BVY 05-024
Docket No. 50-271

Exhibit 2

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 24

Extended Power Uprate

Response to RAI SPSB-C-35

VYC-1924, Rev. 0

Total number of pages in Exhibit 2 (excluding this cover sheet) is 89

QA RECORD?

XX YES

______ NO

RECORD TYPE NO. 09.C16.003

Safety Class/P.O. NO. (if applicable): SC2/ PO# 97-58141-00

YANKEE NUCLEAR SERVICES DIVISION
CALCULATION/ANALYSIS FOR

TITLE DE&S Calc. DC-A34600-006,"Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment.RHR and CS Debris Head Loss Calculations".

PLANT VERMONT YANKEE CYCLE NA

CALCULATION NUMBER VYC-1924

	PREPARED BY /DATE	REVIEWED BY /DATE	APPROVED BY /DATE	SUPERSEDES CALC./REV. NO.
ORIGINAL	DUKE (DE&S)	N/A	S.D. GOODWIN S.D. Goodwin 11/5/99	NA

KEYWORDS : ECCS, Suction, Strainer, Head, Loss, Performance,Debris,RHR,CS,Calculation

COMPUTER CODES: NONE (SEE DE&S CALC COVER SHEET)

EQUIP / TAG NOs.: ST-X-224A, ST-X-224B, ST-X226A, ST-X-226B

SYSTEMS: CORE SPRAY, RHR, PRIMARY CONTAINMENT

REFERENCES: See Page ii

Form WE-103-1
Revision 4

Calculation/Analysis Review - DE&S Calc:DC-A34600-06

Calc No. VYC-1924 Revision No. 0

The following calculation (or Technical report) was done by a Vendor as part of a Contract to Vermont Yankee. All work on this document was done under the Vendors approved QA program. The purpose of using this VY calculation number and cover sheet is for entering the document into the VY Information Management System. Reviews, Approvals, and Software control are handled under the Vendor's QA program.

Company's Name: DE&S
VY Contract Number: VY-1097-08

Summary of Pages In this Calculation	No. of Pages
VY Calculation Cover Page	2
DE&S Calculation	50*
DE&S Calculation Attachment	
A	29
B	8
* Includes Page 1A	
Total Pages	89

REFERENCES*: EDCR 97-423, VYS-049rev2,

*For a complete list of references see DE&S Calculation Section 7.0

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CALCULATION COVER SHEET

FORM DPR-3.2A
PAGE 1 OF 1
REVISION 2

CALCULATION NUMBER:	DC-A34600.006	REV: 1
CALCULATION TITLE:	Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.	
PROJECT NAME:	ECCS Suction Strainer Replacement	
WID NUMBER / PROJECT NUMBER:	A346	CLIENT: Vermont Yankee Nuclear Power Corporation

SOFTWARE USAGE

(Retain usage from prior revisions, if still applicable)

* Pre-Use Verification	Software Name	Version	Hardware Platform/ Operating System	Description of Functions, Features, Modules, Libraries, Modeling Techniques
PKM	HLOSS	1.0	MICRON / WINDOWS NT	CALCULATION OF HEAD LOSS DUE TO FIBROUS AND PARTICULATE DEBRIS
PKM	BLOCKAGE	2.5	MICRON / WINDOWS 95	DEBRIS SEDIMENTATION IN A BWR SUPPRESSION POOL

* Review Software Capabilities, Review Open Error Notices, Ensure Installation Test Completed, and Access Control Satisfied; per DPR-3.5..

DESIGN VERIFICATION METHOD:

- [x] Design Review
- [ ] Alternate Calculation
- [ ] Qualification Testing

DESIGN REVIEW CRITERIA

YES	NA	ITEM
[x]	[ ]	Design Input Correctly Selected
[x]	[ ]	Assumptions Adequate / Reasonable
[ ]	[x]	Assumptions Noted for Verification
[x]	[ ]	Appropriate Design Methods
[x]	[ ]	Design Inputs Incorporated in Design
[x]	[ ]	Reasonable Output for the Inputs
[ ]	[x]	Interfacing Organizations Specified

SOFTWARE REVIEW CRITERIA

YES	NA	ITEM
[x]	[ ]	Software Capabilities Reviewed
[ ]	[x]	Open Error Notices Reviewed
[x]	[ ]	Software Used Correctly
[x]	[ ]	Software Results Documented
[x]	[ ]	Key Program Features Recorded

	Preparer	Verifier	Approver
Signature	[illegible] (for)	[illegible]	[illegible]
Printed Name	Ervin R. Copus	FRANCISCO J. SOUTO	David DeGrush
Date	8/6/98	8/6/98	8/24/98

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REVISION DOCUMENTATION SHEET

Calculation No. : DC-A34600.006

REVISION NO.	DESCRIPTION OF REVISION
1	A more detailed parametric analysis is now included to assess the effect of variations in all debris source terms on the calculated results.
1 (Cont.)	Input errors in the IBA calculations were identified and corrected. The conclusions for the strainer performance were not impacted by correcting these errors.
1 (Cont.)	The HLOSS 1.0 computer code printouts for the IBA calculations are now included in Attachment A.

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1	PYM	8/6/98	FS	8/6/98	**Client/Project:** Vermont Yankee Nuclear Power Corporation
					Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
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Rev.	Orig.	Date	Chkd.	Date
1	PYM	8/6/98	FS	8/6/98

1.0 PURPOSE/OBJECTIVE

The purpose of this calculation is to determine the head loss across the newly designed emergency core cooling system (ECCS) inlet suction strainers at the Vermont Yankee nuclear station as a result of debris accumulation following a postulated loss of coolant accident (LOCA). The new ECCS strainers were designed to trap debris generated during a LOCA (fibrous insulation, reflective metallic insulation (RMI), particulate, etc.) that was greater than 1/8th inch in size and preclude its transport to the ECCS pumps, spray nozzles, etc. Head loss calculations are required to verify that the new strainers are of sufficient size to maintain adequate net positive suction head (NPSH) to the ECCS pumps, even under limiting debris load and pump flow conditions.

This calculation will tabulate the head losses that result from several different flow scenarios for Residual Heat Removal (RHR) and Core Spray (CS) operation following a LOCA. The analysis will account for the different types of debris present in the drywell and suppression pool and/or generated as a result of a LOCA. The primary debris sources at Vermont Yankee are insulation that is dislodged from drywell piping by the break flow, such as RMI, NUKON®, Temp-Mat™, FiberMat, and Armaflex. In addition, sludge initially present in the suppression pool, dirt and rust within containment, and coatings dislodged by the force of the LOCA jet all represent particulate debris that could contaminate the ECCS water supply, deposit on the strainer, and increase the pumping head loss. Finally, the Vermont Yankee containment has significant quantities of unqualified coatings that can fail as a result of the LOCA environmental conditions and transport to the suppression pool and possibly to the strainers therein. Each of these debris sources will be explicitly addressed in this calculation. It should be emphasized that the calculated results do not include a contribution from the clean strainer head loss. The contribution of the clean strainer to total system head loss is tabulated in the Vermont Yankee specification document VYS-049 " Specification for RHR and CS Suction Strainers" [Betti, 1997].

In addition to providing conservative, test-related estimates of strainer head loss for a number of ECCS system flow scenarios, the calculation also provides parametric analyses of the variation in calculated head loss with varying debris loading, ECCS pump flow rate, and suppression pool temperature. These results can be used by Vermont Yankee staff to evaluate the impact on strainer head loss of possible future plant design changes.

2.0 CALCULATION METHODS

To determine the hydraulic performance of replacement ECCS suction strainers during a postulated LOCA event, it is necessary to quantify:

- The quantity of insulation material damaged by the LOCA and subsequently transported to the suppression pool,
- The quantity of particulate debris generated by the LOCA or already present in the drywell and transported to the suppression pool,
- The transport of debris within the suppression pool (deposition on the strainers or sedimentation on the suppression pool floor), and
- The head loss associated with a given quantity of debris transported to the strainer for a given flow rate and temperature.

In general, the debris transported to the suppression pool at Vermont Yankee will be an arbitrary combination of:

- fibrous insulation debris (NUKON, Temp-Mat, and FiberMat),
- small particulate (sludge, rust, dirt/dust, LOCA jet-induced coatings debris, and failed unqualified Inorganic Zinc [IOZ]coatings),
- fragments of Armaflex insulation,
- relatively large paint chips due to failed unqualified coatings,
- and RMI debris.

All, part, or none of these debris types could be deposited on the ECCS strainer. The quantity of insulation debris transported to the suppression pool, the quantity of particulate debris in the suppression pool, and the deposition of these debris constituents to the RHR and CS strainers under a range of ECCS flow conditions were provided in the Vermont Yankee specification VYS-049 [Betti, 1997]. These quantities will be used directly for strainer sizing purposes. Thus, this calculation focuses exclusively on the determination of head loss associated with flow through debris on the strainer.

The methodology used to determine head loss due to fibrous debris, small particulate, and Armaflex fragments is described in Section 2.1. The methodology used to determine head loss due to RMI debris is discussed in Section 2.2. Each of these contributions to head loss are considered separately, and the total head loss is determined by summing the two individual contributions. Finally, the impact of large paint chips on strainer head loss is considered in Section 2.3

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2.1 Head Loss Methodology for Fibrous Debris with Entrained Particulate

The methodology used for determining head loss across a fiber/particulate debris bed is based on the modeling approaches presented in the NRC-sponsored NUREG/CR-6224, *Parametric Study of the Potential for BWR ECCS Strainer Blockage due to LOCA Generated Debris* [Zigler, *et al*, 1995]. This explicitly accounts for all important parameters and phenomenology including:

- Mixtures of different fibrous and particulate debris constituents,
- Available strainer surface area, which may change with time for a stacked disk strainer design as the gap interstitials fill with debris,
- Compression of the fiber bed as a function of the pressure drop across the fiber bed, and
- Filtration (trapping) of less than 100% of the particulate debris transported to the strainers as a function of fibrous debris thickness.

The following sections present:

- A summary description of the head loss methodology,
- A discussion of the filtration model for small particulate debris,
- A discussion of how mixtures of fibrous debris constituents are modeled,
- A discussion on the treatment of Armaflex insulation,
- Rationale for choice of NUREG/CR-6224 correlation in lieu of URG/CDI algorithm, and
- Discussion of experimental verification

2.1.1 Summary Description

The NUREG/CR-6224 head loss correlation is described in detail in Appendix B to NUREG/CR-6224 [Zigler, *et al*, 1995] and is a semi-theoretical head loss model. The correlation is based on the theoretical and experimental research for the pressure drops across a variety of fibrous porous media carried out since the 1940s. The NUREG/CR-6224 head loss model, proposed for laminar, transient and turbulent flow regimes through mixed debris beds (i.e., debris beds composed of fibrous and particulate matter) is given by:

$$\Delta H = \Lambda\,[3.5\,S_v^2\,\alpha_m^{1.5}\,(1+57\,\alpha_m^3)\,\mu\,U + 0.66\,S_v\,\alpha_m/(1-\alpha_m)\,\rho\,U^2\,]\,\Delta L_m$$

where,

ΔH is the head loss,
S_v is the average surface to volume ratio of the debris,
μ is the dynamic viscosity of water,
U is the approach velocity,

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1	PHM	8/6/98	TS	8/6/98	**Client/Project:** Vermont Yankee Nuclear Power Corporation **Title:** Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
					Project No.: A346
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ρ is the density of water,
α_m is the mixed debris bed solidity,
ΔL_m is the mixed debris bed thickness, and
Λ is a unit conversion factor ($\Lambda = 1$ for SI units).

