identified. No major water ponding areas were observed.	
Roof Joints	Visual inspection of the topside roof welds found no relevant indications for further inspection or examination.	
Frangible Joint (Size/Condition)	3/16 inch nominal roof plates, lap welded to rim angle. The roof connection at the shell meets the definition of a frangible joint for emergency venting.	
Roof Vents (Size & Type)	Tank 27 is equipped with two 10 inch diameter Shand & Jurs Kaneko pressure/vacuum vents.	Recommend disassembling and cleaning the pressure/vacuum vents.
Roof Manways	The roof is equipped with two 24 inch diameter manways. There is an access ladder into the tank at one manway.	
Roof Hatches	Tank 27 is not equipped with any roof hatches.	
Roof Nozzles	Roof nozzles include an 8 inch near perimeter thief hatch for the ITT Barton ATG system, two 1 inch threaded plugs, an 8 inch diameter near center thief hatch for manual gauging, a 10 inch near shell with blind, a 10 inch with blind at center, an 8 inch with blind near center, a 10 inch near shell with blind and the penetrations for tape gauge float and guide wires	

ROOF		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
Handrails	Handrails exist at the spiral stair access platform. A perimeter handrail is present at the roof level. The handrail includes a 4 inch kicklate.	
Roof Access From Ground	Roof access is by spiral stair.	
Roof Access to Adjacent Tank	None	
Roof Framing/Roof Underside Condition	The interior roof structure appears to be in good condition with no twisting or bending of components. Visual inspection of the roof underside from the floor found no indications for further examination.	
Roof Elevation	The center of the cone roof is raised above the shell elevation.	
Interior Columns	There are sixteen 6 inch diameter pipe columns with base plates. Each column has been provided with a mousehole. A number of base plates do not meet current API 650 weld clearance requirements to the floor joints. The columns are welded to the base plates and the base plates are welded to the floor.	No further action is recommended at this time with respect to the clearance requirements. Although the columns and bases were welded in violation of API 650, no repair is recommended at this time. Thule AB is located in a Seismic Zone 1 region, thus there is low probability of damage due to seismic activity. No evidence of distress in the floor was observed.
INTERNAL FLOATING ROOF		
Type	Tank 27 does not have an internal floating pan.	
SEE TANK APPURTENANCES FOR ATG, GAUGING, LEVEL ALARMS, ETC.		
Additional Roof Items, Comments or Notes: None.		

COATINGS		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
Exterior Coatings		
Shell		
Type/age	An epoxy polyamide system. The age of the coating is not known.	
General Condition	In general, the exterior coating system on the shell and appurtenances is in good condition with minor areas requiring repair.	Recommend removing the coating from the affected areas and recoat.
Isolated Conditions	Small isolated areas were identified with minor corrosion.	Recommend removing the coating from the affected areas and recoat.
Nominal Thickness	The average thickness of the shell coating for all five courses is 11.2 mils; with a maximum thickness of 16.0 mils and a minimum thickness of 8.6 mils. The average thickness of the floor extension (chine) coating is 20.8 mils. Coating failure and corrosion were observed on the floor extension.	Recommend removing the coating from the affected areas and recoat.
Lead and Chromate Testing	Not performed.	
Roof		
Type/age	An epoxy polyamide system. The age of the coating is not known.	
General Condition	In general, the exterior coating system on the shell and appurtenances is in good condition with minor areas requiring repair.	Recommend removing the coating from the affected areas and recoat.
Isolated Conditions	Small isolated areas were identified with minor corrosion.	
Nominal Thickness	The average thickness is 7.8 mils.	
Lead and Chromate Testing	Not performed.	
Interior Coatings		
Floor		
Type/age	A white epoxy polyamide system. The coating was installed with the new floor in 1999-2000.	
General Condition	In general, the floor coating system is in good condition.	

COATINGS		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
Isolated Conditions	No isolated areas of coating failure were observed on the interior floor.	
Nominal Thickness	The coating thickness ranges between 6.7 mils and 14.9 mils with an average thickness of 10.7 mils	
Lead and Chromate Testing	Not performed.	
Shell		
Type/age	The interior shell is coated to approximately 54 inches above the floor with a white epoxy system. It is believed that the coating was installed during the 1999-2000 repair work.	
General Condition	In general, the interior coating system on the shell and appurtenances is in good condition with minor areas requiring repair.	
Condition at Floor to Shell	Coating at the floor-to-shell joint is in good condition.	
Isolated Conditions	No localized areas of coating failure were observed on the interior shell.	
Nominal Thickness	The coating thickness ranges between 5.5 mils and 13.5 mils with an average thickness of 8.4 mils.	
Lead and Chromate Testing	Not performed.	
Underside Roof		
Type/age	The underside of the roof is not coated.	
Additional Coating Items, Comments or Notes: None.		

APPURTENANCES

Evaluation Item	Finding(s)	Comments/Recommendations <small>(A blank in comments column indicates lack of significance, or condition is acceptable.)</small>
APPURTENANCES		
Float Gauge	Tank 27 is equipped with a Shand & Jurs tape gauge. The float is not functional.	Recommend providing a new tape gauge, head, float, tape and springs.
ATG (Automatic Tank Gauging) or RTG (Remote Tank Gauging) System	ITT Barton ATG probe assembly.	
HI/Hi-HI Level Alarms	The HI and HI/Hi level alarms are incorporated as part of the ITT Barton ATG. Alarm points of 35 feet 6 3/8 inches and 36 feet 3 1/2 inches are built into the software program that is connected to the POL office.	
Low/Low-Low Level Alarms	The Low and Low/Low level alarms are incorporated as part of the ITT Barton ATG. Alarm points of 5 feet 7 3/8 inch and 1 foot 10 1/2 inch are built into the software program that is connected to the POL office.	
Independent Level Alarms	Tank 27 is not equipped with an independent level alarm.	UFC 3-460-01 Table 2 Item (j) requires an independent level alarm for the HI, HI-HI and Low levels.
Temperature Probe	The ITT Barton ATG system includes a temperature sensor.	
Gauge Tube – ATG	The probe assembly for the ITT Barton ATG is located within an 8 inch diameter near shell gauge tube.	
Gauge Tube – Sampling/Testing/Hand Gauging	A gauge tube is not present at the manual roof top thief hatch.	
Datum Plate on Floor	A datum plate is present in the gauge tube for the ITT Barton ATG system.	
Tank Grounding	Tank 27 has one static ground clip attached to the old floor.	
Fire Suppression System	A water fire suppression system exists with two 3 inch injection nozzles on the 5 th course.	Inspection and testing is maintained by Base Fire Department.
Product Saver	Tank 27 is not equipped with a product saver or water separator tank.	The base provides a centrifuge system for separating water from product. No further action is required.

Additional Appurtenance Items, Comments or Notes:

None

PIPING		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
PIPING		
Fill / Receipt Piping		
Interior Piping, Size, Type, UT	The interior fill piping consists of a 12 inch diameter pipe with a 19 inch x 12 inch diffuser at 45-degrees. UT thickness of pipe is 0.537 inches.	
Valve (Type/Condition)	12 inch 150 lb class, General Twin Seal double block and bleed steel plug valve in good condition with gear actuator.	
High Level Shut-Off Valve (Type/Condition)	12 inch 150 lb class, Cla Val high level shut-off valve (HLV).	
Pressure Relief Piping	Valve has 1 inch diameter pressure relief piping with a relief valve and two ¼-turn ball valves.	
Issue Piping		
Interior Piping, Size, Type, UT	The interior issue piping consists of a 10 inch diameter pipe that runs inward from the shell towards the center sump. UT thickness of pipe is 0.495 inches.	
Valve (Type/Condition)	10 inch, 150 lb class, General Twin Seal double block and bleed steel plug valve in good condition with gear actuator.	
Pressure Relief Piping	Valve has 1 inch diameter pressure relief piping with a relief valve and two ¼-turn ball valves.	
Low Fuel Draw –Off/Drain		
Interior Piping, Size, Type, UT	The interior low fuel piping/drain consists of a 3 inch diameter pipe that runs inward from the shell to the center sump. UT thickness of pipe is 0.293 inches	
Valve (Type/Condition)	3 inch, 150 lb class, ¼-turn ball valve.	
Water Draw-Off		
Interior Piping, Size, Type, UT	The interior water draw-off piping consists of a 2 inch diameter pipe that runs inward from the shell to the center sump. UT thickness of pipe is 0.167 inches	

PIPING		
Evaluation Item	Finding(s)	Comments/Recommendations (A blank in comments column indicates lack of significance, or condition is acceptable.)
Valve (Type/Condition)	2 inch, 150 lb class, ¼-turn steel ball valve in good condition with manual operator. A cam-lock connection is present.	
Additional Piping Items, Comments or Notes: None.		

END OF DATA

APPENDIX B

Non-Destructive Examination (NDE) and Evaluation Criteria

TANK EVALUATION

Codes and Standards

API Standard 653, Third Edition, Addendum 3, February 2008.

API Standard 650, Eleventh Edition, June 2007.

UFC 3-310-01 Structural Load Data

UFC 3-460-01 Petroleum Fuel Facilities (Formerly MIL HDBK 1022A)

Loads

Ground Snow: 25 psf

Seismic: $S_s = 0.37$, $S_1 = 0.15$

Wind: 135 mph

NON DESTRUCTIVE EXAMINATION

Tank Inspection (General)

In accordance with API Standard 653, Third Edition, Addendum 3, November 2008.

Visual Inspection

1. Inspection Items

- In accordance with API Standard 653 and EEI STD for API 653 Out-of-Service Inspection
- Floor, shell and roof plate welded joints (where accessible).
- Floor, shell and roof plate surfaces.
- Items affecting structural and hydraulic integrity

2. Method

- In accordance with API Standard 653.

Ultrasonic Testing (UT)

Ultrasonic thickness measurements were taken to establish floor, shell, and roof plate thicknesses.

1. Inspection Items

- In accordance with EEI NDE Procedure, EEI-UT-002, Ultrasonic Thickness Examination.
- Floor plates

- Shell plates
 - Roof plates
 - Tank appurtenances
2. Equipment
 - Stresstel Flaw Mike.
 3. Method
 - Perform on a spot basis to determine thickness.
 - Perform in areas of low UT thickness readings to determine the nature of the low reading, that is backside corrosion, lamination, or inclusion within the parent material.
 - Perform as follow-up to MFE indications to determine the nature of the indication.
 - Echo/Echo (E/E) mode for determining metal thickness and backside corrosion on coated surfaces without including thickness of coating in reading.
 - Perform in areas not accessible to MFE scanning to determine if backside corrosion is present.

Magnetic Flux Exclusion (MFE) Scanning

1. Inspection Items
 - In accordance with EEI NDE Procedure EEI-MFL-001, Magnetic Flux Leakage.
2. Equipment
 - MFE 2412 Mark 2

The equipment utilizes a permanent magnet to generate lines of magnetic flux in the material under test. Metal loss such as bottom side or topside corrosion will cause changes in the lines of flux. Coils are utilized to detect the flux variations. The MFE unit has a panel of LED indicators that indicate the amplitude of the flux variations as well as the general axial location of the flux leakage field.

3. Detection Capability

The equipment is calibrated on a 1/4-inch thick function test plate with three machined metal loss defects:

- 1/8-inch diameter hole in 1/4-inch thick plate
- A tapered hole drilled 40% backside metal loss of plate thickness on surface opposite the detection equipment

Any signal that can be clearly distinguished from background noise during floor scanning is marked for follow-up testing by ultrasonic A-Scan.

4. Acceptance Criteria

- Indication - Full screen LED display in “red” zone requires follow-up ultrasonic testing to determine nature of the indication.

5. Areas Not Accessible to Scanning

- Within one inch of tank shell
- Within one inch of welded joints
- Floor areas below interior piping and appurtenances where the equipment cannot fit
- Sumps
- Below column bases and pipe supports
- Patch plates

Pit Survey

1. Inspection Items

- Tank floor
- Tank shell

2. Equipment

- Mechanical pit gauges

Tank Bottom Settlement Measurements

1. Equipment

- Laser level

2. Method

- In accordance with API Standard 653, Third Edition, Appendix B, measure the floor profile from the shell to the center of the tank at a minimum of eight locations around the tank perimeter not greater than 30 feet apart.

Coating Thickness Measurements

1. Equipment

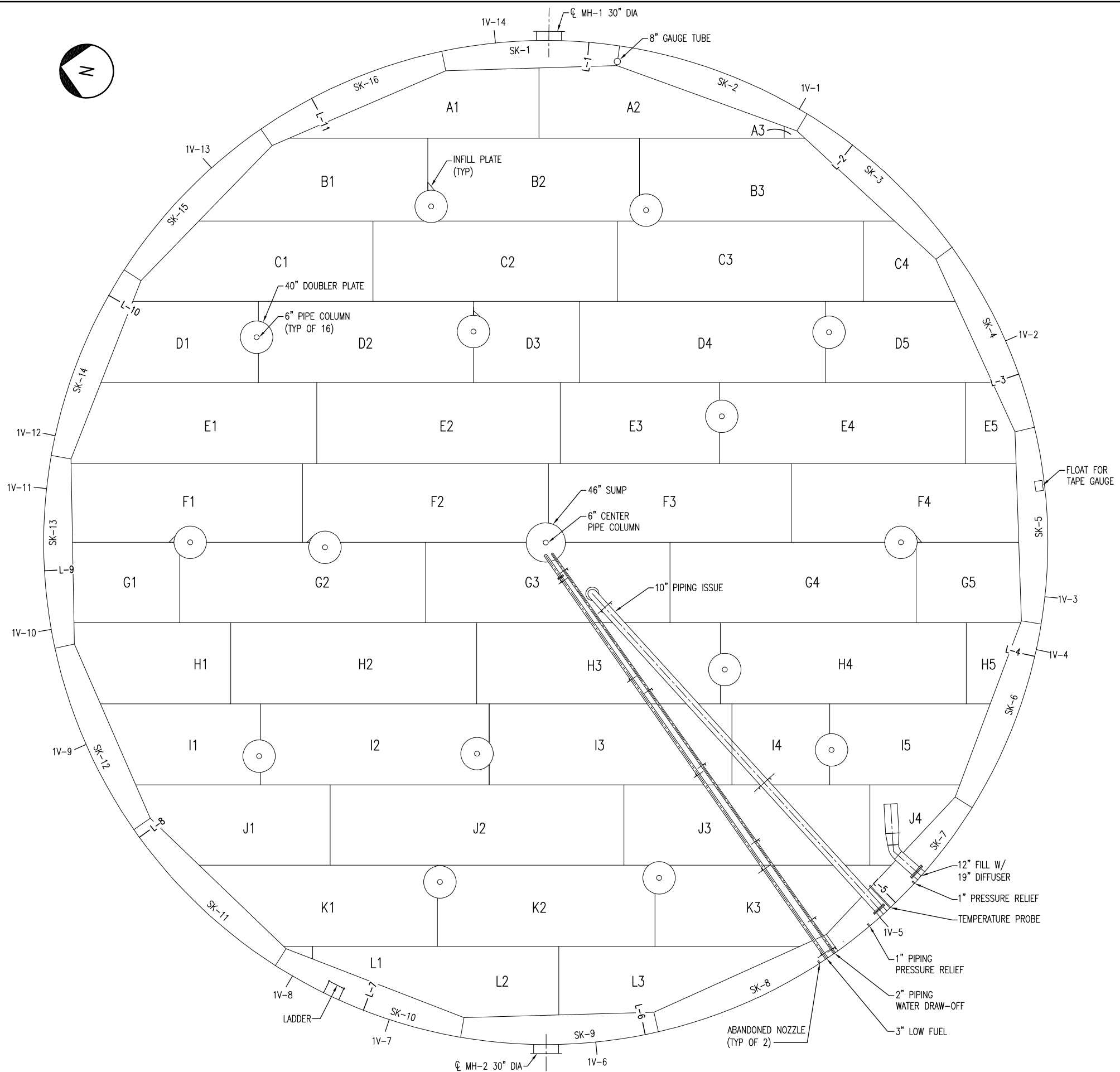
- PosiTector 6000 Thickness Gauge

2. Method

- Measurements taken at UT locations.

APPENDIX C

Tank Drawings



TANK 27 FLOOR PLAN
SCALE: 3/16" = 1'-0"

NOTE

A FULL OUT-OF-SERVICE TANK INSPECTION WAS PERFORMED BY ENTERPRISE ENGINEERING, INC, ANCHORAGE, ALASKA ON JUNE 6th TO 8th, 2008 IN ACCORDANCE WITH API 653, 3rd EDITION, ADDENDUM 3, FEBRUARY 2008.

TANK INFORMATION

1. TYPE OF CONSTRUCTION: WELDED, STEEL ABOVEGROUND TANK WITH A FIXED COLUMN SUPPORTED ROOF.
2. YEAR OF CONSTRUCTION 1951, NEW FLOOR IN 1999-2000.
3. TANK SIZE: DIAMETER: 100'-0"
SHELL HEIGHT: 37'-6"
4. STORAGE CONTENTS: JP-8

LEGEND

- A1 FLOOR PLATE DESIGNATION
- L-# FLOOR EDGE PROFILE LOCATION (SHELL TO CENTER OF TANK)
- 1V-# FIRST COURSE SHELL VERTICAL JOINT DESIGNATION

INSPECTED UNDER
SUBCONTRACT TO
SHAW ENVIRONMENTAL, INC.
PURCHASE ORDER
DATED 15 MAY 2008

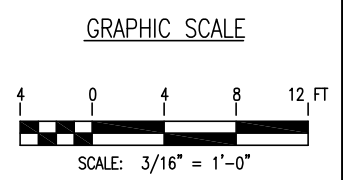
**API 653 INSPECTION
TANK 27**
THULE AIR BASE, GREENLAND

REV	DATE	BY	DESCRIPTION

DESIGN: DAS	SEAL
DRAWN: SPU	
CHKD: DAS	
APRVD: SSB	
SCALE: AS NOTED	

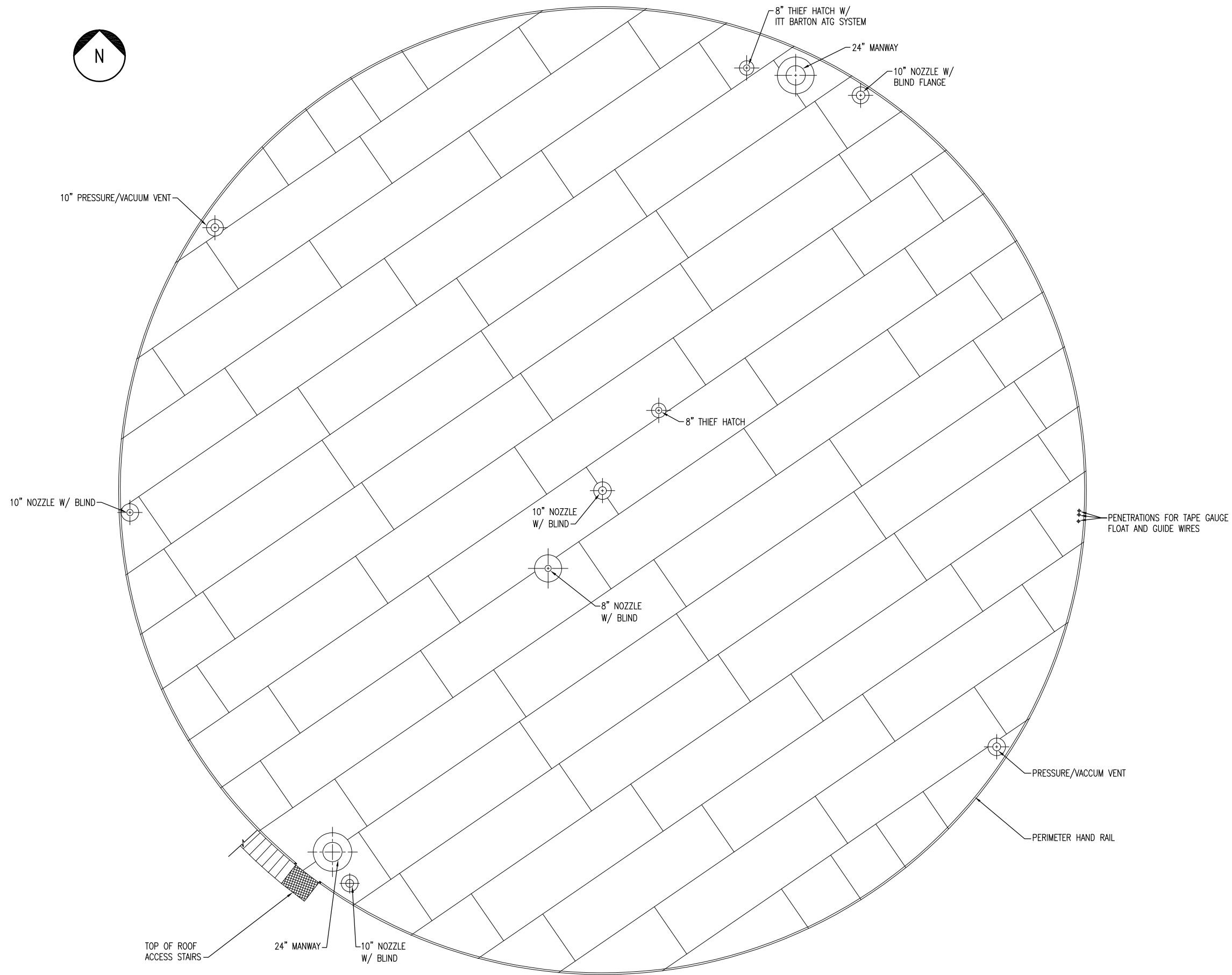
ENTERPRISE
ENGINEERING, INC
5 DEPOT ST. SUITE 23 FREEPORT, ME 04032
TEL: (207) 869-8006 FAX (207) 869-8015
2525 GAMBELL STREET SUITE 200 ANCHORAGE, AK 99503
TEL: (907) 563-3835 FAX (907) 563-3817

