FRAMATOME ANP

An AREVA and Siemens company

FRAMATOME ANP, Inc.

August 8, 2003
NRC:03:051

Document Control Desk
ATTN: Chief, Planning, Program and Management Support Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Closure of Interim Report 02-002, "Spacer Grid Crush Strength - Effects of Irradiation"

Ref.: 1. Letter, J. F. Mallay (Framatome ANP) to Document Control Desk (NRC), "Interim Report of Evaluation of a Deviation Pursuant to 10 CFR 21.21(a)(2)," NRC:02:031, July 10, 2002.

Ref.: 2. Letter, J. F. Mallay (Framatome ANP) to Document Control Desk (NRC), "Status of the Evaluation of a Deviation Pursuant to 10 CFR 21.21(a)(2)," NRC:03:041, June 27, 2003.

Two interim reports were made to the NRC concerning the effects of irradiation on spacer grid crush strength (see References 1 and 2). The final evaluation of this situation has been completed and Framatome ANP has concluded that the deviation is not reportable under 10 CFR 21.

Framatome ANP's evaluation, including a summary of results, is provided in Attachment A. A proprietary and a non-proprietary version of Attachment A is provided. The strength requirements were evaluated for all plants to which Framatome ANP supplies fuel in the U.S., and we conclude that the applicable requirements are satisfied.

In addition to closing out the interim reports on this situation, the purpose of this letter is to point out the possibility that the reduction in spacer grid crush strength with increased irradiation may be generic to all fuel assembly designs.

Framatome ANP considers some of the information contained in the attachment to be proprietary. An affidavit is provided which satisfies the requirements of 10 CFR 2.790(b) to support the withholding of this information from public disclosure.

Very truly yours,

Gerald S Holm for

James F. Mallay, Director
Regulatory Affairs

Attachments

cc: F. M. Akstulewicz
D. G. Holland
E. S. Peyton
J. S. Wermiel
Project 728

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Y601

FRAMATOME ANP, Inc.
2101 Horn Rapids Road - Richland, WA 99352
Tel.: 509-375-8100 Fax: 509-375-8402 www.us.framatome-anp.com

AFFIDAVIT

STATE OF WASHINGTON)
) ss.
COUNTY OF BENTON)

1. My name is Jerald S. Holm. I am Manager, Product Licensing, for Framatome ANP ("FANP"), and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by FANP to determine whether certain FANP information is proprietary. I am familiar with the policies established by FANP to ensure the proper application of these criteria.

3. I am familiar with the FANP information in letter number NRC:03:051 dated August 8, 2003, and referred to herein as "Document." Information contained in this Document has been classified by FANP as proprietary in accordance with the policies established by FANP for the control and protection of proprietary and confidential information.

4. This Document contain information of a proprietary and confidential nature and is of the type customarily held in confidence by FANP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure.

6. The following criteria are customarily applied by FANP to determine whether information should be classified as proprietary:

(a) The information reveals details of FANP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for FANP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for FANP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by FANP, would be helpful to competitors to FANP, and would likely cause substantial harm to the competitive position of FANP.

7. In accordance with FANP's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside FANP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. FANP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 8

day of August, 2003.

Susan K. McCoy
NOTARY PUBLIC, STATE OF WASHINGTON
MY COMMISSION EXPIRES: 1/10/04

SUSAN K. McCOY
COMMISSION EXPIRES
NOTARY
PUBLIC
1-10-04
STATE OF WASHINGTON

Attachment A
Evaluation of Irradiated Spacer Grid Strength

1.0 Introduction

Framatome ANP, Inc. performs mechanical analyses for its fuel products under LOCA and seismic accident conditions in accordance with the approved methodology described in References 1 through 7. These topical reports were prepared and approved following the NUREG 800 Standard Review Plan (SRP). Section 4.2, Appendix A of the SRP provides specific guidance on how to establish the minimum buckling load of a grid design by testing in the non-irradiated beginning of life (BOL) condition. The SRP states that uncertainties in the fuel behavior due to irradiated grid strength are compensated for by an increase in material strength due to irradiation.

