NRC Research and/or Technical Assistance Rept

PDR

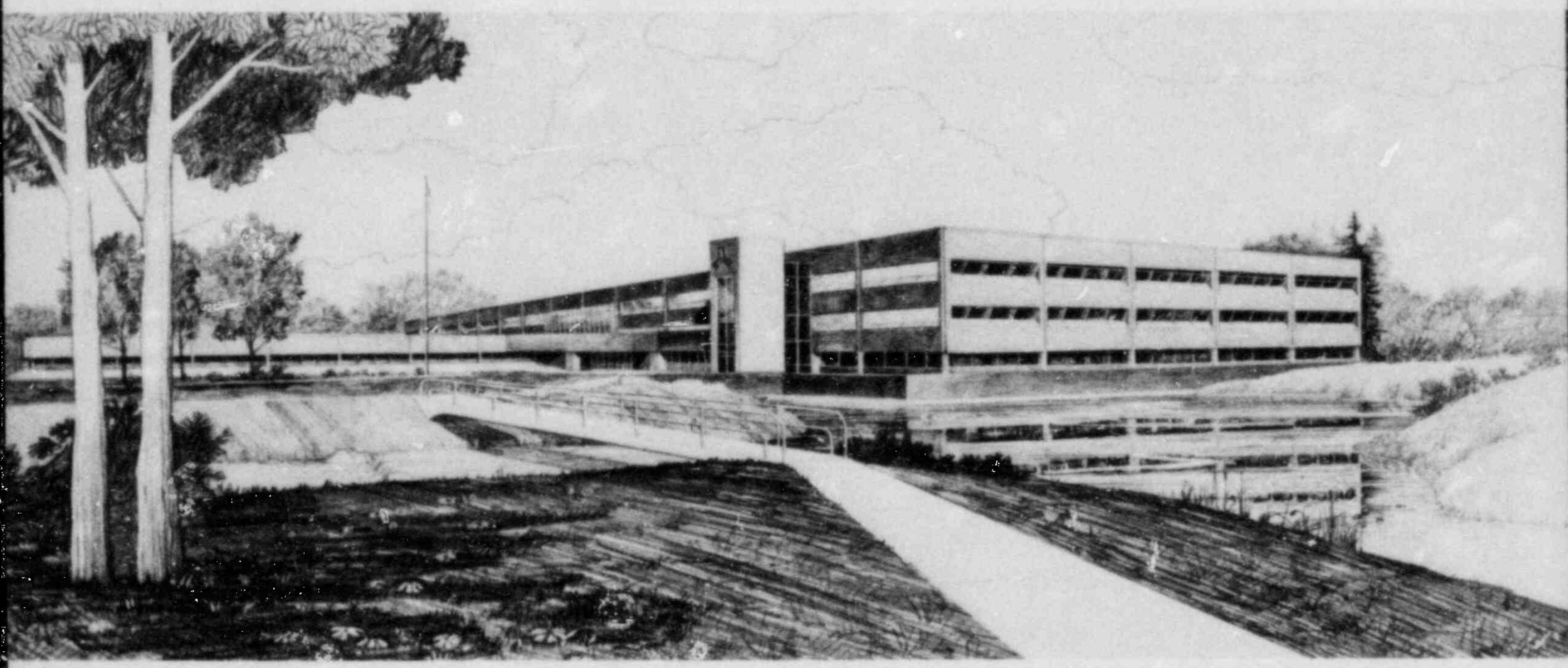
EGG-TFBP-6179

February 1983

PULSED EDDY CURRENT TESTING OF ZIRCALOY TUBE SAMPLES FROM THE OECD HALDEN REACTOR PROJECT

Beverly A. Cook
Merlin E. Yancey

Idaho National Engineering Laboratory
Operated by the U.S. Department of Energy



This is an informal report intended for use as a preliminary or working document

Prepared for the
U.S. NUCLEAR REGULATORY COMMISSION
Under DOE Contract No. DE-AC07-76ID01570
FIN No. A6041

EG&G Idaho

EG&G Idaho, Inc

FORM EG&G-398
(Rev 03-82)

INTERIM REPORT

Accession No. ______

Report No. EGG-TFBP-6179

Contract Program or Project Title:

Thermal Fuels Behavior Program

Subject of this Document:

Pulsed Eddy Current Testing of Zircaloy Tube Samples from the OECD Halden Reactor Project

Type of Document:

Test Results Report

Author(s):

Beverly A. Cook and Merlin E. Yancey

Date of Document:

February 1983

Responsible NRC Individual and NRC Office or Division:

R. VanHouten   Fuel Behavior Branch

This document was prepared primarily for preliminary or internal use. It has not received full review and approval. Since there may be substantive changes, this document should not be considered final.

EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

Prepared for the
U.S. Nuclear Regulatory Commission
Washington, D.C.
Under DOE Contract No. DE-AC07-76ID01570
NRC FIN No. A6041

INTERIM REPORT

ABSTRACT

Two dummy rods, one with twenty machined defects and one with eight mechanically induced cracks, were pulsed eddy current scanned at EG&G Idaho, Inc., as part of an international project to compare eddy current testing techniques used by various laboratories involved in postirradiation examinations. The test equipment and procedures are described, and the data from the scans are presented and interpreted.

SUMMARY

Two dummy rods, one with twenty machined defects and one with eight mechanically induced cracks, were pulsed eddy current scanned at EG&G Idaho, Inc., using eddy current point probes. Eighteen of the twenty defects in Dummy Rod I were definitely identified, but two (Number 2, an internal groove; and Number 17, a ridge) were questionable indications and would probably have been missed during regular inspection. In addition to the eight mechanically induced cracks, three other defect areas were identified on Dummy Rod II. The absolute size and type of defect could not be distinguished.

CONTENTS

FIGURES

TABLES

PULSED EDDY CURRENT TESTING OF ZIRCALOY TUBE SAMPLES FROM THE OECD HALDEN REACTOR PROJECT

INTRODUCTION

The work described in this report is part of an international project to compare eddy current testing techniques used by various laboratories involved in postirradiation examinations. EG&G Idaho, Inc., became involved in this study to compare our eddy current capabilities with what is generally used in the industry. Testing was performed on two unirradiated zircaloy-2 dummy rods, one prepared with 20 artificial defects and one prepared with 8 internal fatigue cracks. The rods were supplied by the Institute for Energiteknikk (I.F.E) OECD-Halden, Norway. The information received with the rods is presented in Appendix A.

The dummy rods were received at EG&G Idaho on November 29, 1982, and were sent back to the Technical Research Center of Finland on December 2, 1982. EG&G Idaho was the last facility to scan the dummy rods before destructive examination, and was added to the list of participants in the round robin eddy current testing program at a late date. Since only two days were allowed for testing at EG&G Idaho, full use of the scanning equipment's potential was not possible.

The information requested of the testing laboratories included background information on the testing equipment used, test procedures, an example of the eddy current data obtained, and interpretation of the eddy current results.

TEST EQUIPMENT

The equipment used in the testing of the rods was the standard system used in-cell during the pre- and postirradiation examination of light water reactor fuel rods tested in the Power Burst Facility (PBF) at the Idaho National Engineering Laboratory (INEL). The equipment was removed from the hot cell and decontaminated before use so as to avoid contamination of the dummy rods. The equipment had last been used in the examination of fuel rods tested during the PBF Operational Transient (OPTRAN) tests.

The electronics used in scanning the dummy rods were developed by Argonne National Laboratory, Argonne, Illinois. A point-type defect probe was used during the scanning of the two rods. Additional sensors available for use with the system include a point-type wall thickness probe and an encircling-type sensor developed by EG&G Idaho that detects inner and outer surface defects, as well as wall thickness variations. These sensors were not used due to the time factor involved.

The pulsed eddy current probe was fabricated using a 12.7-mm-diameter nylon body and consists of two pickup coils and a field coil mounted on the inner surface of a short piece of copper tubing known as a mask. The two pickup coils are wound in opposite directions and connected in parallel to provide a null output when properly located on the outer surface of the mask. A view of the active end of the probe is shown in Figure 1. The two pickup coils are wound on a 9.6-mm-diameter x 12.7-mm-long ferrite rod. The coils are 3.5 mm long, with 2 layers, 3 banks, and 96 turns of No. 43 AWG wire. One coil is wound forward and one is wound reversed. The field coil is forward wound on a 15.7-mm-diameter x 12.7-mm-long ferrite rod. The coil is 6.4 mm long, with 5 layers, 3 banks, and 192 turns of No. 40 AWG wire.

The EG&G Idaho equipment uses a pulsed eddy current (PEC) technique rather than a continuous frequency. The pulse repetition rate was 1 kHz, with a pulse amplitude of 500 V. A time sampling technique was used to extract the defect information from the induced voltage pulse. The system was adjusted to provide inner and outer surface defect information. A