DRAWING TITLE
TANK 27 FLOOR PLAN



DWG NO. 08-4889	S-1	DATE 01/08
PN: 08-4889	GRID: 1 OF 3	SHEET 1 OF 3

Plot Date: Jul 24, 2008 - 2:27pm Drawing File: P:\Projects\08-4889\Cad\Current Dwg %Struct%\Tank-27 F-1.dwg Last modified by: VM



INSPECTED UNDER
SUBCONTRACT TO
SHAW ENVIRONMENTAL, INC.
PURCHASE ORDER
DATED 15 MAY 2008

API 653 INSPECTION TANK 27

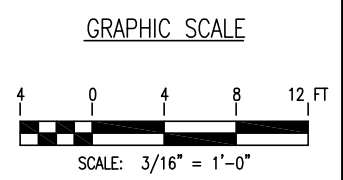
THULE AIR BASE, GREENLAND

REV	DATE	BY	DESCRIPTION

DESIGN:	SEAL
DAS	
DRAWN:	
SPU	
CHKD:	
DAS	
APRVD:	
SSB	
SCALE:	
AS NOTED	

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FAX: (907) 563-3817

DRAWING TITLE
TANK 27 ROOF PLAN



TANK 27 ROOF PLAN
SCALE: 3/16" = 1'-0"

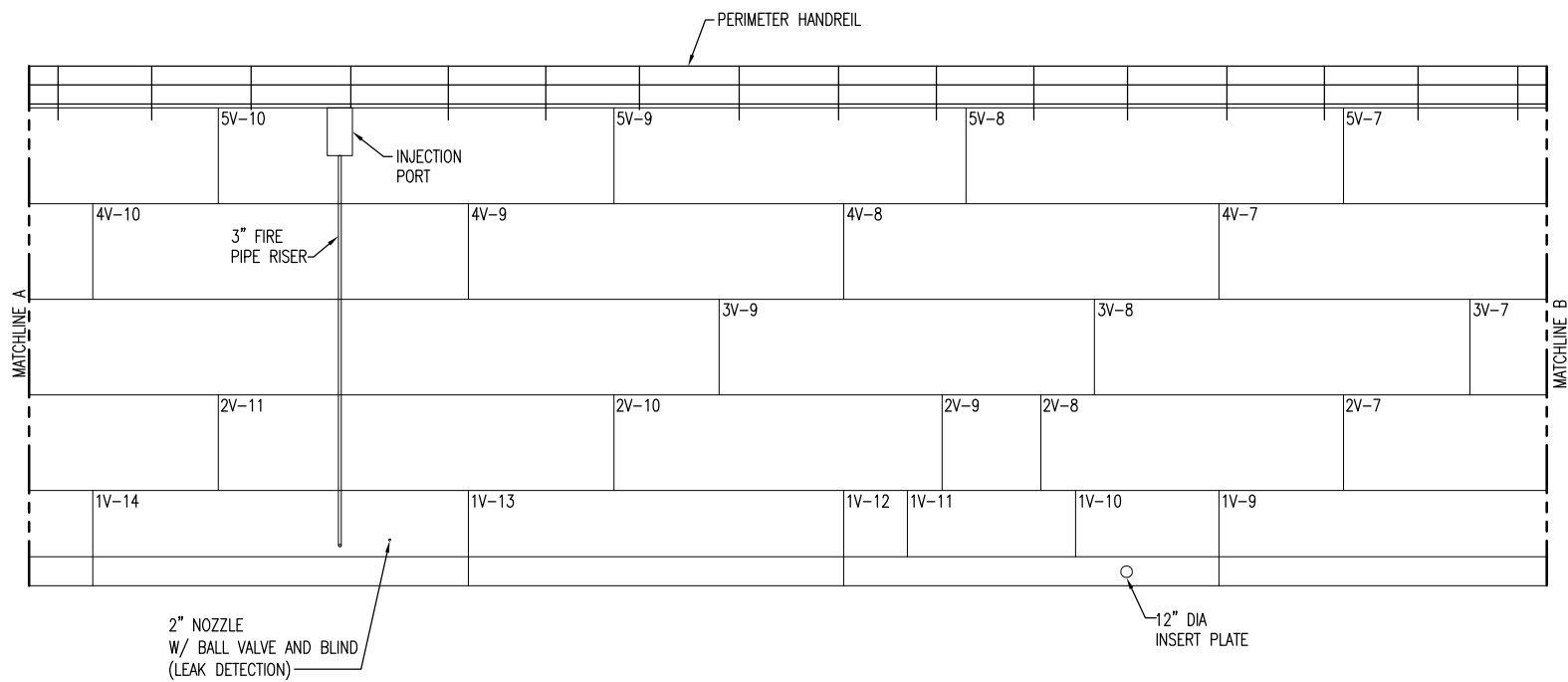
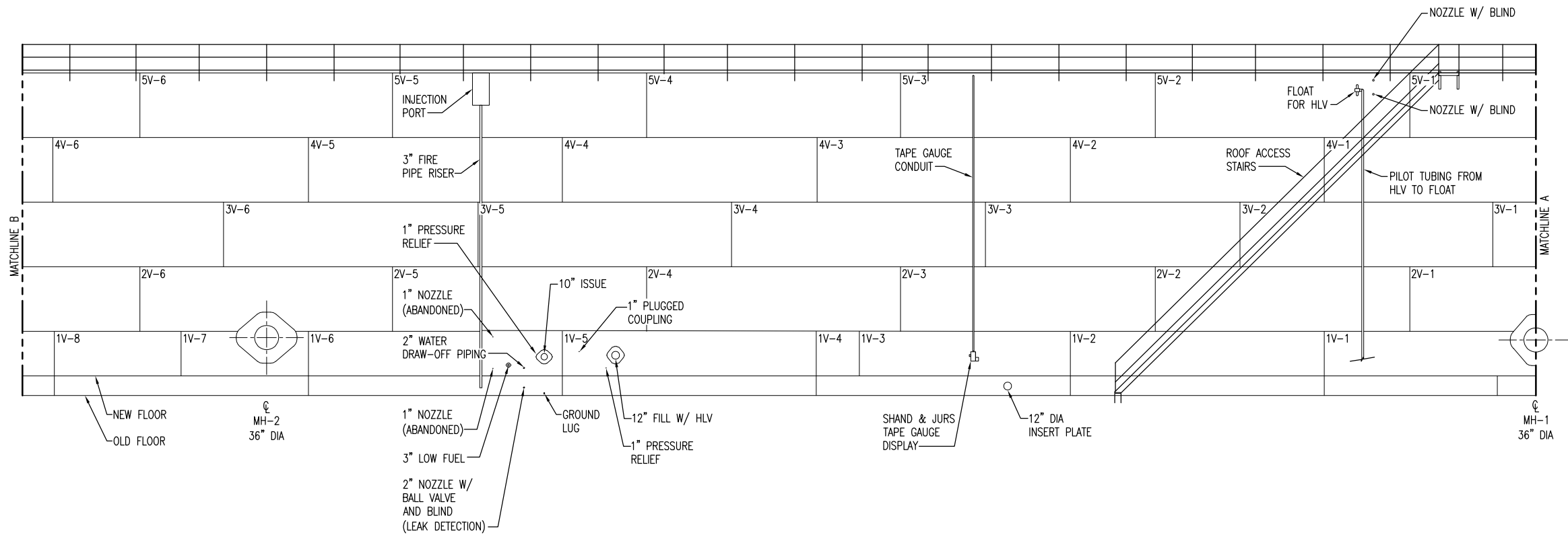
DWG NO.	DATE
S-2	01/08
PN:	SHEET
08-4889	2 OF 3

Plot Date: Jul 24, 2008 - 2:27pm Drawing File: P:\Projects\08-4889\Cad\Current Dwg %Struct%\TANK-27 R-2.dwg Last modified by: VM

INSPECTED UNDER
SUBCONTRACT TO
SHAW ENVIRONMENTAL, INC.
PURCHASE ORDER
DATED 15 MAY 2008

API 653 INSPECTION TANK 27

THULE AIR BASE, GREENLAND



TANK 27 SHELL ELEVATION

SCALE: 1/8" = 1'-0"

GRAPHIC SCALE



REV	DATE	DESCRIPTION

DESIGN:	SEAL
DAS	
DRAWN:	
SPU	
CHKD:	
DAS	
APRVD:	
SSB	
SCALE:	
AS NOTED	

ENTERPRISE
ENGINEERING, INC
5 DEPOT ST. SUITE 23
FREEPORT, ME 04032
TEL: (207) 869-8006
FAX (207) 869-8015
2525 GAMBELL STREET
SUITE 200
ANCHORAGE, AK 99503
TEL: (907) 563-3835
FAX (907) 563-3817

DRAWING TITLE
TANK 27 SHELL

DWG NO.	DATE
S-3	01/08
PN:	SHEET
08-4889	3 OF 3

Plot Date: Jul 24, 2008 - 2:27pm Drawing File: P:\Projects\08-4889\Cad\Current Dwg %Struct%\TANK-27 S-3.dwg Last modified by: VM

APPENDIX D

Tank Photographs



Tank 27 – North Elevation



Tank 27 – East Elevation



Tank 27 – South Elevation



Tank 27 – West Elevation



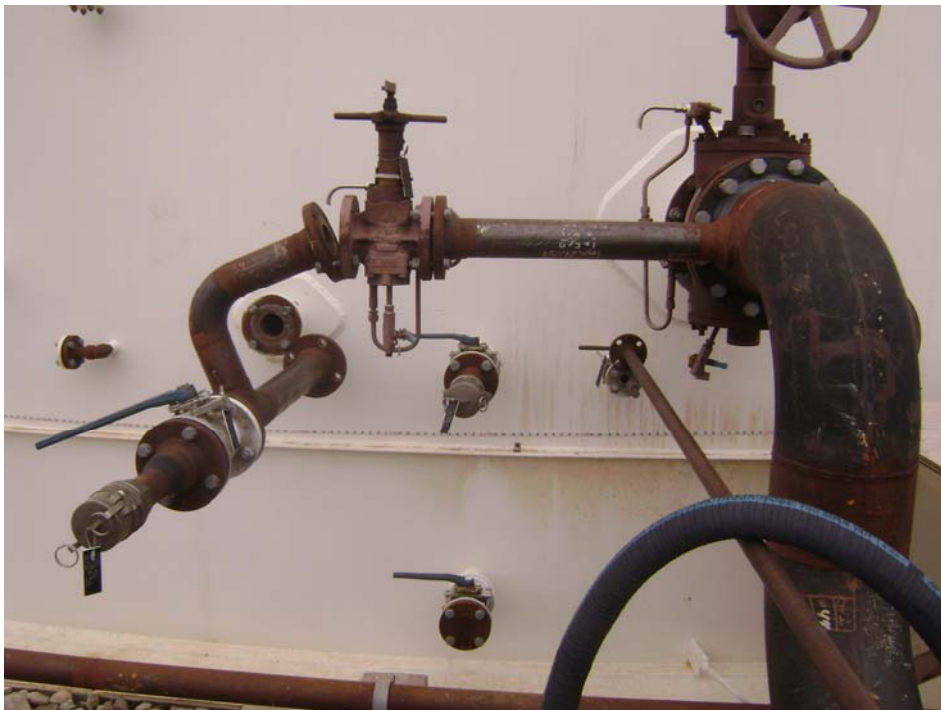
36" Diameter Manway #1



New Floor Extension, Old Floor Extension and Dead Shell



12" Fill Nozzle with HLV Pilot Tubing and 1" Pressure Relief



Left to Right: 1" Nozzle with Blind, 3" Low Fuel, 2" Water Draw-Off, 1" Pressure Relief and 10" Issue Nozzle
(Note: 2" Leak Detection in Interstitial Space)



2" with ¼ Turn Ball Valve in Dead Shell (Typical of 2) and Tab with Ground Wire
(Note: Ball valve used for leak detection in interstitial space.)



Spiral Stairs
(Note: Minor coating failure and corrosion.)



Shand & Jurs Tape Gauge Display



36" Diameter Manway #2



10" Thief Hatch with ITT Barton ATG Probe Assembly and 24" Manway



AFF Foam Nozzle (Typical of 2)



Penetrations for Shand & Jurs Tape Gauge Float and Guide Wires



Shand & Jurs Pressure/Vacuum Vent (Typical of 2)



10" Nozzle with Blind and 24" Diameter Roof Manway



Left to Right: Center Roof Support Column, 3" Low Fuel Piping and 2" Water Draw-Off Piping in Center Sump



12" Fill Piping with Diffuser



Left to Right: 12" Fill Nozzle, 1" Thermal Relief Nozzle
and Temperature Thermowell (Not Used)



Left to Right: 12" Fill Nozzle, 1" Thermal Relief Nozzle, 2" Water Draw-Off, 3" Low Fuel and Abandoned Nozzles for Low Level Alarm



Float for Shand & Jurs Tape Gauge
(Note: Tape was not functional.)



8" Gauge Tube with ITT Barton ATG Probe Assembly
(Note: Gauge tube includes a datum plate approximately at chine elevation.)



Roof Access Ladder



Roof Support Column (Typical of 16)

APPENDIX E

NDE Results

Tank No.: 27
 Location: Thule AB, Greenland
 EEI Project No.: 08-4889
 Performed By: KBW/TOL
 Date: 6/8/08

Revised March 2008

Form 06 Shell Exterior: UT & Coating

UT Equipment (Echo-Echo)

36 DLT

DFT Equipment

POSITECTOR 6000

Shell Course No.	Reading No.	UT Reading	Coating Thickness (At Same Location)
1	1	0.583	9.1
	2	0.586	9.1
	3	0.593	8.7
	4	0.597	9.1
	5	0.594	14.0
	6	0.594	16.0
	Average	0.591	11.0
2	1	0.451	10.8
	2	0.456	9.2
	3	0.460	9.2
	4	0.460	10.3
	5	0.467	11.7
	6	0.460	14.5
	Average	0.459	11.0
3	1	0.340	9.9
	2	0.343	15.1
	3	0.342	8.6
	4	0.350	11.0
	5	0.348	11.3
	6	0.342	10.7
	Average	0.344	11.1
4	1	0.244	10.0
	2	0.236	9.7
	3	0.244	9.4
	4	0.244	9.2
	5	0.241	12.9
	6	0.240	13.0
	Average	0.242	10.7

Tank No.: 27
 Location: Thule AB, Greenland
 EEI Project No.: 08-4889
 Performed By: KBW/TOL
 Date: 6/8/08

Revised March 2008

Form 06 Shell Exterior: UT & Coating

UT Equipment (Echo-Echo)

36 DLT

DFT Equipment

POSITECTOR 6000

Shell Course No.	Reading No.	UT Reading	Coating Thickness (At Same Location)
5	1	0.245	15.1
	2	0.247	14.5
	3	0.251	12.3
	4	0.252	11.4
	5	0.250	9.1
	6	0.251	10.0
	Average	0.249	12.1
_____	1		
	2		
	3		
	4		
	5		
	6		
	Average		
_____	1		
	2		
	3		
	4		
	5		
	6		
	Average		
Rim Angle (3 locations)	1		
	2		
	3		
	Average		

Tank No.: 27
 Location: Thule AB, Greenland
 EEI Project No.: 08-4889
 Performed By: KBW/TOL
 Date: 6/9/08

Revised March 2008

Form 10 Roof Exterior: UT and Coating

UT Equipment (Echo-Echo)

STRESSTEL 945a

DFT Equipment

POSITECH 6000

Plate Designation	Reading No.	UT Reading	Coating (At Same location
-------------------	-------------	------------	---------------------------

PERIMETER ROOF PLATES

C1	1	0.187	9.0
	2	0.186	8.2
	3	0.185	9.5
G6	1	0.193	7.4
	2	0.186	9.1
	3	0.194	12.1
M1	1	0.180	6.6
	2	0.182	6.7
	3	0.181	11.5
Q5	1	0.188	7.8
	2	0.190	8.0
	3	0.187	6.3

INTERIOR ROOF PLATES

E3	1	0.171	6.0
	2	0.179	7.7
	3	0.179	4.2
J2	1	0.183	9.3
	2	0.181	4.7
	3	0.180	9.8
O4	1	0.190	8.5
	2	0.191	6.6
	3	0.183	7.0
P2	1	0.185	5.7
	2	0.181	8.0
	3	0.179	6.7
	AVERAGE	0.184	7.8
	Minimum	0.171	4.2
	Maximum	0.194	12.1

Tank No.: 27
 Location: Thule AB, Greenland
 EEI Project No.: 08-4889
 Performed By: KBW
 Date: 6/8/08

Revised March 2008

Form 14 Floor Extension Exterior: 1st Course UT & Coating

UT Equipment (Echo-Echo)

36 DLT

DFT Equipment

POSITECTOR 6000

Clockwise Distance from MH-1	Reading No.	UT Reading	Coating Thickness at Same Location
MH-1	1	0.265	14.9
30'	2	0.250	33.0
60'	3	0.272	21.0
90'	4	0.269	19.9
120'	5	0.257	13.9
150'	6	0.270	19.4
180'	7	0.267	15.6
210'	8	0.267	26.7
240'	9	0.263	21.5
270'	10	0.270	21.6
	Average	0.265	20.8
	Minimum	0.250	13.9
	Maximum	0.272	33.0

Tank No.: 27
 Location: Thule AB, Greenland
 EEI Project No.: 08-4889
 Performed By: TOL/KDM
 Date: 6/8/08