The mixed debris bed solidity is given by:

$$\alpha_m = \left(1 + \frac{\rho_f}{\rho_p}\eta\right)\alpha_o \frac{\Delta L_o}{\Delta L_m}$$

where,

α_o is the uncompressed fiber bed solidity,
ΔL_o is the theoretical (uncompressed) fibrous debris bed thickness,
$\eta = m_p/m_f$ is the particulate to fiber mass ratio of the debris bed,
ρ_f is the fiber density, and
ρ_p is the average particulate material density.

For N_p classes of particulate materials, m_p and ρ_p are defined by:

$$m_p = \sum_{i=1}^{N_p} m_i$$

and

$$\rho_p = \frac{\sum_{i=1}^{N_p} \rho_i V_i}{\sum_{i=1}^{N_p} V_i}$$

where m_i, ρ_i and V_i are the mass, density and volume of a particulate material *i*.

Compression of the fibrous bed due to the pressure gradient across the bed is also accounted for. The empirical relation that accounts for this effect, which must be satisfied in parallel to the previous equation for the head loss, is given by (valid for $(\Delta H/\Delta L_o) > 0.5$ ft-water/inch-insulation, below this value there is no compression):

$c = 1.3\ c_o\ (\Delta H / \Delta L_o)^{0.38}$ for $c \leq 65 / (1+\eta)$ lb/ft^3.

where,

c is the compressed debris bed density (in lb/ft^3),
c_o is the uncompressed insulation density (in lb/ft^3), and
$\Delta H / \Delta L_o$ is the head loss in ft-water per inch of insulation.

For a calculated value of c greater than $65 / (1+\eta)$ lb/ft^3, α_m is calculated directly by [Zigler, *et al*, 1995]:

$\alpha_m = 65$ lb/ft$^3/\rho_p$

where 65 lb/ft^3 is the macroscopic density of a granular media such as sand, gravel, or clay.

The NUREG/CR-6224 models were implemented by the U.S. Nuclear Regulatory Commission in the BLOCKAGE 2.5 computer code [Rao, *et al*, 1996], [Shaffer, *et al*, 1996], which is publicly available from the Oak Ridge National Laboratory code center. The BLOCKAGE 2.5 code includes an assessment of:

- the time-dependence of debris transport from the BWR drywell to the suppression pool,
- the buildup of debris on the strainers as a function of pump flow rate and pool water volume,
- the potential reduction in debris buildup as a result of sedimentation to the floor of the suppression pool,
- the potential reduction in the buildup of particulate debris as a result of less than perfect filtration of such particulate by the fibrous debris,
- and the head loss resulting from the flow through the deposited debris.

However, the BLOCKAGE 2.5 code was developed under the assumption that the surface area of the strainer could be treated as a constant, user-supplied input to the analysis, with the debris buildup being calculated as though the strainer could be represented as a flat surface with the same surface area. This simplifying assumption is valid in the case where one has a large surface area relative to the debris volume, such that only a thin debris layer would be calculated. However, in the case where one has a large volume of debris, with a complex strainer geometry involving stacked disks and curved surfaces, the BLOCKAGE 2.5 approach to debris deposition is no longer valid. There are two principal reasons for this:

1. A stacked disk strainer has a very large surface area relative to the overall strainer volume. With large volumes of fibrous debris, the interstitial gaps between the disks can become filled with debris.

When that occurs, the effective surface area of the strainer for additional debris deposition is reduced to the circumscribed area of the strainer.
2. For thick layers of debris on the outside of a cylindrical shape, the debris thickness relative to the debris volume is a function of the surface curvature, and is less than the thickness that would result from deposition on a flat surface of the same area.

In light of these limitations in BLOCKAGE 2.5 and the unavailability of the BLOCKAGE 2.5 source code, ITS Corporation developed the HLOSS 1.0 code [Mast and Souto, 1997] to provide a computational tool that could be used to assess stacked-disk strainer performance under varying fiber loads with particulate debris. Thus, the HLOSS 1.0 code incorporates the following features:

- head loss estimates based on the head loss correlation presented in NUREG/CR-6224,
- time-dependent debris build-up on the strainers that may be input by the user based on strainer flow rate and pool water volume as in BLOCKAGE 2.5 (with all debris assumed to be suspended in the suppression pool at time zero),
- filtration efficiencies and sedimentation fractions that may be input by the user,
- use of the full strainer surface area for debris deposition until the gaps between the stacked disks are filled with debris,
- use of the strainer circumscribed area for further debris deposition after the gaps are filled,
- calculation of debris thickness on the outside of the circumscribed area that accounts for the surface curvature, and
- use of an averaging algorithm for the debris-specific surface area that eliminates potential non-conservative results associated with a volume-weighted average in cases of large quantities of particles with low specific surface area.

As with BLOCKAGE 2.5, debris constituents are modeled strictly through the input of such physical parameters as density and particle characteristic size. Except for the debris bed compression correlation, there is no adjustment of any correlation coefficients for different fiber types, particulate constituents, or strainer configuration.

One limitation in HLOSS 1.0 is the lack of an explicit model for debris sedimentation in the suppression pool following the early high-turbulence phase of a LOCA. However, since any impact of sedimentation had already been accounted for in the debris quantities specified in VYS-049, this limitation has no significance for these analyses. Thus, the HLOSS 1.0 code was chosen to perform the fiber/particulate head loss calculations herein.

2.1.2 Particulate Filtration Model

It has been shown experimentally that not all of the particulate debris reaching the strainer would be trapped or filtered by the fibrous debris on the strainer surface. The fraction of the debris particles approaching the strainer that are deposited and trapped within the fibrous debris bed is referred to as the filtration efficiency. Several experiments were conducted by the NRC to provide bounding estimates for the filtration efficiency of small particulate such as sludge [Rao and Souto, 1996]. Based on these experiments, a conservative upper-bound value of 0.50 was used for the particle filtration efficiency for debris bed thickness greater than 0.25 inches in the NUREG/CR-6224 analysis[1]. For debris bed thickness lower than 0.25 inches, the 0.50 filtration efficiency was deemed overly conservative and a linear variation for the filtration efficiency from 0 to 0.5 was used for theoretical thickness lower than 0.25 inches. For small particulate (2 μm to 10 μm), the dominant filtration mechanisms are impaction and interception, and the filtration efficiency is essentially the same for all particles in this size range [Fuchs, 1964], [Reist, 1984]. Thus, this filtration model is applied to all particulate constituents with a diameter of 10 microns or less. For larger particulate, a filtration efficiency of 1.0 is conservatively assumed.

2.1.3 Treatment of Mixed Fiber Beds

The head loss correlation described in Section 2.1.1 is based on fibrous insulation material properties that include fiber density, debris density, and fiber diameter. In the case where more than one type of fibrous debris component is present, it is necessary to use average values for these parameters. In the calculations described herein, average values for the microscopic fiber density are determined using a debris volume weighted average. The average macroscopic density of the debris mixture is obtained by dividing the total debris mass by the total debris volume where the total debris volume is derived by using the observed estimated debris thickness from tests specifically conducted for Vermont Yankee at the Alden Research Laboratories (ARL) [Copus, 1998].

2.1.4 Impact of Armaflex Insulation Debris on Head Loss

Armaflex is a closed cell foam type insulation. Because of the closed cell construction, the as fabricated insulation floats and would not be expected to deposit on the strainer surface. However, the LOCA jet forces are expected to fragment some of this material, thereby impacting its buoyancy. This is particularly true if very small fragments are generated. For conservatism, it will be assumed herein that Armaflex will be fragmented into small (less than 1mm size) pieces that are transported to the suppression pool. Test results will then be used to determine whether or not this debris can transport to the strainer surface.

2.1.5 Comparison to URG/CDI Head Loss Algorithm

Prior to adopting the NUREG/CR-6224 head loss correlation approach, ITS Corporation performed an independent assessment of all the available fibrous head loss correlations. These included:

[1] Note that the thickness in these experiments was less than 4 inches. For very thick beds, higher efficiencies may be expected but no experimental data is available.

- Correlations documented in the OECD/CSNI International Task Group Report entitled "Knowledge Base for Emergency Core Cooling System Recirculation Reliability" [NEA, 1996].
- The GE/BWROG correlation "Passive Strainer Head Loss Prediction with Fibrous Debris" documented in NEDO-32686, *Utility Resolution Guidance for ECCS Suction Strainer Blockage* [BWROG, 1996], hereafter denoted URG.
- The NRC Semi-Theoretical Head Loss Model documented in NUREG/CR-6224.

All the correlations suffered from the generic problem of their applicability being limited to the data for which the correlation was developed. This was especially true for correlations developed prior to 1994, which, in general, did not address the effect of particulate in fibrous debris beds. ITS Corporation concentrated its efforts on performing a detailed review of the GE/BWROG URG fibrous head loss correlation and the NRC NUREG/CR-6224 fibrous head loss model.

Specific insights from the comparison of the URG correlation and NUREG/CR-6224 model include:

1) Flow velocity - The URG correlation only has a first order term in U (laminar), whereas the NUREG/CR-6224 model has explicitly both laminar and turbulent (U^2) terms.
2) Fiber diameter - The surface to volume ratio of the fiber material is proportional to the inverse fiber diameter. The two analysis methods handle this effect the same way.

3) Bed porosity (solidity) - Both analysis methods show increased head-loss with increasing bed solidity. However, the form of the dependence on solidity is somewhat different. Previous historical work (documented in NUREG/CR-6224) had shown that the form employed in the URG correlation was in fact more appropriate for head-loss through porous media than for head-loss through a fiber bed.

4) Strainer geometry - Neither the URG correlation nor the NUREG/CR-6224 model explicitly accounts for strainer geometry. The URG model, in fact, was derived from data obtained from stacked disk as well as 60-point star strainer geometries, without attempting to determine what the effective strainer area was for a given experiment (the circumscribed area was used in developing the correlation). Consequently, it was determined that there was no basis for applying the URG correlation to arbitrary strainer geometries.

5) Bed Compression – Unlike the NUREG/CR-6224 correlation, the URG algorithm does not explicitly account for fiber bed compression. This has been shown to be an important effect. In many of the tests used to "calibrate" the URG correlation, compression was certainly occurring, and the effect thereof was included (in an average sense) in the correlation coefficients. However, the form of the correlation does not allow one to determine whether this treatment is conservative under all conditions.

