ENCLOSURE 2

Ginna Reactor Vessel Bottom Mounted Instrumentation Paint Cracking Analysis

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Summary:

- Cracking due to aging, thermal cycling, and brittleness in the Ginna BMI annulus paint has resulted in leak paths that would allow detection of any leakage or deposits that might occur.

- The presence of paint micro-cracking was verified in the 2009 head paint samples, the 2011 replicas at the annulus, and the thermally cycled mock-up samples.

- The leakage paths from micro-cracking in the Ginna annulus paint are more extensive than in the SwRi mock-up paint. Since the mock-up paint did not prevent leakage detection, the aged Ginna paint will not act as a barrier to leak detection either.

Background:

The discovery of a cavity in the Davis-Besse reactor vessel upper head resulted in an industry wide examination of reactor vessels for areas of possible pressure boundary leakage, including bottom mounted instrument (BMI) penetration nozzles. Unlike most BMI nozzles in the industry, the Ginna Nuclear Plant nozzles were painted prior to installation. A 2008 visual exam (WO 20602552) determined that ten of the Ginna nozzles are fully occluded with paint, twenty-one are 50% occluded, and five are less than 50% occluded.

This report compares the results of three analyses that characterize the paint and the effect on leak detection at the BMI nozzle-to- head annulus.

Southwest Research Institute - "Evaluation of Leakage and Deposit Formation in Painted Full-Scale BMI Mockups"

Southwest Research Institute (SwRi) ran a series of tests on painted full-scale BMI mockups in order to:

- Determine whether a paint layer would plug the annulus exit and prevent leakage.
- Determine if deposit formation outside the annulus would be obscured by the paint.
- Obtain information on the éffect of the paint on the pressure within a leaking annulus.

SwRi concluded that the mockup paint is not an effective barrier for either water or steam exiting the annulus. In addition, thermal cycling produces paint cracking that serves as an effective leak path. [1]

2009 Refueling Outage (RFO) BMI Coating Analysis

During the 2009 RFO, two 0.5 mm diameter samples of paint from the Ginna Reactor Vessel BMI were removed for analysis. The purpose was to confirm that the paint was Koppers Hi-Heat Bitumastic and to examine the paint for cracking that could reduce the adhesion of the paint to the metal surface. The samples were taken from the machined head surface approximately 20" from a nozzle.

Electron microscope images of the paint showed multiple cracks in the brittle paint surface that are likely to reduce adhesion. [2]

2011 RFO BMI Coating Annulus Replication

During the 2011 Ginna Refueling Outage, replicas of the nozzle-to-head annulus at three locations were taken in order to:

- Confirm that the paint at the annulus has cracking similar to the paint samples obtained in 2009.
- Compare the Ginna BMI annulus paint to the SwRi BMI painted mock-ups.

Replication is a method for obtaining a high resolution copy of a surface for examination in an optical or scanning electron microscope. Replication produces a negative image of the surface so that cracks in the paint show up as ridges in the replica. Struers RepliSet silicone rubber was used to produce the copies of the annulus paint surfaces. Struers states that the resolution of their Repliset material is 0.1 micron. The width of the paint cracks varied however the size of the smallest micro-cracking seen in the electron microscope was greater than 25 microns. The Struers RepliSet material has sufficient resolution to characterize the annulus surface.

Replication was selected rather than paint chip sampling because it allows more contiguous surface area to be examined. It also produces an accurate copy of the paint without any cracking caused by removal from the annulus. Three locations (See Attachment 1.) were selected and replicated per ASTM Standard E 1351 "Standard Practice for Production and Evaluation of Field Metallographic Replicas".

The replicas were taken at the annulus surface between the head and the nozzle. Figures 1a and 1b show images of an annulus compared to a silicone replica. The ridge of material between the head and nozzle is where the replica material penetrated into the annulus gap between the nozzle and head. This could not occur if paint were sealing that area.

