Prince William Sound Regional Citizens Advisory Council

Valdez Marine Terminal Storage
Storage Tank Mechanical Integrity Investigation
(Contract No. 505.2007.02)

for:

Dr. Thomas H. Kuckertz

PWSRCAC
P.O. Box 3089
Valdez, AK 99686

The Hendrix Group, Inc. Report No. H27053

by:

The Hendrix Group, Inc.
15823 N. Barkers Landing
Houston, TX 77079
(281) 556-8774

September 14, 2007

Table of Contents

EXECUTIVE SUMMARY

Prince William Sound Regional Citizens Advisory Council (PWSRCAC) requested The Hendrix Group, Inc.'s assistance to investigate the alleged tank integrity issues for Valdez Marine Terminal (VMT) Tank Number 55 and Tank Number 16. The tank mechanical integrity issues were based on allegations of irregularities associated with repairs and inspections made to the two tanks by contractors and employees of the Alyeska Pipeline Service Company (APSC) during the 2002 time frame.

The efforts described in this report were a joint effort funded by Prince William Sound Regional Citizens' Advisory Council and Alyeska Pipeline Service Company. In addition to jointly funding the effort, Alyeska provided complete access, as and when requested, to its quality documentation, personnel, and physical plant that greatly aided the exploration of the tank integrity issues described herein.

Allegations associated with Tank 55 that were investigated included:

1. Door sheet welded with wrong welding procedure

2. No heat input monitoring for door sheet weld

3. Welding out of sequence on door sheet

Allegations associated with Tank 16 included:

A. Leaking of product under the tank floor.

This report summarizes the work completed by The Hendrix Group, Inc. in the course of the investigation into the issues related to Tanks 16 and 55. PWSRCAC requested that the investigation include specific tasks associated with the two tanks, including the following:

Task 1 – Review welding documentation, radiographic film and other quality documentation associated with welds used to reinstall Tank 55 door sheet during 2002. Perform on-site visual inspection of the welds. If appropriate, recommend and observe nondestructive testing performed by APSC or contractor of the welds and adjacent heat-affected zones.

Task 2 – Determine if the welding procedures were prepared and qualified acceptably in accordance with applicable standards (e.g., API 650, API 653, ASME Section IX), APSC procedures, federal and state regulations, and other applicable industrial codes and practices. Assess the extent to which the procedures used were equivalent and the extent to which the integrity of the welds made in accordance with the procedure for the thicker material and of the adjacent heat affected zones may have been compromised. Assess the extent to which the design basis of the tank may have been compromised.

Task 3 – Assess the extent to which existing in-process information is sufficient to demonstrate adherence to the essential variables and heat input requirements and limitations of the welding procedures.

Task 4 -- Assess the impact of any variances to procedure essential variables (including heat input) on weld properties, the significance of any variances on weld integrity and overall concern for weld failure. Evaluate weld workmanship and acceptability with respect to the radiographic examination acceptance criteria.

Task 5 – Prepare a written report summarizing the review, findings, and recommendations

The investigation results showed that:

Tank 55

- While certain irregularities occurred during installation of the doorsheet, those irregularities did not influence the tank fitness for service, based on brittle fracture and weld integrity concerns.

- While the original welding procedures approved for welding the Tank 55 doorsheet were not in compliance with API Standard 650, *Welded Steel Tanks for Oil Storage*, and APSC project specifications, revisions to the essential variables of the original procedures made by APSC to correct the deficiencies (as documented by inspection UNSATS) were proper and did not violate any code or project specification requirements.

- Welding with initially incorrect welding procedures versus welding to the revisions made to correct those procedures would not have materially altered the actual welding process and did not compromise the doorsheet welds.

- Issues regarding the doorsheet welding procedures and the actual welds made did not compromise the original tank design.

- Review of the available documents did not permit an unqualified verification as to whether project specification and welding procedure requirements pertaining to heat input requirements were met; however, the discussion will show that, based on the available information and the line of thought conducted, any deviations from the requirements did not compromise the quality or fitness -for-service of the doorsheet welds.

- An API Recommended Practice 579, *Fitness-for-Service*, Level 1 and Level 2 assessment regarding the potential for brittle fracture showed that, based on the available information, Tank 55 passed the Level 1 and 2 assessments and is considered fit-for-service, based on brittle fracture concerns.

Tank 16

- It could not be verified whether Tank 16 ever leaked hydrocarbon during the 2002 time period; however, an inspection of the exterior of the tank in June 2007 showed that it could not have been leaking significant quantities of product into the ground.

RECOMMENDATIONS

An observation that we made during the course of the VMT employee interview process at Valdez and based on our document review were perceived deficiencies in ASPC's aboveground storage tank mechanical integrity procedures and processes. An example of this arose when discussing whether APSC conducting a hydrotest of Tank 55 after the doorsheet replacement. APSC had apparently exempted the tank from a hydrotest, based on the exemption criteria in API 653; however, they did not have documentation of the exemption in the tank files nor did they have an engineering review procedure for conducting a hydrotest exemption engineering review.

A review of documents submitted by APSC showed two procedures which appeared to apply to API 650 storage tanks: (1) X052-T-411 (rev. 0), "Aboveground Storage Tank Repair and Alteration and, (2) MP-166-3.20 (rev. 6), Integrity Management Engineering Monitoring Program Procedures. Both procedures referenced other APSC internal procedures and external documents. MP-166-3.20 appears to be the governing procedure assuring compliance with State and Federal Regulations. Curiously, MP-166-3.20 references X052-T-411, but X052-T-411 does not reference MP-166-3.20. MP-166-3.20 is a high level document generally outlining an overall process but is short on lower level "how to" procedures, such as the above mentioned hydrostatic exemption issue.

As an example, other tank procedures that might prove useful to APSC would include:

(1) Requirements for the Evaluation of Tank Inspection Data,

(2) Requirements for the Evaluation of Tank Change-of-Service Requests,

(3) Procedure for the Development of an Inspection Company Approved Vendor List.

(4) Requirements for The Inspection of Fixed Roof, Atmospheric, Welded Storage Tanks.

(5) Requirements for The Inspection of Internal Floating Roof, Welded Storage Tanks.

(6) Requirements for The Inspection of External Floating Roof, Welded Storage Tanks.

(7) Tank hydrostatic test requirements and exemptions

(8) Procedure for evaluating non-conforming tank inspection data.

(9) Procedure for granting tank next inspection interval extensions.

Background Information

During the year 2002 various repairs and modifications were made to several aboveground storage tanks at the Valdez Marine Terminal (VMT). In May 2006 PWSRCAC (the Council) received a series of letters from a whistle blower that alleged faulty welds, incorrect use of welding procedures, and regulatory indifference pertaining to unspecified welding situations at the Valdez Marine Terminal involving the 2002 tank repairs and modifications. The Council and Alyeska Pipeline Service Company (APSC) identified a set of welds used to reinstall a door sheet in 2002 that had been cut to allow access to Tank 55 as, at least in part, the basis for the allegations. PWSRCAC wanted to verify the extent to which the Tank 55 door sheet welds might have compromised the mechanical integrity of Tank 55 by examining the procedures used to make the welds, the standards and regulations pertaining to the welds, and the welds themselves.

This report addresses certain focused issues related to allegations of improper tank repairs for Tank 55 and leaks associated with Tank 16. Specifically, it addresses the following “Unsat” numbers generated during the repairs.

UNSAT 19 - Shell thickness variable in weld procedure greater than actual. Requires new procedure.

UNSAT 20 - Welding out of sequence on door sheet.

Scope

As requested by RCAC, the VMT investigation initially covered the following specific project tasks related to Tank 55:

Task 1 – Review welding documentation, radiographic film and other quality documentation (*Appendix A*) associated with welds used to reinstall Tank 55 doorsheet during 2002. Perform on-site visual inspection of the welds. If appropriate, recommend and observe nondestructive testing performed by APSC or contractor of the welds and adjacent heat-affected zones.

Task 2 – Determine if the welding procedures were prepared and qualified acceptably in accordance with applicable standards (e.g., API 650, API 653, ASME Section IX), APSC procedures, federal and state regulations, and other applicable industrial codes and practices. Assess the extent to which the procedures used were equivalent and the extent to which the integrity of the welds made in accordance with the procedure for the thicker material and of the adjacent heat affected zones might have been compromised. Assess the extent to which the design basis of the tank might have been compromised.

Task 3 – Assess the extent to which existing in-process information is sufficient to demonstrate adherence to the essential variables and heat input requirements and limitations of the welding procedures.

Task 4 -- Assess the impact of any variances to procedure essential variables (including heat input) on weld properties, the significance of any variances on weld integrity and overall concern for weld failure. Evaluate weld workmanship and acceptability with respect to the radiographic examination acceptance criteria.

Task 5 – Prepare a written report summarizing the review, findings, and recommendations.

During the course of the project, another task was added to the project scope involving investigating certain issues related to allegations of leaking of product from Tank 16 and circumstances surrounding an uplift event to the Tank 16 sump.

SITE VISIT

This writer visited the VMT terminal facility during the week of June 26, 2007. During the visit the following activities were conducted:

(1) Observed the exterior of Tanks 16 and 55.

(2) Interviewed APSC personnel regarding the tank issues.

(3) Participated in hardness testing of the Tank 55 doorsheet welds.

(4) Reviewed radiographic film taken of the doorsheet welds.

