SEP 30 1994
35 Station 21

ENGINEERING DATA TRANSMITTAL

Page 1 of 1
1. EDT № 141024

2. To: (Receiving Organization) Mechanical Equipment/ Inservice Inspection / 18230	3. From: (Originating Organization) Materials Engineering/8D330	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: FFTF	6. Cog. Engr.: L. D. Blackburn	7. Purchase Order No.: N/A

8. Originator Remarks:

APPROVAL/RELEASE

9. Equip./Component No.: N/A

10. System/Bldg./Facility: N/A

11. Receiver Remarks:

12. Major Assm. Dwg. No.: N/A

13. Permit/Permit Application No.: N/A

14. Required Response Date: 9-94

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	WHC-SD-FF-ER-099		0	Interim Storage of Sodium in Ferritic Steel Tanks at Ambient Temperature	Q	1	1	

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
1	1	Cog.Eng. WF Brehm	MBPalm for WFB	9/20/94	H5-67						
1	1	Cog. Mgr. LD Blackburn	LD Blackburn	9-20-94	H5-67						
1	1	QA AK Sharma	AKSharma	9-23-94	H5-60						
		Safety									
		Env.									

18.
L. D. Blackburn
LDBlackburn 9-26-94
Signature of EDT Originator — Date

19.
SBowman 9/27/94
C. G. McCargar
CGMcCargar 9/27/94
Authorized Representative for Receiving Organization — Date

20.
W. F. Brehm
WFBrehm 9-28-94
Cognizant Manager — Date

21. DOE APPROVAL (if required)
Ctrl. No.
☐ Approved
☐ Approved w/comments
☐ Disapproved w/comments

BD-7400-172-2 (04/94) GEF097

eb

MASTER

BD-7400-172-1 (07/91)

DISCLAIMER

RELEASE AUTHORIZATION

Document Number:	WHC-SD-FF-ER-099, REV. 0
Document Title:	Interim Storage of Sodium in Ferritic Steel Tanks at Ambient Temperature
Release Date:	9/29/94

* * * * * * * * * * * * *

This document was reviewed following the procedures described in WHC-CM-3-4 and is:

APPROVED FOR PUBLIC RELEASE

* * * * * * * * * * * * *

WHC Information Release Administration Specialist:

N. L. Solis N.L. SOLIS 9/29/94

(Signature) (Date)

A-6001-400 (07/94) WEF256

SUPPORTING DOCUMENT

1. Total Pages 9

2. Title

Interim Storage of Sodium in Ferritic Steel Tanks at Ambient Temperature

3. Number

WHC-SD-FF-ER-099

4. Rev No.

0

5. Key Words

Sodium Storage Tanks
Ferritic Steel
Brittle Fracture

APPROVED FOR PUBLIC RELEASE
9/29/94 D. Dolie

6. Author

Name: L. D. Blackburn

L D Blackburn
Signature

Organization/Charge Code 8D330/B1151

7. Abstract

Sodium tanks originally fabricated for elevated temperature service in the Clinch River Breeder Reactor Plant (CRBRP) will be used to store sodium removed from the Fast Flux Test Facility (FFTF) in the Sodium Storage Facility (SSF) at ambient temperature. This report presents an engineering review to confirm that protection against brittle fracture of the ferritic steel tanks is adequate for the intended service.

8. ~~PURPOSE AND USE OF DOCUMENT - This document was prepared for use within the U.S. Department of Energy and its contractors. It is to be used only to perform, direct, or integrate work under U.S. Department of Energy contracts. This document is not approved for public release until reviewed.~~

~~PATENT STATUS - This document copy, since it is transmitted in advance of patent clearance, is made available in confidence solely for use in performance of work under contracts with the U.S. Department of Energy. This document is not to be published nor its contents otherwise disseminated or used for purposes other than specified above before patent approval for such release or use has been secured, upon request, from the Patent Counsel, U.S. Department of Energy Field Office, Richland, WA.~~

9. Impact Level Q

10. RELEASE STAMP

OFFICIAL RELEASE
BY WHC
DATE SEP 30 1994
35 Station 21

INTERIM STORAGE OF SODIUM IN FERRITIC STEEL TANKS AT AMBIENT TEMPERATURE

October 1994

Prepared by: LD Blackburn 9-20-94
L. D. Blackburn, Fellow Engineer
Materials Engineering
Date

Reviewed by: F H Huang 9-20-94
F. H. Huang, Principal Scientist
Materials Engineering
Date

Approved by: WBPalmer for WFB. 9/20/94
W. F. Brehm, Manager
Materials Engineering
Date