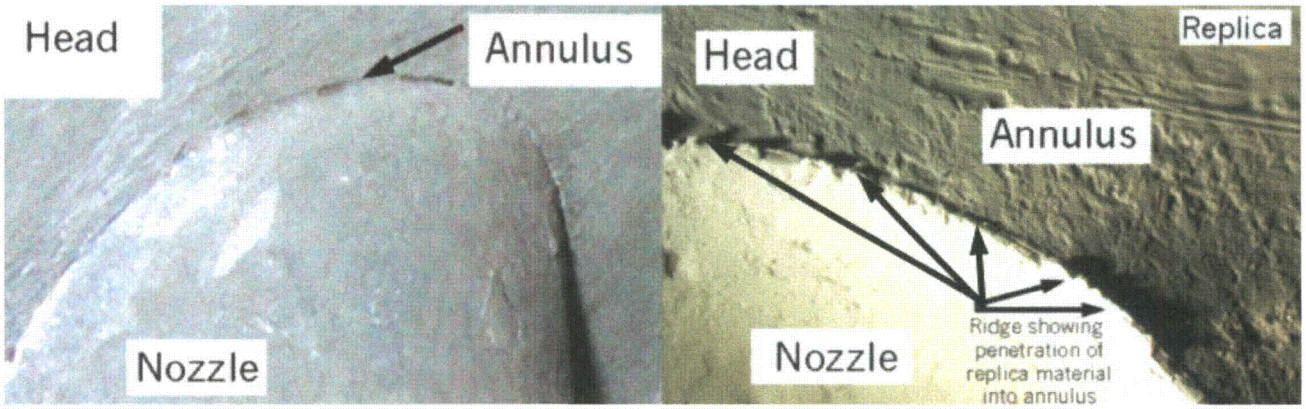


Figure 1a
Optical Image of the Head, Annulus, and Nozzle

Figure 1b
Replica of the Head, Annulus, and Nozzle

Figure 2 shows an electron microscope image of a replica from the annulus. Two approximately 0.5 mm paint particles pulled away from the metal and adhered to the replica material when it was removed from the annulus. It is likely that cracks in the paint reduced the paint adhesion to the metal. One of the chips has a second crack running diagonally across it.

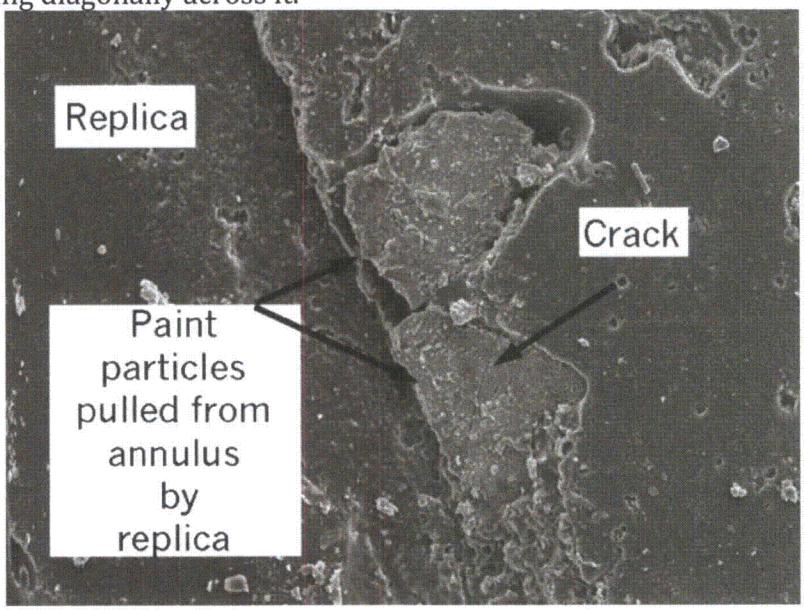


Figure 2 Location 89-2 Magnification ~ 60x
SEM Image of a replica with paint chips imbedded

Figure 3 shows a SEM image of the replica of the cracked paint. The cracks show up as protrusions since the replica material penetrates into the cracks and produces an inverse image.