In March 2002, Framatome ANP, Inc. (U.S. Region) was notified of test results indicating that the buckling strength of irradiated AFA2G grids used by Framatome ANP (France Region) decreases. These test results put the conservatism of the SRP assumption in question. This issue affects all fuel designs manufactured by Framatome ANP.

In order to evaluate the effect of irradiation on the grid strength criteria for safe operation with Framatome ANP's U.S. Region designs, a four-step plan was developed to reproduce the grid buckling behavior under simulated EOL conditions and then to reassess the safety margins.

1) Development of a test procedure to simulate the strength performance of irradiated grids.
2) Execution of the procedure to define parameters and then re-test U.S. Region grids under simulated EOL conditions.
3) Re-evaluation of seismic-LOCA margins based on results from simulated EOL grid tests.
4) Revision of existing analyses, if necessary, to resolve any negative margin issues.

2.0 Summary

The conclusion that the strength of grids decreases with irradiation is based on tests of irradiated Framatome ANP AFA2G grids. Framatome ANP's AFA2G grids, which had been irradiated up to four cycles, were compressed until failure [

]. Visual examinations revealed that the grids retained significant ductility with only a limited number of broken intersection welds. The testing, which was conducted in a hot cell, revealed a dependence of grid strength on irradiation exposure. [

]

The data from simulated end of life (EOL) grid tests were compared to the existing design basis loads for all plants fueled by Framatome ANP. All but three had positive margin. The design basis loads for the three plants with negative margin were reassessed or recalculated using the latest approved methods and have been shown to have positive margin.

The following can be concluded.

a) French (AFA2G) grid behavior is representative of U.S. designs – that is, the influence of grid spring forces on buckling stability.

b) The EOL grid condition is well simulated by the spring relaxation method, i.e., the test results are well correlated between actual and simulated EOL grids, and grid ductility is retained as was observed in the hot cell testing.

c) *Sufficient margin exists to accommodate a reduction of grid strength due to irradiation.* The requirements of 10 CFR 50.46 and Standard Review Plan NUREG 0800, Section 4.2 for control rod insertion and fuel coolability are satisfied.

3.0 Framatome ANP Spacers

A description of the Framatome ANP grids used in the United States is presented below. A description of the French Framatome AFA2G grid is also provided for comparison. The U.S. Framatome ANP PWR grid designs share many similarities to the AFA2G grids tested in the hot cell.

The French Framatome AFA2G grid has an "egg-crate" configuration of intersecting strips. Four "hard" stops (or dimples) integral to the Zircaloy grid strip and two Inconel 718 ("soft" stops) springs provide the fuel rod support. In each of two directions, there are two hard stops at a lower and upper elevation and an opposing spring at a central elevation. Figure 1 shows the major features of the AFA2G grid design.

The U.S. Framatome ANP grids can be divided into five primary product groups:

- Mark-BW PWR design (17x17 W)
- Mark-B PWR design (15x15 B&W)
- HTP PWR design (14x14 W, 15x15 W, 17x17 W, 14x14 CE, 15x15 CE)
- Bi-metallic PWR design (formerly Exxon Nuclear) (17x17 W, 14x14 CE)
- ATRIUM™-9B and ATRIUM™-10 ULTRAFLOW BWR design (BWRs 3, 4, 5, and 6)

The Mark-BW and Mark-B designs use six-point rod contact monometallic, zirconium alloy grids. The six-point contact system is quite similar to that of the AFA2G design. The Mark-BW design is shown in Figure 2. The Mark-B design, not shown, is fundamentally the same design in a 15x15 configuration. This same design configuration is used in fuel for both Westinghouse and B&W designed reactors.

The HTP design has four dual-line contact pairs for fuel rod support. The grids are made of Zircaloy-4. Figure 3 shows a section of the grid. This design is used in Westinghouse and CE type reactors.

In addition, Framatome ANP has provided a U.S. bi-metallic PWR design, shown in Figure 4, which incorporates a five-point rod contact support using corner springs. The bi-metallic grid design is made with a Zircaloy-4 structure and Inconel 718 springs. The hard stop contacts are like those used in the AFA2G design. The principal difference is that there is a single grid spring in the corner for this design compared to two opposing springs for the AFA2G design.