Revised March 2008

Form 19 Floor: UT and Coating

UT Equipment (Echo-Echo)
 DFT Equipment

STRESSTEL 945a
POSITECTOR 6000

Notes: 1. See Project Scope For Number of UT Readings per Plate							
Plate Design.	UT No. 1	UT No. 2	UT No. 3	UT No.4	UT No.5	DFT 1	DFT 2
A1	0.230	0.237	0.240	0.233	0.239	10.1	11.6
A2	0.233	0.238	0.238	0.230	0.229	10.6	8.0
B1	0.231	0.228	0.237	0.231	0.237	11.3	9.5
B2	0.231	0.230	0.237	0.233	0.231	9.5	8.5
B3	0.231	0.231	0.238	0.231	0.230	10.6	10.2
C1	0.230	0.231	0.235	0.225	0.227	9.5	12.5
C2	0.227	0.228	0.235	0.227	0.226	10.8	10.3
C3	0.229	0.227	0.233	0.227	0.224	8.3	8.2
C4	0.227	0.226	0.230	0.225	0.230	7.4	7.5
D1	0.221	0.223	0.232	0.225	0.227	10.9	10.3
D2	0.224	0.223	0.232	0.225	0.224	10.5	11.6
D3	0.230	0.236	0.235	0.233	0.238	9.2	11.0
D4	0.225	0.223	0.230	0.225	0.223	10.0	10.1
D5	0.222	0.223	0.228	0.223	0.221	12.0	11.0
E1	0.222	0.223	0.230	0.224	0.223	6.7	10.1
E2	0.222	0.220	0.231	0.224	0.221	12.6	9.9
E3	0.221	0.221	0.229	0.223	0.224	12.6	11.4
E4	0.226	0.224	0.233	0.224	0.225	8.0	8.8
E5	0.222	0.223	0.221	0.222	0.231	9.9	9.9
F1	0.236	0.229	0.237	0.227	0.226	8.7	9.0
F2	0.225	0.226	0.230	0.227	0.225	7.9	12.1
F3	0.225	0.231	0.224	0.226	0.224	13.1	10.6
F4	0.232	0.233	0.238	0.230	0.230	9.7	12.7
G1	0.222	0.221	0.227	0.223	0.220	9.0	13.6
G2	0.227	0.220	0.228	0.221	0.223	11.6	12.5
G3	0.227	0.230	0.227	0.237	0.225	9.8	12.5
G4	0.218	0.217	0.227	0.226	0.221	11.6	11.1
G5	0.224	0.221	0.228	0.220	0.223	10.1	9.2
H1	0.225	0.225	0.232	0.228	0.228	11.1	9.7
H2	0.228	0.226	0.224	0.227	0.225	13.2	12.5

Tank No.: 27
 Location: Thule AB, Greenland
 EEI Project No.: 08-4889
 Performed By: TOL/KDM
 Date: 6/8/08

Revised March 2008

Form 19 Floor: UT and Coating

UT Equipment (Echo-Echo)
 DFT Equipment

STRESSTEL 945a
POSITECTOR 6000

Notes: 1. See Project Scope For Number of UT Readings per Plate <div style="float: right; text-align: center;"> </div>							
Plate Design.	UT No. 1	UT No. 2	UT No. 3	UT No.4	UT No.5	DFT 1	DFT 2
H3	0.223	0.222	0.232	0.226	0.226	12.6	12.0
H4	0.221	0.223	0.233	0.226	0.224	9.4	14.9
H5	0.227	0.227	0.234	0.226	0.228	11.1	9.4
I1	0.232	0.229	0.235	0.227	0.229	11.6	13.2
I2	0.227	0.230	0.236	0.228	0.227	13.1	13.4
I3	0.231	0.229	0.236	0.233	0.230	9.2	12.4
I4	0.230	0.232	0.236	0.238	0.230	11.6	11.7
I5	0.232	0.230	0.238	0.232	0.233	10.5	14.1
J1	0.223	0.223	0.232	0.233	0.227	13.4	10.6
J2	0.226	0.225	0.232	0.224	0.221	7.6	9.2
J3	0.225	0.227	0.234	0.227	0.227	10.7	14.2
J4	0.231	0.231	0.239	0.236	0.232	11.7	10.6
K1	0.222	0.225	0.230	0.231	0.227	9.0	12.1
K2	0.221	0.220	0.227	0.228	0.223	10.3	12.8
K3	0.224	0.223	0.230	0.229	0.223	10.5	9.4
L1	0.225	0.223	0.231	0.232	0.226	7.3	8.7
L2	0.227	0.222	0.227	0.224	0.217	11.6	9.9
SK-1	0.251	0.268				13.0	14.3
SK-2	0.262	0.261				10.3	10.4
SK-3	0.270	0.273				13.0	7.5
SK-4	0.266	0.269				14.3	10.0
SK-5	0.268	0.265				13.1	9.8
SK-6	0.271	0.273				10.3	9.8
SK-7	0.271	0.261				13.5	13.9
SK-8	0.272	0.271				10.2	12.9
SK-9	0.263	0.262				9.8	9.7
SK-10	0.267	0.272				10.8	10.1
SK-11	0.272	0.272				12.5	8.7
SK-12	0.271	0.272				10.2	11.0

Tank No.: 27
 Location: Thule AB, Greenland
 EEI Project No.: 08-4889
 Performed By: KBW/TOL
 Date: 6/8/08

Revised March 2008

Form 23 Shell Interior: 1st Course UT & Coating

UT Equipment (Echo-Echo) Stresstel FlawMIKE
 DFT Equipment Positector 6000

Notes:			
1. ALWAYS TAKE INTERIOR DFT			
2. Take UT readings when there is visible banding at the tank bottom.			
Vertical Welds	Reading No.	UT Reading 6"-12" From Floor	Coating Thickness at Same Location
1V-1	1		7.1
	2		7.7
	3		7.3
1V-2	4		8.4
1V-2	1		8.0
	2		10.5
	3		13.5
1V-3	4		10.6
1V-3	1		8.8
	2		7.5
	3		8.5
1V-4	4		9.6
1V-4	1		8.0
	2		8.5
	3		7.2
1V-5	4		8.5
1V-5	1		9.2
	2		10.6
	3		10.5
1V-6	4		7.7
1V-6	1		11.7
	2		9.6
	3		8.9
1V-7	4		8.9
1V-7	1		6.2
	2		9.4
	3		8.0
1V-8	4		8.6

Tank No.: 27
 Location: Thule AB, Greenland
 EEI Project No.: 08-4889
 Performed By: KBW/TOL
 Date: 6/8/08

Revised March 2008

Form 23 Shell Interior: 1st Course UT & Coating

UT Equipment (Echo-Echo) Stresstel FlawMIKE
 DFT Equipment Positector 6000

Notes:			
1. ALWAYS TAKE INTERIOR DFT			
2. Take UT readings when there is visible banding at the tank bottom.			
Vertical Welds	Reading No.	UT Reading 6"-12" From Floor	Coating Thickness at Same Location
1V-8	1		9.2
	2		8.3
	3		10.1
1V-9	4		7.8
1V-9	1		7.7
	2		9.1
	3		8.1
1V-10	4		7.2
1V-10	1		7.0
	2		8.5
	3		6.1
1V-11	4		7.8
1V-11	1		7.4
	2		9.9
	3		7.1
1V-12	4		6.6
1V-12	1		6.1
	2		7.4
	3		6.5
1V-13	4		6.7
1V-13	1		7.9
	2		8.5
	3		6.9
1V-14	4		5.5
1V-14	1		8.4
	2		7.1
	3		10.0
1V-15	4		11.0

Tank No.: 27
 Location: Thule AB, Greenland
 EEI Project No.: 08-4889
 Performed By: KBW/TOL
 Date: 6/8/08

Revised March 2008

Form 23 Shell Interior: 1st Course UT & Coating

UT Equipment (Echo-Echo) Stresstel FlawMIKE
 DFT Equipment Positector 6000

Notes:			
1. ALWAYS TAKE INTERIOR DFT			
2. Take UT readings when there is visible banding at the tank bottom.			
Vertical Welds	Reading No.	UT Reading 6"-12" From Floor	Coating Thickness at Same Location
1V-15	1		10.3
	2		7.4
	3		6.3
1V-16	4		9.4
N/A	1		
	2		
	3		
	4		
N/A	1		
	2		
	3		
	4		
N/A	1		
	2		
	3		
	4		
N/A	1		
	2		
	3		
	4		
N/A	1		
	2		
	3		
	4		
N/A	1		
	2		
	3		
	4		
Average			8.4
Minimum			5.5
Maximum			13.5

APPENDIX F

Calculations

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
REL 9/15/2007 EXP 9/15/2012 #####
REV 2/29/2008

INPUT DATA

(Shaded values are input data)

PROJECT: **API 653 Inspection**
LOCATION: **Thule AB, Greenland**
EEI PROJECT NO.: **08-4889**

TANK NO. **27**

PREPARED BY: **DAS**
DATE: **7/9/2008**

CHECKED BY:
DATE:

TANK DATA: GENERAL

NEW/EXISTING **EXISTING**
YEAR BUILT **1951**

TANK DATA: PHYSICAL PROPERTIES

FOUNDATION

TYPE OF FOUNDATION **EARTH** (RINGWALL, EARTH, CONCRETE CONFINING RING, ET
TANK ANCHORED (YES OR NO) **NO**
NUMBER OF ANCHORS N =
DIAMETER OF BOLT CIRCLE d = FT
DIAMETER OF ANCHOR BOLT: dB = INCHES

SPACING OF ANCHOR BOLTS S= FT

ANCHOR BOLT YIELD STRENGTH F_{yab} = KSI
ANCHOR BOLT SHEAR STRENGTH F_{vbolt} = KSI

COEFFICIENT OF FRICTION BETWEEN TANK AND FOUNDATION μ = **0.40** (μ max = 0.4 PER API 650 E.7.6., USE SMALLER μ BASED ON FOUNDATION CONSIDERATIONS)

FLOOR

MATERIAL **UNKNOWN**
FLOOR THICKNESS t_f = **0.2280** INCHES
FLOOR CORROSION ALLOWANCE CA_{floor} = **0.0000** INCHES
FLOOR THICKNESS BELOW SHELL t_b = **0.2650** INCHES

ANNULAR PLATE (YES/NO) **YES**
ANNULAR PLATE THICKNESS t_{ann} = **0.2680** INCHES
ANNULAR PLATE WIDTH L_s = **2.000** FT

YIELD STRENGTH OF FLOOR PLATE BELOW SHELL F_{BY} = **30,000** PSI

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV 2/29/2008

INPUT DATA

(Shaded values are input data)

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO.: **08-4889**
 TANK NO. **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**
 CHECKED BY:
 DATE:

TANK DATA: PHYSICAL PROPERTIES

SHELL

DIAMETER D = **100.00** FT

SHELL CORROSION ALLOWANCE CA_{shell} = **0.0000** INCHES

OVERFLOW PORTS = **NONE** (Input YES if overflow ports are present, input NONE if no overflow ports)

TOP OF SHELL TO BOTTOM OF OVERFLOW PORT Hop = **0.000** FT (Input 0 if no overflow ports)

TYPE OF SHELL JOINTS **BUTT WELDED** (Input BUTT WELDED, LAP WELDED, or RIVETED)

USE JOINT EFFICIENCY PER API 650 FOR NEW TANK, PER API 653 FOR EXISTING TANK

	COURSE NO.	HEIGHT h FT	THICKNESS t INCHES	JOINT EFFICIENCY E	MATERIAL	YIELD STRESS F_y PSI	ALLOWABLE STRESS	
							PRODUCT S_d PSI	HYDROTEST S_t PSI
BOTTOM COURSE	1	5.500	0.5910	0.850	UNKNOWN	30000	23600	26000
	2	8.000	0.4590	0.850	UNKNOWN	30000	23600	26000
	3	8.000	0.3440	0.850	UNKNOWN	30000	26000	27000
	4	8.000	0.2420	0.850	UNKNOWN	30000	26000	27000
	5	7.750	0.2490	0.850	UNKNOWN	30000	26000	27000
RIM ANGLE		0.250	0.2500					

SHELL HEIGHT H_s = **37.500** FT

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV 2/29/2008

INPUT DATA

(Shaded values are input data)

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO.: **08-4889**
 TANK NO. **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**
 CHECKED BY: _____
 DATE: _____

TANK DATA: PHYSICAL PROPERTIES

ROOF AND ROOF FRAMING

ROOF SLOPE THETA = **3.60** DEG

Assumed roof slope

ROOF THICKNESS $t_R =$ **0.1840** INCHES
 ROOF CORROSION ALLOWAN $CA_{roof} =$ **0.0000** INCHES
 WEIGHT OF ROOF FRAMING $r_F =$ **5.000** PSF
 WEIGHT OF RIM ANGLE $r_A =$ **5.000** LB/LF

ROOF FRAMING SYSTEM **4**

- (Input
- or 0 no interior columns
 - or 1 single center column with simple span radial rafters only
 - or 2 single center column with simple span radial trusses only
 - or 3 single center column with trusses and framing
 - or 4 center column with perimeter columns)

(Leave cell blank if framing system 3 is NOT selected)

(Leave cell blank if framing system 3 is NOT selected)
 (Leave cell blank if framing system 3 is NOT selected)
 (Leave cell blank if framing system 3 is NOT selected)

COLUMN	SIZE	NUMBER OF COLUMNS	COLUMN WEIGHT (LB/LF)
CENTER	PS6	1	20.0
INNER COLUMNS	PS6	5	20.0
OUTER COLUMNS	PS6	10	20.0

(If no interior columns, input NONE in "SIZE" column input 0.0 in "NO. of COLUMNS" and "COLUMN WEIGHT" column)

RADIAL DISTANCE TO OUTER COLUMN $R_2 =$ **34** FT

(Input 0 if no radial columns)

APPURTENANCES

WEIGHT OF STAIRS, PIPING, ETC **2** %

(Input weight as a percentage of total weight of tank. Input 2% if unknown)

FLOATING PAN/ROOF

WT OF FLOATING PAN/ROOF $W_{pan} =$ **0.00** K

(Input weight of floating pan/roof, Input 0 if no pan/roof)

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
REL 9/15/2007 EXP 9/15/2012 #####
REV 2/29/2008

INPUT DATA

(Shaded values are input data)

PROJECT: **API 653 Inspection**
LOCATION: **Thule AB, Greenland**
EEI PROJECT NO.: **08-4889**

TANK NO. **27**

PREPARED BY: **DAS**
DATE: **7/9/2008**

CHECKED BY: _____
DATE: _____

TANK DATA: LIQUID STORAGE

FILL HEIGHT $H_f =$ **36.000** FT

PRODUCT STORAGE **JP-8**

(Input product storage service.
Example: GASOLINE, JP-4, JP-5, JP-8, DIESEL, WATER)

SPECIFIC GRAVITY $G =$ **0.820**

Specific gravities of various liquids

product	G
Gasoline	0.730
JP-4	0.760
JP-5	0.820
JP-8	0.820
Diesel	0.840
Water	1.000

TANK DATA: LOADS

DIFFERENTIAL SETTLEMENT

TOLERANCE OF FLOATING PAN SEAL $R_{tol} =$ **N/A** INCHES

(Input N/A if no floating pan)

DIFFERENTIAL SETTLEMENT DELTA $=$ **0.17** FT

(High point EL - Low point EL)
(Input 0 if no data)

ROOF LIVE LOAD

ROOF LIVE LOAD $P_{LL} =$ **25** PSF

SNOW LOAD

CODE: ASCE 7-05

NOTE: FOR MILITARY PROJECTS USE UFC 3-310-01 WHICH REFERENCES ASCE 7 FOR LOADS

GROUND SNOW $P_g =$ **25** PSF
EXPOSURE FACTOR $C_e =$ **0.9**
THERMAL FACTOR $C_t =$ **1.2**
IMPORTANCE FACTOR $I =$ **1.1**

FIG. 7-1 and Table 7-1
TABLE 7-2
TABLE 7-3
TABLE 7-4

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV 2/29/2008

INPUT DATA

(Shaded values are input data)

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO.: **08-4889**
 TANK NO. **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**
 CHECKED BY:
 DATE:

TANK DATA: LOADS

WIND LOAD

CODE: API 650 3.2.1 AND ASCE 7-05

NOTES

1. API 650 WIND LOAD AND VELOCITY PRESSURE IS BASED ON ASCE 7 EXPOSURE C, IMPORTANCE FACTOR OF 1.00.
2. PER API 650 3.2.1, WIND PRESSURES MAY BE DETERMINED IN ACCORDANCE WITH ASCE 7.
3. TO ADJUST THE VELOCITY PRESSURE ON THE TANK SHELL AND ROOF FOR WIND OVERTURNING, ENTER THE EXPOSURE CATEGORY AND IMPORTANCE FACTOR.
4. STIFFENER EVALUATION IS BASED ON API 650 WHICH USES EXPOSURE CATEGORY C, IMPORTANCE FACTOR OF 1.
5. FOR MILITARY PROJECTS USE UFC 3-310-01 WHICH REFERENCES ASCE 7 FOR LOADS.

BASIC WIND SPEED $V = 135$ MPH ASCE 7-0 FIG. 6-1
 EXPOSURE CATEGORY (B, C, D) **D** ASCE 7-05 6.5.6.2
 USE API 650 EXPOSURE C (YES/NO) **NO**
 IMPORTANCE FACTOR $I = 1.00$ TABLE 6-1
 INTERNAL PRESSURE $= 0.00$ PSF ENTER 0 IF NO INTERNAL PRESSURE

TOPOGRAPHIC FACTOR $K_{zt} = 1.00$ SECT 6.5.7, PAGE 29
 (Kzt = 1.00 for most cases)
 WIND DIRECTIONALITY FACTOR $K_d = 0.95$ SECT. 6.5.4.4 and Table 6-4
 (Use Kd = 1.00 unless site dictates otherwise)
 GUST EFFECT FACTOR $G = 0.85$ SECT. 6.5.8, (Use G = 0.85)
 FILL HEIGHT FOR ALLOWABLE SHELL COMPRESSION $H_f = 36.000$ FT (USE $H_f = 0$ FT FOR EMPTY TANK)

SEISMIC LOAD

CODE: API 650 10th EDITION, ADDENDUM 4 APPENDIX E

SEISMIC USE GROUP (I, II, OR) $= \text{II}$ API 650 E.3

SITE GROUND MOTION (API 650 E.4.2 MAPPED ASCE METHOD)

SHORT PERIOD (0.2 S) ACCELERATION $S_s = 0.3700$ %g ASCE 7 FIG 22-11
 1.0 S PERIOD ACCELERATION $S_1 = 0.1500$ %g ASCE 7 FIG 22-12
 REGIONAL- DEPENDENT TRANSITIONAL PERIOD $TL = 6.00$ SEC ASCE 7 FIG 22-17
 SITE CLASS $= \text{D}$ ASCE 7 AND API 650 E.4.6

SITE MODIFICATION COEFFICIENTS (ASCE 7 AND API 650 E.4.5)

$F_a = 1.50$ API 650 APPENDIX E TABLE E-1

$F_v = 2.20$ API 650 APPENDIX E TABLE E-2

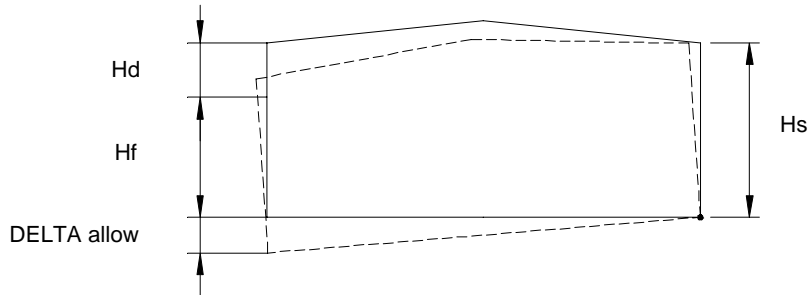
TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**
 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**
 CHECKED BY:
 DATE:

TANK DIFFERENTIAL SETTLEMENT



ALLOWABLE RIGID BODY TILT

BASED ON HOOP STRESS AT BOTTOM OF FIRST COURSE

ALLOWABLE TILT $\Delta_{allow} = [(4S \times 12 (t - CA) \times E) / (G \times G_w \times D)] - 2 (H_f - 1)$

ALLOW HOOP STRESS, 1ST COURSE	S =	23,600 PSI
1ST COURSE THICKNESS	t =	0.591 INCH
SHELL CORROSION ALLOWANCE	CA =	0.0000 INCH
1ST COURSE JOINT EFFICIENCY	E =	0.85
SPECIFIC GRAVITY OF CONTENTS	G =	0.820 JP-8
UNIT WEIGHT OF WATER	G _w =	62.4 LB/FT ³
TANK DIAMETER	D =	100 FT
HEIGHT OF SHELL	H _s =	37.5 FT
FILL HEIGHT	H _f =	36 FT
FREEBOARD	H _d = H _s - H _f =	1.5 FT