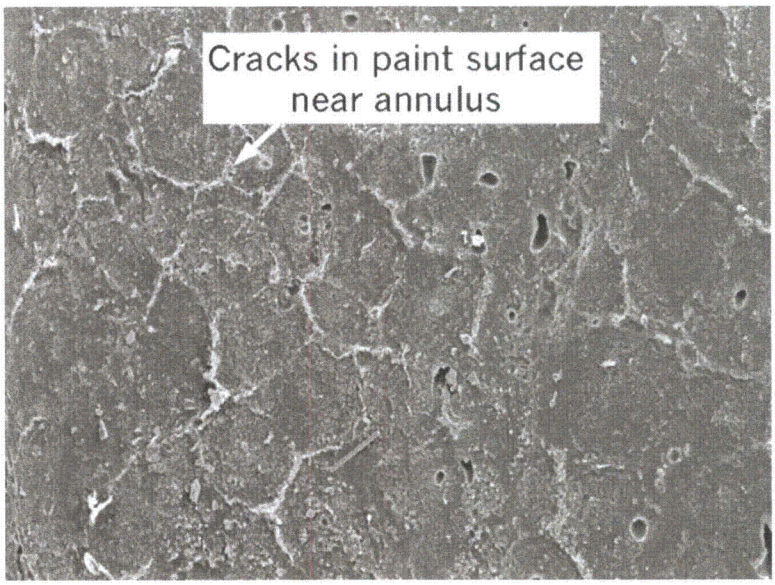


Figure 3 Location 77-1
Replica of Cracked Paint Surface ~ 20x Electron Microscope Image

Comparison of Paint Surface Cracking of the SwRi Mock-up, the Ginna 2009 Paint Samples, and the 2011 Annulus Replication Samples

Images were taken by SwRi and the Ginna Materials Lab using a steromicroscope, scanning electron microscopy, and replication. Corresponding images taken at comparable magnification were not always available.

Figures 4a through 4c below show images of the Ginna head and annulus paint sample locations and an SwRi mockup used for leakage testing. Attachment 1 at the end of this report shows the location of the nozzles that were replicated during the 2011 RFO.

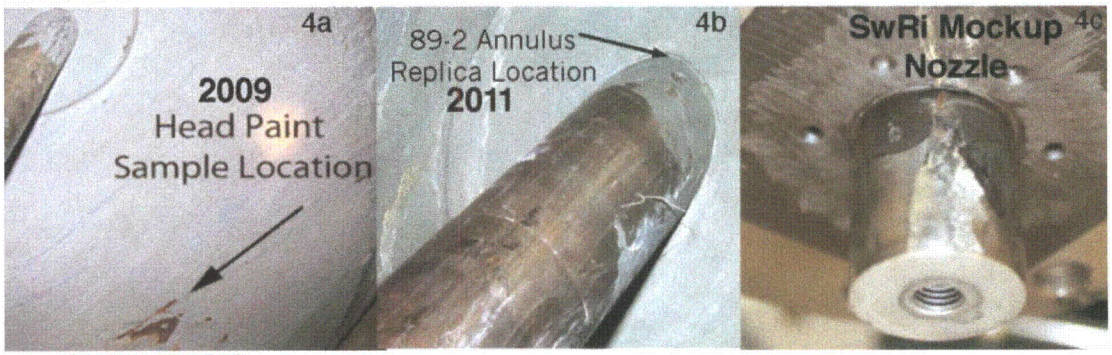
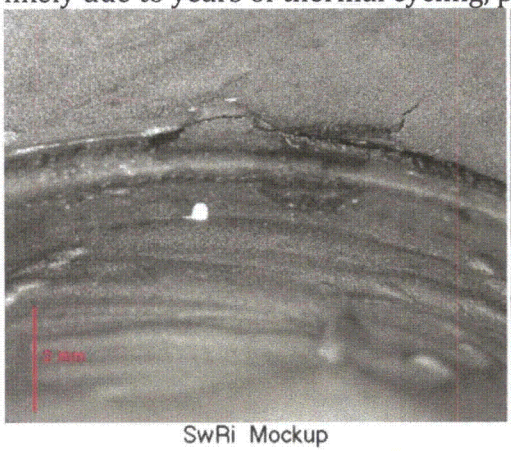