The BWR grid design, ULTRAFLOW (not shown), has a bi-metallic configuration with a six-point fuel rod support system similar to that of the AFA2G. BWR fuel is housed within a fuel channel so that grids are not significantly loaded during a seismic or LOCA accident.

4.0 Irradiated Grid Strength Reduction

Testing was conducted on actual irradiated AFA2G grids in a hot cell. The grids were carefully examined for damage and measured prior to testing. [ ]

Two fuel assemblies, one with one cycle of irradiation and another with four cycles of irradiation, were partially disassembled at the TRICASTIN reactor in France. Fuel assembly exposures were 11.9 and 46.6 MWd/kgU. The cages were transported and further disassembled for grid tests in the hot cells at CEA-SACLAY located in France. Rod insertion and extraction tests were performed to characterize the amount of spring relaxation. Non-irradiated grids of the identical type were prepared as control samples for inclusion in the test program.

Dynamic lateral load tests were conducted using a hydraulically driven load test machine. The tests were conducted at 325 °C [ ]. The grids were loaded in a through-grid manner with the load applied across two opposite faces. [ ] The range of strength reduction includes both the one cycle and four cycle fuel assemblies.

Figure 5 depicts the grid buckling strength test results versus cladding insertion forces for irradiated and non-irradiated (control) grids. These values were obtained from tests conducted in the hot cell. The data exhibit a good fit of buckling strength versus cladding insertion force. The cladding insertion force is indicative of relaxation due to burnup. One first cycle point deviated from the trend. This is not atypical of grid tests and is accounted for in the design limit using a 95%/95% confidence interval. [ ]

[ ] A typical failed grid from the hot cell testing is shown in Figure 6.

[

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5.0 Simulation of EOL Conditions

A comprehensive test program was devised to establish a set of simulated EOL conditions to evaluate the effects of irradiation on Framatome ANP U.S. region fuel designs. [

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Testing was conducted in two phases. For Phase I tests, one typical six-point contact design and one typical HTP design were chosen. The purpose of Phase I was to identify the appropriate test parameters to simulate EOL conditions. In Phase II, each U.S. region grid design type was tested using the parameters developed in Phase I. The tests were performed on a programmable hydraulic high-speed test apparatus that loaded the grid on opposing faces.

In Phase I, 15x15 HTP and Mark-B grids were tested in the relaxed (~0 gap) and unrelaxed condition. Test temperature, load rate, and oxidation level were varied to determine the appropriate conditions to simulate EOL.

Each grid design was tested at 20 °C and 310 °C. Grids were tested at 0.16, 50, 125, 200, and 250 mm/sec. Grids with oxidation levels of approximately 25, 45, and 65 microns were also tested. There is a single failure mode for the Mark-B grid, which is the same as for the AFA2G (racking due to buckling at grid cell intersections). The HTP type grid has two possible failure modes. The first and most predominant is the racking mode found in the AFA2G. The second mode is characterized by a slight compression of the envelope, resulting in a classical yielding load-deflection signature.

The test conditions established from Phase I are:

- [
-
-
-]

6.0 Evaluation of Irradiated Grid Strength

The grid strengths were measured for each of the designs at the simulated EOL conditions and compared to the original design basis for each plant. The test results were used to calculate a 95% lower confidence level grid failure load per the guidance in the SRP.

The results for three plants resulted in negative margins relative to the original design loads. In these cases, revised design basis loads were determined using methodology approved by the NRC after the determination of the original design loads. For plants containing non-Framatome ANP fuel, assumptions were made based on the knowledge gained from in-house testing and the design information provided at the time of initial core transition. A summary of the limiting margins for each grid type is shown in Table 1 except for one plant.

In one plant, the maximum loads were sufficient to cause buckling of the Mark-BW grid in peripheral core locations. In this case, additional evaluations were performed to demonstrate compliance to the criteria in 10 CFR 50.46.

The testing resulted in strength reductions between irradiated grids and un-irradiated PWR grids of [ ] depending on the grid design. The specific amount of strength reduction between BOL and EOL conditions was not determined for the BWR spacers.

