INSPECTION REPORT

Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards

Docket No.: 72-1007

Inspection Report: 72-1007/97-204

Certificate Holder: Sierra Nuclear Corporation

Inspection Locations: Sierra Nuclear Corporation, Scotts Valley, California
March Metalfab, Incorporated, Hayward, California
Nor-Cal Metal Fabricators, Oakland, California

Dates: March 17 - 21, 1997

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ENCLOSURE 1

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Sierra Nuclear Corporation
U.S. Nuclear Regulatory Commission Inspection Report 72-1007/97-204

The team performed an inspection at Sierra Nuclear Corporation (SNC) in Scotts Valley, California, and at its fabricators' facilities in the Oakland, California, area, to followup incidents of cask seal weld failures at Palisades and Arkansas Nuclear One (ANO) nuclear power plants and to identify any information related to the cause of the failures. Additionally, the team reviewed the corrective actions for the findings in Inspection Reports Numbers 72-1007/96-204 and 96-208 regarding the Ventilated Storage Cask (VSC) dry spent fuel storage system, Model VSC-24.

The team reviewed the fabrication records for the two casks that had failed welds, interviewed personnel involved in fabricating the two casks, examined the fabrication facilities, and reviewed information available from ANO and Palisades.

The failed welds were the 1/4-inch bevel-groove seal welds between the 9-inch thick shield lid and the 1-inch thick cylindrical shell of the Multi-assembly Storage Basket (MSB). See Appendix A for a description and sketch of the welds. The welds were performed after fuel was loaded into the casks in which borated water remained. The licensees at ANO and Palisades discovered the failed welds while performing the required helium leak testing after welding was completed. After the licensees removed the defect indications, it was evident that a portion of the MSB shell wall and the weld had been involved in the failure. At Palisades, in March 1995, the defect cavity in the MSB wall was about 6-inches long, 1-3/4-inches high, and 1/8-inch deep. At ANO, in November 1996, the defect cavity was about 3-inches long, 1/2-inch high, and 1/8-inch deep. The cavities were repaired and the seal weld was completed. The repaired welds were tested by helium leak testing and liquid penetrant examination. All repaired welds passed both tests. The licensees then placed the casks in service without further incident.

On March 26, 1997, after this Nuclear Regulatory Commission (NRC) inspection, ANO found a third weld failure on another cask. The same shield-lid seal weld was involved; however, in this case the failure occurred in the root pass of the weld and was discovered by required liquid penetrant testing. The indication was initially 3/4-inches long located about 1/8 inch above the weld. After grinding, the defect was 18-inches long, extended 1/16-inch into the MSB shell, and was through the thickness of the root pass.

SNC personnel's evaluation of the Palisades weld failure concluded that the failure was caused by a subsurface lamination in the MSB shell wall. The SNC corrective action was to require the plate supplier to do an ultrasonic examination (UT) of the shell material. However, the UT acceptance criteria specified by SNC staff would accept defects up to 3 inches in diameter. This was not sufficiently sensitive to identify defects that would be of concern. At the time of the NRC inspection, SNC staff had not performed an evaluation of the November 1996 ANO weld failure nor initiated a problem report.

The licensee for Palisades performed a metallographic analysis and concluded that its weld failure was caused by hydrogen underbead cracking from an unauthorized weld repair. As corrective action, the licensee added additional nondestructive examinations (NDEs) to identify any existing underbead cracking before performing seal welding.

The licensee for ANO concluded that its weld failure was caused by lamellar tearing. As corrective action, the licensee accepted SNC's coarse UT examination for laminations. The team noted that the UT examination acceptance criteria were inadequate to detect the types of small plate defects that assist in lamellar tearing.

The team's examination identified the following:

- The physical configuration of the MSB shell-to-shield-lid weld joint was susceptible to lamellar tearing. The team noted that alternate configurations would reduce the probability of lamellar tearing. .

- SNC staff approved a seal weld, larger than that shown in the Safety Analysis Report (SAR), for use at ANO. The larger weld exacerbated the potential for lamellar tearing. The licensee for Palisades also increased its weld size under the provisions of 10 CFR 72.48.

- The weld joint geometry and environmental conditions were conducive to moisture intrusion and hydrogen underbead cracking.

- The shell material had a high carbon equivalent rating and was susceptible to underbead cracking.

- The material used generally should have weld preheat and post-heat applied to alleviate hydrogen underbead cracking. The presence of water in the cask during welding complicated the ability to have weld preheat and post-heat.

- SNC's corrective action (UT examination of the plate), was not an adequate corrective action, since it would not have detected flaws of the size involved in lamellar tearing.

- Personnel involved in the fabrication of the casks stated that they had no knowledge of unauthorized or undocumented welds.

Additionally, the team concluded that neither SNC staff nor the user licensees had performed a comprehensive root-cause analysis. Consequently, the completeness of the corrective action taken could not be assessed. The fact that multiple cask seal welds failed suggested that the problem might be generic. The team also concluded that SNC had not addressed another significant issue, the potential for delayed cracking of loaded casks.

The team considered the failure to identify the root cause of the MSB seal weld failures to be a nonconformance with 10 CFR 72.172 regarding corrective action. The safety significance of the finding was that the reasons for the failure of a cask confinement boundary were not understood. Therefore, the potential existed for additional failures, perhaps undetected and perhaps delayed, of the confinement boundary at the shield-lid-to-MSB-shell seal weld. Further, the root cause might involve other cask confinement welds such as the structural lid closure weld. Although the failure of both the cask's inner shield-lid seal weld and outer structural-lid weld would not pose an off-site threat to public health and safety, such an occurrence would cause the loss of the helium atmosphere inside the cask. This loss could result in cladding degradation and future fuel handling and retrievability problems. Since one of the design requirements of the cask is the long-term protection of the fuel cladding [10 CFR 122(h)], such degradation would be unacceptable.

The team identified two other nonconformances regarding corrective action:

- A nonconformance with 10 CFR 72.172 was identified for failure to take corrective action to prevent recurrence of conditions adverse to quality. SNC staff had not requested a change to the drain-down time limit specified in the Certificate of Compliance (COC), Technical Specification (TS) 1.2.10. In April 1996, reactor licensees had determined the TS time limit to be nonconservative and had informed SNC. However, at the time of this inspection, SNC staff had not requested an amendment to the COC. The safety significance of the nonconformance was high because future users might not use time limits appropriate to their plant conditions. Inappropriate time limits could lead to boiling and a consequent reduction in the margin to criticality.

- A nonconformance with 10 CFR 72.172 was identified for failure to take corrective action to prevent recurrence. SNC staff failed to update the SAR to include a requirement to perform nondestructive examinations after removing temporary attachments. SNC staff was aware of the SAR deficiency in February 1995.