The visit resulted in a request for production of additional documents pertinent to the investigation and those documents are detailed in *Appendix A* under APSC produced documents.

Hardness testing

At directed and witnessed by this writer, hardness tests of the doorsheet welds, heat-affected zones (HAZ) and adjacent base metal on a sampling basis was conducted by others to address the expressed concerns with fitness-for-service of the Tank 55 doorsheet, i.e., unknown weld quality and brittle fracture. Based on the document review, others also believed that hardness testing of the doorsheet welds would provide useful information; however, for unknown reasons the tests were never done.[1]

Hardness tests can be accurately correlated with the tensile strength of a ferrous metal/alloy and allow a qualitative estimate of the toughness of a material, i.e., as hardness increases, the toughness of a ferrous metal/alloy decreases (although not linearly). As the HAZ can be the hardest and least tough location in a welded component, the hardnesses were conducted using a Krautkramer MIC-10 microhardness test instrument, to permit measurements in this thin layer. *Appendix B* shows photographs of the tank, doorsheet, hardness test locations and test equipment. Hardness results for the Tank 55 doorsheet are detailed in *Appendix C*, Table C1.

The results showed that base metal, HAZ and weld metal hardness measurements were all low, indicating good ductility and toughness. The hardness measurements were slightly low compared with the minimum specified tensile strength for the base and weld metal. However, as they were compared after converting to their equivalent tensile strength (using accepted ASTM conversion factors) and the conversion doesn't represent 100% equivalence, the slightly low measurements are not considered an issue of importance.

Doorsheet Radiographic Film Review

After completion of welding on the Tank 55 doorsheet, the doorsheet welds were 100% radiographically inspected. This writer reviewed all film, including reshoots taken after minor weld repairs to eliminate porosity. The film reviewed showed that the doorsheet welds were of high quality and met and exceeded ASME Section VIII, Paragraph UW-51(b) requirements, the applicable code for the doorsheet welds.

TANK 55

Tank Design and Contents

Summary design information associated with Tank 55 is detailed in *table 1* below.

---

[1]Valdez Marine Terminal, Tank 55, Alleged Integrity Concerns Preliminary Investigation, March 15, 2007, Rev. 2, pg. 4 of 44.

15823 N. Barkers Landing Ph: 281.556.8774
Houston, TX 77079 Fax: 281.870.0659

table 1 **- Tank 55 Design Information**

Size	100' O.D. x 31'-8" ht.
Capacity	40,000 Bbls.
Service	Diesel Fuel
Specific Gravity	0.9
Build Date	1976
Specification	API 650, App. G
Shell Material	JIS SM41
C.A.	None
Max. Product Ht.	28'-9"
Weld Metal	E7018-1

Base and weld metal properties

Drawing No. 73-7235-1A Rev. 7 for Tank 58-TK-55 indicates a notation of 2 for plate material. This notation is found in document "CBI Material Identification for Alyeska Storage Tank," REF-00122. It refers to Specification JIS G 3106 SM 41 C Mod. Class A and states the following material properties in *table 2*.

table 2 **- JIS SM41 Material Specification**

Chemistry (wt.%)	
Carbon	0.18 max.
Silicon	0.15-0.40
Manganese	1.40 max.
Phosphorus	0.035 max.
Sulfur	0.30 max.
Processing	Normalized and fine-grained.
Mechanical Properties	
Tensile Strength	58,000-73,000 psi.
Yield Strength	34,000-58,000 psi
Notch Toughness	35 ft.-l:bs. Min. Average
Hardness	280 HV30 Max.

Tank 55 Unsats

Background

PWSRCAC received a series of letters during May 2006 alleging faulty welds, incorrect use of welding procedures, and regulatory indifference pertaining to unspecified welding situations at the Valdez Marine Terminal. The inquiries included welds that were performed on Tank 55 (diesel fuel) in 2002. Ten welds were needed to reinstall the door sheet in Tank 55. Welding was reportedly started with an incorrect procedure, i.e., one for a crude oil tank having a shell thickness of 0.625 inches of steel. The shell thickness of Tank 55 is nominally 0.312 inches and the range of thicknesses permitted by the procedure for welding crude oil storage tanks did not include the thickness for Tank 55. An inspector refused to accept the welds due to the incorrect procedures. The remaining welds were completed with a valid (and accepted) set of welding procedures. The two sets of procedures specified the same welding variables except that the specified heat input for the thinner shell was less than that permitted for the thicker shell. The welds remaining were then completed using the appropriate set procedures and appear to have been inspected and accepted without controversy. The non-conforming welds were not re-welded, as the in-process parameters would have allegedly been the same. Several welds in question were approved by a welding supervisor. Tank 55 was filled with diesel fuel shortly thereafter. It was reported that the non conforming Tank 55 welding procedures did not consider the differences in maximum heat input of the questionable welds. The tank has been through multiple fill and use cycles and three annual temperature cycles without leaking or showing any other signs of failure.

Issues

The document review revealed several allegations associated with Tank 55 that are included in the scope of this investigation (see reference in footnote 1).

1. Door sheet welded with wrong welding procedure

APSC, the agencies, and this report substantiated that the wrong welding procedure was used while welding a portion of the Tank 55 door sheet; however, there was no consensus on whether or not the use of the wrong welding procedure posed a mechanical integrity issue that warranted additional testing or tank repair. APSC maintained that the procedures were substantially similar, while the inspectors and Mr. Harrison with the JPO disagreed. (The JPO is a joint federal and state office with the Federal Bureau of Land Management and the Alaska Department of Natural Resources as the lead agencies).

2. No heat input monitoring for door sheet weld

APSC's quality assurance documentation substantiated that no heat input monitoring occurred on about 60% of the Tank 55 door sheet welds. No quality control data was collected on any of the exterior welds. No quality control data were collected on the two main interior vertical welds. APSC maintained that monitoring data for 40% of the welds was sufficient to ensure welding quality control. The inspectors maintained that APSC's own welding procedures and quality control program required data to be collected on 100% of the welds. Mr. Harrison (BLM) recommended a simple, cost-effective hardness test be completed on the heat-affected zone prior to returning the tank to service. This test was not done.

While APSC maintained that monitoring data for 40% of the welds was sufficient to ensure welding quality control, the data appeared suspect to some. Even APSC engineers evaluating the data in 2006 agreed the data was abnormally consistent, and did not reflect the variability one would expect for this type of welding process. Allegations of record tampering existed.

3. Welding out of sequence on door sheet

A record review confirmed the door sheet welding was completed out of sequence.

Known Facts and Assumptions

Based on information contained in a report by Harvey Consulting [2], the following is a summary of substantiated and unsubstantiated facts and allegations associated with Tank 55 that are within the scope of this report:

Facts

1. A new tank floor was installed during the summer of 2002.
2. Tank 55 was returned to service on November 26, 2002.
3. ADEC and JPO did not provide a written record approving this tank to be returned to service and there is no written agency finding on or before the tank was returned to service resolving the allegations.

[2] Harvey Consulting LLC, Summary of Findings of Facts, Allegations and Recommendations, April 5, 2007.

Substantiated allegations (by Harvey Consulting)

1. The door sheet was welded with the wrong procedure and APSC did not demonstrate procedural equivalence.

2. The door sheet monitoring data was suspect, and may have not been sufficient to ensure quality control.

3. Alyeska's quality documentation was not sufficient to demonstrate adherence to its own inspection, repair and quality control procedures regarding welding the door sheet out of sequence.

Tank 55 UNSATS

WPS/PQR's (UNSAT #19). There were three main allegations directed at Tank 55: (1) welding using an incorrect (and non-approved) WPS/PQR, (2) the doorsheet data monitoring data was suspect, particularly related to weld heat input and, (3) out-of-sequence welding. However, based on a review of documents produced by PWSRCAC, it would appear that Allegation No. 1 was considered the most egregious non-conforming item.

Below is an abbreviated chronology of the Tank 55 door sheet WPS/PQR allegation, as obtained from a Harvey Consulting, LLC report, Attachment B, March 15, 2007:

1998. TANCO and APSC developed two welding procedures6 for diesel storage tanks of 0.312" thickness, and two welding procedures for crude oil storage tanks of a 0.625" shell thickness.

March 27, 2002. Mr. Stevens (APSC employee at this time) prepared a Tank 55 door sheet removal, replacement, and welding/NDE/pressure testing procedure. This procedure was approved by Tony Balowski (APSC welding engineer). In error, the procedure called for use of a crude oil tank welding procedure rather than a diesel tank welding procedure.

September 14, 2002. The Tank 55 doorsheet was welded using welding procedures for a 0.625"thick crude oil tank shell, instead of a thinner diesel tank shell. Welding continued through September 16, 2002 until the error was found. This error was documented in the Tank 55 records as Unsatisfactory Finding No. 19 (UNSAT #19).

September 20, 2002. Inspector documents an Unsatisfactory Finding No. 20 (UNSAT #20), because an approved welding procedure was not in place for the Tank 55 when the welding of the door sheet occurred. APSC Welding Engineer amends the crude oil tank welding procedure specifications to include diesel tanks such as Tank 55 four days after the welding procedure error was found by Inspector Kale. KAM Inspector changes the Unsatisfactory Inspection Finding No.20 (UNSAT#20) to a satisfactory inspection finding.

