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June 21, 2002
RC-02-0108

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Ms. Karen R. Cotton

Gentlemen:

Subject: VIRGIL C. SUMMER NUCLEAR STATION (VCSNS)
DOCKET NO. 50/395
OPERATING LICENSE NO. NPF-12
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
REGARDING V.C. SUMMER'S MSIP ANALYSIS

Reference:
1. Steve Byrne (SCE&G) to Document Control Desk (NRC) letter (RC-02-0088), May 4, 2002
2. Steve Byrne (SCE&G) to Document Control Desk (NRC) letter (RC-02-0090), May 7, 2002
3. Steve Byrne (SCE&G) to Document Control Desk (NRC) letter (RC-02-0094), May 13, 2002
4. Karen Cotton (NRC) to Steve Byrne (SCE&G) letter (TAC No. MB4870), May 20, 2002

The attached information is provided in response to a May 16, 2002, telephone conference between South Carolina Electric & Gas Company (SCE&G), the Project Manager, and the NRR Technical Reviewer with the subsequent formal correspondence (Reference 4). These communications were in regards to the SCE&G submittal of inspection results after implementation of mechanical stress improvement process (MSIP) to the reactor coolant hot leg nozzle welds. These communications discussed five areas of the MSIP analysis development that the reviewer required further information.

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V. C. Summer Nuclear Station performed ultrasonic and eddy current examinations of these welds in Refuel-13 (RF-13) as required by TAC No. MB0251. The examinations performed in RF-13 identified a flaw in the B-loop weld that exceeded the Code allowable defined in IWB-3514, Table IWB-3514-2 of ASME Code, Section XI. This flaw was accepted without repair, removal or replacement (as addressed in IWA-4000 and IWA-7000), to the requirements of IWB-3132.4, as allowed under IWA-3640. IWB-3132.4 (b) requires subsequent examination of the flaw per IWB-2420 (b) and (c). IWB-2420 (b) and (c) require the accepted flaw to be reexamined during the next three successive inspection periods (as defined in the V. C. Summer Inservice Inspection[ISI] Plan). IWB-2420 (c) permits the utility to revert to the original ISI Plan after these three reexaminations if the results are acceptable. SCE&G will implement the requirements of ASME Section XI, as they relate to this flaw. Although the ASME requirements do not apply to the C-loop weld it is prudent to reexamine both welds in the same manner. This approach will provide definitive evidence that the B and C hot leg nozzle to pipe welds continue to be operable.

The commitment to examine these welds in RF-14 is already established and coincides with our 2nd Interval 10 Year ISI. This examination will be a full scope examination of all Reactor Coolant Pressure Boundary welds that are included in the 10 year ISI scope. This examination will be in accordance with the requirements of ASME Section XI and will assure the continued integrity of these welds from a non-destructive examination standpoint. RF-14 is the end of our current examination period (40-month schedule) and interval (10-year schedule). The examinations performed in RF-14 will be performed in the current examination period and will therefore not count towards the requirement for reexaminations in the next 3 successive periods.

V. C. Summer Nuclear Station will reexamine both the B and C hot leg nozzle to pipe welds, as would be required by IWB-2420 (b) and (c), as follows:

- Period One of Interval Three- RF-15 or RF-16.
- Period Two of Interval Three- RF-17 or RF-18.
- Period Three of Interval Three- RF-19 or RF-20.

Should you have questions, please call Mr. Mel Browne at (803) 345-4141.

