Form LRC-139

**Babcock & Wilcox**

Research and Development Division
LYNCHBURG RESEARCH CENTER
LYNCHBURG, VIRGINIA

| | |
|---|---|
| To | J. E. MATHESON, FUEL ENGINEERING, NPGD |
| From | W. A. MCINTEER WAM<br>G. M. BAIN GMB - IRRADIATED MATERIALS TECHNOLOGY, LRC |
| Cust. | GPUN |
| File No. or Ref. | RDD:83:5489:01 |
| Subj. | TMI-1 RECOVERY — RNS RETAINER EXAMINATION |
| Date | MAY 20, 1982 |

This letter to cover one customer and one subject only.


SUMMARY

As part of the TMI-1 recovery effort, a RNS retainer was examined at the LRC Hot Cell Facility. Although it was unirradiated, the retainer had been installed in-core since the EOC-4 outage in late 1978. Detailed testing of the retainer and its component parts included:

- visual examinations
- spring load-deflection and full-compression tests
- sodium azide spot tests
- liquid penetrant checks
- bend tests
- metallography and SEM examinations
- chemical analysis of surface wipe samples

While sulfur compounds were found on the external retainer surfaces, there was no evidence of mechanical property degradation or sulfur assisted intergranular attack.




DISTRIBUTION:

R&DD

Baty, DL
Bhada, RK
CIS/ARC Library (3)
Davis, HH
Engelder, TC
Inman, SC
Library/LRC (2)
Lynch, ED
Mayer, JT
Project File
Shield, WA

NPGD

Baker, RJ (30)
Carey, RO
Culberson, DG
DeMars, RV
Dideon, CG
Garner, GL
Piascik, RS
Stein, KO
Uotinen, VO

## ACKNOWLEDGMENTS

The authors greatly appreciate the contributions of J. E. Bullard (chemical analysis), V. D. Downs (scanning electron microscopy), and B. J. Parham (metallography) to the successful completion of this effort.

# 1. INTRODUCTION

Analysis of cracked tubes from both A and B steam generators at TMI-1 indicated the failure mode was intergranular stress corrosion cracking with a reduced form of sulfur most likely acting as the corrosive agent.[1] Since the tube cracks were initiated from the ID surface, the presence of sulfur contaminents in the primary system implies the potential for material degradation of other RCS components.

A detailed examination of a regenerative neutron source (RNS) retainer from the TMI-1 core was conducted at B&W's Lynchburg Research Center as part of an effort to assess potential damage to various core components.[2] Although the retainer was unirradiated, it had been installed during the end-of-cycle four outage, and the retainer spring and load legs had been in a stressed condition while exposed to the RCS environment. A RNS retainer was selected for examination since it contained materials representative of a wide range of core components (304 SS, 308 SS weld metal, and Inconel X750).

After receipt at the LRC, the retainer (#L106) was visually examined and load-deflection tests of the spring were performed. The retainer was then disassembled and the following tests were conducted on the components:

- detailed visual examination
- spring compression test
- sodium azide spot tests
- liquid penetrant checks
- bend tests
- metallography
- SEM examinations

Chemical analyses were also performed on cloth wipe samples from the retainer components and on samples obtained at the reactor site. Wipe samples taken at TMI-1 were from the north face of a new fuel assembly (NJ0132) and from the retainer, prior to shipment.

This letter report presents results from the examination of the retainer at the LRC and the chemical analysis of the cloth wipe samples.

# 2. EXAMINATIONS AND RESULTS[3,4]

## 2.1 Visual Examinations

### 2.1.1 Method

Visual examination of the retainer and its component parts was conducted at magnifications up to 60X with a stereo microscope. Photographic records of visual observations were taken with a 4X5 camera attached to the microscope. Macrophotographs of the retainer were taken with a MP-3 copy camera.

### 2.1.2 Results

A visual inspection of the retainer, prior to disassembly, showed no cracks in the weld, knee, or foot regions of the retainer legs. A schematic view of a retainer identifying its various components is shown in Figure 1. Typical macrophotos of the leg weld, knee, and foot regions are shown in Figure 2. Virtually no crud was observed on the outside surface. Overall views of the retainer are shown in Figures 3 and 4.

After disassembly all retainer components were examined in detail. Disassembly consisted of cutting the top fitting off the can and cutting the numbered leg from the hub through the weld area. Examination of the retainer legs showed no cracks or evidence of sulfur assisted attack of the surfaces. Several areas of black and white deposits and two small areas of yellow deposits were noted. The black areas are most likely crud and the white areas appear to be boron crystals from the coolant. Attempts to identify the composition of the yellow deposits by SEM/EDAX analysis were unsuccessful, and the previously reported compositions[4] were obtained from a contaminated sample. Other EDX analyses on similar deposits found on the reactor vessel o-ring indicate the composition is mostly Fe with some Cr.[5] The spring surface was a uniform dark gray with localized areas of black and white deposits (see Figure 5). Two small areas also had yellow deposits similar to those found on the retainer leg. Examination of the retainer can showed no signs of surface degradation. The outside of the can had a thin, black oxide layer with a blue tint. The inside of the can had a dark, powdery crud layer with several areas of localized crud deposits.

## 2.2 Spring Load-Deflection Tests

### 2.2.1 Method

Prior to disassembly the X750 spring was tested for preload and spring rate using a load-deflection test rig previously used for irradiated retainers from Oconee 3.[6] The retainer spring was compressed using known weights of up to 100 pounds, while spring deflection was measured with two dial indicators accurate to 0.001 inch.

### 2.2.2 Results

Three load-deflection curves were recorded and are shown in Figure 6. Measured spring preloads ranged from 40 to 41 pounds and spring rates from 47-50 pounds per inch. These values are considered normal and agree with other retainer data.