Appendix D, Table D1 contains a matrix of the original and revised ad resubmitted Welding Procedure Specifications (WPS) and Procedure Qualification Records (PQR) used for the Tank 55 doorsheet welding.

To distill the WPS/PQR issue:

A. Two welding procedures were originally issued for the doorsheet welding: (1) T-400-2G-1 and T-400-3G-1. The 2G procedure was for the horizontal doorsheet welds and the 3G was for the vertical doorsheet welds. Both procedures were impact tested procedures with heat input restrictions using E7018-1 SMAW welding electrodes. The original procedures T-400-3G-1Q PQR which was welding using a 0.625" coupon, which qualified the associated welding procedures for a 2T thickness range of 0.625"-1.25". Obvious, this thickness range exceeded the doorsheet thickness of 0.312"; therefore, did not meet API 653, API 650 or ASME Section IX requirements.

B. To correct this non-conformance, APSC produced a PQR that had been pre qualified with a welded coupon thickness (0.280") appropriate for the doorsheet thickness (T-400-3G-6Q), associated it with the two original WPS's, added the new thickness range to the WPS's and reissued them with a new revision number. Other than the new PQR coupon thickness, all essential and supplemental essential variables were identical between the old and the new WPS and PQR, except that the maximum actual heat input for the revised PRQ (6Q) was 40,500 J/in. instead of 46,800 J/in. in the original PQR (1Q).

Professional Opinion

It is the opinion of this writer, while the revised WPS/PQR was produced after the fact, it did not violate any code requirements and did not invalidate the actual doorsheet welds as the essential variables associated with the revised PQR were identical to those of the initial PQR and met the requirements of the WPS. It is technically correct to reissue a WPS with a new revision no. when associated with a new PQR that does not violate ASME Section IX requirements. Therefore, this writer, if he had been in a responsible position regarding reviewing the doorsheet WPS/PQR non conformance, would have accepted the revisions and changed UNSAT #19 to a satisfactory inspection finding.

No heat input monitoring for doorsheet weld (UNSAT #20)

Background. On 9/20/02 a KAM Inspector listed an Unsatisfactory Condition No. 20 (UNSAT #20), based on requirement #6 in Work Order Package 32001526, which stated that the inspector must "verify that the preheat requirements of the WPS are followed and closely monitored per the SRP TM 1 Welding Engineering Review and T-411." According the WPS TG-400-3G-1 (Rev. 5) and its associated Procedure Qualification Report (PQR) T-400-6G-1Q, heat input is a supplemental essential variable. However, the WTR does not have any records of the parameters for two vertical welds: FW-4 and FW-8. It is not indicated how the heat input was monitored for the vertical weld for TK 55.

In *table 3* below is a table summarizing data from a Tanco Weld Tracking Report with our addition of the heat input in kJ/in. in the rightmost column. It shows that no data was collected for doorsheet welds FW-4 and FW-8. It also shows that the welding variables were, to quote from the reference in *footnote 1*, “abnormally consistent.”

table 3 *- 58-TK-55 Diesel Storage Tank*
Weld Tracking Report (WTR) (1)
Inspector James Mark Hodges
NDE Type Radiographic Test

Inside Weld No.	Preheat Temp (F)	Welding Speed (in./min.)	Amps	Volts	A= Accept R= Reject	kJ/in
FW-1	165	6	120	23	A	27.6
FW-2	155	6	135	23	A	31
FW-3	165	6	125	23	A	28.7
FW-4	N/A	N/A	N/A	N/A	R	-
FW-5	170	6	125	23	A	28.7
FW-6	165	6	135	23	R	31
FW-7	170	6	120	23	A	27.6
FW-8	N/A	N/A	N/A	N/A	A	-
FW-9	155	6	135	23	A	31
FW-10	170	6	140	23	A	32.2

Note: No data for the corresponding outside welds.
(1) WeldReport1.doc

Additional information [3] regarding the doorsheet heat input issue stated that:

The maximum heat input should have been 40,800 J/in. instead of 46,800 J/in. in the revised WPS T-400-2G-1 (Rev. 5) and T-400-G-1 (Rev. 4) per ASME Section IX, QW-409.1 for the shell thickness range of 0.280-0.560 inches. The heat input for welds FW-1, FW-2, FW-3, FW-5,

[3] WeldReport1.doc

FW-6, FW-7, FW-9 and FW-10, as calculated from the in-process information documented in the “abnormally consistent” Weld Tracking Report (WTR), ranged from a low of 27,600 J/in to a high of 32,200 J/in. No in-process welding variables (preheat, amperage, voltage, travel speed) were documented for the welding of the door sheet welds: FW-1A thru FW-10A (outside welds) and FW-4 and FW-8 (inside welds). Based on a review of the ASPC Surveillance/Repair Procedure TM-1, Rev. 1 (8/7/02) the extent of examination was to: “perform welding and visual in-process examination on a random basis.” Additionally, there is no requirement in API 650 or API 653 for in-process inspection of welding.

Professional Opinion

The heat input into a weld can be important or not, depending on many variables, including the hardenability of the alloy being welding, its thickness, it’s service requirements and distortion control. The doorsheet welding procedures included maximum heat input as a supplemental variable as the procedures were required to be impact tested. Too low heat input and too high heat input can detrimentally influence as-welded toughness properties; however, it is common to specify a maximum heat input, as too high a heat input can degrade the HAZ of the weld, reducing its toughness. Everything else being equal, if the actual structure weld does not exceed the heat input of a Charpy tested welding procedure, then the weld should be expected to exhibit similar toughness values.

The available project Weld Tracking Sheets (WTS) show that the doorsheet heat input, as measured by the welding voltage, current and travel speed were not monitored for several inside welds and none of the outside welds. Also, the WTS data that is available is apparently suspect, based on its unusual consistency. If one chooses not to believe the data that is available, an argument could be made that it is not known whether any of the doorsheet welds conformed to the maximum 40,800 J/in. or not. However, if one were to choose to believe the available data, then the heat input of the monitored inside welds did not exceed ~32,000 J/in., well below 40,800 J/in. Based on the requirements of the APSC TM-1 Repair Procedure, repair examinations were only required on an unspecified “random” basis, which the degree of monitoring, as represented by the available WTS met. Also, as correctly pointed out, there is no specific requirement in API 650 or API 653 for in-process inspection of welding addressing this issue. Therefore, rather than approach the issue based on whether project requirements were met or not, a more constructive approach would be to discuss: (a) the likelihood of exceeding the maximum of 40,800 J/in. and, (b) if other, indirect evidence would suggest whether the doorsheet welds are susceptible to brittle fracture or not.

This writer, for several reasons, believes that it is likely that the doorsheet welds did not exceed 40,800 J/in. If one considers the three variables controlling heat input of a weld, i.e., voltage, current and travel speed, it is probably going to be the travel speed that is the most subject to variation. The voltage and current are constrained by the diameter and weld metal transfer characteristics of the electrode. In the monitored WTS inside weld data the voltage is a constant 23 volts and the current ranges from 120 amps to 140 amps. These parameters closely resemble the voltage and current used in the Lincoln Easy Arc 528 MR E7018-1 Procedure Development Data Record from the Testing Institute of Alaska (11/28/94) that qualified the Lincoln 7018-1 electrode' notch toughness data. In that data record, for an electrode diameter of 1/8", the recorded volts for all passes ranged from 20.6- 22.8 volts and the current from 118-122 amps. The travel speed ranged from 3.7-6.7 in. with all but two passes being greater than 4.8 in./min. Thus, one could conclude that the voltage and amperage recorded on the WTS for the inside welds were probably similar. If so, then the most influential variable on heat input would be the travel speed. Based on a worse case combination of 140 amps and 23 volts (*table 3*, FW-10) it would require that the travel speed be ~4.8 in./min. or less to exceed 40,800 J./in. A normal weld speed for the doorsheet conditions would be more like 8-9 in. min. and it's not in a welder's nature to maximize the time spent welding. Figures 6, 7 and 8 in *Appendix B* show lengths of the doorsheet exterior weld cap pass. To this writer, the weld appearance does not suggest an excessively slow travel speed.

The above addresses the probability that the doorsheet welds conformed to the 40,800 J/in. requirement. Approached from another perspective, what is the probability that the doorsheet welds are prone to brittle fracture? This argument is partly addressed by the doorsheet weld hardness measurements. The measurements are all very low, suggesting a ductile, tough weld and HAZ. Also, the radiograph review showed that all welds were free from injurious defects that could affect toughness. Therefore, it is this writer's opinion that the doorsheet welds probably met the maximum 40,800 J/in. requirement, and that the weld quality is excellent and that the material appears to be ductile and tough, based on the hardness data. So, while the heat input monitoring might be procedurally an issue, technically it is not.

Welding out of sequence on door sheet

Background. An unsat was written to because the door sheet welding was completed on the outside of the tank (including corners and 12" cutbacks) before the inside horizontal corner and 12" cutback welds were complete. After the outside of the doorsheet was completely welded, TANCO welded the inside horizontal joints and then the corners and cutbacks.

The sequence of welding that took place is as noted below (*footnote 1)*:

1) outside vertical joints

2) inside vertical joints

3) outside horizontal joints (along with outside corners and cutbacks)

4) inside horizontal joints (along with inside corners and cutbacks)

<u>References</u>

This writer found two APSC project document references that addressed the issue of doorsheet welding sequence:

(1) Drawing D-54-TM1-C01, Tank Maintenance Typical Crude Tank Doorsheet Details, Note No. 6, "Prior to welding vertical cuts, cut at existing horizontal weld for a minimum of 12" beyond new vertical joints. Weld horizontal cuts last."

