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WCAP-13694

PRIMARY LOOP LEAK-BEFORE-BREAK RECONCILIATION TO ACCOUNT FOR THE EFFECTS OF STEAM GENERATOR REPLACEMENT/UPRATING

April 1993

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Work Performed Under Shop Order VSPP-950

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SECTION 1.0
INTRODUCTION

An evaluation was performed to demonstrate that pipe breaks in the Reactor Coolant System (RCS) primary loop of the Virgil C. Summer plant need not be considered in the structural design basis. The evaluation was documented in Westinghouse topical report WCAP-13206 (Reference 1). This evaluation was re-examined as described in this report to incorporate the effects of hardware changes and uprating in the plant. The hardware changes include removal of steam generator support snubbers, removal of crossover leg whip restraints and the replacement of the steam generators.

The objective of this report is to evaluate the RCS loop piping under the conditions imposed by the new configuration and uprating condition and revalidate the conclusions reached in Reference 1 regarding Leak-Before-Break (LBB). This is accomplished by demonstrating the following:

a. An ample margin exists between critical crack size and a postulated crack which yields a detectable leak rate.

b. Sufficient margin exists between leakage through a postulated crack and the leak detection capability of the plant.

c. Ample margins on applied loads are present.

Under the old plant configuration, these conditions had been met[1]. The evaluation described in this report will compare the two configurations by evaluating the RCS piping for LBB against these same criteria using the revised loads.

SECTION 2.0
EVALUATION

The normal operating loads and faulted condition loads used in WCAP-13206 (Reference 1) are provided in Tables 2-1 and 2-2 for ready reference. The corresponding loads resulting from the revised configuration are provided in Tables 2-3 and 2-4. Review of faulted loads in Table 2-4 shows that the highest stressed location is Location 3 (see Figure 2-1). Since this is an elbow, this location is the toughness critical location (refer to Section 3 of Reference 1 for an explanation of load and toughness critical locations). The highest stressed pipe location is Location 1, therefore it is the load critical location. Detailed fracture mechanics evaluations and leak rate calculations were performed at these locations.

2.1 Leak Rate Calculations

Leak rate calculations were performed as a function of crack length at the governing locations using normal loads. The normal operating loads at Location 1 are:

F_x = 1362 kips

M_b = 13847 in-kips

The normal operating loads at Location 3 are:

F_x = 1527 kips

M_b = 10913 in-kips

The crack opening areas were estimated and leak rates were calculated using the same method described in Reference 1. The flaw sizes yielding a 10 gpm flow rate were determined to be [ ].[a,c,e]

2.2 Fracture Mechanics Evaluation

A fracture mechanics evaluation was performed taking into account both local and global failure mechanisms applying the same methodology used in the previous evaluation[1]. J-Integral calculations and limit moment calculations were performed at Location 3 (As the Location 3 material is cast stainless steel it is susceptible to thermal aging). The pipe material is forged stainless steel namely

SA376 TP304N. Therefore limit moment calculations were performed at Location 1 with the Z factor correction for the weld at Location 1. The SMAW weld Z factor corrections were applied in the limit moment calculations as per Reference 1. Plots of the limit load versus critical crack length are provided in Figures 2-2 and 2-3 for Locations 1 and 3, respectively. The results of the J-Integral evaluation are provided in Table 2-5. Table 2-6 gives the stability analyses results based on limit moment for Locations 1 and 3.

2.3 Assessment of Margins

The results of the leak rate calculations of Section 2.1 and the corresponding flaw stability and fracture toughness evaluations of Section 2.2 are used in performing the assessment of margins. These margins are shown in Table 2-7.

In summary, at all the critical locations relative to:

1. Flaw Size - Using faulted loads obtained by the absolute sum method, a margin of 2 or more exists between the critical flaw and the flaw giving a leak rate of 10 gpm (the leakage flaw).

2. Leak Rate - A margin of 10 exists between the calculated leak rate from the leakage flaw and the leak detection capability of 1 gpm.

3. Loads - At the critical locations the leakage flaw was shown to be stable using the faulted loads obtained by the absolute sum method (i.e., a flaw twice the leakage flaw size is shown to be stable; hence the leakage size flaw is stable).