CONTENTS

INTERIM STORAGE OF SODIUM IN FERRITIC STEEL TANKS AT AMBIENT TEMPERATURE

1.0 INTRODUCTION

Several tanks for containing sodium were fabricated for use in the Clinch River Breeder Reactor Plant (CRBRP) and were subsequently stored at the Hanford Site after termination of the CRBRP project. These tanks are now being considered for interim storage of sodium removed from the Fast Flux Test Facility (FFTF). The proposed service for these tanks is to fill them with liquid sodium, let the liquid metal solidify, store the sodium-filled tanks at ambient temperature, then reheat the sodium to liquid and remove it from the tanks for ultimate disposal. For three of the tanks (sodium dump tanks), the original design was based only on liquid sodium service at elevated temperature. For the fourth tank (ex-containment storage tank), the original design included operation with liquid sodium and also encompassed lower temperatures where sodium would solidify. This report describes the results of an engineering review to establish that control of ambient temperature in the Sodium Storage Facility (SSF) is adequate to protect against brittle fracture of the ferritic steel tanks.

2.0 BACKGROUND

The following subsections present information on the ex-containment storage tanks, the sodium dump tanks, and methods of brittle fracture control.

2.1 EX-CONTAINMENT STORAGE TANK

This tank was constructed to requirements of Section III of the ASME Boiler and Pressure Vessel Code (hereafter called the ASME Code) as a Class 3 component and bears the appropriate code symbol stamp (ASME 1975a). Available documentation included drawings, the ASME N-1 report form that specified a lowest service temperature of +10 °C (+50 °F) and a lowest construction temperature of -12 °C (+10 °F), and material test reports giving results of Charpy V-notch impact tests. Neither a design specification nor a design report is available. Information on postweld heat treatment or nondestructive examination of the tank was not available. The materials and maximum section thicknesses obtained from a review of the drawings are as follows:

Plate	SA 515 Grade 60	19 mm (3/4 in.) for shell 38 mm (1.5 in.) for stiffeners
Pipe	SA 106 Grade B	8 mm (0.322 in.) wall
Nozzles	SA 210 Grade A-1	16 mm (0.625 in.) wall
Pipe caps	SA 234 Grade B WPB	3 mm (0.124 in.) wall.

2.2 SODIUM DUMP TANKS

These tanks were constructed to the requirements of Section III of the ASME Code as a Class 2 component and bear the appropriate code symbol stamp (ASME 1975b). Available documents included drawings, ASME N-1 report form, operation and maintenance manual (O&MM), and reports by the vendor of magnetic particle and liquid penetrant examination of the transition ring forgings. Copies of the design specification or the design report were not available. The ASME N-1 report form records that the tank was given a postweld heat treatment at 565 to 593 °C (1,050 to 1,100 °F) for 2 to 3 hours. The O&MM gave the operating temperature range for the tanks as 204 to 357 °C (400 to 675 °F). Material test reports did not include Charpy V-notch test results. The materials and maximum section thicknesses obtained from a review of the drawings are as follows:

Plate	SA 515 Grade 60	29 mm (1.125 in.) for shell
Forgings	SA 266 Class 2	>76 mm (>3 in.) for transition ring
Pipe	SA 106 Grade B	7 mm (0.280 in.) wall.

2.3 BRITTLE FRACTURE CONTROL

A wide range of ferritic steels are susceptible to brittle fracture at "low" temperatures. Depending on composition and microstructure, "low" temperature may range from normal ambient temperature to cryogenic temperatures. The common low-strength steels used in the tanks undergo a transition from brittle fracture to ductile fracture at moderate temperatures (e.g., +93 °C [+200 °F]). The brittle behavior at low temperatures can lead to fast fracture at stresses below the yield strength, producing catastrophic rupture. Brittle fracture within the normal temperature range of engineering applications can occur only if the component contains a crack-like flaw. Two factors that increase the propensity for brittle fracture are thick sections and high loading rates.

The ASME Code (e.g., Section III [ASME 1992a] or Section VIII [ASME 1992b]) provides protection against brittle fracture by requiring the design to identify the lowest service temperature and specifying rules to ensure that materials of construction exhibit ductile behavior at this temperature. The basic approach in the ASME Code requires impact testing (either drop weight tests or Charpy V-notch tests) of the actual construction materials to demonstrate adequate resistance to brittle fracture. However, the ASME Code also provides exemptions from impact testing for selected materials on a generic basis. In addition to this approach to fracture control based on the ductile-to-brittle transition temperature, Section III of the ASME Code also allows the use of fracture mechanics calculations to demonstrate protection against brittle fracture. These calculations involve considerations of fracture toughness, maximum flaw size (as verified by nondestructive examination), and stress to show that initiation of brittle fracture is precluded.