(2) Project Technical Specification X052-T-411, Aboveground Storage Tank Repair and Alteration, paragraph. 3.4.6, Fit-up, Alignment, and Weld Sequence - "Use fit-up methods and welding sequences for tank welding, welding bottom, shell, and roof plates that minimize distortion due to weld shrinkage ...."Control weld distortion of large replacement plates by strictly adhering to fit-up procedures and weld placement sequences.

API 653 (December 2001) addresses sequence welding in paragraph 9.2.2.2, "Prior to welding the new vertical joints, the existing horizontal welds shall be cut for a minimum distance of 12 in. beyond the new vertical joints. The vertical joints shall be welded prior to welding the horizontal joints."

<u>Professional Opinion</u>

This writer believes that APSC technically met the project specification requirements and those of API 653, related to welding sequence. As suggested in APSC Project Technical Specification X052-T-411, welding sequence is important for several reasons: (1) to control distortion and, (2) to control excessive weld stresses that could lead to cracking. Based on observation of the finished doorsheet during the site visit, there was no observable tank shell distortion associated with the doorsheet replacement and the 100% magnetic particle and radiographic inspection verifies that the doorsheet welds are of good quality with no injurious defects.

Fitness-for-Service Discussion

<u>Introduction to brittle fracture</u>

Brittle fracture is fracture that involves little or no plastic deformation. It is usually associated with flaws or defects in the material where bulk stresses concentrate. A stress intensity is associated with flaws or geometric notches and a stress concentration factor can be assigned to the flaw or notch based on its geometry, location and orientation. The more acute the flaw or notch, the greater the stress intensity.

For a brittle fracture to occur in a normally ductile material, the following factors must be present simultaneously:

1. A stress concentrator must be present. This can be a weld defect, a fatigue crack, or a geometric notch such as a sharp corner, thread, hole, etc. The stress concentrator must be large enough and sharp enough to be a "critical flaw" in terms of fracture mechanics.

2. A tensile stress must be present. The tensile stress must be of a magnitude high enough to provide microscopic plastic deformation at the tip of the stress concentration. The tensile stress need not be an applied stress on the structure, but may be a residual stress inside the structure, i.e., from welding or uneven cooling, etc.

3. The temperature must be relatively low for the steel concerned. The lower the temperature for a given steel, the greater the possibility that brittle fracture will occur. For some steels the ductile/brittle transition temperature may be above room temperature.

A fracture is "brittle" when it is associated with very little plastic deformation. Such fractures can take place in otherwise ductile materials if they contain cracks. Brittle fractures have certain characteristics that permit them to be identified:

1. There is no gross permanent or plastic deformation of the metal in the region of brittle fracture.

2. The surface of a brittle fracture is perpendicular to the principle tensile stress.

3. Characteristic markings on the fracture surface frequently point back to the location from which the fracture originated. These markings are sometimes referred to as "chevron" or "herringbone" marks.

Brittle fractures are dangerous because they occur suddenly, without warning (plastic deformation), and the cracks travel rapidly. Equipment/components that are ductile can deform in the presence of a tensile stress and a flaw (crack) without fracturing. The vessel deforms (yields) instead of sustaining a rapid fracture. Brittle equipment/components can fracture at stresses below the yield strength of the material in the presence of a flaw and the cracks travel rapidly and without prior warning. This is what makes brittle fracture dangerous. In summary, brittle fracture can occur in a susceptible material (low toughness) under a tensile stress at which a “critical” size flaw is present. Implicit in this definition is that if a material containing a specific size flaw has survived worse case conditions of the highest encountered stress and lowest toughness conditions then it should survive all conditions as severe and less severe in the future. In the case of Tank 55 the worse case conditions would coincide with the highest product level (stress) at the lowest ambient temperature (toughness).

The most commonly used measure of a material’s toughness (resistance to brittle fracture) is the Charpy impact test, typically reported in foot-pounds (ft.-lbs.). It is widely used as a measure of toughness because it is a relatively easy test to conduct. The ASME boiler and pressure vessel code (and API 650) recognized the importance of brittle fracture in their specifying a minimum level of toughness, historically 15 ft.-lbs. Today's ASME and API codes address brittle fracture with "charpy-impact exemption curves," which state the lowest temperature a specific material can be used at a specified thickness.

Based on the low ambient temperatures that Tank 55 is exposed to in the winter season, the tank base metal and welds included required Charpy impact testing, in this case, 30 ft-lbs. at 0^{o}F. This toughness requirement was intended to insure that the tank base metal and welds contained sufficient charpy-impact toughness to resist defects at the lowest expected ambient temperature, i.e., 0F. Implicit in the code toughness philosophy is that the code mandated non destructive inspection requirements will detect any defects that would be injurious to the vessel at the specified minimum charpy-impact toughness value.

Brittle Fracture Assessment to API 579, Section 3

The current "best practice" for conducting fitness-for-service assessments is API 579. API 579 has procedures for assessing the potential for a brittle fracture, based on three, increasing complexity levels, i.e. Level 1, Level 2 and Level 3. Usually, a Level 3 brittle fracture assessment involves a fracture mechanics analysis. The Level 1 assessment is based on comparing a Critical Exposure Temperature (CET) with a minimum allowable temperature (MAT). A Level 1 assessment passes if CET > MAT. A Level 2 assessment follows the right-hand path in the *Appendix E* figure.

Appendix E contains a logic diagram and supporting material extracted from API 579 used to assessment the potential for brittle fracture of an API 650 storage tank. In the Governing Plate Thickness graph this writer believes that SM41 tank shell plate material belongs to Curve B (all non-cast materials in Curve A if produced to fine-grained practice and normalized and not in Curves C and D). Based on the governing thickness for Tank 55 (0.312"), the charpy impact exemption temperature for the Tank 55 shell plate material is -20F. As the minimum design metal temperature (MDMT) for Tank 55 is 0F, the original tank base metal construction passes a Level I brittle fracture assessment, i.e., (CET = 0^{o}F > MAT = -20^{o}F)

Based on fitness-for-service considerations, the question then becomes does the doorsheet replacement fabrication pass a Level 1 assessment criteria. This writer believes that it does, based on the charpy-impacted T-400-6G-1Q PQR used to qualify doorsheet welding procedures T-400-3G-1, Rev. 5 and T-400-2G-1, Rev. 4.

Tank 55 was constructed with SM41 carbon steel produced to a normalized and fine-grained practice[4]. The Alyeska Aboveground Storage Tank Repair and Alteration specification used for the project call for a design toughness of 30 ft.-Lbs. at 0^{o}F for weld metal of plate thickness 1/4"

[4] CBI material Identification for Alyeska Storage Tanks, REF-00122, Rev. 4/16/74

to 3/4" [5]. The PQR was qualified using 10mm x 5mm charpy-impact test specimens (at -20°F). Based on the miminum 30 Ft.-Lbs. charpy-impact requirement, Table 2 (footnote 5) allows a 0.67 reduction factor for 10mm x 5mm subsize charpy-impact test specimens for plate material 1/4" to 3/8". This reduction factor corresponds to a required 20 Ft.-Lbs. minimum charpy-impact value for the PQR (30 x 0.67). The average impact value for the T-400-6G-1Q PQR weld material was 25 Ft.-Lbs. and 39 Ft.-Lbs for the heat-affected zone. Also, no individual charpy value fell below 80% of the minimum average value requirement.

Based on the above logic, the original Tank 55 construction and the doorsheet replacement pass a Level 1 brittle fracture assessment, based on API 579. It is also worth noting that the tank also is considered safe from brittle fracture, based on two additional Level 2 pass/fail criteria, (see the right-hand path in the *Appendix E* figure). The tank shell course thickness is less than the 0.5" inch where API 579 considers brittle fracture to be an operative damage mechanism. Also the tank also normally operates below the 8 ksi tensile strength cut off where, at stresses below 8 ksi, experience has shown that there is insufficient applied stress to run a brittle crack (based on API 650 formulas, the Tank 55 shell at the bottom of the doorsheet does not exceed 8-ksi until the tank if filled to greater than 11 feet of diesel product). Liquid fill height vs. ambient temperature data submitted by APSC for Tank 55 for the years 2004, 2006 and 2007 show that the tank product height rarely exceeded 11 feet and the maximum fill height reported was 14 feet.

Tank 55 Fitness-for-Service Opinion

Based on the above tank data and design information, the doorsheet replacement fabrication passes a Level I brittle fracture assessment per API 579. The brittle fracture assessment implicitly assumes that the plate and weld material are free from injurious defects (greater than code allowable) and that is the case here.

TANK 16

Tank Design and Contents

Summary design information associated with Tank 16 is detailed in *table 4* below.

