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Radiographic Inspection of Fueled Clads

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SUMMARY

Five general purpose heat source (GPHS) fueled clads were radiographically inspected at the Idaho National Laboratory (INL). The girth weld region of each clad had previously passed visual examination, ring gauge test, and leak test but showed “positive” indications on the ultrasonic (UT) test. Positive ultrasonic indications are allowable under certain weld conditions; radiographic inspection provides a secondary nonintrusive means of clad inspection and may confirm allowable anomalies from the UT inspection. All the positive UT indications were found to exhibit allowable weld shield fusion or mismatch conditions. No indication of void defects was found. One additional clad (FCO371) was deemed unacceptable for radiographic inspection due to an unknown black substance that obscured the angular origin on the weld so that the angular offset to the UT indication could not be found.

ACKNOWLEDGMENTS

Facility personnel involved in the operations of Building 792A enabled the radiography task to occur by providing substantial support to the radiographers in addition to their responsibilities associated with handling fueled clads and other daily tasks. Their professional manner and patience were greatly appreciated.

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Radiographic Inspection of Fueled Clads

1. INTRODUCTION

Five general purpose heat source (GPHS) fueled clads underwent radiographic inspection during April 4-8, 2005 in Building 792A at the Materials and Fuels Complex (MFC) at the Idaho National Laboratory (INL). The girth weld region of each clad had previously undergone extensive inspections, including a visual examination, ring gauge test, leak test, and ultrasonic examination.[1,2] Each clad passed the visual, ring, and leak tests but showed "positive" indications on the ultrasonic (UT) test.[2] Positive ultrasonic indications are allowable under certain weld conditions including weld shield fusion, internal mismatch, and internal concavity/external bulge as described in Reference 1. Radiographic inspection provides a secondary nonintrusive means of clad inspection and may confirm allowable anomalies from the UT inspection.

One additional clad (FCO371) was not radiographically inspected because an unknown black substance obscured the angular origin on the weld. Without this origin, the angular offset to the UT indication could not be found.

2. RADIOGRAPHIC EXAMINATION

Previous inspections of fueled clads at Los Alamos National Laboratory (LANL)[3,4] provided guidance for the radiography examinations in Building 792A. In addition to the procedural guidance, two LANL radiographers (Mr. Alex Rodriguez and Mr. Gerald Langner) with experience in radiographic inspection of fueled clads were consulted. Configurations for radiographic inspections of fueled clads at LANL are provided in References 3 and 4. LANL has previously used three types of accelerators to generate x-ray bremstrahlung radiation for radiography: a 24 MeV Betatron, a 2.5 MeV X-ray generator, and a 6 MeV linear accelerator (linac). The configuration used in Building 792A was similar to these earlier configurations. For x-ray generation, INL obtained the use of a 4 MeV linac from a local vendor associated with the Idaho Accelerator Center (IAC) in Pocatello, ID. The linac was operated by Mr. Mike Smith from the IAC. Tangential radiography (see Figure 1 of Ref. 3 and Figure 1) was employed to maximize visibility of the region of interest in each weld.

The configuration and operating parameters for the radiography were determined based on several factors including:

- Configurations and exposures used previously at LANL
- Dimensions of the examination room in Building 792A
- Footprint of the linear accelerator, electronics, and waveguide
- Output dose of the linear accelerator
- Spot size of the linear accelerator
- Pre-job tests run in Pocatello
- Simulations of the projection geometry.

Figure 2 shows the business end of the linear accelerator and a photograph of the rotational stage as used in the preliminary tests at the IAC.

An initial survey of the radiation field generated by the linac was performed per Linac Installation and Test Instruction[5] in Building 792A on March 26 with the linac operating at 100 R/min @ 1 m.

Radiation boundaries were established for the field produced at 100 R/min @ 1 m even though the dose to be used for radiographic examination had been determined to be 50 R/min @ 1 m.

The center of the fueled clad was placed 84 in. from the source point (spot) of x-rays. The film plane was located 2 ¾ in. from the center of the fueled clad. Film was held in place by a film cassette holder, allowing close positioning to the clad and easy placement for the material handlers. To limit radiation dose external to the examination room, two lead shields were stationed approximately 1 m behind the film plane. To limit scatter in the room, two tungsten bricks(1 ¾ in. long and 6 in. high) were placed approximately 1 in. apart in front of the linac output port and used to collimate the linac beam. A thin sheet of lead was placed in front of the output port to harden the beam (i.e. remove unwanted low-energy radiation). Film loading was 10/R/10; 10 mil lead front screen for intensification, Kodak DR50 film, and the 10 mil back to reduce scatter. Exposure time was initially set to 7 min but changed to 8 min to provide increased film density. A procedure generated by the radiographers, safety review personnel at MFC, and Building 792A operations personnel was followed for placement of the clad on the rotational stage and angular orientation of the clad with respect to the x-ray beam.

