Jeffrey B. Archie
Vice President, Nuclear Operations
803.345.4214

SCE&G®
A SCANA COMPANY

February 9, 2005
RC-05-0008

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Dear Sir / Madam:

Subject: VIRGIL C. SUMMER NUCLEAR STATION (VCSNS)
DOCKET NO. 50/395
OPERATING LICENSE NO. NPF-12
RESPONSE TO PRELIMINARY WHITE FINDING
NRC INSPECTION REPORT 2005006

On January 14, 2005, the U.S. Nuclear Regulatory Commission (NRC) issued NRC Inspection Report 05000395/2005006 to South Carolina Electric and Gas Company (SCE&G) announcing a preliminary White Finding resulting from an assessment of Unresolved Item (URI) 0500395/2004009-01 identified in Section 40A5.2.1 of NRC Inspection Report 05000395/2004009 issued on December 22, 2004. Two apparent violations were also discussed in Inspection Report 2005006, involving a perceived inadequacy in corrective actions associated with a deficiency in the design of the Emergency Feedwater (EFW) system flow control valves at VC Summer (VCS).

The NRC was informed by phone that VCS requested a Regulatory Conference to discuss issues related to the Preliminary Finding. A February 17, 2005 date for that conference was agreed upon. As requested in your January 14, 2005 letter SCE&G is providing supporting documentation in advance of the conference.

Summary of Positions

During the February 17, 2005 Regulatory Conference, SCE&G will present to the NRC plant-specific information on several issues raised in the subject inspection reports. This information results in a more accurate and applicable significance determination regarding the as-found EFW design.

SCE&G has performed its review of this matter from deterministic and probabilistic perspectives. Deterministically, SCE&G has focused on the tornado induced loss of the Condensate Storage Tank (CST) and the associated EFW suction line. The analysis considers the construction of the tank and impact of wind loads and credible missiles that could result from an F2 tornado (used by the NRC in its analysis). The tank design is very robust (based of the FSAR seismic design requirements) and it has been determined (with significant margin) that tornado wind loads or missiles would not result in loss of function of CST. This conclusion contributes to the overall conclusion that the safety significance of the finding should be "green."

IE01

SCE&G also has performed a probabilistic analysis which focuses on a full range of credible F-scale tornadoes. NRC accepted methodologies used at the Seabrook Station were regionalized for use at VCS. This methodology also was used by other plants (e.g., Ft. Calhoun) for the analysis of similar issues. The SCE&G analysis concludes that the risk from tornado missile impact and perforation of the CST and EFW suction line is 4.5 x E-8. SCE&G concludes that based on plant-specific information, the probability of a loss of function of the CST and/or EFW suction line from a tornado missile is significantly less than what has been more generally postulated by the NRC.

Other key factors discussed in this submittal (which improve upon the calculated change in CDF) include: (1) the likelihood that the CST could randomly fail is very remote, (2) the reactor will not always trip upon a loss of the CST as postulated by the NRC, (3) operators are trained to only introduce SW water into the steam generators as a last resort and (4) based on previous attempts to remove the tubercles, it is unlikely that they will be dislodged to a degree that clogging will occur.

In summary, SCE&G's position focuses on the NRC's white finding in two different categories: 1) unavailability of the CST due to an F2 tornado and 2) random tank failure. The SCE&G analysis concludes that 1) an F2 tornado will not render the CST unavailable and 2) based on plant-specific information provided, the random tank failure event is not risk significant and the change in CDF supports a green finding.

Loss of Function & Risk Significance

Attached are five documents:

1. **"Evaluation of the VC Summer Condensate Storage Tank for Tornados."** Included are:
   a. A deterministic evaluation of the impact of an F2 tornado on the CST.
   b. A risk analysis of tornado missile impact and perforation of the CST.

   The evaluation in Item 1a demonstrates that there is no impact of an F2 tornado which will result in loss of function of the CST and the analysis in Item 1b demonstrates that the potential loss of function of the CST from tornado missiles is not risk significant.

2. **"Expected Operator Actions for Condensate Storage Tank Random Tank Failure."**

   This document provides operator actions and plant responses in the event of a loss of the CST due to a random failure.

3. **"VC Summer Engineering Assessment of Service Water Flow through Emergency Feedwater Flow Control Valves."**

   In the January 14, 2005 letter the NRC provided information which lead it to draw the conclusion that plugging would likely occur in the EFW flow control valves when SW swap over occurs. SCE&G is providing the following document, which provides our perspective on these flow conditions.

4. **"Probabilistic Risk Assessment Review of the VC Summer Emergency Feedwater (EFW), Service Water (SW) NRC Significance Determination Process."**

   This review provides VC Summer's perspectives on the NRC's assumptions used to arrive at the issue significance.

   a. It takes into account the tornado evaluation provided above in Item 1 and reiterates that there is no impact of an F2 tornado which results in loss of function of the CST and that the potential loss of function of the CST from tornado missiles is not risk significant.

   b. It provides additional information concerning a number of assumptions made by the NRC regarding random failure of the CST and piping segments from the CST to EFW as follows:

      i. Failure of the CST will not always cause a reactor trip during the ensuing plant shutdown.

      ii. Basis to reduce the probability of a random failure of the CST.

      iii. Basis to reduce the probability of random failure of the critical piping segment from the CST to EFW.

      iv. Additional factors not considered by the NRC.

The information above is provided to demonstrate how function is not lost, and to show that the risk significance is within the expected performance level.

5. **"Design History of VC Summer Emergency Feedwater Flow Control Valves"**

   The NRC discussed in the inspection report as part of an associated apparent violation, several concerns regarding the initial design of the EFW flow control valves. Although this submittal is not focused on responding to that apparent violation, this attachment provides the NRC with additional and clarifying information for its consideration. In summary, SCE&G does not believe that the violation noted by the NRC is appropriate. We are available to discuss the design-related violation as a separate matter.

Regulatory Conference

While we understand the NRC's "white" finding, which was based on more general information, SCE&G believes that the plant-specific information and analyses clearly support a "green" finding in this instance. During the conference on February 17, 2005, SCE&G will present a summary of each of the above topics to support this conclusion." This information supports a finding of "green." However, notwithstanding the final safety significance ranking of this matter by the NRC, SCE&G is committed to taking appropriate corrective actions regarding the design and performance of the EFW system. These actions are anticipated to include pipe cleaning, fouling assessments, improved routine maintenance, and evaluations of design changes to the system. These activities will be communicated to the NRC as a separate matter.

If the NRC has questions that do not appear to be addressed by this submittal, but would like to be addressed at the Regulatory Conference, please do not hesitate to call Ron Clary at (803) 345-4757.

Very truly yours,

Dan Datta for J.A.

Jeffrey B. Archie

JT/JBA/mbb
Attachment

c: C. R. Ogle
N. O. Lorick
S. A. Byrne
N. S. Carns
T. G. Eppink
R. J. White
W. D. Travers
K. R. Cotton
NRC Resident Inspector
K. M. Sutton
General Managers
Managers
NSRC
CER (C-05-0116)
File (815.01)
DMS (RC-05-0008)

Evaluation of VC Summer Condensate Storage Tank For Tornados

Condition Description

NRC Inspection Report 2005-006 states that the VC Summer (VCS) Condensate Storage Tank (CST) function will be assumed to be lost at medium wind speed/intensity of an F2 Tornado (135 mph).

Condition Evaluation

This evaluation will consider: 1) Deterministically, if loss of function of the CST could occur from F2 Tornado wind loads or missiles, and 2) Probabilistically, if the risk of loss of function of the CST (when considering all tornado events) is considered acceptable. Note that the Emergency Feedwater 10" suction line located at the base of the CST will be included in these evaluations.

1. DETERMINISTIC EVALUATION FOR AN F2 TORNADO EVENT

F2 TORNADO – CST LOSS OF FUNCTION FROM WIND LOADS

Background

The Fujita Tornado Scale specifies an F2 Category Tornado with maximum wind speeds of 113 – 157 mph (average of 135 mph). *Description: Significant Tornado. Considerable damage: Roofs torn off frame houses; mobile homes demolished; frame houses with weak foundations lifted and moved; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.*

The CST is a large circular 500,000 gallon tank: 47' diameter, 41' high, with a shallow dome roof (1/4" plate). Nominal maximum liquid height is 35' - 6" (up to the overflow). The CST is a carbon steel tank with vertical shell plate thickness varying from 5/8" (lower section) to 5/16" (top section). The tank rests on a 4' thick circular reinforced concrete foundation. Refer to Vendor Drawings 1MS-17-090 & 095. The tank base perimeter is anchored to the concrete foundation with 80 – 2-1/2" diameter cast-in-place anchor bolts, typically spaced at 1' - 10".

Evaluation

The CST fabricator and designer (Pittsburgh-Des Moines [PDM] Steel Company) was required by VCS Design Specification (DSP-209) to design and supply a tank meeting the FSAR design requirements for OBE/SSE earthquakes and 100 mph wind loads.

The Seismic Qualification Report (Ref. 1) for the CST (as prepared by PDM) shows that the tank shell was modeled as a series of 5 beam elements, each corresponding to a shell course approximately 8' high. The maximum design pressure on the tank shell from the earthquake loads varied from 19.6 psi (top) to 41.1 psi (bottom), which included liquid pressure varying from 3.5 psi (top) to 17.8 psi (bottom).

Although wind loading analyses can become very complicated (by use of shape coefficients, exposure coefficients, etc.), a simplified approach will be used:

1) From the Standard Building Code, for maximum F2 winds of 157 mph, the equivalent external wind load = (0.00256) (157^2) = 63.1 psf = 0.44 psi.

2) ANSI/ANS-2.3-1983 (Ref. 2) provides tornado characteristics (for maximum winds up to 320 mph), including maximum pressure drop as a function of wind speed. From the ANSI Standard, an F2 Tornado with maximum winds of 157 mph would produce a maximum pressure drop of 0.52 psi.

Conclusion

The CST tank shell is designed to withstand earthquake stress loads (19.6 to 41.1 psi) which are significantly greater than the stress loads capable of being produced on the tank shell by maximum wind load (0.44 psi) and pressure differential (0.52 psi) from an F2 Tornado, regardless of how these loads are combined. Therefore, there would be no loss of function of the CST or loss of inventory given an F2 Tornado event.

A sensitivity review of wind loads for all tornado categories is presented in Appendix A (attached).

F2 TORNADO – CST LOSS OF FUNCTION FROM MISSILES

As noted earlier, the Fujita Tornado Scale description for an F2 Tornado indicates that "light-object missiles" can be generated. Such missiles would typically be sheet-metal, roofing, small wood pieces, tree debris, etc.

As shown on the attached plant layout drawing (Appendix C), the CST is located in the east yard area of the plant site in close proximity to and protected by the Turbine Building, Diesel Generator Building, Water Treatment Building, Auxiliary Boiler House, and other large tanks (Demineralized Water and Filtered Water Storage). These structures provide a significant level of shielding for the CST, especially since most of the missile sources are located to the south and west of the power block structures and the predominant direction of weather approaches from the south and west. It is also noted that the Technical Specifications low-level safety limit for the CST is 14.1' (Ref. Calculation DC09620-013) and the tank shell plate material below this limit is a minimum of 0.50" thick (Ref. Drawing 1MS-17-095).

Reference 3 provides information on tornado missile impact tests, expected missile speeds, and equations to predict missile penetration into steel plates. From Reference 3, the minimum thickness (t) of steel plate (inches) that potentially can be perforated is:

$$t = [(0.5)(M)(V_s^2)]^{2/3} \div [(672)(d_m)]$$

M = Mass of the Missile (slugs)
V_s = Velocity of the Missile (ft/sec)
d_m = Diameter of the Missile (inch)

Reference 4 (Tables 8 & 9) provides a list of tornado generated missiles that should be considered for design of structures, along with horizontal missile wind speed given the tornado design speeds. The Fujita Tornado Scale states that F2 Tornados only generate light-object missiles; however, for this evaluation we will conservatively use the two missile types (timber plank and steel pipe) injected into the F2 wind speed of 150 mph.