[5] Alyeska Pipeline Specification No. X052-T-411, Rev. 0.

table 4 **- Tank 16 Design Information**

Size	250' O.D. x 62'-3" ht.
Capacity	510,000 Bbls.
Service	Crude Oil
Specific Gravity	0.9
Build Date	1976
Specification	API 650, App. G
Shell Material	JIS SM50
C.A.	1/8"
Max. Product Ht.	58'-6"
Weld Metal	unknown

Base and weld metal properties

Drawing No. 1-2 Rev. 0 for Tank 58-TK-16 indicates notations of “1" and “2" for plate material. This notation is found in document “CBI Material Identification for Alyeska Storage Tank”, REF-00122. Material spec “1" is a specification for JIS G 3106 SM 50 C Mod. Class A and states the following material properties in *table 5*.

table 5 - **JIS SM50 Material Specification**

Chemistry (wt.%)	
Carbon	0.18 max.
Silicon	0.15-0.40
Manganese	1.50 max.
Phosphorus	0.035 max.
Sulfur	0.30 max.
Niobium	0.05 max.
Vanadium	0.08 max.
Processing	fine-grained and normalized.
Mechanical Properties	
Tensile Strength	70,000-85,000 psi.
Yield Strength	50,000-68,000 psi
Notch Toughness	35 ft.-l:bs. Min. Average
Hardness	280 HV30 Max.

15823 N. Barkers Landing Ph: 281.556.8774
Houston, TX 77079 Fax: 281.870.0659

<u>Background</u> [6]

Concerns originally arose during the 2002 Tank 16 inspection and repair work when employees and inspectors noticed tank floor damage in the area of the sump that put the integrity of the tank floor in question. It was alleged that the floor buckling was so significant that the sump was removed. The floor was patched to cover the hole left after the sump was removed. Not only were there problems with the tank floor around the sump, but Tank 16's floor had historically been patched in a number of places, and required more patching in 2002, contributing to the integrity concerns. Of particular concern was the potential for ground water and soil contamination from the crude oil stored in Tank 16.

One submitted document, an e-mail from Bonnie Friedman to John Engles, dated "1011 712002" states: "...a concerned employee came by my office to express concern about the issue of possible contamination in the West Tank Farm. This employee was doing tank work in TK 16. Apparently water pressure under the tank was so high as to cause the sump to be jacked up about 5 inches. The sump bottom was removed during the tank work and the employee noted what he perceived as contaminated water under the sump area. He said the sump had been open for several days and the water was moving so he did not believe it was from the inlet of the tank. Also, the tank bottom to 16 was found to be in good condition so he felt it was unlikely that Tank 16 was the cause of the oil. The employee infers that there is contaminated water in the tank farm within the gravel layer between the surface and the CBA liner."

The below is an abbreviated chronology of events surrounding the Tank 16 floor issue, as abstracted from the reference in *footnote 6*:

- <u>Summer and Fall 2002</u> - Tank 16 was cleaned, inspected, repaired (sump replaced due to deformation). It is not clear exactly when Tank 16 was returned to service, but it appears that it was sometime during the Fall of 2002.

- <u>October 1, 2002</u> - Mr. Harrison (BLM) and Ms. Friedman (ADEC) met with a concerned employee. The employee was working at the VMT and alleged that there might be a leak in Tank 16's floor. According to Mr. Harrison, Mr. Moore (APSC) obtained and tested samples from the Tank 16 sump area, reporting no contamination. Mr. Harrison said he had not handled the sample or testing; this was all handled by ADEC and he never actually saw the test results, but was told that the tests were negative for contamination by Ms. Friedman.

[6] Valdez marine Terminal Tank 16, Alleged Integrity Concerns, Preliminary Investigation, Harvey Consulting, LLC, March 13, 2007.

- January 21, 2003 - An internal APSC memorandum from Ms. Lee (APSC) to Mr. Stokes (APSC) summarized the 2002 inspection findings for Tank 16. The report states that 80 floor plate patches were installed on 49 of the original floor plates. There are 260 original tank floor plates; 49 plate repairs out of 260 is approximately 19% of the total tank floor. The report confirms the entire sump was replaced due to deformation of some of the plates.

There was little documentation submitted regarding the above allegation and this apparently reflects the statement in the Harvey Tank 16 report, i.e., " Very few sources of written records were available for this report." No reviewed document verifies whether oil was actually leaking from under Tank 16 nor not.

Discussion

The Tank 16 sump documents suggests that the tank floor was repaired and "inspected" following the floor patch plates installation and sump removal. This writer could find no documentation that detailed exactly what inspection was conducted on the floor after the repairs. So a documentation review will not be sufficient to resolve the tank floor leaking issue.

To address the issue of Tank 16 leaking, this writer conducted a visual inspection of the exterior of Tank 16 during the site visit. As part of the inspection, caps were removed from plastic pipe inspection ports placed below the tank floor around the circumference of the tank. When the inspection port caps were removed, water typically exited from the inspection port pipe. Close visual observation and sniffing the water for hydrocarbons did not detect any trace hydrocarbons. In addition, various plants, grass and weeds, etc. around the periphery of the tank were healthy and green, also suggesting no exposure to hydrocarbons.

Professional Opinion

Based on the available information, it is not known whether Tank 16 ever leaked hydrocarbons into the ground; however, a visual inspection of the exterior of the tank showed no evidence of existing hydrocarbon leaks.

TANK 55 AND 16 CONCLUSIONS

- While certain irregularities occurred during installation of the doorsheet, those irregularities did not influence the tank fitness for service, based on brittle fracture and weld integrity concerns.

- While the original welding procedures approved for welding the Tank 55 doorsheet were not in compliance with API Standard 650, *Welded Steel Tanks for Oil Storage*, and APSC project specifications, revisions to the essential variables of the original procedures made by APSC to correct the deficiencies (as documented by inspection UNSATS) were proper and did not violate any code or project specification requirements.

- Welding with initially incorrect welding procedures versus welding to the revisions made to correct those procedures would not have materially altered the actual welding process and did not compromise the doorsheet welds.

- Issues regarding the doorsheet welding procedures and the actual welds made did not compromise the original tank design.

- Review of the available documents did not permit an unqualified verification as to whether project specification and welding procedure requirements pertaining to heat input requirements were met; however, the discussion will show that, based on the available information and the line of thought conducted, any deviations from the requirements did not compromise the quality or fitness -for-service of the doorsheet welds.

- An API Recommended Practice 579, *Fitness-for-Service*, Level 1 and Level 2 assessment regarding the potential for brittle fracture showed that, based on the available information, Tank 55 passed the Level 1 and 2 assessment and is considered fit-for-service, based on brittle fracture concerns.

- It could not be verified whether Tank 16 ever leaked hydrocarbon during the 2002 time period; however, an inspection of the exterior of the tank in June 2007 showed that it could not have been leaking significant quantities of product into the ground.

The Hendrix Group Inc.

15823 N. Barkers Landing Ph: 281.556.8774
Houston, TX 77079 Fax: 281.870.0659

Appendix A

REFERENCE MATERIAL

Provided by PWSRCAC

KakivikLitigation

kalevskakivikTSC4n502.pdf
kalevskakivikTSC4n5.pdf
vamvoras031204.pdf
SarbaneOxley030304.pdf
DOL030917.pdf
kalevkakivik.pdf

May07BoardPack

ADECLetter030425.pdf
Tank93Report.pdf
Tank16Report.pdf
Tank5Report.pdf
Tank55Report.pdf
FindingsSummary.pdf
BriefingSheet.pdf

Misc

StaffFindingSummaryRev03a.doc
Tank 55 - Weld Report1.doc
OutlineofVMTWeldReportTKEdits.doc
ListQuestionsMikeStevensAlyeskaEdits060629.doc
ListQuestionsTonyBalowskiAlyeskaEdits060629.doc
6-26-02 Draft List of Questions for Tony Bilowski.doc
6-26-02 Draft List of Questions for Mike Stevens.doc
WeldDocuments060620.doc
WeldMeetingsHandWrittenNotes0606.pdf
WeldDocuments060614.doc
WeldNotes060601.PDF
500.300.060510.HamelNSCtank.pdf
ChuckHammelGlenPlumlee.pdf

SlewisInquiry

WTRXO52Tank55DoorPg1.pdf
WTRX052TankDOORPg2.pdf
WTRX052ColumnPlatesPg1.pdf
WTRTank55SUMPExt.pdf

Indicates an electronic file folder.