6) Particulate Filtration – Unlike the NUREG/CR-6224 correlation, the URG algorithm does not explicitly account for particulate filtration. The effect of particulate debris is accounted for through the use of "Bump-Up Factors" that are functions of the debris quantities. Bump-up factors are not treated as being functions of debris quantity (or thickness). Thus, it is unclear whether the use of bump-up factors is conservative under all conditions.

Based on the above assessment, it was felt that there was a much better basis for using the NUREG/CR-6224 correlation. There is a much more extensive database to demonstrate the validity of that correlation (see below). In addition, because all-important phenomena are treated explicitly in a semi-theoretical manner, it is much easier to argue the conservatism associated with its application in a particular circumstance.

2.1.6 Experimental Validation of Head Loss Algorithm

The NUREG/CR-6224 model relies on fundamental characteristics of the debris bed composition, such as the bed thickness, average (microscopic) density, characteristic debris size, etc. Its results have been extensively validated for debris beds composed of fiberglass and simulated suppression pool sludge [Rao and Souto, 1996], as well as mineral wool fibrous materials [NEA, 1996]. The NUREG/CR-6224 model was also extensively validated in support of the OECD/CSNI International Task Group. The experimental data base [NEA, 1996] included:

1) NRC Experimental Head Loss Data - NUREG/CR-6367
2) PP&L Head Loss Data
3) PCI Head Loss Data
4) NUREG/CR-2982 Head Loss Data
5) Vatenfall Development Co. Data Base
6) ABB-Atom, Sweden Head Loss Data Base
7) Forsmark Head Loss Data Base
8) Ringhals Head Loss Data Base
9) KKL Head Loss Data Base

In all cases, as reported in NEA/CSNI/R (95)11, "Knowledge Base for Emergency Core Cooling System Recirculation Reliability", the NUREG/CR-6224 model consistently predicted the experimental results within an acceptable error band.

In addition, a detailed analysis of the head loss testing done for the PCI stacked disk strainers at EPRI has been completed. These experiments were conducted for a wide range of fiber (NUKON) quantities, sludge to fiber mass ratios, and effective surface area (gap filling). Excellent agreement was obtained for model predictions both in the case of small fiber quantities (gaps not filled) as well as for large fiber quantities (gaps filled with additional fiber buildup on the circumscribed area of the strainer. These results have been summarized as part of the HLOSS 1.0 documentation [Mast and Souto, 1997] and presented to the NRC in a public meeting on February 18, 1997.

More recently, an experiment was performed at EPRI for the PCI stacked disk strainer using Temp-Mat rather than NUKON fibrous debris [Hart, 1997]. Comparison of the measured head loss with that predicted using the HLOSS 1.0 code showed agreement to within 20%, with the predicted result conservatively higher than that measured.

2.2 Head Loss Methodology for RMI Debris

Given the deposition of a certain amount (and type) of RMI debris on the strainer, ITS Corporation uses a head loss correlation for stacked disk strainer head loss through an RMI debris bed based on that given in the BWROG URG [Diertl, *et al*, 1996]. This head loss correlation explicitly treats the effects of:

- the formation of a "saturated bed" of RMI foil debris - the maximum theoretical debris bed which could be formed on the strainer, and
- different types of RMI foils.

The BWROG URG RMI head loss correlation is based on the head loss data obtained with several strainer geometries at the EPRI strainer test facility located in Charlotte, North Carolina. These tests [Diertl, 1996] were conducted with stainless steel RMI foil debris with characteristics similar to the RMI debris resulting from the USNRC sponsored full scale tests at the SIEMENS-KWU facility in Karlstein, Germany.

The URG based correlation to estimate the head loss due to RMI foil debris can be written as:

$$\Delta H = K_t K_p \frac{A_{RMI}}{A_c} U^2$$

where,

ΔH is the head loss across the RMI bed (ft-water),
U is the fluid approach velocity (ft/sec) at the circumscribed surface of the strainer, which is given by $Q/(450*A_c)$,
Q is the volumetric flow rate (gpm) through the strainer,
K_t&K_p are experimentally determined constants that describe the head loss characteristics of the RMI,
A_{RMI} is the total (single-sided) surface area (ft^2) of the RMI foil on the strainer,
A_c is the cylindrical circumscribed area (ft^2) of the strainer (conservatively set equal to πDL),

D is the outer diameter (ft) of the strainer, and
L is the active length (ft) of the strainer.

An independent assessment of this correlation and the experimental data used to determine the proportionality constants [Heames, 1997] concluded that there was some question as to the defensibility of the value of those coefficients for some materials (aluminum vs. stainless steel). However, it was concluded that use of values for the two coefficients based on stainless steel foils would result in a conservative prediction of head loss that was defensible based on available data.

The URG also provides a methodology for determining whether a saturation thickness of RMI foils has been reached. The formula provided to determine the saturation bed thickness, τ_s, is given by:

$$\tau_s = \frac{\sqrt{D\,L}}{2}\left[\sqrt{\frac{2\,U}{U_s}} - 1\right]$$

where,

U_s is the settling velocity (ft/sec) of the RMI foil type being analyzed.

The RMI foil quantity that corresponds to this saturation thickness, A_{max}, is then given by:

$$A_{max} = \frac{\tau_s\, A_c}{K_t}$$

such that the smaller of the actual value of A_{RMI} or the saturation value of A_{max} is used in the prior expression for the RMI head loss.

The only additional constraint for the application of the URG based methodology to estimate head losses due to RMI debris is:

$A_{RMI} / A_C \leq 40.$

Ratios beyond this value of 40 may not be justified based on the limited range of conditions previously tested.

ITS Corporation has performed a detailed independent review [Heames, 1997] of the RMI head loss correlation presented in the URG. The following conclusions were drawn:

1) **Dependence Upon Flow Rate** - In applying the URG head loss correlation for RMI, ITS Corporation checks whether or not the calculated approach velocity is less than 2.0 ft/s for a stacked disk strainer (the upper bound of data that has been reported).

The correlation expresses head loss as a simple function of the square of the strainer flow rate (i.e., velocity), indicating head loss is governed by turbulent flow through the RMI debris. Analysis of the experimental data for fiber clearly shows that the measured head loss is a more complex function of velocity, with both viscous and inertial components. Analysis of the experimental data for RMI indicates the possibility of a similar complex relationship. However, the experimentally derived constant in the head loss correlation is set so that head losses larger than measured values (i.e., conservative values) are generated over the range of velocities investigated.

2) **Dependence on RMI Debris Loads** - In applying the URG head loss correlation for RMI, ITS Corporation checks whether or not the calculated RMI load is less than approximately 40 ft^2 of RMI per ft^2 of strainer circumscribed area (the upper bound of data that has been reported).

Correlation coefficients in the head loss equation were derived for a limited range of debris loads. As with any correlation, care must be exercised in extrapolating to regions outside the database. In order to ensure that the correlation developed for the stacked disk strainer is conservative relative to the available data, the anticipated RMI loads should not exceed the upper bound of the test data: 40 ft^2 of RMI per ft^2 of strainer circumscribed area

3) **Dependence on RMI Material** - In applying the URG head loss correlation for RMI, ITS Corporation assumes that all RMI debris will have the same debris head loss characteristics as the 2.5 mil stainless steel debris obtained by the USNRC at the Siemens-KWU Karlstein steam blast test and tested at the EPRI facility. As such, ITS Corporation always employs the RMI proportionality constant determined in the EPRI full-scale tests irrespective of the RMI foil material type and thickness.

Experiments were conducted to measure the head loss across a representative full scale truncated cone strainer exposed to debris from two different types of 2.5 mil stainless steel RMI at the EPRI test facility. Significantly different head losses were measured for these two types of stainless steel debris. To ensure the head loss correlation generated conservative results, the correlation coefficients were developed to envelope measured head losses for both types of stainless RMI. Subsequently, experiments were performed at the CDI gravity head loss test facility (using a flat plate strainer) with the objective of comparing head loss for stainless RMI to head loss for other RMI materials, such as aluminum. This second series of experiments also re-examined the same two types of stainless RMI debris studied in the earlier truncated cone strainer experiments.

Results of these tests also confirmed that the head loss for the two types of stainless debris are significantly different; however, the type of RMI that produced the larger head loss in the full scale EPRI tests produced the smaller head loss at the CDI gravity head loss test facility. The clear contradiction between the two sets of stainless RMI experiments raises questions about the technical basis of the factors (as derived from the gravity head loss tests) used to estimate the head loss for aluminum foils. In particular, the current data does not uniformly support the values for the head loss proportionality constants, K_p, applied in the URG correlation. Conservative strainer design implies the use of the largest proportionality constant (i.e., generate the largest pressure drop for all situations) and the use of the most prototypical experimental results. The RMI proportionality constant determined in the EPRI full scale tests satisfies both conditions and is thus used for all RMI debris, regardless of the actual material composition. For the case of a stacked disk strainer, this conservatism yields a value for K_tK_p = 0.0686 ft-water/(ft²/sec²).

4) **Saturation Bed Thickness** - The URG presents data on the RMI saturation bed thickness, bed thickness proportionality constant, and settling velocity for different RMI types. These data are used directly by ITS Corporation in the prediction of RMI head loss.

Thus, in summary, ITS Corporation implements the RMI head loss correlation proposed in the URG with the exception that the head loss proportionality constant for 2.5 mil stainless is used regardless of RMI type. It should be noted that neither of the bounding conditions (limitations on flow rate and debris load) identified above are reached for Vermont Yankee.

2.3 Head Loss Methodology for Large Paint Chips

The NUREG/CR-6224 head loss methodology characterizes the impact of any particulate on fibrous debris head loss through that particulate's impact on bed porosity and that particulate's impact on the average debris surface to volume ratio. This has been shown to work very well for small size particulate such as sludge. However, for paint chips that are very large (1/8th inch by 1/8th inch to 2 inches by 2 inches in size), there is no available experimental data to validate the NUREG/CR-6224 modeling approach.

Given the current uncertainty in head loss due to large paint chips, a series of tests were conducted for Vermont Yankee at ARL to better quantify the impact of large paint chips on strainer head loss [Johnson, 1997]. The results indicated that large paint chips could not deposit on the ECCS strainers for the combined Vermont Yankee DBA conditions of pool turbulence and ECCS inlet flow [Copus, 1998]. A specific methodology for determining the head loss under alternative suppression pool loading conditions was subsequently unnecessary since the predicted head loss in all cases was defined to be zero.

2.4 Applicable Codes/Standards

The following codes and standards are applicable to this calculation: 1) 10CFR50, Appendix B, and 2) 10CFR21.

2.5 QA Requirements

This calculation is safety related and has been prepared and reviewed in accordance with DE&S procedure DPR-3.2 [DPR-3.2, 1997].

2.6 Use of Software

As previously discussed, calculations documented herein were performed using the HLOSS 1.0 computer code and the BLOCKAGE 2.5 computer code without new assumptions or coding modifications. These programs are verified and validated in accordance with the DE&S QA Program Procedure, DPR-3.5 [DPR-3.5, 1997] and are on the DE&S approved software list.

