St. Lucie Pressurizer Nozzle DM Weld Examination Project
Internal Office Report

St. Lucie Pressurizer DM weld examinations

The scope of this project for EPRI was to oversee the examination of six dissimilar metal (DM) welds associated with the Combustion Engineering Pressurizer vessel that was recently removed from service from the St. Lucie Nuclear Power Station. The examinations were to include surface and volumetric examinations, specifically visible liquid dye penetrant (PT) examinations of both the outside (OD) surface and inside (ID) surface of each DM weld, and Phased-Array ultrasonic (UT) examination of the volume of each DM weld. The examination area and volume were to be the same as for a normal Inservice Inspection (ISI) examination of these welds.

EPRI contracted Structural Integrity Associates, Inc.(SIA) to perform the NDE, which also required a procedure expansion of the SIA phased-array UT procedure SI-UT-130.

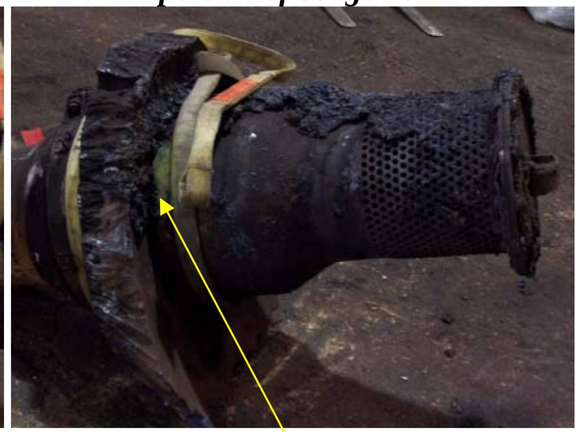
Initial Visit to the Memphis Facility:

I first met with Kevin Butler and David Jennings, at the Studsvik/Race facility on President's Island in Memphis on January 25th, in order to look at the Pressurizer heads and to give the facility instructions on how to prepare the 6 associated dissimilar metal welds for examination. The as-found condition of the nozzles was that they were fully intact and in the same condition as they had come from the plant. The lower head piece contained one nozzle, which was the 14" Surge nozzle. This nozzle had a screen/filter associated with it, which was located on the inside surface of the head. The upper head piece contained five nozzles, which were the 3" Spray nozzle, the 4" Relief nozzle, and three 4" Safety nozzles. The Spray nozzle also had a nozzle associated with it on the opposite surface of the head, which had been internal to the Pressurizer during operation. Each of the 6 nozzles appeared to have end caps welded on them, and the external surface of both head pieces appeared to be coated with some sort of paint or protective coating.

Upper Head Piece showing five nozzles and the internal portion of the Spray nozzle

Cut line

Lower head containing the Surge nozzle ***Internal portion of Surge nozzle***



Cut line

During the initial visit to the facility, I explained a little bit about the examinations that we were going to be performing on the nozzles and why. I requested that the two internal nozzles be cut off of the head pieces, and that each end cap be completely removed, so that we would have access to the ID of each nozzle. I instructed them to remove any internal thermal sleeves that would interfere with our access to the inside surfaces of the welds, as well. I also requested that all paint, coatings, rust and scale be removed from all surfaces of the pieces, down to the bare metal. At that time, they expressed concern for their ability to remove the end cap from the Surge nozzle, due to the size of the weld. We discussed that it should only involve cutting along the weld at the edge of the cap, and that the cap should come off fairly easily. They also asked me if it would be a problem if the flanges on the Safety nozzles were damaged during the cutting, and I said that it was not a concern as long as the weld area of the nozzle was not affected.

