This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

WSRC-TR-2005-00216

FY04 Inspection Results for Wet Uruguay Fuel in L-Basin (U)

Philip R. Vormelker and Dennis W. Vinson

Savannah River National Laboratory
Materials Science and Technology

Publication Date: September 2005

UNCLASSIFIED
DOES NOT CONTAIN
UNCLASSIFIED CONTROLLED
NUCLEAR INFORMATION

ADC &
Reviewing
Official:______________________________

Date: ______________________________

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

This document was prepared in connection with work done under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy

DISCLAIMER

DOCUMENT: WSRC-TR-2005-00216

TITLE: FY04 Inspection Results for Wet Uruguay Fuel in L-Basin (U)

MS&T APPROVALS

______________________________ Date:______________
Philip R. Vormelker, Author
Materials Application and Process Technology Group
Materials Science and Technology

______________________________ Date: ______________
Dennis W. Vinson, Author
Materials Application and Process Technology Group
Materials Science and Technology

______________________________ Date:______________
J. I. Mickalonis, Technical Reviewer
Materials Science and Technology

______________________________ Date:______________
R. L. Sindelar, Manager
Materials Application and Process Technology Group
Materials Science and Technology

______________________________ Date:______________
N. C. Iyer, Director
Materials Science and Technology

DOCUMENT: WSRC-TR-2005-00216

TITLE: FY04 Inspection for Wet Uruguay Fuel in L-Basin (U)

CUSTOMER APPROVALS

_____________________________ Date:_____________

R. W. Deible, Engineer
SFP Operations Engineering
Operations Business Unit

_____________________________ Date:_____________

T. J. Spieker, Manager
SFP Operations Engineering
Operations Business Unit

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Al-SNF	Aluminum Spent Nuclear Fuel
DOE	Department of Energy
DRR	Domestic Research Reactor
FRR	Foreign Research Reactor
IAEA	International Atomic Energy Association
NDE	Non-Destructive Evaluation
RBOF	Receiving Basin for Offsite Fuel
SNF	Spent Nuclear Fuel
SRS	Savannah River Site
SRNL	Savannah River National Laboratory
SS	Stainless Steel

1.0 Summary

The 2004 visual inspection of four Uruguay nuclear fuel assemblies stored in L-Basin was completed. This was the third inspection of this wet stored fuel since its arrival in the summer of 1998. Visual inspection photographs of the fuel from the previous and the recent inspections were compared and no evidence of significant corrosion was found on the individual fuel plate photographs. Fuel plates that showed areas of pitting in the cladding during the original receipt inspection were also identified during the 2004 inspection. However, a few pits were found on the non-fuel aluminum clamping plates that were not visible during the original and 2001 inspections.

2.0 Introduction

Nineteen aluminum-based nuclear fuel assemblies from Uruguay were shipped to the Savannah River Site (SRS) in the summer of 1998 as part of the DOE fuel receipts program. These assemblies were previously dry-stored in vented steel cans in the reactor building in Uruguay. Fifteen of the nineteen assemblies are currently in dry storage in the K-Area facility awaiting transfer to the L-Area facility for continued dry storage while the remaining four assemblies are in wet storage in the L-Area storage basin.

The fuel assemblies are periodically monitored to identify and investigate corrosion induced changes that may occur over time. K-Assembly Area dry storage inspection was last conducted on August 5, 2002 and L-Disassembly wet storage inspection was recently conducted on September 22, 2004. The first inspection of the wet Uruguay fuel, stored in L-Basin, was originally performed in October 1998 with a second fuel inspection performed in May 2001.

Acceptance criteria governing the drying and storage conditions for safe, interim dry storage (up to 40+ years) of Al-SNF were previously developed.[1-2] The technical basis for these criteria was that the primary degradation modes under low temperature (< 200 °C) storage conditions are general and pitting corrosion due to the presence of water vapor on the Al-SNF surface. It has been observed that vapor corrosion of aluminum is a function of time, temperature, relative humidity, gamma radiation field, and alloy type. Corrosion models that predict behavior of the aluminum cladding alloys under various conditions including exposure to low-temperature ambient air, were developed.[3] Based on these models, pitting corrosion of the dry stored Uruguay fuel is not expected and general corrosion is predicted to be well within acceptable limits.[3] The next dry storage inspection will be scheduled when the fuel is relocated to L-Area. Results from this field test will allow validation of the storage criteria for interim dry storage under ambient room conditions (e.g., unsealed canister) and results from the instrumented canister test will support validation of the sealed canister storage criteria.

The wet Uruguay fuel are stored in the controlled water chemistry of L-Basin where conductivity is currently maintained less than 5 µS/cm with a pH level of approximately 6. The L-Basin conductivity limit is 10 µS/cm while the pH limiting range is 5.5 to 8.5. Inspection of the Uruguay fuel in L-Basin storage supports the technical basis for short-term continued wet storage of SNF and provides an early indication of Al-SNF cladding corrosion versus L-Basin water quality. Also, inspection of the wet Uruguay fuel stored in L-Basin enables a direct comparison of Al-SNF with the current coupon surveillance program.

3.0 Physical Description and History of RU-1 Fuel

Section 54 of the Atomic Energy Act of 1954, as amended, and the Agreement for Cooperation between the United States and the IAEA authorized the United States to supply special nuclear material to the IAEA to assist and encourage research on peaceful uses of nuclear energy.[1] In 1965, the Government of Uruguay entered into a firm arrangement with Lockheed Nuclear Products to purchase the 10 kW Lockheed training and research reactor. The United States provided more than 16,000 grams of uranium containing nearly 3,200 grams of ^{235}U contained in 14 fuel elements, 4 special elements, and 5 spare fuel plates for the Lockheed reactor.

The Research and Training Reactor in Montevideo, Uruguay (RU-1) is a 10 kW Lockheed reactor originally in operation between 1959 and 1962, during the US Atomic Energy Commission's South American exhibit. This reactor is a special adaptation of the Ohio State University Training and Research Reactor design that incorporates several features that facilitate safety and portability. The reactor was dismantled in 1963 and rebuilt in 1973. It was put into operation again in 1978 and operated in Montevideo at the Nuclear Research Center for research purposes only through 1984. In 1985, it was shut down due to corrosion problems, and the fuel elements were removed from the core and placed in dry storage awaiting transport to the United States.

The RU-1 reactor was a pool-type reactor core and consisted of a 4-by-4 plus two array of fuel elements reflected on four sides with graphite and on the top and bottom with water.[4] The core structure of the RU-1 reactor contained a 6 × 7 position grid plate that held the 18 fuel/control elements and 24 reflector elements including one row of graphite reflector elements along the pool face of the core designed to hold samples for isotope production. Approximate active core dimensions were 30.5-cm × 30.5-cm × 61-cm.