Very truly yours,

Stephen A. Byrne

JT/SAB/dr
Attachment

c: N. O. Lorick (w/o Attachment)
N. S. Carns
T. G. Eppink (w/o Attachment)
R. J. White (w/o Attachment)
L. A. Reyes
K. R. Cotton
NRC Resident Inspector
J. B. Archie
C. H. Rice (w/o Attachment)
K. M. Sutton
NSRC
RTS (0-C-00-1392)
File (810.58)
DMS (RC-02-0108)

REQUEST FOR ADDITIONAL INFORMATION ON

V. C. SUMMER'S MSIP ANALYSIS

V. C. SUMMER REPORT 3768-4-001-00

1. **On page 8 of 36, it states, "Also, the nodes at the free end of the pipe are coupled in the axial direction. This ensures that these nodes all move in the axial direction at the same amount." Provide justification for this assumption considering piping supports specific to your plant. Is this consistent with the finite element modeling mentioned in Chapter 6 of the EPRI report that was provided to us earlier?**

   Response 1:

   The boundary of the subject axisymmetric finite element model at the pipe end is selected to be sufficiently remote from the location of, so as to be unaffected by, the applied MSIP loading and the structural discontinuities in the vicinity of the nozzle-to-safe-end-to-pipe welds. Therefore the only displacement response possible is compatible translation of all pipe end nodes in the axial direction. <u>This assumption is consistent with the models used for the finite element analyses mentioned in Section 6.5, page 6-12 of the subject EPRI report.</u> The pipe end nodes were coupled in the axial direction to facilitate application of the internal pressure blow-off load for superposition of axisymmetric stresses due to system normal operating pressure and temperature to the post-MSIP results.

   The axial direction displacements have been considered in the piping supports of the RCS. The gaps in the appropriate supports were measured before and after MSIP application and the difference in the gaps were accounted for in the adjustment of the shimming of the supports.

2. On page 11 of 36, it states, "The elastic and inelastic properties used in the finite element analysis are provided in the table below...". What is the stress-strain curve after yielding? Is this consistent with the finite element modeling mentioned in Chapter 6 of the EPRI report that was provided to us earlier?

Response 2:

The ANSYS finite element analysis program option for Bilinear Kinematic Hardening is used to represent the stress-strain curves for the different materials in the nozzle-to-safe-end-to-pipe weldments. Typically, a strain hardening coefficient of 1.0% is used such that the tangent modulus for each material is equal to 0.01 times the material's elastic modulus. This approach has proven to be effective for representing the inelastic behavior of the different types of materials in piping system weldments, and is consistent with the finite element modeling performed for both V. C. Summer and others as mentioned in Section 6.5 of the subject EPRI report.

3. Your finite element analysis does not consider the effect of existing weld repairs on the pre-mechanical stress improvement processing (MSIP) and post-MSIP piping weld stresses. Provide an assessment of this effect.

Response 3:

The purpose of the axisymmetric finite element analyses performed for V. C. Summer and others is to demonstrate that severe as-welded tension stresses at inner weld regions are significantly improved to favorable high compressive stresses, in both the axial and hoop directions, by the application of MSIP.

The residual stress pattern, in general, is linear through wall in the axial direction for pipes with t<1" and it is "u-shaped" for pipes with t ≥1" (see figure 2.3-1 of the subject MSIP analysis report). For V. C. Summer, a "u-shaped" through-wall axial stress pattern was assumed with a relatively uniform through-wall hoop stress to represent the tension stresses in the weld region that result from the welding process. The levels of maximum axial and hoop stress generated were significantly higher than the yield strengths of the materials and hence much greater than those recommended for austenitic stainless steel pipe welds. The conservatism used serves to bracket stress levels that would normally result from most types of weld repairs.

The specimen used in the subject EPRI report contained a full thickness local weld repair using the manual GTAW process. Generally, this type of repair is known to produce very high tensile residual stresses in the inner weld region axially and through-wall in the hoop direction which may be even greater than the conservatively high values generated as part of the finite element analysis. In addition, the EPRI specimen was known to have had several repairs during original construction that would contribute to even higher tensile stresses. Section 6.4 of the subject EPRI report (See Tables 6-1 and 6-2, page 6-10), demonstrates the effectiveness of MSIP based on the pre and post MSIP residual stress measurements even with the presence of this worst case full thickness local weld repair.