7.0 References

1. BAW-10133P-A, Revision 1 with Addendums 1 and 2, *Mark-C Fuel Assembly LOCA-Seismic Analysis*, Babcock & Wilcox, November 2000.

2. XN-76-47(P)(A), *Combined Seismic-LOCA Mechanical Evaluation for Exxon Nuclear 15x15 Reload Fuel for Westinghouse PWRs*, Exxon Nuclear Company, January 1982.

3. XN-NF-696(P)(A), *ENC's Solution to the NRC Sample Problems - PWR Fuel Assemblies Mechanical Response to Seismic and LOCA Events*, Exxon Nuclear Company, April 1986.

4. EMF-93-074(P)(A) and Supplement 1, *Generic Mechanical Licensing Report for Advanced 17x17 Fuel Design*, Siemens Power Corporation, June 1994.

5. XN-NF-81-51(P)(A), *LOCA-Seismic Structural Response of an Exxon Nuclear Company BWR Jet Pump Fuel Assembly*, Exxon Nuclear Company, May 1986.

6. XN-NF-84-97(P)(A), *LOCA - Seismic Structural Response of an ENC 9x9 BWR Jet Pump Fuel Assembly*, Exxon Nuclear Company, August 1986.

7. EMF-93-177(P)(A) and Supplement 1, *Mechanical Design for BWR Fuel Channels*, Siemens Power Corporation, August 1995.

Table 1 Limiting Margin for Each Grid Type

Grid Type	Allowable Load 95% Confidence (lbs)	Maximum Load (lbs)	EOL Margin %
HTP	[		]
Bi-metallic	[		]
BWR ULTRAFLOW	[		]
Mark-B	[		]
Mark-BW	[		]