Fuel for the RU-1 reactor initially consisted of eighteen fuel assemblies including fourteen fully loaded (11-plates) fuel assemblies and four special fuel assemblies. Six active fuel plates plus two guard plates of 1100 aluminum alloy were contained in each of the four special assemblies, which have a gap of 1.8 cm × 7.1 cm filled with water. Three of the special assemblies were used for control rods and one was in the lattice for experiments. In addition, there were 5 fuel plates that were used as spares. The eighteen original fuel assemblies and five spare fuel plates were modified from their original configurations into nineteen fuel assemblies that were shipped to Savannah River Site in compliance with the Agreement for Cooperation between the United States and the IAEA. This agreement allowed the return of the special nuclear material to the United States.

Each individual fuel plate is rectangular in design and clad with Al 1100 using a metallurgically bonded picture frame assembly as shown in Figure 1.[4] Individual fuel assemblies are contained within two clamping plates, also called a jacket (Figure 2), which contain various numbers of fuel plates. The wet fuel assembly contains 6 fuel plates as shown in Figure 2 and 3. The wet fuel plates are bolted together in two groups of three plates each. The clamping plates are fabricated from Al 5083 and are clipped together with three stainless steel clips on each side. The clips are fastened to the clamping plates with rivets. The rivet material was not identified but may be either stainless steel or aluminum. The four sets of wet stored Uruguay fuel assemblies (A-5, B-2, B-3, and 5-5) are stacked within one tube bundle, identified as L-RU-1-0465. The L tube bundle is fabricated from either Al 6061-T6 or Al 6063-T6.[5]

4.0 Wet and Dry Storage Monitoring Program Overview

Monitoring programs have been established to evaluate the response of Al-SNF assemblies to an uncontrolled, ambient air, dry storage environment in K Area and to the controlled water chemistry of L-Basin. The test data will support the validation of the interim dry storage criteria for Al-SNF previously developed at SRS.[2] The radiation field of the nineteen Uruguay Al-SNF assemblies from the RU-1 reactor in Uruguay was measured, and the SNF assemblies were characterized through visual examination using video and photographic cameras. Fifteen of the nineteen assemblies were subsequently placed in dry storage in the K-Area borated racks. The remaining four assemblies were placed in the vertical tube storage section in L-Basin. Table 1 lists the current assemblies in dry and wet storage.

Table 1. SRS Storage Environment for Nuclear Fuel from the RU-1 Reactor in Uruguay

K-Area Dry Storage Racks			L-Area Wet Storage
A-3	C-4	E-4	A-5
A-4	C-5	E-5	B-2
A-6	D-2	M-1	B-3
B-4	D-4	P-1	5-5
C-2	E-3	X-4	

Nineteen Al-SNF assemblies are identified by the respective designations indicated by the Appendix A documents of the respective fuels.[6-9] Identification of particular sides of a given assembly is afforded through the use of chloride free indelible markers. This practice allows direct comparison of particular features of fuel assemblies from one inspection to the next. There are ten 11-plate assemblies designated A-4, A-6, B-4, C-2, C-4, C-5, D-2, D-4, E-4, and X-4, four 10-plate assemblies designated A-3, E-3, M-1, and P-1, one 9-plate assembly designated E-5, and four 6-plate assemblies designated A-5, B-2, B-3, and 5-5. The identification numbers of all assemblies were engraved on the clamping plates of the respective assemblies prior to shipment to SRS.

5.0 Dry Fuel Inspection

Inspections of four Al-SNF assemblies (E-3, A-3, B-4, A-6) from K-Basin dry storage were conducted in May and November 1999, July 2000, and July 2001. The next inspection of these dry stored assemblies will be conducted in L-Basin (after relocation) with future inspection intervals adjusted to maximize the cost effectiveness of data collection without compromising data integrity. During an inspection, each of the four assemblies is removed from the rack and positioned on an inspection table. The radiation field associated with each assembly is measured after removal from the aluminum tube. Radiation measurements are taken at prescribed locations on the assembly surface. The outer surface of each assembly clamping plate is inspected and data recorded on video and/or photographs. The assembly identification number is recorded for each inspection. Some of the fuel plates are taken apart, based on the quantity and size of corrosion product nodules, to allow visual inspection of all plate surfaces. The number of assemblies directly examined in future inspections may be adjusted based on extent of damage expected. The previous examinations with video and photographic equipment have been documented. The presence of corrosion products has been noted and the condition of the fuel is being compared to the documented condition of the assemblies prior to emplacement. Moisture or loose corrosion product found on the housing or on fuel plate surfaces during any future inspections will be analyzed using inductively coupled plasma electron spectroscopy. After an inspection, the assemblies are returned to their original position in the fuel assembly rack for storage until the next inspection.

6.0 Corrosion Evaluation for Uruguay Fuel in Wet Storage

Previous inspections of Uruguay spent fuel assemblies A-5, B-2, B-3, and 5-5 were documented in photographic records (1998, 2001, and 2004) which were used for comparison with the current inspection photographs to determine if any changes in appearance such as oxide build-up, blistering, flaking, and pitting have occurred since the previous inspection. The clamping plates are removed from the fuel bundle (Figures 2 and 3), photographed to show the fuel assembly identification (A-5, B-2, B-3, or 5-5), and then opened up to remove the fuel assembly. The first side of the six fuel plate assembly was previously marked with an indelible marker on the right side and identified as Side A. The assembly is then rotated clockwise 90° to show side B (edges of fuel plates), rotated again to side C (face of plate) and finally rotated to side D (edges of fuel plates) as seen in Figure 3. The six plate assembly is not further disassembled to minimize contamination exposure to the operators. Photographs are taken at each rotation step so that visual inspection can be documented on the face of two fuel plates and on the edges of both sides of the fuel plates.

For comparison purposes, sections of the following fuel assemblies are presented as examples of the condition of all four fuel assemblies (A-5, B-2, B-3, and 5-5). The examples show that little or no fuel degradation is occurring. In Figure 4, photos of Side C (fuel assembly 5-5) from inspections in 1998 and 2004 are shown and pit locations and surface markings are repeated in the same location. Some differences in surface stains or markings may be due to light exposure at the time photographs were taken. Side A of fuel assembly B-2 is shown in Figure 5 where multiple pit locations are repeated in photographs from the first inspection in 1998 and the recent one in 2004. Similar characteristics are also noted when viewing another section of side A of fuel assembly B-3 as shown in Figure 6. The two images of Side D of fuel assembly B-3 are also very similar (Figure 7). Particles or tubercles are noted in similar locations in photographs taken in 1998 and 2004. One difference that appears is that more oxide growth around the fastener locations is visible in the 2004 photograph versus the original inspection photograph in 1998. The fasteners appear to be much cleaner in the 1998 photograph.