The team reviewed the implementation of corrective actions for the findings identified during two previous NRC inspections performed at SNC and its VSC-24 fabrication vendor, March Metalfab Incorporated (MMI); Inspection Reports 72-1007/96-204 and 96-208. These findings related to nonconformances with the requirements for the classification of components, procedure control, nonconforming material control, and measuring and test equipment control. The team concluded that SNC and MMI staff's corrective actions for the individual findings were adequately implemented. However, the team identified a new nonconformance with 10 CFR 72.164 regarding MMI's control of measuring and test equipment. Contrary to procedures, one gage had not been marked with a unique number and did not have a calibration label. Additionally, there was no procedure describing the proper use of the gage. Since one of the 1996 nonconformances had dealt with a lack of controls for measuring and test equipment, the team further concluded that SNC staff had neither determined the root cause of that nonconformance, nor taken action appropriate to prevent recurrence.

Table 1 presents a summary of the nonconformances identified.

Table 1
Summary of Nonconformances

10 CFR Section	Description of Nonconformances	Number	Report Location Section
72.172	Corrective Action	3	3.2.1, 3.2.2, 3.2.3
72.164	Control of Measuring and Test Equipment	1	3.3

PERSONS CONTACTED

The team held an entrance meeting on March 17, 1997, to present the scope and objectives of the NRC inspection. On March 21, 1997, at the conclusion of the inspection, the team had an exit meeting with SNC management in the SNC offices in Scotts Valley, California, to present the findings of the inspection. The individuals present at the entrance and exit meetings are listed in Table 2.

Table 2
Entrance/Exit Meeting Attendees

NRC		
**	W. F. Kane	Director, Spent Fuel Project Office (SFPO)
**	J. P. Jankovich	Chief, Transportation and Storage Inspection Section, SFPO
*	P. P. Narbut	Team Leader, SFPO
*	C. K. Battige	Materials Engineer, SFPO
****	P. V. Joukoff	Special Agent, OI, Region IV, Walnut Creek Field Office
*	T. J. Kobetz	Project Manager, SFPO
*	T. O. Matula	Inspector, SFPO
Idaho National Engineering and Environmental Laboratory (INEEL)		
*	M. Anderson	Nondestructive Examination Specialist,
Sierra Nuclear Corporation		
*	A. J. McSherry	President
*	G. N. Dixon, Jr.	Vice President, Quality Assurance/Control
*	B. A. Chechelnitsky	Engineering Manager
**	W. J. McConaghy	Manager of Licensing
*	K. E. Moeckel	Manager of Products
**	J. E. Rollo	Project Manager
**	M. A. Simpson	Quality Assurance/Quality Control Coordinator
*	T. J. Wenner	Executive Vice President of Operations
British Nuclear Fuels Limited		
**	K. E. Wooley	Head of Technology Development
Consumers Energy, Palisades Plant		
***	J. P. Broschak	Dry Fuel Storage Project Manager
***	D. Engle	Licensing Engineer
***	D. Jones	Audit Supervisor, Nuclear Performance Assessment Department
*	D. L. Morse	Nuclear Fuels Quality Lead, Palisades
***	G. Szczotka	Manager, Nuclear Performance Assessment Department
***	E. Zernick	Dry Fuel Storage Engineering Lead
Entergy Nuclear Inc., Arkansas Nuclear One Plant		
***	J. J. Dosa	Licensing Engineer
***	R. L. Kellar	Dry Fuel Project Manager
***	S. J. McWilliams	Manager, Plant Modifications/ Dry Fuel Project Lead
***	D.R. Williams	Senior Engineer Dry Fuel Project
March Metalfab Incorporated		
****	R. Allmon	Project Manager
****	D. C. Campbell	Nuclear Quality Assurance Manager
Nor-Cal Metalfab Incorporated		
****	S. Bailey	Production Manager
Wisconsin Electric Power Company, Point Beach Plant		
***	T. Pridgeon	Manager, Phase II Recovery
*	Present at entrance and exit meetings.	
**	Present at exit meeting only.	
***	Present at the exit meeting by telephone conference.	
****	Principle contacts but not at the entrance and exit meetings.	

REPORT DETAILS

1. INSPECTION OBJECTIVES AND SCOPE

The objective of the team inspection was to examine information related to incidents of cask seal weld failures at Palisades and ANO nuclear power plants and to identify information related to the causes of the failures. Additionally, the team reviewed the corrective actions for the findings in Inspection Reports Numbers 72-1007/96-204 and 96-208 regarding the Ventilated Storage Cask (VSC) dry spent fuel storage system, Model VSC-24.

The team performed the inspection at SNC in Scotts Valley, California, and at two of SNC's fabrication contractors' facilities: March Metalfab Incorporated (MMI) in Hayward, California, and Nor-Cal Metal Fabricators in Oakland, California.

The team reviewed the fabrication records for the two casks that had failed welds, interviewed personnel involved in fabricating the two casks, examined the fabrication facilities, and reviewed information available from ANO and Palisades.

2. BACKGROUND

The failed welds were the 1/4-inch bevel-groove seal welds between the 9-inch thick shield lid and the 1-inch thick cylindrical shell of the MSB. See Appendix A for a description and sketch of the welds. The welds were performed after fuel was loaded into the casks in which borated water remained. The licensees for ANO and Palisades discovered the failed welds when the required helium leak testing was performed after the completion of the welds. After the licensees removed the defect indications, it was evident that a portion of the MSB shell wall had been involved in the failure. At Palisades, in March 1995, the defect cavity in the MSB wall was about 6-inches long, 1-3/4-inches high, and 1/8-inch deep. At ANO, in November 1996, the defect cavity was about 3-inches long, 1/2-inch high, and 1/8-inch deep. The cavities were repaired and the seal weld was completed. The repaired welds underwent helium leak testing and liquid penetrant examination (PT). All repaired welds passed both tests. The licensees then placed the casks in service without further incident.

After this Nuclear Regulatory Commission (NRC) inspection, a third failure occurred. On March 26, 1997, a weld failure on a different cask occurred at ANO. The same shield-lid seal weld was involved; however, in this case the failure occurred in the root pass of the weld and was discovered by required PT testing. Initially, the indication was 3/4-inch long located about 1/8-inch above the weld. After grinding, the defect was 18-inches long and extended 1/16-inch into the MSB shell, and was through the thickness of the root pass.

SNC staff concluded that the Palisades failure was caused by a subsurface lamination in the MSB shell wall. The SNC corrective action was to require the plate supplier to do a UT examination of the shell material. The team determined that the UT specified by SNC staff would only reject defects greater than 3 inches in diameter. At the time of the NRC inspection, SNC staff had not performed an evaluation of the November 1996 ANO weld failure nor initiated a problem report.

The licensee at Palisades, based on a metallographic analysis, concluded that the weld failure was caused by hydrogen underbead cracking from an unauthorized weld repair. The licensee's corrective action was to do additional NDE to identify existing underbead cracking before doing seal welding.

The licensee for ANO concluded that its weld failure was caused by lamellar tearing. The licensee's corrective action was to accept SNC's coarse UT examination for laminations. The team determined that the UT examination was inadequate to reject the types of small plate defects which assist in lamellar tearing.