3.0 DESIGN INPUT DATA

This section describes the information used to determine the ECCS strainer head loss at Vermont Yankee. This information consists of strainer sizing data, plant specific flow and suppression pool temperature data, debris quantities, and debris material properties. As was mentioned previously, the debris quantities expected to be transported to the individual strainers have been calculated elsewhere for a range of ECCS system flow scenarios. Thus, the combinations of flow scenario/debris quantities provided in specification VYS-049 are simply repeated here.

3.1 Strainer Data

The Vermont Yankee suppression pool has separate residual heat removal (RHR) system strainers and core spray (CS) strainers. Because the anticipated pump flows for the two systems are considerably different, and because the available NPSH margin for the CS and RHR pumps are different, optimized designs were developed for the CS and RHR strainers. A summary of the parameters that define the strainer geometry for each system [VY-ECCS, 1997-Rev.0 – 11/19/97] is provided in Table 1.

Table 1. Vermont Yankee: Strainer Module Geometry.

Parameter	RHR Strainers	CS Strainers
Fitting - Attachment to Penetration	Ram's Head [2 sides]	Elbow [1 side]
Active Length (in) per side	114.5	139
# of modules per side	2	2
Outer Diameter (in)	47	47
Gap Diameter (in)	26	26
Core Tube Diameter (in)	24	24
# of Disks per side	19	20
Disk Width (in)	2	2
Gap Width (in)	4.5	5.5

For both the RHR and CS strainers, the total length of the strainer requires that the strainers be fabricated in two sections (per side of the ram's head for RHR). The quoted active length represents the total length of the two modules in both cases. It has been assumed that the core tube design in the two modules will result in uniform flow along the entire length of both modules.

3.2 Suppression Pool Temperature/Pump Flow/Debris Specification

A range of expected CS and RHR strainer flow rates along with the associated suppression pool temperature and strainer debris loading were designated in Vermont Yankee Specification VYS-049 [Betti, 1997- Rev. 2, Change 1 – 11/12/97]. These quantities are summarized in Table 2 for the expected conditions following a Design Basis Accident (DBA) LOCA. A similar summary for the expected conditions following an Intermediate Break Accident (IBA) LOCA is provided in Table 3. The IBA LOCA is specified to generate very little fibrous debris (a ¼" layer of uncompressed NUKON is assumed) and larger quantities of unqualified coatings debris.

Table 2. Vermont Yankee: DBA LOCA Strainer Sizing Requirements.

Strainer Parameter	Units	RHR System			CS System			
		Case 1	Case 2a	Case 2b	Case 3a	Case 3b	Case 3c	Case 3d
Flow Rate	GPM	7400	14200	14200	4600	4000	4300	4600
Design Fluid Temperature	Deg F	173	164	170	164	173	173	173
NUKON	Lbm	258	174	235	74	152	159	159
Fibermat	Cu-ft	9.6	6.4	8.7	2.8	5.7	5.9	5.9
TempMat	Lbm	20.5	13.8	18.7	5.9	12.1	12.6	12.6
Armaflex	Cu-ft	16.5	11.1	15	4.8	9.7	10.2	10.2
Sludge	Lbm (dry)	546	366	497	156	322	336	336
Rust Flakes	Lbm	35.3	23.7	32.2	10.1	20.8	21.7	21.7
LOCA Jet Coating Debris	Lbm	61	41	55	18	36	37	37
IOZ Coating Debris	Lbm	70	47	64	20	42	43	43
Non-IOZ Coating Debris	Sq-ft	6619	6619	6619	2295	2295	2295	2295
RMI Debris	Sq-ft	sat	sat	sat	sat	sat	sat	sat

Table 3. Vermont Yankee: IBA LOCA Strainer Sizing Requirements.

Strainer Parameter	Units	RHR System			CS System			
		Case 4	Case 5a	Case 5b	Case 6a	Case 6b	Case 6c	Case 6d
Flow Rate	GPM	7400	14200	14200	4600	4000	4300	4600
Design Fluid Temperature	Deg F	173	164	170	164	173	173	173
NUKON	in	(1/4")	(1/4")	(1/4")	(1/4")	(1/4")	(1/4")	(1/4")
Fibermat	Cu-ft	0	0	0	0	0	0	0
TempMat	Lbm	0	0	0	0	0	0	0
Armaflex	Cu-ft	0	0	0	0	0	0	0
Sludge	Lbm (dry)	546	366	497	156	322	336	336
Rust Flakes	Lbm	35.3	23.7	32.2	10.1	20.8	21.7	21.7
LOCA Jet Coating Debris	Lbm	61	41	55	18	36	37	37
IOZ Coating Debris	Lbm	70	47	64	20	42	43	43
Non-IOZ Coating Debris	Sq-ft	8410	12966	12966	3665	5403	8081	8081
RMI Debris	Sq-ft	sat	sat	sat	sat	sat	sat	sat

3.3 Debris Characteristics

The debris characteristics relevant to the determination of strainer head loss are summarized in the following sections.

3.3.1 Fiber Parameters

The NUREG/CR-6224 head loss correlation for fibrous debris head loss is based on the fiber diameter, the macroscopic debris density, and the microscopic fiber density. The macroscopic debris density is related to the as-fabricated blanket density, but may differ from this value depending upon the "severity" of destruction. For NUKON debris, the debris density appears to be close to the as-manufactured blanket density, and this assumption has been used in previous analyses using the HLOSS 1.0 code. TempMat and Fibermat, both of which are a higher density (lower porosity) material than NUKON, have lower initial debris densities than their as-fabricated blanket densities. However, this debris might be expected to re-compress to a density close to the initial blanket density as it collects on a strainer. Given these uncertainties, it is assumed that the debris density for a mixed fiber bed can be best approximated by the density observed in the C tests performed for Vermont Yankee at ARL [Copus,1997].

The as-manufactured fiber properties were summarized in the URG [Diertl, *et al*, 1996] for both NUKON and TempMat. Fibermat fiber properties were taken from the Carborundum Company Product Specification for this material [Carborundum, 1990]. Table 4 provides a summary of these parameters. The input values for the microscopic fiber density and debris mass are derived using the values from Table 4. The effective fiber diameter for the mixed fiber bed was approximated by using a value which reasonably predicts the head loss results observed in the C tests performed for Vermont Yankee at ARL [Copus, 1998]. The mixed bed debris density was based on C test observations [Copus, 1998].

Table 4. Vermont Yankee: Fibrous Debris Material Properties.

Fiber Type	Fiber Diameter	Fiber Density	Blanket Density	Debris Density
	(ft)	(lbm/cu-ft)	(lbm/cu-ft)	(lbm/cu-ft)
NUKON	2.33E-05	180	2.4	2.4 [IBA]
Fibermat	9.84E-06	170	6	-
TempMat	2.93E-05	159	11.3	-
Mixed Bed	2.70E-05	177	-	2.1 [DBA][2]

3.3.2 Particulate Parameters

For those debris constituents modeled as particulate trapped within the fibrous debris bed using the NUREG/CR-6224 head loss correlation, the relevant parameters are the total volume and the characteristic size and shape of each debris constituent. Since particulate loads are typically expressed in terms of mass, the density of the particulate material is also needed.

The microscopic density of sludge, which is basically iron oxide, is 324 lb/ft^3 [Zigler, *et al*, 1995]. The mass median diameter of the sludge particle size distribution is estimated to be 2.5 μm [OG94-661-161, 1994]. This value represents the size distribution of the sludge in the suppression pool. However, the size distribution of the sludge particles actually deposited on the fibers in the debris bed has a mass median diameter much larger than the corresponding mass median diameter of the sludge particles in the suppression pool, as suggested by the SEM photographs of typical debris beds [Rao

[2] The mixed bed debris average density was estimated in the analysis of the tests specifically conducted for Vermont Yankee [Copus, 1998].

and Souto, 1996], which show particle sizes on the order of 100 μm. Consequently, in these calculations an average debris bed sludge particle diameter of 10 μm will be conservatively used.

Rust flakes are also iron oxides, with a microscopic density of 324 lb/ft^3. Typically, rust flakes appear to be visually similar to small paint chips, with an equivalent thickness of at least 1 mil (25.4 μm). This value of 1 mil will be used herein.

The LOCA jet induced coatings debris is anticipated to be very small particulate because of direct jet impingement. Thus, a characteristic spheroid particle size of 10 micron is assumed for this debris constituent. All coatings, regardless of qualification, are assumed to fail if they are within the cone of a LOCA jet. Thus, an average density value for all coatings is used for this debris constituent. The URG suggests an average coatings density value of approximately 120 lb/ft^3.

Unqualified IOZ coatings debris is expected to mostly be the zinc microspheres present in paint. Specification VYS-049 provides a recommended value of 10 micron for the characteristic particle size of this debris constituent. The URG provides a density of approximately 185 lb/ft^3 for IOZ coatings.

Armaflex insulation is not a particulate as installed in the drywell. In fact, Armaflex, which is a closed-cell foam type insulation with a density of less than 5 lb/ft^3, is expected to float. In order for the Armaflex debris fragments not to float, they would have to have a density at least equal to that of water. Visual inspection of Armaflex shows that typical voids within the foam structure are on the order of 1-2 mm. Thus, for the voids to be destroyed, fragments of that characteristic size would have to be produced. Thus, Armaflex debris is conservatively modeled (smaller debris has a larger surface to volume ratio and a larger head loss component) as being of 1 mm characteristic size with a density comparable to that of water. An as-fabricated density of 5 lb/ft^3 is used to calculate the mass of Armaflex debris for the initial insulation volume specified. It should be noted that even after destruction in a high pressure LOCA jet, Armaflex debris is still expected to float. A simple table top experiment wherein a sample of Armaflex is violently shredded in a blender, completely destroying the as-manufactured character of the material, results in sub-millimeter size fragments that still float. Tests perfomed for Vermont Yankee at ARL confirmed that Armaflex could not be transported from the pool to the strainer and consequently the debris removal factor for Armaflex was assigned a value of zero.

The particulate debris characteristics used in this calculation are summarized in Table 5.

Table 5. Vermont Yankee: Particulate Debris Characteristics

Debris Type	Microscopic Density (lb/ft^3)	Characteristic Size (micron)
Sludge	324	10
Rust	324	25
LOCA coating debris	120	10
IOZ coating debris	185	10
Armaflex	62	1000

3.3.3 *RMI Parameters*

Specification VYS-049 [Betti, 1997] lists the Vermont Yankee RMI to be comprised of 6 mil Al foils. Since a saturation thickness of such foils is to be considered in the analysis, no other information regarding these foils is required.