It is also noted that the missile dimensions from Reference 4 are not considered typical of the predominant missile types at VCS (Appendix B). Therefore, the two most common missile types (scaffold poles & scaffold planks) are also evaluated.

1) Timber Plank: 4" x 12" x 12' @ 139# weight, V_s = 72 mph

$$M = 139 / 32.2 = 4.3 \text{ slugs}$$
$$d_{m\,(equivalent)} = (2)[(4)(12) / \pi]^{1/2} = 7.8 \text{ inch}$$
$$V_s = (72)(5280) / 3600 = 105.6 \text{ ft/sec}$$

$$t = [(0.5)(4.3)(105.6)^2]^{2/3} \div [(672)(7.8)] = \underline{0.16}"$$

2) VCS Scaffold Plank: 2" x 12" x 8' @ 46.3# weight, V_s = 72 mph

$$M = 46.3 / 32.2 = 1.5 \text{ slugs}$$
$$d_{m\,(equivalent)} = (2)[(2)(12) / \pi]^{1/2} = 5.5 \text{ inch}$$
$$V_s = (72)(5280) / 3600 = 105.6 \text{ ft/sec}$$

$$t = [(0.5)(1.5)(105.6)^2]^{2/3} \div [(672)(5.5)] = \underline{0.11}"$$

3) Steel Pipe: 3" Ø (3.5" OD) x 10' @ 75.8# weight, V_s = 50 mph

$$M = 75.8 / 32.2 = 2.4 \text{ slugs}$$
$$d_m = 3.5 \text{ inch}$$
$$V_s = (50)(5280) / 3600 = 73.3 \text{ ft/sec}$$

$$t = [(0.5)(2.4)(73.3)^2]^{2/3} \div [(672)(3.5)] = \underline{0.15}"$$

4) VCS Scaffold Pole: 2" Ø (OD) x 10' @ 30# weight, V_s = 50 mph

$$M = 30 / 32.2 = 0.9 \text{ slugs}$$
$$d_m = 2.0 \text{ inch}$$
$$V_s = (50)(5280) / 3600 = 73.3 \text{ ft/sec}$$

$$t = [(0.5)(0.9)(73.3)^2]^{2/3} \div [(672)(2.0)] = \underline{0.14}"$$

The above calculations are also considered very conservative, since according to Reference 4, each missile is assumed to travel in a non-tumbling mode, while the largest surface area of the missile is always assumed to be normal to the relative wind vector. Subsequently, the missile is assumed to be perfectly oriented (as a spear) at the time of impact.

Reference 3 defines the plate thickness to prevent perforation as:

$$t_p = 1.25\,t$$

$$t_p = (1.25)(0.16) = 0.20" \ll 0.50"$$

Since the minimum thickness of the tank shell (below the safety level limit of 14.1') is 0.50", it is concluded that there is virtually no chance of loss of function of the CST or loss of inventory due to tornado missile impact and perforation up to and including F2 Tornado events.

F2 TORNADO – EFW SUCTION LINE LOSS OF FUNCTION FROM MISSILES

In addition to the CST, a 10" diameter Emergency Feedwater (EFW) suction line exits from the northwest base of the CST (at 301.5° azimuth), immediately bifurcates (T-Section) into 10" primary and by-pass lines, then both lines turn downward below grade. The total length of exposed pipe for both the primary and by-pass lines is approximately 15'. These lines (which are encased with several inches of insulation) run horizontally just above grade level with their centerline at approximately 16" height. The 10.75" OD steel pipe lines have a wall thickness t = 0.365" (Ref. Drawing 1MS-17-098).

The previous discussion for the CST shows that the maximum perforation capability for F2 Tornado missiles (of 0.16") is attributed to the Timber Plank. Applying the 25% safety factor to prevent perforation yields:

$$t_p = (1.25)(0.16) = 0.20" << 0.365"$$

Since the minimum thickness of the EFW pipe wall is <u>0.365</u>" (and also protected by several inches of insulation), it is concluded that there is virtually no chance of loss of function of the EFW lines or loss of inventory due to tornado missile impact and perforation up to and including F2 Tornado events.

<u>Summary Conclusion – F2 Tornado Evaluation</u>

As shown above, loss of function of the CST and EFW suction lines will not occur from F2 Tornado wind loads or missiles. The seismic design stresses on the tank shell dominate all potential stress loads on the tank shell from wind velocity and pressure drop which are capable of being produced by an F2 tornado. The tank shell plate thickness (below the safety level limit of 14.1') and the EFW pipe wall thickness are significantly greater that which can potentially be perforated by missiles generated by the F2 Tornado.

2. PROBABILISTIC EVALUATION OF FOR ALL F-SCALE TORNADOS

<u>Background</u>

NRC licensing criteria concerning tornado missile protection are provided in Standard Review Plan (SRP) Sections 3.5.1.4 and 3.5.2. These criteria specify the tornado missile protection requirements for safety-related systems. SRP Section 3.5.1.4 also provides guidance on the use of probabilistic risk assessment (PRA) methodology in lieu of a deterministic approach for assessing tornado missile protection. The probabilistic acceptance criterion for tornado missiles is the same as that identified in SRP Section 2.2.3.

The probabilistic acceptance criteria From the SRP 2.2.3 is as follows: *"... the expected rate of occurrence of potential exposures in excess of the 10 CFR Part 100 guidelines of approximately 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower."*

Use of PRA methodology in the assessment of tornado missile damage to systems that could cause a release of radioactivity in excess of the 10 CFR Part 100 limits are described in NUREG-0896, Safety Evaluation Report Related to the Operation of Seabrook Station, Supplement 3, July 1985 (Ref. 10). This SER documents acceptability of the approach with the NRC. Due to the acceptably low risk, hardened tornado missile protection was not required at Seabrook Station for some safety-related items.

Tornado missile strike probabilities are typically estimated using Monte Carlo simulation techniques developed by EPRI (Ref. 5,6). These analyses require detailed modeling of the number, type and location of missiles, tornado movement and wind field, missile injection and aerodynamic characteristics, and missile interaction with the plant. This level of detail is well beyond the scope of this study. However, the results from detailed tornado studies at other plants can be used to develop a simplified analytical technique, such that when corrected for regional tornado differences and target sizes, the results are reasonable for use at VCS. The simplified tornado missile analysis used in this evaluation is based upon use of the results from the Seabrook tornado missile analysis (Ref. 7).

For the Seabrook approach, missile strike probabilities per ft^2 were calculated for each of 30 targets analyzed, and then the mean missile strike probability per ft^2 was calculated. This is valid because the tornado missile impact probability is approximately proportional to the area of the target. The missile impact probability is then adjusted (normalized) to account for the higher level of tornado activity at VCS using information from Reference 8. Therefore, given an estimate of the target area associated with the Condensate Storage Tank (CST), an estimate of the probability of a tornado missile striking the CST can be calculated, under the assumption that it is another target in the Seabrook study.

Seabrook Nuclear Power Plant Evaluation

Personal conversations (Ref. 7) were held with Thomas F. O'Hara (formerly Yankee Atomic / Duke Engineering Services employee) who was responsible for detailed tornado missile risk analyses at Millstone NPP and Seabrook NPP. These analyses included calculations of Point Strike Probability (PSP) occurrence rates for the plant sites, plant walk downs to quantify missile types and numbers, and development of the Mean Annual Impact Probability per ft^2 of target area for these sites.

Mr. O'Hara also performed a simplified study for Ft. Calhoun Nuclear Power Station whereby the estimates from the detailed studies at Seabrook were adjusted (normalized) to the Ft. Calhoun site by accounting for differences in tornado Point Strike Probability between the two locations.

Mr. O'Hara provided the following calculation data From the Seabrook studies:

1) Point Strike Probability -- $PSP_{Seabrook} = 7.8 \times 10^{-5}$
2) Mean Annual Impact Probability -- $MAIP_{Seabrook} = 5.5 \times 10^{-9}$
3) Number of Missiles (N) = 66,796 (2-Unit site with 1 Unit under construction)

VCS EVALUATION – CONDENSATE STORAGE TANK

Tornado Point Strike Probability (PSP) is based on the following equation (Ref. 7):

$$PSP = (\check{n} \times \bar{a}) \div A$$

- $\check{n}$ = Annual tornado occurrence rate
- $\bar{a}$ = Average tornado area
- A = Geographical area

From the VCS IPEEE "High Winds Evaluation" Report, Table C-3 (Ref. 8), the following data are provided:

$\breve{n}$ = 102 events / 38 years = 2.68 events / year
$\bar{a}$ = 0.59 mi^2 (average area for all tornado events)
A = 57.5 mile radius = 10,387 mi^2

$$PSP_{Summer} = (2.68 \times 0.59) \div 10{,}387 = 1.52 \times 10^{-4}$$

Normalizing to Seabrook:

$$PSP_{Summer} / PSP_{Seabrook} = (1.52 \times 10^{-4}) / (7.8 \times 10^{-5}) = 1.95 \quad (\sim 2^{**})$$

** A factor of 2 indicates that the likelihood of a tornado point strike at Summer is twice that of Seabrook. From Reference 7, the Ft. Calhoun study determined their tornado point strike probability to be 5 times that of Seabrook. Based on regional differences of tornado frequency, these results seem reasonable.

Applying this factor to the Mean Annual Impact Probability:

$$MAIP_{Summer} = MAIP_{Seabrook} \times 2$$

$$MAIP_{Summer} = (5.5 \times 10^{-9}) \times 2 = 1.1 \times 10^{-8} \text{ (per ft}^2\text{ target area)}$$

CST Target Area (for maximum water height of 35' - 6") is calculated as follows:

$$A_{CST} = \pi D h = (3.14)(47)(35.5) = 5240 \text{ ft}^2$$

The following baseline Mean Annual Impact Probability is calculated for the CST using the number of missiles (66,796) as assumed for Seabrook:

$$MAIP_{CST} = (1.1 \times 10^{-8})(5.240 \times 10^{3}) = 5.8 \times 10^{-5}$$

REDUCTION FACTORS APPLICABLE FOR CST EVALUATION

1) Calculation of the $MAIP_{Seabrook}$ was based on 66,796 missiles identified for a 2-unit site with one unit under construction. A reduction in the number of missiles at VCS is considered appropriate and is quantified in Appendix B to this study.

   As shown in Appendix B, a walk down of the VCS plant site was recently performed to quantify the number of missiles which should be assumed for this evaluation. Based on this review and insight provided by EPRI NP-769 (Ref. 6) from other representative sites, use of 6,000 missiles is considered conservative and appropriate for this evaluation. This results in a missile reduction factor of <u>~0.10</u> (6,000 / 66,796).

2) The CST is located in the east yard area of the plant site in close proximity to and protected (surrounded) by the Turbine Building, Diesel Generator Building, Water Treatment Building, Auxiliary Boiler House and other large Tanks (Demineralized & Filtered Water). These structures

provide a significant level of protection for the CST, especially since most of the missile sources are located to the south and west of the power block structures, and the predominant direction of weather approaches from the south and west.

Additionally, as shown in Reference 4, missile velocity is considerably less than maximum wind speeds of the actual tornado events. Missiles are typically lifted and then dropped without ever approaching the maximum speeds developed by rotation and translation of the tornado. Thus, large-object missiles are generally lobbed towards a target rather than thrust directly from a tornado.

Since the CST is generally protected/shielded around most of its circumference, a reduction factor of 0.50 is considered conservative for the number of missiles which can potentially impact the tank.