SourceDocuments

DS012.PDF

ADEC Tank Docs

CD_1

Photo's 1

Photo's2

Photos 3

Tank 5

Tank 55

Photo's TK 55

TK 55 GUIDE CLIPS

Guide Clips p.1.doc

TK 55 SUMP WTR

TK. 55 NDE Sump attachments .xls
Tank 55 SUMP Ext.doc
TK 55 WTR SUMP FLOOR PLATES.doc
TK 55 WTR SUMP piping.doc
TK. 55 NDE SUMP .xls

TK 55 WTR COLUMN PLATES

WTR X052 Column Plates Pg. 1.doc

TK 55 WTR FLOOR

WTR X052 Tank 55 Floor page 1.doc
WTR X052 Tank 55 Floor page 2.doc
WTR X052 Tank 55 Floor page 3.doc

WTR ANNULAR RING

TK. 55 NDE ANULLAR RING .xls
WTR X052 Tank 55 Annular page 1.doc

WTR TK 55 DOOR

TK 55 LUG REPAIR

WTR XO52 LUG REMOVAL pg 2.doc
WTR XO52 LUG REMOVAL pg1.doc

NDE Request Tank 55 RT .xls
NDE Request Tank 55 weld repair.xls
TK. 55 NDE door sheet .xls
WTR XO52 Tank 55 Door Pg.1.doc
WTR XO52 Tank 55 Door Pg.2.doc
WTR XO52 Tank 55 Door Pg.3.doc
WTR XO52 Tank 55 Door Pg.4.doc

Tank 55 Arc Strike Repair Ext.doc

Tank 55 Ballard Ext.doc
Tank 55 Shell nozzles (2).xls
Tank 55.xnk

Tank 93
photos 4
README.TXT
Tank 16.xnk
Misc E-mail.xnk

important docs

060510Hamel.PDF
060516Hamel.PDF
060518Hamel.PDF
021011ADEC.PDF
030404ADEC.PDF
030425ADEC.PDF

JPO Info

503.300.031211.APSCbwtTanks.pdf
500.300.030702.APSCcorMonit.pdf
500.300.030702.APSCcpSystem.pdf
500.300.030813.APSCbwtTanks.pdf
500.300.031121.APSCtnkReqst.pdf
500.300.060510.HAMELnsTank.pdf
500.300.060512.APSCHamelCmt.pdf
500.300.060516.HamelrespVMT.pdf
500.300.060518.HAMELvmtTank.pdf
500.400.060524.APSCweldInv.pdf
503.300.031028.APSCreqInsp.pdf
500.300.021220.APSCinspProg.pdf
500.300.030129.APSC2002Acmp.pdf
500.300.030131.APSCcrudeTnk.pdf
500.300.030214.APSCtnkSched.pdf
500.300.030306.ADECps12Tnks.pdf
500.300.030318.APSCps12Tnk.pdf
500.300.030410.APSCinspSchd.pdf
500.300.030509.APSCweldActv.pdf
030404ADEC.PDF
030425ADEC.PDF
500.107.020625.APSCweldBref.pdf
500.300.020625.APSCweldProj.pdf
500.300.020920.APSCtnk5Repr.pdf
500.300.020925.APSCtnk55Inf.pdf
500.300.021010.APSCcrudeIns.pdf
500.300.021011.ADECtnkReprs.pdf
500.300.021016.APSCtnkReprs.pdf

000128APSC.PDF
000228APSC.PDF
000308.APSC.PDF
010319JPO.PDF
010402APSC.PDF
010418APSC.PDF
020129APSC.PDF
020620JPO.PDF
020627ADEC.PDF
020701APSC.PDF
030324APSC.PDF

Alyeska
NewcomerCoverEmailForGJonesQandA.pdf
RCAC QuestionsAnsweredByGregJones.doc
ADEC Weld Report Cover Letter.pdf
APSC Controlled Report_2002 Valdez Tank Project Review final.pdf
500.410.060703.APSCtnkRev02.pdf
060512APSC.PDF

Reference Material Provided by Alyeska

Tank 55 documents requested and supplied by Alyeska

Column Guides.JPG
DSC00034.JPG
DSC00035.JPG
DSC00038.JPG
SKMBT_C35207073012050.pdf
stillingwell1.JPG
stillingwell2.JPG
stillingwellroof2.JPG
Sump1.JPG
Terminal Fuel Tanks Report (624) 2005.ZIP
2004.XLS
2006 (2).XLS
2007.XLS

Hardcopy Documents

Tank 55
Drawings
Material specifications of tank wall
MTR of wall material - **Unable to locate**
Inspection reports that verify the tank doorsheet filler material - Unable to locate
Hydrotext exemption - **Unable to locate**
Floor replacement drawings
TMPS of door sheet
API 653 report

Welding sequence - **Unable to locate**
Project report - X052-T411
Inspection report - X052-T500
IM manual/plan for AST
Original design calculations - **Unable to locate**

Appendix B

figure 1 - Tank 58-TK-55 at the APSC facility in Valdez, AK

figure 2 - 58-TK-55 tank nameplate. The contract number (73-7235) and build year (1976) are legible.

figure 3 - The taped areas represent where hardness measurements were taken on the door sheet.

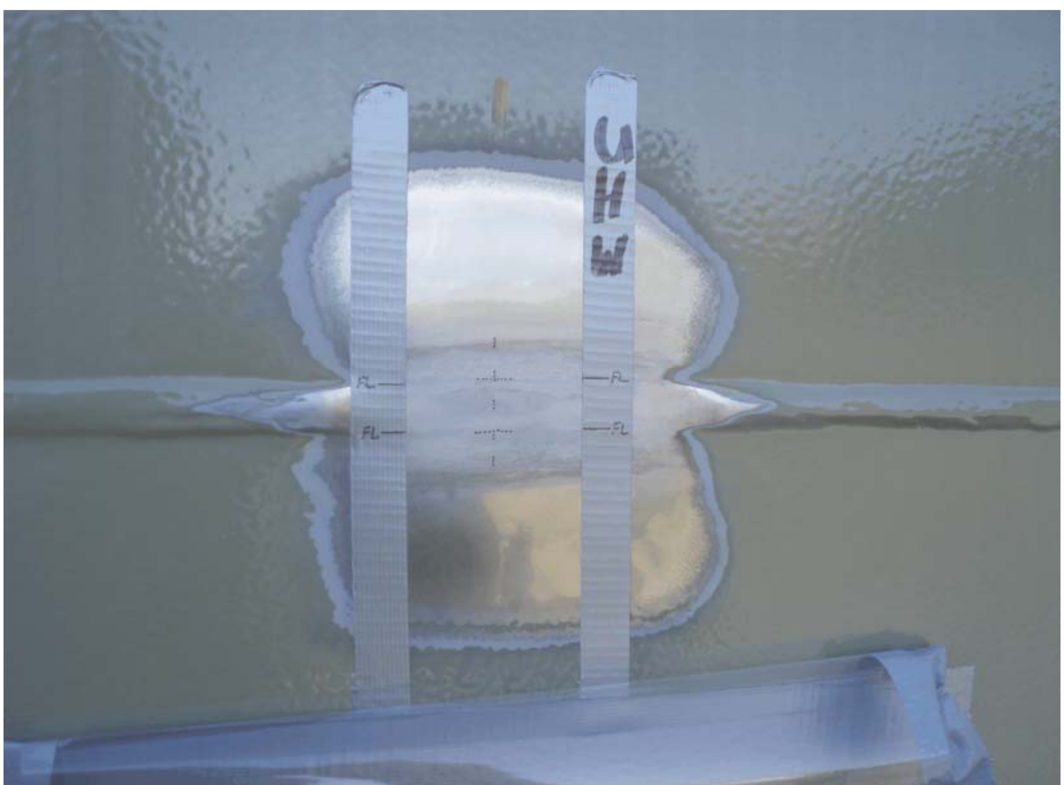


figure 4 - An example of a door sheet weld prepared for hardness testing.

figure 5 - Krautkramer Model KB-MIC 10 hardness tester used to take the hardness measurements (SN#4633).

figure 6 - Close-up of a doorsheet corner weld.

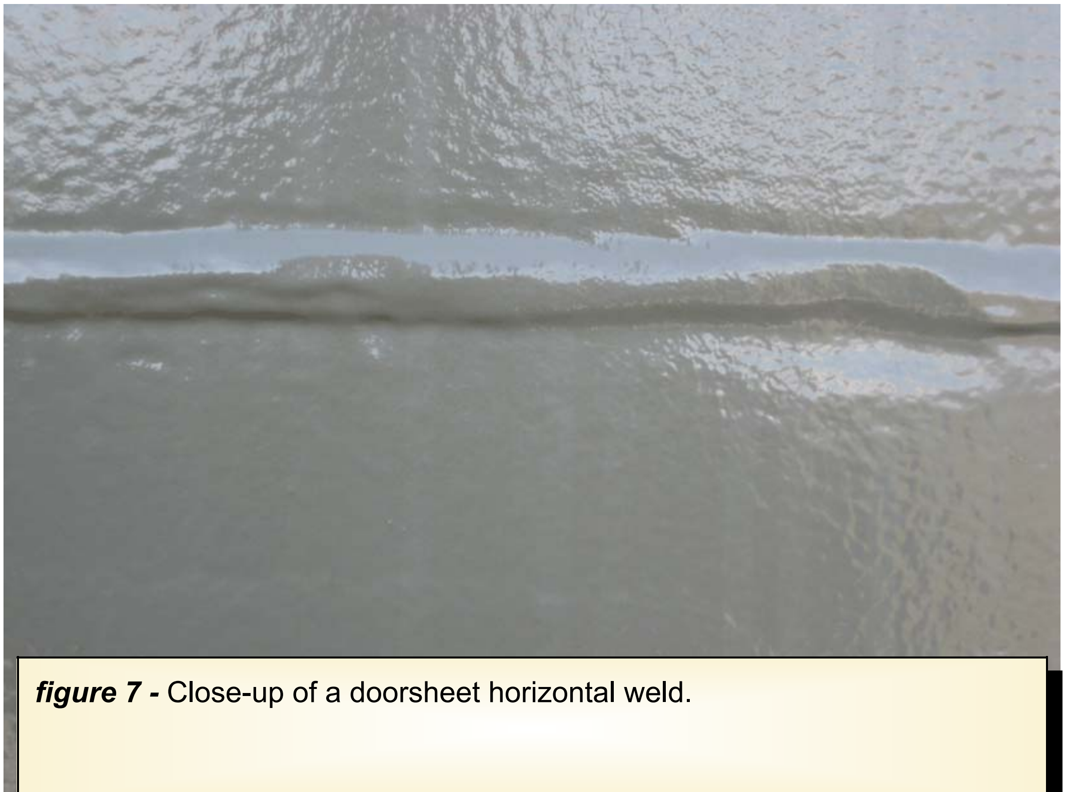


figure 7 - Close-up of a doorsheet horizontal weld.