The February 4th Week at the Memphis Facility:

Upon arrival to the facility on Monday, February 4th, we received radiation worker training and facility safety training and were then allowed to dress out and enter the Sectional Shop, where the pieces were staged. The as-found condition of the upper head piece, at this time, was that the internal nozzle and end caps had been completely removed and the surfaces had been bead blasted with some sort of carbon steel metallic material, which had removed all paint and coatings but left the surface in a rough rusty looking condition. Even the stainless and inconel surfaces were rusty. Our assumption was that this was caused from carbon steel blast material being embedded into the surfaces. The flanges at the ends of the three Safety nozzles were completely removed along with the end caps. On the lower head piece, the DM weld on the Surge nozzle was actually damaged from the cutting and there were portions of the end plug still in place. When I inquired about this, they told me that the end cap had actually been a plug and that it had been very difficult to remove. I took one of the facilities cutting technicians out to the nozzle and showed him the portions of the plug that were still in place and asked him to carefully remove the weld around the edge of it, and that it would come out. He followed these instructions and was able to remove the remaining portion of the plug.

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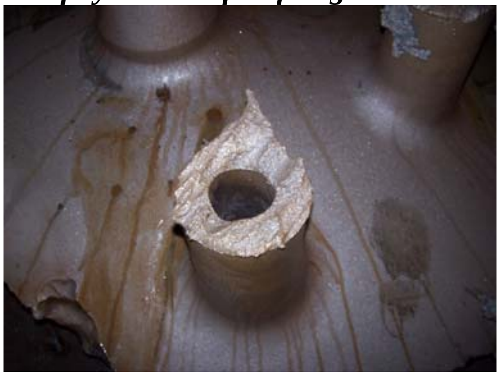
An assessment of the Surge nozzle, after complete plug removal showed that a great deal of the ID of the weld had been damaged by flame cutting.

Upper Head after initial prep work

Safety nozzle after flange removal

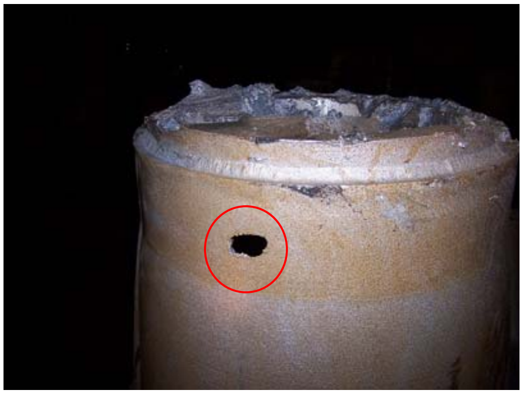


Surge nozzle after initial prep work

(note ID damage caused by flame cutting)

Portions of the end plug still in place

Flame cut hole in the DM weld



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We had brought our own side grinder and flapper wheels, so we proceeded to prepare the outside surfaces of the nozzle weld areas to remove the rust and smooth out the rough surfaces. By the end of the first day, we had managed to adequately prepare the outside surfaces of the welds for PT and UT examinations.

Upper head after flapping

Surge nozzle after flapping and plug removal

On Tuesday, we set up and performed liquid dye penetrant (PT) examinations of the OD surface of each DM welds. There were two small rounded indications noted during the OD PT exams. One was on the Relief nozzle, in the DM weld surface area. And the other was on the "C" Safety nozzle, also in the DM weld surface.