During the 2004 inspection of fuel assembly A-5, side C was photographed (Figure 8) but it was not the same side C as found in the 1998 and 2001 inspection photographs. Apparently one of the two plate assemblies was inadvertently rotated separately from the other one. This will be carefully reviewed during the next inspection.

In Figure 9 and Figure 10, pitting is visible on the exterior of the A-5 clamping plates examined in 2004. This was not seen in the 2001 inspection photographs. Also, some discoloration is noted in the area around the stainless steel clips in Figure 10. The relatively small area of the clip versus the large aluminum area should prevent anodic corrosion of the aluminum. However, the stainless steel clips were riveted and there could be a crevice at the clip edges.

Interior views of the B-3 clamping plate surfaces, shown in Figure 11 and Figure 12, reveal individual pits that were observed during the 2004 inspection. The internal pits appear to be located in wear tracks from the fuel plates and are probably the result of crevice corrosion. Figure 11 reveals a view of the bottom of the B-3 clamping plates that shows the position of the six fuel plates. The edges of the six fuel plates contact the clamping plates but not the face (Sides A and C) of the fuel. Thus, the fuel edge in contact with the interior surface of the clamping plate creates a crevice condition. Figure 12 also shows the inside surface of the rivets used to fasten the clips onto the clamping plate. The rivets were ground flush and appear to be intact.

Visual inspection of Uruguay spent fuel is currently adequate to assess the fuel condition as long as future changes in pit depth and diameter do not occur. A quantitative inspection method is necessary to provide depth and diameter measurements for comparison between future inspection intervals.

7.0 Conclusions

There is no significant corrosion occurring in the wet stored Uruguay fuel assemblies (A-5, B-2, B-3, and 5-5). This is based upon photographs taken during inspections performed in 1998, 2001 and 2004. However, pits were observed in the clamping plates used to hold the fuel assemblies within the L bundle.

8.0 References

1. Burke, S. D., "Summary Plan for Dry Storage of Uruguay Fuel (U)," Westinghouse Savannah River Company Inter-Office Memorandum to R. J. Skwarek (January 22, 1998).
2. Sindelar, R. L, Peacock, H. B., Jr., Lam, P. S., Iyer, N. C., and Louthan, M. R., Jr., "Acceptance Criteria for Interim Dry Storage of Aluminum-Alloy Clad Spent Nuclear Fuels (U)," Westinghouse Savannah River Company, WSRC-TR-95-0347 (March 1996).
3. Peacock, H. B., Jr., Sindelar, R. L, Lam, P. S., and Murphy, T. H., "Evaluation of Corrosion of Aluminum Base Reactor Fuel Cladding Materials During Dry Storage (U)," Westinghouse Savannah River Company, WSRC-TR-95-0345 (November 1995).
4. San Pedro, I.A.E.A. Interregional Training Course on the Technical and Administrative Preparations Required for Shipment of Research Reactor Spent Fuel to its Country of Origin, January 13-24, 1997.
5. Drawing C-CS-L-0962 Rev. 7, Disassembly Area Bundling Tube Structural Aluminum (U), July 17, 2002
6. "Spent Nuclear Fuel Acceptance Criteria No. 1 Rev. 1, Under Contract No. DE-AC09-98SR18934 with Ministerio de Industria, Energia, Y Mineria de Uruguay," Appendix A Document for Uruguayan RU-1 Spent Nuclear Fuel, DOESRAAF-98-012.
7. Spent Nuclear Fuel Acceptance Criteria No. 2 Rev. 1, Under Contract No. DE-AC09-98SR18934 with Ministerio de Industria, Energia, Y Mineria de Uruguay," Appendix A Document for Uruguayan RU-1 Spent Nuclear Fuel, DOESRAAF-98-012.
8. "Spent Nuclear Fuel Acceptance Criteria No. 3 Rev. 1, Under Contract No. DE-AC09-98SR18934 with Ministerio de Industria, Energia, Y Mineria de Uruguay," Appendix A Document for Uruguayan RU-1 Spent Nuclear Fuel, DOESRAAF-98-012.
9. "Spent Nuclear Fuel Acceptance Criteria No. 4 Rev. 1, Under Contract No. DE-AC09-98SR18934 with Ministerio de Industria, Energia, Y Mineria de Uruguay," Appendix A Document for Uruguayan RU-1 Spent Nuclear Fuel, DOESRAAF-98-012.

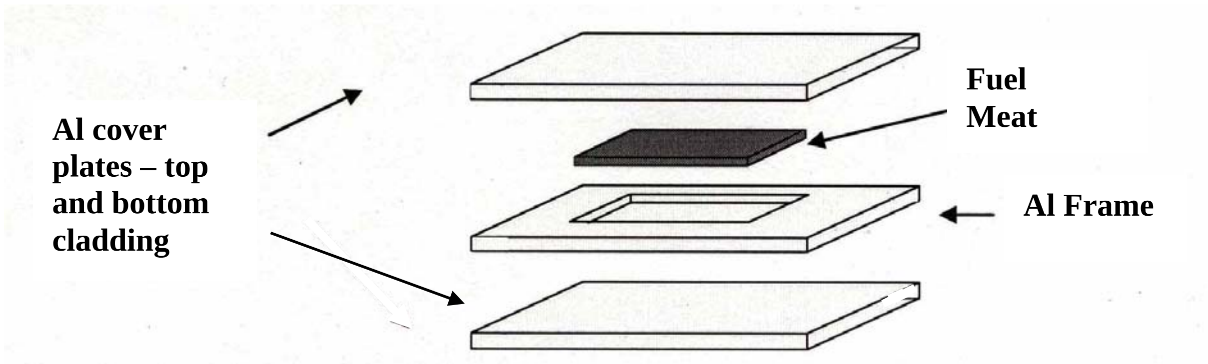


Figure 1. Typical picture frame assembly of plate type fuel with fuel mounted within a frame. The assembly is hot rolled to create a metallurgically bonded assembly.