3) The CST must also maintain water level at 14.1' height in the tank to satisfy the Technical Specifications low-level safety limit (Ref. Calculation DC09620-013). Therefore, a reduction factor of 0.40 (= 14.1 / 35.5) is considered appropriate for reduction of target area to define the critical surface area of the tank which is required to maintain water.

4) Due to the increased thickness of shell plate material in the lower portion of the CST (minimum t = ½" in the lower 16'), the ability of missiles to penetrate the tank is considered relatively low. From Reference 7, a study was conducted at Millstone NPP to evaluate the conditional probability of missile penetration through steel plates. The Millstone study evaluated the probability per year of tornado missile perforation of 0.2" thick carbon steel plate located at the opening of diesel generator exhaust piping. Results showed the conditional probability of perforation (given missile impact) to be about 0.07. This factor was considered reasonable and conservative for use since the exhaust piping material was actually 0.50" thick. [Note: Conditional Probability of Perforation as calculated at Millstone NPP is the ratio of the "perforation probability" divided by the "impact probability".]

Reference 3 provides information on tornado missile impact tests, expected missile speeds, and equations to predict missile penetration into steel plates. From this reference, the thickness (t) of steel plate (inches) that potentially can be perforated is:

$$t = [(0.5)(M)(V_s^2)]^{2/3} \div [(672)(d_m)]$$

M = Mass of the Missile (slugs)
V_s = Velocity of the Missile (ft/sec)
d_m = Diameter of the Missile (inch)

Reference 4 (Tables 8 & 9) provides a list of tornado generated missiles that should be considered for design of structures, along with the horizontal missile wind speed given tornado design speeds. The four (4) missile types evaluated were determined to be the most likely to be transported under ideal tornado conditions. These missiles are: 1) Timber plank 4" x 12" x 12', 2) Steel pipe 3" x 10', 3) Utility Pole 13.5" x 35', and 4) Automobile 4000#.

Two (2) of these missile types (automobiles and utility poles) are not considered as credible for impact of the CST as follows:

- From Reference 9, automobiles were determined to generally tumble and flip along the ground (at heights < 30'). Due to the enclosure (protection) of the CST, there is no direct line of path available for an automobile to approach and impact the tank.

- There are a limited number (~ 25) of wood utility poles existing at the plant site, all located to the west / northwest at distances generally greater than 1000'. If these poles are broken-off by the tornado, the likelihood of being transported > 1000' is small. Also, due to their weight, transport heights of > 30' are not assumed; therefore, the power block structures (Reactor Building, Auxiliary Building, Control Building, Diesel Generator Building, Turbine Building, etc.) provide shielding which would not allow the missile to approach and impact the CST. Additionally, a recent 1999 study (Ref. 9) has found that utility poles are no longer considered as credible design missiles at winds of F5 Tornado and below.

For this evaluation, the Reference 4 missiles (timber plank and steel pipe) will be used, although their dimensions are not considered typical of the predominant missile types at VCS (Appendix B). Therefore, the two most likely missile types (scaffold poles & scaffold planks) are also evaluated.

From Table 9 of Reference 4, an F5 Tornado with wind speeds of 300 mph results in the following calculations:

1) Timber Plank: 4" x 12" x 12' @ 139# weight, V_s = 125 mph

$$M = 139 / 32.2 = 4.3 \text{ slugs}$$
$$d_{m\,(equivalent)} = (2)[(4)(12) / \pi]^{1/2} = 7.8 \text{ inch}$$
$$V_s = (125)(5280) / 3600 = 183.3 \text{ ft/sec}$$

$$t = [(0.5)(4.3)(183.3)^2]^{2/3} \div [(672)(7.8)] = \underline{0.34}"$$

2) VCS Scaffold Plank: 2" x 12" x 8' @ 46.3# weight, V_s = 125 mph

$$M = 46.3 / 32.2 = 1.5 \text{ slugs}$$
$$d_{m\,(equivalent)} = (2)[(2)(12) / \pi]^{1/2} = 5.5 \text{ inch}$$
$$V_s = (125)(5280) / 3600 = 183.3 \text{ ft/sec}$$

$$t = [(0.5)(1.5)(183.3)^2]^{2/3} \div [(672)(5.5)] = \underline{0.24}"$$

3) Steel Pipe: 3" Ø (3.5" OD) x 10' @ 75.8# weight, V_s = 90 mph **

$$M = 75.8 / 32.2 = 2.4 \text{ slugs}$$
$$d_m = 3.5 \text{ inch}$$
$$V_s = (90)(5280) / 3600 = 132 \text{ ft/sec}$$

$$t = [(0.5)(2.4)(132)^2]^{2/3} \div [(672)(3.5)] = \underline{0.33}"$$

4) VCS Scaffold Pole: 2" Ø x 10' @ 30# weight, V_s = 90 mph **

$$M = 30 / 32.2 = 0.9 \text{ slugs}$$
$$d_m = 2.0 \text{ inch}$$
$$V_s = (90)(5280) / 3600 = 132 \text{ ft/sec}$$

$$t = [(0.5)(0.9)(132)^2]^{2/3} \div [(672)(2.0)] = \underline{0.30"}$$

** Reference 4 (1985) specifies a missile velocity for the 3" steel pipe of V_s = 110 mph, based on studies by Dr. McDonald of Texas Tech University. A more recent 1999 study by Dr. McDonald (Ref. 9) now shows that the maximum velocity of the 3" diameter steel pipe missile does not exceed 90 mph in an F5 Tornado event.

Applying the 25% safety factor to prevent perforation yields:

$$t_p = (1.25)(0.34) = 0.42" < 0.50"$$

The above calculations are also considered very conservative, since according to Reference 4, *each missile is assumed to travel in a non-tumbling mode, while the largest surface area of the* missile is always assumed to be normal to the relative wind vector. Subsequently, the missile is assumed to be perfectly oriented (as a spear) at the time of impact.

Since the minimum thickness of the CST tank shell (below the safety level limit of 14.1') is 0.50", it is concluded that there is a negligible chance of loss of function of the CST or loss of inventory due to tornado missile impact and perforation. Since the likelihood of perforation is considered extremely low, the reduction factor for conditional probability of perforation (as calculated at Millstone NPP to be 0.07) is considered appropriate and conservative for use at VCS.

A validation of CST shell plate thickness is also considered. The interior of the tank is lined with a protective polymer coating (Plasite), while the condensate water chemistry is also used to inhibit internal corrosion. Therefore, internal corrosion is considered to be insignificant. Carbon steel exposed to the outside ambient, moist air environment is not expected to experience significant corrosion rates. This aging effect was reviewed and addressed as part of the recent VCS License Renewal Project (2004), with details provided in response to NRC Request for Information RAI B.2.11-6. For unprotected carbon steel, this response determined a maximum corrosion rate of approximately 1 mil per year for the first 10 years, followed by a rate of approximately 0.3 mils per year for the next 50 years. For a 60-year plant life, this yields a total potential material loss of 25 mils (0.025"). Since the CST has a protective paint coating on the exterior surface, corrosion is considered negligible to date. However, under worst case evaluation, the tank shell would maintain a minimum wall thickness of 0.475" over the current plant life which maintains adequate margin to prevent tornado missile perforation.

5) A reduction due to missile injection height variation is also considered appropriate for use. EPRI Report NP-768, Section 3.2.2.2 (Ref. 5) describes a simulation of 3,000 missiles impacting a vertical wall of a diesel generator building. For a uniform height interval up to 50', simulations were used to determine the vertical distribution (for each 10' increment) of impact positions. These simulations showed a range of vertical distribution for missile impacts as follows:

TARGET IMPACT VERTICAL HEIGHT	PERCENT (%) OF MISSILE IMPACTS	
	SIMULATION 1	SIMULATION 2
0 – 10'	33	23
10' – 20'	21	19
20' – 30'	23	22
30' – 40'	14	22
40' – 50'	9	14

Since the VCS CST dimensions are generally comparable, but smaller than the target wall area studied by EPRI, a reduction factor of 0.54 (= .33 + .21) is considered conservative for determining the height distribution of missile impacts postulated for the critical lower section (14.1') of the CST.

VCS EVALUATION – EMERGENCY FEEDWATER (EFW) SUCTION LINE

In addition to the CST, a 10" diameter Emergency Feedwater (EFW) suction line exits from the northwest base of the CST (at 301.5° azimuth), immediately bifurcates (T-Section) into 10" primary and by-pass lines, then both lines turn downward below grade. The total length of exposed pipe for both the primary and by-pass lines is approximately 15'. These lines (which are encased with several inches of insulation) run horizontally just above grade level with their centerline at approximately 16" height. The 10.75" OD steel pipe lines have a wall thickness t = 0.365" (Ref. Drawing 1MS-17-098).

EFW suction line target area is calculated as follows:

$$A_{EFW} = \pi D L = (3.14)(10.75 / 12)(15) = 42 \text{ ft}^2$$

The following baseline Mean Annual Impact Probability is calculated for the EFW suction lines using the number of missiles (66,796) as assumed for Seabrook:

$$MAIP_{EFW} = (1.1 \times 10^{-8})(4.2 \times 10^{1}) = 4.6 \times 10^{-7}$$

REDUCTION FACTORS APPLICABLE FOR EFW EVALUATION

1) A missile reduction factor of ~0.10 (6,000 / 66,796) is considered appropriate, similar to the CST evaluation.

2) Since the EFW suction lines are comparably protected/shielded as demonstrated for the CST, a reduction factor of 0.50 is considered conservative for the number of missiles which can potentially impact the lines.

3) The EFW suction lines exit from the base of the CST and run horizontally just a few inches above the ground surface before going below ground. Therefore, the lower half of each pipe would not be exposed sufficiently to allow for missile impact. A reduction factor of 0.50 is considered appropriate for reduction of target surface area potentially susceptible to missile impact.

4) As shown for the CST, the maximum perforation capability (for steel plate) postulated for F5 tornado missiles is 0.34" which is less than the minimum wall thickness (0.365") of the EFW pipe. Although a 25% safety factor to preclude perforation does not exist, it is concluded that there is a

negligible chance of loss of function of the EFW suction lines or loss of inventory due to tornado missile impact and perforation. Since the likelihood of perforation is considered extremely low, the reduction factor for conditional probability of perforation (as estimated at Millstone NPP to be 0.07) is considered appropriate and conservative for use.

OVERALL CONCLUSION FOR PROBABILISTIC EVALUATION

The baseline VCS Mean Annual Impact Probability was calculated for the CST and EFW suction lines as follows:

$$MAIP_{CST} = MAIP_{Summer} \times A_{CST}$$

$$MAIP_{CST} = (1.1 \times 10^{-8})(5.240 \times 10^{3}) = 5.8 \times 10^{-5}$$

$$MAIP_{EFW} = MAIP_{Summer} \times A_{EFW}$$

$$MAIP_{EFW} = (1.1 \times 10^{-8})(4.2 \times 10^{1}) = 4.6 \times 10^{-7}$$

Applying the appropriate reduction factors provides the summary and cumulative MAIP as follows:

REDUCTION CRITERIA	CST FACTOR	EFW FACTOR
Missiles: $6{,}000_{Summer} : 66{,}796_{Seabrook}$	0.10	0.10
Protection by Other Structures	0.50	0.50
CST Low-Level Water Height (14.1')	0.40	---
EFW Ground Protection	---	0.50
Missile Perforation Capability	0.07	0.07
Missile Height Distribution (0 - 20')	0.54	---
Summary of Reduction Factors	7.6×10^{-4}	1.8×10^{-3}
Baseline MAIP	5.8×10^{-5}	4.6×10^{-7}
SUMMARY MAIP	**4.4×10^{-8}**	**8.3×10^{-10}**
CUMULATIVE MAIP $_{CST+EFW}$	**4.483×10^{-8} or (4.5×10^{-8})**	

The risk from tornado missile impact and perforation of the CST & EFW suction lines is shown to be 4.5×10^{-8}. Therefore, potential loss of function of the CST & EFW suction lines from tornado missiles is not considered to be risk significant.