FOR JP-8 Service

$\Delta_{allow} = [(4(23600) \times 12(0.591 - 0) \times 0.85) / (0.82 \times 62.4 \times 100)] - 2(36 - 1) = 41.21 \text{ FT}$

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV

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TANK DIFFERENTIAL SETTLEMENT

ALLOWABLE RIGID BODY TILT

BASED ON OVERFLOWING

ALLOWABLE TILT	DELTA allow = 2(Hd)			
HEIGHT OF SHELL	Hs =	37.5	FT	
TOP OF SHELL TO BOT	Hop =	0	FT	
OF OVERFLOW PORT				
HEIGHT TO BOTTOM	Hp = Hs - Hop =	N/A	FT	Tank does not have overflow ports
OF OVERFLOW PORT				
FILL HEIGHT	Hf =	36	FT	
FREEBOARD	Hd =	1.5	FT	
DELTA allow =	2 (1.5)	=	3.00	FT

BASED ON TOLERANCE OF FLOATING ROOF/PAN

ALLOWABLE TILT	DELTA allow = 2 x SQR[Rtol x D]			
FLOATING PAN SEAL TOLERANCE	Rtol =	N/A	INCH	
TANK DIAMETER	D =	100	FT	
DELTA allow =	2 SQR(N/A/12 x 100)	=	N/A	FT

ALLOWABLE RIGID BODY TILT SUMMARY

AT FILL HEIGHT = 36 FT

ALLOWABLE SETTLEMENT BASED ON OVERFLOWING CRITERIA GOVERNS

DELTA allow = 3.00 FT

EVALUATE ACTUAL DIFFERENTIAL SETTLEMENT

DIFFERENTIAL SETTLEMENT	DELTA actual =	0.17	FT
ALLOWABLE TILT	DELTA allow =	3.00	FT

DELTA actual = 0.17 FT < DELTA allow = 3.00 FT PASSES CRITERIA

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
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 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**

 CHECKED BY:
 DATE:

WIND LOAD EVALUATION: UN-ANCHORED TANK

CODE: API 650 AND ASCE 7-05

BASIC WIND SPEED V = 135 MPH
 EXPOSURE CATEGORY = D
 USE API 650 EXPOSURE C (YES/NO) = NO

TANK PARAMETERS

TANK DIAMETER D = 100.00 FT
 ROOF SLOPE = 3.60 DEG = 0.0628 RAD

 MEAN ROOF HT = (1/2)(D/2)(TAN THETA) = 1.57 FT
 SHELL HEIGHT Hs = 37.50 FT
 MEAN ROOF HEIGHT ABOVE GROUND = 39.07 FT
 TO DETERMINE λ, USE MEAN ROOF HEIGHT = 40 FT
 IMPORTANCE FACTOR I = 1.00
 INTERNAL PRESSURE = 0.00 PSF
 TANK ANCHORED = NO
 FILL HEIGHT Hf = 36.00 FT
 THICKNESS OF FLOOR BELOW SHELL tb = 0.27 INCHES
 YIELD STRENGTH OF FLOOR BELOW SHI Fby = 30000.00 PSI

API 650 WIND PRESSURE (EXPOSURE C, BASIC WIND SPEED = 120 MPH)

DESIGN WIND PRESSURE ON VERTICAL PROJECTED AREA OF CYLINDRICAL SURFACES, API 650 3.2.1

$$P_{SHELL} = (18)(V/120)^2 = 22.78 \text{ PSF}$$

DESIGN WIND PRESSURE ON HORIZONTAL PROJECTED AREA OF CONICAL OR DOUBLY CURVED SURFACES, API 650

$$P_{ROOF} = (30)(V/120)^2 = 37.97 \text{ PSF}$$

WIND PRESSURE ADJUSTMENT FACTOR FOR HEIGHT AND EXPOSURE - ASCE 7 FIG 6-2

ADJUSTMENT FACTOR FOR HEIGHT AND EXPOSURE, λ
 MEAN ROOF EXPOSURE

MEAN ROOF HEIGHT	B	C	D
15	1.00	1.21	1.47
20	1.00	1.29	1.55
25	1.00	1.35	1.61
30	1.00	1.40	1.66
35	1.05	1.45	1.70
40	1.09	1.49	1.74
45	1.12	1.53	1.78
50	1.16	1.56	1.81
55	1.19	1.59	1.84
60	1.22	1.62	1.87

λ = 1.49 MEAN ROOF HEIGHT= 39.07 FT, EXPOSURE C

λ AT SITE = 1.74 MEAN ROOF HEIGHT =39.07 FT, EXPOSURE D

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

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 DATE:

WIND LOAD EVALUATION: UN-ANCHORED TANK

ADJUSTED WIND PRESSURES FOR HEIGHT, EXPOSURE, IMPORTANCE FACTOR, AND WIND SPEED

$$\begin{aligned} \text{ADJUSTED } P_{\text{SHELL}} &= (\lambda \text{ AT SITE} / \lambda) (I) (P_{\text{SHELL}}) \\ &= (1.74 / (1.49) (1) (22.78) && 26.60 \text{ PSF} \end{aligned}$$

$$\begin{aligned} \text{ADJUSTED } P_{\text{ROOF}} &= (\lambda \text{ AT SITE} / \lambda) (I) (P_{\text{ROOF}}) \\ &= (1.74 / (1.49) (1) (37.97) && 44.34 \text{ PSF} \end{aligned}$$

WIND OVERTURNING MOMENT

PROJECTED AREA OF SHELL

$$A_{\text{SHELL}} = (D)(H_s) = (100) (37.5) = 3,750.00 \text{ SF}$$

PROJECTED AREA OF ROOF

$$A_{\text{ROOF}} = \pi (D)^2 / 4 = \pi (100)^2 / 4 = 7,853.98 \text{ SF}$$

WIND FORCE ON SHELL

$$\begin{aligned} F_{\text{WSHELL}} &= (\text{ADJUSTED } P_{\text{SHELL}}) (A_{\text{SHELL}}) \\ &= (26.6) (3750) / 1000 && = 99.76 \text{ K} \end{aligned}$$

WIND UPLIFT FORCE ON ROOF

$$\begin{aligned} F_{\text{WROOF}} &= (\text{ADJUSTED } P_{\text{ROOF}}) (A_{\text{ROOF}}) \\ &= (44.34) (7853.98) / 1000 && = 348.24 \text{ K} \end{aligned}$$

OVERTURNING MOMENT FROM EXTERNAL WIND PRESSURE ON SHELL AND ROOF

$$\begin{aligned} M_w &= (F_{\text{WSHELL}})(H_s/2) + (F_{\text{WROOF}})(D/2) \\ &= (99.76) (37.5/2) + (348.24) (100/2) && = 19,282.59 \text{ K-FT} \end{aligned}$$

INTERNAL PRESSURE OVERTURNING MOMENT

INTERNAL PRESSURE FORCE UPLIFT ON ROOF

$$\begin{aligned} F_{\text{piROOF}} &= (\text{INTERNAL PRESSURE}) (A_{\text{ROOF}}) \\ &= (0) (7853.98) / 1000 && = 0.00 \text{ K} \end{aligned}$$

OVERTURNING MOMENT FROM INTERNAL PRESSURE

$$\begin{aligned} M_{\text{pi}} &= (F_{\text{piROOF}})(D/2) \\ &= (0) (100/2) && = 0.00 \text{ K-FT} \end{aligned}$$

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: **API 653 Inspection**
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 DATE: **7/9/2008**

 CHECKED BY:
 DATE:

WIND LOAD EVALUATION: UN-ANCHORED TANK

RESISTANCE TO OVERTURNING (API 650 3.11.2)

RESISTANCE TO OVERTURNING CRITERIA

CASE 1: $0.6M_w + M_{pi} < M_{DL}/1.5$
 CASE 2: $M_w + 0.4M_{pi} < (MDL + MF)/2$

UNANCHORED TANK MUST SATISFY BOTH CRITERIA

DEAD LOAD RESISTING MOMENT

SHELL WEIGHT	=	175.27 K
WEIGHT OF ROOF ON SHELL	=	28.93 K
SHELL WEIGHT + ROOF		
WEIGHT ON SHELL	DL =	204.20 K

RESISTING MOMENT FROM DEAD LOAD

$$M_{DL} = (DL)(D/2)$$

$$= (204.2)(100/2) = 10,210.05 \text{ K-FT}$$

INTERNAL FLUID RESISTING MOMENT

PER API 650 3.11.2 UNANCHORED TANKS, USE ONE HALF THE DESIGN LIQUID HEIGHT AND A SPECIFIC GRAVITY OF 0.70 TO DETERMINE THE RESISTING MOMENT DUE TO INTERNAL FLUID.

$$w_a = 4.67 \text{ tb } [(F_{by})(H_f)]^{0.5} \text{ LB PER LF OF CIRCUMFERENCE}$$

$$= 4.67 (0.265) \text{ SQRT}[(30000)(36)] = 1,286.10 \text{ lb/lf}$$

WEIGHT OF LIQUID (HOLD DOWN WEIGHT)

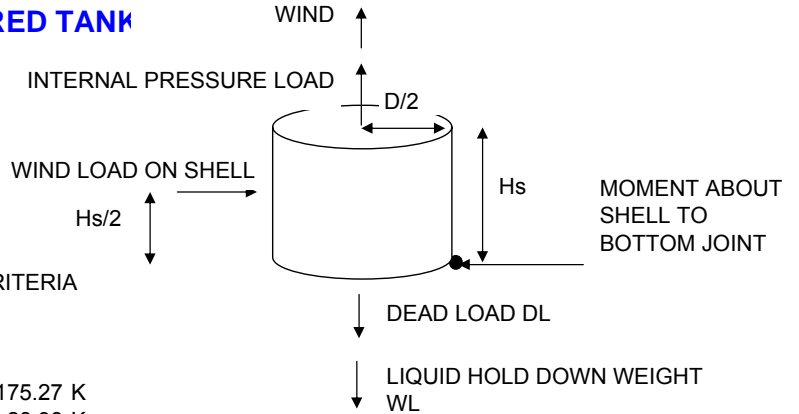
$$W_L = (w_a)(\pi D)$$

$$= (1286.1)(\pi 100) / 1000 = 404.04 \text{ K}$$

RESISTING MOMENT FROM INTERNAL LIQUID

$$M_F = (W_L)(D/2)$$

$$= (404.04)(100/2) = 20,202.01 \text{ K-FT}$$



TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

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WIND LOAD EVALUATION: UN-ANCHORED TANK

RESISTANCE TO OVERTURNING (API 650 3.11.2)

CASE 1: $0.6M_w + M_{pi} < M_{DL}/1.5$

$0.6M_w + M_{pi}$	=	0.6 (19282.59) + 0	=	11,569.55 K-FT
$M_{DL}/1.5$	=	(10210.05)/1.5	=	6,806.70 K-FT

11,569.55 > 6,806.70 FAILS CRITERIA

CASE 2: $M_w + 0.4M_{pi} < (MDL + MF)/2$

$M_w + 0.4M_{pi}$	=	(19282.59) + (0.4) (0)	=	19,282.59 K-FT
$(MDL + MF)/2$	=	(10210.05 + 20202.01)/2	=	15,206.03 K-FT

19,282.59 > 15,206.03 FAILS CRITERIA

MINIMUM LIQUID HEIGHT TO RESIST OVERTURNING (APPLIES TO CASE 2 ONLY)

$M_w + 0.4M_{pi}$	=	(MDL + MF)/2	=	(WL)(D/2)
MF	=	$2[M_w + 0.4M_{pi}] - MDL$	=	567.10 K
WL	=	$\{2[M_w + 0.4M_{pi}] - MDL\} / (D/2)$	=	
WL	=	$(wa)(\pi D)$	=	
wa	=	$[WL / (\pi D)] (1000 \text{ LB/K})$	=	1,805.14 LB/LF
wa	=	$4.67 \text{ tb } [(F_{by})(H_f)]^{0.5}$	=	
Hf	=	$(wa / 4.67 \text{ tb})^2 / (F_{by})$	=	70.92 FT

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
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 CHECKED BY:
 DATE:

WIND LOAD EVALUATION: UN-ANCHORED TANK

RESISTANCE TO SLIDING

WIND BASE SHEAR

V = 99.76 K (WIND FORCE ON SHELL)

SLIDING RESISTANCE

Vs = $\mu(Ws + Wr + Wf + Wp)$

SHELL WEIGHT	Ws =	175.27 K	
ROOF WEIGHT	Wr =	98.28 K	
FLOOR WEIGHT	Wf =	73.12 K	
FILL HEIGHT	Hf =	36.00 FT	
CONTENTS WEIGHT	Wp =	$(\pi D^2/4)(62.4)(G)(Hf)$	
	Wp =	$[(\pi) (100)^2 / 4] (62.4)(0.82) (36)/1000$	= 14,467.41 K

FOR EMPTY TANK

Hf = 0 FT

Wp = $[(\pi) (100)^2 / 4] (62.4)(0.82) (0)/1000$ = 0.00 K

Vs = $(0.4) (175.27 + 98.28 + 73.12 + 0)$ = 138.67 K

Vs = 138.67 K > V = 99.76 K

FOR EMPTY TANK SLIDING RESISTANCE CRITERIA SATISFIED

MINIMUM PRODUCT HEIGHT REQUIRED TO SATISFY SLIDING RESISTANCE

V = Vs

V = $\mu(Ws + Wr + Wf + Wp)$

Wp = $(V / \mu) - (Ws + Wr + Wf)$ = $(\pi D^2/4)(62.4)(G)(Hf)$

Hf min = $[(V / \mu) - (Ws + Wr + Wf)] / [(\pi D^2/4)(62.4)(G)]$

Hf min = $[(99.76 / 0.4) - (175.27 + 98.28 + 73.12)] \{1000 / [(\pi) (100^2) / 4] (62.4) (0.82)]\}$

Hf min = < 0 FT

SUMMARY

1. TANK DOES NOT MEET RESISTNACE TO OVERTURNING CRITERIA
2. TANK MEETS SLIDING RESISTANCE CRITERIA

COMMENT:

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV 3/14/2007

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
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 DATE: **7/9/2008**

 CHECKED BY: _____
 DATE: _____

SHELL STIFFENER REQUIREMENTS

EVALUATION CRITERIA

API 650 CRITERIA, Sec. 3.9.7

TRANSFORMED SHELL HEIGHT

TRANSFORMED SHELL HEIGHT $H_{tr} = \text{SUM}(W_{tr})$ FT
 TRANSFORMED SHELL COURSE HEIGHT $W_{tr} = \text{SQRT} [(t_{TOP} / t)^5] \times W$
 COURSE HEIGHT = W FT
 THICKNESS OF TOP COURSE = t_{TOP} INCH

COURSE NO	t INCH	W FT	W_{tr} FT
1	0.591	5.5	0.634
2	0.459	8	1.734
3	0.344	8	3.566
4	0.242	8	8.591
5	0.249	7.75	7.750

$$H_{tr} = \frac{\quad}{\quad} = 22.28 \text{ FT}$$

3-SECOND GUST DESIGN WIND VELOCITY

$$V = 135 \text{ MPH}$$

MAXIMUM HEIGHT OF UNSTIFFENED SHELL

$$H_1 = 600,000 (t_{TOP}) \text{SQRT} [(t_{TOP} / D)^3] (120 / V)^2$$

$$H_1 = 600,000 \times (0.249 \times \text{SQRT} [(0.249 / (100)^3]) (120 / 135)^2 = 14.67 \text{ FT}$$

SHELL STIFFENER REQUIREMENTS

$$H_1 = 14.67 \text{ FT} < H_{tr} = 22.28 \text{ FT}$$

INTERMEDIATE SHELL STIFFENERS REQUIRED

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
REL 9/15/2007 EXP 9/15/2012 #####
REV 3/14/2007

PROJECT: **API 653 Inspection**
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SHELL STIFFENER REQUIREMENTS

MAXIMUM WIND VELOCITY WITHOUT SHELL STIFFENERS

$$H_1 \geq H_{tr}$$

$$\text{THEREFORE: } 600,000 (t_{TOP}) \text{ SQR} [(t_{TOP} / D)^3] (120/V)^2 = H_{tr}$$

SOLVING FOR V:

$$V_{max} = 120 / \{ \text{SQRT} [H_{tr} / (600,000 (t_{TOP}) \text{ SQR} (t_{TOP} / D)^3)] \}$$

$$V_{max} = 120 / \{ \text{SQRT} [22.275 / (600,000 (0.249 \text{ SQR} (0.249 / 100)^3)] \} = 109.55 \text{ MPH}$$

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
REL 9/15/2007 EXP 9/15/2012 #####
REV #####

PROJECT: API 653 Inspection
LOCATION: Thule AB, Greenland
EEI PROJECT NO: 08-4889

TANK NO: 27

PREPARED BY: DAS
DATE: 7/9/2008

CHECKED BY:
DATE:

SEISMIC EVALUATION: UN-ANCHORED TANK

TANK PARAMETERS

DIAMETER D = 100.00 FT
SHELL HEIGHT Hs = 37.50 FT
PRODUCT STORAGE = JP-8
FILL HEIGHT H = 36.00 FT
PRODUCT SPECIFIC GRAVITY G = 0.820
TYPE OF FOUNDATION = EARTH
TANK ANCHORED = NO

TANK HAS ANNULAR PLATE = YES

E.3 PERFORMANCE BASIS

SEISMIC USE GROUP SUG = II

IMPORTANCE FACTOR I = 1.25 API 650 APPENDIX E TABLE E-5

E.4 SITE GROUND MOTION

E.4.2 MAPPED ASCE METHOD

Ss = 0.3700 %g
S1 = 0.1500 %g
TL = 6.00 SEC

So = 0.4Ss = 0.1480 %g

E.4.6 SITE CLASS

SITE CLASS = D

E.4.5 SITE MODIFICATION COEFFICIENTS

Fa = 1.50
Fv = 2.20

ASCE 7 ADJUSTED MCE SPECTRAL RESPONSE ACCELERATION PARAMETERS

Sms = (Fa) (Ss) = 0.55648
Sm1 = (Fv) (S1) = 0.3300

SCALING FACTOR FROM MCE TO DESIGN LEVEL SPECTRAL ACCELERATIONS

Q = 2/3

ASCE 7 DESIGN SPECTRAL RESPONSE ACCELERATION PARAMETERS

S_{DS} = Q (Sms) = 0.3710
S_{D1} = Q (Sm1) = 0.2200

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
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 CHECKED BY:
 DATE:

SEISMIC EVALUATION: UN-ANCHORED TANK

E.4 SITE GROUND MOTION

E.4.8 STRUCTURAL PERIOD OF VIBRATION

IMPULSIVE NATURAL PERIOD

$$T_i = C_i (H_f) [\text{SQRT}(p) / \text{SQRT}(E)] / \text{SQRT}(2 (tu) / D)$$

CONVECTIVE (SLOSHING) PERIOD, T_c

$$K_s = 0.578 / [\tanh(3.68H_f/D)]^{0.5}$$

$$= 0.578 / [\tanh(3.68(36)/100)]^{0.5} = 0.6204$$

$$T_c = K_s(D)^{0.5}$$

$$= 0.62(100)^{0.5} = 6.20 \text{ SEC}$$

E.5.1.1 RESPONSE MODIFICATION FACTORS

TABLE E-4 RESPONSE MODIFICATION FACTORS FOR ASD METHODS

ANCHORAGE SYSTEM	Rwi (IMPULSIVE)	Rwc (CONVECTIVE)
1 SELF-ANCHORED	3.5	2
2 MECHANICALLY ANCHORED	4	2
ANCHORAGE SYSTEM = SELF-ANCHORED		
Rwi	= 3.5	
Rwc	= 2	