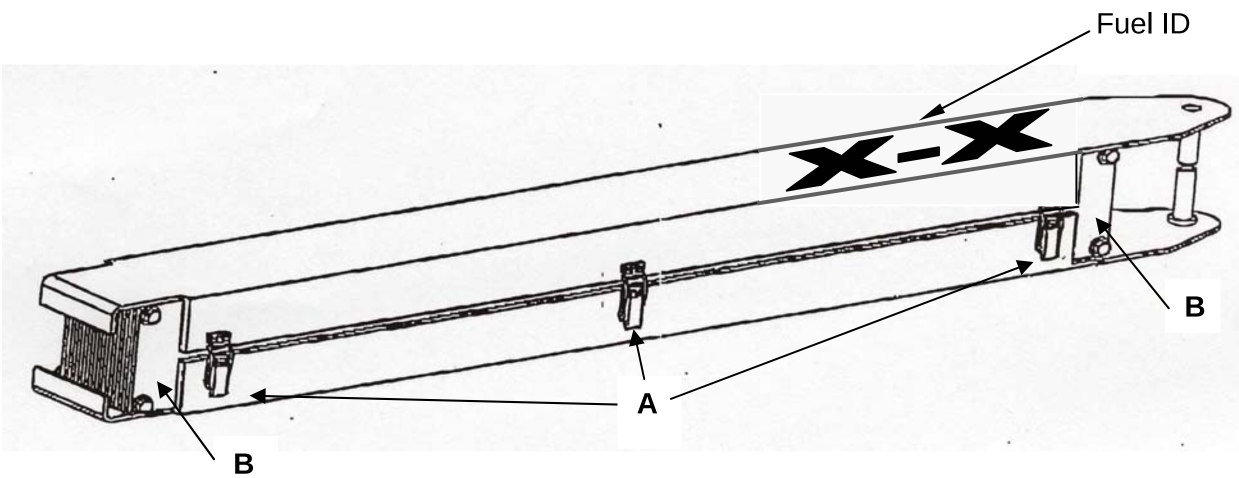


Figure 2. Two clamping plates with stainless steel attachment clips (A) containing six fuel plates inside (B). X-X shows location of fuel identification. Uruguay wet fuel is marked as A-5, B-2, B-3, or 5-5. Four clamping plate assemblies are stacked within one tube bundle.

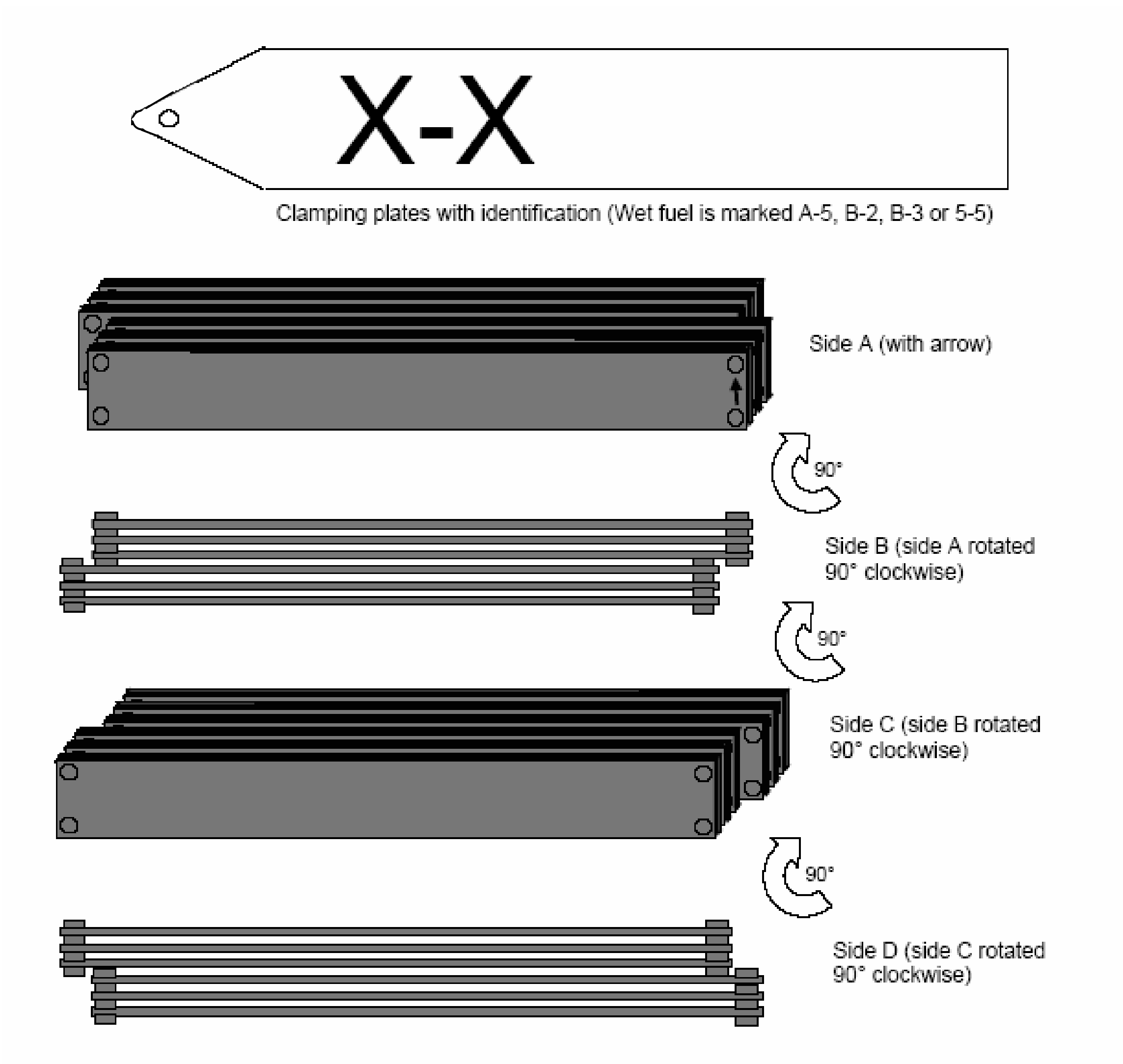
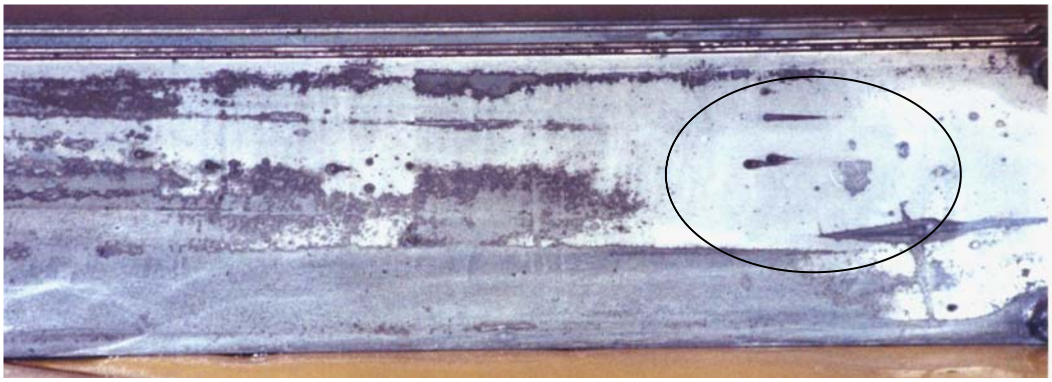
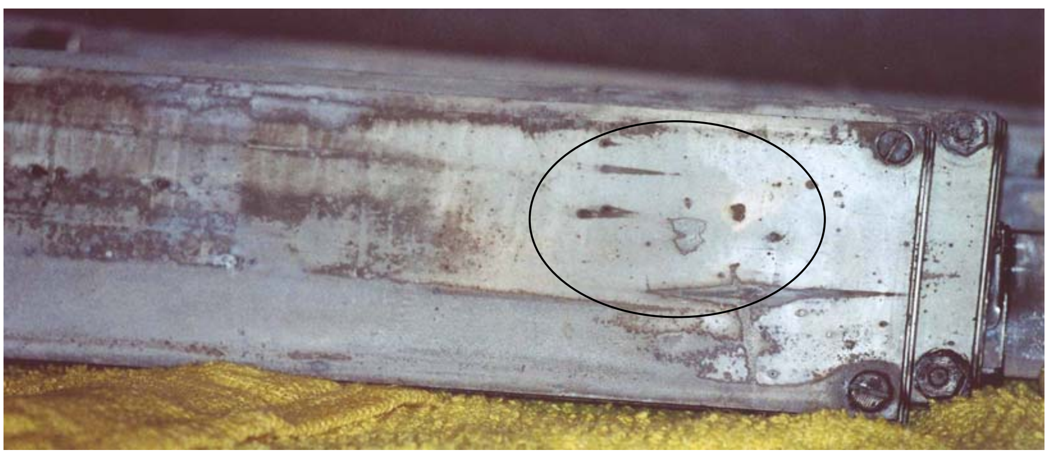