## 2.3 Spring Compression Test

### 2.3.1 Method

After the retainer was disassembled, the spring was compressed to its solid spring height using five lead bricks. Each brick weighed a nominal 26 pounds. Relaxed spring height was measured before and after full compression with dial calipers accurate to 0.001 inch.

### 2.3.2 Results

Relaxed spring height before and after full compression was 4.00 inch, indicating no plastic deformation occurred during testing. After testing, the outer surface of the spring was visually examined at 10X magnification with a stereo microscope. No cracks or other forms of damage were observed.

## 2.4 Sodium Azide Spot Tests

### 2.4.1 Method[7]

Sodium azide spot tests for the presence of reduced forms of sulfur were conducted by placing drops of test solution on surfaces of interest (spring, leg,

weld area, inner and outer can surfaces). The areas where the drops were placed were then observed through the stereo microscope. Bubbles from the solution indicate the presence of reduced forms of sulfur (sulfide, thiosulfate, etc.). The basis for the test is the catalytic acceleration of the iodine-azide reaction by reduced forms of sulfur. This reaction evolves free nitrogen gas to produce bubbles and will detect reduced forms of sulfur at concentrations less than one ppm.

### 2.4.2 Results

Outside surfaces of the retainer components showed positive reactions to the sodium azide spot test. The inner surface of the can and the retainer spring showed negative reactions. Results of the tests are summarized below:

| | Retainer Component | | | | |
|---|---|---|---|---|---|
| Run | Spring | Leg | Leg-Weld | Can (outside) | Can (inside) |
| 1 | neg. | pos. | neg. | pos. | neg. |
| 2 | neg. | pos. | pos. | pos. | neg. |

Tests indicated the presence of reduced sulfur on outer surfaces of the retainer. The inside of the can and the Inconel X750 spring showed no evidence of reduced sulfur, but results may have been affected by crud deposits.

## 2.5 Liquid Penetrant Tests

### 2.5.1 Method

Liquid penetrant tests were conducted on the retainer leg and hub and on the spring using the procedure specified in Reference 6. The pieces were ultrasonically degreased with tichloroethylene, cleaned with Spotcheck Cleaner/Remover, and dried with clean cloths. The parts were sprayed with Spotcheck Penetrant and kept thoroughly wetted for 20 minutes. The spring was tested while under compression to open any cracks that may have been present. After removing excess penetrant, the parts were uniformly covered with Spotcheck developer and visually inspected.

2.5.2 Results

No indications of cracks were observed in either the leg, weld area, or spring. The only positive indications observed were from elongated surface inclusions on the sides of the leg.

2.6 Bend Tests

2.6.1 Method

Bend tests were performed on the leg/hub weld region and a 1-1/2 inch piece from the middle coil of the spring. The parts were clamped in a vise and bent to open any cracks which may have been present.

2.6.2 Results

The leg weld was bent through approximately 45 degrees with no visible crack initiation, indicating a sound weld. The spring sample was bent and fractured. The fracture surface was examined with an SEM to characterize the mode of failure. The SEM examination showed the fracture surface was new and failure was 100 percent ductile. Examples of the appearance of the fracture surface are shown in Figure 7. No evidence of intergranular cracking was observed.

2.7 Metallography

2.7.1 Method

Samples from the leg, knee, weld area, and the active coil and contact region of the spring were mounted in Buehler Epomet. The samples were ground flat on silicon carbide through 600 grit and polished with alumina. Final polishing was done with 0.05 micron alumina. The samples were then metallographically examined at 400X magnification for evidence of intergranular attack. The samples were examined in both polished and etched conditions. The Inconel X750 spring material was etched with copper regia and the 304 and 308 stainless steel samples with glycerol regia.

2.7.2 Results

The microstructure of all the samples appeared normal and no evidence of intergranular attack was observed. Figure 8 shows typical etched microstructures of the 304 SS base metal, 308 SS weld metal, and X750 spring. The weld area and heat-affected zone are shown at 50X in Figure 9.

2.8 Chemical Analysis of Surface Wipe Samples

2.8.1 Method

Cloth wipe samples were taken from the RNS retainer and a new fuel assembly, NJ0132, at TMI-2 prior to shipment of the retainer to the LRC. The retainer wipe covered 15.5 square-inches of the leg area. The fuel assembly wipes covered one face of a grid and across 15 rods just below a grid. Wipe samples were taken from the retainer after disassembly at the LRC. Samples were obtained from one retainer leg, two coils of the spring, and the inner and outer surfaces of the can.

Wipe samples from the disassembled retainer were analyzed for chlorine content by a LRC procedure similar to ASTM D512, "Tests for Chloride Ion in Water and Waste Water," and for sulfur content by a procedure similar to ASTM D516, "Tests for Sulfate Ion in Water and Waste Water." Since the chloride ion results were low (8 μg total or less) and used half the wipe sample, wipe samples from TMI-1 were only tested for sulfate content.

2.8.2 Results

Chloride and sulfate ion contents of wipe samples from the retainer parts were low, $< 5$ to 8 μg total $Cl^-$ and $< 20$ to 50 μg total $SO_2^{-2}$. When the background from the cloth samples was subtracted, only the sample from the spring showed any removable sulfur. Results of the sulfate analysis of wipe samples are given below:

LRC Wipe Sample Results

(cloth batch 67)

| RNS Component | Total $SO_4$, µg | Less Blank | Total* Sample S, µg | Wipe Area, $in^2$ | Removable Sulfur, µg/$in^2$ |
|---|---|---|---|---|---|
| blank | 18 | | | | |
| blank | 15 | | | | |
| Avg | <20 | | | | |
| Leg | <20 | -- | -- | 20 | -- |
| Spring | 50 | >30 | >20 | 9 | ∿2 |
| Can (outside) | 25 | >5 | >3 | 28 | -- |
| Can (inside) | <20 | -- | -- | -- | -- |