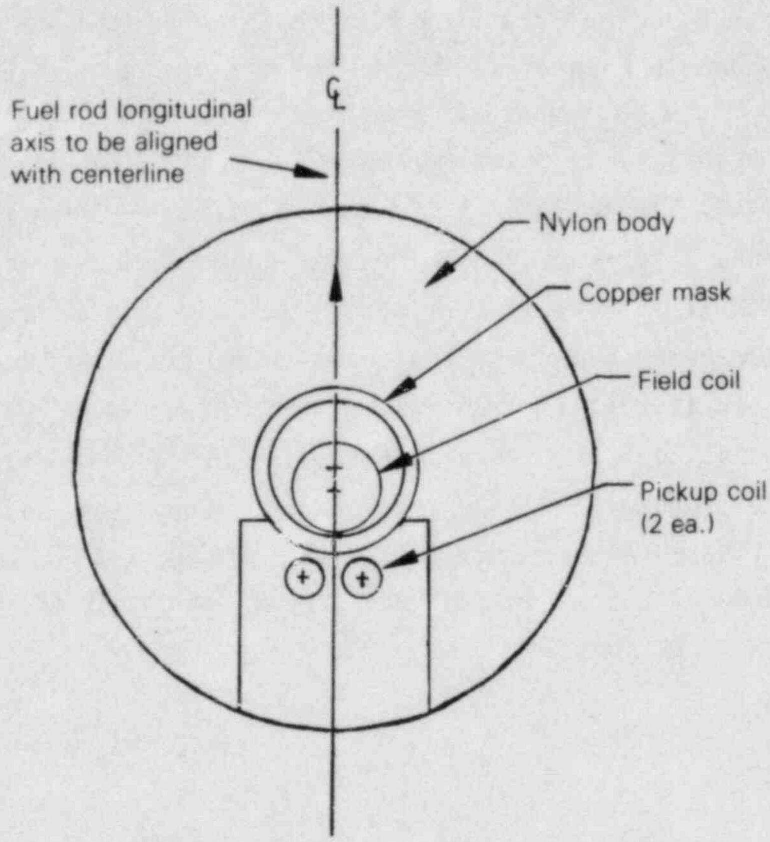


Figure 1. View of the active end of the defect-detection transducer.

voltage output suitable for strip chart recording was provided, and a six-channel, brush, 260 recording oscillograph provided readout of the data. The chart speed was 25 mm/s.

The electromechanical scanning fixture was designed and built by EG&G Idaho and is shown in Figure 2. During the scanning operation, the dummy rods were held fixed in a vertical position in an indexing fixture, which provided the capability of rotating the rod a full 360 degrees in steps as small as 1 degree. To maintain a constant distance between the sensor coil and the cladding, a servo-mechanism was designed to automatically position the PEC sensor coil laterally. The sensor is held approximately 0.13 mm from the surface being scanned. The servo-mechanism uses two opposing linear variable differential transformers (LVDTs) as sensors. In addition to providing input to the servo-mechanism, the LVDTs also produce information on the rod diameter and extent of bowing. The fuel rod is held stationary while the sensors are moved past the sample. All scans of the samples were made with the sensors traveling in the same direction, at a rate of approximately 50 mm/s.