Figure 3. Inspection process for wet Uruguay fuel to allow viewing and photography of each of the four sides of a fuel assembly (six fuel plates). The process includes; identification of fuel assembly by letter/numbers on side of clamping plates, location of fuel plate with arrow (Side A) marked with indelible ink, rotation of 90° to Side B (plate edges), rotation of 90° to Side C, with final rotation to Side D (plate edges), and then reassembly.

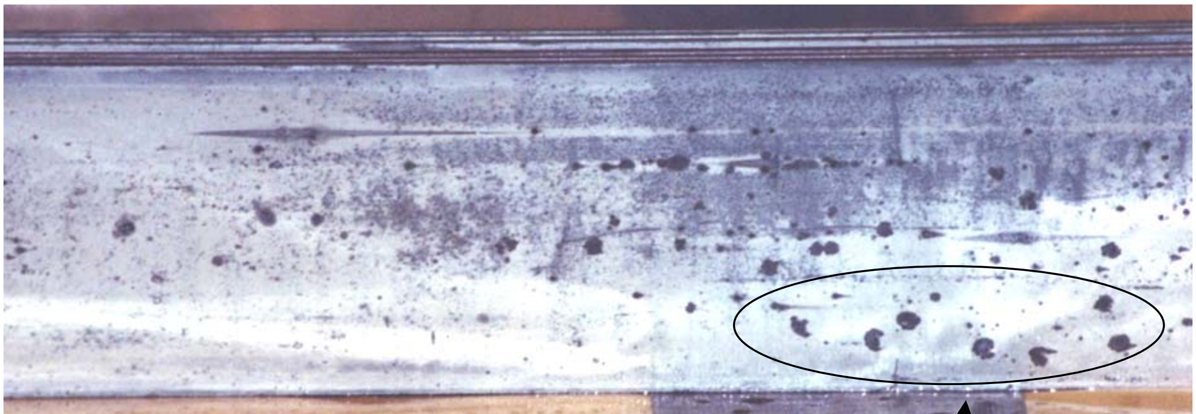


(A) Fuel 5-5, Side C, right end inspected October 1998 upon fuel receipt

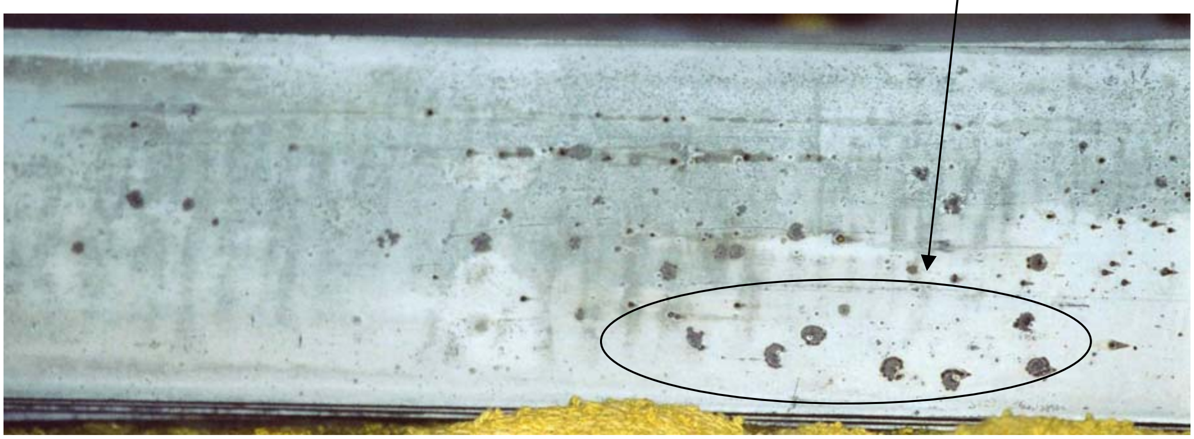


(B) Fuel 5-5, Side C, right end Inspected August, 2004

Figure 4. Photo comparison of inspections performed on fuel assembly 5-5, side C (right end) in 1998 (A) and 2004 (B). Circled areas in both photos reveal pits that show little or no changes since the original receipt inspection. Pitted areas are duplicated in the 2004 inspection photograph. Differences in the appearance of surface stains or markings to the left of circled areas may be due to light exposure at the time photographs were taken.