* on a whole cloth basis

Cloth wipe samples taken from the retainer after it was removed from the core and from the fuel assembly grid and rods showed slightly higher levels of removable sulfur, in the range of three to five µg/$in^2$. Results of the sulfate analysis are given below:

TMI-1 Wipe Sample Results

| Cloth Batch | Sample | Total $SO_4$, µg | Less Blank | Total Sulfur, µg | Wipe Area, $in^2$ | Removable Sulfur, µg/$in^2$ |
|---|---|---|---|---|---|---|
| 75 | blank | 30 | | | | |
| | blank | <10 | | | | |
| | Avg | <20 | | | | |
| | Zr Fuel Rods | 50 | >30 | >10 | 2.7 | ∿4 |
| | Inconel Grid | 90 | >70 | >23 | 8.1 | ∿3 |
| 71 | blank | <10 | | | | |
| | blank | 20 | | | | |
| | Avg | <15 | | | | |
| | Cloth Dipped in core | 20 | >5 | >1.7 | | |
| | Retainer | 243 | 228 | 76 | 15.5 | ∿5 |

## 3. CONCLUSIONS

While reduced forms of sulfur were detected on the retainer components, there was no evidence of mechanical property degradation or intergranular attack.

# 4. REFERENCES

1. M. A. Rigdon and E. B. S. Pardue, "Evaluation of Tube Samples from TMI-1 — Final Report," RDD:83:5390-03:01, Babcock & Wilcox, Lynchburg, Virginia, April 1982.

2. C. G. Dideon to D. G. Culberson, Memorandum, "TMI-1 Recovery — Core Examination Task," FPO-82-41, March 24, 1982.

3. W. A. McInteer and G. M. Bain to Distribution, Memorandum, TMI Core Recovery — Initial Retainer Exam," April 30, 1982.

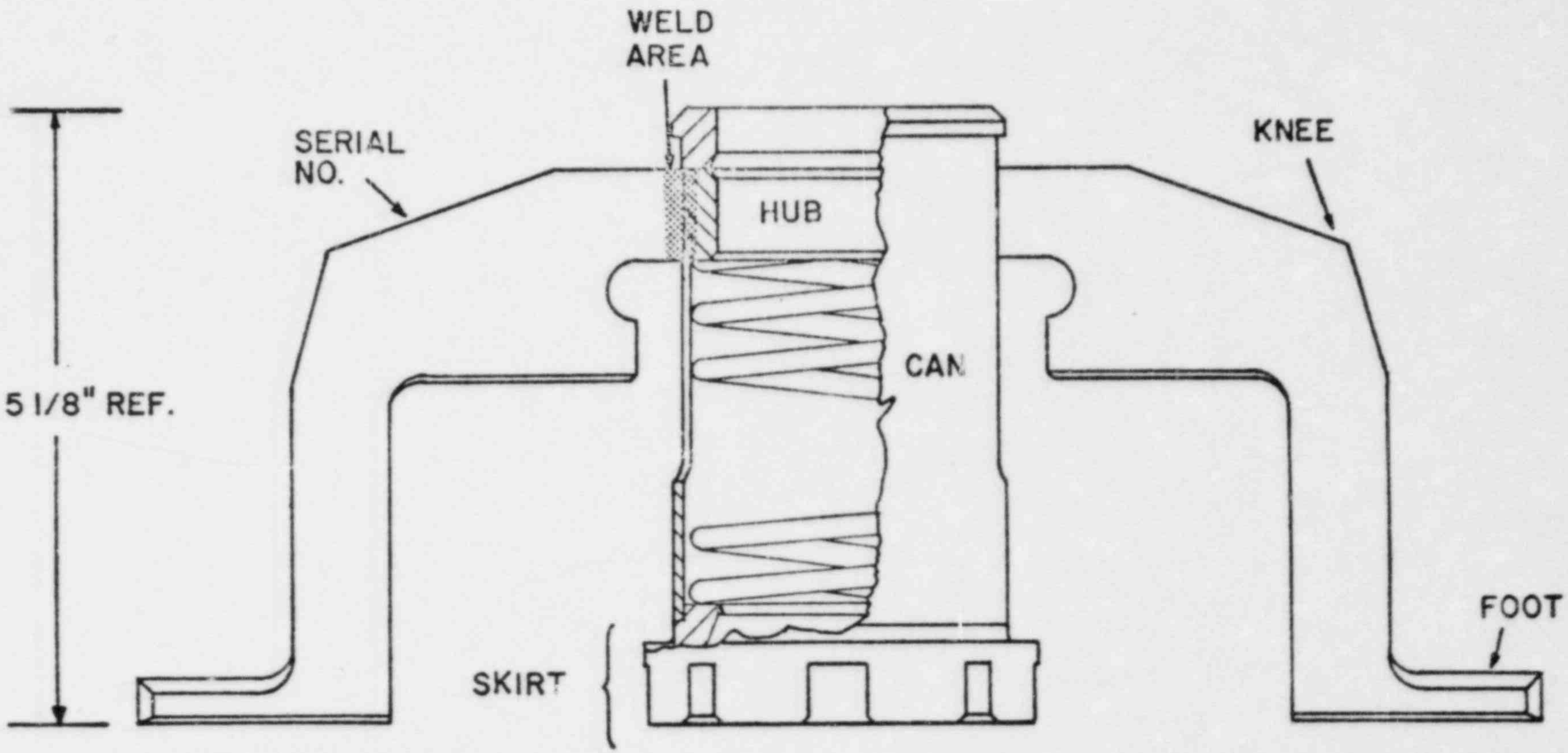
4. W. A. McInteer to C. G. Dideon, Memorandum, "TMI Core Recovery — RNS Retainer Detailed Exam," May 6, 1982.