E.4.9.1 SPECTRAL ACCELERATION COEFFICIENTS

IMPULSIVE SPECTRAL ACCELERATION PARAMETER, A_i

$$A_i = S_{DS} (I/Rwi) \quad \text{EQ E-4}$$

$$S_{DS} (I/Rwi) = 0.371 (1.25 / 3.5) = 0.132 \text{ GOVERNS}$$

$$A_i \text{ MIN} \geq 0.007$$

$$A_i = 0.132$$

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
REL 9/15/2007 EXP 9/15/2012 #####
REV #####

PROJECT: API 653 Inspection
LOCATION: Thule AB, Greenland
EEI PROJECT NO: 08-4889

TANK NO: 27

PREPARED BY: DAS
DATE: 7/9/2008

CHECKED BY:
DATE:

SEISMIC EVALUATION: UN-ANCHORED TANK

E.4 SITE GROUND MOTION

E.4.9.1 SPECTRAL ACCELERATION COEFFICIENTS

IMPULSIVE SPECTRAL ACCELERATION PARAMETER, AC

FOR $T_c < T_L$

$$A_c = K S_{D1}(1/T_c)(I/R_w c) \leq A_i \quad \text{EQ E-7}$$

$$K = 1.5 \quad \text{K = COEFFICIENT TO ADJUST FROM 5% TO 0.5% DAMPING, K = 1.5 UNLESS SPECIFIED OTHERWISE}$$

FOR $T_c > T_L$

$$A_c = K S_{D1}(T_L/T_c^2)(I/R_w c) \leq A_i \quad \text{EQ E-8}$$

$$T_c = 6.20 \text{ SEC}$$

$$T_L = 6.00 \text{ SEC}$$

$$T_c > T_L \quad \text{EQ E-8 GOVERNS}$$

$$A_c = 1.5(0.22) [6 / (6.2)^2] (1.25/2) = 0.032 < A_i$$

$$A_c = 0.032$$

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**

CHECKED BY:
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SEISMIC EVALUATION: UN-ANCHORED TANK

E.6 DESIGN

DESIGN / EVALUATION PARAMETERS

WEIGHT OF TANK FLOOR	Wf =	73.12 K	
WEIGHT OF SHELL	Ws =	175.27 K	
WEIGHT OF ROOF	=	98.28 K	
WT OF FLOATING PAN/ROOF	Wpan =	0.00 K	
ROOF SNOW LOAD	=	172.79 K	
WEIGHT OF ROOF + 10% ROOF SNOW LOAD	Wr =	115.56 K	
PRODUCT STORAGE	=	JP-8	
FILL HEIGHT	Hf =	36 FT	
PRODUCT SPECIFIC GRAVITY	G =	0.82	
WEIGHT OF CONTENTS	Wp = $\pi (D^2 / 4) (Hf) Y_w (G) / 1000$		
	= $\pi (100^2 / 4) (36) (62.4) (0.82) / 1000$	=	14,467.41 K

E.6.1.1 EFFECTIVE WEIGHT OF PRODUCT

IMPULSIVE WEIGHT Wi

FOR $D/H \geq 1.333$

$$W_i = \{ \tanh [0.866 (D/H)] / 0.866 (D/H) \} W_p \quad \text{EQ E-13}$$

FOR $D/H < 1.333$

$$W_i = [1.00 - 0.218 (D/H)] W_p \quad \text{EQ E-14}$$

$$D/H = 2.778 > 1.333 \quad \text{EQ E-13 GOVERNS}$$

$$W_i = \{ \tanh [0.866 (100/36) / 0.866 (100/36)] \} 14467.41 = 5,917.06 \text{ K}$$

CONVECTIVE (SLOSHING) WEIGHT Wc

$$W_c = 0.230 (D/H) \tanh(3.67H/D) W_p \quad \text{EQ E-15}$$

$$W_c = 0.230 (100/36) \tanh[(3.67)36/100] 14467.41 = 8,014.50 \text{ K}$$

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
REL 9/15/2007 EXP 9/15/2012 #####
REV #####

PROJECT: API 653 Inspection
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EEI PROJECT NO: 08-4889

TANK NO: 27

PREPARED BY: DAS
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CHECKED BY: _____
DATE: _____

SEISMIC EVALUATION: UN-ANCHORED TANK

E.6 DESIGN

E.6.1.2.1 CENTER OF ACTION FOR RINGWALL OVERTURNING MOMENT

THE RINGWALL MOMENT, M_{rw} , IS THE PORTION OF THE TOTAL OVERTURNING MOMENT THAT ACTS AT THE BASE OF THE TANK SHELL PERIMETER. THIS MOMENT IS USED TO DETERMINE LOADS ON A RINGWALL FOUNDATION THE TANK ANCHORAGE FORCES, AND TO CHECK THE LONGITUDINAL SHELL COMPRESSION.

HEIGHT TO THE CENTER OF THE IMPULSIVE FORCE W_i

X_i = HEIGHT FROM BOTTOM OF SHELL TO CENTER OF IMPULSIVE FORCE W_i

FOR $D/H \geq 1.333$

X_i = 0.375H EQ E-16

FOR $D/H < 1.333$

X_i = $[0.5 - 0.094(D/H)] H$ EQ E-17

D/H = 2.778 > 1.333 EQ E-16 GOVERNS

X_i = (0.375) (36) = 13.500 FT

HEIGHT TO THE CENTER OF THE CONVECTIVE FORCE W_c

X_c = HEIGHT FROM BOTTOM OF SHELL TO CENTER OF CONVECTIVE FORCE W_c

X_c = $[1.0 - \{ \cosh((3.67H/D) - 1) / ((3.67H/D) \sinh(3.67H/D)) \}] H$ EQ E-18

X_c = $[1.0 - \{ \cosh((3.67) (36/100) - 1) / ((3.67) (36/100) \sinh((3.67) (36/100)) \}] (36)$

X_c = 19.531 FT

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
REL 9/15/2007 EXP 9/15/2012 #####
REV #####

PROJECT: API 653 Inspection
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EEI PROJECT NO: 08-4889

TANK NO: 27

PREPARED BY: DAS
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SEISMIC EVALUATION: UN-ANCHORED TANK

E.6 DESIGN

E.6.1.2.2 CENTER OF ACTION FOR SLAB OVERTURNING MOMENT

THE SLAB MOMENT, M_s , IS THE TOTAL OVERTURNING MOMENT ACTING ACROSS THE ENTIRE TANK BASE CROSS SECTION. THIS OVERTURNING MOMENT IS USED TO DESIGN SLAB AND PILE CAP FOUNDATIONS.

HEIGHT TO THE CENTER OF THE IMPULSIVE FORCE W_i

X_{is} = HEIGHT FROM BOTTOM OF SHELL TO CENTER OF IMPULSIVE FORCE W_i

FOR $D/H \geq 1.333$

$X_{is} = 0.375 [1.00 + 1.333 \{ (0.866(D/H) / \tanh(0.866(D/H)) - 1.00) \}] H$ EQ E-19

FOR $D/H < 1.333$

$X_{is} = [0.5 + 0.600(D/H)] H$ EQ E-20

$D/H = 2.778 > 1.333$ EQ E-19 GOVERNS

$X_{is} = 0.375 \{ 1.00 + 1.333 \{ 0.866 (100/36) / \tanh(0.866(100/36)) - 1.00 \} \} (36)$

$X_{is} = 39.504$ FT

HEIGHT TO THE CENTER OF THE CONVECTIVE FORCE W_c

X_{cs} = HEIGHT FROM BOTTOM OF SHELL TO CENTER OF CONVECTIVE FORCE W_c

$X_{cs} = [1.0 - \{ \cosh((3.67H/D) - 1.937) / ((3.67H/D) \sinh(3.67H/D)) \}] H$ EQ E-21

$X_{cs} = [1.0 - \{ \cosh((3.67(36/100)) - 1.937) / ((3.67(36/100) \sinh(3.67(36/100))) \}] (36)$

$X_{cs} = 17.282$ FT

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

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 DATE: **7/9/2008**

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SEISMIC EVALUATION: UN-ANCHORED TANK

E.6 DESIGN

HEIGHT TO THE CENTROID OF SHELL

COURSE NO.	WEIGHT K	CENTROID FT	M K-FT
1	41.70	2.750	114.67
2	47.11	10.750	506.38
3	35.30	18.750	661.93
4	24.84	26.750	664.35
5	24.76	34.500	854.05
RIM ANGLE	<u>1.57</u>	37.500	<u>58.90</u>
	175.27		2860.29
MISC. WEIGHT	<u>5.47</u>	18.750	<u>102.58</u>
	180.74		2962.87
Xs	=	2962.87 / 180.74	=
			16.39 FT

HEIGHT TO THE CENTROID OF ROOF

Xr = 37.5 FT

HEIGHT TO THE CENTROID OF FLOATING PAN/ROOF

Xpan = 36 FT

E.6.1.3 VERTICAL SEISMIC EFFECTS

Av = 0.14S_{DS}

Av = 0.14 (0.371) = 0.0519

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: **API 653 Inspection**
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 TANK NO: **27**

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SEISMIC EVALUATION: UN-ANCHORED TANK

E.6 DESIGN

E.6.1.4 DYNAMIC LIQUID HOOP FORCES

Y = DISTANCE DOWN FROM LIQUID SURFACE TO ANALYSIS POINT.

SINCE DYNAMIC HOOP FORCES ARE COMBINED WITH HYDROSTATIC HOOP FORCES WHICH ARE CALCULATED AT ONE FOOT ABOVE THE BOTTOM OF EACH SHELL COURSE, USE Y BASED ON DISTANCE FROM LIQUID SURFACE TO ONE FOOT ABOVE THE BOTTOM OF EACH SHELL COURSE.

IMPULSIVE HOOP MEMBRANE FORCE Ni

FOR $D/H \geq 1.333$

$$N_i = 4.5 A_i G D H [(Y/H) - 0.5 (Y/H)^2] \tanh \{ 0.866 (D/H) \} \quad \text{LB/IN}$$

FOR $D/H < 1.333$ AND $Y < 0.75D$

$$N_i = 2.77 A_i G (D^2) [(Y/0.75D) - 0.5 (Y/0.75D)^2] \quad \text{LB/IN}$$

FOR $D/H < 1.333$ AND $Y \geq 0.75D$

$$N_i = 1.39 A_i G (D^2) \quad \text{LB/IN}$$

D = 100.000 FT
 H = 36.000 FT FILL HEIGHT
 D/H = 2.778 > 1.333
 Ai = 0.132
 G = 0.820

IMPULSIVE HOOP FORCES AT ONE FOOT ABOVE THE BOTTOM OF EACH SHELL COURSE

	COURSE NO.	THICKNESS t INCHES	HEIGHT FT	ELEV AT BOT OF COURSE B	IMPULSIVE		
					Y = H - B - 1 FT	FORCE Ni LB/IN	STRESS Ni / t PSI
BOTTOM	1	0.5910	5.500	0.000	35.000	865	1,464
	2	0.4590	8.000	5.500	29.500	838	1,825
	3	0.3440	8.000	13.500	21.500	725	2,109
	4	0.2420	8.000	21.500	13.500	528	2,180
	5	0.2490	7.750	29.500	5.500	244	981

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

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SEISMIC EVALUATION: UN-ANCHORED TANK

E.6 DESIGN

E.6.1.4 DYNAMIC LIQUID HOOP FORCES

CONVECTIVE HOOP MEMBRANE FORCE N_c

$$N_c = 0.98 A_c G(D^2) \cosh [3.68 (H - Y) / D] / \cosh [3.68 H / D] \quad \text{LB/IN}$$

$D = 100.000 \text{ FT}$
 $H = 36.000 \text{ FT FILL HEIGHT}$
 $A_c = 0.032$
 $G = 0.820$

CONVECTIVE HOOP FORCES AT ONE FOOT ABOVE THE BOTTOM OF EACH SHELL COURSE

COURSE NO.	THICKNESS t INCHES	HEIGHT FT	ELEV AT BOT OF COURSE B	CONVECTIVE			
				Y = H - B - 1 FT	FORCE N_c LB/IN	STRESS N_c / t PSI	
BOTTOM	1	0.5910	5.500	0.000	35.000	128	217
	2	0.4590	8.000	5.500	29.500	132	288
	3	0.3440	8.000	13.500	21.500	147	427
	4	0.2420	8.000	21.500	13.500	175	723
	5	0.2490	7.750	29.500	5.500	218	875

PRODUCT HYDROSTATIC DESIGN HOOP FORCE

PRODUCT DESIGN HOOP STRESS S_d

$$S_d = [2.6 \times D (H - 1 + \text{DELTA}/2) \times G] / (t - CA) \quad \text{PSI}$$

S_d IS BASED ON API 650 EQUATION FOR SHELL THICKNESS MODIFIED FOR SETTLEMENT

FILL HEIGHT $H_f = 36.000 \text{ FT}$
 TANK DIAMETER $D = 100.00 \text{ FT}$
 HEIGHT OF LIQUID ABOVE BOTTOM OF SHELL COURSE = $H \text{ FT}$
 DIFFERENTIAL SETTLEMENT $\text{DELTA} = 0.17 \text{ FT}$
 PRODUCT SPECIFIC GRAVITY $G = 0.820 \text{ JP-8}$
 JOINT EFFICIENCY = $E \text{ PER API 650 OR API 653}$
 SHELL COURSE THICKNESS = $t \text{ INCHES}$
 SHELL CORROSION ALLOWANCE $CA_{\text{shell}} = 0.000 \text{ INCHES}$

PRODUCT DESIGN HOOP FORCE $N_h = (S_d)(t) \quad \text{LB/IN}$

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: **API 653 Inspection**
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 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

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SEISMIC EVALUATION: UN-ANCHORED TANK

E.6 DESIGN

E.6.1.4 DYNAMIC LIQUID HOOP FORCES

PRODUCT HYDROSTATIC DESIGN HOOP FORCE

PRODUCT HYDROSTATIC HOOP FORCES AT ONE FOOT ABOVE THE BOTTOM OF EACH SHELL COURSE

	COURSE NO.	t INCHES	CA _{shell} INCHES	h FT	B FT	H=(Hf - B) FT	JOINT EFFICIENCY	Sd PSI	Nh LB/IN
							E		
BOTTOM	1	0.5910	0.0000	5.50	0.00	36.00	0.85	12,657	7,480
	2	0.4590	0.0000	8.00	5.50	30.50	0.85	13,742	6,308
	3	0.3440	0.0000	8.00	13.50	22.50	0.85	13,378	4,602
	4	0.2420	0.0000	8.00	21.50	14.50	0.85	11,968	2,896
	5	0.2490	0.0000	7.75	29.50	06.50	0.85	4,782	1,191

E.6.2.4 ALLOWABLE HOOP STRESS

THE ALLOWABLE HOOP STRESS SHALL BE THE LESSER OF:

1. THE BASIC ALLOWABLE MEMBRANE STRESS FOR THE SHELL PLATE MATERIAL, INCREASED BY 33%
2. 0.9F_y X JOINT EFFICIENCY

	COURSE NO.	MATERIAL ALLOW STRESS Sd PSI	YIELD STRESS Fy PSI	JOINT EFFICIENCY E	4/3(Sd) PSI	0.9F _y (E) PSI	ALLOWABLE HOOP STRESS PSI
BOTTOM	1	23600	30000	0.850	31467	22950	22950
	2	23600	30000	0.850	31467	22950	22950
	3	26000	30000	0.850	34667	22950	22950
	4	26000	30000	0.850	34667	22950	22950
	5	26000	30000	0.850	34667	22950	22950

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

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E.6 DESIGN

E.6.1.4 DYNAMIC LIQUID HOOP FORCES

COMBINED STRESS DUE TO PRODUCT HYDROSTATIC DESIGN HOOP FORCE AND DYNAMIC HOOP FORCES

$$St = \{Nh \pm [(Ni)^2 + (Nc)^2 + (AvNh)^2]^{0.5}\} / t$$

	COURSE NO.	Nh LB/IN	Ni LB/IN	Nc LB/IN	Av	AvNh LB/IN	t INCH	St PSI	ALLOW STRESS PSI
BOTTOM	1	7,480	865	128	0.0519	389	0.5910	14,276	22950 PASS
	2	6,308	838	132	0.0519	328	0.4590	15,722	22950 PASS
	3	4,602	725	147	0.0519	239	0.3440	15,639	22950 PASS
	4	2,896	528	175	0.0519	150	0.2420	14,348	22950 PASS
	5	1,191	244	218	0.0519	62	0.2490	6,120	22950 PASS

E.6.1.5 OVERTURNING MOMENT

RINGWALL MOMENT

$$Mrw = \text{SQRT}\{ [Ai(WiXi + WsXs + WrXr + WpanXpan)]^2 + [Ac(WcXc)]^2 \}$$

$$Mrw = \text{SQRT}\{ [0.132((5917.06)(13.5)+(175.27)(16.39)+(115.56)(37.5)+(0)(36))]^2 + [(0.032)(8014.5)(19.531)]^2 \}$$

$$Mrw = 12539.32 \text{ K-FT}$$

SLAB MOMENT

$$Ms = \text{SQRT}\{ [Ai(WiXis + WsXs + WrXr + WpanXpan)]^2 + [Ac(WcXcs)]^2 \}$$

$$Ms = \text{SQRT}\{ [0.132((5917.06)(39.504)+(175.27)(16.39)+(115.56)(37.5)+(0)(36))]^2 + [(0.032)(8014.5)(17.282)]^2 \}$$

$$Ms = 32113.22 \text{ K-FT}$$

E.6.2.1.1 RESISTANCE TO DESIGN LOADS: SELF-ANCHORED TANK

WEIGHT OF LIQUID RESISTING OVERTURNING

$$Wa = 7.9(t_a) [(Fby)(Hf)(Ge)]^{0.5} \leq 1.28(H)(D)(Ge) \quad \text{LB/FT} \quad \text{EQ E-23b}$$

THICKNESS OF BOTTOM PLATE UNDER SHELL LESS CORROSION ALLOWANCE

$$t_a = t_b - CA_{\text{floor}}$$

TANK HAS AN ANNULAR PLATE, CHECK IF ANNULAR PLATE CAN BE USE TO DETERMINE t_a

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: API 653 Inspection
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 TANK NO: 27

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E.6 DESIGN

E.6.2.1.1 RESISTANCE TO DESIGN LOADS: SELF-ANCHORED TANK

WEIGHT OF LIQUID RESISTING OVERTURNING

ANNULAR PLATE REQUIREMENTS

tf = 0.2280 INCHES FLOOR THICKNESS
 tann = 0.2680 INCHES ANNULAR PLATE THICKNESS

ANNULAR PLATE IS THICKER THAN TANK BOTTOM

WHEN THICKNESS OF ANNULAR PLATE BELOW SHELL tann IS THICKER THAN THE TANK BOTTOM, ANNULAR PLATE WIDTH Ls SHALL BE EQUAL TO OR GREATER THAN L

Ls = 2.000 FT
 L = 3.5% (D) = 3.500 FT

WIDTH OF ANNULAR PLATE DOES NOT MEET CRITERIA, CANNOT USE tann TO DETERMINE ta. USE THICKNESS OF TANK BOTTOM TO DETERMINE ta OR PROVIDE WIDER ANNULAR PLATE

tb = tf = 0.228 INCHES
 ta = 0.228 - 0 = 0.2280 INCHES

USE ta = 0.2280 INCHES

EFFECTIVE SPECIFIC GRAVITY

Ge = G (1-0.4Av)
 = 0.82 [1-(0.4)(0.0519)] = 0.803

Wa = 7.9(0.228) [(30000)(36)(0.803)]^0.5 = 1,677.34 LB/FT GOVERNS

1.28(Hf)(D)(Ge) = 1.28 (36)(100)(0.803) = 3,700.22 LB/FT

Wa = 1,677.34 LB/FT GOVERNS

Wa = 1.677 K/FT

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

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E.6 DESIGN

E.6.2.1.1 RESISTANCE TO DESIGN LOADS: SELF-ANCHORED TANK

ANCHORAGE RATIO

$$J = Mrw / \{D^2 [Wt(1-0.4Av) + Wa]\}$$

RINGWALL MOMENT	Mrw	=	12539.32	K-FT
WEIGHT OF TANK SHELL	Ws	=	175.27	K
WEIGHT OF ROOF ACTING ON SHELL		=	28.93	K
ROOF SNOW LOAD ON SHELL		=	50.87	K
WEIGHT OF ROOF ACTING ON SHELL + 10% SNOW LOAD		=	34.02	K
	Wrs	=	34.02 / πD	K/FT
TANK AND ROOF WEIGHT ACTING AT BASE OF SHELL	wt	=	[Ws/πD]+Wrs	K/FT
		=	[175.27 / π(100)] + 34.02 / π(100)	
	wt	=	0.6662	K/FT

$$J = 12539.32 / \{(100)^2 [(0.6662)(1-0.4(0.0519)) + 1.677]\}$$

$$= 0.5382$$

J < 0.785, NO CALCULATED UPLIFT, TANK IS SELF-ANCHORED

E.6.2.2.1 SHELL COMPRESSION IN SELF-ANCHORED TANKS (BOTTOM SHELL COURSE)