Relief Nozzle OD PT indication

"C" Safety nozzle OD PT indication

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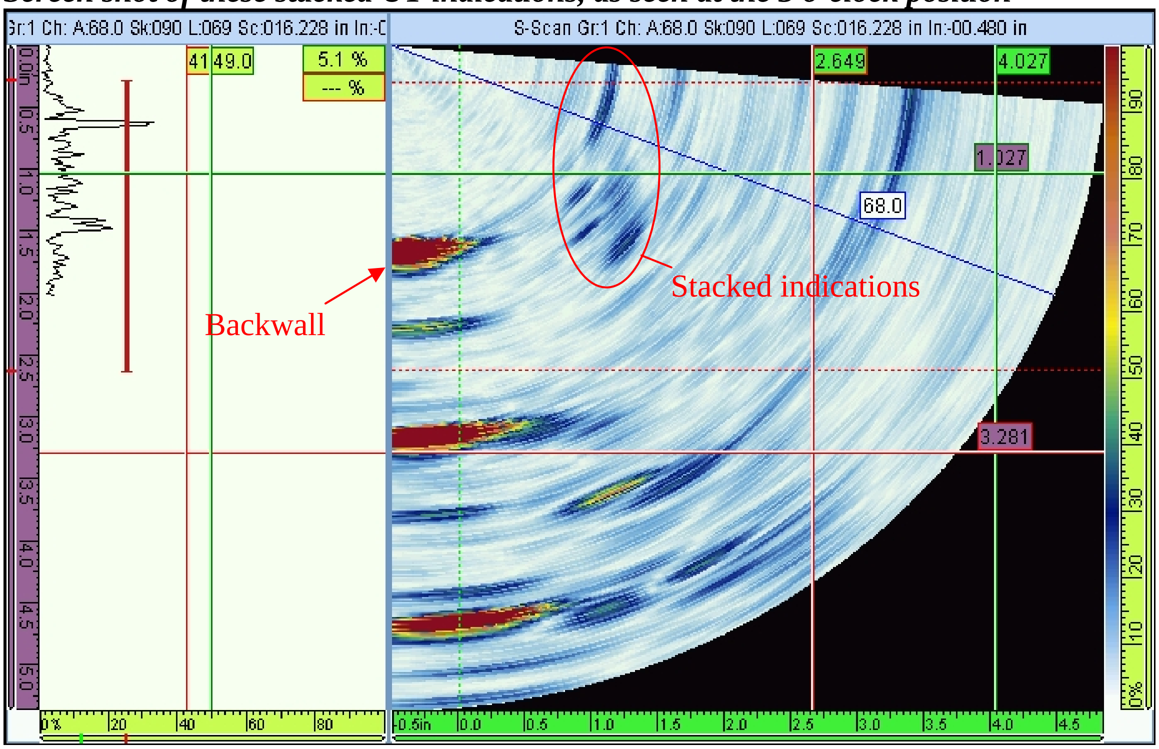
Tuesday afternoon, we began Phased-Array UT examination on the “A” Safety nozzle DM weld, using longitudinal ultrasonic sound beams projected from 0° to 80° angles. We immediately noted a large number of planar reflectors in the weld, which were stacked on top of each other and appeared to extend from the ID surface of the weld up to approximately 0.325” from the OD surface of the weld, at the deepest point. These reflectors were numerous and were present 360° around the circumference of the weld. When scanning across the tops of these indications, the UT sound beams that were projected normal to the surface (straight beams) did not pick up the indications, as you would expect them to if the indications were caused by internal inclusions. Under normal field examination conditions, these types of indications would have to be recorded and evaluated as one continuous linear planer flaw, seen 360° around the weld.

Screen shot of these stacked UT indications, as seen at the 3 o’clock position



On Wednesday, we continued UT examination of the remaining nozzles. The two other Safety nozzle DM welds also contained 360° linear planar indications. The “B” Safety DM weld indication was measured from the ID surface to within 0.396” of the outside surface. The “C” Safety nozzle DM weld indication was measured from the ID surface up to 0.495” of the outside surface. These indication exhibited the same features as that of the “A” Safety nozzle DM weld.

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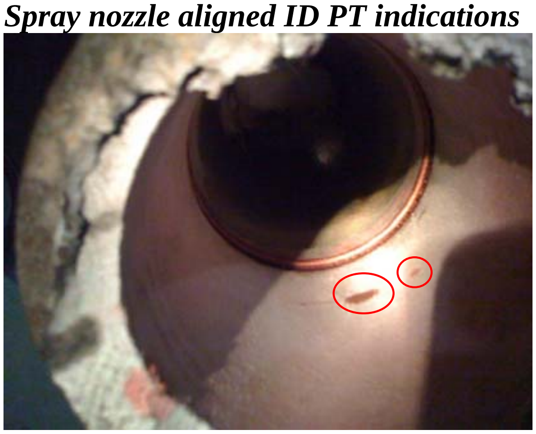
The Spray nozzle DM weld was found to contain one embedded planar indication that did not appear to be connected to the ID surface, and was indicative of a lack of fusion type flaw located along the upper bevel of the weld to base material interface. The Relief and Surge nozzles did not contain any recordable indications.