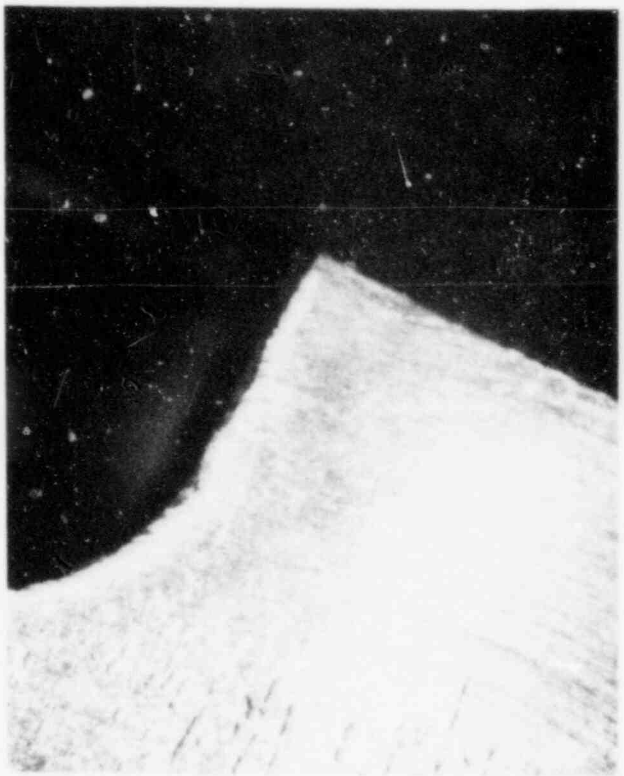
5. D. L. Baty, "Examination of TMI-2 Reactor Vessel O-Ring and CRDM Closure Insert," RDD:83:5490/5491:01, Babcock & Wilcox, Lynchburg, Virginia, May 25, 1982.

6. E. B. S. Pardue, "Examination of Oconee 3 RNS Retainers," LRC 9085, Babcock & Wilcox, Lynchburg, Virginia, February 1982.

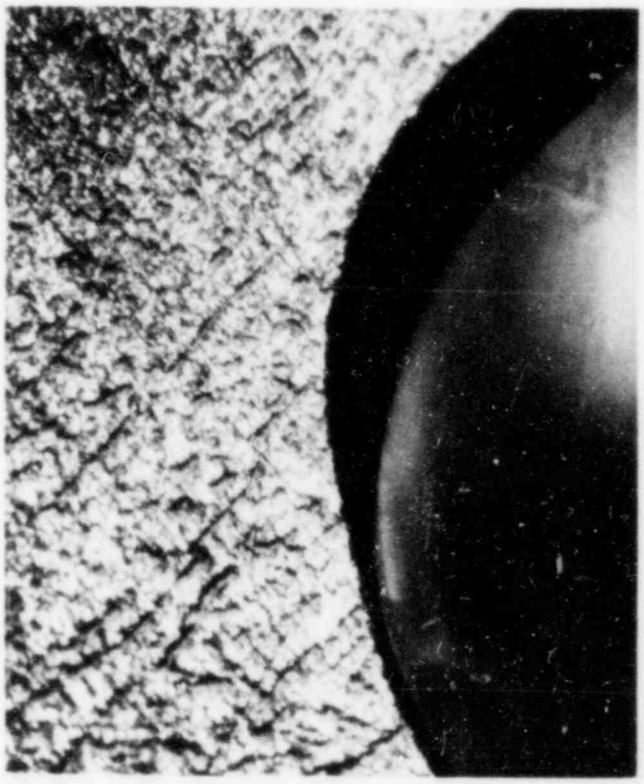
7. F. Feigl, Laboratory Manual of Spot Tests, p. 163-166, Academic Press, New York, 1943.