3.3.4 *Paint Chip Parameters*

The parameters needed to characterize the large paint chip debris are the paint density, paint chip thickness, and paint chip size. Each of these parameters is provided in specification VYS-049. Rather than providing a single size, a range of sizes is provided. These parameters are summarized below:

Density	-	94 lb/ft^3 (specific gravity of 1.5)	
Thickness	-	15 mil (average)	
Size characterization	-	1/8" x 1/8" to ½" x ½"	50%
		½" x ½" to 1" x 1"	25%
		1" x 1" to 2" x 2"	25%

Results from the C test series performed for Vermont Yankee at ARL indicated that paint debris could not be removed effectively from the suppression pool and deposited on the strainer under the Vermont Yankee ECCS strainer flow conditions of 0.02 to 0.04 ft/sec. At all turbulence levels, no paint debris could deposit on the strainer at strainer flow velocities less than 0.12 ft/sec. Consequently, paint debris was assigned a debris removal factor of zero for these calculations.

3.4 Miscellaneous Input Parameters

To perform a time dependent assessment of strainer head loss, or to estimate debris sedimentation subsequent to the termination of the high-energy chugging phase of the accident, the suppression pool volume is required as an input parameter. Specification VYS-049 provides a minimum value for this parameter of 68,000 cubic feet. (No such time dependent assessment has been included herein; the value is provided for information only).

4.0 ASSUMPTIONS

- The debris types, quantities, and (selected) characteristics; system flow rates; and fluid temperatures used in this calculation are taken directly from *Specification For RHR and CS Suction Strainers, VYS-049* [Betti, 1997]. These values will be assumed to be applicable for this analysis without further verification.
- The debris bed is formed and distributed uniformly over the surface of a strainer module.
- For strainers involving multiple modules, the core tube design is assumed to result in uniform flow along the combined length of both modules.
- The debris bed is homogeneous in composition, i.e., the particulate-to-fiber mass ratio remains constant along the debris bed.
- Particulate debris – IOZ, rust, sludge, and dirt/dust – are assumed to be spherical for the purpose of determining a surface-to-volume ratio.
- The test data from the C tests performed at ARL for Vermont Yankee are most representative of the ECCS strainer conditions for the purpose of determining an effective fiber diameter and a debris bed density for the mixed fiber bed.

5.0 CALCULATION RESULTS

Separate calculations are provided for the determination of head loss due to fiber/particulate debris and the determination of head loss due to RMI debris. In this calculation, head loss contribution due to large paint chip debris is set to zero based on test results.

5.1 Fiber/Particulate Head Loss Results

This section provides the results of calculations performed to determine ECCS suction strainer head loss due to the deposition of fibrous debris and entrained particulate. These results were obtained using the HLOSS 1.0 code, as discussed in Section 2. A complete description of HLOSS 1.0, including descriptions of input files and output files can be found in the HLOSS 1.0 reference manual [Mast and Souto, 1997].

Section 5.1.1 provides the supporting calculations needed to generate certain input values for the HLOSS 1.0 code. Section 5.1.2 provides the base-case head loss results for the DBA LOCA conditions. Section 5.1.3 provides the base-case head loss results for the IBA LOCA conditions. Section 5.1.4 provides parametric results for head loss as a function of debris quantity, debris types, flow rate, and fluid temperature for the DBA scenarios.

5.1.1 Supporting Calculations

Average Fibrous Debris Parameters: As indicated in Section 2.1.3, it is necessary to determine average values for the mixed bed fiber diameter and mixed bed fibrous debris density. The first of these parameters, 2.7×10^{-5} ft, is calculated using a debris volume-weighted average of the individual values. The average fibrous debris density, 2.1 lb/ft^3 for the DBA conditions and 2.4 lb/ft^3 for the IBA conditions, were estimated based on the analysis of the tests specifically conducted for Vermont Yankee [Copus, 1998].

Strainer Length/Surface Area Adjustment: As noted in Section 3.1, both the CS and RHR strainers are being fabricated in two modules (per side of the rams head for RHR), because the total length of these strainers would preclude their installation in one section. The HLOSS 1.0 code does not have the flexibility to model multiple, unequal strainer module lengths per flow channel. However, this limitation is easily overcome by modeling the combined length of the two modules as the sum of the actual module lengths plus an additional (fictitious) gap section. The cylindrical piping segments within the gaps are made of perforated plate, and thus the fictitious gap will be modeled as having a perforated cylindrical surface. Since in reality the piping between strainer modules is solid, this results in HLOSS 1.0 calculating too high a total strainer surface area. This can be easily negated by inputting the appropriate surface area reduction (a standard input variable in HLOSS 1.0). This area reduction is simply given by (AR=3.14159*gap-diameter*gap-width). Table 6 summarizes the actual strainer dimensions along with the values used in HLOSS 1.0, for both the CS and RHR strainers.

Table 6. Vermont Yankee: Strainer Dimensions Used in HLOSS 1.0 Analyses

Parameter	RHR (per side of Rams Head)		CS	
	Actual	Model	Actual	Model
Length	114.5"	119"	139"	144.5"
Area Reduction	0 sq-ft	2.55 sq-ft	0 sq-ft	3.12 sq-ft
Total area	811 sq-ft	808 sq-ft	433 sq-ft	433 sq-ft

Filtration Efficiency for Small Particulate Matter Debris: A parameter that must be specified in the HLOSS 1.0 input is the effect of a less than perfect filtration efficiency on the debris removal factor. As will be shown below, the calculated debris thickness for all scenarios is on the order of three inches or less. Based on the NUREG/CR-6224 filtration efficiency model, the filtration efficiency for small particulate matter debris (i.e., of about 10 μm in characteristic size) is 0.5. Although the initial filtration efficiency while the bed is thinner than ¼" is even lower, this effect was generally ignored for conservatism.

Note that these calculations conservatively ignore gravitational sedimentation onto the suppression pool floor for fibrous debris and particulate matter debris other than relatively large unqualified paint chips, which were shown to settle under the conditions at the ARL tests specifically conducted for Vermont Yankee [Copus, 1998]. To illustrate the conservatism associated with neglecting debris sedimentation, a limited calculation was conducted.

The HLOSS 1.0 computer code, used in this calculation note to estimate the head loss across a fibrous debris bed formed on the strainer surface, does not have mechanistic models for less than perfect filtration efficiency for particulate matter within the fibrous debris bed or for debris sedimentation onto the suppression pool floor. Instead, HLOSS 1.0 considers overall factors to account for filtration of particulate debris within the fibrous bed and debris sedimentation as part of the input data.

The BLOCKAGE 2.5 computer code, on the other hand, does have a mechanistic model for potential debris sedimentation onto the suppression pool floor. Hence, the BLOCKAGE 2.5 computer code is used in this calculation to illustrate the conservatism associated with neglecting gravitational sedimentation of debris onto the suppression pool floor. The following sections describe the rationale to model debris sedimentation using the BLOCKAGE 2.5 computer code, as well as the rationale used in this calculation to account for less than perfect filtration of particulate matter within the fibrous debris bed.

In these calculations, it is considered that sedimentation of debris in the suppression pool can not occur during the high-energy phase of a LOCA, which is assumed to last for about 60 s [GE, 1981][3]. In the settling tests performed for Vermont Yankee as part of the C test series at ARL, it was seen that after cessation of the high energy turbulence phase in the pool, the settling rates for fiber and paint debris were between 50% - 90% of those corresponding to the settling velocities for quiescent pools [Zigler, *et al*, 1995, p. B-30]. To have an upper bound, a turbulence correction factor of 0.5 which produces a settling history 2 times longer than that of the quiescent pool settling velocity was used in this calculation for each type of debris.

For fibrous debris and suppression pool sludge, the experimentally determined terminal settling velocity groups presented in the NUREG/CR-6224 study are used [Zigler, *et al*, 1995, pp. B-31 and B-33] as the baseline settling velocities. For dirt/dust particles, a single terminal settling velocity group, characterized by the median settling velocity determined for sludge (i.e., a terminal settling velocity of 0.01 ft/s (3 mm/s)) is used as a baseline value. No experimental data are available to estimate the sedimentation rate of rust flakes. However, with a characteristic size comparable to paint chips and a density factor between 2 and 3 higher, a very high sedimentation rate is expected for rust. For conservatism, a typical settling velocity for paint chips, 0.3 ft/s (90 mm/s), is used to characterize a single terminal settling velocity group for rust flakes.

Based on these considerations, the BLOCKAGE 2.5 computer code was used to provide guidance for the HLOSS 1.0 computer code calculations used in this analysis. To achieve this objective, the debris quantities and the flow rate conditions referred to in VY specification VYS-049 (pool volume = 68000 ft^3, total flow = 18600 gpm, total fiber = 502 lbm, total sludge = 772 lb, dirt = 50 lb, rust = 150 lbs) were used to prepare the BLOCKAGE 2.5 computer run presented in Attachment B. Note that the only purpose of this analysis with the BLOCKAGE 2.5 code is to estimate the debris sedimentation factors, which are not affected by the strainer dimensions or the total amounts of debris. Hence, the strainer dimensions and some of the debris amounts included in this BLOCKAGE 2.5 input data file are arbitrary and do not necessarily correspond to Vermont Yankee conditions.

The BLOCKAGE 2.5 calculations which provide additional support for the filtration factors used in the HLOSS 1.0 calculations are summarized in Table 7. The corresponding detailed BLOCKAGE 2.5 output file is presented in Attachment B.

[3] The Mark I containment Load Definition Report [GE, 1981], the turbulent phase due to chugging for a DBA lasts 65 s (about 1 min), whereas the corresponding phase for an IBA lasts for 905 s (about 15 min).

Table 7. VY: Debris Sedimentation Factors Calculated by BLOCKAGE 2.5

Debris	Initially in the Pool [ft^3]	Settled on floor or in piping [ft^3]	Sedimentation Fraction	HLOSS 1.0 Debris Removal Factor due to filtration alone
Fibrous	209	40.847	0.2	1
Rust Flakes	0.154	0.142	0.9	1
Dirt/Dust	1.0	0.509	0.5	0.5
Sludge	2.4	1.211	0.5	0.5

As indicated in Table 7, BLOCKAGE 2.5 calculations suggest that a factor of about 0.9 (or 90%) of the rust flakes (i.e., relatively large particulate matter debris) will settle onto the suppression pool floor following the highly turbulent conditions expected during blowdown, assuming that the turbulence level afterwards effectively reduces the settling velocity of these particles by a factor of 2 with respect to the average terminal settling velocity. Similarly, BLOCKAGE 2.5 calculations in Table 6 suggest that a factor of about 0.5 (or 50%) of the sludge or the dirt/dust particles will settle after the blowdown period. Note also that 20% of the relatively buoyant fiber debris tends to settle out of the pool. Although BLOCKAGE 2.5 calculations indicate greater amount of debris removal, the HLOSS 1.0 strainer performance analysis is conducted assuming no fibrous removal and only a 50% removal factor due to filtration (see Section 2.1.2) for small particulate matter debris.

5.1.2 Base Case Calculations – DBA LOCA Conditions

Using the design input parameters summarized in Section 3, along with the calculated parameters summarized in Section 5.1.1, each of the DBA LOCA flow/temperature/debris scenarios listed in specification VYS-049 was analyzed using the HLOSS 1.0 code. Although HLOSS 1.0 has the ability to perform time-dependent debris buildup and head loss calculations, only a simple steady-state head loss determination was made. (The time-dependence was already accounted for in the combination of parameters provided in specification VYS-049.)