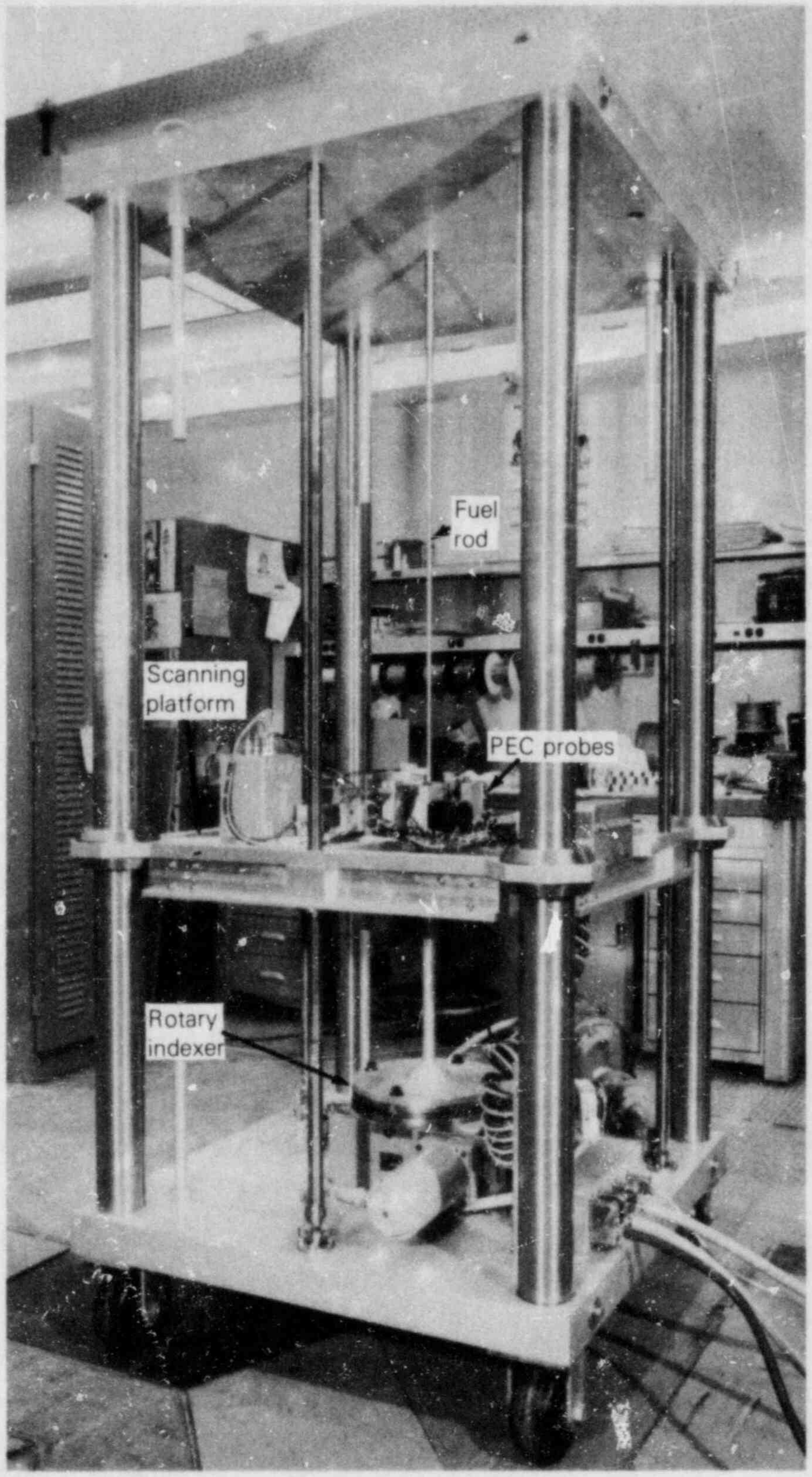


Figure 2. PEC scanning fixture.

TEST PROCEDURES

During normal operation of the PEC scanning system, six channels of information are recorded; outer diameter, centerline deviation, wall thickness, OD defects, ID defects, and a channel combining OD and ID defects. During the scanning of the OPTRAN fuel rods and the Halden samples, only the OD defect and OD plus ID combination defect channels were operating. Therefore, each of these signals was sent through two channels in the recording system. The charts from the scanning of the samples show two OD defect signals and two OD plus ID defect signals. The duplication permitted electronic noise to be more easily identified. A defect indication that was present on all four channels was assumed to be a definite OD defect, and a defect signal that appeared on the two OD plus ID channels, but not on the two OD channels, was assumed to be an ID defect.

A calibration standard containing small transverse and longitudinal defects was used to determine that the PEC system was operating properly, but not for calibration of the defect signals to a specific defect size and geometry. The calibration standard was scanned in a manner similar to the dummy rods. The defects were electron-discharge machined into zircaloy tubing, and details of the size and orientation of the defects on the calibration standard are given in Figure 3. Note that all of the defects are machined grooves, with no holes.

The EG&G Idaho PEC machine has been primarily used, in conjunction with other nondestructive examinations (neutron radiography, gamma scanning, visual examination), to identify the most likely areas for further destructive examinations (metallography, scanning electron microscopy). The equipment was originally built, however, to screen previously irradiated rods prior to testing in the PBF. Rods were rejected if the defect indications were greater than those resulting from a machined groove of a chosen size (used to calibrate the equipment) at an axial elevation of interest. Rods were also rejected if the neutron radiographs of the rod showed a broken up fuel stack in the axial region of interest. Obviously, pretest cladding defects and disturbances in the fuel stack could affect the failure of the fuel rod during transient testing.

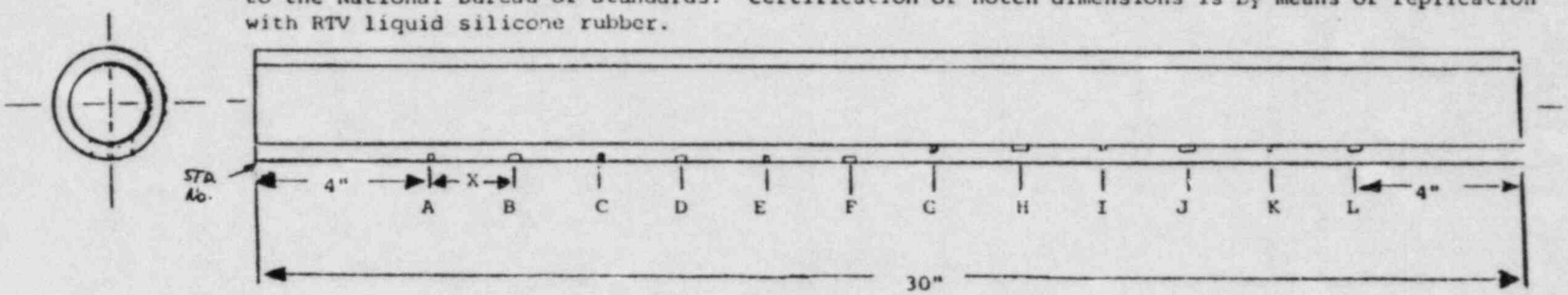
METCUT
RESEARCH
ASSOCIATES
INC.