Response 3 (Cont'd):

The two-dimensional FEM analysis prepared specifically for the V. C. Summer Hot Legs does not consider the actual repairs that were made during construction; to do so would require the use of a three-dimensional model. Instead, conservatively high stresses throughout the entire weld are modeled to simulate a stress level that would bound a reasonable level of weld repairs. The EPRI report shows that the application of MSIP is successful in significantly improving severe as-welded tension stresses at the inner weld regions to favorable high compressive stress in both the axial and hoop directions. Therefore, the fact that the exact pre-MSIP stress distribution is not explicitly modeled makes little difference.

EPRI REPORT DATED SEPTEMBER 27, 1993

4. **Chapter 6 reports the simulated and measured residual stresses at the inside-diameter (ID) and outside-diameter (OD) of the piping and weld after receiving MSIP. To assess the effectiveness of MSIP, I need corresponding information on the pre-MSIP residual stresses. Measured ID residual stresses shown in Tables 6-1 and 6-2 do not seem to relate to the finite element method (FEM) model. Provide the FEM and measured residual stresses at the ID and OD of the piping and weld before receiving the MSIP.**

   Response 4:

   The primary objective of the EPRI study was to evaluate the measured residual stress changes achievable through the application of the MSIP to an actual nozzle/safe-end weldment. In particular, the effectiveness of the MSIP to treat a nozzle/safe-end weldment having a worst case local full thickness weld repair was thoroughly evaluated. The nozzle/safe-end used in the study had been fabricated for a discontinued nuclear power plant, and was typical in that the nozzle, safe-end and welds were of dissimilar materials. This weldment also contained the full thickness local weld repair which was made using the manual GTAW process that is known to produce very high tensile residual stresses in the inner weld region both axially and through-wall in the hoop direction.

   The computer simulated post-MSIP stress results presented in Section 6.5 of the EPRI report are based on an informal three-dimensional FEM. EPRI requested this informal FEM after the OD strain gage rosettes mounted on the through wall coupon failed. It was used to obtain the general post-MSIP through-wall stress patterns and to confirm the generation of compressive stresses in the inner weld region. No attempt was made to correlate any of the EPRI measured residual stress results. The as-welded stresses generated in the model were axisymmetric as no attempt was made to simulate the three-dimensional effects of the local weld repair. Since no formal report was written, neither stress contour plots for the as-welded condition nor ANSYS Program input/output files for generation of these plots are available.

Response 4 (Cont'd):

The EPRI study focused on the stresses local to the weld repair, and therefore mounted the blind hole strain gage rosettes used to measure the as-welded and post-MSIP residual stresses all on the weldment ID proximate to the local weld repair. The actual stresses developed proximate to the local weld repair were greater than those of the conservatively high as-welded stresses that were computed as part of the axisymmetric finite element analyses performed to simulate the application of MSIP. Therefore, the pre-MSIP ID measured stresses shown in Table 6-1, of the subject EPRI report do not relate directly to the FEM model results.

Although the informal FEM prepared for EPRI is no longer available, a similar FEM was used to make the pre-MSIP and post-MSIP stress comparisons presented in Table 1. This FEM model was a two-dimensional, axisymmetric model of a nozzle/safe-end weldment with geometry and materials of construction that were identical to the EPRI specimen. Conservatism was added to this model by using ASME Code minimum allowable yield strength for all modeled materials. The contour plot outputs of this model are documented in a safety-related report titled "Analytical verification of the MSIP for 12" recirculation inlet nozzle." The results of this analysis are nearly the same as those referred to in Section 6.5 of the EPRI report.