The results of the HLOSS 1.0 analyses for all the DBA cases analyzed are presented in Table 8. Listed are the calculated head losses as well as the calculated debris thicknesses. The HLOSS 1.0 output files for each of these cases are provided in Attachment A.

It should be noted that some of the output labels for particulate debris constituents in HLOSS 1.0 are fixed, even though the actual material properties are user-defined inputs. Thus, the output parameters labeled "Dirt/Dust" actually correspond to LOCA jet-induced coatings debris, those labeled "Cal-Sil" correspond to Armaflex, and those labeled "Other" correspond to IOZ coatings debris.

Table 8. Vermont Yankee: DBA LOCA Base Case Head Loss Results.

Calculated Parameter	Units	RHR System			CS System			
		Case 1	Case 2a	Case 2b	Case 3a	Case 3b	Case 3c	Case 3d
Head Loss	Ft water	0.33	0.19	0.48	0.09	0.21	0.30	0.32
Debris thickness	inches	1.91	1.60	2.16	1.3	2.6	2.7	2.7

5.1.3 Base Case Calculations – IBA LOCA Conditions

The conditions specified for the IBA LOCA scenarios have a lower fiber/sludge debris ratio than the DBA conditions. The turbulent blowdown time is specified to be 900 seconds in this scenario and the sedimentation factor is conservatively assumed to be 1.0 (no sedimentation) for both fiber and sludge/rust/particulate. An initial fiber bed depth of ¼ inch NUKON fiber is assumed with a bed density of 2.4 lb/ft^3, an average fiber diameter of 2.33 x 10^{-5} ft, and a microscopic fiber density of 180 lb/ft^3. All of these input assumptions tend to conservatively pack the debris bed and result in higher calculated head loss values. Calculations for the IBA LOCA are presented in Table 9. A comparison between IBA calculations and DBA calculations indicates that the IBA case is comparable to the DBA case.

Table 9. Vermont Yankee: IBA LOCA Case Head Loss Results.

Calculated Parameter	Units	RHR System			CS System			
		Case 4	Case 5a	Case 5b	Case 6a	Case 6b	Case 6c	Case 6d
Head Loss	Ft water	0.19	0.25	0.42	0.10	0.24	0.30	0.34
Debris thickness	inches	0.21	0.19	0.16	0.25	0.19	0.18	0.17

5.1.4 Parametric Calculations for DBA LOCA Conditions

The results presented in Section 5.1.3 represent the head loss estimates for the base case set of conditions from a strainer performance perspective. It is desirable to also know what the head loss would be for somewhat different sets of conditions, including the limiting cases of a perfect filtration efficiency for all particulate matter debris, regardless of their characteristic size.

- The fibrous debris quantities provided in specification VYS-049 and used herein represent the bounding estimates of debris generation. It is quite likely that a different break location would generate less fibrous debris, while keeping the total particulate debris (mostly sludge) source term essentially constant. In addition, this parametric analysis includes the possibility of having a

110% fibrous insulation debris case. Accordingly, head loss estimates will be provided for varying fibrous debris loads down to a minimum value corresponding to an 1/8" layer of debris. At this thin of a debris layer, previous testing [Zigler, 1995] has shown that it is not possible to maintain a sufficiently uniform debris layer and that the associated head loss is very low.

- The temperatures specified in these calculations represent conservative, peak temperature estimates. Actual peak temperatures are expected to be lower. In addition, late in an accident, pool temperatures would start to decrease. Thus, head loss estimates will be provided for the temperature range of 40F to 180F.
- Flow rates may vary and will probably be lower. To understand how head loss varies with flow rate, head loss estimates will be provided for a range of flows [30-110%] of the nominal value.
- The amounts of sludge, qualified coating debris, paint chips, IOZ, and rust flakes provided in specification VYS-049 as input to the suppression pool could vary. Filtration through the fiber debris bed could also affect the amount of particulate debris in the fibrous debris bed. Head loss estimates are provided for particulate debris in the suppression pool which range from 50% to 300% of the amount in VYS-049.

Each of these parametric analyses was conducted for all seven of the base case DBA flow scenarios previously analyzed. The results are summarized in the following tables. These parametric results can be used to estimate the effect on head loss for the variation of the listed parameter over the range in its respective table. Combined effects of varying two parameters simultaneously or the effects of varying a parameter outside its range may not be reasonably predicted by extrapolation or combination of the tables. It should be noted that for the reduced fibrous debris quantity analyses, the particulate filtration efficiency used in these calculations was reduced according to the NUREG/CR-6224 algorithm for debris bed thicknesses less than ¼". The actual values used in the analyses are summarized in the appropriate tables.

Table 10. Vermont Yankee: Case 1 - Head Loss as a Function of Fiber Volume.

Fiber Volume (cu ft)	Debris Thickness (inches)	Head Loss (ft water)	Filtration Efficiency
176 (1.1 base case)	2.5*	.41	.5
160 (base case)	1.9*	.33	.5
144	2.1*	.21	.5
120	1.8	.12	.5
80	1.2	.12	.5
64	.96	.12	.5
48	.72	.12	.5
40	.6	.13	.5
24	.36	.14	.5
8	.12	.09	.24

* Strainer gaps are full, transition from full strainer area to a smaller cylindrical area. An "effective" debris thickness is calculated which accounts for the amount of debris held under each condition.

Table 11. Vermont Yankee: Case 1 - Head Loss as a Function of Fluid Temperature.

Fluid Temperature	Head Loss
(Deg F)	(ft water)
180	.31
173	.33
160	.36
140	.42
120	.47
100	.59
80	.67
60	.97
40	1.4

Table 12. Vermont Yankee: Case 1 - Head Loss as a Function of Pump Flow Rate.

Flow Rate	Head Loss
(GPM)	(ft water)
8000	.36
7400	.33
7000	.31
6000	.27
5000	.23
4000	.18
2000	.09

Table 13. Vermont Yankee: Case 1 - Head Loss as a Function of Sludge fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.26	.33	.49	.66

Note: The 2x case also represents 100% filtration efficiency

Table 14. Vermont Yankee: Case 1 - Head Loss as a Function of Qualified Coatings fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.31	.33	.38	.42

Note: The 2x case also represents 100% filtration efficiency

Table 15. Vermont Yankee: Case 1 - Head Loss as a Function of Rust Flakes fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.33	.33	.33	.33

Table 16. Vermont Yankee: Case 1 - Head Loss as a Function of Paint Chip fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.33	.33	.33	.33

Table 17. Vermont Yankee: Case 1 - Head Loss as a Function of ARMAFLEX fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.33	.33	.33	.33

Table 18. Vermont Yankee: Case 1 - Head Loss as a Function of IOZ fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.32	.33	.36	.40

Note: The 2x case also represents 100% filtration efficiency

Table 19. Vermont Yankee: Case 2a - Head Loss as a Function of Fiber Volume.

Fiber Volume (cu ft)	Debris Thickness (inches)	Head Loss (ft water)	Filtration Efficiency
119 (1.1 base case)	1.8	.2	.50
108 (base case)	1.6	.19	.50
79	1.2	.18	.50
52	.8	.17	.50
35	.5	.17	.50
17	.25	.09	.25
8.5	.12	.04	.12

Table 20. Vermont Yankee: Case 2a - Head Loss as a Function of Fluid Temperature.

Fluid Temperature	Head Loss
(Deg F)	(ft water)
180	.17
164	.19
160	.2
140	.23
120	.27
100	.33
80	.41
60	.55
40	.82

Table 21. Vermont Yankee: Case 2a - Head Loss as a Function of Pump Flow Rate.

Flow Rate	Head Loss
(GPM)	(ft water)
15000	.20
14200	.19
13500	.18
12000	.16
10000	.14
5000	.07

Table 22. Vermont Yankee: Case 2a - Head Loss as a Function of Sludge fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.15	.19	.28	.39

Note: The 2x case also represents 100% filtration efficiency

Table 23. Vermont Yankee: Case 2a - Head Loss as a Function of Qualified Coatings fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.18	.19	.22	.25

Note: The 2x case also represents 100% filtration efficiency

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Table 24. Vermont Yankee: Case 2a - Head Loss as a Function of Rust Flakes fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.19	.19	.19	.19

Table 25. Vermont Yankee: Case 2a - Head Loss as a Function of Paint Chip fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.19	.19	.19	.19

Table 26. Vermont Yankee: Case 2a - Head Loss as a Function of ARMAFLEX fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.19	.19	.19	.19

Table 27. Vermont Yankee: Case 2a - Head Loss as a Function of IOZ fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.18	.19	.21	.23

Note: The 2x case also represents 100% filtration efficiency

Table 28. Vermont Yankee: Case 2b - Head Loss as a Function of Fiber Volume.

Fiber Volume (cu ft)	Debris Thickness (inches)	Head Loss (ft water)	Filtration Efficiency
160 (1.1 base case)	1.9*	.66	0.50
145 (base case)	2.2*	.48	0.50
118	1.8	.24	0.50
95	1.4	.23	0.50
59	.88	.22	0.50
35	.53	.23	0.50
24	.35	.16	0.35
12	.18	.08	0.18

* Strainer gaps are full, transition from full strainer area to a smaller cylindrical area. An "effective" debris thickness is calculated which accounts for the amount of debris held under each condition.

Rev.	Orig.	Date	Chkd.	Date
1	PHM	8/6/98	JTS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

Table 29. Vermont Yankee: Case 2b - Head Loss as a Function of Fluid Temperature.

Fluid Temperature	Head Loss
(Deg F)	(ft water)
180	.45
170	.48
160	.52
140	.61
120	.69
100	.86
80	1.1
60	1.4
40	2.2

Table 30. Vermont Yankee: Case 2b - Head Loss as a Function of Pump Flow Rate.

Flow Rate	Head Loss
(GPM)	(ft water)
15000	.51
14200	.48
13500	.45
12000	.40
10000	.34
5000	.17

Table 31. Vermont Yankee: Case 2b - Head Loss as a Function of Sludge fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.38	.48	.71	1.02

Note: The 2x case also represents 100% filtration efficiency

Table 32. Vermont Yankee: Case 2b - Head Loss as a Function of Qualified Coatings fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.45	.48	.54	.61

Note: The 2x case also represents 100% filtration efficiency

Table 33. Vermont Yankee: Case 2b - Head Loss as a Function of Rust Flakes fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.48	.48	.48	.48

Table 34. Vermont Yankee: Case 2b - Head Loss as a Function of Paint Chip fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.48	.48	.48	.48

Table 35. Vermont Yankee: Case 2b - Head Loss as a Function of ARMAFLEX fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.48	.48	.48	.48

Table 36. Vermont Yankee: Case 2b - Head Loss as a Function of IOZ fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.45	.48	.52	.57

Note: The 2x case also represents 100% filtration efficiency

Table 37. Vermont Yankee: Case 3a - Head Loss as a Function of Fiber Volume.