REFERENCES:

1) Condensate Storage Tank – Seismic Qualification Report, Contract 14082, Pittsburgh-Des Moines Steel Company, 1975.

2) American Nuclear Society Standard ANSI/ANS-2.3-1983, Standard for Estimating Tornado and Extreme Wind Characteristics at Nuclear Power Sites, Approved October 17, 1983.

3) McDonald, Dr. James R., Extreme Winds and Tornados: Design and Evaluation of Buildings and Structures, Institute for Disaster Research, Texas Tech University, UCRL-15747, October 10, 1985.

4) Coats, D. W. and Murray, R. C., Natural Phenomena Hazards Modeling Project: Extreme Wind / Tornado Hazard Models for DOE Sites, Lawrence Livermore National Laboratory, UCRL-53526, August, 1985.

5) EPRI Report NP-768, Tornado Missile Risk Analysis, May, 1978.

6) EPRI Report NP-769, Tornado Missile Risk Analysis - Appendixes, May 1978.

7) Personal conversations with Thomas F. O'Hara (formerly Yankee Atomic / Duke Engineering Services employee), January 2005. Mr. O'Hara was principle investigator for Tornado Probability Evaluations at Millstone NPP, Seabrook NPP, and Ft. Calhoun NPS.

8) VCS Individual Plant Examination for External Events Report in Response to Generic letter 88-20, Supplement 4, High Winds Evaluation, SAIC, June 1995.

9) McDonald, Dr. James R., Rationale for Wind-Borne Missile Criteria for DOE Facilities, UCRL-CR-135687, Lawrence Livermore National Laboratory, September 1999.

10) NUREG-0896, Supplement 3, Safety Evaluation Report Related to the Operation of Seabrook Station, USNRC, July 1985.

DESIGN DOCUMENT REFERENCES:

- FSAR Sections 3.3 (Wind and Tornado Loadings) & 3.5.1.4 (Missiles Generated by Natural Phenomena)
- Design Drawings 1MS-17-090, 095 & 098, Condensate Storage Tank (PDM)
- Design Specification DSP-209, Field Erected – Nuclear Safety Class Storage Tanks
- Standard Building Code – 1997 Edition, Table 1606.2A
- Design Calculation DC09620-013, CST Level Instrument Loop Error Analysis
- NRC Request for Information RAI B.2.11-6 (VCS License Renewal)

APPENDIX A

SENSITIVITY REVIEW FOR ALL TORNADO CATEGORIES

Wind velocity pressure (q) is proportional to the velocity squared as [$q = 0.00256 V^2$ (psf)]. Maximum pressure drop (ΔP) is obtained from ANSI/ANS-2.3-1983 (Ref. 2), except for the F6* Category which is specified by the FSAR.

CATEGORY	MAX. WIND (mph)	PRESSURE (psf)	PRESSURE [P] (psi)	Δ P (psi)	SUM P + Δ P (psi)
F0	72	13.3	0.09	< 0.20	< 0.29
F1	112	32.1	0.22	0.26	0.48
F2	157	63.1	0.44	0.52	0.96
F3	206	108.6	0.75	0.91	1.66
F4	260	173.1	1.20	1.46	2.66
F5	318	258.9	1.80	1.94	3.74
F6*	360	331.8	2.30	3.00	5.30

* Note that the F6 Tornado Category is no longer considered as a credible event. The Fujita Tornado Scale states that winds of 319 mph or greater are not expected (inconceivable).

APPENDIX B

TORNADO MISSILES NUMBER DETERMINATION

The detailed study performed at Seabrook NPP determined a potential population of 66,796 missiles as calculated from plant inventory walk downs. At the time of the study, Seabrook had one operating unit and one unit under construction. The Millstone 3 study (site co-shared with non-nuclear units) modeled 41,733 missiles.

EPRI NP-769 (Ref. 6) performed on-site missile characterization studies for seven (7) sites as shown on Tables 2-1 and 6-2. Only three (3) of the plant sites were judged to be applicable for this evaluation at VCS as follows:

- Plant # 2 – Two Units (Operating & Construction) = 65,685 Missiles
- Plant # 5 – Three Units (All Operating) = 9,294 Missiles
- Plant # 6 – One Unit (Operating) = 2,918 Missiles

The number of missiles for Plant # 2 agrees with the estimates for Seabrook for comparable units and construction status. Also, from EPRI NP-768 (Ref. 5), a total of 50,000 missile histories were simulated for a similar case of one operating unit and one under construction.

EPRI NP-769, Section 2.3.3 (Ref. 6) evaluated the significance of off-site missile sources and the potential for long-range missile transport. Their study concludes that missiles which are in excess of 2000' from any component need not be considered. Missiles greater than 1000' are not expected to contribute significantly to the risk (described as rare, very unlikely); however, some of the heavier missile types did exceed 1000' in transport. Thus, a reduced subset of missiles from between 1000' and 2000' would be appropriate in the evaluation. [The Fujita Tornado Scale (F5) states that automobile-size missiles may fly through the air in excess of 300'. The EPRI study shows the mean range for all missiles to be less than 350'.] EPRI also states that all missiles within 1000' should be included.

In order to validate the appropriate number of missiles for evaluation at VCS, plant walk downs and warehouse inventory reviews were conducted (January 2005) of the primary non-engineered (commercial grade) storage locations which house the predominance of potential missile types. EPRI NP-769, Table 2-2 (Ref. 6) was used to define the 26 basic missile sets used for the evaluation. All potential missiles within 1000' are included. Since EPRI shows the mean annual transport range of missiles to be less than 350', only 50% of the missiles between 1000' – 2000' will be considered as potential for transport to the 1000' boundary (i.e., not reaching any plant structures within the Protected Area). Also, since all potential missiles between 1000' and 2000' are considered by EPRI as low risk significant (rare, very unlikely), only 10% of the remaining missiles are assumed to be transported and counted.

Structural debris missiles (non - sheet metal, siding, roofing, etc.) from commercial grade and non-reinforced concrete buildings can only be estimated. For this study, a minimum factor of 10% will be applied to the inventory results, along with a general assessment of the types of existing structures which could be damaged and subsequently generate missiles. Therefore, approximately 500 missile pieces (trusses, beams, columns, etc.) are estimated to be generated and transported from these type buildings (located w/in 1000'). Since there are significantly more and larger commercial grade buildings located beyond 1000', approximately 2,000 structural debris missile pieces are estimated to be generated. However, applying the same criteria as previously used from the EPRI guidance on missile transport capability reduces this number to 100 (= 2,000 x 50% x 10%).

Summary Results

Walk down / Inventory Results:

- Total Missile Inventory per EPRI Table 2-2 (w/in 1000'): 4,409
- Total Missile Inventory per EPRI Table 2-2 (1000' – 2000'): 11,980

Missile Summary:

• Missiles per EPRI Table 2-2 (w/in 1000'):	4,409
• Estimated Structural Debris (w/in 1000'):	500
• 50% x 10% - Missiles per EPRI Table 2-2 (1000' – 2000'):	599
• 50% x 10% - Estimated Structural Debris (1000' – 2000'):	100
TOTAL:	5,608

Based on the plant specific walk down / inventory review, and guidance from EPRI and other plant studies, the tornado missile population for evaluation of the CST and EF suction lines at VCS is conservatively estimated to be **6,000**.

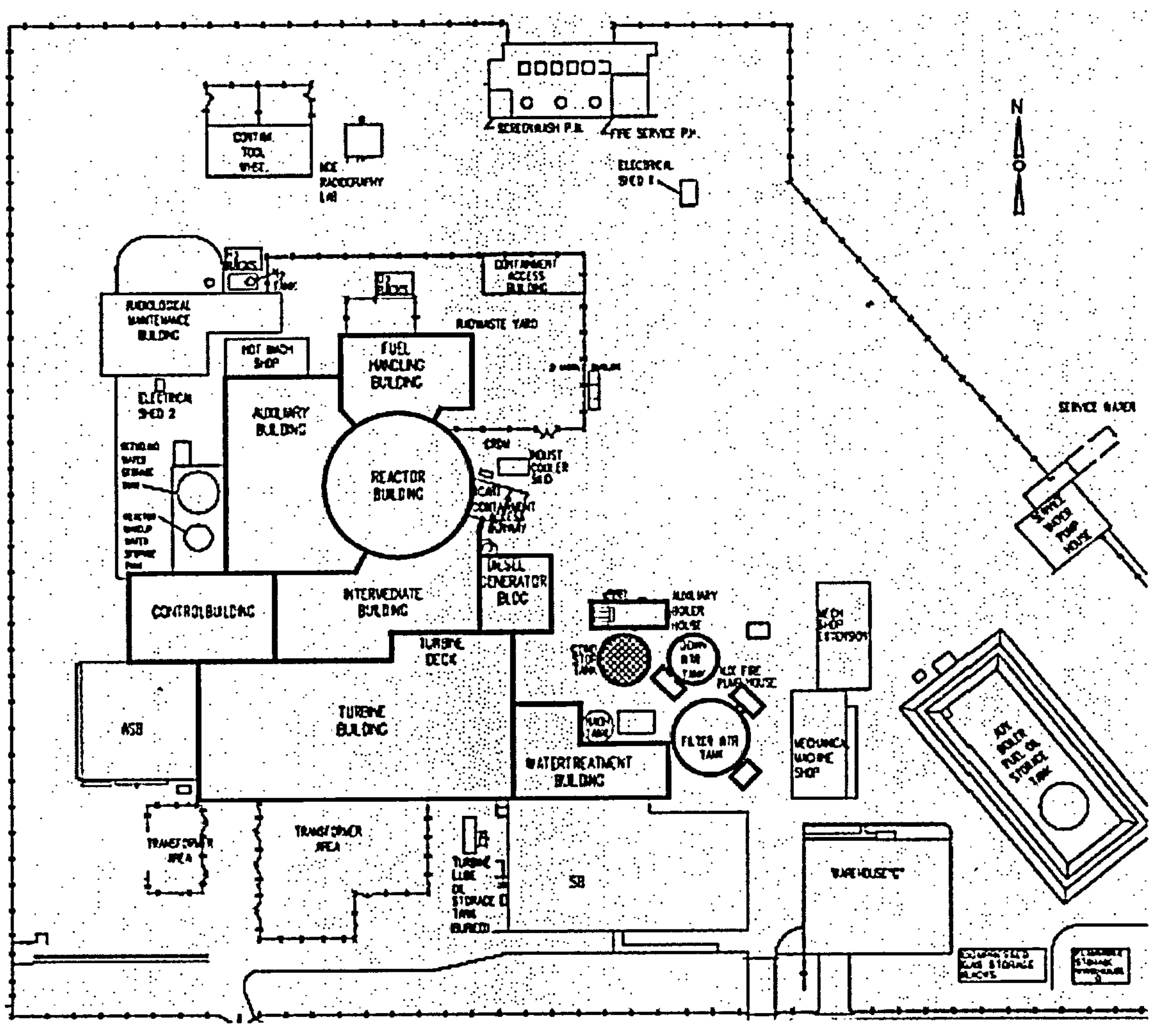
Predominant Missile Types

The plant walk downs determined that two (2) missile types accounted for greater than 50% of the total missile population at VCS:

- Scaffold Plank: 2" x 12" x 8' - Weight: 46.3 #
- Scaffold Pole: 2" Ø (OD) x 10' - Weight: 30 #

APPENDIX C

PLANT LAYOUT DRAWING



EXPECTED OPERATOR ACTIONS FOR RANDOM CONDENSATE STORAGE TANK FAILURE

Introduction:

The random catastrophic failure of the Condensate Storage Tank (CST) is an occurrence which would be easily detected by operators through multiple means. Once the failure had occurred, the Station would attempt to repair the CST so as to avoid shutdown and potential use of Emergency Feedwater (EFW) on Service Water (SW) suction supply, as this would adversely impact Steam Generator water chemistry. If shutdown were required, operators would conduct a deliberate, orderly shutdown of the plant at a controlled rate of decrease.