FOR J < 0.785

$$\sigma_c = [wt(1 + 0.4Av) + 1.273Mrw / D^2] (1/12ts)$$

FOR J > 0.785

$$\sigma_c = \{ [wt(1 + 0.4Av) + Wa] / [0.607 - 0.18667(J)^{2/3}] - Wa \} (1/12ts)$$

SINCE J = 0.5382 < 0.785

$$\sigma_c = [0.6662(1 + 0.4(0.0519)) + 1.273(12539.32 / (100)^2)] \{1/ [(12)(0.591)]\}$$

$$\sigma_c = 0.321 \text{ KSI}$$

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV #####

PROJECT: **API 653 Inspection**
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SEISMIC EVALUATION: UN-ANCHORED TANK

E.6 DESIGN

E.6.2.2.3 ALLOWABLE SHELL COMPRESSION IN BOTTOM COURSE

WHEN $(G Hf D^2) / t^2 > 10^6$

$$\text{EQ. 1} \quad F_a = \frac{10^6 t}{D} \quad \text{PSI} \quad \leq 0.5(F_{ty})$$

WHEN $(G Hf D^2) / t^2 < 10^6$

$$\text{EQ. 2} \quad F_a = \frac{10^6 t}{2.5 D} + (600) \text{SQRT}[(G)(Hf)] \quad \text{PSI} \quad \leq 0.5(F_{ty})$$

$$(G)(Hf)(D^2)/t^2 = (0.82)(36)(100)^2 / (0.591)^2 = 845,165 < 10^6 \quad \text{USE EQ. 2}$$

$$F_a = \frac{\{[(10^6)(0.591)] / (2.5)(100)\} + (600 \times \text{SQRT}(0.82 \times 36))}{1000} = 5.62 \text{ KSI}$$

$$0.5 \times F_{ty} = 0.5 \times 30000 / 1000 = 15.00 \text{ KSI}$$

$$F_a = 5.62 \text{ KSI} \quad \text{GOVERNS}$$

$$\sigma_c = 0.321 \text{ KSI} < F_a = 5.62 \text{ KSI}$$

SHELL COMPRESSION CRITERIA SATISFIED, TANK IS SELF-ANCHORED

SLIDING RESISTANCE

E.6.1 SEISMIC BASE SHEAR

$$V = \text{SQRT}[(V_i)^2 + (V_c)^2]$$

$$V_i = A_i(W_s + W_r + W_f + W_{pan} + W_i)$$

$$V_i = 0.132 (175.27 + 73.12 + 0 + 5917.06) = 813.84 \text{ K}$$

$$V_c = A_c W_c$$

$$V_c = (0.032)(8014.5) = 256.46 \text{ K}$$

$$V = \text{SQRT}[(813.84)^2 + (256.46^2)] = 853.29 \text{ K}$$

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
REL 9/15/2007 EXP 9/15/2012 #####
REV #####

PROJECT: API 653 Inspection
LOCATION: Thule AB, Greenland
EEI PROJECT NO: 08-4889

TANK NO: 27

PREPARED BY: DAS
DATE: 7/9/2008

CHECKED BY: _____
DATE: _____

SEISMIC EVALUATION: UN-ANCHORED TANK

SLIDING RESISTANCE

E.7.6 SLIDING RESISTANCE

$$V_s = \mu(W_s + W_r + W_f + W_p)(1.0 - 0.4A_v)$$

$$W_p = (\pi)(D^2)/4(62.4)(G)(H_f) \text{ TOTAL WEIGHT OF TANK CONTENTS}$$

$$W_p = [(\pi)(100)^2 / 4] (62.4)(0.82)(36) / 100 = 14,467.41 \text{ K}$$

$$V_s = (0.4)(175.27 + 98.28 + 73.12 + 14467) = 5,802.52 \text{ K}$$

$$V_s = 5802.52 \text{ K} > V = 853.29 \text{ K}$$

SLIDING RESISTANCE CRITERIA SATISFIED

SUMMARY

1. TANK HAS AN ANNULAR PLATE BUT WIDTH OF ANNULAR PLATE DOES NOT MEET CRITERIA; THUS THICKNESS OF TANK FLOOR IS USED TO DETERMINE WEIGHT OF LIQUID RESISTING OVERTURNING.
2. ANCHORAGE RATIO $J = 0.5382$
3. $J < 0.785$, NO CALCULATED UPLIFT, TANK IS SELF-ANCHORED
4. SHELL COMPRESSIVE STRESS IN BOTTOM COURSE MEETS CRITERIA, I.E. $\sigma_c = 0.321 \text{ KSI} < F_a = 5.62 \text{ KSI}$.
5. $V = 853.29 \text{ K} < V_s = 5802.52 \text{ K}$, SLIDING RESISTANCE CRITERIA SATISFIED

CONCLUSIONS

TANK IS SELF-ANCHORED.

COMMENT:

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV 12/8/2007

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**

CHECKED BY:
 DATE:

LONGITUDINAL SHELL STRESS: GRAVITY LOADS

ALLOWABLE STRESS

GENERAL CRITERIA

WHEN $(G H_f D^2) / t^2 > 10^6$

EQ. 1 $F_a = \frac{10^6 t}{D}$ PSI BUT NOT GREATER THAN 0.5(Fty)

WHEN $(G H_f D^2) / t^2 < 10^6$

EQ. 2 $F_a = \frac{10^6 t}{2.5 D} + (600) \text{ SQR}(G H_f)$ PSI BUT NOT GREATER THAN 0.5(Fty)

ALLOWABLE STRESS IN SHELL COURSE: EMPTY TANK

FOR EMPTY TANK, $H_f = 0$

$G H_f D^2 / t^2 = 0$ EQ. 2 GOVERNS

SHELL COMPRESSIVE STRESS: DEAD LOAD

COMPRESSIVE STRESS $S = \text{UNIT WEIGHT} / 12t$

	COURSE NO.	THICKNESS INCH	WEIGHT K	CUMULATIVE WEIGHT K	UNIT WEIGHT K/FT	STRESS KSI	ALLOW STRESS KSI	
BOTOTM	1	0.591	41.70	204.20	0.650	0.092	2.364	PASS
	2	0.459	47.11	162.50	0.517	0.094	1.836	PASS
	3	0.344	35.30	115.40	0.367	0.089	1.376	PASS
	4	0.242	24.84	80.09	0.255	0.088	0.968	PASS
	5	0.249	24.76	55.26	0.176	0.059	0.996	PASS

RIM ANGLE 1.57
 ROOF DEAD LOAD ON SHELL 28.93

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV 12/8/2007

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**

 CHECKED BY:
 DATE:

LONGITUDINAL SHELL STRESS: GRAVITY LOADS

SHELL COMPRESSIVE STRESS: DEAD LOAD + ROOF LIVE LOAD

COMPRESSIVE STRESS S = UNIT WEIGHT/ 12t

	COURSE NO.	THICKNESS	WEIGHT	CUMULATIVE	UNIT	STRESS	ALLOW
		INCH	K	WEIGHT K	WEIGHT K/FT	KSI	STRESS KSI
BOTTOM	1	0.591	41.70	233.07	0.742	0.105	2.364 PASS
	2	0.459	47.11	191.37	0.609	0.111	1.836 PASS
	3	0.344	35.30	144.27	0.459	0.111	1.376 PASS
	4	0.242	24.84	108.97	0.347	0.119	0.968 PASS
	5	0.249	24.76	84.13	0.268	0.090	0.996 PASS

RIM ANGLE 1.57
 ROOF LIVE LOAD ON SHELL 57.81

SHELL COMPRESSIVE STRESS: DEAD LOAD + ROOF SNOW LOAD

COMPRESSIVE STRESS S = UNIT WEIGHT/ 12t

	COURSE NO.	THICKNESS	WEIGHT	CUMULATIVE	UNIT	STRESS	ALLOW
		INCH	K	WEIGHT K	WEIGHT K/FT	KSI	STRESS KSI
BOTTOM	1	0.591	41.70	226.14	0.720	0.101	2.364 PASS
	2	0.459	47.11	184.44	0.587	0.107	1.836 PASS
	3	0.344	35.30	137.33	0.437	0.106	1.376 PASS
	4	0.242	24.84	102.03	0.325	0.112	0.968 PASS
	5	0.249	24.76	77.19	0.246	0.082	0.996 PASS

RIM ANGLE 1.57
 ROOF LIVE SNOW ON SHELL 50.87

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**
 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**
 CHECKED BY:
 DATE:

SHELL HYDROSTATIC HOOP STRESS (API 650 AND 653 MODIFIED FOR SETTLEMENT)

HOOP STRESS AT BOTTOM OF EACH SHELL COURSE

BASED ON PRODUCT SERVICES $S_d = [2.6 \times D (H - 1 + \text{DELTA}/2) \times G] / (t - CA)$
 BASED ON HYDROTEST $S_t = [2.6 \times D (H - 1 + \text{DELTA}/2) \times G] / t$

TANK DIAMETER	D =	100.00 FT
HEIGHT OF LIQUID ABOVE BOT. OF COURSE	=	H FT
DIFFERENTIAL SETTLEMENT	DELTA =	0.17 FT
SPECIFIC GRAVITY	G =	0.820 JP-8
	G =	1.00 WATER HYDROTEST
COURSE THICKNESS	=	t INCH
SHELL CORROSION ALLOWANCE	=	CA _{shell} INCHES
SHELL HEIGHT	H _s =	37.50 FT
FILL HEIGHT	H _f =	36.00 FT
COURSE HEIGHT	=	h FT
HEIGHT TO BOTTOM OF COURSE	=	B FT
ALLOWABLE STRESS	=	S PSI
JOINT EFFICIENCY		

AT JOINTS: E = PER API 653
 SHELL PLATE AWAY FROM VERTICAL WELDS: E = 1.00 AWAY FROM WELDS BY GREATER OF 1 INCH OR 2t
 SHELL PLATE AWAY FROM RIVETS: E = 1.00 AWAY FROM RIVETS BY 6 INCHES OR MORE

HOOP STRESS: PRODUCT SERVICE JP-8

COURSE NO.	t INCHES	CA _{shell} INCHES	h FT	B FT	H=(H _f - B) FT	S _d	JOINT	ALLOWABLE STRESS, (S)(E)			
						STRESS PSI	EFFICIENCY E	AT JOINT PSI		SHELL PLATE PSI	
1	0.591	0	5.50	0.00	36.00	12,657	0.85	20,060	PASS	23,600	PASS
2	0.459	0	8.00	5.50	30.50	13,742	0.85	20,060	PASS	23,600	PASS
3	0.344	0	8.00	13.50	22.50	13,378	0.85	22,100	PASS	26,000	PASS
4	0.242	0	8.00	21.50	14.50	11,968	0.85	22,100	PASS	26,000	PASS
5	0.249	0	7.75	29.50	06.50	4,782	0.85	22,100	PASS	26,000	PASS

HOOP STRESS: HYDROSTATIC TEST

COURSE NO.	t INCHES	CA _{shell} INCHES	h FT	B FT	H=(H _f - B) FT	S _t	JOINT	ALLOWABLE STRESS, (S)(E)			
						STRESS PSI	EFFICIENCY E	AT JOINT PSI		SHELL PLATE PSI	
1	0.591	0	5.50	0.00	36.00	15,435	0.85	22,100	PASS	26,000	PASS
2	0.459	0	8.00	5.50	30.50	16,758	0.85	22,100	PASS	26,000	PASS
3	0.344	0	8.00	13.50	22.50	16,314	0.85	22,950	PASS	27,000	PASS
4	0.242	0	8.00	21.50	14.50	14,595	0.85	22,950	PASS	27,000	PASS
5	0.249	0	7.75	29.50	06.50	5,832	0.85	22,950	PASS	27,000	PASS

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 1513.38
 REV

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**
 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**
 CHECKED BY:
 DATE:

SHELL MINIMUM THICKNESS (API 650 AND API 653 MODIFIED FOR SETTLEMENT)

SHELL MINIMUM THICKNESS PRODUCT $t_{d \min} = [2.6 D (H - 1 + \Delta/2) G] / SE + CA$ BUT NOT LESS THAN 0.1 INCH
 HYDROTEST $t_{t \min} = [2.6 D (H - 1 + \Delta/2) G] / SE$ BUT NOT LESS THAN 0.1 INCH

PARAMETERS

TANK DIAMETER D = 100.00 FT
 HEIGHT OF LIQUID ABOVE BOTTOM OF COURSE H = Hf - B FT
 FILL HEIGHT Hf = 36.00 FT
 HEIGHT TO BOTTOM OF COURSE = B FT
 DIFFERENTIAL SETTLEMENT DELTA = 0.17 FT
 SPECIFIC GRAVITY G = 0.820 JP-8
 G = 1.00 WATER HYDROTEST
 COURSE THICKNESS = t INCH
 COURSE HEIGHT = h FT
 ALLOWABLE STRESS = S PSI
 SHELL CORROSION ALLOWANCE CAshell = 0 INCHES
 JOINT EFFICIENCY

AT JOINTS: E = PER API 653

SHELL PLATE AWAY FROM VERTICAL WELDS: E = 1.00 AWAY FROM WELDS BY GREATER OF 1 INCH OR 2t
 SHELL PLATE AWAY FROM RIVETS: E = 1.00 AWAY FROM RIVETS BY 6 INCHES OR MORE

SHELL MINIMUM THICKNESS: PRODUCT SERVICE JP-8

COURSE NO.	h FT	B FT	H=(Hf - B) FT	SE PSI	t _{min} at JOINTS			t _{min} IN PLATE AWAY FROM JOINTS			
					t _{d min} INCH	t _{t actual} INCH	PASS	SE PSI	t _{d min} INCH	t _{t actual} INCH	PASS
1	5.50	0.00	36.00	20,060	0.373	0.591	PASS	23,600	0.317	0.591	PASS
2	8.00	5.50	30.50	20,060	0.314	0.459	PASS	23,600	0.267	0.459	PASS
3	8.00	13.50	22.50	22,100	0.208	0.344	PASS	26,000	0.177	0.344	PASS
4	8.00	21.50	14.50	22,100	0.131	0.242	PASS	26,000	0.111	0.242	PASS
5	7.75	29.50	06.50	22,100	0.100	0.249	PASS	26,000	0.100	0.249	PASS

SHELL MINIMUM THICKNESS: HYDROSTATIC TEST

COURSE NO.	h FT	B FT	H=(Hf - B) FT	SE PSI	t _{min} at JOINTS			t _{min} IN PLATE AWAY FROM JOINTS			
					t _{d min} INCH	t _{t actual} INCH	PASS	SE PSI	t _{d min} INCH	t _{t actual} INCH	PASS
1	5.50	0.00	36.00	22,100	0.413	0.591	PASS	26,000	0.351	0.591	PASS
2	8.00	5.50	30.50	22,100	0.348	0.459	PASS	26,000	0.296	0.459	PASS
3	8.00	13.50	22.50	22,950	0.245	0.344	PASS	27,000	0.208	0.344	PASS
4	8.00	21.50	14.50	22,950	0.154	0.242	PASS	27,000	0.131	0.242	PASS
5	7.75	29.50	06.50	22,950	0.100	0.249	PASS	27,000	0.100	0.249	PASS

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 1513.38
 REV

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**

 CHECKED BY:
 DATE:

SHELL MINIMUM THICKNESS (API 650 AND API 653 MODIFIED FOR SETTLEMENT)

SHELL MINIMUM THICKNESS: MAXIMUM ALLOWABLE PIT DEPTH

API 653 CRITERIA: SECTION 2.3.2.2

FOR WIDELY SCATTERED PITS: THE SUM OF THE LENGTH OF PITS ALONG A VERTICAL LINE SHALL NOT EXCEED 2 INCHES IN AN 8 INCH LINE

MAXIMUM PIT DEPTH	$dpit = t_{actual} - CA - 0.5 \times t_{min}$	
ACTUAL SHELL THICKNESS AWAY FROM PIT	$= t_{actual}$	INCH
MINIMUM PERMISSIBLE SHELL THICKNESS	$= t_{min}$	INCH
CORROSION ALLOWANCE	$CA =$	0 INCH
RECOMMENDED CORROSION ALLOWANCE =	0.125 INCH	BUT NOT LESS THAN 0.0625 INCH FOR CONTINUED SERVICE UNTIL NEXT INSPECTION

ANALYSIS RESULTS: PRODUCT SERVICE JP-8

COURSE NO.	t_{actual} INCH	MAX PIT AT JOINTS		MAX PIT IN SHELL	
		t_{min} INCH	dpit INCH	t_{min} INCH	dpit INCH
1	0.591	0.373	0.405	0.317	0.433
2	0.459	0.314	0.302	0.267	0.325
3	0.344	0.208	0.240	0.177	0.256
4	0.242	0.131	0.176	0.111	0.186
5	0.249	0.100	0.199	0.100	0.199

ANALYSIS RESULTS: HYDROSTATIC TEST

COURSE NO.	t_{actual} INCH	MAX PIT AT JOINTS		MAX PIT IN SHELL	
		t_{min} INCH	dpit INCH	t_{min} INCH	dpit INCH
1	0.591	0.413	0.385	0.351	0.416
2	0.459	0.348	0.285	0.296	0.311
3	0.344	0.245	0.222	0.208	0.240
4	0.242	0.154	0.165	0.131	0.177
5	0.249	0.100	0.199	0.100	0.199

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
REL 9/15/2007 EXP 9/15/2012 1513.38
REV

PROJECT: **API 653 Inspection**
LOCATION: **Thule AB, Greenland**
EEI PROJECT NO: **08-4889**

TANK NO: **27**

PREPARED BY: **DAS**
DATE: **7/9/2008**

CHECKED BY:
DATE:

SHELL MINIMUM THICKNESS (API 650 AND API 653 MODIFIED FOR SETTLEMENT)

SHELL MINIMUM THICKNESS: LOCALIZED AREAS OF CORROSION

CRITERIA FOR CONTINUED OPERATION

$$t_1 \geq t_{\min}$$

$$t_2 \geq 0.6 \times t_{\min}$$

t1 = lowest average thickness

t2 = least thickness excluding pits

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**

 CHECKED BY:
 DATE:

HYDROSTATIC TEST FILL HEIGHT (API 650 AND API 653 MODIFIED FOR SETTLEMENT)

HYDROSTATIC TEST FILL HEIGHT $H_f = [(t \times (SE) / (2.6 \times D \times G)) + 1 + B - (\text{DELTA} / 2)]$

COURSE THICKNESS = t INCH
 ALLOWABLE STRESS = S PSI

JOINT EFFICIENCY

AT SHELL VERTICAL JOINTS
 AWAY FROM SHELL VERTICAL JOINTS

AT JOINTS: E = PER API 653

SHELL PLATE AWAY FROM VERTICAL WELDS: E = 1.00 AWAY FROM WELDS BY GREATER OF 1 INCH OR 2t
 SHELL PLATE AWAY FROM RIVETS: E = 1.00 AWAY FROM RIVETS BY 6 INCHES OR MORE