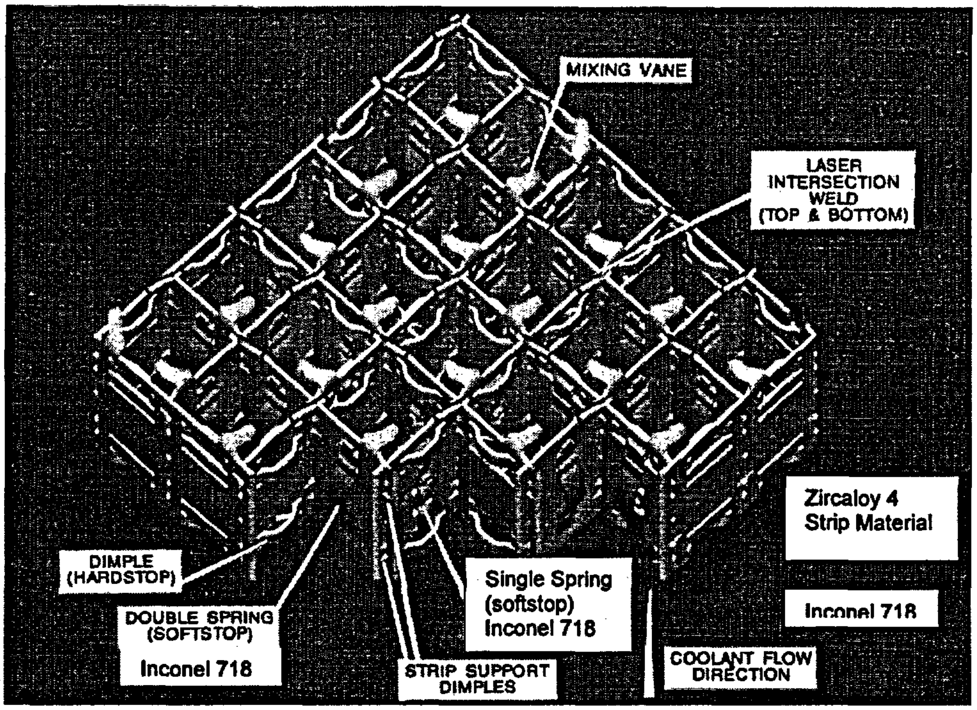

Figure 1 AFA2G Bi-metallic Grid Details

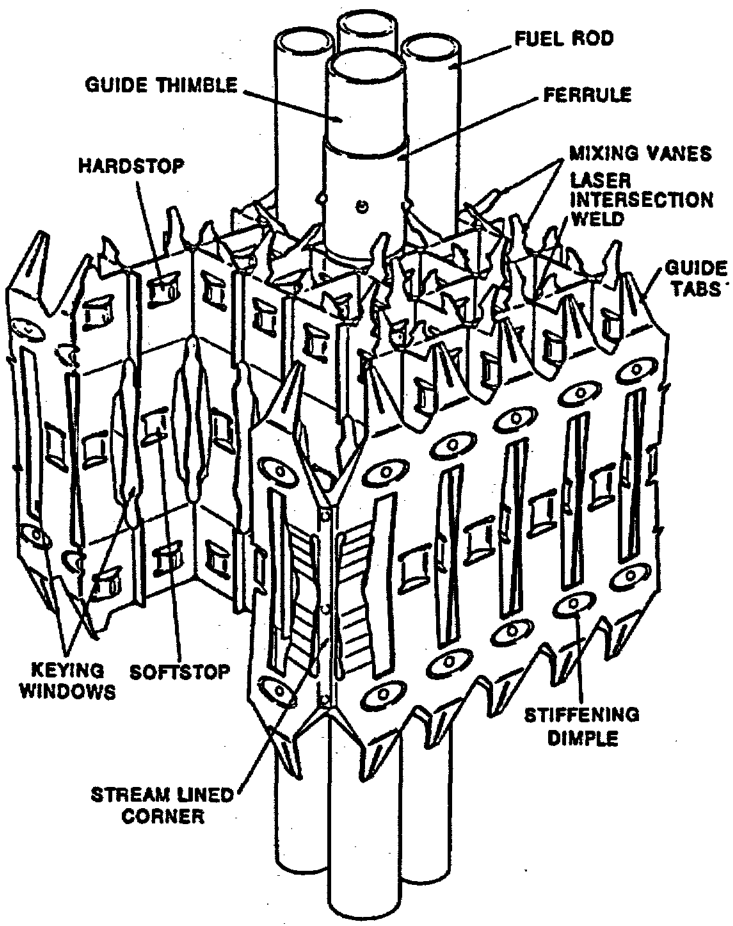

Figure 2 PWR Mark-BW Grid Details

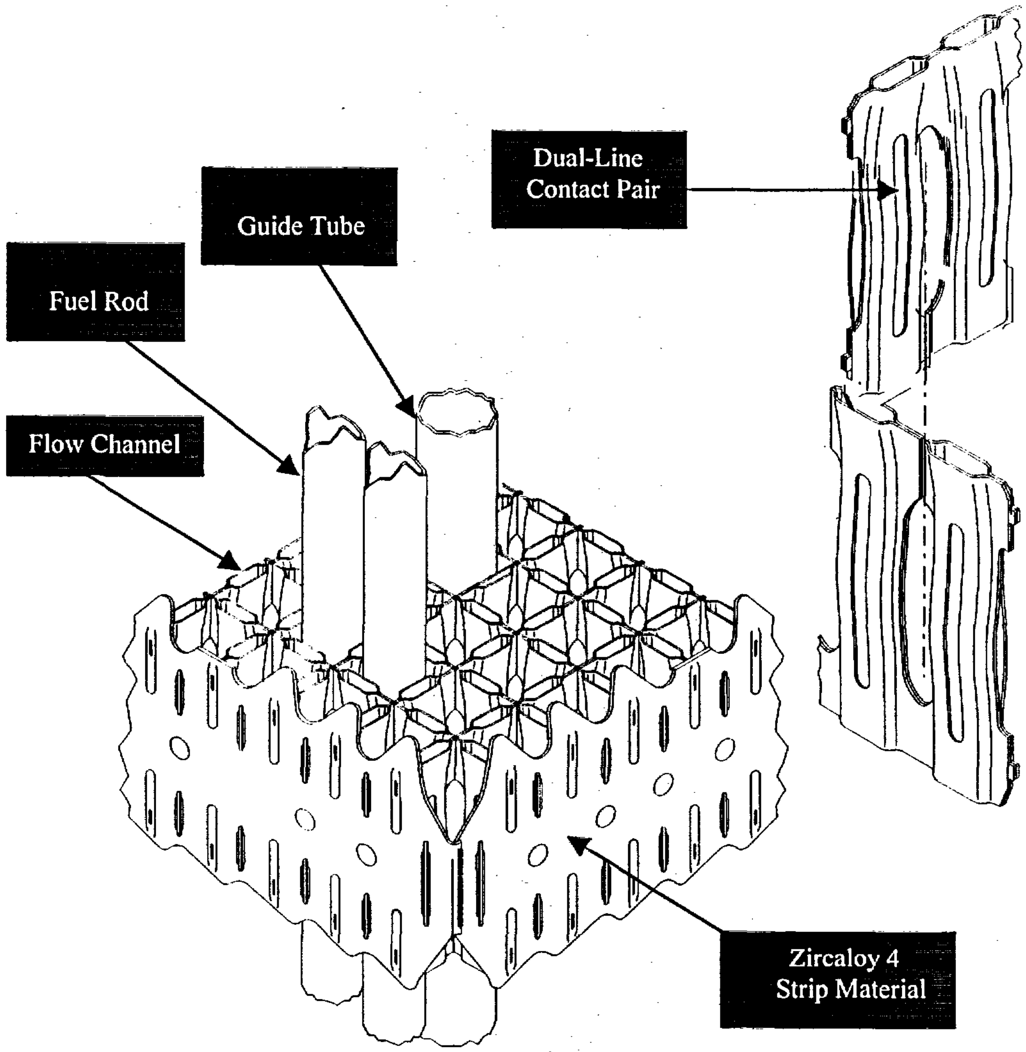