Indications of Decreasing Condensate Storage Tank (CST) level.

There are numerous indications and alarms available to the operator to notify him of decreasing Condensate Storage Tank (CST) level.

1. There is a CST level recorder on the Main Control Board (MCB) continuously tracking CST level.
2. There are two CST level instruments on the MCB, one in the vicinity of the Emergency Feedwater (EFW) station, and one in the area of Condensate control.
3. A walk down of the CST area is performed by the watch stander each shift, looking for any abnormalities, leakage, or potential missile hazards in the area.

Discussion

The CST level is normally maintained by automatic Demineralized Water makeup when CST level decreases to 30 feet (404,000 gallons) to fill it to 35 feet (468,500 gallons), at which time demineralized makeup stops.

It is Operations' policy to maintain all MCB alarms cleared, so if level is less than 29 feet (Lo Level Alarm), action would be taken to raise level above 29 feet as soon as possible. On review of CST level for the last 5 years, it was found that CST level has never been below 29 feet except during plant shutdowns.

If automatic Demineralized Water makeup is not available (via the Main Condenser Hotwell) SOP-208, "Condensate System," contains procedures to supply Demineralized Water directly to the CST. If the Demineralized Water Storage Tank (500,000 gallons) is not available, SOP-208 also contains instructions to fill the CST directly from the Water Treatment demineralizer. SOP-208 also contains instructions to drain and refill the CST at power, but includes a Caution to never lower level below 21 feet at power. This provides substantial margin above the Tech Spec minimum of 14.11 feet. This procedure also references a fire hose connection on the tank that could be used if needed.

EOP-6.0, "Loss of All ESF AC Power," has an Attachment which could be referenced for additional sources of makeup water if needed when power is not available (Demineralized Water, Filtered Water (1,000,000 gallons), and Fire Service Water), and also references AOP-304.3, "Loss of All BOP Busses," for restoring offsite power if it should be lost.

Annunciations and Automatic/Manual Actions

1. If CST level decreases to 29 feet, a LO/LO-LO CST LEVEL Annunciator alarms on the Main Control Board. The Annunciator Response Procedure directs verifying automatic Demineralized Water makeup. If the condenser is not available, makeup is aligned directly to the CST.

2. At 14.5 feet (202,500 gallons) the same Annunciator reflashes at the LO-LO set point. The Annunciator Response Procedure directs opening the manual bypass valve for makeup.

3. At 14.11 feet, two CST TO EFP LVL LO/LO-LO Annunciators alarm on the MCB (A & B train). **At this point, the CST is inoperable per Tech Specs.**

4. At 6.1 feet (93,500 gallons) an EFP SUCT HDR PRESS LO XFER TO SW Annunciator alarms on the MCB. The Annunciator Response Procedure directs the operator to SOP-211, "Emergency Feedwater System," to prepare for swapover to Service Water. The SOP contains a Caution to monitor for blockage while using Service Water (SW) as a source for EFW.

5. At 5.3 feet (80,500 gallons) on 2 of 4 bistables, after a five second time delay, six SW valves open, aligning SW to both MD EFPs and two trains of SW to the TD EFP. Both trains of SW Pumps get a start signal, and a BISI alarm sounds when the valves are realigned. There are also MCB switches and indication of valve position for each of the valves. **Absent a Reactor trip, EFW is not operating, so there would be no SW flow to EFW.**

6. At 2.5 feet (46,800 gallons) 3 Annunciators alarm on the MCB: MD EFP A(B) SUCT PRESS LO, and TD EFP SUCT PRESS LO. The Annunciator Response Procedure directs verification of proper Service Water supply valve realignment.

7. At 1.66 feet, the two CST TO EFP LVL LO/LO-LO Annunciators reflash on LO-LO level. The top of the EFW pipe, from the CST to the EFW Pumps, is at 1.36 feet.

Operator Actions

1. If CST level can not be maintained greater than 179,950 gallons in Modes 1, 2, or 3, Tech Specs requires that within 4 hours, the operability of the SW backup supply be demonstrated by verifying SW system pressure. If Service Water is operable, **the CST must restored to operable status within 7 days**, or be in Hot Standby within the next 6 hours and Hot Shutdown within the following 6 hours.

2. The plant would be maintained on line for the 7 days, while repairs to the CST are attempted. **Makeup can be maintained via Demineralized Water to the Condenser hotwell, while the CST is unavailable.** If progress were being made toward repair, it would not be prudent to shut down and supply the Steam Generators with Service Water during cooldown. **Since the EFW supply from the CST is at the 1.36 foot level, it is reasonable to assume that in 7 days, we could fashion a tank barrier that would maintain water level above two feet. At this point, SOP-208 could be used to supply normal Demineralized Water makeup to the CST, or an EOP-6.0 Attachment could be used to supply alternate emergency makeup from the Demineralized Water Tank, or the Filtered Water Storage Tank via the Alternate Fire Pump test header and a fire hose.**

3. The plant would delay shutdown and remain on line as long as would be possible until repairs are complete, at least to the extent that some CST level could be maintained for EFW supply. Again, it would never be prudent to supply SW to the Steam Generators if it can be avoided safely. If repairs could not be effected within the required shutdown time frame, or if there is <u>no way</u> to supply clean water to the Steam Generators:

    a. After 7 days Reactor power would be reduced to 1-3% power using Main Feedwater, per GOP-4B, "Power Operation (Mode 1 Descending)."

    b. At less than 10% power, EFW would be started using SW supply, per SOP-211, "Emergency Feedwater System."

    c. GOP-4B directs stabilizing power at 1-3%, transferring SG feed to EFW via the Motor Driven EFW Pumps, closing MFW flow control valves, and verifying control on EFW, maintaining SG level at 60-65%.

    d. Only after adequate EFW flow is verified, would Main Feedwater be secured, and plant cooldown commenced using EFW. If adequate EFW flow could not be maintained, or if evidence of flow instability or degradation were noted, flow to the SG's would be shifted back to the Main Feedwater Pump, which is still operating, and plant power would be maintained at 1-3% power until the problem with EFW is resolved.

    e. **SOP-211 contains a Caution to continuously monitor for blockage when using SW to supply EFW.**

- Assuming EFW plugging does not occur immediately when SW is used, but occurs later, the Operator would detect fluctuations in EFW flow, pump discharge pressures, and amps.
- The operator would attempt to stroke the EFW valves open, and start the TD EFP if necessary to supply more flow.
- Cooldown would be stopped to reduce flow requirements

Conclusion

The random catastrophic failure of the Condensate Storage Tank (CST) is an event which would be easily detected by operators through diverse means. Should this failure occur, the Station would attempt to repair the CST to avoid shutdown and the subsequent use of Emergency Feedwater (EFW) while on Service Water (SW) suction supply. If shutdown were required, operators would conduct an orderly shutdown of the plant. Based on Operational History, operating crews have demonstrated the ability to conduct such a shutdown without causing a reactor trip. During the shift of secondary heat sink supply from Main Feedwater to EFW, operating procedures require that successful flow be verified from EFW prior to shutdown of the Main Feedwater system. If this were not the case, the plant would be maintained stable at 1-3% power on Main Feedwater until such time as EFW flow could be restored, thereby precluding a loss of both sources of secondary feed and a potential Reactor Trip on Lo-Lo SG Level.

VC Summer Engineering Assessment of Service Water Flow Through Emergency Feedwater Flow Control Valves

Introduction

During an NRC audit conducted in November 2004, the NRC expressed concerns that if the Service Water (SW) suction source to Emergency Feed Water (EFW) were used, parts of tubercles in the SW to EFW cross-tie piping could become dislodged, flow into the EFW system, and potentially plug flow restricting passages in the EFW flow control valves. The NRC team sampled some tubercles that were on the VC Summer SW intake traveling screen. The team physically agitated these samples by rapidly shaking them in a container, to simulate turbulent flow through an EFW pump, and found that most of the tubercle pieces did not pulverize but instead broke into small solid pieces large enough to potentially plug the orifices. The team calculated that with a 100 psi operating differential pressure across a flow control valve, the differential pressure across each orifice would be about 0.2 pounds. The team found that the samples taken from SW intake traveling screens were resistant to compressive forces, so that if they became wedged into the orifices, they would likely be able to withstand much more than 0.2 pounds of compressive forces without breaking up. (NRC Inspection Report 05000395/2004009, December 22, 2004; and Enforcement Action EA-05-008 dated January 14, 2005).

In response to these concerns CER 04-3416 was initiated. The evaluations attached to that CER conclude that the EFW system could perform its safety function based on the assumptions that the tubercles were unlikely to come loose from the SW pipe wall upon initiation of flow and that any debris that did pass through the EFW pumps would be pulverized by turbulent flow in the pumps so that it would be able to pass through the flow control valves.

This position is reviewed in NRC Inspection Report 05000395/2004009 (December 22, 2004), and the NRC states that the team was concerned that the licensee's operability evaluation did not provide reasonable assurance that the system could perform its design function. This concern was based on the fact that a relatively small amount of tubercle debris (about a handful) could be sufficient to plug the six EFW flow control valves, and could result in a common mode failure of the EFW system. The licensee's evaluation did not provide quantitative or empirical data to support the assumptions that significant tubercle pieces or other material would not come loose from the SW pipe wall and be transported from SW into the EFW system. In fact, periodic flushing of the SW piping to auxiliary feed water (AFW) in another plant revealed that pieces of tubercles did come loose and were flushed out. The licensee also did not have quantitative or empirical data to support the assumption that any debris that did pass through the EFW pumps would be pulverized so that it would be able to pass through the flow control valves.

This discussion will provide an evaluation of the Service Water flow path, from the Service Water Pond, through the SW to EFW cross-connect piping, through the EFW pumps and into the flow control valves. It will provide information regarding the type of debris that could be transported to the EFW control valves and evaluate the effect that this debris could have on the flow capacity of these valves.

Debris from the SW Pond

The VC Summer Service Water Pond is virtually free of debris. VC Summer treats the Service Water Pond with Spectrus Clam-Trol 1300 (1000 ppb) which is a biocide that is added seasonally to control mollusks, bacteria, fungus and algae. There has been no evidence of plant debris, fish or mussel shells in Service Water piping, valve or heat exchangers since this chemical treatment began in the early 1990's.

Plant growth is controlled on the Service Water Pond dams and there is limited plant growth on the natural abutments between the dams. The abutments have generally stabilized so that only a minimal amount of plant debris could be transported into the Service Water Pond. If there were floating debris in the pond it would not be drawn into the Service Water system because the intake structure is approximately 40 feet below the surface of the pond, and the maximum velocity of water through the intake is 0.75 feet per second. This velocity is not great enough to draw floating debris from the surface; nor is it great enough to transport any metallic debris or rocks. These denser items would settle to the bottom of the pond before they entered the intake. Finally, the Service Water Intake Structure incorporates a bar screen and a traveling screen with a ¼ inch grid upstream of the Service Water Pumps. Any sizable debris that might approach the intake structure would be stopped by one of these screens.

The VC Summer Service Water system is free from appreciable amounts of sand or silt. Particle size analyses have recently been performed by GE Betz on SW Pond samples and the average size particle is approximately 15 micrometers (0.0006 inches). The Service Water Pond is treated with HPS-1 (Dianodic at 15 ppm) which is a dispersant intended to prevent settling of these very fine particles inside the service water system. Full strength of this chemical (approximately 15 ppm) was achieved in the fall of 2002. No appreciable accumulations of sand or silt have ever been observed during inspections inside Service Water piping and heat exchangers.

