CAROLINA POWER & LIGHT COMPANY
BRUNSWICK STEAM ELECTRIC PLANT
UNITS 1 & 2

Review of Recirculation System Safe End NDE Program

Revision 1

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Abstract

CP&L has been requested by the NRC to review the NDE program for the detection of intergranular stress corrosion cracking (IGSCC) in the Brunswick Recirculation System Pump Riser Safe Ends. This report describes the program and considers alternate inspection techniques and their impact on plant operations.

Description of NDE Program

The primary inspection technique utilized for detection of IGSCC at the Brunswick Plant is ultrasonic testing (UT). Radiographic tests (RT) were performed on safe end N2D to better characterize indications found by UT.

The UT procedure used is based on the latest state-of-the art techniques and equipment. The transducer used is a 1.5 MHz pitch-catch device that has been developed by EPRI and SWRI specifically for the detection of IGSCC. The 1.5 MHz transducer produces a focused beam of ultrasonics to the area of concern. A comparative test was made at the Brunswick Plant between a conventional 2.25 MHz pulse echo transducer and the modified 1.5 MHz transducer. The test demonstrated the increased sensitivity afforded by the 1.5 MHz unit.

In addition to the Section XI scanning techniques, such as scanning speed, overlap, and increased gain setting, the procedure used a Brunswick specified that the examinations be run at the maximum test sensitivity permitted by the instrument's signal-to-noise ratio. The sensitivity is 16 dB above the established reference level and is 10 dB above the code required level. Running at this increased sensitivity provides maximum assurance that any reflector will be picked up by the instrument's recording device. The instrument records the test parameters of DAC amplitude and metal path on strip chart recorders so that future interpretation can be easily accomplished.

The shear wave angle used in the examination was 45 degrees, based on its ability to better detect IGSCC whose orientation would be similar to Duane Arnold's. The alternate conventional inspection angle of 60 degrees was determined to be inappropriate for this application. The safe end configuration and the orientation of the IGSCC would cause the sound beam to reflect off at a skewed angle. After the Unit 1 inspections, a 36 degree shear wave examination was performed in an effort to better characterize the indication found on safe end N2D. The examination confirmed the presence of the indication, but did not improve the ability to determine more about the indication.

A longitudinal wave scan of the safe end material and the associated thermal sleeve weld area was performed to provide assurance that the configuration and physical dimensions of the part were as depicted in the plan drawings. A question was raised by the NRC inspectors on site as to the validity of the drawings, particularly the size of the thermal sleeve weld. The L wave tests confirmed the configurations and dimensions were as depicted.

Calibrations for the exminations were performed on a 12" diameter, 1" thick Inconel standard using a 10% notch reflector.

Preferentially oriented radiography was performed on a safe end N2D to better characterize the indication found by UT. During the

initial stages of the program development, RT film was placed around a selected safe end to determine the effects of local background radiation on the film. The results of the experiment showed that significant darkening of the film (fogging) could be expected in the lower quadrant of the pipe due to crud buildup in the pipe and annulus space next to the thermal sleeve. The effects of the background radiation were tolerable on the upper quadrant of the pipe.

The results of the preferentially oriented RT of N2D revealed one hook-shaped indication in the area of the indication found by UT and two slag inclusions in the thermal sleeve attachment weld. Computer image-enhancing techniques were used to better define the indications seen on the film. After enhancing the hook-shaped indication was determined to be a film artifact and of no significance. The slag inclusions were better defined. Image-enhancing did not reveal anything on the film that would conclusively define the UT indication.

Due to the nature of IGSCC, for a crack to be detectable by RT, the radiation beam must be lined up within 3° to 5° of the crack. The air path that the beam penetrates must be greater than 2% of the wall thickness and the crack must have sufficient width (subject scatter) to afford film resolution. These factors significantly lower the probability of seeing a crack unless the UT examinations can confirm the existence and orientation of the crack.

Supplemental Examinations Considered

A. UT with water in line

As stated in the Program Description, the test methods currently being employed are considered to be the best state-of-the-art techniques and equipment available. There are other techniques and more exotic equipment that have been considered to supplement the present program to try to better characterize the indications found. In some instances the technology is still experimental and unproven for field use.

In an effort to enhance the ability to characterize the indications found with the water still in the line, CP&L is pursuing the following items:

1. Increase the precision of data reporting by recording the analog amplitude and position signals on magnetic tape for subsequent analysis on digital storage scopes. The interpretability of the data is enhanced by providing a distance/amplitude plot for all machine recordable indications.

2. Perform studies of test blocks constructed of materials and dimensions the same as the Brunswick safe ends. The purpose of the studies would be to establish ultrasonic beam coverage (eliminate concerns over "blind spots"), determine conclusively the effect of water backing, detectable flow growth rates, and beam spread upon the examinations, as well as investigate in more detail alternate shear wave angles and scanning techniques. The advantage of this type of study is that the data can be recorded and analyzed without subjecting the test personnel to radiation exposures.