3980 ROSSLYN DRIVE CINCINNATI, OHIO 45209

TWX: 810-461-2840 TELEPHONE 513/271-5100

Project No.: 1331-30312 Client: EG&G Idaho, Inc. P.O. # F468052 Item 1

All instruments used in the certification of this standard are calibrated against standards traceable to the National Bureau of Standards. Certification of notch dimensions is by means of replication with RTV liquid silicone rubber.



"X" = 2" ± 0.010"; 11 places

Dimensions in Inches

No.	Length	Width	Depth [a]	Location	Type
A	.101	.0022	.0059	O.D.	Trans.
B	.101	.0019	.0059	O.D.	Long.
C	.101	.0019	.0040	O.D.	Trans.
D	.100	.0018	.0040	O.D.	Long.
E	.100	.0015	.0020	O.D.	Trans.
F	.100	.0016	.0019	O.D.	Long.
G	.101	.0023	.0060	I.D.	Trans.
H	.101	.0018	.0059	I.D.	Long.
I	.100	.0019	.0039	I.D.	Trans.
J	.100	.0019	.0039	I.D.	Long.
K	.100	.0016	.0019	I.D.	Trans.
L	.100	.0016	.0020	I.D.	Long.

Standard No.: 2

Tube Size

O.D. 0.493" Wall 0.034"

Length 30"

Material

Heat No. N/A

Specification Sketch by M. Yancey dated August 12, 1980

(a) Depth measurement accuracy is a function of surface variations.

Date: September 5, 1980

Certified by:

Chester E. Armstrong, Jr.
EDM Specialist

Figure 3. PEC scanner calibration standard schematic.

RESULTS

Adaptors were made for the dummy rods, so that they would fit in the EG&G Idaho PEC machine, based on rough dimensions received one week before the rods arrived at the INEL. The PEC signals indicate that the zero-degree orientation on the dummy rods may not have been exactly aligned with the zero-degree mark on the bottom adaptor. The line of holes on Dummy Rod I seems to corrrespond with about 18 degrees on the adaptor. The data were therefore adjusted by that amount. Since the zero-degree orientation on Dummy Rod II seemed to be aligned with the adaptor, no adjustments were made to the data for this rod.

The data from the PEC scans of Dummy Rod I are presented in Table 1, and comments about the defects are presented in Table 2. The original scans are in Appendix B, which is on microfiche attached to the back cover of this report. Included in Table 1 are the orientations over which the defect signals were obtained. The rod outer diameter is 14.3 mm and the circumference is 28.6 mm, or 0.079 mm/degree of rotation. Therefore, a defect that appeared over an area of 10 degrees would be 0.79 mm wide. A defect area includes any disturbed area around a hole, for instance, and not just the hole diameter.

Dummy Rod II was examined and all eight areas where fatique cracks were initiated were identified. Three elevations corresponding to those of Cracks 2, 3, and 4 showed defect indications at 155 to 160 degrees, as well as at zero degrees. The data from Dummy Rod II are summarized in Table 3, and the original scans are in Appendix C, which is on microfiche attached to the back cover of this report.

All eight of the major defects that appeared at the zero-degree orientation had both OD and ID indications. Therefore, the cracks apparently exist through a major portion of the tubing wall. The indications at 155 to 160 degrees also appear on both the OD and ID defect channels. All 11 areas would have been identified during regular test fuel rod examination as areas containing possible defects and requiring further examination.

TABLE 1. DUMMY ROD I
(machined defects)