Radiographic examination operations in Building 792A commenced April 2 and were completed April 8, 2005.

3. RESULTS

Forty-two radiographs were initially acquired for the five fueled clads. Two test shots were acquired using vacuum seal packages surrounding the film cassettes. The vacuum seal did not appear to enhance the images so its use was discontinued. Following review of the films, four additional shots were acquired for clad FCO351. The films were reviewed on April 8th and 9th. The results are provided in Table 1. All positive UT indications were correlated with allowable conditions, including weld shield fusion and mismatch. No voids were indicated in the welds.

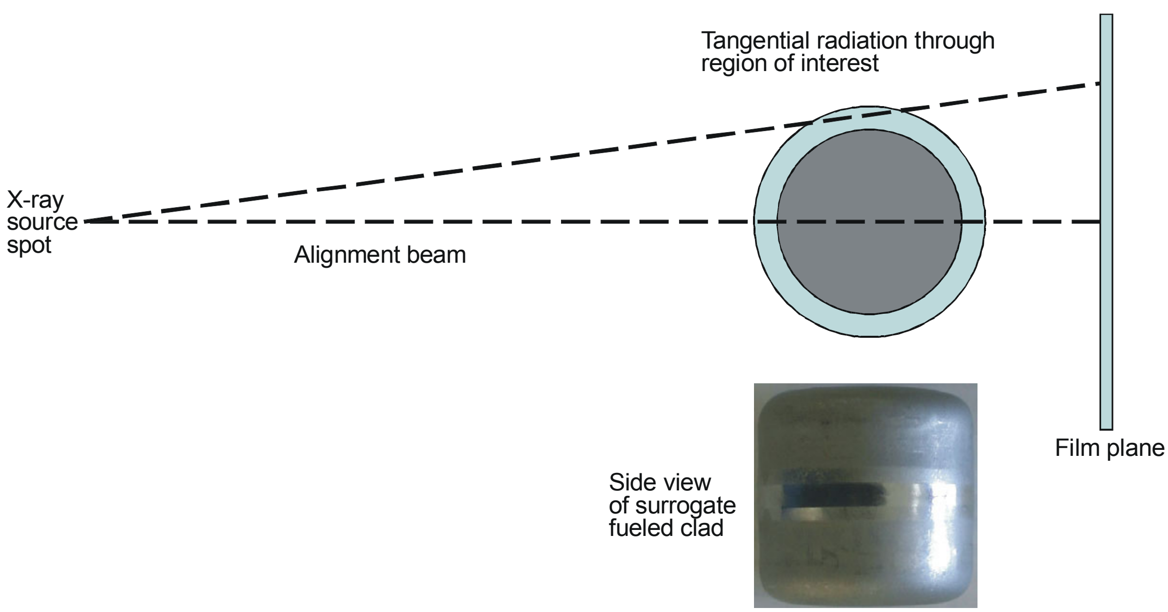

Figure 1. Tangential radiography (top view). The region of interest is the girth weld (bright horizontal strip in the side view of the photograph). The top view indicates the path of the tangential radiation along the weld.