In addition to the biocide and dispersant discussed above, the chemical treatment of the VC Summer Service Water Pond includes a corrosion inhibitor as well as an agent that loosens tubercles and wears away the existing corrosion layer. Alkyl Epoxy Carboxylate (Depositrol at 10 ppm) is added as a corrosion inhibitor. Tetrapotassium Pyrophosphate (Flogard initially at 1 to 2 ppm and continued until the reverted pyro to orthophosphate reached 25 ppm) is an iron sequestering agent that loosens tubercles and wears away the existing corrosion layer. It also acts as a corrosion inhibitor as it changes from a pyrophosphate to an orthophosphate. The concentration of Flogard is measured in ppm and coupled with a short effective life, would have a negligible effect on stagnant sections of piping such as the SW to EFW cross-connect. For the Flograd to be effective at such a low concentration, the system must constantly be dosed with a fresh supply of the chemical while in its pyrophosphate from. Therefore, there should be very little or no loosening of tubercles in the SW to EFW cross-connect due to this chemical. The target concentration of Flogard in the Service Water Pond was reached in September, 2003. Flograd has not been added since that time and there are no plans to resume adding it in the future. This decision is based on the fact that the total phosphate concentration of 25 ppm has been reached, and will not decay.

Conclusion

Due to the construction and chemical treatment of the Service Water Pond it is highly unlikely that water from pond will contain any debris that could plug the EFW flow control valves.

Debris From 8" SW Cross-Connect to EFW

Service Water is provided to the suction of each EFW pump through one of two (A train or B train) normally stagnate portions of 8-inch, carbon steel piping approximately 20-feet long. Each of these cross connects contain approximately 10 feet of vertical piping (flow to the EFW pumps in the upward direction). Recent inspections have shown that this piping contains a nominal ¼ to ½ inch thick tubercle corrosion growth layer (see Attachment 1), with diameters generally between ½ and ¾ inches.

Although the exact composition of these tubercles is not known conclusively, industry literature describes tubercles as having a fragile, hematite outer crust; a brittle magnetite inner shell surrounding fragile core material (see Attachment 2). Discussions with personnel at other nuclear facilities whom have experience with tubercles reveal that the characteristics of tubercles change they are dried, with dry tubercles becoming very hard.

Inspection data for this section of Service Water pipe taken between RF-4 through RF-12 (see Attachment 3) consistently document that the tip of the probe would break the tubercles releasing a fine silty material. This indicates that the nature of the tubercles is as described above. It also indicates that the samples taken from the SW screen during the November, 2004 NRC audit are not representative of the tubercles in the SW piping (either because they were rust fragments, or because the tubercles had dried). Therefore, these samples should not be used in forming an opinion regarding the ability of the EFW pumps to reduce the size of tubercles.

Several sources document that tubercles are bound tightly to the pipe wall.

- An EPRI sponsored Service Water Assistance Program (SWAP) survey document (SWAP Survey 90-355, Heat Exchanger plugging Following A Seismic Event Results Summary, 10/02/1990) provided documentation that earthquake forces in the range of 0.4 - 0.6 g's (peak ground acceleration) did not dislodge corrosion products and cause plugging of strainers, valves or heat exchangers.

- Discussions with a GE Betz metallurgist who has studied and worked in the field of tubercle growth for 20 years revealed that the type tubercle growth (80% iron oxide) observed in the SW system is considered to be very tenacious and stable in that it is not easily dislodged.

- NALCO (a company that chemically cleans corrosion found in piping systems) typically treats the corrosion product with an acid treatment to soften the product. Subsequently the piping is subjected to flow conditions on the order of

12 to 15 feet per second in an effort to remove the corrosion layer from the pipe wall over an extended time period. This flush is performed in both the forward and reverse directions. It is notable that with this process, the flow rate required to dislodge the chemically treated corrosion material is at least double the rate that would be experienced in the SW to EF lines.

V.C. Summer experience with cleaning Service Water piping has demonstrated that the tubercles on the Service Water pipe walls are not easily dislodged. A typical tubercle is a small mound with a thickness of approximately 0.25 to 0.5 inches. The hydrodynamic force on a one square inch flat plate perpendicular to the expected mean flow was conservatively calculated based on 900 gpm inside the eight inch SW to EFW cross-connect pipe. It was determined that this force is 0.25 pounds, and the force would be lower by around two orders of magnitude if the plate is oriented parallel to the flow (more closely approximating the orientation and geometry of a tubercle). It is unlikely that tubercles would be removed from the pipe wall due to the flow.

Conclusions

1. The samples taken from the Service Water Screens during the November, 2004 NRC audit are not representative of the tubercles found in the SW supply to the EFW. These samples were much harder than would be expected for a typical tubercle.
2. Tubercle fragments consist of fragile and brittle shells, and some silty material.
3. Tubercles adhere tenaciously to the pipe wall; very few tubercles would be expected to be removed by normal EFW flow rates which would impose a force much less than 0.25 pounds on a large tubercle with a one square inch surface area.

Transport of Debris Through the SW System

Balancing the upward drag force exerted on a loose particle in the vertical section of 8" SW cross-over pipe against the downward force of gravity indicates that particles with dimensions less than ¾" will be carried upward to the EFW pumps.

Reaction of Debris to the Forces Inside an EFW Pump

As particles travel through the EFW pumps they will be acted upon by several forces that could reduce the size of soft or brittle particles. These forces include those associated with the extremely turbulent flow through the pump, as well as impact forces with the rotating impeller vanes as well as impact with the pump casing (most notable at the outlet of the impeller). Pressure variations through the pump would also impose compressive forces that could reduce the size of particles that contain voids or gases.

Southwest Research Institute performed a test to determine the potential for EFW orifice blockage from debris in their Service Water system. The test demonstrated the ability of pumps to break down and homogenize large, hard debris. To simulate the effects of the pumps on mussel shells, silt, and sand, a mix of this debris was cycled through a single stage pump in a test loop. The pump ground this material into a fine, uniform slurry with no fragments bigger than large sand particles. Southwest Research Institute classified sand as particles with diameters in the range of 0.35 mm to 0.7 mm (0.014 to 0.028 inches). Anything with a smaller diameter was categorized as silt.

The tubercles observed inside the SW to EFW cross-connect pipe are generally ¼ to ½ inch thick, with diameters generally between ½ and ¾ inches. Based on tubercle composition and geometry describe in industry literature (see Attachment 2) it appears that a large tubercle would consist of a friable (easily pulverized) outer hematite crust less than 3/16 inch thick, a brittle magnetite inner shell no more than 1/16" thick, and a friable ferrous hydroxide core no more than ¼ inch thick. If a typical Emergency Feedwater Pump will reduce a hard mussel shell to less than 0.028 inch in diameter, it may be reasonable to conclude that any large tubercles entering the pump would be reduced to a size that would allow passage though the flow control valves.

Conclusions

The seven and nine stage EFW pumps are capable of breaking down tubercles into small particles, most of which will pass through the EFW flow control valve cages without plugging the cages or otherwise reducing the flow capacity of the valves.

Reaction of Debris Inside the Flow Control Valve

Flow streams inside the flow control valve, around the cage will be highly turbulent. Flow behind the cage will be characterized by strong eddies and oscillating currents. If any soft or fragile particles were to enter the valves, they would be broken down due to impacts with each other, the valve body and the valve cage. Other particles that may eventually become trapped in a hole in the valve cage would be further eroded by the high velocity flow (> 60 fps) through the hole.

The differential pressure across a completely plugged orifice in the EFW flow control valve was calculated based on two motor driven pumps supplying 400 gpm to three steam generators at 1,000 psig, while the EFW pump suction pressure is 50 psig based on SW supply pressure. The "normal" 900 gpm total EFW flow is not considered because it is postulated that there is some valve plugging. Therefore the minimum design basis flow of 400 gpm to three steam generators is used to represent total flow with plugged valves. Under these conditions the differential pressure across each valve is 400 psi. This pressure applied to the larger (counter-bored) area of an orifice at the surface of the cage (0.115 inch diameter) is 4.2 pounds. This is considerably higher than the 0.2 pound force calculated based on a normal operational differential pressure of 100 psi, and an area across the 0.049" diameter hole inside the valve cage.

The Cv of the EFW flow control valves are 26.6 for the valves associated with the turbine driven pump, and 27 for the valves associated with the motor driven pumps. The required Cv to pass design basis flows is reduced when EFW is being supplied by SW, due to the higher EFW pump suction pressure provided by the TDH of the SW pumps. The verified / benchmarked EFW flow model (calculation DC05220-076) was used to determine the minimum Cv required to provide design basis function with SW providing flow to the EFW pumps. With two motor driven pumps a Cv of 6 is required to supply 400 gpm to three steam generators; and a Cv of 8.5 is required to provide 380 gpm to two steam generators. Lower Cv values would be required if one motor driven and one turbine driven pump were available. The minimum required Cv of 8.5 will be available if at least 32% of the valve flow area is available (68% of the valve could be plugged).

Conclusions

1. The force on a fragment completely blocking a single orifice in the EFW valve would be approximately 4 pounds, assuming that the valve is plugged to the point of passing minimum design basis flow.
2. If debris fragments were to reach the EFW flow control valves they would be broken down by violent flow patterns around and through the cage, and by the high velocity through the cage.
3. The EFW flow control valves can maintain design basis functionality with up to 68% of the flow area plugged.

Summary Conclusions

The following conclusions are supported by the discussions presented above.

1. Water from the Service Water Pond will not contain any debris that could plug the EFW flow control valves.

2. The samples taken from the Service Water Screens during the November, 2004 NRC audit were much harder than the tubercles found in the SW supply to the EFW.

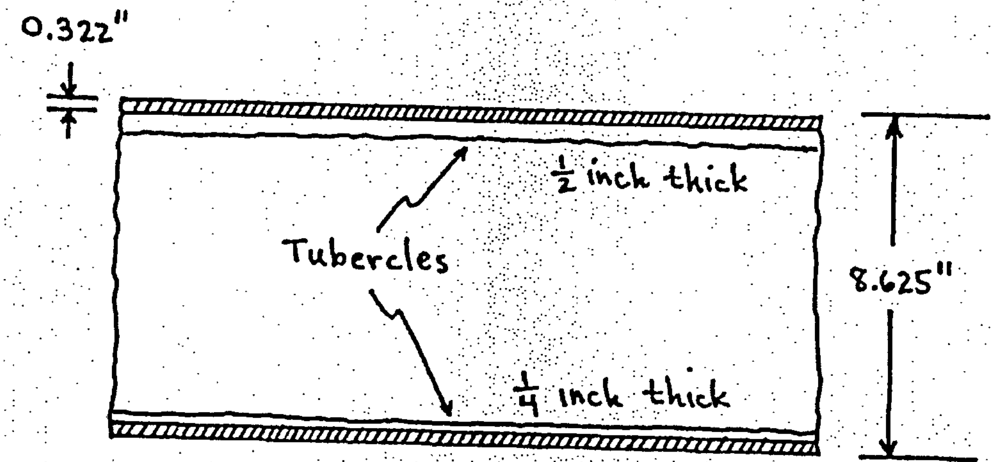
3. Tubercles adhere tenaciously to the pipe wall; very few tubercles would be expected to be removed by normal EFW flow rates.

4. Tubercle fragments consist of fragile and brittle shells, and some silty material. The EFW pumps are expected to be capable of reducing this type of material to small particles, most of which will pass through the EFW flow control valves, without significant reduction in their flow capacity.