Clockwise Orientation (degrees)	Defect Number[a]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	--	--	--	0	x	✓	0	✓	✓	x	x	x	0	x	0	x	0	x	0	0
2	--	--	--	0	✓	x	0	✓	x	x	x	x	0	x	0	x	0	x	0	0
4	--	--	--	0	✓	x	✓	x	x	x	x	x	0	x	0	x	--	x	0	0
6	--	--	--	0	x	✓	✓	x	x	x	x	x	0	x	0	x	--	x	0	0
8	0	--	--	--	x	0	✓	x	x	x	x	x	0	x	0	x	--	x	0	0
10	--	--	--	0	x	0	✓	x	x	x	x	x	0	x	--	x	--	x	0	--
12	--	--	--	0	x	x	0	✓	x	x	x	x	0	x	--	x	--	x	0	0
14	--	--	--	--	x	x	0	✓	x	✓	x	x	0	✓	--	x	--	x	0	✓
16	--	--	--	0	x	x	0	0	✓	0	✓	✓	0	✓	0	x	0	x	0	0
18	--	--	--	0	✓	✓	--	0	0	0	0	✓	0	✓	0	✓	0	x	0	0
20	--	--	--	--	0	0	0	0	0	0	0	✓	0	0	0	✓	0	x	0	0
22	--	--	--	0	0	0	--	0	0	0	0	0	0	0	0	0	--	✓	0	0
24	--	--	--	0	0	0	--	0	0	0	0	0	0	0	--	0	--	✓	0	--
26	--	--	--	--	0	--	--	0	0	0	0	0	0	0	0	0	--	0	0	--
28	--	--	--	--	0	--	--	0	0	0	0	0	0	0	0	0	--	0	0	--
30	--	--	--	0	--	0	--	0	0	0	0	0	0	--	--	0	--	0	0	--
32	--	--	--	--	--	0	--	--	--	--	--	--	0	--	--	--	--	0	0	--
34	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	--	0	--
36	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	--	0	--
38	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
40	--	--	--	0	0	0	--	--	--	--	--	--	0	--	--	--	--	--	0	--
42	--	--	--	0	0	0	--	0	--	--	0	--	0	--	--	--	--	--	0	--
47	--	--	--	0	--	--	--	--	--	--	--	--	0	--	--	--	--	--	0	--
52	--	--	--	0	--	--	--	--	--	--	--	--	0	--	--	--	--	--	0	--
57	--	--	--	0	--	--	--	--	--	--	--	--	0	--	--	--	--	--	0	--
62	--	--	--	0	--	--	--	0	--	--	--	--	0	--	0	--	--	--	0	--
67	--	--	--	0	--	--	--	--	0	--	--	--	0	--	0	--	--	--	0	--
72	--	--	--	0	--	--	--	--	0	--	--	--	0	--	0	--	--	--	0	--
77	--	0	--	0	--	--	--	--	0	--	--	--	0	--	0	--	--	--	0	--
82	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	0	--	--	0	--
87	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
92	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
97	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	--	0	--
102	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	0	0	--
107	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--

TABLE 1. (continued)

Clockwise Orientation (degrees)	Defect Number[a]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
112	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
117	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	0
122	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
127	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
132	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	--	✓	--
137	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	--	✓	--
142	0	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	--	✓	--
147	0	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	0	0	--
152	✓	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	--	0	--
157	✓	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	--	0	--
162	✓	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	0	0	--
167	✓	--	--	0	--	--	--	--	--	0	--	--	0	--	0	--	--	--	0	--
172	✓	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	0	--	0	--
177	x	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	--	0	--
182	x	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
187	✓	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
192	0	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
197	0	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	0	✓	--
202	0	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	0	0	✓	--
207	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	0	0	✓	--
212	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	0	✓	--
217	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
222	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
227	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	0	--	✓	--
232	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
237	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
242	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
247	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
252	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
257	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	✓	--
262	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
267	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
272	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
277	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
282	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--

TABLE 1. (continued)

Clockwise Orientation (degrees)	Defect Number[a]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
287	--	--	0	0	--	--	0	--	--	--	--	--	0	--	0	--	--	--	✓	--
292	--	--	--	--	--	--	--	0	--	--	--	--	0	--	0	--	--	--	✓	--
297	--	--	--	0	--	--	--	--	--	--	--	--	0	--	--	--	--	--	0	--
302	--	--	--	0	--	--	--	--	--	--	--	--	0	--	--	--	--	--	0	--
307	--	--	0	0	--	--	--	--	--	--	--	--	0	--	--	--	--	--	0	--
312	--	--	0	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
317	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
322	--	--	--	0	--	--	--	--	--	--	--	--	0	--	0	--	--	--	0	--
327	--	--	--	0	--	--	--	--	--	--	--	--	0	0	0	0	--	0	0	--
332	--	--	--	0	--	--	--	--	--	--	0	0	0	0	--	0	--	0	0	--
334	--	--	0	0	--	--	--	--	--	0	0	0	0	✓	--	0	--	0	0	--
336	--	--	--	0	--	--	--	--	--	0	0	0	0	✓	0	✓	--	✓	0	--
337	--	--	--	0	--	--	--	--	--	0	0	0	0	✓	--	✓	--	✓	0	--
338	--	--	0	0	--	--	--	0	--	0	0	✓	0	x	0	x	--	x	0	--
340	--	--	0	0	--	--	--	0	--	0	✓	✓	0	x	--	x	--	x	0	--
342	--	--	--	--	0	--	--	0	0	0	✓	✓	--	x	--	x	--	x	0	--
344	--	--	0	0	0	--	0	0	0	0	✓	x	0	x	0	x	--	x	0	--
346	--	--	--	--	0	--	0	0	0	✓	x	x	0	x	--	x	0	x	0	--
348	--	--	--	0	0	0	0	0	0	x	x	x	0	x	0	x	--	x	0	--
350	--	--	--	--	✓	0	0	✓	✓	x	x	x	0	x	0	x	--	x	0	--
352	--	--	0	0	✓	0	0	✓	x	x	x	x	0	x	0	x	0	x	0	--
354	--	--	0	0	x	0	✓	x	x	x	x	x	0	x	0	x	--	x	0	0
356	--	--	--	--	x	0	0	x	x	x	x	x	0	x	0	x	0	x	0	0
358	--	--	--	--	x	0	0	x	x	✓	x	x	0	x	0	x	--	x	0	0