Figure 1. Front View of RNS Retainer

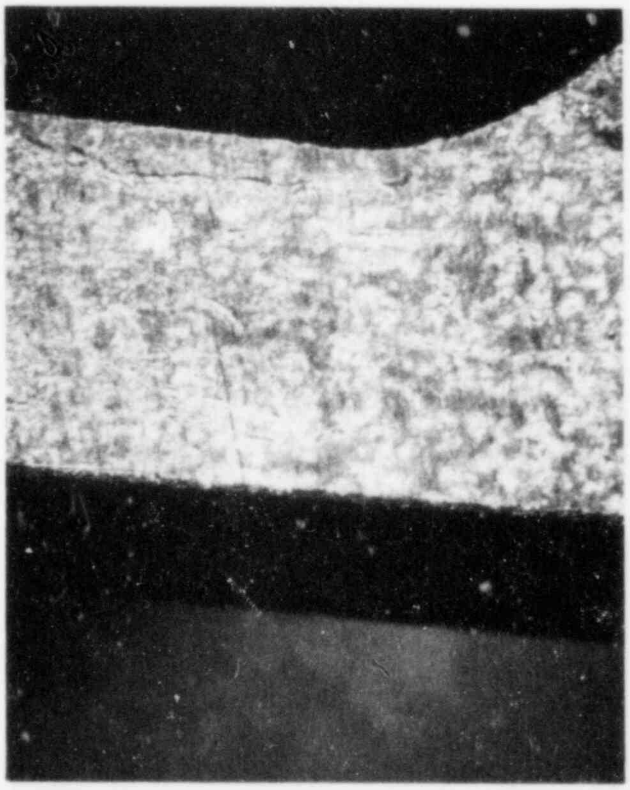




Weld Area

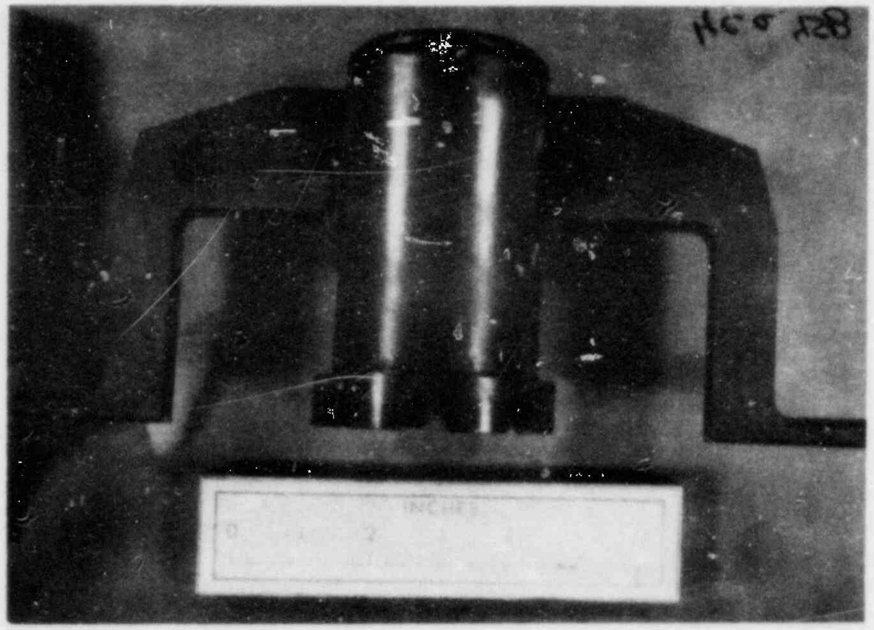


Inside Knee

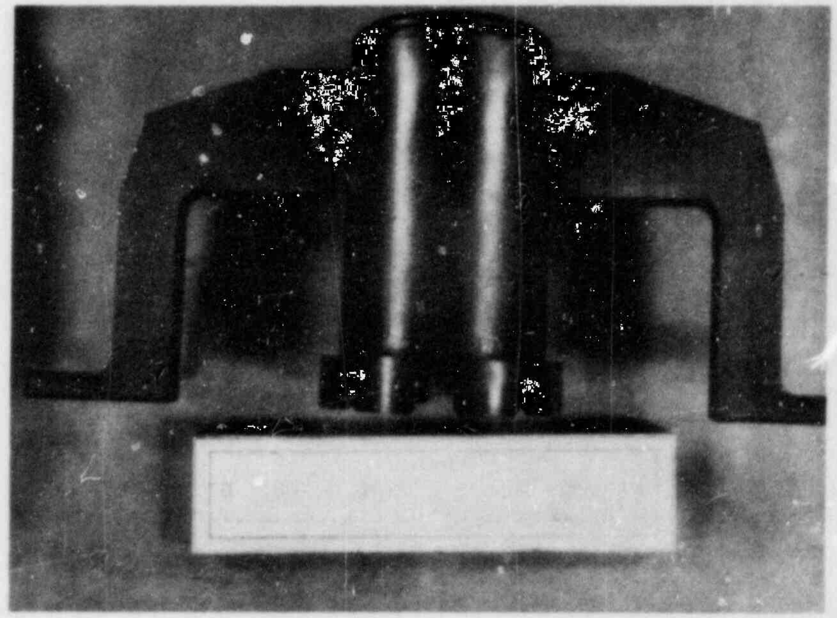


Foot

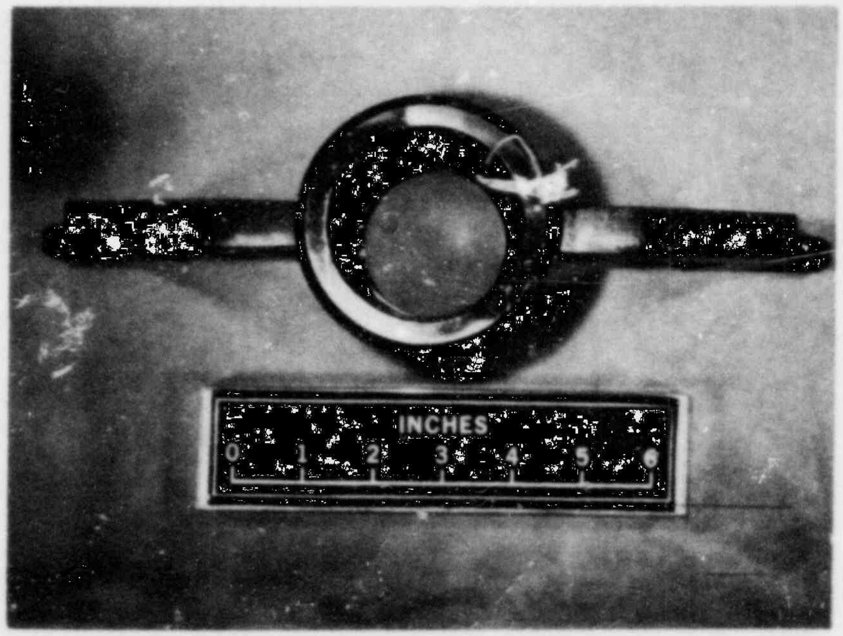
Figure 2. Typical Macro Appearance of Retainer Leg