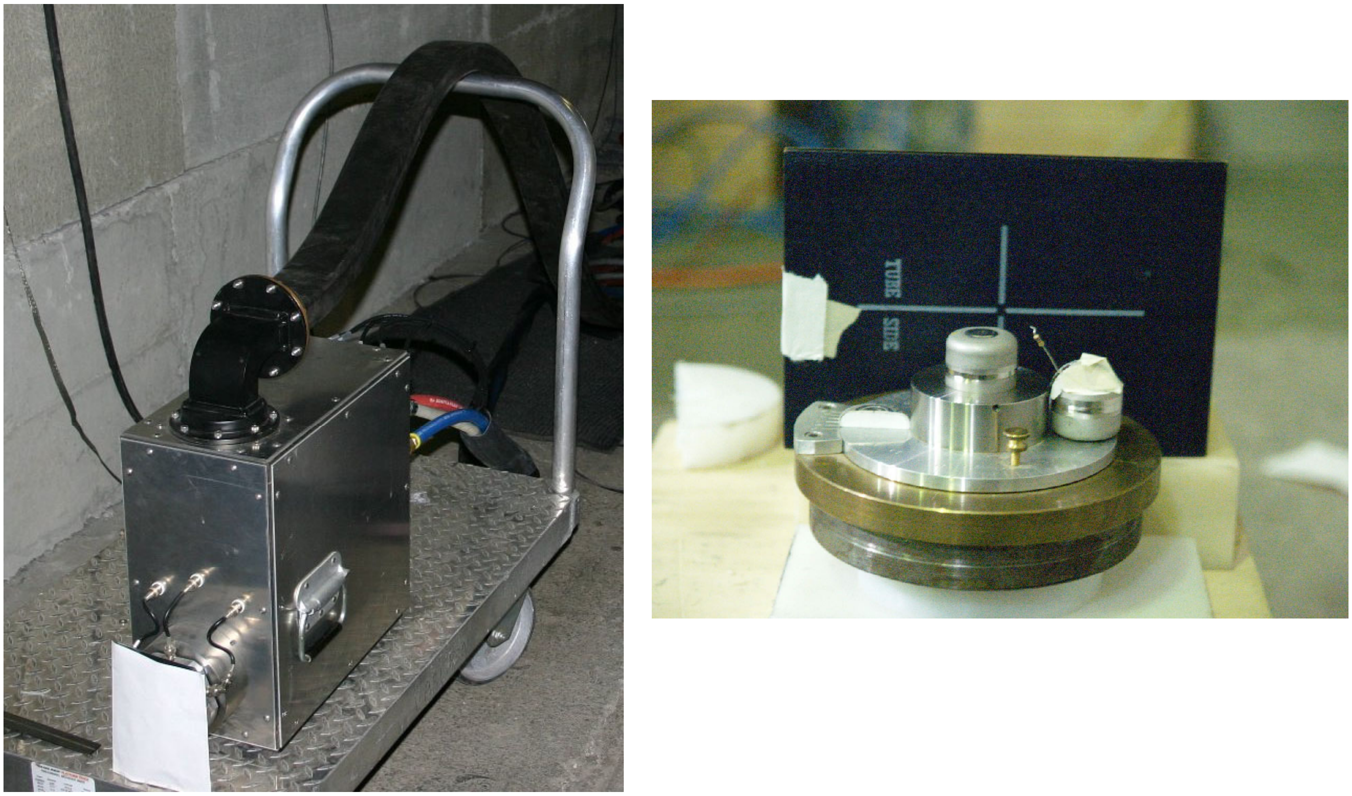

Figure 2. Components used for radiographic testing at the Idaho Accelerator Center Annex in Pocatello, ID. Left: Linear accelerator and waveguide (the paper does not attenuate much radiation!). Right: Rotational stage used for holding and angular positioning fueled clads. A full-scale surrogate is in the clad holder and pieces of another surrogate are at the sides.

Table 1. Interpretation of fueled clad radiographs.

Angular Position	Interpretation	Ultrasonic indication	Comments[a]
FCO348			
208.6	Mismatch, Weld shield not touching weld		
211.6	Mismatch, Weld shield not touching weld	X	
214.6	Mismatch, Weld shield not touching weld		
253.7	WSF[b]		
256.7	WSF	X	
259.7	WSF		
328.3	Mismatch, WSF		
331.3	Mismatch, WSF	X	
334.3	Mismatch, WSF	X	
337.3	Mismatch, WSF		

Table 1. (continued).

Angular Position	Interpretation	Ultrasonic indication	Comments[a]
FCO351			
229.0	WSF		
232.0	WSF	X	
234.3	WSF		reshoot
235.0	WSF	X	236
239.0	WSF		
284.0	Mismatch, WSF		
287.0	Mismatch, WSF	X,X	286.5, 287.5
287.0	Mismatch, WSF	X,X	286.5, 287.5, reshoot
290.0	Mismatch, WSF		
291.0	Mismatch, WSF	X	reshoot
294.0	Mismatch, WSF		
295.5	Mismatch, WSF		
298.5	Mismatch, WSF	X,X	298.0, 299.0
301.5	Mismatch, WSF		
349.0	Mismatch, WSF		
352.0	Mismatch, WSF	X	
355.0	Mismatch, WSF		
358.0	Mismatch, WSF	X	
358.5	Mismatch, WSF		reshoot
361.0	Mismatch, WSF		
FCO353			
229.0	WSF		
232.0	WSF	X	
235.0	WSF		
FCO378			
13.0	WSF		
16.0	WSF	X	
19.0	WSF		
26.0	WSF		
29.0	WSF	X	
32.0	WSF		
36.0	WSF		
39.0	WSF	X	
42.0	WSF		
FCO383			
96.0	WSF		
99.0	WSF	X	
103.0	WSF	X	
106.0	WSF		

a. Numbers in this column represent the angular position of the UT indication
b. WSF: Weld shield fusion.

Table 1. (continued).

4. REFERENCES

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