a. 0 = less than 25 divisions, ✓ = greater than 25 but less than 50 divisions, and x = greater than 50 divisions. Full scale = 50 divisions.

TABLE 2. DUMMY ROD I DEFECT DESCRIPTIONS

Defect Number and Description	Comments
1-Two internal scars at 50 mm	Shows as one defect indication; penetrates the wall thickness enough to show also as an OD defect indication; would have been identified during regular inspection
2-Internal groove at 1000 mm	No indications definitely above background; would not have been identified during regular inspection
3-External groove at 150 mm	Defect indications regular, although small, and would have been identified as a defect region during regular inspection
4-External groove at 200 mm	Small defect indications at almost all orientations; would have been identified during regular inspection
5-External scan at 250 mm	Full-scale indication from 342 to 28 degrees; definite area for investigation during regular inspection
6-Hole at 300 mm	Definite indication over 36 degrees
7-Hole at 350 mm	Definite indication over 32 degrees
8-Hole at 400 mm	Definite indication over 52 degrees
9-Hole at 450 mm	Definite indication over 52 degrees
10-Hole at 500 mm	Definite indication over 46 degrees
11-Hole at 550 mm	Definite indication over 48 degrees
12-Hole at 600 mm	Definite indication over 58 degrees
13-Ridge at 625 mm	Small indications at all orientations; easily distinguished and consistent
14-Hole at 650 mm	Definite indication over 61 degrees
15-Ridge at 675 mm	Small indications at most orientations; easily distinguished
16-Hole at 700 mm	Definite indication over 63 degrees
17-Ridge at 725 mm	Small indications at a few orientations; would not have been identified during regular inspection

TABLE 2. (continued)

Defect Number and Description	Comments
18-Hole at 750 mm	Definite indication over 65 degrees
19-External reduced wall at 810 mm	Definite small and medium indications at all orientations
20-Internal scar at 950 mm	Small indications over 28 degrees; would have been identified during regular examination

TABLE 3. DUMMY ROD II (fatigue cracks)

Clockwise Orientation (degrees)	Defect Number[a]							
	1	2	3	4	5	6	7	8
0	0	0	0	0	✓	x	✓	x
5	0	0	0	0	0	x	x	x
10	--	--	--	--	0	✓	x	x
15	--	--	--	--	--	0	x	✓
20	--	--	--	--	--	0	0	0
25	--	--	--	--	--	--	0	0
30	--	--	--	--	--	--	0	--
35	--	--	--	--	--	--	--	--
40	--	--	--	--	--	--	--	--
50	--	--	--	--	--	--	--	--
55	--	--	--	--	--	--	--	--
60	--	--	--	--	--	--	--	--
65	--	--	--	0	--	--	--	--
80	--	--	--	--	--	--	--	--
100	--	--	--	--	--	--	--	--
120	--	--	--	--	--	--	--	--
140	--	--	--	--	--	--	--	--
150	--	--	--	--	--	--	--	--
152	--	--	--	--	--	--	--	--
154	--	--	--	--	--	--	--	--
155	--	0	0	0	--	--	--	--
156	--	0	0	0	--	--	--	--
158	--	0	0	0	--	--	--	--
160	--	0	0	0	--	--	--	--

TABLE 3. (continued)

Clockwise Orientation (degrees)	Defect Number[a]							
	1	2	3	4	5	6	7	8
162	--	--	--	--	--	--	--	--
164	--	--	--	--	--	--	--	--
166	--	--	--	--	--	--	--	--
168	--	--	--	--	--	--	--	--
180	--	--	--	--	--	--	--	--
200	--	--	--	0	--	0	--	--
220-	--	--	--	--	--	--	--	--
240	--	--	--	0	--	--	--	--
260	--	--	--	--	--	--	--	--
280	--	--	--	--	--	--	--	--
300	--	--	--	--	--	--	--	--
320	--	--	--	--	--	--	--	--
330	--	0	--	--	--	--	--	--
335	0	--	--	--	0	--	--	0
340	--	--	0	0	✓	0	0	✓
345	0	0	0	0	0	✓	✓	x
350	0	--	--	0	✓	✓	x	✓
355	0	0	0	0	x	✓	✓	x

a. 0 = less than 25 divisions, ✓ = greater than 25 but less than 50 divisions, and x = greater than 50 divisions. Full scale = 50 divisions.