Front

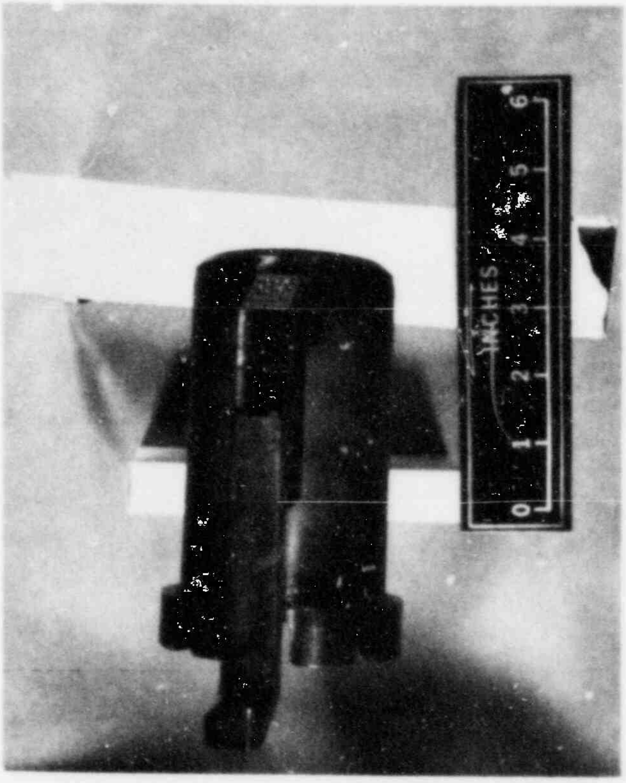


Back

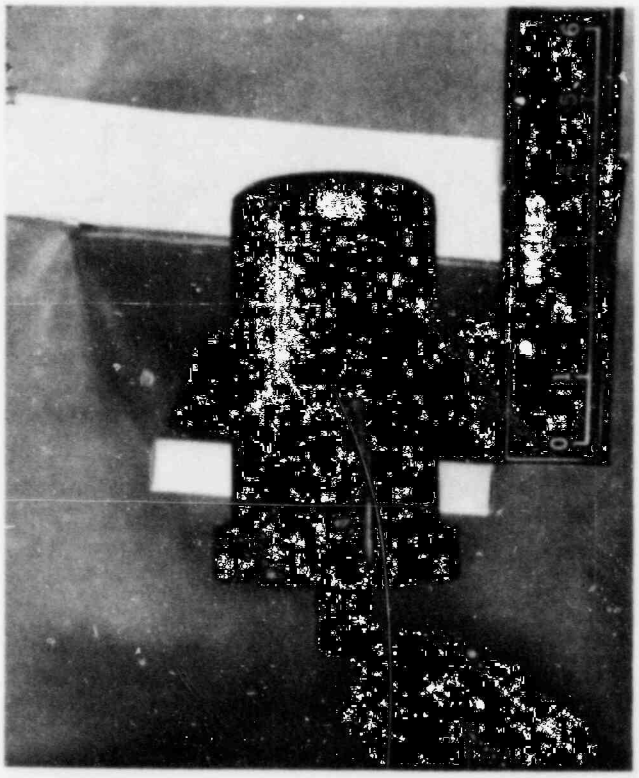



Top

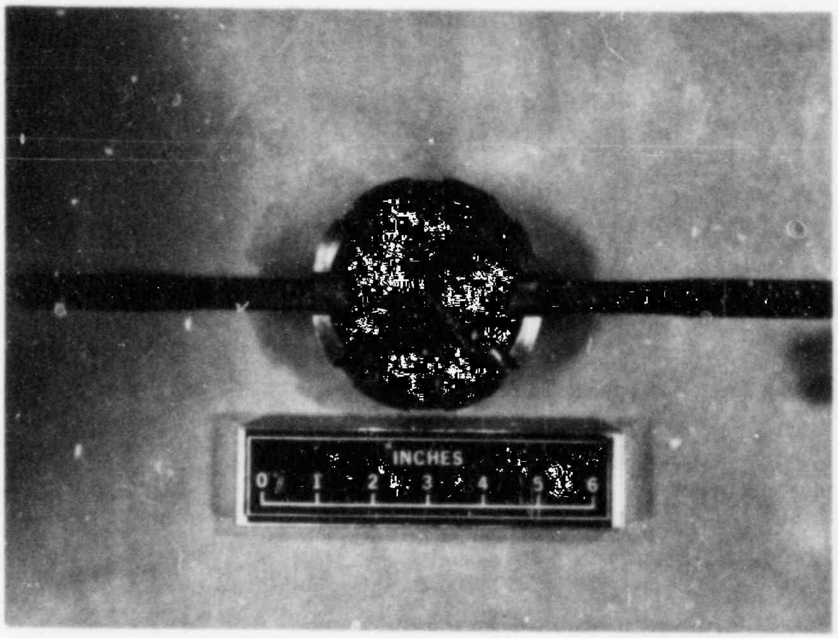
Figure 3. Overall Appearance of Front, Back, and Top of Retainer L106