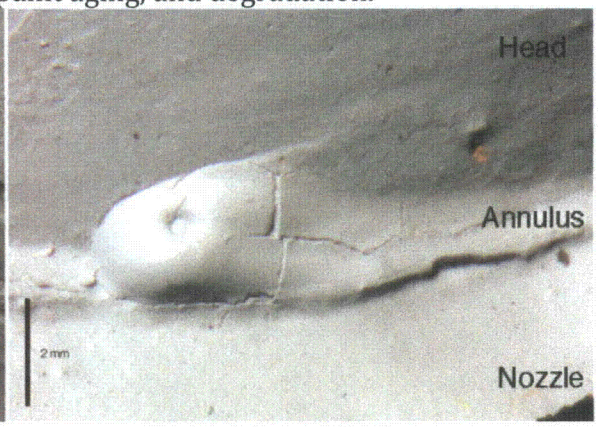
Figure 4a through 4c
Ginna Nozzle Paint Test Locations and SwRi Mockup

Figures 5a, 5b, 6a, and 6b show optical images of the cracks in the SwRi Mockup annulus compared to the Ginna 2011 annulus replica, Location 89-2. The SwRi mock-up paint cracked more often in a circumferential direction while the 2011 annulus replicas showed cracking in multiple directions. It is possible that some of the circumferential cracking occurred when the paint separated from the annulus during the leak testing. This would not be seen in the Ginna paint since no leakage has occurred. The frequent cracking seen in the Ginna paint and replicas is most likely due to years of thermal cycling, paint aging, and degradation.



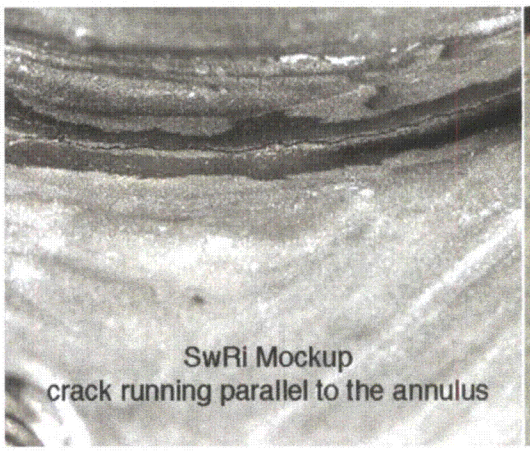
SwRi Mockup
annulus with cracking after testing