Fiber Volume (cu ft)	Debris Thickness (inches)	Head Loss (ft water)	Filtration Efficiency
52 (1.1 base case)	1.4	.09	0.50
47 (base case)	1.3	.09	0.50
33	.93	.08	0.50
18	.5	.08	0.50
7.5	.2	.03	0.20

Table 38. Vermont Yankee: Case 3a - Head Loss as a Function of Fluid Temperature.

Fluid Temperature (Deg F)	Head Loss (ft water)
180	.08
164	.09
160	.09
140	.11
120	.12
100	.15
80	.19
60	.26
40	.35

Table 39. Vermont Yankee: Case 3a - Head Loss as a Function of Pump Flow Rate.

Flow Rate (GPM)	Head Loss (ft water)
5000	.1
4600	.09
4000	.08
2000	.04

Table 40. Vermont Yankee: Case 3a - Head Loss as a Function of Sludge fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.07	.09	.13	.18

Note: The 2x case also represents 100% filtration efficiency

Table 41. Vermont Yankee: Case 3a - Head Loss as a Function of Qualified Coatings fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.08	.09	.10	.12

Note: The 2x case also represents 100% filtration efficiency

Table 42. Vermont Yankee: Case 3a - Head Loss as a Function of Rust Flakes fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.09	.09	.09	.09

Table 43. Vermont Yankee: Case 3a - Head Loss as a Function of Paint Chip fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.09	.09	.09	.09

Table 44. Vermont Yankee: Case 3a - Head Loss as a Function of ARMAFLEX fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.09	.09	.09	.09

Table 45. Vermont Yankee: Case 3a - Head Loss as a Function of IOZ fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.09	.09	.10	.11

Note: The 2x case also represents 100% filtration efficiency

Table 46. Vermont Yankee: Case 3b - Head Loss as a Function of Fiber Volume.

Fiber Volume (cu ft)	Debris Thickness (inches)	Head Loss (ft water)	Filtration Efficiency
105 (1.1 base case)	2.2*	.32	0.50
95 (base case)	2.6*	.21	0.50
72	2.0	.14	0.50
46	1.3	.13	0.50
23	.6	.14	0.50
7.5	.2	.06	0.20

* Strainer gaps are full, transition from full strainer area to a smaller cylindrical area. An "effective" debris thickness is calculated which accounts for the amount of debris held under each condition.

Table 47. Vermont Yankee: Case 3b - Head Loss as a Function of Fluid Temperature.

Fluid Temperature	Head Loss
(Deg F)	(ft water)
180	.2
173	.21
160	.23
140	.27
120	.3
100	.38
80	.48
60	.62
40	.86

Table 48. Vermont Yankee: Case 3b - Head Loss as a Function of Pump Flow Rate.

Flow Rate	Head Loss
(GPM)	(ft water)
5000	.26
4000	.21
2000	.11

Table 49. Vermont Yankee: Case 3b - Head Loss as a Function of Sludge fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.17	.21	.32	.43

Note: The 2x case also represents 100% filtration efficiency

Table 50. Vermont Yankee: Case 3b - Head Loss as a Function of Qualified Coatings fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.20	.21	.24	.27

Note: The 2x case also represents 100% filtration efficiency

Table 51. Vermont Yankee: Case 3b - Head Loss as a Function of Rust Flakes fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.21	.21	.21	.21

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Table 52. Vermont Yankee: Case 3b - Head Loss as a Function of Paint Chip fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.21	.21	.21	.21

Table 53. Vermont Yankee: Case 3b - Head Loss as a Function of ARMAFLEX fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.21	.21	.21	.21

Table 54. Vermont Yankee: Case 3b - Head Loss as a Function of IOZ fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.20	.21	.23	.26

Note: The 2x case also represents 100% filtration efficiency

Table 55. Vermont Yankee: Case 3c - Head Loss as a Function of Fiber Volume.

Fiber Volume (cu ft)	Debris Thickness (inches)	Head Loss (ft water)	Filtration Efficiency
108 (1.1 base case)	2.4*	.38	0.50
98 (base case)	2.7*	.28	0.50
72	2.0	.16	0.50
40	1.1	.15	0.50
24	.67	.16	0.50
8	.22	.07	0.22

* Strainer gaps are full, transition from full strainer area to a smaller cylindrical area. An "effective" debris thickness is calculated which accounts for the amount of debris held under each condition.

Table 56. Vermont Yankee: Case 3c - Head Loss as a Function of Fluid Temperature.

Fluid Temperature (Deg F)	Head Loss (ft water)
180	.29
173	.3
160	.34
140	.39
120	.45
100	.56
80	.7
60	.91
40	1.3

Table 57. Vermont Yankee: Case 3c - Head Loss as a Function of Pump Flow Rate.

Flow Rate (GPM)	Head Loss (ft water)
5000	.35
4300	.3
4000	.28
2000	.14

Table 58. Vermont Yankee: Case 3c - Head Loss as a Function of Sludge fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.24	.30	.45	.61

Note: The 2x case also represents 100% filtration efficiency

Table 59. Vermont Yankee: Case 3c - Head Loss as a Function of Qualified Coatings fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.28	.30	.34	.39

Note: The 2x case also represents 100% filtration efficiency

Table 60. Vermont Yankee: Case 3c - Head Loss as a Function of Rust Flakes fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.30	.30	.30	.30

Table 61. Vermont Yankee: Case 3c - Head Loss as a Function of Paint Chip fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.30	.30	.30	.30

Table 62. Vermont Yankee: Case 3c - Head Loss as a Function of ARMAFLEX fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.30	.30	.30	.30

Table 63. Vermont Yankee: Case 3c - Head Loss as a Function of IOZ fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.20	.30	.33	.37

Note: The 2x case also represents 100% filtration efficiency

Table 64. Vermont Yankee: Case 3d - Head Loss as a Function of Fiber Volume.

Fiber Volume (cu ft)	Debris Thickness (inches)	Head Loss (ft water)	Filtration Efficiency
108 (1.1 base case)	2.4*	.41	0.50
98 (base case)	2.7*	.30	0.50
72	2.0	.17	0.50
40	1.1	.16	0.50
24	.67	.17	0.50
8	.22	.08	0.22

* Strainer gaps have filled, transition to cylindrical area.

Table 65. Vermont Yankee: Case 3d - Head Loss as a Function of Fluid Temperature.

Fluid Temperature (Deg F)	Head Loss (ft water)
180	.31
173	.32
160	.36
140	.42
120	.48
100	.59
80	.74
60	.96
40	1.3

Table 66. Vermont Yankee: Case 3d - Head Loss as a Function of Pump Flow Rate.

Flow Rate (GPM)	Head Loss (ft water)
5000	.35
4600	.32
4000	.28
2000	.14

Table 67. Vermont Yankee: Case 3d - Head Loss as a Function of Sludge fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.25	.32	.48	.65

Note: The 2x case also represents 100% filtration efficiency

Table 68. Vermont Yankee: Case 3d - Head Loss as a Function of Qualified Coatings fraction

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	30	.32	.36	.41

Note: The 2x case also represents 100% filtration efficiency

Table 69. Vermont Yankee: Case 3d - Head Loss as a Function of Rust Flakes fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.32	.32	.32	.32

Table 70. Vermont Yankee: Case 3d - Head Loss as a Function of Paint Chip fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.32	.32	.32	.32

Table 71. Vermont Yankee: Case 3d - Head Loss as a Function of ARMAFLEX fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.32	.32	.32	.32

Table 72. Vermont Yankee: Case 3d - Head Loss as a Function of IOZ fraction.

Debris Fraction	.5x	1x	2x	3x
Head Loss (ft. water)	.31	.32	.35	.39

Note: The 2x case also represents 100% filtration efficiency

In reviewing these results several conclusions can be reached.

- For the range of flow rates relevant to the Vermont Yankee strainer performance assessment, head loss is essentially a linear function of flow rate, indicating that flow through the debris bed is laminar.
- Because the flow through the debris is laminar, the temperature dependence of the head loss is proportional to the temperature dependence of the fluid viscosity.
- Variation in head loss as a function of fibrous debris quantity is not a simple function. Over most of the range explored, the variation in head loss is relatively small. The reason for this is the constant quantity of particulate debris assumed in these calculations. Thus, even at lower fiber quantities, the increasing particulate to fiber mass ratio keeps head loss nearly constant. At very low fiber quantities (less than ½" debris thickness), head loss shows the potential for increasing. However, the decreasing filtration efficiency for these thin debris beds becomes an important factor, such that overall head loss decreases as the minimum bed thickness of 1/8" is reached.
- For the ranges of particulate debris studied, head loss is totally insensitive to variations in rust flakes (due primarily to their small mass and small contribution to the surface to volume ratio), paint chips (due to their inability to accumulate effectively in the debris bed), and ARMAFLEX insulation (due to its inability to accumulate effectively in the debris bed). Head loss is relatively insensitive to the variations in the debris amounts of qualified coatings and IOZ due to their relatively small mass fractions in the debris bed. For the sludge debris amounts studied, head loss varies by approximately a factor of two if the amount in the suppression pool is increased by a factor of three.

5.2 RMI Head Loss Results

Head loss due to a saturation bed thickness of RMI is calculated using the approach outlined in Section 2.2. To do this, we note that the average settling velocity, U_s, for the 6 mil AL foils is 0.25 ft/sec [Diertl, *et al*, 1996]. Using the thickness constant for 6 mil Al foils given by K_t = 0.073 ft [Diertl, *et al*, 1996], the saturation bed thickness, τ_s, and subsequent head loss can then be calculated. The results of these calculations are shown in Table 72 for each of the seven cases analyzed.

Table 73. Vermont Yankee: RMI Head Loss Calculation Results.

Strainer Parameter	Units	RHR System			CS System			
		Case 1	Case 2a	Case 2b	Case 3a	Case 3b	Case 3c	Case 3d
D	(inches)	47	47	47	47	47	47	47
L	(inches)	229	229	229	139	139	139	139
A_c	(sq ft)	234.8	234.8	234.8	142.5	142.5	142.5	142.5
Q	(GPM)	7400	14200	14200	4600	4000	4300	4600
U	ft/sec	0.07	0.13	0.13	0.07	0.06	0.07	0.07
τ_s	(ft)	0	0.16	0.16	0	0	0	0
Head Loss	(ft-water)	0	0.003	0.003	0	0	0	0

It should be noted that the length listed for the RHR strainer (Cases 1 and 2) corresponds to the combined length for both sides of the ram's head (since the total flow for both sides of the ram's head is also listed). By using the conservative definition of strainer surface area given in the URG (which ignores the area associated with the ends of the strainer), one calculates a strainer approach velocity for Case 2 that just barely exceeds half the RMI foil settling velocity. The associated head loss for the RMI foils is less than 0.005 ft-water, and is thus negligible. For all other cases analyzed, the RMI head loss is identically zero.