3. INSPECTION RESULTS

3.1 TEAM EVALUATIONS OF THE FAILED MULTI-ASSEMBLY BASKET WELDS

The team examined eight areas:

- Root-cause analysis review
  The team reviewed the problem reports, root-cause analysis, and corrective action taken by SNC staff in response to the two weld failures.
- Personnel interviews
  In response to the Palisades problem report conclusion that the failure was caused by an undocumented weld repair, the team interviewed personnel who may have had knowledge of unauthorized and undocumented welds.
- Fabrication records review
  Fabrication records for the two casks that failed were reviewed in detail for any information which might provide insight into the reasons for failure.
- Nonconformance review
  Nonconformance Reports (NCRs) and Supplier Deviation Requests (SDRs) applicable to the two casks were reviewed in detail for insight into the reasons for failure.
- Nondestructive examination review
  The NDE records and methodology applied to the casks were examined and evaluated for adequacy and for insight into the material quality.
- Design review
  A review of the weld joint design was performed to determine if the joint design was in accordance with industry standards.
- Materials review
  Materials involved in the fabrication of the two involved MSBs were examined to determine if they met the chemical and physical properties required by their material specifications.
- Welding procedure review
  Welding procedures were reviewed to determine if the procedures were adequate.

3.1.1 ROOT-CAUSE ANALYSIS

Inspection Scope

The team examined SNC's problem reports and supporting information about the shield-lid-to-MSB-seal-weld failures at Palisades and ANO.

Observations and Findings

SNC staff prepared Corrective Action Request (CAR) 95-06, dated March 3, 1995, to document the seal weld failure that occurred at the Palisades plant on cask CMSB-05. SNC staff concluded that the failure was caused by a subsurface laminar defect in the MSB shell wall. SNC staff's corrective action was to revise the fabrication specification to include a UT of the shell material at the suppliers. As discussed in detail in Section 3.1.5 below, the UT acceptance criteria were not effective in identifying sources of lamellar tearing. The CAR did not address or resolve the issues subsequently raised by the inspection team regarding joint design, lamellar tearing, or hydrogen underbead cracking.

At the time of the inspection, SNC staff had neither written a CAR for the November 1996 weld failure at ANO nor determined the root cause and corrective actions. SNC staff did not have any information on the event other than a one-page FAX from an ANO materials engineer who had seen a photograph of the PT indication. Based on the photograph, the engineer indicated lamellar tearing had occurred. In response to the NRC inspection team's findings, SNC staff issued CAR 97-04, dated March 19, 1997.

The team considered the failure to perform a comprehensive and timely root-cause analysis of the confinement boundary seal weld failures that occurred in March 1995 and November 1996 at Palisades and ANO power plants respectively, to be a nonconformance with NRC regulations. 10 CFR 72.172, "Corrective Actions," requires that conditions adverse to quality be promptly identified and corrected, the cause of the condition be determined, and corrective action be taken to preclude repetition.

Conclusions

The team concluded that SNC staff's root-cause analysis was not adequate. The team considered SNC staff's failure determine the cause of the failed welds to be a nonconformance with 10 CFR 72.172.

3.1.2 PERSONNEL INTERVIEWS

Inspection Scope

The team interviewed personnel at the three facilities to determine if they had knowledge of any unauthorized and undocumented weld repairs during fabrication. The licensee for Palisades had attributed the root cause of its weld failure to hydrogen underbead cracking resulting from an unauthorized base metal weld repair. The SNC, MMI, and Nor-Cal personnel interviewed were those personnel most likely to have been aware of the fabrication activities during the manufacture of the Palisades and ANO casks which later failed their helium leak tests. The team conducted six interviews at SNC, six interviews at MMI, and three interviews at Nor-Cal.

Observations and Findings

The personnel interviewed stated that they had no knowledge of unauthorized and undocumented weld repairs.

Conclusions

The personnel interviews did not identify any known instances of unauthorized and undocumented welds.

3.1.3 FABRICATION RECORD REVIEW

Inspection Scope

The team reviewed SNC's fabrication data packages for the two casks that had weld failures: "Inspection Procedure/Report for the Shop Fabrication of the Multi-Assembly Sealed Basket" CMSB-94-001, Rev. 1, dated April 1994 for the Palisades cask, and AMSB-01, dated 1994, for the ANO cask.

Observations and Findings

The review found two instances of weld repair on CMSB-05. The first involved repair of "handling" gouges on the inner surface of the shell approximately 1 inch below the top edge. This weld repair was performed in July 1994 per MMI procedure WPS-4901SM, Rev. 1. Documentation concerning the cause of the gouges, as well as a description of the repair process was evident in the fabrication records. The repair was not in the area that subsequently failed. The second repair was made to correct welding anomalies detected in the shield-lid support ring-to-shell weld. Lack of fusion, tears in edges, and incomplete start/stops were reported as a result of the visual and PT inspections. This repair was described in NCR 05-21-MSB, issued September 6, 1994. As before, the repair weld was performed in accordance with MMI procedure WPS-4901SM, Rev. 1. Likewise, this repair was not in the area of interest.

The review of the fabrication records for AMSB-01 identified one repair made for a weld defect discovered by radiography. The defect was in weld D, which was not in the area of interest.

Conclusions

After reviewing fabrication documentation, the team concluded that the fabricator (MMI) had been forthright and thorough in documenting weld repair activities. Further, the repairs made were not in the areas of interest, the areas that subsequently failed. The team found no evidence in the fabrication records to suggest that an unauthorized and undocumented weld repair had been made to casks CMSB-05 or AMSB-01.

3.1.4 NONCONFORMANCE REVIEWS

Inspection Scope

The team examined the NCRs and SDRs pertaining to the two casks that had experienced weld failures to determine if there was any information applicable to the cause of the failures.

Observations and Findings

The review did not identify information that suggested the reasons for the failures. The team observed that repair welds were noted and documented. The locations of these repairs were not in the area of the MSB shell that subsequently failed.

One NCR documented an out-of-round condition of the Palisades' cask. The cask was out-of-round after welding of the vertical seam weld on the MSB. The most significant out -of-round condition was about 6 inches on each side of the weld where the initially flat plate had been bent or "knuckled" in preparation for rolling and welding. The team questioned whether the knuckle areas, subsequently rolled smooth, correlated to the area of the failed seal welds. The team was unable to correlate the location of the knuckles or the vertical seam weld to the failure areas because the fabricator did not record that information. Each shell did get marked with a zero point, but that point was established randomly, without regard to the vertical weld.

SNC personnel stated that they would change their fabrication requirements for future casks to establish the zero point with a known reference to the vertical weld since that information might be of interest in future root-cause analyses.

Conclusions

The review of NCRs and SDRs did not identify information which could be related to the failed welds. The team observed that MMI documented surface defects and weld repairs in accordance with their procedures.

3.1.5 NONDESTRUCTIVE EXAMINATION

Inspection Scope

The team reviewed reports of NDE performed in the areas of the shield and structural-lid welds, and interviewed the fabricator's and licensee's inspection personnel, to determine if the NDE results revealed any information about the overall quality of the MSB plate material. The review included PT and UT reports for 10 rolled and welded shells, designated by MMI as Units A-J. The team interviewed Palisades Nuclear Plant personnel during a conference call on March 19, 1996, to discuss the nature of their NDE results.