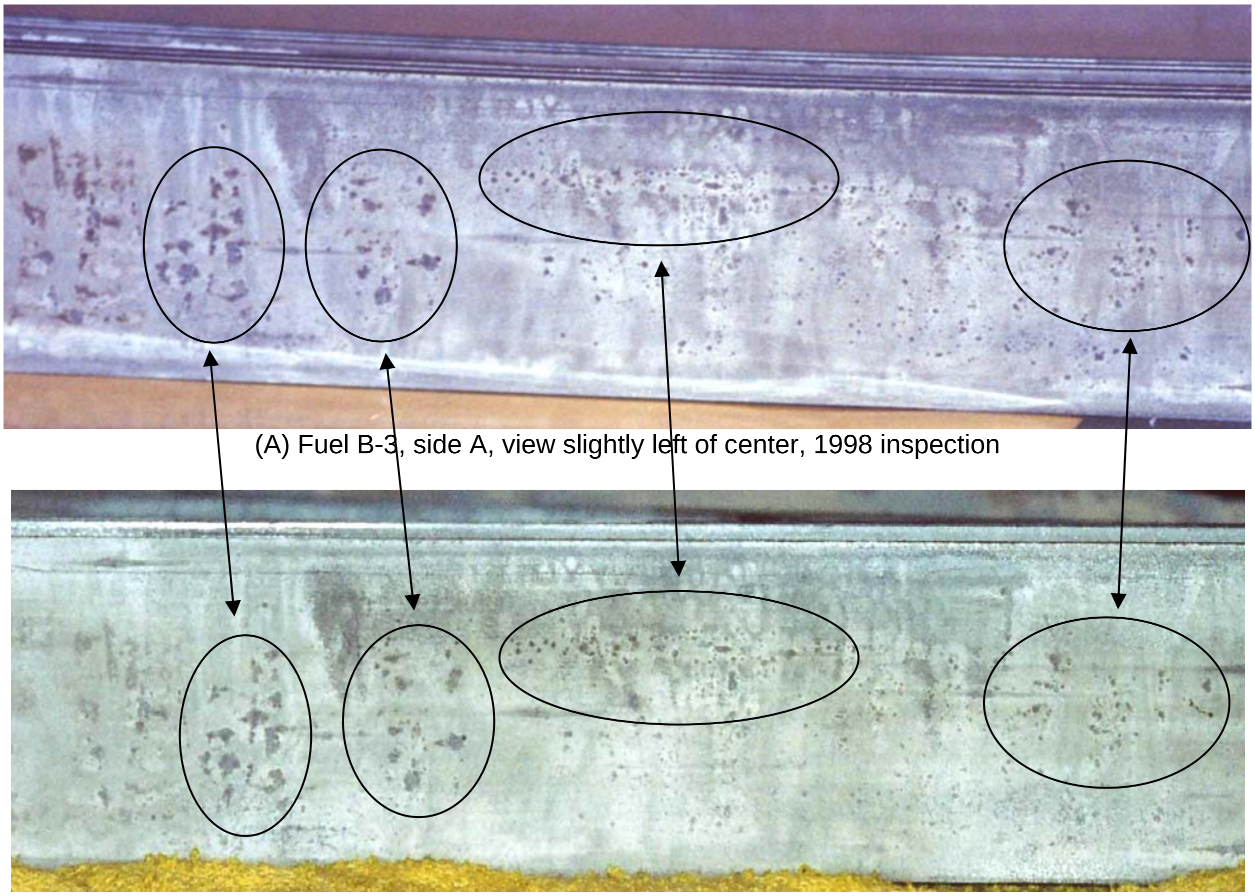


(A) Fuel B-2, side A, left of center, 1998 inspection



(B) Fuel B-2, side A, left of center, 2004 inspection

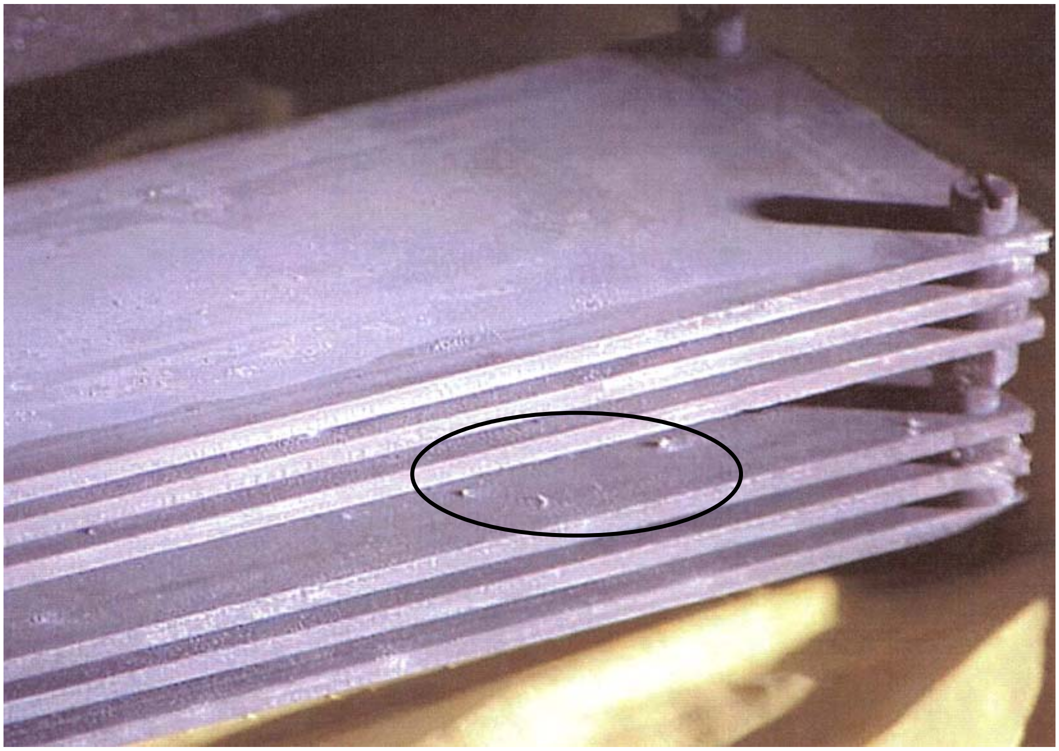
Figure 5. Photo comparison of inspections performed on fuel assembly B-2, side A (slightly left of center) in 1998 (A) and 2004 (B). Circled areas in both photos show pits and other surface marks that show little or no changes since the original receipt inspection. Pitted areas appear to have the same shape in the 2004 inspection.



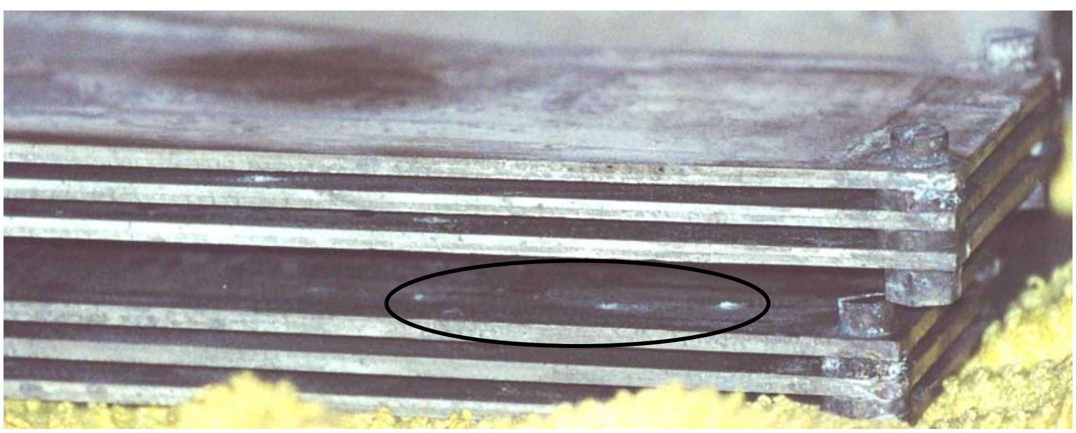
(A) Fuel B-3, side A, view slightly left of center, 1998 inspection

(B) Fuel B-3, side A, view slightly left of center, 2004 inspection

Figure 6. Photo comparison of inspections performed on fuel assembly B-3, side A (slightly left of center) in 1998 (receipt inspection) and 2004. Circled areas in both photos show pits and other surface marks that show little or no changes since the original receipt inspection. Pitted areas are duplicated in the 2004 inspection.