Left Side



Right Side




Bottom

Figure 4. Overall Appearance of Sides and Bottom of Retainer L106

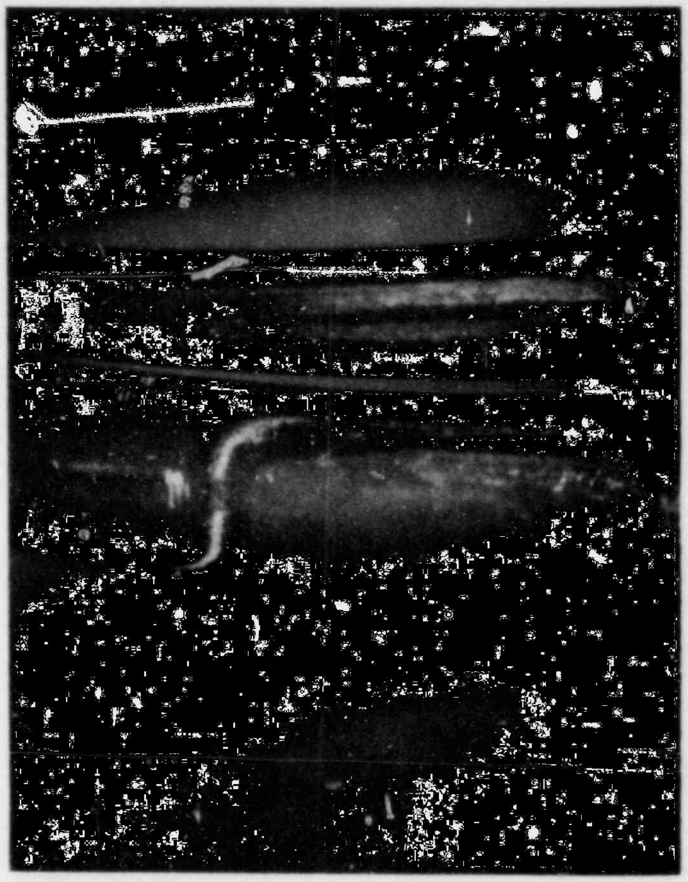
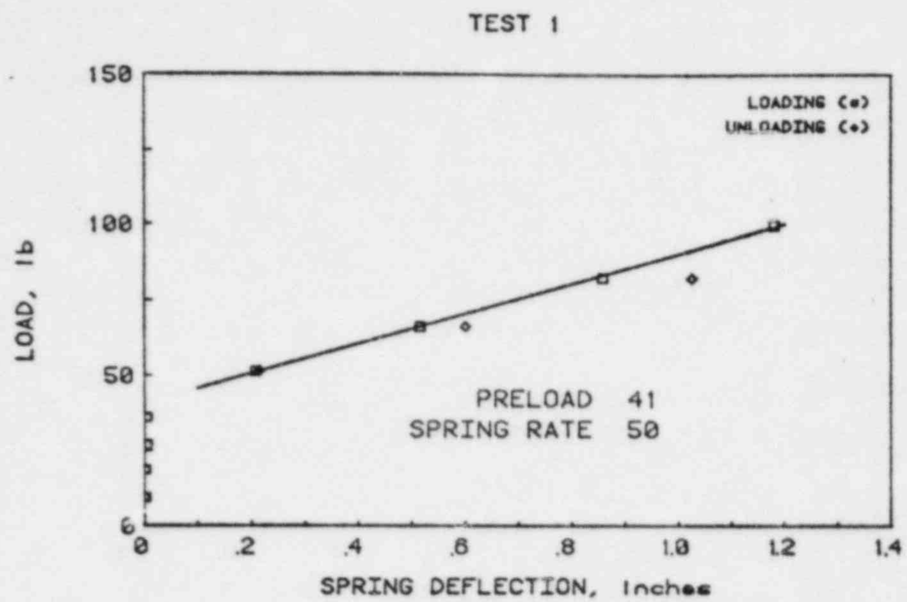
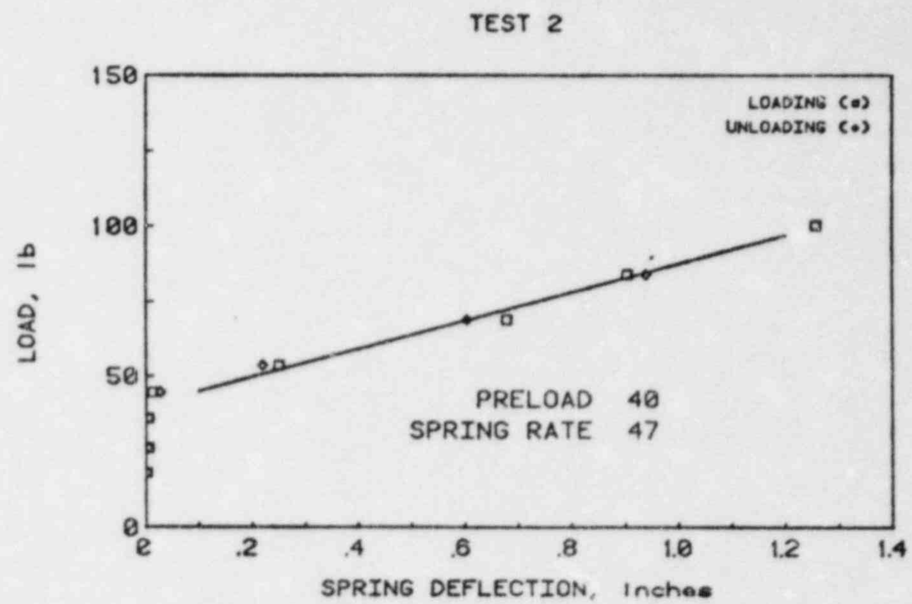