Observations and Findings

As a result of the defect observed on a shield-lid seal weld for cask number CMSB-05 at Palisades, SNC staff initiated corrective actions in an attempt to ensure that preexisting anomalies would not impact future shield-lid and structural-lid welds. SNC staff's actions, as documented in its CAR 95-06, included:

- changing the material procurement specification to include supplier-performed UT to detect laminations that might have been introduced when the plates were rolled.

- revising fabrication specifications to include additional PT of the interior shell surface, and UT examinations to detect laminar flaws, in the areas of the shield-lid and structural-lid welds.

Neither the UT nor the PT performed by the fabricator (MMI) on the 10 rolled and welded shells revealed abnormalities that might indicate poor quality plate material.

After the March 1995 incident at Palisades, Consumers Energy, the parent utility company, implemented similar NDE measures, to be performed before the shield-lid and structural-lid welding. No relevant indications were reported in the area of the shield-lid seal welds for any MSB cask shells. The licensee for Palisades detected one PT indication in the weld preparation area of the structural-lid weld on cask CMSB-12. This 1/4-inch linear indication was located on the MSB shell at the interface between the sheet base metal and the longitudinal weld metal. The indication was subsequently repaired and radiographically examined before the structural-lid was welded. This defect indication location was not in the area of the failed welds.

The team noted that the UT implemented to detect laminar indications did not provide adequate flaw characterization, relative to the types of anomalies that would impact the shield and structural-lid welds. SNC staff and the licensee for Palisades had implemented UT in accordance with American Society of Mechanical Engineers (ASME) specifications SA-435/435M, "Specification for Straight-Beam Ultrasonic Examination of Steel Plates," and SA-578/578M, "Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications," respectively. The acceptance standards found in both of these specifications allow laminar flaws as large as 3 inches in diameter to exist in the plate material. Therefore, the team considered the acceptance criteria to be too coarse to be of practical use in detecting the small flaws that contribute to lamellar tearing. Additionally, the rejection criteria in the ASME specifications allowed a relatively large lamination. Since the MSB shell-to-shield-lid weld loads the shell in tension, in a direction transverse to any laminations, the separation of a large near-surface lamination would be likely. Therefore, the team concluded that the specified UT acceptance criteria were not appropriate for the weld joint configuration.

The team noted that the NDE performed on the completed shield-lid-to-MSB-shell weld and the structural-lid-to-MSB-shell weld would not detect subsurface flaws which did not extend to the inspection surface. If the cracking mechanism was a delayed mechanism, the subsurface defects could propagate to the surface after the NDE was completed. Section 3.1.7 discusses the potential for delayed cracking.

Conclusions

The absence of reportable UT and PT indications in the records reviewed suggested that the quality of the material used for the manufacture of these casks was acceptable. However, the team concluded that, although the specified PT might be beneficial in finding surface flaws, the specified UT was inadequate to identify laminar defects which might open during welding. The team concluded that the NDE methodology implemented by CAR 95-06 was not adequate to detect discontinuities with the potential for lamellar tearing nor delamination.

3.1.6 DESIGN REVIEW

Inspection Scope

The team examined the weld joint design for adequacy.

Observations and Findings

The team determined that the weld joint configurations for the shield-lid-to-MSB-shell and the structural-lid- to MSB-shell were joint designs which may increase the chances of lamellar tearing. Alternate joint configurations would reduce the chances of lamellar tearing.

SNC personnel noted that the American Institute of Steel Construction (AISC), "Structural Steel Detailing," had standard weld joint designs with the same configuration as the MSB joint design. The team noted that AISC information concerned building structures, where highly restrained joints are not ordinarily encountered. The team observed that the circular configuration of the MSB weld joints created a highly restrained joint, which increased the tensile forces on the shell material. Since the tensile loading was transverse to the direction of the plate's rolling during manufacture, the chances of lamellar tearing were increased.

The team also noted that the shield-lid seal welds were made shortly after the water level in the cask was lowered about 3 inches below the shield lid. The design configuration of the shield lid, which included shims, appeared to be more likely to retain water in the interstitial gaps between the mating parts. The presence of moisture could promote hydrogen underbead cracking in the root pass of the weld. The underbead cracking could provide a stress riser point from which lamellar tearing could propagate.

Conclusions

The team concluded that the highly restrained MSB weld joint designs for the shield-lid and structural-lid closure welds could promote lamellar tearing. The team also concluded that the moist environment present for the shield-lid root-weld might promote hydrogen underbead cracking, which could serve as a stress riser point from which lamellar tearing could propagate.

3.1.7 MATERIALS REVIEW

Inspection Scope

The team examined the receipt inspection records for the plates used for the two MSBs that exhibited welding problems during welding of the shield lids (Palisades' CMSB-05 and ANO's AMSB-01). The team also reviewed the susceptibility of the material used to welding problems, such as hydrogen-induced cracking (cold cracking), solidification cracking (hot cracking), and delayed cracking.

Observations and Findings

Receipt Inspection Records
The team reviewed the receipt inspection records for the carbon steel plates used for CMSB-05 and AMSB-01. The records did not indicate rejected plates, damage, or other detrimental conditions. The team compared the actual physical and chemical test results provided by the steel manufacturer to the requirements of the materials specification, ASME SA-516, "Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate and Lower Temperature Service" for Grade 70 material. The material met specification requirements.

Potential for Hydrogen Underbead Cracking and Hot Cracking (Carbon Equivalent and Manganese-to-Sulfur Ratio)
Using chemistry data from the steel maker's test certificate, the team calculated the carbon equivalent (CE) of the ASME SA-516, Grade 70 base metal used in fabricating CMSB-05,. The team used the methodology in the AWS *Welding Handbook*, Seventh Edition. The calculated CE was 51.5. When the CE exceeds 40, hydrogen-induced underbead cracking could occur. Additionally, the team calculated the Manganese-to-Sulfur ratio of the base metal. The team used the methodology in the *Welding Handbook*. The calculated ratio was in the range of 79.2 to 86.4. With ratios greater than 60, hot cracking (solidification cracking) is not likely to occur.

Potential for Delayed Cracking
Hydrogen-induced cracking is usually a delayed phenomenon, occurring weeks or even months after the welding operation. The primary source of hydrogen in weld metal is considered to be the disassociation of water vapor in the arc, and absorption of gaseous or ionized hydrogen in the weld metal. Since the shield-lid weld is made in a damp environment, using material susceptible to underbead cracking, there is a potential for delayed hydrogen underbead cracking.

Under certain service conditions, the onset of lamellar tearing may occur shortly after welding or occasionally months later. As discussed in Section 3.1.6. the weld joint design is conducive to lamellar tearing.

Plate Material Samples
The team noted that MMI had retained samples of the plates used to fabricate the MSB's. The sample sizes were 4-inches by 6-inches by 1-inch The samples from Palisades' CMSB-05 were marked "C5056/4BA" and "C5056/4AB." The samples from ANO's AMSB-01 were marked "C5051/3DA" and "C5051/4CA."