(A) Fuel B-3, Side D, Right, 1998 inspection



(B) Fuel B-3, Side D, Right, 2004 inspection

Figure 7. Photo comparison of inspections performed on fuel assembly B-3, side D, right corner in 1998 (receipt inspection) and 2004. Circled areas show similar positions of particles or tubercles although the photos are taken at different angles. They may be the same. The fasteners in the 1998 photograph appear to be much cleaner than in 2004 which appear to have more oxide. This may also be due to the lighting and differences in the photographic angle.

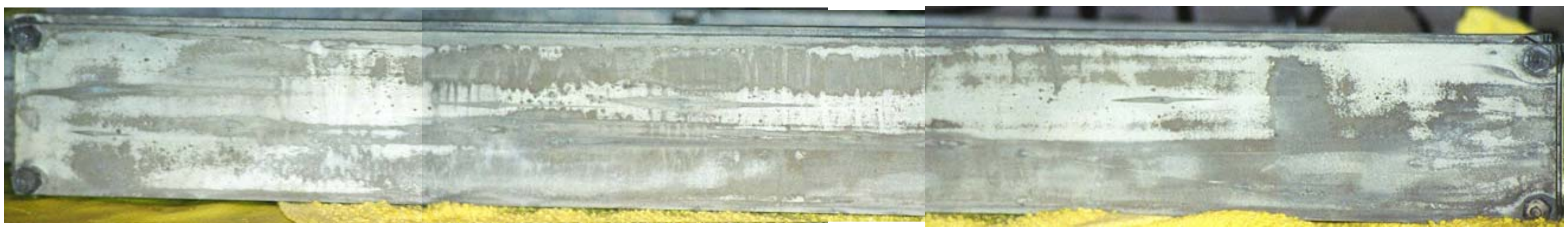


Figure 8. Image of side C of fuel A-5 (from 2004 inspection) is shown without screw heads showing. This is the inside surface that was not photographed during prior inspections. A match could not be made with prior inspection photographs.

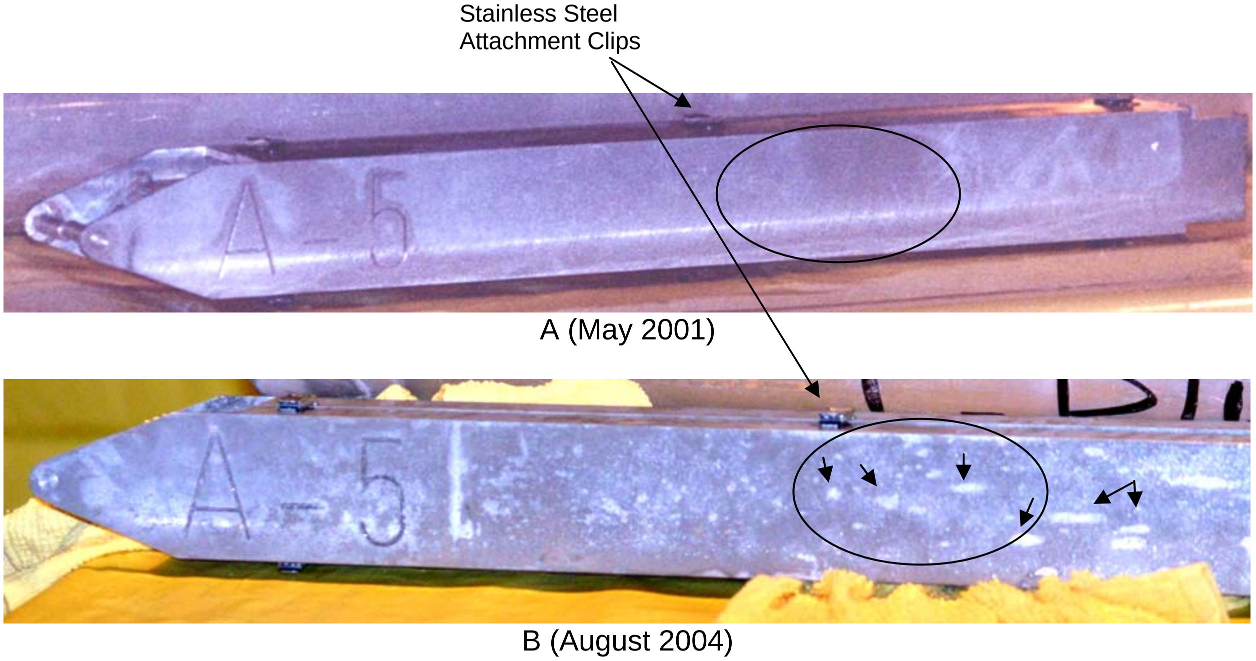


Figure 9. Exterior of clamping plates for Uruguay fuel assembly A-5 showing evidence of pitting to the right of the middle stainless steel attachment clip from 2004 inspection (B). None was visible in the 2001 inspection (A).

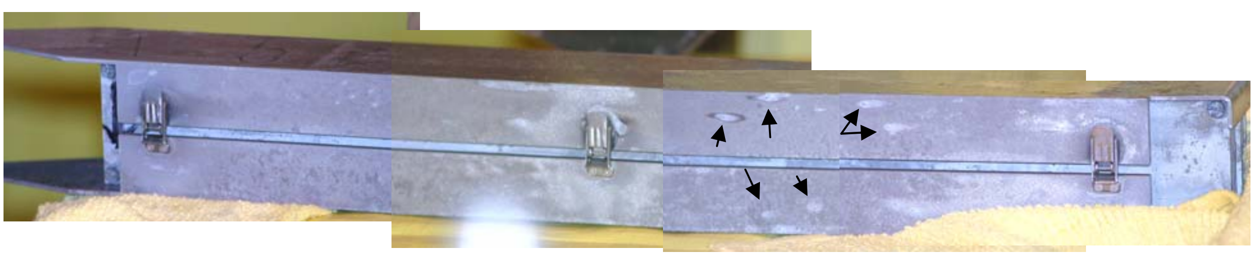


Figure 10. Side view of A-5 fuel assembly clamping plates with stainless steel attachment clips and evidence of pitting as photographed in August 2004 inspection.