TANK DIAMETER D = 100.00 FT
 SPECIFIC GRAVITY (WATER) G = 1.00
 ELEV. TO BOTTOM OF COURSE = B FT
 DIFFERENTIAL SETTLEMENT DELTA = 0.17 FT

HYDROTEST FILL HEIGHT BASED ON ACTUAL NOMINAL THICKNESS

DEPTH OF CORROSION IN SHELL
 AT SHELL VERTICAL JOINTS = Xw INCH

AWAY FROM SHELL JOINTS = Xs INCH

BASED ON SHELL JOINTS

COURSE NO.	t _{actual} INCH	h FT	B FT	Xw INCH	t _{actual} - Xw INCH	SE PSI	Hf FT
1	0.591	5.50	0.00	0.000	0.591	22,100	51.15
2	0.459	8.00	5.50	0.000	0.459	22,100	45.43
3	0.344	8.00	13.50	0.000	0.344	22,950	44.78
4	0.242	8.00	21.50	0.000	0.242	22,950	43.78 GOVERNS
5	0.249	7.75	29.50	0.000	0.249	22,950	52.39

BASED ON SHELL PLATE

COURSE NO.	t _{actual} INCH	h FT	B FT	IN SHELL		SE PSI	Hf FT
				Xs INCH	t _{actual} - Xs INCH		
1	0.591	5.50	0.00	0.000	0.591	26,000	60.02
2	0.459	8.00	5.50	0.000	0.459	26,000	52.32
3	0.344	8.00	13.50	0.000	0.344	27,000	50.14
4	0.242	8.00	21.50	0.000	0.242	27,000	47.55
5	0.249	7.75	29.50	0.000	0.249	27,000	56.27

TANK EVALUATION CALCULATIONS

VERSION 7.00 TANK EVALUATION
 REL 9/15/2007 EXP 9/15/2012 #####
 REV

PROJECT: **API 653 Inspection**
 LOCATION: **Thule AB, Greenland**
 EEI PROJECT NO: **08-4889**

 TANK NO: **27**

PREPARED BY: **DAS**
 DATE: **7/9/2008**

 CHECKED BY:
 DATE:

HYDROSTATIC TEST FILL HEIGHT (API 650 AND API 653 MODIFIED FOR SETTLEMENT)

HYDROTEST FILL HEIGHT BASED ON NO CORROSION

DEPTH OF CORROSION IN SHELL
 AT SHELL VERTICAL JOINTS $X_w = 0.000$ INCH

 AWAY FROM SHELL JOINTS $X_s = 0.000$ INCH

BASED ON SHELL JOINTS

COURSE NO.	t_{actual} INCH	h FT	B FT	X_w INCH	$t_{actual} - X_w$ INCH	SE PSI	Hf FT
1	0.591	5.50	0.00	0.000	0.591	22,100	51.15
2	0.459	8.00	5.50	0.000	0.459	22,100	45.43
3	0.344	8.00	13.50	0.000	0.344	22,950	44.78
4	0.242	8.00	21.50	0.000	0.242	22,950	43.78 GOVERNS
5	0.249	7.75	29.50	0.000	0.249	22,950	52.39

BASED ON SHELL PLATE

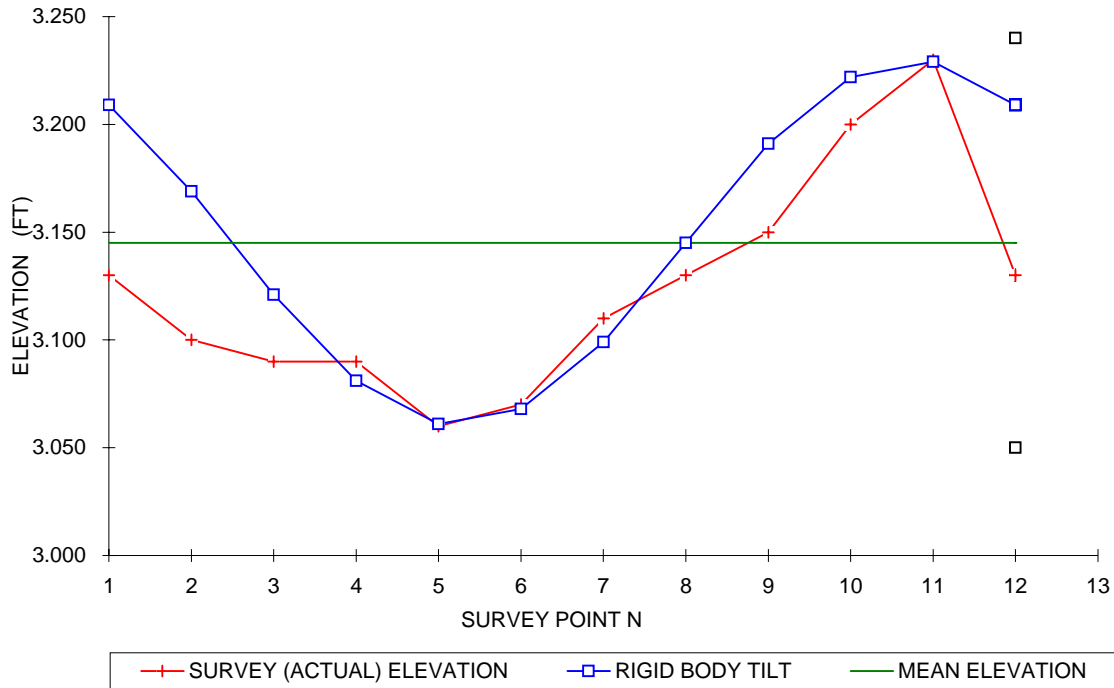
COURSE NO.	t_{actual} INCH	h FT	B FT	X_s INCH	$t_{actual} - X_s$ INCH	SE PSI	Hf FT
1	0.591	5.50	0.00	0.000	0.591	26,000	60.02
2	0.459	8.00	5.50	0.000	0.459	26,000	52.32
3	0.344	8.00	13.50	0.000	0.344	27,000	50.14
4	0.242	8.00	21.50	0.000	0.242	27,000	47.55
5	0.249	7.75	29.50	0.000	0.249	27,000	56.27

API 653 TANK SETTLEMENT EVALUATION

PROJECT: API 653 INSPECTION
EI PROJECT NO. : 08-4889
LOCATION: Thule AB, Greenland
TANK NO.: 27
SURVEY DATE: 6/8/2008

INPUT BY: DAS
DATE: 6/27/2008
 REL: 1/18/2000
 TANK SETTLEMENT

TANK SHELL SETTLEMENT

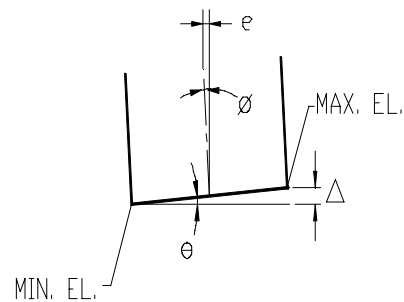


- NOTES:
1. THE HIGHEST SURVEY POINT NUMBER N SHOWN ON THE ABOVE GRAPH CORRESPONDS TO POINT NUMBER 1 ON THE TANK
 2. 8 (Input starting point no. of rigid body tilt curve)

RIGID BODY TILT

MAXIMUM DIFFERENTIAL SETTLEMENT BETWEEN MAX. ELEV. AND MIN. ELEVATION:

MAX. ELEVATION =	3.23		
MIN. ELEVATION =	3.06		
DELTA =	0.17 FT	=	2.04 IN.
ANGLE OF SLOPE			
THETA = SIN ⁻¹ (DELTA / D) =	SIN ⁻¹ (0.17/10)	=	0.10 deg.
ANGLE OF TILT			
PHI = THETA		=	0.10 deg.
AMOUNT OF TILT			
e = 37.5 SIN(PHI) =	0.06 FT	=	0.77 IN



API 653 THIRD EDITION, DECEMBER 2001, SECTION B.3.4. EDGE SETTLEMENT EVALUATION

TANK NO. 27
LOCATION Thule AB, GreenlandINPUT BY: DAS
DATE: 6/27/2008SURVEY BY: KBW
DATE: 6/6/2008

Floor Edge Settlement Evaluation							
Profile Location	Calculated Edge Settlement			Allowable Edge Settlement or Maximum Bulge B _{allowable} Inches	Pass/ Fail	% Exceeding Criteria	Floor Slope
	B Inches	R Feet					
L-1	0.96	4.00	BULGE	1.48	PASS		-4.20%
L-2	-0.28	0.50	SETTLEMENT	2.00	PASS		-4.47%
L-3	-0.03	4.00	0	1.48	PASS		-4.44%
L-4	0.91	4.00	BULGE	1.48	PASS		-4.29%
L-5	0.33	4.00	BULGE	1.48	PASS		-4.44%
L-6	0.61	5.00	BULGE	1.85	PASS		-4.38%
L-7	0.93	5.00	BULGE	1.85	PASS		-4.24%
L-8	0.16	3.00	BULGE	1.11	PASS		-4.33%
L-9	0.99	5.00	BULGE	1.85	PASS		-4.16%
L-10	0.39	5.00	BULGE	1.85	PASS		-4.16%
L-11	1.23	4.00	BULGE	1.48	PASS		-3.96%

NOTES

Average Slope -4.35%

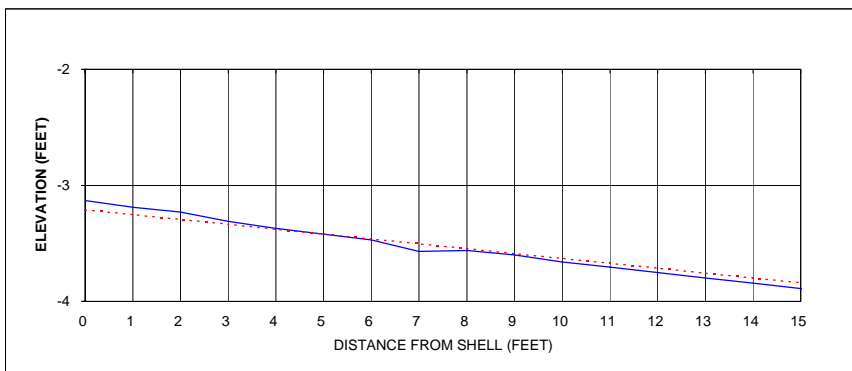
1. L-X Designates location of floor profile survey from shell to center of tank
2. B = calculated edge settlement or height of bulge at Shell
3. R = Radius (I.e. Distance from Shell) which Edge Settlement Occurs
4. Allowable Settlement or Maximum Bulge Height is based on B, B_e, B_{ew}, or B_{alpha} as indicated in the floor profile charts
5. Floor slope is calculated based on the slope of the floor between X = 5 ft from the shell and center of tank

API 653 THIRD EDITION, DECEMBER 2001, SECTION B.3.4. EDGE SETTLEMENT EVALUATION

TANK NO. 27
 LOCATION Thule AB, Greenland

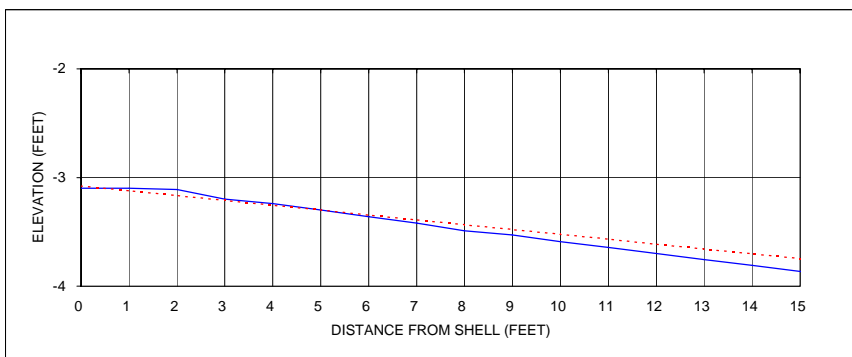
INPUT BY: DAS
 DATE: 6/27/2008

SURVEY BY: KBW
 DATE: 6/6/2008



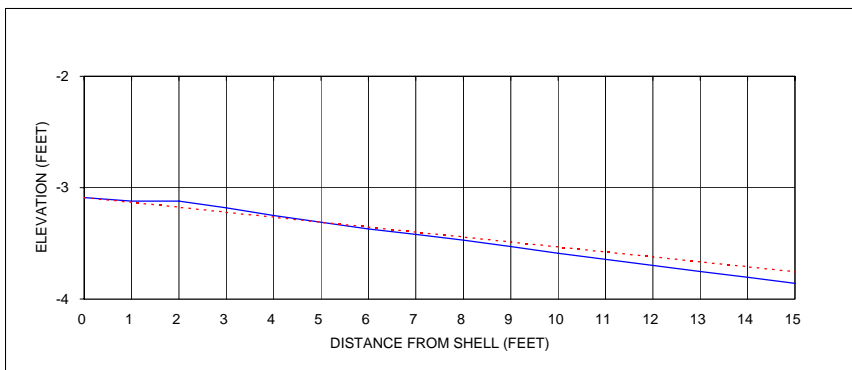
L-1 Criteria= **Bew**
 'Alpha'= DEG.
 'B'= 0.96 INCHES
 'R'= 4.000 FEET
 BULGE
 'B' ALL= 1.48 INCHES
 PASS
 CENTER ELEV= -5.31
 FLOOR SLOPE = -4.20%

Note:
 If Alpha = Bank, Bew is used



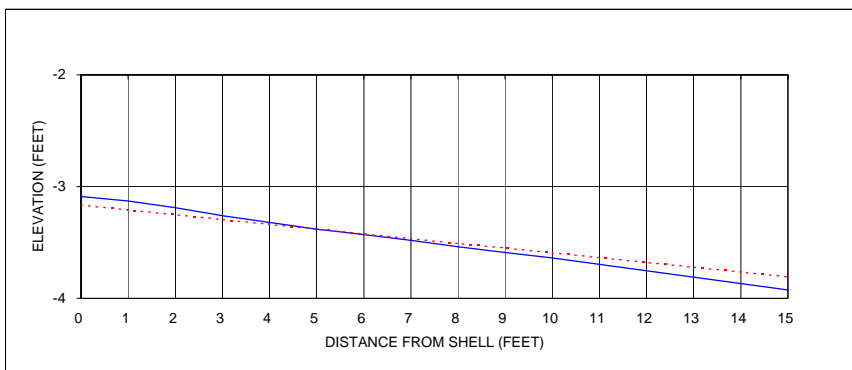
L-2 Criteria= **Bew**
 'Alpha'= DEG.
 'B'= -0.28 INCHES
 'R'= 0.500 FEET
 SETTLEMENT
 'B' ALL= 2.00 INCHES
 PASS
 CENTER ELEV= -5.31
 FLOOR SLOPE = -4.47%

Note:
 If Alpha = Bank, Bew is used



L-3 Criteria= **Bew**
 'Alpha'= DEG.
 'B'= -0.03 INCHES
 'R'= 4.000 FEET
 0
 'B' ALL= 1.48 INCHES
 PASS
 CENTER ELEV= -5.31
 FLOOR SLOPE = -4.44%

Note:
 If Alpha = Bank, Bew is used



L-4 Criteria= **Bew**
 'Alpha'= DEG.
 'B'= 0.91 INCHES
 'R'= 4.000 FEET
 BULGE
 'B' ALL= 1.48 INCHES
 PASS
 CENTER ELEV= -5.31
 FLOOR SLOPE = -4.29%

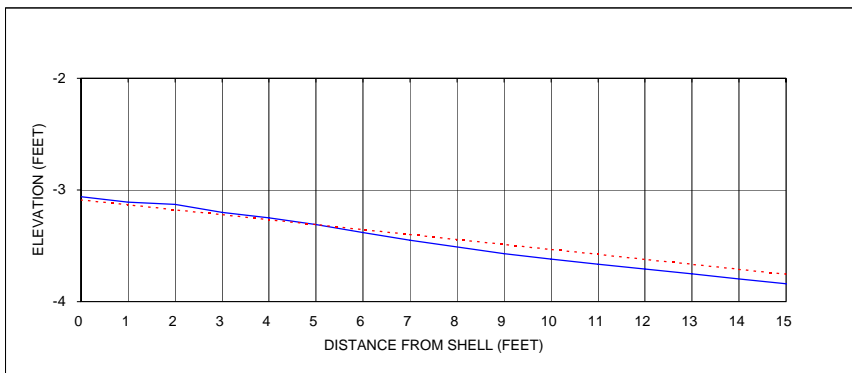
Note:
 If Alpha = Bank, Bew is used

API 653 THIRD EDITION, DECEMBER 2001, SECTION B.3.4. EDGE SETTLEMENT EVALUATION

TANK NO. 27
 LOCATION Thule AB, Greenland

INPUT BY: DAS
 DATE: 6/27/2008

SURVEY BY: KBW
 DATE: 6/6/2008



L-5 Criteria= Bew

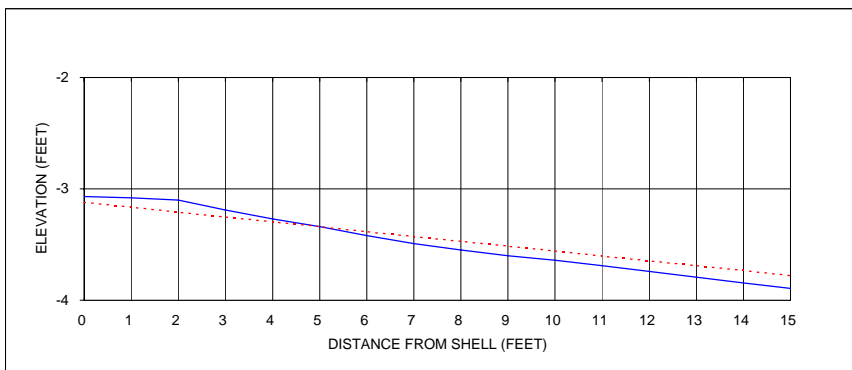
'Alpha'= DEG.
 'B'= 0.33 INCHES
 'R'= 4.000 FEET
 BULGE

'B' ALL= 1.48 INCHES

PASS

CENTER ELEV= -5.31
 FLOOR SLOPE = -4.44%

Note:
 If Alpha = Bank, Bew is used



L-6 Criteria= Bew

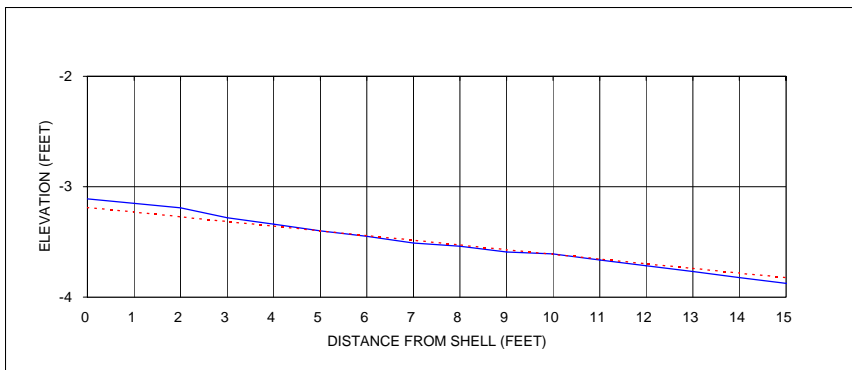
'Alpha'= DEG.
 'B'= 0.61 INCHES
 'R'= 5.000 FEET
 BULGE