Conclusions

The plate materials used for the MSBs met their chemical and physical requirements. The material used was not likely to experience solidification cracking (hot cracking) but was susceptible to hydrogen-induced cracking (cold cracking). The material was susceptible to delayed cracking from both hydrogen underbead cracking and lamellar tearing.

3.1.8 WELD PROCEDURES

Inspection Scope

The team reviewed MMI's welding procedures and specifications for shell fabrication and repair, SNC's weld design as depicted in the SAR, and Palisades' and ANO's field welding procedures for the shield and structural-lid welds. In addition, the team interviewed the Palisades welding engineer. These activities were performed to gather information about the potential causes of the failed seal welds.

Observations and Findings

The team found no unusual process parameters in MMI welding specifications WPS-6450SAW and WPS-4901SM. All specified variables met the minimum requirements listed in ASME Sections III and IX. This was also true for Palisades Welding Procedure Specifications SM-LID and FC-LID and ANO Weld Procedure Specifications P1-A-B-CVN and P1-F-B-M-CVN for manual shielded metal arc welding and automated flux-core welding, respectively. One notable difference, from ASME recommendations, was that MMI's specifications required minimum preheat temperatures of 100°Fahrenheit (F) for the shell welds. Palisades' and ANO's procedures, although not precluding a preheat of the component, only required that the temperature of the materials be in the range of 50 to 500°F, which allowed welding at ambient temperatures.

ASME Section III, paragraph NC-4600, refers to nonmandatory Appendix D for recommended welding preheats. Appendix D states that 200°F is suggested for material that has a maximum carbon content of 0.30% or less and a thickness in excess of 1 inch. The MSB material meets these criteria.

MMI performed welding in a dry condition amenable to preheat. However, as a practical matter, the reactor licensees did not apply any preheat before welding. The licensees performed the shield-lid welding when the MSB was full of warm borated water. The presence of water made the application of weld preheat difficult for a number of reasons. First, the water acted as a substantial heat sink, pulling the heat away from the weld area. Second, cask loading requirements had a time limit based on the water temperature and related criticality margins. Therefore, preheat would have affected the allowed loading time.

However, the absence of preheat exacerbated the potential for hydrogen underbead cracking. The shield-lid weld was made a shortly after the water was drained down about 3 inches below the lid. The configuration, as discussed in 3.1.6 above, was likely to entrap water in the shim area below the weld. Water is hydrogen-rich and can lead to hydrogen underbead cracking.

Ordinarily, preheat would drive off any residual moisture. The absence of preheat and the probable presence of water increased the chances of hydrogen underbead cracking.

The team noted that, for the shield-lid seal weld, the licensee's procedures called for a different weld bevel, root opening, and reinforcement than were shown on SNC's SAR. The original SAR depicted a 1/4-inch "J"-type weld design, with no root opening, and a 20° bevel on the weld. The Palisades' procedure showed a 1/4-inch groove-weld, with as much as a 5/16-inch root opening, and a 45° bevel on the shield lid. In addition, the SAR showed no reinforcement, whereas the Palisades' procedure allowed as much as a 1/2-inch weld cap. The structural-lid weld specifications were unchanged, except that a 3/32-inch reinforcement was allowed by the Palisades procedure, whereas none was specified in the SAR.

The team questioned the Palisades' Welding Engineer about these changes. The engineer explained that the changes had been made to prevent centerline cracks and facilitate access for automated welding. The engineer stated that the changes had been developed based on engineering evaluations and field experience with the first casks. The engineer provided the safety evaluation for these changes (Palisades document EA-FC-864-02) completed in accordance with 10 CFR 72.48, Subpart K.

The team noted one discrepancy in the safety evaluation at Palisades; the evaluation did not address excess weld reinforcement authorized in the Palisades' procedures. For the structural lid, a 3/32-inch cap would be acceptable per ASME Section III, Part NC-4426, whereas on the shield-lid seal weld, the 1/2-inch cap added by the licensee on its drawings was outside of Code-allowable tolerances. The table listed in Part NC-4426.1 allowed only 3/32 inch of weld reinforcement for this material thickness. The excess weld did not appear to be necessary to achieve an effective seal, and the larger weld would exacerbate the potential for lamellar tearing.

The team reviewed the weld configurations used by the licensee for ANO. The licensee had requested, and SNC staff had approved, a maximum 1/2-inch reinforcement on top of the shield-lid seal weld. The approved weld was shown on SNC drawing AMSB-24-001, Revision 5, "MSB Assembly." In this case too, the excess weld did not appear necessary to achieve be an effective seal, and the larger weld would exacerbate the potential for lamellar tearing.

The team reviewed Palisades' and ANO's welding procedures. Other than the excess weld reinforcements, the team found no deviations from standard practices.

Other than specifying a weld type and size, SNC staff did not provide requirements or guidance to the users for performing the closure welds for the shield lid and the structural lid. Neither before nor after the incidents at ANO and Palisades, did SNC staff provide compensating strategies for welding with moisture present and without the recommended preheat.

Through a subcontractor, SNC did review and approve all welding procedure specifications for fabrication (shop) welding by MMI.

Conclusions

Welding was performed according to approved procedures during both fabrication and lid closure activities. Both reactor licensees used a larger reinforcement on the shield-lid to-shell seal weld than allowed by the ASME Code. The licensee for Palisades authorized the excess weld through the 10 CFR 72.48 process, whereas the licensee for ANO had received SNC staff approval. The larger welds exacerbated the potential for lamellar tearing. Also, the licensee's welding procedures required effectively no preheat above ambient conditions. The absence of preheat and the probable presence of water increased the chances of hydrogen underbead cracking. SNC staff had not provided strategies for dealing with moisture and lack of preheat.

3.2 ADDITIONAL EXAMPLES OF INADEQUATE CORRECTIVE ACTION

3.2.1 NONCONSERVATIVE TECHNICAL SPECIFICATION

Inspection Scope

The team examined the circumstances involving nonconservative limits in TS 1.2.10, "Time Limit for Draining the MSB."

Observations and Findings

TS 1.2.10, "Time Limit for Draining the MSB," required that the water inside the MSB be drained within 47 hours after the MSB was removed from the spent fuel pool (SFP), if the MSB was loaded with fuel producing 24 kilowatts (kW) of heat. The time limit could be adjusted for fuel that produced less then 24 kW of heat by using a specified equation.

The purpose of TS 1.2.10 was to ensure that the water in the MSB did not exceed the boiling point. At the boiling point, the multiplication factor $K_{eff,}$ would exceed 0.95, thereby reducing the desired margin of safety to criticality. The TS action statement required that, if the water could not be drained within the specified time, the MSB be placed back into the SFP and allowed to cool.