Table 1 presents both an as-welded and post-MSIP comparison of the measured stresses and the corresponding computed stresses as predicted by axisymmetric finite element analysis, including stresses on the OD. When making comparisons between the measured stresses and the analytical stresses presented in Table 1, keep in mind that the yield strengths of the materials in the EPRI nozzle/safe-end weldment would be significantly higher than the ASME Code minimum values used in the FEM model. Since MSIP is a displacement controlled process, the higher the yield strengths of the materials are, the higher the post-MSIP residual stresses would be. Likewise, the as-welded residual stresses would normally be higher. Also, the residual stress values, which are based on the blind hole strain gage rosette measurements, are computed using formulas from the theory of elasticity. This results in an overestimate of stress levels when plastic strains are measured. As seen in Table 1 for the pre-MSIP data, the measured ID residual stresses are consistently higher in magnitude than those predicted by the FEM model. Again, this is largely due to the extremely high residual stresses induced by the local full thickness weld repair. However, for the post-MSIP data, there is reasonably good correlation between the measured

Response 4 (Cont'd):

and predicted values of residual stress. Differences here may be attributed to the materials in the EPRI specimen having higher yield strengths than those used in the FEM model along with overestimation of stresses computed based on measurements of plastic strains, as discussed earlier. Therefore, the post-MSIP ID measured stresses shown in Table 6-2 of the subject EPRI report do relate to the FEM model results.

Table 1

ID MEASURED AND FEM MODEL RESIDUAL STRESSES

Rosette Number		Location Distance from Weld Centerline / Component	STRESS (ksi)					
			Axial			Hoop		
			ID Measured	ID FEM	OD FEM	ID Measured	ID FEM	OD FEM
PRE-MSIP	1	Weld Centerline / Repair	141.8	24.4 to 31.0	-21.7 to 28.3	175.8	27.6 to 33.4	4.8 to 10.5
	3	0.5" / Safe-end	171.7	24.4 to 31.0	-21.7 to -28.3	133.4	27.6 to 33.4	4.8 to 10.5
	4	Weld Centerline	47.1	24.4 to 31.0	-21.7 to -28.3	-5.8	27.6 to 33.4	4.8 to 10.5
	5	2.75" / Nozzle	-33.4	-1.9 to -8.5	17.8 to 24.4	-32.6	-12.4 to -18.1	-6.6 to -12.4
	6	4.75" / Nozzle	-5.5	*	*	1.6	*	*
	7	0.5" / Butter	111.0	24.4 to 31.0	-21.7 to -28.3	69.9	27.6 to 33.4	10.5 to 16.2
	8	3.75" / Nozzle	-30.6	*	*	-29.7	*	*
POST-MSIP	9	Weld Centerline / Repair	-46.4	-36.0 to -48.1	36.0 to 48.1	-51.6	-26.6 to -47.4	0.0 to 6.7
	10	0.5" / Safe-end	-46.2	-24.0 to -36.0	36.0 to 48.1	-39.6	-26.6 to -47.4	0.0 to 6.7
	12	4.75" / Nozzle	-6.8	*	*	-5.0	*	*
	13	3.75" / Nozzle	-13.7	*	*	-27.6	*	*
	14	2.75" / Nozzle	-35.4	-24.0 to -36.0	24.0 to 36.0	-81.5	-13.3 to -20.0	0.0 to 6.7
	15	Weld Centerline	-87.2	-36.0 to -48.1	36.0 to 48.1	-87.9	-26.6 to -47.4	0.0 to 6.7
	16	0.5" / Butter	-81.4	-36.0 to -48.1	36.0 to 48.1	-95.7	-13.3 to -20.0	13.3

NOTE: * - FEM Stress Contour Plots were not extended far enough to cover this region of the model.

5. **The wall thickness for the EPRI BWR nozzle to safe-end is 1.2 inches, and the wall thickness for the Summer pipe is 2.42 inches. I don't think (r/t) ratio, which is used to determine the applicability of thin-shell theory, is the right parameter for determining the appropriateness of the pre-MSIP residual stresses. Provide justification for using the MSIP experience documented in the EPRI report for a thin-wall pipe to the current case for a thick-wall pipe. Provide information on the MSIP application to pipes of similar thicknesses by other plants.**

   Response 5:

   MSIP works by locally contracting the pipe near the weld. This produces a concave axial contour at the weld, which along with the corresponding contraction generate compressive stresses in both the axial and hoop directions at the inner weld region.