'B' ALL= 1.85 INCHES

PASS

CENTER ELEV= -5.31
 FLOOR SLOPE = -4.38%

Note:
 If Alpha = Bank, Bew is used



L-7 Criteria= Bew

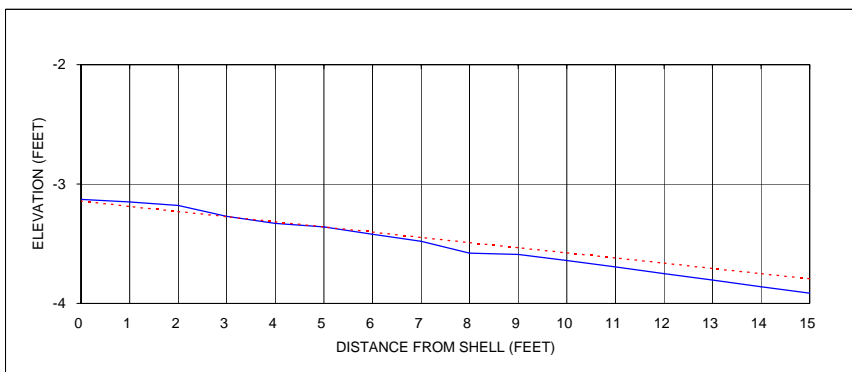
'Alpha'= DEG.
 'B'= 0.93 INCHES
 'R'= 5.000 FEET
 BULGE

'B' ALL= 1.85 INCHES

PASS

CENTER ELEV= -5.31
 FLOOR SLOPE = -4.24%

Note:
 If Alpha = Bank, Bew is used



L-8 Criteria= Bew

'Alpha'= DEG.
 'B'= 0.16 INCHES
 'R'= 3.000 FEET
 BULGE

'B' ALL= 1.11 INCHES

PASS

CENTER ELEV= -5.31
 FLOOR SLOPE = -4.33%

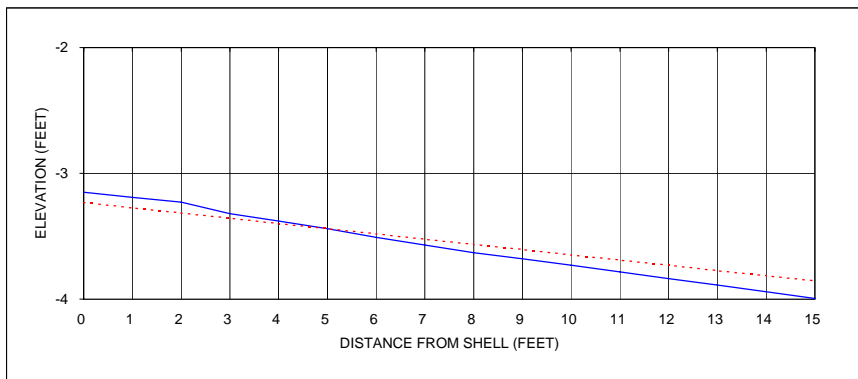
Note:
 If Alpha = Bank, Bew is used

API 653 THIRD EDITION, DECEMBER 2001, SECTION B.3.4. EDGE SETTLEMENT EVALUATION

TANK NO. 27
 LOCATION Thule AB, Greenland

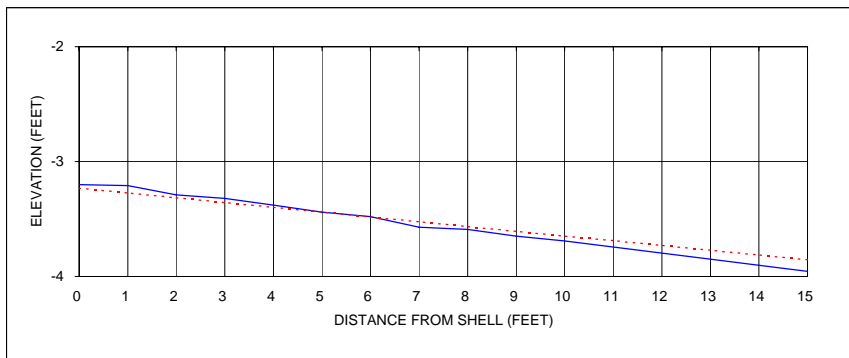
INPUT BY: DAS
 DATE: 6/27/2008

SURVEY BY: KBW
 DATE: 6/6/2008



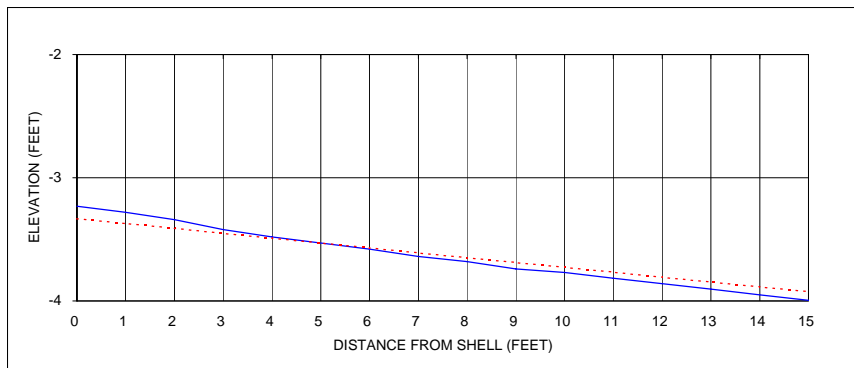
L-9 Criteria= **Bew**
 'Alpha'= 0 DEG.
 'B'= 0.99 INCHES
 'R'= 5.000 FEET
 BULGE
 'B' ALL= 1.85 INCHES
 PASS
 CENTER ELEV= -5.31
 FLOOR SLOPE = -4.16%

Note:
 If Alpha = Bank, Bew is used



L-10 Criteria= **Balpha**
 'Alpha'= 0 DEG.
 'B'= 0.99 INCHES
 'R'= 5.000 FEET
 BULGE
 'B' ALL= 1.85 INCHES
 PASS
 CENTER ELEV= -5.31
 FLOOR SLOPE = -4.16%

Note:
 If Alpha = Bank, Bew is used



L-11 Criteria= **Bew**
 'Alpha'= 0 DEG.
 'B'= 1.23 INCHES
 'R'= 4.000 FEET
 BULGE
 'B' ALL= 1.48 INCHES
 PASS
 CENTER ELEV= -5.31
 FLOOR SLOPE = -3.96%

Note:
 If Alpha = Bank, Bew is used

CORROSION CALCULATIONS

Updated May 2, 2006

Project No 08-4889 Tank No 27 Location Thule AB, Greenland

TANK SHELL

Note: This spreadsheet calculates corrosion rates and not the minimum thickness required to remain in service.

Year Constructed 1951 Year of Inspection 2008 Age of Shell 57 years

Assumed Original Nominal Metal Thickness	Mill Tolerance	Mill Tolerance Original Shell Thickness Range
Course 1 0.625 inches	0.030 inches	0.615 to 0.655 inches
Course 2 0.500 inches	0.030 inches	0.490 to 0.530 inches
Course 3 0.344 inches	0.030 inches	0.334 to 0.374 inches
Course 4 0.250 inches	0.030 inches	0.240 to 0.280 inches
Course 5 0.250 inches	0.030 inches	0.240 to 0.280 inches

Measured Thickness	Mill Tolerance Check
Course 1 0.591 inches	The Thickness of Course 1 is Less than Mill Tolerance
Course 2 0.459 inches	The Thickness of Course 2 is Less than Mill Tolerance
Course 3 0.344 inches	The Thickness of Course 3 is Within Mill Tolerance
Course 4 0.242 inches	The Thickness of Course 4 is Within Mill Tolerance
Course 5 0.249 inches	The Thickness of Course 5 is Within Mill Tolerance

Corrosion Rate

Course 1	0.00060 inches/year
Course 2	0.00072 inches/year
Course 3	N/A Corrosion Rate is Negligible
Course 4	N/A Corrosion Rate is Negligible
Course 5	N/A Corrosion Rate is Negligible

The Straight Line Corrosion Rate for the Shell is: 0.00072 inches/year

Minimum Shell Thickness from Tank Evaluation Spreadsheet	0.373 inches
Difference Between Measured Thickness and Minimum	0.218 inches
Service Period Based on Current Corrosion Rate	303.1 years

TANK ROOF

Year Constructed 1951 Year of Inspection 2008 Age of Roof 57 years
Assumed Original Nominal Metal Thickness 0.188 inches Mill Tolerance 0.030 inches
Mill Tolerance Original Roof Thickness Range: 0.178 inches to 0.218 inches.
Avg Remaining Roof Thickness 0.184 inches The Remaining Thickness is Within Mill Tolerance

The Corrosion Rate for the Roof is Negligible

APPENDIX G

Field Trip Report

**FIELD INSPECTION REPORT – 6/13/08
TANK No. 27
THULE AIR BASE, GREENLAND**

Repair decisions should not be finalized until the complete API 653 Inspection Report with engineering evaluations has been issued. Additions and changes may be made upon review of field data and additional engineering suitability for service assessments. Client will be notified via email if assessment identifies substantive revisions to this Field Inspection Report.

Enterprise Engineering Inc. has been retained to perform an out-of-service internal and external inspection of Tank 27 at Thule Air Base, Greenland. The inspection was performed on June 8th, 2008 in accordance with applicable portions of API Standard 653, Third Edition, and UFC 3-460-1 (MIL HDBK - 1022A). Inspection findings and recommended repairs are enclosed.

GENERAL

Tank 27 is a field erected above ground storage tank. The tank was fabricated and erected in 1951. The tank is 100 feet in diameter, 40 feet high and is of welded construction with butt-welded shell plates and lap-welded floor and roof plates. A new floor was installed in 2000. The nominal shell capacity is 49,000 BBLs. Tank 27 is currently in JP-8 service and is not equipped with a floating pan.

REPAIR SUMMARY

Mandatory Repairs: Mandatory repairs are repairs that are critical to the hydraulic or structural integrity of the tank or are required to meet code prior to placing Tank 27 in service.

- The inspection of Tank 27 found no repairs that would prevent Tank 27 from returning to service.

Recommended Repairs: Recommended repairs are repairs not mandatory per API 653 or for structural and hydraulic integrity of the tank but should be performed for long-term preservation and integrity of the tank.

1. Line relieving / differential thermal relief (LR/DTR) at the 10 inch Issue nozzle is set at 25 psi while the thermal relief loop piping is set at 200 psi. The following repair is recommended:
 - Remove the LR/DTR piping.
2. A double block and bleed (DB&B) plug valve is present on the Low Fuel Piping to isolate it from the Issue Piping. The LR/DTR piping relieves into the pipeline rather than into the tank. The following repair is recommended:
 - Remove the LR/DTR on the Low Fuel Piping.

3. Body cavity relief (BCR) is present on the valves at the Issue and Fill nozzles. The BCR currently relieves into the pipeline rather than into the tank. The following repair is recommended:
 - Revise the BCR to relieve into the tank.
4. The float for the Shand & Jurs tape gauge is not functional. The following repair is recommended:
 - Provide a new tape gauge head, float, tape and springs.
5. Tank 27 has been equipped with two 10 inch pressure/vacuum vents. The following repair is recommended:
 - Disassemble and clean the pressure/vacuum vents.
6. Localized coating failures and corrosion were observed on the exterior shell, floor extension, shell appurtenances, stairs, roof and roof appurtenances. The following repair is recommended:
 - Remove the coating from the affected areas, clean and recoat to prevent further degradation.
7. Tank 27 is equipped with two 2 inch ¼-turn ball valves in the dead shell that provide a means of leak detection. The flanges have been blinded. The following repair is recommended:
 - Remove the blind flanges to allow monitoring of the interstitial space.
8. Replace the gasket for the manway prior to reinstalling the manway cover plate.
9. Provide surface preparation and recoat all interior and exterior repair areas, new materials and areas damaged as a result of repairs in accordance with Coating Requirements.

Recommended Repairs per Current Military Criteria: The following recommended repairs are in accordance with UFC 3-460-1 (formerly MIL-HDBK-1022A):

1. The 12 inch Fill Piping includes a diffuser with a 12 inch x 19 inch opening and appears to be undersized. Section 8.3.9 of UFC 3-460-01 limits the velocity to 12 ft/s at maximum flow and 3 ft/s until the fill piping is submerged. The following repair is recommended:
 - Verify that the product transfer rate does not exceed prescribed velocity maximums.
2. The floor and lower 4 feet of the interior tank shell and columns of Tank 27 are coated. Section 8.3.7 of UFC 3-460-01 states that vertical tanks storing aviation fuel should be 100% coated, including floor, shell and underside of roof. Rust was observed falling from the underside of the roof during the inspection. The following repair is recommended:
 - Coat the remaining interior surfaces of the tank.
 - Note: The decision to proceed with this recommendation requires consideration of multiple variables such as the difficulty of applying coatings at low temperatures and the low corrosion rate of uncoated plate steel in the ambient dry air.

3. Tank 27 is not equipped with a product recovery system per Section 8.3.12 of UFC 3-460-01. The following repair is recommended:
 - Provide a product recovery system.
4. Table 2 of UFC 3-460-01 describes appurtenances for atmospheric storage tanks. Tank 27 is not equipped item (j) an individual automatic level alarm system independent of the gauging system.
 - DESC to resolve policy for independent level alarms.
5. Table 2 of UFC 3-460-01 describes appurtenances for atmospheric storage tanks. Tank 27 is not equipped item (dd) striker plates under all openings used for manual gauging. The following repair is recommended:
 - Provide a ¼ inch thick x 12 inch diameter round striker plate.
 - Seal weld the reinforcing plate to the shell. The completed repair shall have no cracks and shall have complete penetration and complete fusion with the shell plate.
 - Provide visual examination, vacuum box testing (BT) and either liquid penetrant testing (PT) or magnetic particle testing (MT) of the completed repair.

COATING REQUIREMENTS

All repairs involving steel surface grinding, cutting, and welding shall be preceded by proper coating removal. At this time it is not known if any of the existing coating layers have significant lead or chromate components. The contractor shall be responsible for testing coating systems for lead and chromate levels, and develop engineered controls to prevent worker safety hazards, and spread of contaminated dusts. Coating removal method shall be contractor determined, to suit contamination levels and follow-up steps.

Coating System at Localized Repair Locations Only (Interior and Exterior)

Provide repair of localized areas of failed and damaged coatings on the interior and exterior of the tank and areas affected by the contractor's work. Provide a coating system that complies with MIL-PRF-4556F, two-coat application, 4 to 8 mils DFT per coat. Provide surface preparation in accordance with the coating manufacturer's recommendations. For tank interior coating, provide surface preparation in accordance with the coating manufacturer's recommendations for immersion service. Provide 2 to 3 mil surface profile unless recommended otherwise by the coating manufacturer. Prior to surface preparation, test surfaces for soluble salts, oil and grease and clean as required to remove contaminants. Tank interior coatings shall cure for not less than 14 days prior to introducing fuel into the tank. Provide longer cure time when recommended by the coating manufacturer.

MIL-PRF-4556F (superseding MIL-C-4556) is an epoxy polyamide coating system that was used for coating the interior of storage tanks prior to the development of the MIL-DTL-24441 epoxy polyamide coating system and is still used on the interior of filter separators and other process vessels. Coatings that meet MIL-PRF-4556F are "Ameron 395" manufactured by Ameron Coating Company, "Interline 850" manufactured by International Protective Coating Company, and others.

As an alternative for interior repairs, use the 3 coat MIL-DTL-2441 epoxy polyamide system as specified in Unified Facilities Guide Specifications (UFGS) specification 09 97 13.17, Interior Coating of Petroleum Storage Tanks. As an alternative for exterior repairs, use the 2 coat MIL-DTL-2441 epoxy polyamide system with polyurethane topcoat as specified in UFGS specification 09 97 13.27, Exterior Coating of Steel Structures.

Interior Coating System

For complete coating of the tank interior, provide a three coat epoxy polyamide coating system in accordance with UFGS 09 97 13.17 "Three Coat Epoxy Interior Coating of Welded Steel Petroleum Storage Tanks". Care shall be taken during abrasive blasting that the surface profile does not exceed that specified in this specification. The Contractor shall test a representative number of locations with abrasive media that removes coatings but does not affect surface profile. If surface profile is found to be greater than 3 mils, the Contractor shall notify the Government for further direction. Requirements for the surface preparation and coating applications include dehumidification and process quality control by an independent certified NACE inspector. Interior coatings shall cure for not less than fourteen days prior to introducing fuel into the tank.

GAUGE TUBE (STILLING WELL) REQUIREMENTS

Overall Requirements and Decisions Required

The requirements for stilling wells have been reviewed. These requirements are based on our latest understanding for the upcoming SPAWAR executed ATG system, as issued by PMO of DESC and other agencies. There have been ongoing discussions with respect to modifications to the current published requirements. At this time, the criteria are still under refinement and formal direction has not been published. The comments below represent concept solutions for this tank. We recommend the concept be submitted to DESC for ratification or redirection. Field verification of constructability by the prime contractor is also recommended.

Tank Parameters Affecting Gauging and Stilling Wells

The Tank is a typical aboveground tank with a cone-down floor, one center low point sump and no floating pan. The sump is 4 feet in diameter and 18 inches deep. Within the sump is the 2" Water Draw-Off Piping, 3" Diameter Low Fuel Piping and a 6" Roof Support Pipe Column. The roof rafters are supported on a plate welded to the top of the center pipe column. The diameter of the support plate appears to be less than the diameter of the sump.

Current Requirements: SK-1, SK-2 and SK-3

Strict adherence to SK-1, SK-2 and SK-3 as provided by the government may not be practical or possible due to the configuration of the tank structure and lack of a floating pan. The direction in these documents will most likely change once requirements are clarified.

Manual Gauging

The tank is currently equipped with an 8 inch thief hatch located approximately 10 feet from the center sump. The thief hatch is not equipped with a gauge tube.

It is our understanding that a gauge tube is desirable, but not a mandatory requirement for manual gauging and sampling in a tank lacking a floating pan. Therefore, the present thief hatch for manual gauging should be acceptable for use as is.

VITO Combination Water/Temperature Probe Requirements

The current temperature sensor and the ATG level sensor are located within an 8 inch thief hatch near the tank shell. An 8 inch gauge tube with a datum plate is present on the tank floor. However, the gauge tube is only 4 feet tall and is not equipped with slots. This location is undesirable for water probe sensing, but is acceptable for the level sensor.

There appears to be adequate space available to locate the VITO probe directly over the sump. The probe must be located with a minimum clearance of 2 inches to any steel object, such as the sump wall and the piping. To install the probe, it will be necessary to cut a hole in the steel roof and position it between roof rafters.

Option 1 – No Gauge Tube

Option 1 consists of cutting a hole in the steel roof plate and installing a 2 inch flanged spool above the opening. The hole must be located between roof rafters and over the sump.

Option 2 – Gauge Tube Below Roof

Option 2 includes a gauge tube supported from the roof. The gauge tube may have a diameter of 2, 4, 6 or 8 inches. It is our understanding that the DESC preference is 6 or 8 inches to permit greater flexibility in the future with a variety of manufacturers.

As the tank is 40 feet tall, the installation of a single pre-assembled gauge tube would require a crane. It would likely be more practical to fabricate the gauge tube in multiple flanged sections for assembly within the tank. Diagonal bracing would be required to stabilize the tube at the sump. The bracing can be attached to the center roof support pipe column.

Field verification of dimensions is highly recommended with this option. Placement of a larger diameter gauge tube between the roof rafters and over the sump may not be possible.

ATG Servo Float Stilling Well Requirements

The current ATG level sensor and temperature sensor are located within an 8 inch thief hatch near the tank shell. An 8 inch gauge tube with a datum plate is present on the tank floor. However, the gauge tube is only 4 feet tall and is not equipped with slots. This location is acceptable for the level sensor.

Tank 27 is equipped with two spare flanged roof nozzles; a 10 inch near-shell and an 8 inch near-center nozzle. Neither spare nozzle is equipped with a gauge tube.

The ATG level sensor gauge tube may have a diameter of 4, 6 or 8 inches. It is our understanding that the DESC preference is 8 inches to permit greater flexibility in the future with a variety of manufacturers.

The new gauge tube would be aluminum, fully slotted and supported from the roof nozzle. Diagonal bracing would be required to stabilize the tube at the floor.

CONCLUSION

Tank 27 appears to be in acceptable structural and hydraulic integrity. Tank 27 is suitable for service until the next API 653 inspection.



David A. Stchyrba, P.E.

API 653 AST Inspector Certificate No. 27187

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