In April 1996, the licensee for ANO identified that potentially nonconservative heat transfer rates were used in the SNC calculation that determined the heat-up rate of water inside of the MSB. The calculation was referenced in the Basis for TS 1.2.10. In addition, the licensee identified that the temperature of its SFP exceeded the starting temperature assumed in the SNC calculation. Specifically, the calculation assumed a SFP temperature of 70 °F as a starting temperature, whereas the ANO SFP temperature was closer to 100 °F. At that time, the licensee requested that SNC staff examine the nonconservative assumptions. At the same time, the licensee expressed the concern that a potential generic issue existed for all users of the VSC-24 system.

On April 25, 1996, SNC staff initiated CAR No. SNC 96-05, to address the drain time issue. On May 16, 1996, SNC staff closed the CAR, stating that: "The methodology used to determine the heat-up-rate, by ANO, is considered to be a conservative analysis, vs. that used by SNC. Actual data obtained from loaded VSC-24's at Palisades confirms that SNC heat-up-rate calculations are conservative when compared to the actual measured data. Accordingly, it is the conclusion of the Management Review Board that a reportable condition does not exist."

The CAR evaluation did not discuss the concern with SFP temperatures nor address any potential generic implications. The licensee for ANO implemented administrative controls to govern the time when the MSB should be drained.

The licensee for Palisades also raised this concern to SNC in April 1993. At that time, the licensee also implemented administrative controls to shorten the drain-down time limit. Neither the licensee for Palisades nor SNC staff recalled or documented any technical exchanges they may have had regarding the problem.

The team noted that the COC should have been changed to reflect a conservative drain-down time limit. NRC has accepted the temporary use of administrative controls only for short periods while the TS were being revised. All users of the VSC-24 system had previously discussed their administrative controls with NRC, and NRC had concluded that the administrative controls were adequate. Therefore, no safety issue was involved in previous cask-loading operations. In addition, the licensees had agreed to continue to use the administrative controls until the COC was changed.

The team noted that SNC staff did not pursue appropriate corrective actions, in accordance with SNC Procedure Number QAP 16.0, "Corrective Action," Revision 3, to revise TS 1.2.10 and eliminate the need for users of the VSC-24 system to implement administrative controls. As a result, future users of the VSC-24 system might be unaware that the time limit was nonconservative. The team discussed the fact that SNC staff had not submitted a change request for the COC to the NRC. Subsequently, on March 19, 1997, SNC staff wrote CAR 97-03 to readdress the issue.

The failure to request a timely change to TS 1.2.10 to ensure a conservative drain-down time limit was considered a nonconformance with 10 CFR 72.172, "Corrective Action," which requires that measures be established to ensure that conditions adverse to quality are promptly identified and corrected, and that corrective action be taken to preclude repetition.

Conclusions

The team concluded that SNC staff had not taken appropriate nor timely corrective action to correct the nonconservative drain-down time limit in TS 1.2.10. This was considered a nonconformance with 10 CFR 72.172.

3.2.2 ASME CODE OMISSION

Inspection Scope

The team noted that SNC staff had identified that the ASME Code edition, referenced in the SAR, did not require base metal NDE after the removal of temporary attachment welds.

Observations and Findings

In February 1995, SNC staff identified that ASME Code Section III, 1986 Edition, addended through 1988, as referenced in the SAR for fabrication of the MSB, omitted certain requirements for the installation and removal of temporary attachments to the MSB. Specifically, ASME Code Section III, NC-4435, omitted the requirement that areas, where a temporary attachment has been removed, be examined by PT or magnetic particle methods, in accordance with the requirements of NC-5110. The testing was required in Code editions before and after the edition referenced in the SAR. In 1995, SNC staff took corrective actions to update all fabrication documents to reflect the need for a PT examination. However, action was not taken as required by SNC Procedure Number QAP 16.0, "Corrective Action," Revision 3, to document the problem, determine its scope, and devise corrective action to prevent recurrence. Additionally, SNC staff had not performed a documented evaluation for casks already in service.

The team noted that the SAR had not been updated to reflect the need for PT or magnetic particle examinations. The team noted that opportunities had existed since February 1995 for SNC staff to update the SAR.

The failure to take action as required by SNC procedures for problem identification and resolution was considered a nonconformance with 10 CFR 72.172, which requires that conditions adverse to quality be promptly identified and corrected and corrective action taken to preclude repetition. The team considered that the SAR should have been updated to recognize the Code omission.

Conclusions

The team concluded that SNC staff had not taken appropriate or timely corrective action to update the SAR and resolve the omission, in the ASME Code edition referenced in the SAR, of NDE after the removal of temporary attachments.

3.3 REVIEW OF PREVIOUS CORRECTIVE ACTIONS

Inspection Scope

The team verified implementation of corrective actions for the findings identified during two previous NRC inspections performed at SNC and its VSC-24 fabrication vendor, MMI. Specifically, NRC performed an inspection at SNC June 3-5, 1996 (Inspection Report 72-1007/96-204) to verify that VSC-24 design activities had been established, documented, and executed to meet the requirements of 10 CFR Parts 21 and 72, COC No. 72-1007, and the VSC-24 SAR and Safety Evaluation Report (SER). NRC performed a second inspection at MMI August 6-8, 1996 (Inspection Report 72-1007/96-208) to verify that VSC-24 fabrication activities had been executed in accordance with the provisions in the COC and 10 CFR Parts 21 and 72.

The nonconformances identified during the two 1996 inspections are listed in Table 3.

Table 3
Summary of Inspection Findings from 1996 Inspections at SNC

June 3-5, 1996, Inspection		
10 CFR Section	Nonconformance and Description	Number of Findings
72.144	Quality assurance program: Classification of components according to importance to safety	2
72.150	Instructions, procedures, and drawings: Design controls, independent verification	2
72.150	Instructions, procedures, and drawings: Design controls, lack of analysis for environmental compatibility	1
August 6-8, 1996, Inspection		
10 CFR Section	Nonconformance and Description	Number of Findings
72.150	Instructions, procedures, and drawings: Fabrication procedures	5
72.164	Control of measuring and test equipment: Calibrated test equipment	2
72.170	Nonconforming materials, parts, or components: Control of nonconforming items	2

<u>Observations and Findings</u>

Corrective Action Review
In its letters dated August 5 and October 7, 1996, SNC staff provided specific corrective actions in response to the Notices of Nonconformance in Inspection Reports 72-1007/96-204 and -208, respectively. Through review of procedures and records, personnel interviews, and observations, the team verified that the specific corrective actions had been implemented as committed. However, during this inspection, as described below, the team found an additional nonconformance regarding a lack of controls for measuring and test equipment. Since one of the 1996 nonconformances involved a lack of controls for measuring and test equipment, the team concluded that SNC staff had not determined the root cause of the 1996 nonconformance nor taken action to prevent recurrence.

New Findings
During the current inspection, the team identified a nonconformance at MMI regarding 10 CFR 72.164, "Control of measuring and test equipment." The team identified instances where the measuring and test equipment was not controlled in accordance with procedures.

- The storage sleeve go/no go gage, used to determine the dimensional acceptability of the VSC-24 storage sleeve tubes, did not have a serial number or other unique identifier on it as required by MMI Procedure No. NQP-12A, "Calibration and Control of Measuring and Test Equipment," Revision 0.