DISCUSSION

The two dummy rods were scanned using the PEC equipment at EG&G Idaho, Inc. Of the 20 machined defects in Dummy Rod I, 18 were definitely identified and 2 of them (Number 2, internal groove; and Number 17, ridge) were questionable indications and would probably have been missed during regular inspection. Eleven possible defect areas were identified in Dummy Rod II, but the type of defects could not be determined from the data obtained. Because of the short notice received on performing the examination, only the defect probes were operating properly at the time. If more time had been available, the wall thickness probe and the LVDTs, which give outer diameter and centerline deviation, would have been operating. Indications from these devices would have helped to qualify the defect indications.

The absolute size of the defects could not be determined because calibration standards made of the same material and with the same type of defects were not available. The relative size of the defects was available, although many of the defect signals went off scale. Had more time been available, the scale on the strip chart could have been adjusted so that the maximum peak height could have been determined. The rods were scanned using the same procedures as for scanning PBF tested fuel rods. No special care was taken to identify the defect areas.

APPENDIX A

DESCRIPTION OF TEST SAMPLES AND LIST OF PARTICIPANTS

APPENDIX A

DESCRIPTION OF TEST SAMPLES AND LIST OF PARTICIPANTS

Description of Samples

Two samples have been prepared, one (1.2 m long) with artificial defects and one (0.6 m long) with internal fatigue cracks.

Both samples consist of an open-ended, empty Zircaloy-2 tube, 14.3 mm OD and 0.8 mm wall thickness.

The tubes contain the defects listed in Tables I and II.

Table I

Artificial Defects on Dummy Rod I

Defect No.	*Axial Position (mm)*	*Kind of Defect*
1	50	2 internal scars
2	100	internal groove
3	150	external groove
4	200	external groove
5	250	external scar
6	300	hole
7	350	hole
8	400	hole
9	450	hole
10	500	hole
11	550	hole
12	600	hole
13	625	ridge
14	650	hole
15	675	ridge
16	700	hole
17	725	ridge
18	750	hole
19	810	external reduced wall
20	950	internal scar

(Note: The axial positions are measured from an external, circumferential groove, 100 mm from the end of the tube that has *no* chamfer. Locations around the tube may be described by regarding the lines of holes as 0^{o} and measuring angular separation from this line, clockwise when viewed from the end of the tubes with *no* chamfer).

Table II

Fatigue Cracks in Dummy Rod II

A number of fatigue cracks have been induced extending from the inner surface of this tube. The number of axial locations at which cracks were attempted introduced are eight. It is not known whether single or multiple cracks have occurred at each location.

(Note: The reference end of this tube is marked with a short axial groove. Axial locations should be measured from an imaginary axial line drawn through the reference mark, clockwise when viewed from the reference end).

Information Required from Testers

1. *Background Information*
   - i) Manufacturer of equipment, type designation
   - ii) Method of scanning sample, drive speed
   - iii) Numbers and types of coils, how wound, spacing and other geometrical features
   - iv) Frequency(ies) used
   - v) Form of output
   - vi) Method of calibration

2. *For Each Dummy Rod*

   Supply one copy output/chart, marked to show the position of the ends of the tube being tested.

3. *For Each Defect Identified*
   - i) Indicate axial location on chart
   - ii) Give best estimate of axial location and where possible, of circumferential locations
   - iii) Express opinion on type of defect
   - iv) Estimate dimensions of defect indicating uncertainty of estimate
   - v) Comment on care of detection of defect
   - vi) Any other comments

Please indicate whether each aspect of interpretation is based on line traces, oscilloscope traces, or other form of output.

List of Participants

C. Bagger	Risö National Laboratory (RNL), Risö, Denmark
D. Clough	Atomic Energy Research Establishment (AERE), Harwell, United Kingdom
P. Dewes	Kraftwerk Union (KWU), Erlangen, Germany
L.A. Hanson	General Electric (GE), Vallecitos, U.S.A.
M. Herren	Kernforschungsanlage (KFA), Jülich, Germany
G.F. Hines	Central Electricity Generating Board (CEGB), Winfrith, United Kingdom
E.D. Hyam	U.K. Atomic Energy Authority (UKAEA), Windscale, United Kingdom
M. Ichikawa	Japan Atomic Energy Research Institute (JAERI), Tokái-Mura, Japan
T. Kawada	Nippon Nuclear Fuel Development Co. (NFD), Oarai, Japan
G. Lysell	Studsvik Energiteknikk (SE), Studsvik, Sweden
M. Ojanen	VTT Technical Research Centre, Espoo, Finland
J. Verheugen	Netherlands Energy Research Roundation (ECN), Petten, the Netherlands