Figure 3 PWR HTP Grid Details

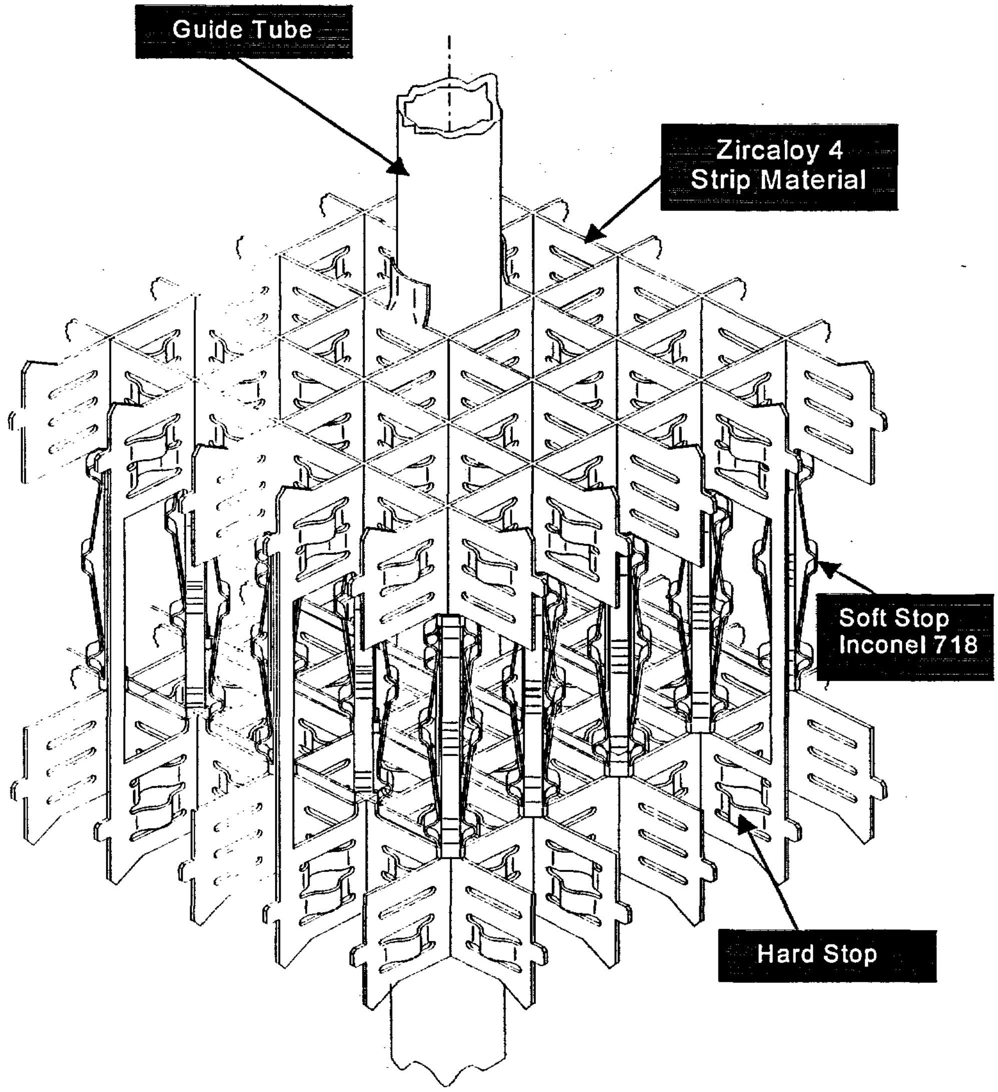

Figure 4 PWR Bi-metallic Grid Details

Figure 5 Buckling Load vs. Cladding Insertion Force

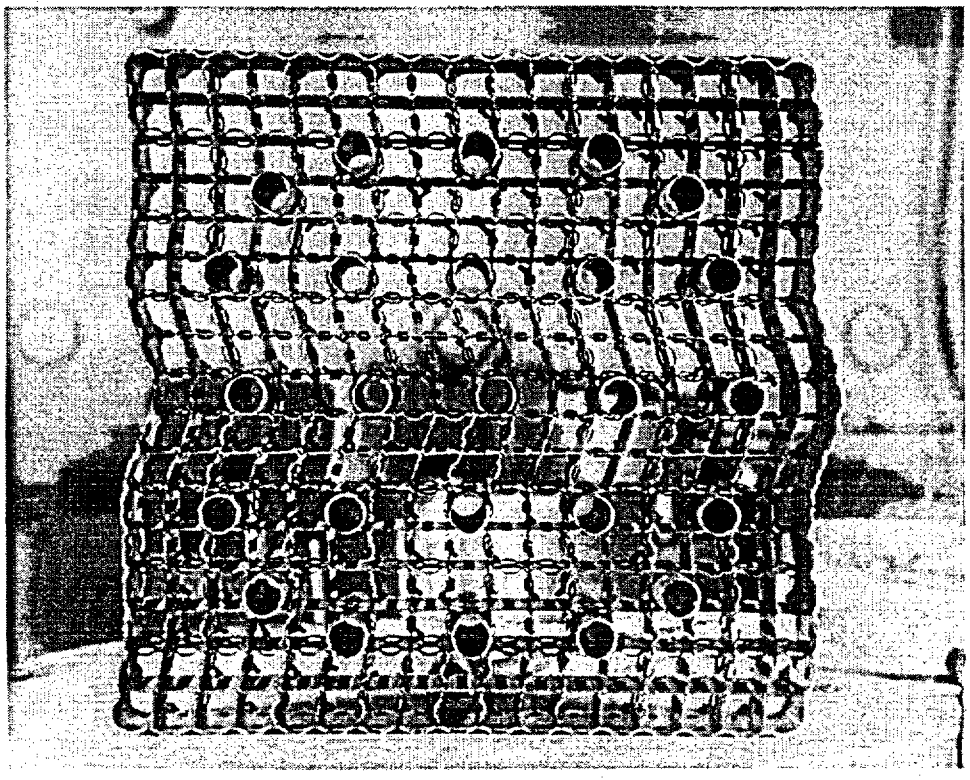

Figure 6 Typical Racking Failure Mode - Grid A32823

Figure 7 Typical Load vs. Deflection Behavior of Irradiated Grid

Figure 8 Buckling Load vs. Fuel Pin Diameter for Non-irradiated Grids