There are some additional formalized methods of brittle fracture control. The U.S. Nuclear Regulatory Commission (NRC) has published two regulatory guides that address brittle fracture protection for ferritic steel shipping casks (NRC 1991a, NRC 1991b). The methods used for fracture control in these guides range from ensuring that material toughness is sufficient to arrest a through-thickness, rapidly propagating crack (a very conservative approach) to preventing fracture initiation at minor defects typical of good fabrication practice. Pellini (1983) presents guidelines for fracture control on which these regulatory guides were based (Holman and Langland 1981, Schwartz 1984). The Pellini guidelines use either the fracture arrest method or prevention of fracture initiation method for brittle fracture control and can be used independent of the regulatory guides for evaluating protection against brittle fracture.

3.0 EVALUATION

3.1 APPLICABLE CODES, STANDARDS, OR CRITERIA

The CRBRP tanks operating in SSF have been classified as Safety Class 2 according to the provisions of WHC-CM-1-3. This designation means that the tanks are non-safety class equipment in the nomenclature of DOE Order 6430.1A (Blackburn 1993, DOE 1989). The actual construction to ASME Section III requirements would permit classification as Westinghouse Hanford Company (WHC) Safety Class 1 (Doe Order 6430.1A safety class). However, special consideration of brittle fracture that was not part of the original design, but is now needed for this application, can be addressed by using industrial codes or standards (DOE 1989). Applicable codes or criteria for the present evaluation could include Section VIII of the ASME Code (ASME 1992b), the Pellini (1983) guidelines, or Regulatory Guide 7.11 (NRC 1991a).

3.2 EX-CONTAINMENT STORAGE TANK

The drawing for this tank specified SA 515 Grade 60 steel as the material of construction for the shell and stiffeners, with a note that substitution of SA 516 Grade 60 was acceptable. This note suggests that the original designers recognized that improved fracture resistance might be required to construct and operate the tank at ambient temperatures. The material test reports show that Charpy V-notch results for the shell and stiffeners meet ASME Code requirements for the original edition and addenda (ASME 1975a) or for the current edition (ASME 1992a) at a temperature of -12 °C (+10 °F). A number of the components for this tank have section thicknesses below 16 mm (0.625 in.) and the ASME Code permits use of such materials without impact testing. Therefore, this tank meets ASME Code requirements for operation at -12 °C (+10 °F) and is qualified for operation in SSF to this temperature.

3.3 SODIUM DUMP TANKS

There is no evidence that impact tests were performed on materials for these tanks. This finding is not surprising in view of the indication that operation below 204 °C (400 °F) was not expected. The current edition of the relevant subsection of the ASME Code (ASME 1992a) provides an exemption from impact testing when the lowest service temperature is above +66 °C (+150 °F). The ASME Code for original design (ASME 1975b) required that needed impact tests be identified in the design specification. The SA 515 Grade 60 steel specified for the tank shell is manufactured to a coarse grain-size practice and therefore has a relatively high brittle-to-ductile transition temperature. The ASME Code gives no guidance on transition temperature for SA 515 steel. The Pellini (1983) guidelines give an upper limit of +21 °C (+70 °F) for the nil-ductility transition (NDT) temperature of hot-rolled, pearlitic steels as a class; this temperature provides a conservative value intended for use in the absence of actual impact test results. When this value of NDT temperature is applied in the method of Appendix R of the current ASME Code (ASME 1992a), the lowest service temperature for the tank would be +38 °C (+100 °F). However, since the safety class designation does not require conformance to the ASME Code, it is appropriate to examine other methods that might demonstrate protection against brittle fracture at lower temperatures.

The current edition of Section VIII of the ASME Code (ASME 1992b) provides exemptions for impact testing for selected plate materials. When Figure UCS-66 of Section VIII is applied, the SA 515 shell material that is 29 mm (1.125 in.) thick is exempt from impact testing if service temperatures are above +2 °C (+35 °F). The Section VIII method is obviously less conservative than the Section III method described in the preceding paragraph. However, the ring forging in the tank has a section thickness greater than 76 mm (3 in.), and if Figure UCS-66 of the code is assumed applicable for forgings, the lowest service temperature permitted without impact testing is +25 °C (+77 °F) at best.

The sodium dump tanks also can be assessed using Regulatory Guide 7.11 (NRC 1991a). The appropriate level of protection against brittle fracture is Category III in the guide. This category provides sufficient material toughness to prevent fracture initiation at minor defects typical of good fabrication practices. Impact testing is not required, even for hot-rolled steels like SA 515, provided welds are stress-relieved and inspected by nondestructive evaluation techniques. The tanks were stress-relieved and nondestructive examination was required by the ASME Code. Experience indicates that hot-rolled plate material typically does not contain defects of sufficient size to cause brittle fracture (e.g., see Stone and Pellini 1986). The focus for avoiding defects therefore falls on fabrication practices, particularly welding. However, neither the Pellini (1983) guidelines nor Regulatory Guide 7.11 provide definitive statements regarding the propensity for detrimental defects in forgings.