- The storage sleeve go/no go gage did not have a calibration label on it as required by Procedure NQP-12A.

- MMI did not have a procedure, nor acceptance criteria, for the use of the storage sleeve go/no go gage.

Additionally, the team observed errors in the administration of SNC's corrective action tracking program. Specifically, SNC's Deficiency Tracking Log showed CAR 95-08 as being closed on June 12, 1996. However, the CAR was still open at the time of inspection. A second example was an SNC letter issued to MMI (MAS-96-048-QAD), dated April 2, 1996. The letter requested a response to two open issues by April 5, 1996. MMI did not respond by the due date, and no followup action was taken by SNC staff until January 31, 1997.

Sleeve Cracking
During the August 6-8, 1996, inspection at MMI, the team identified concerns about the fabrication and quality control inspection of the VSC-24 storage sleeve tubes. MMI found cracks in the bends of the storage sleeve tubes during its inspection process and repaired them by welding. In its letter dated December 16, 1996, NRC staff requested information from SNC regarding the procedures and criteria for inspecting the storage sleeve tubes, identifying and repairing cracks, and accepting the storage sleeve tubes.

In its letter dated February 14, 1997, SNC staff responded to NRC staff's request for information regarding the storage sleeve tubes. SNC staff provided specific procedures and criteria for inspecting, controlling, and repairing storage sleeve tubes. During this inspection, the team verified that MMI had developed and implemented a detailed procedure for inspecting storage sleeve tubes for cracks, prepared nonconformance reports and weld repair travelers for defective storage sleeve tubes, and repaired storage sleeve tubes using an approved weld procedure and using qualified personnel.

<u>Conclusions</u>

The team determined that SNC staff implemented the corrective actions listed in its responses to the nonconformances identified during the two 1996 NRC inspections. However, while reviewing corrective action implementation, the team identified a new nonconformance in the control of measuring and test equipment at MMI, indicating a lack of SNC oversight of MMI's QA program. MMI's activities were under the direct surveillance of SNC's representative at the MMI facility. Since one of the 1996 nonconformances had dealt with a lack of controls for measuring and test equipment, the team further concluded that SNC staff had neither determined the root cause of that nonconformance nor taken action appropriate to prevent recurrence.

4.0 CONCLUSIONS

The team concluded that:

- The physical configuration of the MSB shell-to-shield-lid weld joint was susceptible to lamellar tearing. The team noted that alternate configurations would reduce the probability of lamellar tearing. .
- SNC staff approved a seal weld, larger than that shown in the SAR, for use at ANO. The larger weld exacerbated the potential for lamellar tearing. The licensee for Palisades also increased its weld size under the provisions of 10 CFR 72.48.
- The weld joint geometry and environmental conditions were conducive to moisture intrusion and hydrogen underbead cracking.
- The shell material had a high carbon equivalent rating and was susceptible to underbead cracking.
- The material used generally should have weld preheat and post-heat applied to alleviate hydrogen underbead cracking. The presence of water in the cask during welding complicated the ability to have weld preheat and post-heat.
- SNC staff's corrective action (UT examination of the plate), was not an adequate corrective action, since it would not have detected flaws of the size involved in lamellar tearing.
- Personnel involved in the fabrication of the casks stated that they had no knowledge of unauthorized or undocumented welds.

Additionally, the team concluded that neither SNC staff nor the user licensees had performed a comprehensive root-cause analysis. Consequently, the completeness of the corrective action taken could not be assessed. The fact that multiple cask seal welds failed suggested that the problem might be generic. The team also concluded that SNC staff had not addressed another significant issue, the potential for delayed cracking of loaded casks.

The team considered the failure to identify the root cause of the MSB seal weld failures to be a nonconformance with 10 CFR 72.172 regarding corrective action. The safety significance of the finding was that the reasons for the failure of a cask confinement boundary were not understood. Therefore, the potential existed for additional failures, perhaps undetected and perhaps delayed, of the confinement boundary at the shield-lid-to-MSB-shell seal weld. Further, the root cause might involve other cask confinement welds such as the structural lid closure weld. Although the failure of both the cask's inner shield-lid seal weld and outer structural-lid weld would not pose an off-site threat to public health and safety, such an occurrence would cause the loss of the helium atmosphere inside the cask. This loss could result in cladding degradation and future fuel handling and retrievability problems. Since one of the design requirements of the cask is the long-term protection of the fuel cladding [10 CFR 122(h)], such degradation would be unacceptable.

The team identified two other nonconformances regarding corrective action:

- A nonconformance with 10 CFR 72.172 was identified for failure to take corrective action to prevent recurrence of conditions adverse to quality. SNC staff had not requested a change to the drain-down time limit specified in the COC, TS 1.2.10. In April 1996, reactor licensees had determined the TS time limit to be nonconservative and had informed SNC. However, at the time of this inspection, SNC staff had not requested an amendment to the COC. The safety significance of the nonconformance was high because future users might not use time limits appropriate to their plant conditions. Inappropriate time limits could lead to boiling and a consequent reduction in the margin to criticality.

- A nonconformance with 10 CFR 72.172 was identified for failure to take corrective action to prevent recurrence. SNC staff failed to update the SAR to include a requirement to perform nondestructive examinations after removing temporary attachments. SNC personnel were aware of the SAR deficiency in February 1995.

The team reviewed the implementation of corrective actions for the findings identified during two previous NRC inspections performed at SNC and its VSC-24 fabrication vendor, March Metalfab Incorporated (MMI); Inspection Reports 72-1007/96-204 and 96-208. These findings related to nonconformances with the requirements for the classification of components, procedure control, nonconforming material control, and measuring and test equipment control. The team concluded that SNC and MMI staff's corrective actions for the individual findings were adequately implemented. However, the team identified a new nonconformance with 10 CFR 72.164 regarding MMI's control of measuring and test equipment. Contrary to procedures, one gage had not been marked with a unique number and did not have a calibration label. Additionally, there was no procedure describing the proper use of the gage. Since one of the 1996 nonconformances had dealt with a lack of controls for measuring and test equipment, the team further concluded that SNC staff had neither determined the root cause of that nonconformance, nor taken action appropriate to prevent recurrence.

5.0 EXIT MEETING

The team presented the inspection results to members of SNC's staff and management on March 21, 1997. SNC management acknowledged the findings presented.