Figure 5. Crud and Boron Crystal Deposits on Spring From Retainer L106



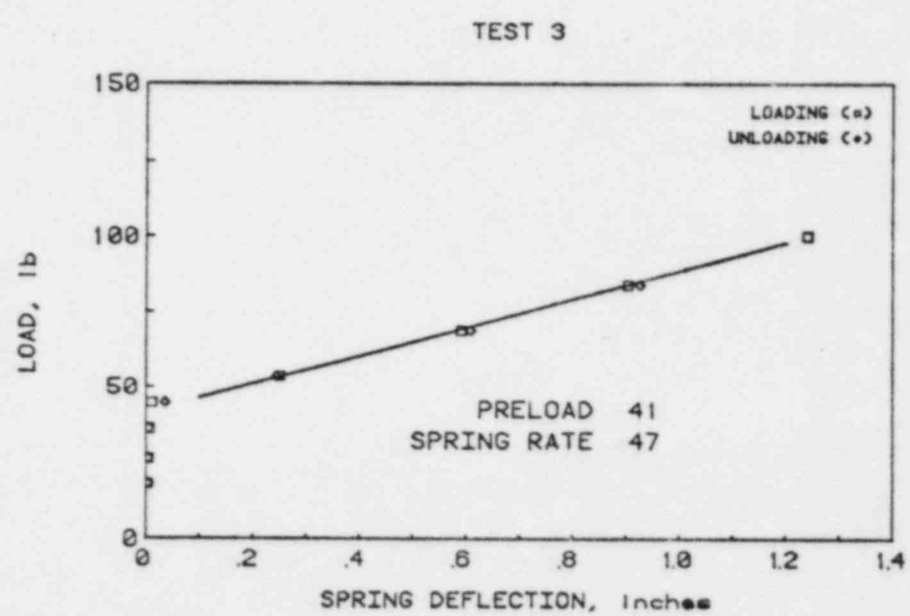




Figure 6. Load-Deflection Data From Retainer L106

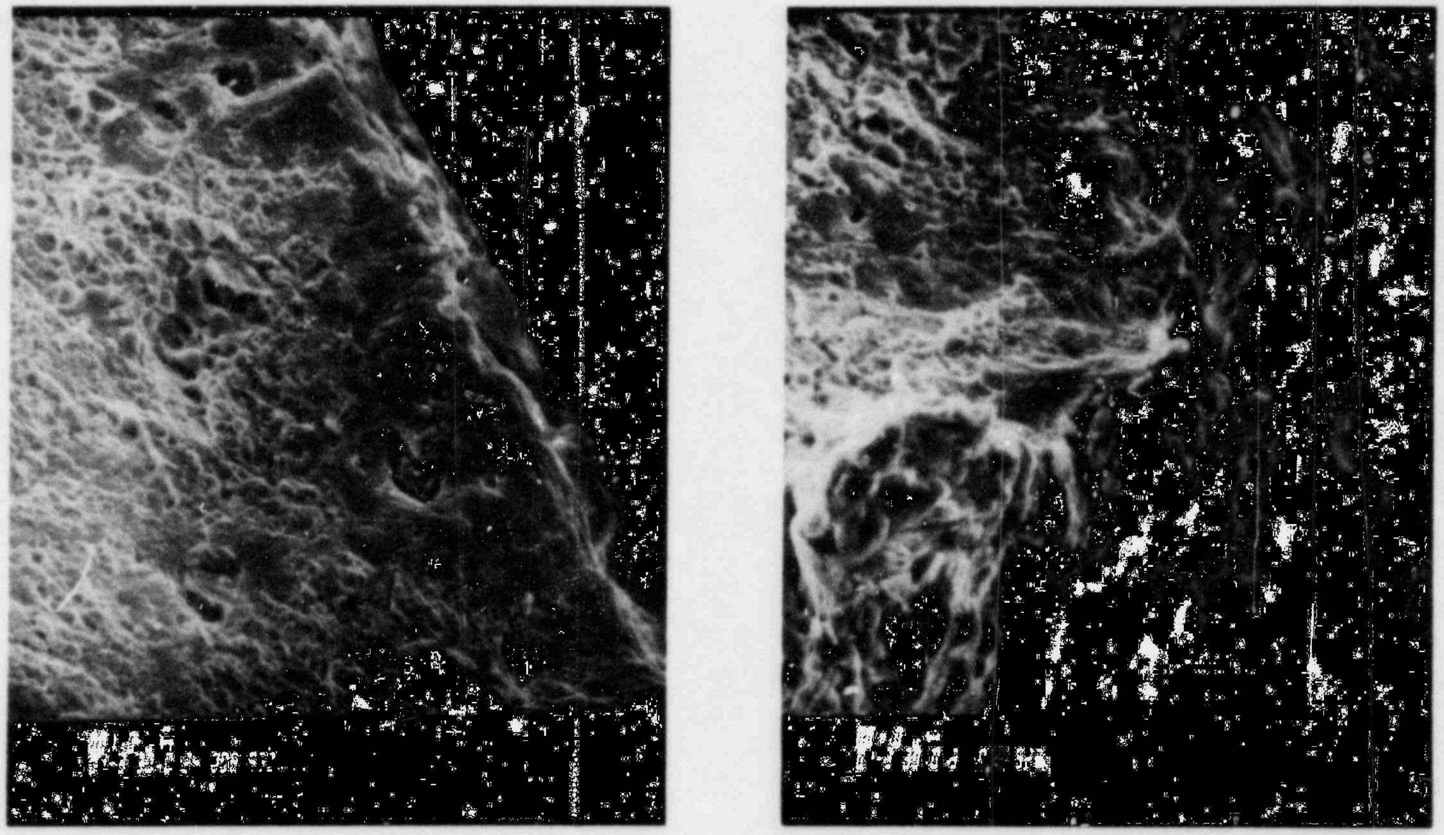
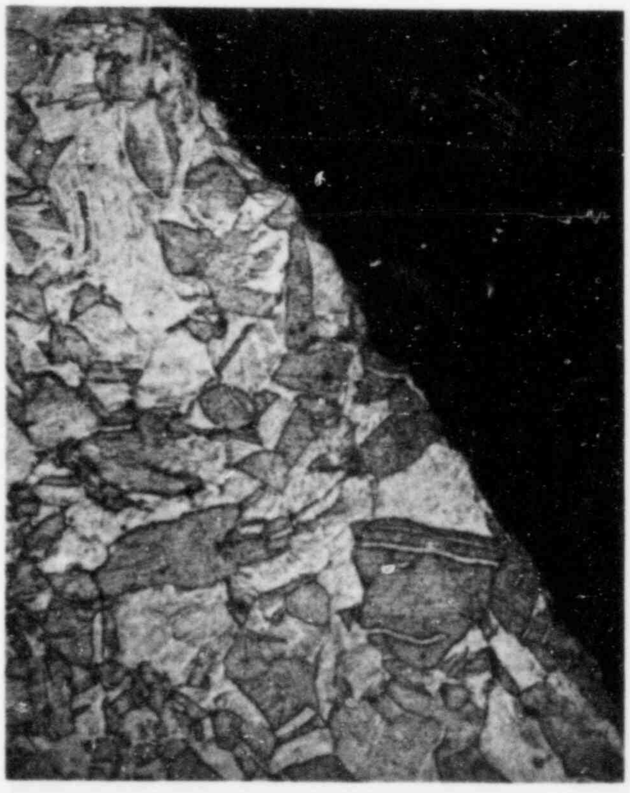


Figure 7. Typical Appearance of Inconel X750 Spring Fracture Surface (1000X)

308 SS Weld

304 SS Knee



X750 Spring

Figure 8. Typical Etched Appearance of Retainer Component Microstructures (400X)

Figure 9. Retainer Leg Weld and Heat Affected Zone (50X)