TABLE 2-1

DIMENSIONS, PREVIOUS NORMAL LOADS AND NORMAL STRESSES FOR VIRGIL C. SUMMER*

Location[a]	Outside Diameter (in.)	Minimum Thickness (in.)	Axial Load[b] (kips)	Bending Moment (in-kips)	Stress (ksi)
1	33.90	2.205	1476	22052	20.21
2	33.90	2.205	1500	3600	9.03
3	36.23	2.349	1590	9677	11.22
4	36.23	2.349	1588	6675	9.71
5	36.20	2.340	1567	5952	9.30
6	36.20	2.340	1562	6484	9.55
7	36.20	2.340	1687	718	7.14
8	36.20	2.340	1687	3341	8.46
9	36.20	2.340	1840	11138	13.02
10	32.20	2.070	1392	4131	10.08
11	32.20	2.070	1392	3987	9.98
12	32.20	2.070	1391	4449	10.31

a See Figure 2-2
b Includes pressure
* WCAP-13206

TABLE 2-2
PREVIOUS FAULTED LOADS AND STRESSES FOR
VIRGIL C. SUMMER*

Location[a,b]	Axial Load[c] (Kips)	Bending Moment (in-Kips)	Total Stress (ksi)
1	1857	23996	23.14
2	1843	11101	15.19
3	2049	17721	17.10
4	1887	17281	16.23
5	1893	18455	16.93
6	1888	11554	13.42
7	1842	7084	10.98
8	1828	10212	12.50
9	1905	16457	15.96
10	1883	17789	22.43
11	1906	10952	17.62
12	1824	11769	17.79

a See Figure 2-2
b See table 2-1 for dimensions
c Includes pressure
* WCAP-13206

TABLE 2-3
DIMENSIONS, NORMAL LOADS AND NORMAL STRESSES FOR
VIRGIL C. SUMMER

Location[a]	Outside Diameter (in.)	Minimum Thickness (in.)	Axial Load[b] (kips)	Bending Moment (in-kips)	Stress (ksi)
1	33.90	2.205	1362	13487	14.45
2	33.90	2.205	1361	8018	11.10
3	36.23	2.349	1527	10913	10.91
4	36.23	2.349	1656	4164	8.72
5	36.20	2.340	1645	3527	8.39
6	36.20	2.340	1640	3584	8.40
7	36.20	2.340	1697	537	7.09
8	36.20	2.340	1697	1980	7.82
9	36.20	2.340	1783	6153	10.27
10	32.20	2.070	1345	3445	9.35
11	32.20	2.070	1345	3445	9.35
12	32.20	2.070	1346	3564	9.44

a See Figure 2-2
b Includes pressure

TABLE 2-4
FAULTED LOADS AND STRESSES FOR
VIRGIL C. SUMMER

Location[a,b]	Axial Load[c] (Kips)	Bending Moment (in-Kips)	Total Stress (ksi)
1	2533	18646	22.95
2	2500	14149	20.04
3	2460	26251	23.03
4	1873	18364	16.72
5	1865	13243	14.18
6	1861	7973	11.50
7	1822	7228	10.97
8	1819	9941	12.33
9	1892	15833	15.60
10	1840	17337	21.89
11	1845	9856	16.52
12	1776	11797	17.56

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a See Figure 2-2
b See table 2-3 for dimensions
c Includes pressure

TABLE 2-5

FLAW STABILITY RESULTS FOR VIRGIL C. SUMMER
BASED ON ELASTIC-PLASTIC
J-INTEGRAL EVALUATIONS

		Fracture Criteria			Calculated Values	
Location	Flaw Size (in)	J_{Ic} (in-lb/in²)	T_{mat}	J_{max} (in-lb/in²)	J_{app}	T_{app} (in-lb/in²)

[ ] a,c,e

TABLE 2-6

FLAW STABILITY RESULTS FOR VIRGIL C. SUMMER
BASED ON LIMIT LOAD

Location	Critical Flaw Size (in.)	Leakage Flaw Size (in.)

a,c,e

TABLE 2-7
SUMMARY TABLE

Location	Leakage Flaw Size	Critical Flaw Size	Margin

a,c,e

[ ]

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[a] based on limit load
[b] based on J integral evaluation