   The (r/t) ratio provides an overall guide about the general behavior of the pipe. Since the (r/t) for the V. C. Summer pipe is bounded for higher and lower values of r/t by that of the existing qualification tests and MSIP applications for the BWRs (see Table 2), its general behavior will be similar (i.e., the application of MSIP will generate the similar concave axial contour and corresponding contraction). It is also for this reason that the post-MSIP residual stresses have a similar distribution with the compressive stresses extending at least 50% through the wall.

   The (r/t) parameter is not being used to determine the appropriateness of the pre-MSIP residual stresses. The appropriateness of the pre-MSIP residual stresses being used is based on the pipe thickness. While the wall thickness may affect the pre-MSIP residual stresses, these stresses are redistributed due to the application of MSIP. The post-MSIP stress pattern that is then generated is generally similar for all typical pipe sizes with the same r/t ratio for the reasons discussed above. Thus the post-MSIP stress pattern is similar whether you start with a pre-MSIP residual stress pattern that is linear through the wall in the axial direction (typically for pipes with $t < 1$") or, one that is 'u'-shaped (generally for pipes with $t \geq 1$"), and the corresponding hoop stress (see Figure 2.3-1 of the subject MSIP analysis report). In other words the pre-MSIP residual stresses have a minimal effect on the post-MSIP stress pattern. This was also confirmed with the V. C. Summer analysis in which, starting with the pre-MSIP residual stresses typical of pipes with $t \geq 1$" it was demonstrated that the post-MSIP stresses are compressive in the inner weld region. These are similar to the results obtained when analyzing pipes with

Response 5 (Cont'd):

t < 1" and starting with pre-MSIP residual stresses typical of such pipes and are also consistent with the generation of compressive stresses in the Argonne/NRC and EPRI tests.

MSIP has been applied to the large recirculation nozzle to safe-end welds in BWRs since 1987-88. As a specific example, the Brunswick large nozzle to safe-end welds were treated by applying MSIP to the safe-ends which had ODs of approximately (~) 30" and nominal wall thicknesses of ~ 2.2". These are close to the V. C. Summer dimensions of ~ 34" OD and ~ 2.4" wall thickness.

Table 2
INDEPENDENT MSIP QUALIFICATION TEST

EPRI BWR NOZZLE TO SAFE-END

Nominal OD = 14"
Mean Diameter (DM) = 12.8"
Nominal Wall Thickness (t) = 1.2"

DM/t = 12.8/1.2 = 10.67; RM/t = 5.33

ANL BWR 12" PIPE TO PIPE

Nominal OD = 12.750"
Mean Diameter (DM) = 12.062"
Nominal Wall Thickness (t) = 0.688"

DM/t = 12.062/0.688 = 17.53; RM/t = 8.77

ANL BWR 28" PIPE TO PIPE

Nominal OD = 28"
Mean Diameter (DM) = 26.75"
Nominal Wall Thickness (t) = 1.25"

DM/t = 26.75/1.25 = 21.40; RM/t = 10.70

EPRI BWR 28' PIPE TO ELBOW

Nominal OD = 28"
Mean Diameter (DM) = 26.88'
Nominal Wall Thickness (t) = 1.12"

DM/t = 26.88/1.12 = 24.00; RM/t = 12.00

VC SUMMER PWR HOT LEG NOZZLE TO PIPE

Average OD = 33.93"
Mean Diameter (DM) = 31.51'
Average Wall Thickness (t) = 2.42"

DM/t = 31.51/2.42 = 13.02; RM/t = 6.51

The R/t for V. C. Summer is bounded for higher and lower values of R/t by those for the BWR test specimens. Hence no further process qualification is necessary.