Figure 5a
Optical image 10x



2011 Annulus Replica
showing paint cracking at annulus

Figure 5b
Optical Image of Replica 10x



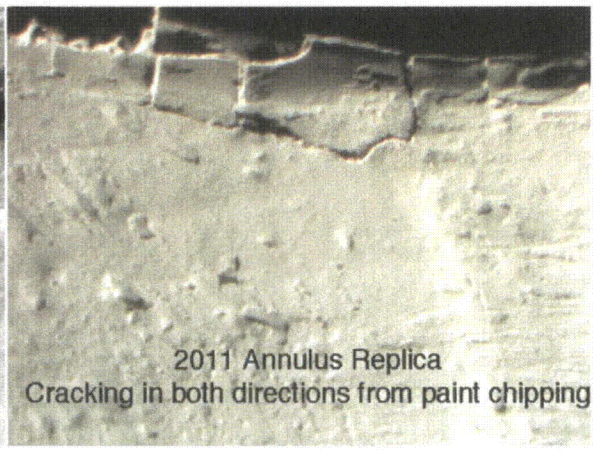
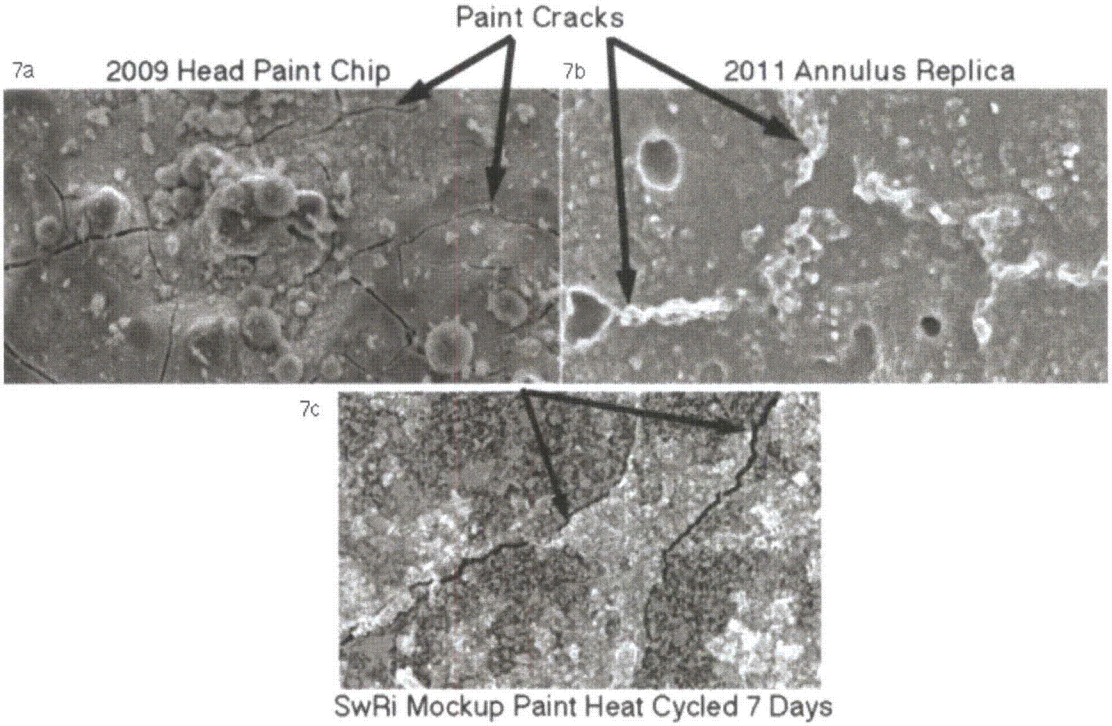


Figure 6a
SwRi Annulus with paralell crack

Figure 6b
2011 Annulus replica with paint micro cracking

At high magnification, microcracking was seen in both the 2009 head paint and the 2011 annulus replicas. No electron microscope images of the actual SwRi Mock-up test paint were available; however, coupon samples of the paint used in the SwRi mockups (Carboline 300 plus zinc) were cycled between room temperature and 350^0 F for 7 days. After 7 days cracking from thermal cycling was apparent.

Figure 7a, 7b, and 7c show electron microscope images of similar cracks in the 2009 head paint chip, the 2011 annulus paint replica, and the SwRi Carboline 300 paint after heat cycling.



Figures 7a, 7b, and 7c Magnification 50x

Conclusions:

- The paint at the Ginna BMI annulus has the same micro-crack pattern as seen on the 2009 Ginna head paint samples.

- More multi-directional cracking was seen in the Ginna paint than in the Carboline 300 paint that failed to hold back leakage during the SwRi testing.

- Aging tests of the Carboline 300 paint used for the SwRi tests showed cracks after only seven days of thermal cycling. It is likely that the thermal cycling experienced at the Ginna annulus produced the fine micro-cracking and brittleness seen in the coating.