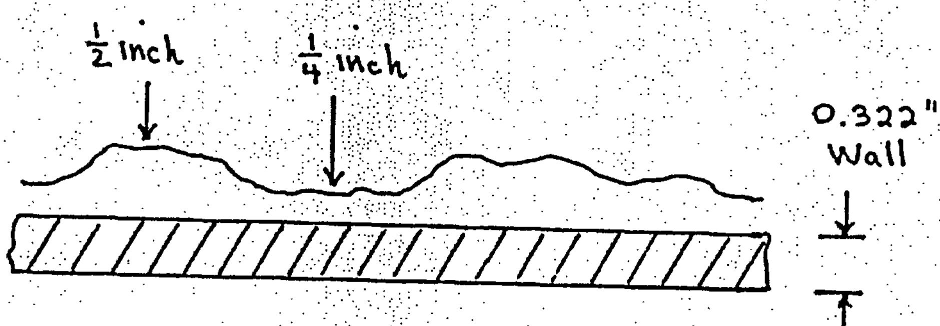
5. The EFW flow control valves can maintain design basis functionality with up to 68% of the flow area plugged.

Attachment 1

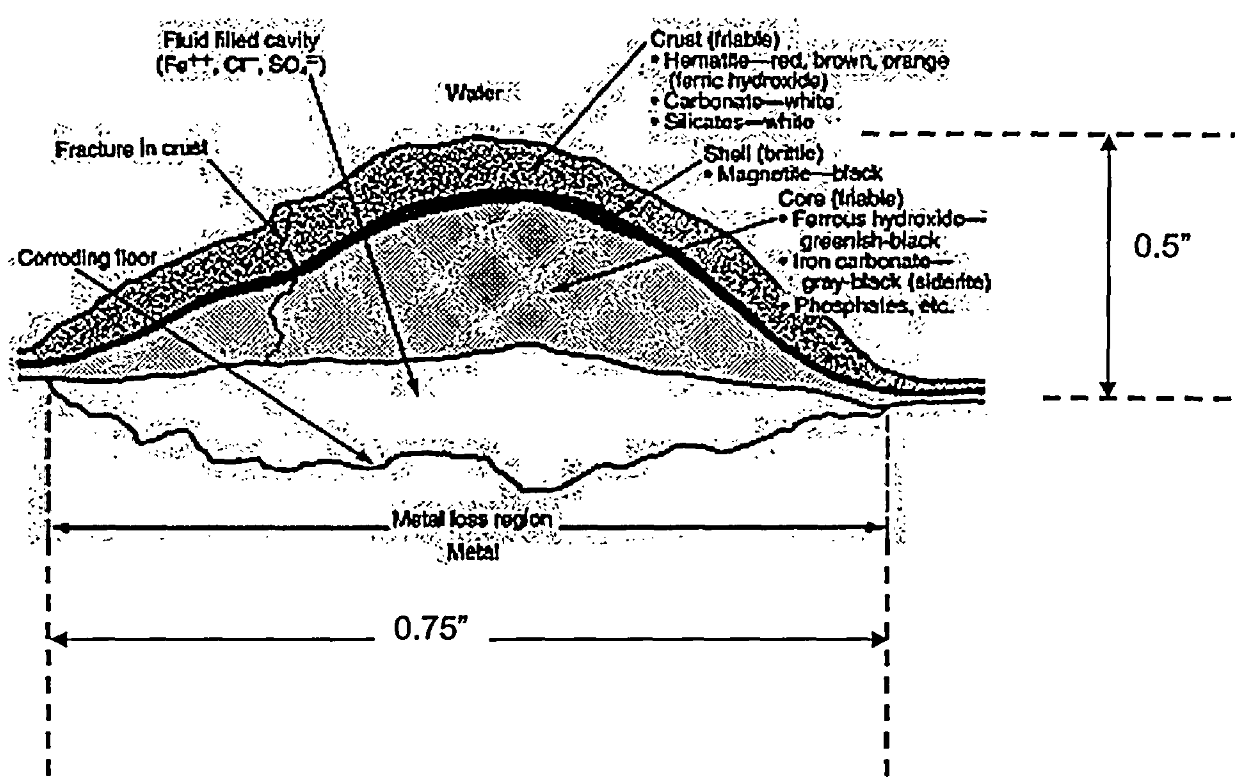
Scale Sketch of Tubercle Layer inside SW to EFW Cross-Connect Pipe



Scale Drawing of 8 inch Schedule 40 Pipe with ½ inch thick tubercles on top of pipe and ¼ inch thick tubercles on bottom of pipe.



Attachment 2
Composition and Geometry of a Typical Tubercle
Showing Dimensions of Large Tubercles Observed at VC Summer



Attachment 3
Summary of Internal Piping Examinations

Date	Activity Descriptions
11/88	MWR 88X0006: This work order was to perform inspection of the Train A piping. During Refuel-4, an inspection of the Service Water piping upstream of XVG01037A was done. A fiber optics scope showed a ¼ to ½ inch thick layer of corrosion on the piping wall. This corrosion was easily broken off the pipe wall with the tip of the scope, and the material dispersed as fine silt. On 10/22/88, the pipe was hydrolazed, and the material removed by the process was fine and silty, with no particles larger than 1/16 inch. Similar actions were taken upstream of XVG01037B with similar results. NCN 3116 and NCN 3128 concluded that no debris was found that could render the Emergency Feedwater flow control valves inoperable.
11/88	MWR 88X0005: Performed in Refuel-4. During inspection of SW piping upstream of XVG01037B with a fiberscope, deposits of potential MIC/corrosion were observed. On 11/1/88, hydrolazing of the SW piping upstream of XVG01037B was performed. A quantity of black/brown fine silty material was removed by the process. The effluent was monitored as it spilled out of the valve body onto the IB floor for any large and / or hard debris, i.e., corrosion products, clam shells, etc. At no time were any large pieces of metallic or other debris observed. Part 21 Evaluation: While corrosion was observed, it was expected in a carbon steel pipe containing stagnant raw water. The above inspection identified no debris in our judgment which would have rendered the EFW system / flow control valves inoperable.
10/91	MWR 91T0116: Performed during Refuel-6. (Pipe filled with water) Approximately 13 ft of the Train A piping was inspected using and Olympus video probe. The water on the SW side was clouded with fine silt-like material. The pipe contained some irregular deposits which appeared to be approx 1/16 – 1/8 inch in size. These deposits were easily removed from the pipe wall by the tip of the video probe. As they were removed, the broke up into smaller pieces and floated around further clouding the water. None of these pieces appeared to have structure and they disintegrated as they floated away. No clams or other large debris were seen throughout the inspection. The Emergency Feedwater side was relatively smooth with a film of black oxide. There were no visible corrosion products present. Conclusion: Although the piping had some corrosion products present, their consistency and size were not considered to be a concern for the Emergency Feedwater flow control valve. The piping is acceptable and requires no further action during this outage.
3/27/93	MWR 92T0338: Performed during Refuel-7. The internal surfaces of the piping were coated with a layer of nodules approx. 3/8 – ½ inches in diameter. The deposits were soft and broke into pieces when the video probe hit them. No clam shells or other hard matter was observed. It looked much like it did during the previous inspection during RF-6 (MWR 91T0116). The pipe was hydro-cleaned and pitting was observed under the deposits. The pipe surface was cleaned to bare metal in locations with

	some mill scale still remaining. The pitting was evident but the video probe distorts the view such that depths are not possible to determine. The material removed was soft and silty. No hard objects such as pieces of metal or clam shells were observed. The post cleaning inspection revealed that all deposits had been removed except for some tightly adhering scale in a few places. Decided not to pursue these locations because they were not likely to become dislodged under flow conditions.
10/16/00	PMTS 9914656: Performed during Refuel-12. Nodules in the Train A pipe were approximately ½ inch in diameter and projected into the pipe approximately ½ - ¾ inch. The nodules were soft and broke off easily. They had the same color and texture as reddish / orange clay. No pitting was felt under the nodules. There was approximately ¼" to ½" depth of silt at the seat, extending upstream approximately 1 ft. (Task did not indicate a boroscopic inspection.)
10/29/00	PMTS 9914659: Performed during Refuel-12. Train B visual examination only. Boroscope light source could not be located. The piping downstream of XVG01037B was black in color due to the tightly adhering corrosion layer. The nodules were very small, about 1/16" in diameter. The piping upstream of XVG01037B had a different look than the tightly adhering black corrosion layer of the valve body. Instead, there were large tubercles that appeared to be composed of clay. The nodules were very soft and so large that there were only 2 to 3 nodules per square inch. Some of the nodules were 1.5" long, ½" tall and ½" wide.
10/21/03	MWR # 0311547: The pipe was completely coated with nodules; however, the nodules were likely no larger than 1 inch in diameter; thus, the pipe was not occluded. The 10 ft vertical section of piping was cleaned. Samples of debris were taken.

Probabilistic Risk Assessment Review of the V.C. Summer Emergency Feedwater (EFW), Service Water (SW) NRC Significance Determination Process

Introduction

During the discussion of the VC Summer Emergency Feedwater (EFW) / Service Water NRC Significant Determination Process, several points of contention were developed. These points of contention were the use of an F2 tornado to cause sufficient damage to the Condensate Storage Tank (CST) to cause loss of function and the less than credible scenario of random tank failure to dominate the potentially "WHITE" finding associated with this issue.

VC Summer had utilized an F4 tornado, as well as a sensitivity study to an F3 tornado, to evaluate that the tornado scenario was considered non risk significant. The random CST failure was initially evaluated similarly to the NRC's evaluation to obtain an overall safety assessment of the issue, although VCS did not assume 100% probability of reactor trip during the random tank failure scenario. The VCS PRA evaluation's purpose stated that "If the results of this evaluation are needed for some other process, PRA may choose to revisit these conservative assumptions." The conservative estimates that the NRC made concerning these two scenarios are being revisited due to the fact that these two NRC developed scenarios conclude in >1E-06 results to determine the significance of the SW/EFW issue. They are:

1) A tornado event with a core damage frequency (CDF) of 1.4E-06/yr was evaluated to show that the CST will not fail in a tornado and that the F2 tornado will not cause loss of function of the CST.

2) Random failure of the Condensate Storage Tank (CST) and the random failure of piping segments from the CST to EFW with a CDF of 5.5E-06 was evaluated to remove conservatism to the 100% reactor trip assumption by evaluating credit for time allowed in Technical Specifications to repair the tank or align an alternate source of condensate or filtered water to EFW, evaluate flow requirements to determine the percentage blockage allowed to meet flow requirements and provide better estimates in the random failure probabilities of the tank and piping.

The VC Summer perspectives on the NRC's conservative assumptions used to arrive at the issue significance are as follows:

Tornado Event with a CDF of 1.4E-06/yr

NRC Assumptions

The CST was not designed to withstand the effects of a tornado and will always fail due to a tornado.

The F2 tornado with a median frequency of 6E-05/yr causes a loss of function of the CST.

VCS Comment

The CST Tornado Loss of Function Evaluation by VC Summer was performed to consider: 1) Deterministically if loss of function to the CST could occur from F2 Tornado wind loads or missiles, and 2) Probabilistically if the risk of loss of function of the CST (when considering all tornado events) is considered acceptable. The results of the evaluation are as follows:

The CST tank shell is designed to withstand earthquake stress loads (19.6 to 41.1 psi) which are significantly greater than the stress loads capable of being produced on the tank shell by maximum wind load (0.44 psi) and pressure differential (0.52 psi) from an F2 Tornado, regardless of how these loads are combined. Additionally, the tank shell plate thickness (below the safety level limit of 14.1') and the EFW suction pipe wall thickness are significantly greater than that which can potentially be perforated by missiles generated by an F2 tornado. **Therefore, there would be no loss of function of the CST nor loss of inventory given an F2 Tornado wind loading and potential missiles.**

Also, the overall conclusion of loss of function of the CST when considering the risk from tornado missile impact and perforation for all F Scale tornados is shown to be 4.5E-08. **Therefore, potential loss of function of the CST from tornado missiles is not considered to be risk significant.**

Random Failure of the CST and Piping Segments from the CST to EFW with a CDF of 5.5E-06/yr

NRC Assumption

Failure of the CST as the suction source for Emergency Feedwater System will cause a reactor trip during the ensuing plant shutdown.