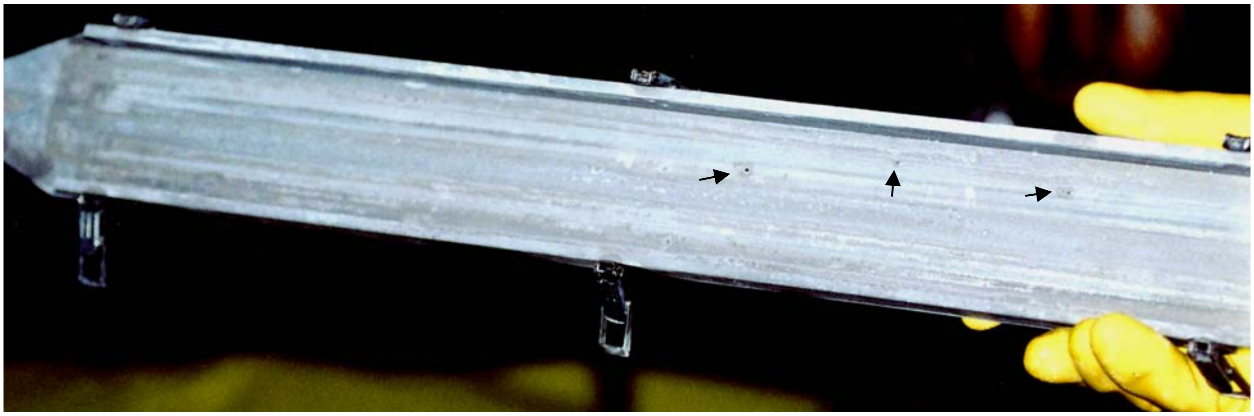


Figure 11. Pit locations are shown on interior surface of one clamping plate from B-3 fuel assembly in 2004. The pits appear to be in locations where fuel plates touch the clamping plate.

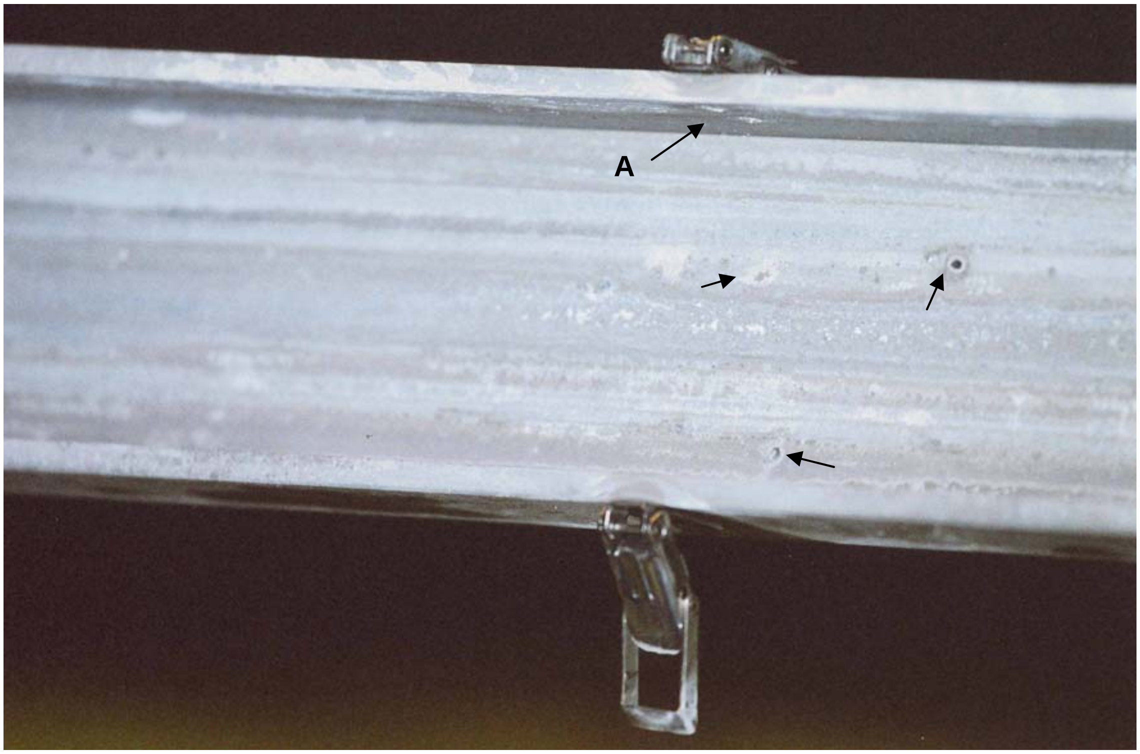


Figure 12. Close-up photograph of a few pit locations from Figure 11 are shown in one clamping plate (B-3 fuel assembly) along with view of stainless steel clip rivet locations (A).

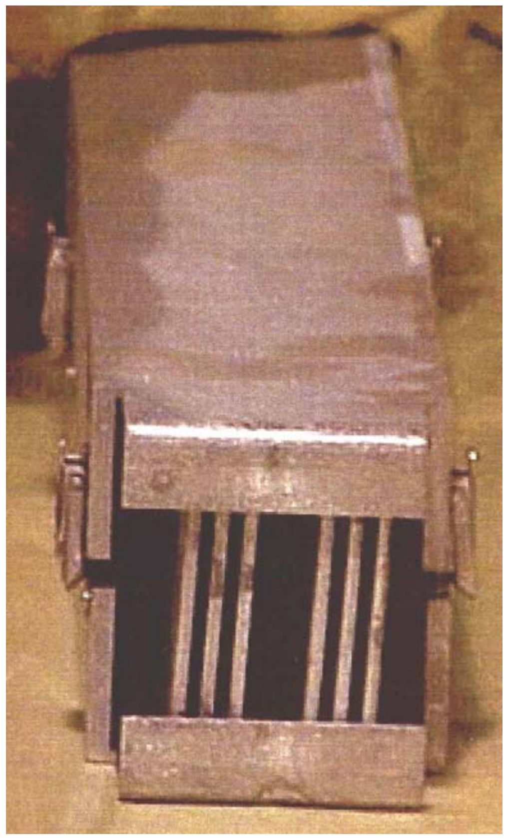


Figure 13. Bottom of clamping plates from B-3 fuel assembly showing position of six fuel plates from inspection in 2001.

WSRC INTERNAL DISTRIBUTION

D. B. Rose, 704-28L
T. J. Spieker, 704-30L
D. L. Melvin, 704-25L
R. W. Deible, 704-26L
S. C. Declue, 704-K
N. C. Iyer, 773-41A
R. L. Sindelar, 773-41A
J. I. Mickalonis, 773-A
P. R. Vormelker, 773-41A
A. J. Duncan, 773-A
T. H. Murphy, 773-A
D. W. Vinson, 773-41A
M. K. Hicks, 773-41A
SRNL Records, 773-52A