LIST OF ACRONYMS USED

AISC	American Institute of Steel Construction
ANO	Arkansas Nuclear One
ASME	American Society of Mechanical Engineers
AWS	American Welding Society
CAR	Corrective Action Request
CE	Carbon Equivalent
CFR	U.S. Code of Federal Regulations
COC	Certificate of Compliance
INEEL	Idaho National Engineering and Environmental Laboratory
IP	Inspection Procedure
IR	Inspection Report
kW	kilowatts
M&TE	Measuring and Test Equipment
MMI	March Metalfab Incorporated
MSB	Multi-assembly Storage Basket
NCR	Nonconformance Report
NDE	Nondestructive Examination
NMSS	Office of Nuclear Material Safety and Safeguards
NRC	Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
OE	Office of Enforcement
OGC	Office of the General Counsel
PDR	Public Document Room
PT	Liquid Penetrant Examination
QA	Quality Assurance
QC	Quality Control
SAR	Safety Analysis Report
SER	Safety Evaluation Report
SDR	Supplier Deviation Request
SFP	Spent Fuel Pool
SFPO	Spent Fuel Project Office
SNC	Sierra Nuclear Corporation
TS	Technical Specifications
UT	Ultrasonic Examination
VSC	Ventilated Storage Cask
WCFO	Walnut Creek Field Office

INSPECTION PROCEDURES

IP 60851	"Design Control of ISFSI Components"
IP 60852	"ISFSI Component Fabrication by Outside Fabricators"
IP 60855	"Operation of an ISFSI"

APPENDIX A- DESCRIPTION OF MSB WELDS

Figure 1 provides a sketch describing the configuration of the MSB welds. The following narrative describes the materials, components and processes involved:

1. Materials

The components involved in the MSB welds are the structural lid, the shield lid, the MSB shell, a backing ring, and shims. All the components are made from moderate strength carbon steel (ASME Specification SA-516, Grade 70).

2. Component Descriptions

MSB Shell

The MSB shell is a cylinder of material made from 1-inch flat plate rolled and welded into shape. The outer diameter of the MSB shell is about 62-1/2 inches and its length is about 15 feet. The cylinder is closed at the bottom with a bottom plate. The top is closed after fuel is loaded with two lids, the structural lid and the shield lid.

Shield Lid

The shield lid is a composite structure with a top plate (about 2-1/2-inches thick), neutron shielding material, and one or two bottom plates (depending on time of manufacture). The entire shield lid is about 9-1/2-inches thick. The diameter is about 60 inches. The top plate of the shield lid is welded to the MSB shell inner diameter with about a 1/4-inch seal weld which spans the shims. Each licensee has made some minor modifications to this weld configuration due to welder preferences.

Structural Lid

The structural lid is about 60 inches in diameter and is 3-inches thick. It is welded to the inner diameter of the MSB with a 3/4-inch weld which spans the backing ring.

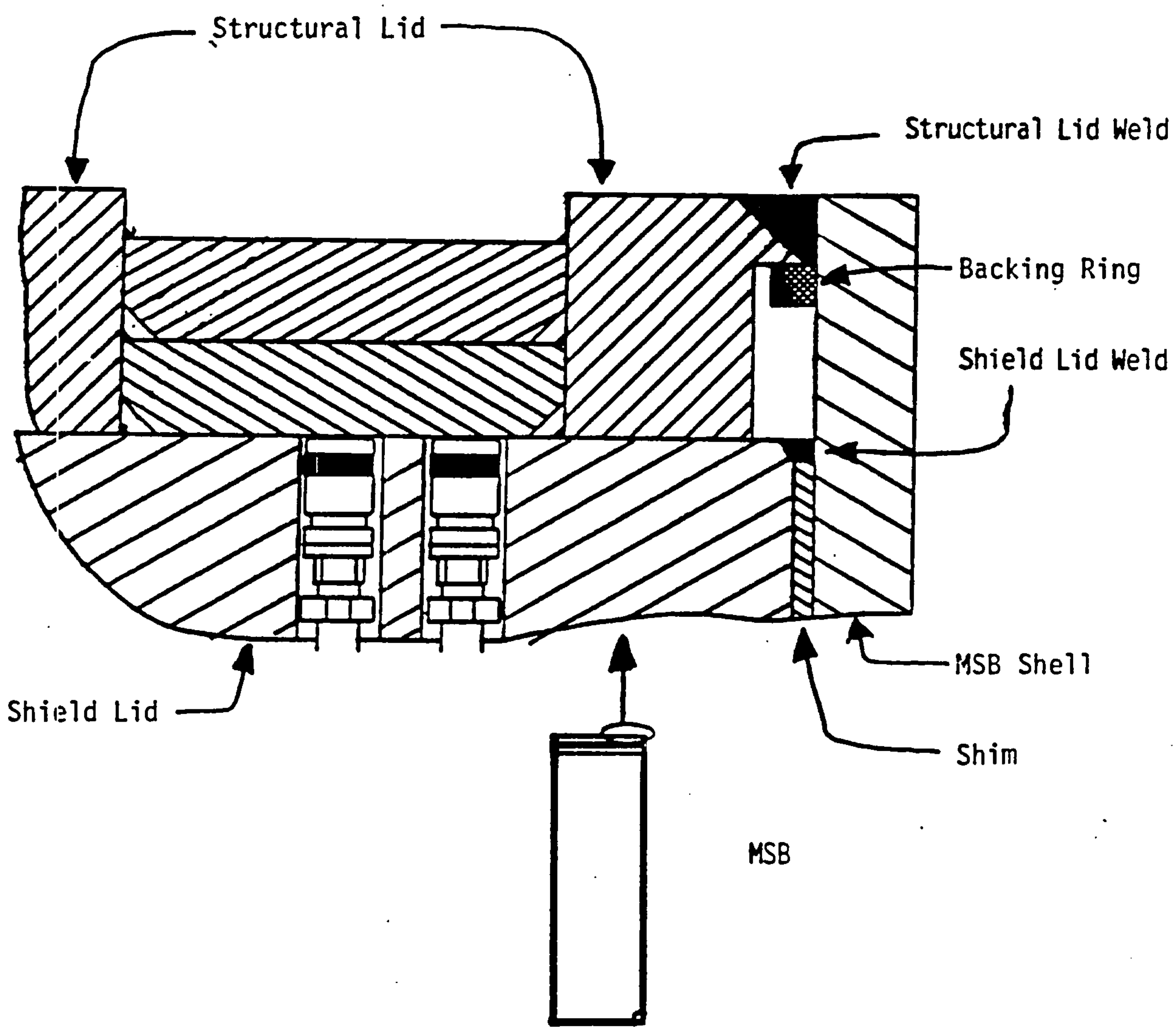
3. Weld Processes

The weld processes are not specified by SNC documents. The welds must meet ASME Code requirements for materials and welding, and must meet the SNC drawing requirements for configuration. The licensees at ANO and Palisades have approved the use of manual shielded metal arc welding and automatic flux core welding. The licensees have used both processes. The majority of the welding was done with automatic flux core welding.

4. Purpose of the Welds

The purpose of the shield-lid-to-MSB-shell weld is to provide a leak-tight seal weld to contain the helium atmosphere in the MSB cask. The weld also acts as a confinement barrier to retain the radioactive materials within the MSB.

The purpose of the structural-lid-to-MSB-shell weld is to provide a strength weld between the structural lid and the MSB shell. The weld is capable of withstanding postulated accident loads. The weld also provides a leak-tight seal and a radioactive material confinement barrier.



Multi-assembly Sealed Basket (MSB) Shield and Structural Lid Welds

FIGURE 1