B. UT with water removed from the line

As previously stated, CP&L does not feel that the presence or absence of water in the pipe has an appreciable effect on the ultrasonic signal response. However, for the purpose of this review, a UT with water removed from the line was considered.

The primary consideration is that the fuel would have to be removed from the vessel and the water level dropped to below the riser nozzles. These measures have to be taken because the area of concern is in the annulus between the safe end and thermal sleeve. Reactor water is constantly in the annulus space. Plugging the jet pumps will not allow the annulus to be drained.

There is a risk involved in draining the vessel to the level required because of the relatively small amount of experience to date in performing this type of operation. Drying out the RPV internals will result in a release of radioactive materials. There is an uncertainty as to the possible effects of overstressing the internal components due to gamma heating, etc.

The following table lists the estimates of outage extensions and personnel radiation exposures associated with draining the vessel to do a dry UT:

	Best	Worst
Associated Man/Rem Exposures	23.2	48.5
Critical Path Time	242 hrs.	436 hrs.
Non-Critical Path Time	212 hrs.	320 hrs.
Associated Man/Rem Exposures	2.5	6.3

C. RT with water removed from line

By performing a double wall RT shot of the safe end with the water removed from the line, there is the equivalent of 1 1/2" of metal removed from between the RT source and film. This equivalent reduction in metal provides for a better radiographic definition and would approach a 2% sensitivity of one wall thickness. The sensitivity could be deteriorated due to the conical shapes of the safe end not allowing intimate contact with the film.

Even with the increased sensitivity over a double wall shot with water in the line, the detectability of IGSCC would still be impaired. A 100 curie Cobolt 60 source would be necessary to effectively penetrate the double walls, but due to the low contrast of CO_{60}, the detectability threshold of indications is low. In order for a crack to be detectable, it must be oriented with the radiation beam within 3° to 5° and have an air path greater than 2% of the wall thickness and have sufficient width (subject scatter) to afford film resolution.

Another consideration to be taken into account is that draining the water from the line removes the shielding capabilities of the water. Consequently, there would be an increase in background radiation resulting in more radiation scattering and darkening of the film. There would also be an increase in the amount of radiation exposure to the personnel working in the area.

Draining the water from the line will require plugging all five jet pumps for the associated riser header. The estimate of outage extension times and man/rem exposures are:

	Best	Worst
Critical Path Time	18 hrs.	180 hrs.
Associated Man/Rem Exposures	9.2	67
Non-Critical Path Time	70 hrs.	258 hrs.
Associated Man/Rem Exposures	4.1	15.3

D. Single wall RT (access through gamma port)

The RT technique that would afford the best sensitivity is the single wall, panoramic shot. To accomplish a single wall shot with the pipe in place would require drilling a hole for a gamma port plug to place the source inside the pipe. Many of the difficulties and limitations noted in the above discussion of dry RT would also apply to this technique. Specifically, the conical configuration of the safe ends restricts the amount of intimate contact between the safe end and the film. The sensitivity is approximately 2 percent, but the requirement to get an accurate orientation with adequate crack width still presents problems. The size and types of sources required would be limited by the size of hole drilled. The increase is background radiation resulting from draining the line remains a problem.

In addition to these problems, there is the overriding concern that a new source of IGSCC is being introduced into the system. Cutting or drilling and subsequent welding of a gamma port plug will result in sensitization of the 304 stainless steel pipes.

The following estimates are for the extended outage time and personnel radiation exposures associated with drilling a gamma port inspection hole for RT:

	Best	Worst
Critical Path Time	49 Hours	242 Hours
Associated Man/Rem Exposures	18.4	125.1
Non-Critical Path Time	70 Hours	258 Hours
Associated Man/Rem Exposure	4.1	15.3

E. Removal and destructive test of one safe end.

The option of removing safe end N2D to perform destructive testing such as sectioning or machining was not considered as a viable alternative by CP&L. Without further evidence that would conclusively prove the indication to be a crack, the outage impact and radiation exposure involved would not be warranted. However, for the purpose of this review, the option was considered for a future refueling outage.

Cutting out the safe end would require unloading the fuel and draining down the reactor water level. Additional shielding both inside and outside the vessel would be required. The unknowns of this type of operation detailed in the previous section on performing dry UT would also exist here.

The estimate for outage impact and personnel radiation exposures are listed below:

	Best	Worst
Critical Path Time	562 Hours	1,376 Hours
Associated Man/Rem Exposure	221.3	637.9
Non-Critical Path Time	640 Hours	1,040 Hours

Summary and Conclusions

In CP&L's opinion, there is no threat to the public health and safety from the Brunswick Recirculation System riser safe ends, even considering the indication on safe end N2D. The NDE techniques and equipment used to monitor the safe ends are the latest, proven state-of-the-arts technology. They are sufficient to adequately detect an indication and track its potential growth.

The alternate inspection techniques considered do not appear to provide a level of safety or confidence commensurate with the increased costs to consumers and personnel radiation exposures incurred.