As a final step in this assessment, a fracture mechanics evaluation is in order to see if temperature requirements can be lowered further. The Pellini (1983) guidelines offer a straightforward assessment of the forgings by fracture mechanics methods. The operation of tanks in SSF is assumed to involve only static loading. Dynamic loading from operational transients or accidents appears to be impossible. Stresses in the tank during intended service are probably low, but this supposition has not been verified by a formal stress analysis. If stress is below 20 percent of the yield strength, the Pellini guidelines indicate fracture arrest regardless of the service temperature. Because design typically limits stress to one-half the yield strength, this stress level can be used to calculate the critical crack size for fracture initiation. With the characteristic yield strength value of 379 MPa (55,000 lbf/in^2) given in the guidelines for low-strength steels, the critical size of a semi-elliptical surface crack, if a four-to-one length-to-depth ratio is assumed, would be approximately 51-mm (2-in.) deep and 203-mm (8-in.) long at a temperature of -1 °C (+30 °F). Records of magnetic particle and liquid penetrant examinations performed by the transition ring manufacturer report that no flaw indications were observed. Although the records do not state the specific acceptance criteria, there should be no question that acceptable indications for these examinations would be far smaller than the critical crack size listed above. This evaluation does not address the issue of embedded cracks in the forgings that do not intersect the surface. The critical size for embedded flaws is larger than that for surface flaws, but there was no volumetric examination to confirm that any embedded flaw indications were acceptable. If the assumption that embedded flaws approaching critical size do not exist is judged to be an unnecessary risk, the simplest resolution may be to perform a stress analysis to see if the stresses are low enough to preclude brittle fracture regardless of embedded flaws.

4.0 CONCLUSIONS

The ex-containment storage tank meets ASME code requirements for service temperatures as low as -12 °C (+10 °F). The sodium dump tanks can be considered acceptable for service temperatures as low as -1 °C (+30 °F) with the assumption that the ring forgings do not contain large embedded flaws.

5.0 REFERENCES

ASME, 1975a, "Rules for Construction of Nuclear Power Plant Components," *ASME Boiler and Pressure Vessel Code*, Section III, Division 1, Subsection ND, Class 3 Components, 1974 Edition with Addenda through Summer 1975, American Society of Mechanical Engineers, New York, New York.

ASME, 1975b, "Rules for Construction of Nuclear Power Plant Components," *ASME Boiler and Pressure Vessel Code*, Section III, Division 1, Subsection NC, Class 2 Components, 1974 Edition with Addenda through Winter 1975, American Society of Mechanical Engineers, New York, New York.

ASME, 1992a, "Rules for Construction of Nuclear Power Plant Components," *ASME Boiler and Pressure Vessel Code*, Section III, Division 1, American Society of Mechanical Engineers, New York, New York.

ASME, 1992b, "Rules for Construction of Pressure Vessels," *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 1, American Society of Mechanical Engineers, New York, New York.

Blackburn, L. D., 1993, *Code Selection for Primary Tank, Secondary Confinement, and Process Piping of the Multi-Function Waste Tank Facility*, WHC-SD-WM-ER-190, Westinghouse Hanford Company, Richland, Washington.

DOE, 1989, *General Design Criteria*, DOE Order 6430.1A, U.S. Department of Energy, Washington, D.C.

Holman, W. R., and R. T. Langland, 1981 (under Lawrence Livermore National Laboratory contract to the NRC), *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers up to Four Inches Thick*, NUREG/CR-1815, U.S. Nuclear Regulatory Commission, Washington, D.C.

NRC, 1991a, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)*, Regulatory Guide 7.11, U.S. Nuclear Regulatory Commission, Washington, D.C.

NRC, 1991b, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Wall Thickness Greater Than 4 Inches (0.1 m)*, Regulatory Guide 7.12, U.S. Regulatory Commission, Washington, D.C.

Pellini, William S., 1983, *Guidelines for Fracture-Safe and Fatigue-Reliable Design of Steel Structures*, The Welding Institute, Abington Hall, Abington, Cambridge CB1 6AL, England.

Schwartz, M. W., 1984 (under Lawrence Livermore National Laboratory contract to the NRC), *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Greater than 4 Inches Thick*, NUREG/CR 3826, U. S. Regulatory Commission, Washington, D.C.

Stone, D. H., and W. S. Pellini, 1986, "Guidelines for Fracture Mechanics Analysis of Pressure Tank Car Structural Integrity Factors," ASME Paper No. 86-PVP-16, American Society of Mechanical Engineers, New York, New York.

WHC-CM-1-3, "Safety Classification of Systems, Components, and Structures," MRP 5.46, Rev. 4 (1991), *Management and Requirements Procedures*, Westinghouse Hanford Company, Richland, Washington.