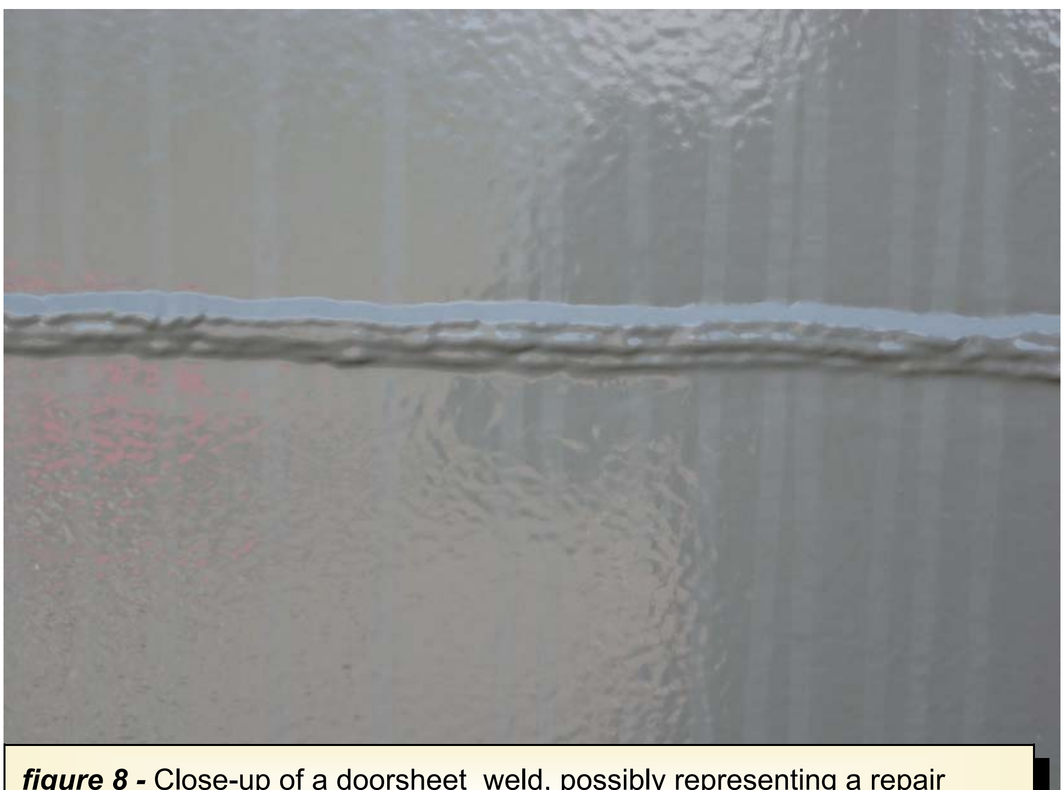


figure 8 - Close-up of a doorsheet weld, possibly representing a repair weld.

Appendix C C

table C1 - **Tank Doorsheet Hardness Measurements in 10Kg Vickers Units**										Thk. (In.)
Location	BM-1	HAZ-1	WM-CL	HAZ-2	BM-2	HAZ-LVT	HAZ-LVB	HAZ-RVT	HAZ-RVB	RWT
LVW	108	107	122	114	113	118	109	107	108	0.312.5
RVW	115	105	126	103	107	126	127	112	111	0.310
UHW	101	136	135	115	112	116	112	124	108	0.305

Notes:
Hardnesses are an average of three readings or more
SM 41 T.S. = 58ksi-73ksi (122-156 Vickers)
E7018-1 electrode = 70ksi min. (~150 Vickers)
BM = base metal
WM-CL = weld metal center line
HAZ = heat-affected zone
LVT = left vertical top
LVB = left vertical bottom

Appendix D C

Table D1

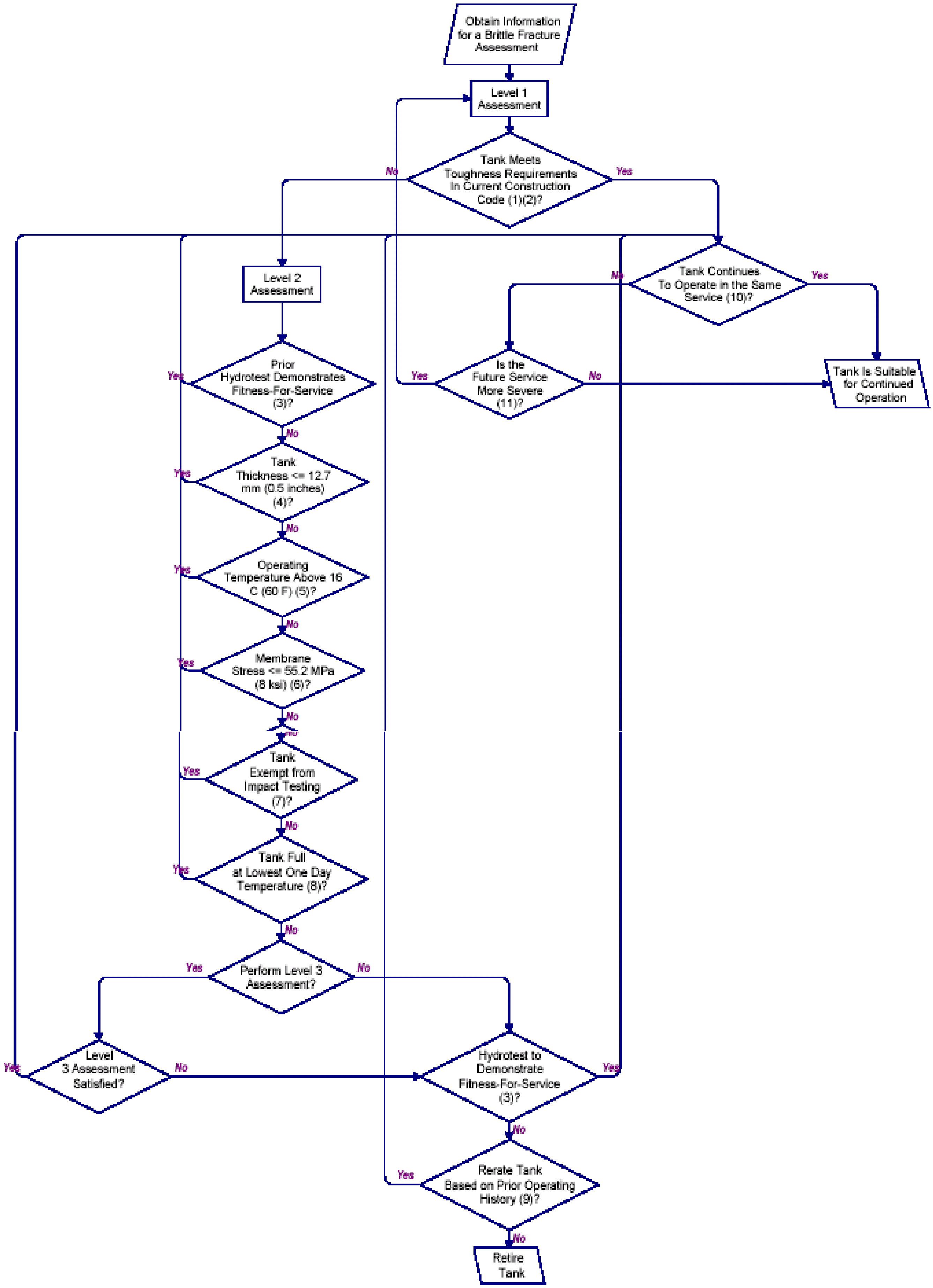
Comparison of Welding Procedure Specification (WPS) Revisions in Accordance with ASME Section IX, QW-253

Applicable Essential or Supplementary Essential Variable	TANCO WPS			
	T-400-2G-1 Rev. 3	T-400-2G-1 Rev. 4	T-400-3G-1 Rev. 4	T-400-3G-1 Rev. 5
Base Metal Group	2	**1** or 2	2	**1** or 2
Base Metal Thickness Range Impacts Minimum	.625" min.	.625" min. **Group 2 to** **Group 2 &** **.280" min.** **Group 1 or 2 to** **Group 1 or 2**	.625" min.	.625" min. **Group 2 to** **Group 2 &.** **.280" min.** **Group 1 or 2 to** **Group 1 or 2**
Base Metal Thickness Qualified	.625-1.25" Group 2 to Group 2	.625-1.25" Group 2 to Group 2 & **.280-.560"** **Group 1 or 2 to** **Group 1 or 2**	.625-1.25" Group 2 to Group 2	.625-1.25" Group 2 to Group 2 & **.280-.560"** **Group 1 or 2 to** **Group 1 or 2**
P-No. Qualified	1	1	1	1
F-Number	3 & 4	3 & 4	3 & 4	3 & 4
A-Number	1	1	1	1
Electrode Diam. > ¼ in.	E6010: 1/8, 5/32 E7018-1:1/8 5/32, 3/16	E6010: 1/8, 5/32 E7018-l: **3/32**, 1/8, 5/32, 3/16	E6010: 1/8, 5/32 E7018-l, 3/32, 1/8, 5/32	E6010: 1/8, 5/32 E7018-1: 3/32, 1/8, 5/32
AWS class.	E6010/E7018-1	E6010/E7018-1	E6010/E7018-1	E6010/E7018-1
Deposit weld thickness	3/16" or less	3/16" or less	3/16" or less	3/16" or less
Position	2G	2G	3G	3G
Preheat	150°F for T<l"& 210°F for T<1"	150°F for T<l"&210°Ffor T<1"	150°F for T < l"&210°Ffor T<1"	150°F for T< l"&210°F for T<1"
PWHT	N/A	N/A	N/A	N/A
Increase in Heat Input	46,800 J/In.	46,800 J/In.*	46,800 J/In.	46,800 J/In.*
Current or polarity	DC Reverse	DC Reverse	DC Reverse	DC Reverse