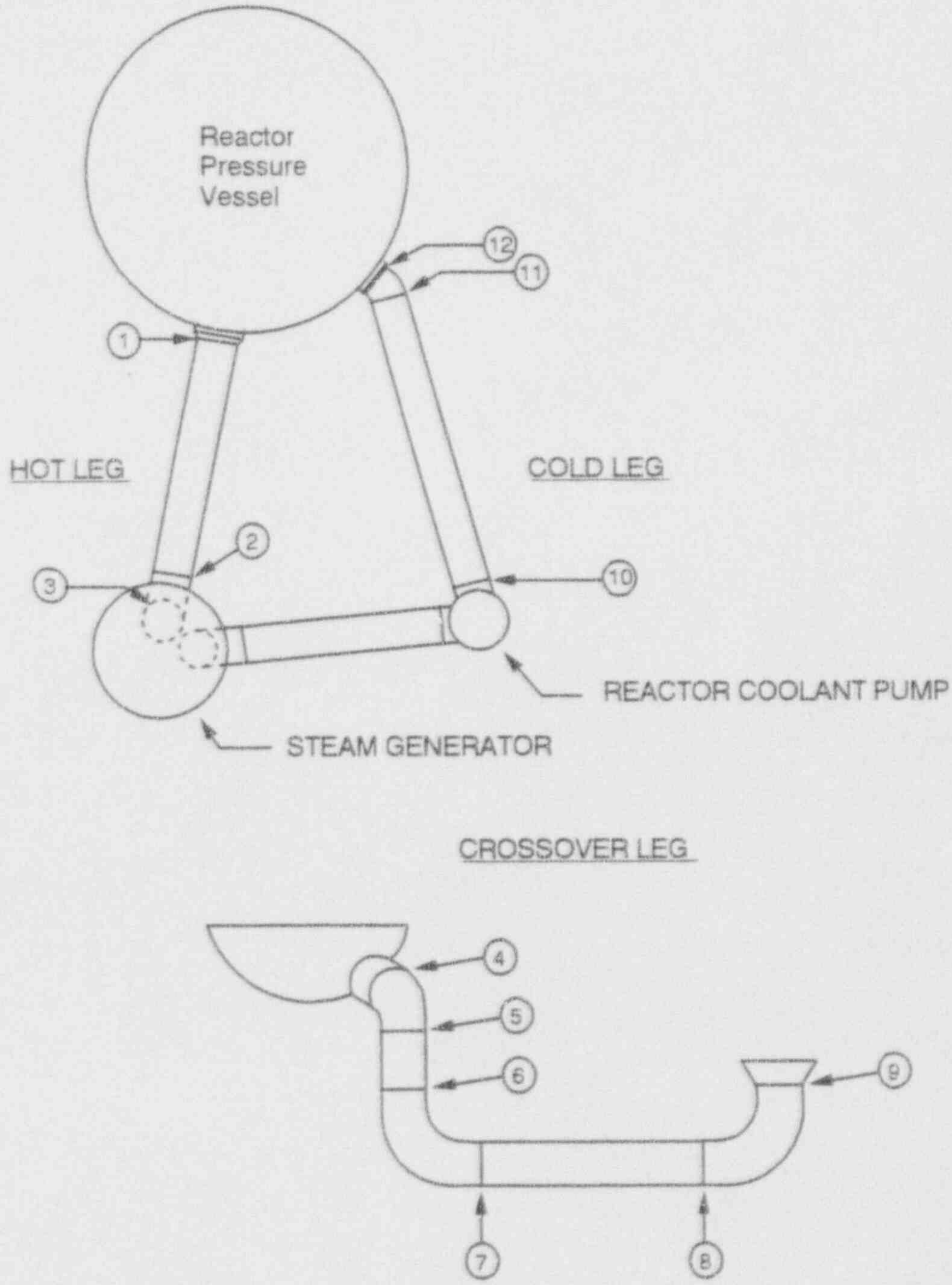

Figure 2-1

Schematic Diagram of Virgil C. Summer Primary Loop Showing Weld Locations

a,c,e

OD = 33.90 in σ_y = 23.8 ksi F_a = 2533 kips
t = 2.205 in σ_u = 71.5 ksi M_b = 18646 in-kips

SA376 TP304N Material With SMAW Weld

Figure 2-2
Critical Flaw Size Prediction - Hot Leg at Location 1

a,c,e

OD = 36.23 in	σ_y = 17.9 ksi	F_a = 2460 kips
t = 2.349 in	σ_u = 56.8 ksi	M_b = 26251 in-kips

SA351 CF8A Material With SMAW Weld

Figure 2-3
Critical Flaw Size Prediction - Hot Leg at Location 3

SECTION 3.0
CONCLUSIONS

The result of the calculations performed to reconcile the elimination of RCS primary loop pipe breaks for the Virgil C. Summer nuclear plant under the new loop configuration and uprating demonstrate that the conclusions reached in Reference 1 remain unchanged. They are listed below to allow ready reference:

1. Stress corrosion cracking is precluded by use of fracture resistant materials in the piping system and controls on reactor coolant chemistry, temperature, pressure, and flow during normal operation.

2. Water hammer should not occur in the RCS piping because of system design, testing, and operational considerations.

3. The effects of low and high cycle fatigue on the integrity of the primary piping are negligible.

4. Adequate margin exists between the leak rate of small stable flaws and the capability of the Virgil C. Summer reactor coolant system pressure boundary Leakage Detection System.

5. Ample margin exists between the small stable flaw sizes of item 4 and larger stable flaws.

6. Ample margin exists in the material properties used to demonstrate end-of-service life (relative to aging) stability of the critical flaws.

For the critical locations flaws are identified that will be stable because of the ample margins in 4, 5, and 6 above.

Based on the above, it is concluded that dynamic effects of RCS primary loop pipe breaks need not be considered in the structural design basis of the Virgil C. Summer plant.

SECTION 4.0

REFERENCES

1. WCAP 13206, "Technical Justification for Eliminating Large Primary Loop Pipe Rupture as the Structural Design Basis for the Virgil C. Summer Nuclear Power Plant." Westinghouse Proprietary Class 2, April 1992.