VCS Comment

Refer to the details discussed in Expected Operator Actions For Condensate Storage Tank Rupture. No plant transients including loss of offsite power are initiated as a result of random failure of the CST and associated piping as a suction source so this failure will not initially cause a reactor trip. Also, plant technical specifications allow operation for up to 7 days prior to shutdown following a CST failure because Service Water operability requirement of system pressure would be met. Seven days allows sufficient time to repair the CST and/or align a source of condensate or filtered makeup to the Emergency Feedwater system. A plan to utilize a condensate or filtered makeup source would be the preferred method to shutdown without using Service Water because supplying Service Water to the Steam Generators would be undesirable due to chemistry considerations for the Steam Generators. This shutdown will be well planned and proceduralized and the crew will be briefed concerning the special circumstances.

Based on the above controlled shutdown scenario, WCAP-14334-NP 'Probabilistic Risk Analysis of The RPS and ESFAS Test Times and Completion Times', was used as a reference for a probability of reactor trip during a controlled shutdown as 0.068 based on 10 reactor trip events during 148 controlled shutdowns (approximately 1 in 15). This factor has not been considered in the NRC assumptions.

The discussion above provides justification that VC Summer Station would not necessarily shut the plant down in the event of a CST failure. Additionally, if a controlled shutdown were commenced, it is not a given that the result would be a reactor trip. If the probability of reactor trip during shutdown (as assumed by the NRC for CST failures) is changed to 1 out of 10 to account for these potential results in CST failure scenarios, the resultant CDF is 5.5E-06 x 1.0E-01 = 5.5E-07/yr. This factor alone would make the issue non risk significant.

NRC Assumption

Upon transfer of the Emergency Feedwater System (EFW) suction to the Service Water (SWS) the tubercles will plug the FCVs stopping sufficient flow to any Steam Generator.

VCS Comment

The design basis flow for the EFW system is 380-400 gpm. The EFW system is capable of producing approximately 1360 gpm. **VCS Design Engineering concluded that the EFW FCVs could be 68% plugged and still meet design basis flow requirements.** Though not considered in the CST failure evaluation above this would provide additional margin to the NRC assumption concerning reactor trip during the ensuing shutdown.

NRC Assumption

The CST tank failure rate is set at 8.76E-04/yr based on INEEL telecon of data base search for equipment failure.

VCS Comment

The hourly tank failure rate of 1.0E-07/hour for tanks leaking catastrophically is consistent with an annual failure rate of 8.76E-04/yr. This is found in the Reliability Database for Passive ALWR (Advanced Light Water Reactors) PRAs. The sources referenced in this database include Seabrook as 2.7E-8/hr, NPRD-3 as 9.4E-07/hr and TMI-1 with 0 failures in 689,000 hours. The footnote associated with this value in the ALWR data base states that "The sources of data for tanks is quite limited, and does not support assessment for tanks of different designs. The data in NPRD-3 is for tanks of widely-varying designs, and is not nuclear power plant experience. Greater weight is therefore given to the two other sources of data. The value chosen seems reasonable given these limitations." **The failure rate that this number replaced was 8E-10/hour from WASH 1400.**

Seabrook uses a value of 2.66E-08/hr based on the study referenced above. This would better estimate number to use for the evaluation. This number also contains a great deal of uncertainty. Actual storage tanks don't randomly rupture, but fail as a result of conditions like a vent being blocked. This type event generally would not be expected to happen for a CST at steady state power. Applying a similar logic to the tank that the NRC used for piping failures, evaluation of design and construction defects and corrosion would appear to be the major methods of random failure. Design and construction defect failures generally appear during startup before commercial operation, as discussed below, and would be minimal due to the fact that the VCS CST has not had any failure due to a design or construction deficiency for over 20 years of commercial service. Also concerning corrosion failures, the VCS CST shell plate thickness was validated in the Tornado Study that is attached. The interior of the tank is lined with Plasite polymer coating with water chemistry to inhibit internal corrosion. The aging effect was reviewed as part of the VCS License Renewal Project (2004). For unprotected carbon steel, the maximum corrosion rate was evaluated for a 60 year plant life and concluded that under the worst conditions, the tank shell would maintain minimum wall thickness. Since the CST also has a protective coating on the outside, corrosion is considered negligible to date.

VCS requested that Westinghouse perform an independent survey of CST failures following commercial operation. The following sources were reviewed: NPRDS Prior to 1997, EPIX from 1997 to present, LERs from 1984 to Present. Only one CST failure was found in the 1984 to present data (LER 87-075 at Nine Mile Point). This is also the only LER found by NRC in their research.

Some unique characteristics of the Nine Mile Point CST failure are that the tank failed during the period between initial criticality and commercial operation, the tank was constructed of reinforced fiberglass and the failure was due to a construction deficiency in the tank. By contrast, VCS uses a carbon steel CST which has not had any failure due to a construction deficiency, and has not failed for over 20 years of commercial service. **Therefore, the Nine Mile Point data is not applicable to VCS.**

The research concerning CST failure rates can be summarized as follows:
- The Nine Mile Point CST failure, which is not applicable to VCS, was the only failure close to commercial operation for BWRs and PWRs in 18,893,154 calendar hours.
- There have not been any documented failures of Condensate Storage tanks in 12,560,984 calendar hours of PWR operations from 1984.

Utilizing the Seabrook value of 2.66E-08/hr x 8760 hours/yr yields an annual failure rate of 2.33E-04/yr. The Seabrook Study appears to be the most applicable value to be used to evaluate the issue.

NRC Assumption

Failure consideration of the critical piping segment from the CST to EFW is based on Table A-33 from "Piping System Failure Rates and Rupture Frequencies for Use in the Risk Informed In-service Inspection Applications" (EPRI-TR 111880). The per ft or per weld failure probabilities are based on the following:

COR = 8.47E-08 failure/yr/ft *90ft = 7.6E-06 failures/yr
D&C= 6.89E-07 failure/yr/weld *10 welds = 6.89E-06 failures/yr

Total = 6.89E-06 + 7.6E-06 = 1.45E-05 failures/year

VCS Comment

The NRC's COR and D&C numbers from Table A-33 of EPRI TR-111880 are for "Failure". Piping "failure" is not necessarily a catastrophic failure and exhibits "leak before break" characteristics and therefore could be considered recoverable. When applying these numbers to loss of CST function due to pipe failure, it is more appropriate to use the failure mechanism "Rupture" which is listed below "Failure" on Table A-33. If "Rupture" values are used instead of the "Failure" values selected by NRC, the loss of function probability due to pipe failure becomes:

COR = 3.03E-09 failure/yr/ft *90 ft = 2.73E-07 failures/yr
D&C= 1.34E-07 failure/yr/weld* 10 welds = 1.34E-06 failures/yr

The resulting failure rate is 1.61E-06 failures/yr which is approximately an order of magnitude less than that used by NRC.

Summary Results of The Random Failure of the CST and Piping Segments from the CST to EFW Evaluation

The VC Summer evaluation of the CST and piping failure results are as follows:

- The probability of reactor trip during shutdown is typically 1 out of 15. If this value is changed to 1 out of 10 (to account for the fact that a shutdown may not be required, but, if one were needed, the shutdown would be conducted in a controlled manner), the resultant CCDP (using the NRC's value of 6.2E-03) is obtained by multiplying 6.2E-03 by 1.0E-01 to result in a value of 6.2E-04.

- The annual tank failure rate is 2.33E-04/yr.

- The pipe failure frequency is 1.61E-06/yr.

- The failure rate for the tank and piping combined would be 2.35E-04/yr.

- Recalculating the CDF for random CST and piping failure based on these assumptions gives the following CDF:

  (2.35E-04/yr * 6.2E-04) =**1.45E-07/yr**

Conclusions

1) The VC Summer CST Tornado Damage Evaluation shows the risk for loss of CST function from tornados is 2 orders of magnitude less than that shown by the NRC evaluation. **Therefore, a tornado event is not considered to be risk significant.**

2) The VC Summer evaluation of the CST and piping failure results (including credit for avoiding plant transients) concludes that the resultant CDF is **1.45E-07/yr.**

3) The conclusions above do not take credit for the fact that the VCS EFW System can meet its Design Basis flows if the Flow Control Valves are less than 68% plugged.

Based on these conclusions, the Significance Determination Process results for the scenarios above should be green.

**Design History of VC Summer
Emergency Feedwater Flow Control Valves**

The design control program used for the original design of the V. C. Summer Station Emergency Feedwater System was adequate when the knowledge basis supporting the original design is considered. This knowledge basis is noted in the following.

Background

Westinghouse supplied a Steam System Design Manual for the purpose of providing secondary plant criteria as required by the Nuclear Steam Supply System. The manual states that a reliable source of water for the auxiliary Feedwater pumps must be assured at all times. The manual further states that usually water is supplied from the condensate storage tanks but may be supplied from other sources such as Service Water, well water, fire main water, city water, etc. Since Service Water was the only safety class system available to provide a secondary source of water this was the system selected during original design. There is no city water supply at the site and the fire system uses essentially the same water source as the Service Water System.

Process Fluid

The procurement Specification (SP-620) notes cold condensate as the fluid under service conditions for the Emergency Feedwater Control valves and does not list Service Water. The listing of the fluid that will be in contact with the valve body and trim for all or almost all of its service life is consistent with paragraph 2:07.2 of the specification which required the bidder to select the body and trim materials most compatible with the process conditions. Listing of a second fluid (Service Water) for the fluid could result in the bidder selecting less suitable or unsuitable body and trim materials. The listing of a single fluid on the specification data sheets was a prudent and proper data entry by the design engineer, during the procurement process, to assure that the materials were suitable for the valve function.

While the Service Water was not expected to equal the purity of condensate (water formed by condensing steam) it was expected to be clean water. This has been confirmed in discussions with the Engineer who was originally responsible for vendor coordination following the purchase on the valves. This design approach is further evidenced by the lack of a strainer on the service water pump discharge. The Service Water System for a SCE&G fossil plant designed immediately before Summer Station, which takes Service Water from a river and was expected to contain debris, was designed with automatic strainers on the Service Water Pump discharge. The same design would have been used for V. C. Summer Station if dirty water were expected. The use of a man made lake for the service water supply was expected to provide operating conditions that would provide relatively clean water with any silt or other debris settling out in the lake. SCE&G had prior satisfactory operating experience with fossil units that used a man made lake for the service water supply and this operating experience was part of the basis for expecting clean service water at V. C. Summer Station.

Other Foreign Materials

V.C. Summer Station was designed before problems with Asiatic Clams or Zebra Mussels had been identified or recognized in cooling water sources, therefore no problems relating to Mollusks in the service water supply were considered in the original design. Problems due to Mollusks in water systems were not reported during the design phase but began to be reported after plant operation began.

At the time of the original design (Early 1970's) Corrosion problems in cooling water systems had been primarily experienced where salt water was used for cooling, where dissimilar metals were used, and in special cases such as the presence of acid drainage from coal mines in the stream supplying cooling water. The biologically induced corrosion mechanism experienced in operating plants starting in the 1980s was essentially unknown in plants in operation when Summer Station was being designed. The lack of biological corrosion in operating plants was probably a result of the treatment of the cooling water systems with a biocide such as chlorine at that time. Because biologically induced corrosion had not been identified as a problem in operating plants, the design process did not consider any design considerations related to it.

Conclusion

Valve specification, selection and procurement was prepared in accordance with prudent and generally accepted design practices based on the known conditions of the process fluid, including SCE&G operating experience. Therefore, the subject design has been developed in accordance with and consistent with 10CFR50 Appendix B, "Design Control.