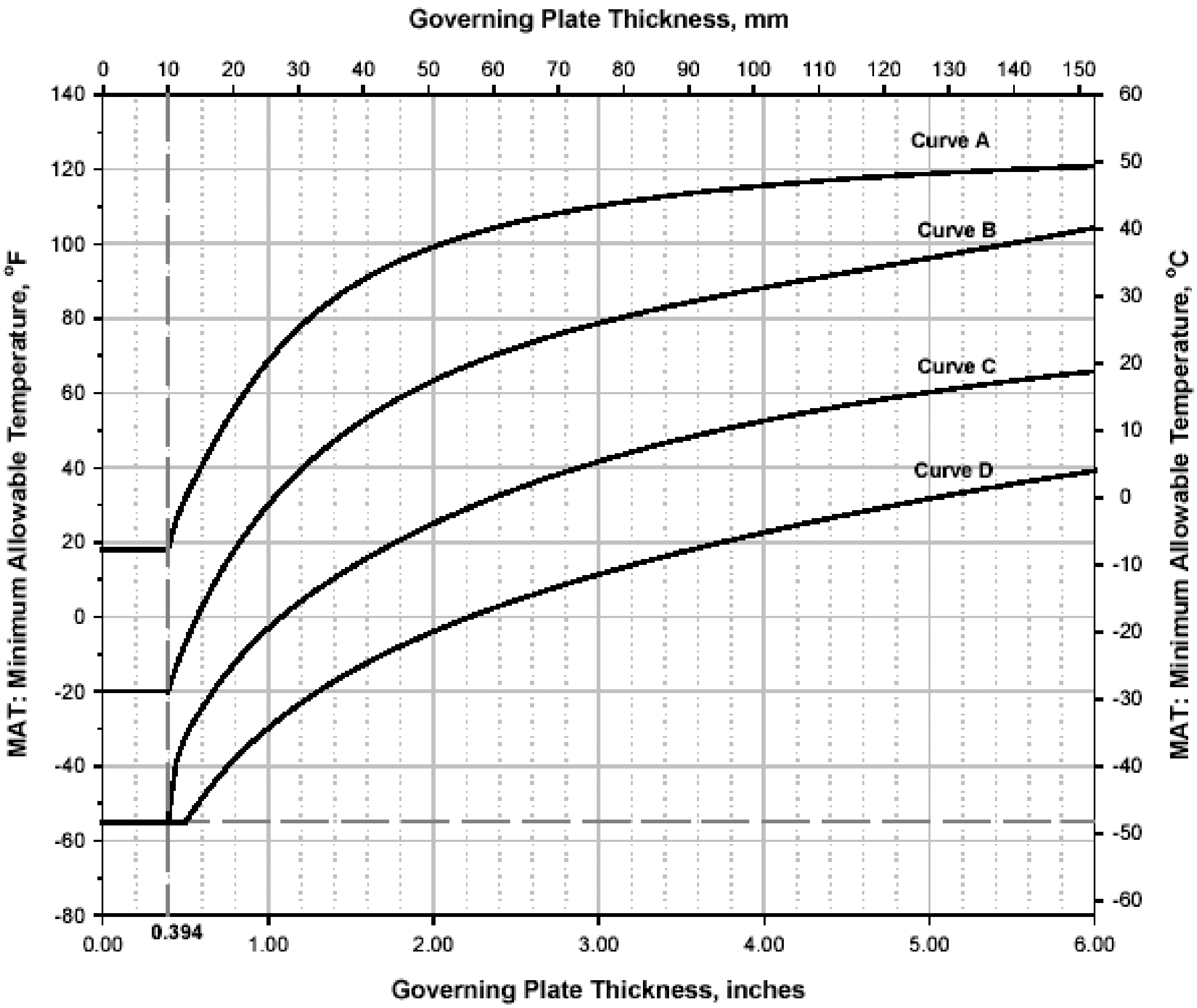
- Should have been 40,800 J/In. for base metal thicknesses of 0.280-0.566-inches.

indicates change from previous WPS version

Appendix E C



Obtain Information for a Brittle Fracture Assessment
Level 1 Assessment
Tank Meets Toughness Requirements In Current Construction Code (1)(2)?
No
Yes
Level 2 Assessment
Tank Continues To Operate in the Same Service (10)?
No
Yes
Prior Hydrotest Demonstrates Fitness-For-Service (3)?
Yes
Is the Future Service More Severe (11)?
Yes
No
Tank Is Suitable for Continued Operation
No
Tank Thickness <= 12.7 mm (0.5 inches) (4)?
Yes
No
Operating Temperature Above 16 C (60 F) (5)?
Yes
No
Membrane Stress <= 55.2 MPa (8 ksi) (6)?
Yes
No
Tank Exempt from Impact Testing (7)?
Yes
No
Tank Full at Lowest One Day Temperature (8)?
Yes
No
Perform Level 3 Assessment?
Yes
No
Level 3 Assessment Satisfied?
Yes
No
Hydrotest to Demonstrate Fitness-For-Service (3)?
Yes
No
Rerate Tank Based on Prior Operating History (9)?
Yes
No
Retire Tank



Governing Plate Thickness, mm
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
MAT: Minimum Allowable Temperature, °F
140
120
100
80
60
40
20
0
-20
-40
-60
-80
MAT: Minimum Allowable Temperature, °C
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
Curve A
Curve B
Curve C
Curve D
0.00
0.394
1.00
2.00
3.00
4.00
5.00
6.00
Governing Plate Thickness, inches

Table 3.3
Assignment Of Materials To The Curves In Figure 3.3

Curve	Material (1), (2), (6)
A	1. All carbon and all low alloy steel plates, structural shapes and bars not listed in Curves B, C, and D below. 2. SA-216 Grades WCB and WCC if normalized and tempered or water-quenched and tempered; SA -217 Grade WC6 if normalized and tempered or water-quenched and tempered 3. The following specifications for obsolete materials: A7, A10, A30, A70, A113, A149, A150 (3). 4. The following specifications for obsolete materials from the 1934 edition of the ASME Code, Section VIII: S1, S2, S25, S26, and S27 (4). 5. A201 and A212 unless it can be established that the steel was produced by a fine-grain practice (5)
B	1. SA-216 Grades WCA if normalized and tempered or water-quenched and tempered SA-216 Grades WCB and WCC for thicknesses not exceeding 2 inches if produced to a fine grain practice and water-quenched and tempered SA -217 Grade WC9 if normalized and tempered SA-285 Grades A and B SA-414 Grade A SA-442 Grade 55>1 in. if not to fine grain practice and normalized SA-442 Grade 60 if not to fine grain practice and normalized SA-515 Grades 55 and 60 SA-516 Grades 65 and 70 if not normalized SA-612 if not normalized SA-662 Grade B if not normalized 2. Except for cast steels, all materials of Curve A if produced to fine grain practice and normalized which are not listed for Curve C and D below; 3. All pipe, fittings, forgings, and tubing not listed for Curves C and D below; 4. Parts permitted from paragraph UG-11 of the ASME Code, Section VIII, Division 1, shall be included in Curve B even when fabricated from plate that otherwise would be assigned to a different curve. 5. A201 and A212 if it can be established that the steel was produced by a fine-grain practice.
C	1. SA-182 Grades 21 and 22 if normalized and tempered. SA-302 Grades C and D SA-336 Grades F21 and F22 if normalized and tempered SA-387 Grades 21 and 22 if normalized and tempered SA-442 Grades 55 < 1 in. if not to fine grain practice and normalized SA-516 Grades 55 and 60 if not normalized SA-533 Grades B and C SA-662 Grade A 2. All material of Curve B if produced to fine grain practice and normalized and not listed for Curve D below
D	SA-203 SA-442 if to fine grain practice and normalized SA-508 Class 1 SA-516 if normalized SA-524 Classes 1 and 2 SA-537 Classes 1 and 2 SA-612 if normalized SA-662 if normalized SA-738 Grade A

Appendix F C

Listing of Acronyms

API - American Petroleum Institute

APSC - Alyeska Pipeline Service Company

ASME - American Society for Mechanical Engineers

ASTM - American Society for Testing Materials

BLM - Bureau of Land Management

FW - Field Weld

HAZ - Heat Affected Zone

JIS - Japanese Institute for Steel

JPO - Joint Pipeline Office

PQR - Procedure Qualification Record

PWSRCAC - Prince William Sound Regional Citizens Advisory Council

VMT - Valdez Marine Terminal

WPS - Welding Procedure Specification

WTR - Weld Tracking Report (same as WTS)

WTS - Weld Tracking Sheet