Wednesday evening, we purchased a die grinder and some abrasive wheels in order to prepare the ID surfaces of these DM welds for PT examination. On Thursday, we were able to use these new tools to prepare a suitable ID surface for examination on each nozzle DM weld. The PT of the inside surfaces the “A” and “C” Safety nozzles produced several aligned dotted indications within the weld material, which were very defined and easy to interpret as surface connected flaws. The “B” Safety nozzle had three very faint indications in one area of the weld inside surface, which were reproducible, but were not as definitive as on the other two Safety nozzles. Surprisingly, the Spray and Surge nozzles also had recordable PT indications on the ID surfaces, in the area of the DM weld. They, too, were aligned. The Surge nozzle indications were somewhat small and faint, similar to that of the “B” safety nozzle. However, the Spray nozzle indications were very defined and sizeable. We re-examined the Surge and Spray nozzle DM welds after the ID PT examinations, but were still unable to record UT indications associated with the PT indications.

Typical Safety nozzle aligned ID PT indications

Spray nozzle aligned ID PT indications



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Faint ID PT indications on the Surge nozzle

Summary of NDE findings:

All six nozzle DM welds on the former St. Lucie Combustion Engineering Pressurizer vessel were successfully examined from both the OD and ID with liquid dye penetrant, and were volumetrically examined by the Phased-Array UT method, using Structural Integrity Associates PDI qualified procedure SI-UT-130. The only limitations to these examinations were on the Surge nozzle, where initial attempts to remove the end plug by flame cutting had resulted in extensive damage to the ID surface and in one area had resulted in a hole through the middle of the DM weld.

The OD surface PT examinations of these six nozzle welds resulted in two recordable indications. One small rounded indication was recorded in the Relief nozzle DM weld crown surface. One small rounded indication was recorded in the “C” Safety nozzle DM weld crown surface. Both of these indications were indicative of porosity-type indications, which may have been uncovered during the bead blasting and flapping processes. Further surface preparations were not performed in the areas of these indications to see if they could be removed.

The phased-array UT examinations of the nozzles resulted in multiple stacked planar indications being recorded in all three of the Safety nozzle DM welds, which under normal field NDE conditions would likely be reported as 360° linear planar flaws. The approximate through-wall depths of these indications at the deepest points were 80% on the “A” Safety nozzle, 75% on the “B” Safety nozzle, and 69% on the “C” Safety nozzle. Additionally, one non-surface connected indication, indicative of lack of fusion was recorded on the Spray nozzle. No recordable indications were noted on the Relief or Surge nozzles, during the UT examinations.

The ID surface PT examinations of the nozzles resulted in multiple, well defined, aligned surface indications being recorded in the weld root area of the “A” and “C” Safety nozzles and the Spray nozzle. The “B” Safety nozzle and Surge nozzle each showed a few faint indications in the weld root area, which were not as well defined, but were recordable. The Relief nozzle did not reveal any ID surface indications. As with the OD surface indications that were noted, all of these ID connected indications could have been uncovered during the surface preparation activities. Further surface preparations were not attempted in the areas of any of these ID indications to see if they could be removed.

Conclusions

The two rounded indications recorded during the OD PT examinations are not unusual, during normal ISI surface examinations. Additional grinding would normally be prescribed to attempt to remove these indications. Surface Eddy Current examination could also be utilized to determine if these indications become linear underneath the surface.

The UT indications recorded on the three Safety nozzles contained multiple planar reflectors, which appear to be vertically stacked and extend from the ID surface to a significant through-wall depth. These indications are indicative of corrosion cracking, but could also be attributed to multiple stacked inclusions in the weld material, left over from construction. Performing automated UT on these three nozzle welds would allow for better flaw mapping and analysis. However, under normal field NDE conditions, these three welds would certainly be reported as containing 360° linear planar flaws of significant through-wall depth, which would require immediate repair.

The aligned ID PT indications noted on several of these nozzles could also be indicative of corrosion cracking. During many recent PT examinations of Reactor Upper Head penetration welds, PWSCC flaws were initially recorded as small aligned “snake bite” indications in the surface of the weld, which upon further surface grinding revealed linear cracking. However, it is also possible that the initial surface preparation of these welds uncovered inclusions in the weld material, which may have been removed upon further surface preparation. Surface Eddy Current examination could also be used to determine whether or not these indications are linked.