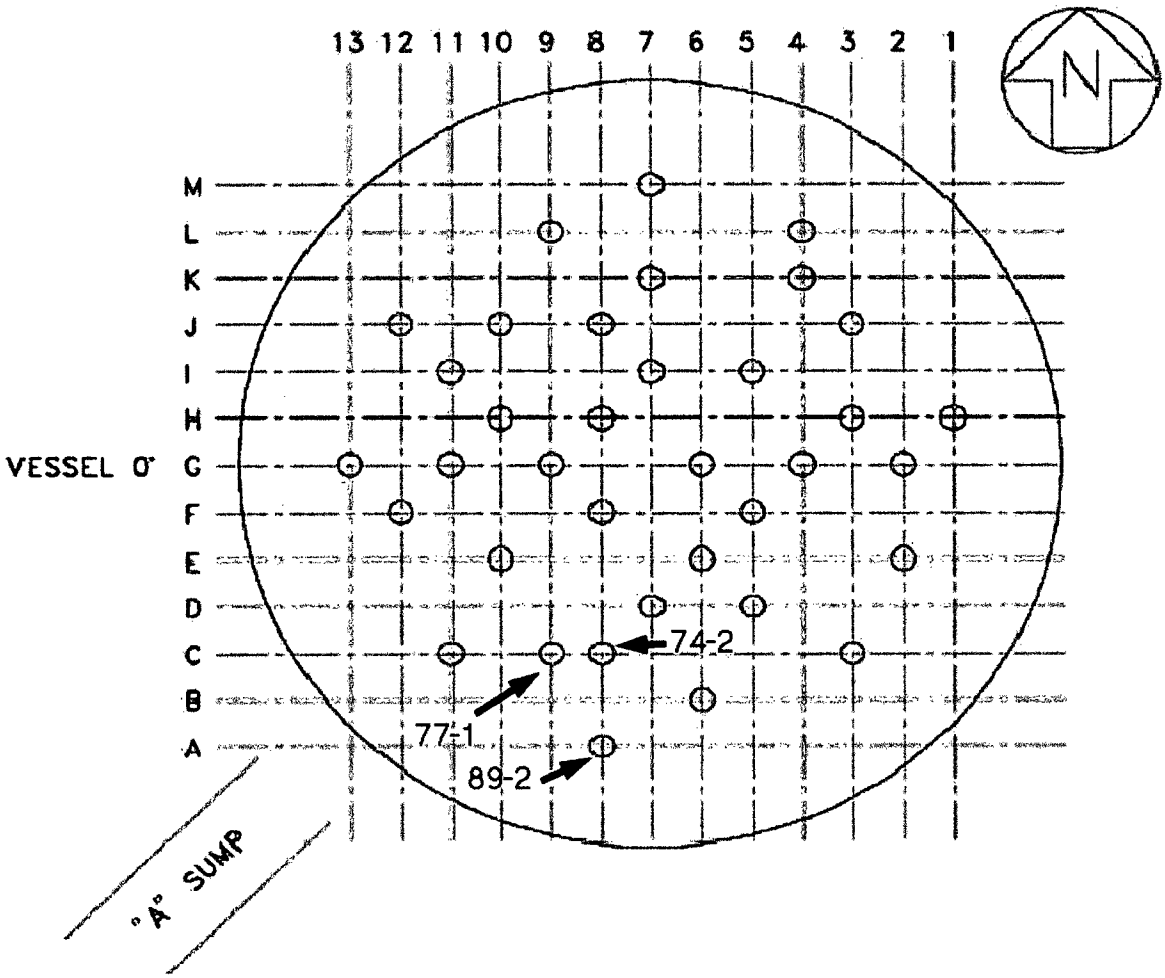
- The 2011 annulus replicas also show multiple areas where gaps in the paint allowed the replica material to penetrate into the annulus. It is likely that these areas will act as paths to the surface for leakage, if it is present.

References:

1. Page, Richard A. "Evaluation of Leakage and Deposit Formation in Painted Full-Scale BMI Mockups." Southwest Research Institute, 2011.
2. Kuchta, Maureen E. "Ginna Reactor Head Vessel Seal Bottom Head Paint Analysis", 2010.

Attachment 1 Lower Head BMI Nozzle Locations

Lower Head BMI Location Map



Replication of the BMI annuli was done at locations 77-1, 89-2, and 74-1.