It should further be noted that use of the actual strainer circumscribed area for Case 2 (given as 279.7 sq ft in the HLOSS 1.0 output) would also result in a calculated strainer approach velocity that is less than half the RMI settling velocity. In that case, the calculated RMI head loss for Cases 2a and 2b would be identically zero.

6.0 SUMMARY AND CONCLUSIONS

A determination of the head loss across the newly designed ECCS inlet suction strainers at the Vermont Yankee nuclear station as a result of debris accumulation following a postulated loss of coolant accident (LOCA) has been presented. These analyses showed the following:

- Head loss due to RMI debris is negligible for both the RHR and CS strainers.
- Head loss due fibrous debris and entrained particulate is limited to 0.48 ft-water for the RHR strainers and 0.32 ft-water for the CS strainers under the specified DBA combinations of pump flow rate, debris loading, and fluid temperature.
- Calculated debris bed thicknesses are slightly greater than that required to fill the gaps in the stacked disk strainer design being used at Vermont Yankee.
- Head losses calculated in the "thin-bed regime", wherein particulate to fiber mass ratios are maximized, do not exceed the head losses calculated for the specified DBA cases.

In addition to the base-case results, a series of parametric analyses were presented to determine the effect on calculated head loss of varying fibrous debris loads, particulate debris loads, pump flow rate, and fluid temperature.

The results presented herein are considered to be quite conservative. In addition to conservatism built into the design input on debris source term and pump flow rates, there are several additional modeling assumptions that are known to be conservative. These include:

- At the low flow rates at the strainer surface, it has been observed that debris buildup will be non-uniform, resulting in a lower head loss than predicted.
- Settling of fiber was not considered. It has previously been shown that in the later stages of the accident (following termination of the chugging phase), sedimentation of both fiber and small particulate will occur [Zigler, *et al*, 1995].
- A source term for rust debris was included, even though it has been observed that similar fragments of paint debris will not deposit on the strainer.

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ATTACHMENT A: BASE CASE HLOSS 1.0 OUTPUT FILES

Rev.	Orig.	Date	Chkd.	Date	
1	P/MM	8/6/98	TS	8/6/98	**Client/Project:** Vermont Yankee Nuclear Power Corporation
					Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
					Project No.: A346
					Calc. No.: DC-A34600.006 **Sht.** 50 **of** 86

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07-Jul-98
10:04:02

Strainer Head Loss Calculation for Vermont-Yankee - Case: 1 (DBA)

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	173.00
Strainer Flow Rate (gpm)	-	3700.00
Total Flow Rate (gpm)	-	7400.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	.500
Fluid Density (lb/cu-ft)	-	60.73
Fluid Viscosity (lb/ft/sec)	-	.246E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	119.00
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	19
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	4.5000
Max Debris Thickness (in)	-	2.0000
Input Surf Area Reduct (sq ft)	-	2.55
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	404.32
Circumscribed Area (sq ft)	-	142.98
Total Gap Volume (cu ft)	-	56.44

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	160.00	336.00	1.00	1.00
Sludge		546.00	1.00	.50
Dirt/Dust		61.00	1.00	.50
Rust Flakes		35.30	1.00	1.00
Paint Chips		524.40	.00	1.00
Cal Sil		82.50	.00	1.00
Other		70.00	1.00	.50

Rev.	Orig.	Date	Chkd.	Date
1	PHM	8/6/98	FB	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006 **Sht.** 51 **of** 86

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STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	80.00	168.00	2.10		
Fiber (micro)	.95	168.00	177.00	.270E-04	148148.10
Sludge	.42	136.50	324.00	.328E-04	182882.20
Dirt/Dust	.13	15.25	120.00	.328E-04	182882.20
Rust Flakes	.05	17.65	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.09	17.50	185.00	.328E-04	182882.20
Ave Particles	.70	186.90	267.98		170503.00
Ave Debris					158742.70

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.33	.058	1.911	1.911	.021

Deposition Flag = cylindrical deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .053

Rev.	Orig.	Date	Chkd.	Date
1	PJM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006 **Sht.** 52 **of** 86

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07-Jul-98
10:07:38

Strainer Head Loss Calculation for Vermont-Yankee - Case: 2a

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	164.00
Strainer Flow Rate (gpm)	-	7100.00
Total Flow Rate (gpm)	-	14200.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	.500
Fluid Density (lb/cu-ft)	-	60.92
Fluid Viscosity (lb/ft/sec)	-	.262E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	119.00
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	19
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	4.5000
Max Debris Thickness (in)	-	2.0000
Input Surf Area Reduct (sq ft)	-	2.55
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	404.32
Circumscribed Area (sq ft)	-	142.98
Total Gap Volume (cu ft)	-	56.44

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	108.00	226.80	1.00	1.00
Sludge		366.00	1.00	.50
Dirt/Dust		41.00	1.00	.50
Rust Flakes		23.70	1.00	1.00
Paint Chips		1026.00	.00	1.00
Cal Sil		55.50	.00	1.00
Other		47.00	1.00	.50

Rev.	Orig.	Date	Chkd.	Date
1	PMM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006

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STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	54.00	113.40	2.10		
Fiber (micro)	.64	113.40	177.00	.270E-04	148148.10
Sludge	.28	91.50	324.00	.328E-04	182882.20
Dirt/Dust	.09	10.25	120.00	.328E-04	182882.20
Rust Flakes	.04	11.85	324.00	.820E-04	24390.24
Paint Chips	.00	.00	5.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.06	11.75	185.00	.328E-04	182882.20
Ave Particles	.47	125.35	267.89		170493.80
Ave Debris					158702.50

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.19	.039	1.603	1.603	.021

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .039

Rev.	Orig.	Date	Chkd.	Date
1	PWM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

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07-Jul-98
10:09:26

Strainer Head Loss Calculation for Vermont-Yankee - Case: 2b-Base

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	170.00
Strainer Flow Rate (gpm)	-	7100.00
Total Flow Rate (gpm)	-	14200.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	.500
Fluid Density (lb/cu-ft)	-	60.80
Fluid Viscosity (lb/ft/sec)	-	.251E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	119.00
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	19
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	4.5000
Max Debris Thickness (in)	-	1.9500
Input Surf Area Reduct (sq ft)	-	2.55
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	404.32
Circumscribed Area (sq ft)	-	142.98
Total Gap Volume (cu ft)	-	56.44

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	145.30	305.13	1.00	1.00
Sludge		497.00	1.00	.50
Dirt/Dust		55.00	1.00	.50
Rust Flakes		32.20	1.00	1.00
Paint Chips		1026.00	.00	1.00
Cal Sil		75.00	.00	1.00
Other		64.00	1.00	.50

Rev.	Orig.	Date	Chkd.	Date
1	PYM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006 Sht. 55 of 86

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	72.65	152.57	2.10		
Fiber (micro)	.86	152.57	177.00	.270E-04	148148.10
Sludge	.38	124.25	324.00	.328E-04	182882.20
Dirt/Dust	.11	13.75	120.00	.328E-04	182882.20
Rust Flakes	.05	16.10	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.09	16.00	185.00	.328E-04	182882.20
Ave Particles	.63	170.10	268.19		170464.90
Ave Debris					158737.40

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.48	.110	2.156	2.156	.021

Deposition Flag = transition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .103

Rev.	Orig.	Date	Chkd.	Date
1	PYM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

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07-Jul-98
10:12:09

Strainer Head Loss Calculation for Vermont-Yankee - Case: 3a

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	164.00
Strainer Flow Rate (gpm)	-	4600.00
Total Flow Rate (gpm)	-	4600.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	1.000
Fluid Density (lb/cu-ft)	-	60.92
Fluid Viscosity (lb/ft/sec)	-	.262E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	144.50
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	24.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	20
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	5.5000
Max Debris Thickness (in)	-	2.5000
Input Surf Area Reduct (sq ft)	-	3.12
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	432.71
Circumscribed Area (sq ft)	-	165.98
Total Gap Volume (cu ft)	-	72.81

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	46.00	96.60	1.00	1.00
Sludge		156.00	1.00	.50
Dirt/Dust		18.00	1.00	.50
Rust Flakes		10.10	1.00	1.00
Paint Chips		356.00	.00	1.00
Cal Sil		24.00	.00	1.00
Other		20.00	1.00	.50

Rev.	Orig.	Date	Chkd.	Date
1	PVM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	46.00	96.60	2.10		
Fiber (micro)	.55	96.60	177.00	.270E-04	148148.10
Sludge	.24	78.00	324.00	.328E-04	182882.20
Dirt/Dust	.08	9.00	120.00	.328E-04	182882.20
Rust Flakes	.03	10.10	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.05	10.00	185.00	.328E-04	182882.20
Ave Particles	.40	107.10	267.10		170560.40
Ave Debris					158762.30

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.09	.024	1.276	1.276	.021

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .024

Rev.	Orig.	Date	Chkd.	Date
1	PHM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

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13-Mar-98
16:29:49

Strainer Head Loss Calculation for Vermont-Yankee - Case: 3b-with_100%_Nukon

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	173.00
Strainer Flow Rate (gpm)	-	4000.00
Total Flow Rate (gpm)	-	4000.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	1.000
Fluid Density (lb/cu-ft)	-	60.73
Fluid Viscosity (lb/ft/sec)	-	.246E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	144.50
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	24.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	20
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	5.5000
Max Debris Thickness (in)	-	2.5000
Input Surf Area Reduct (sq ft)	-	3.12
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	432.71
Circumscribed Area (sq ft)	-	165.98
Total Gap Volume (cu ft)	-	72.81

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	94.40	198.24	1.00	1.00
Sludge		322.00	1.00	.50
Dirt/Dust		36.00	1.00	.50
Rust Flakes		20.80	1.00	1.00
Paint Chips		356.00	.00	1.00
Cal Sil		48.50	.00	1.00
Other		42.00	1.00	.50

Rev.	Orig.	Date	Chkd.	Date
1	PYM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006

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STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	94.40	198.24	2.10		
Fiber (micro)	1.12	198.24	177.00	.270E-04	148148.10
Sludge	.50	161.00	324.00	.328E-04	182882.20
Dirt/Dust	.15	18.00	120.00	.328E-04	182882.20
Rust Flakes	.06	20.80	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.11	21.00	185.00	.328E-04	182882.20
Ave Particles	.82	220.80	267.76		170543.50
Ave Debris					158769.20

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.21	.054	2.618	2.618	.021

Deposition Flag = transition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .050

Rev.	Orig.	Date	Chkd.	Date
1	PMM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

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13-Mar-98
16:39:07

Strainer Head Loss Calculation for Vermont-Yankee - Case: 3c-with_100%_Nukon

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	173.00
Strainer Flow Rate (gpm)	-	4300.00
Total Flow Rate (gpm)	-	4300.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	1.000
Fluid Density (lb/cu-ft)	-	60.73
Fluid Viscosity (lb/ft/sec)	-	.246E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	144.50
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	24.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	20
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	5.5000
Max Debris Thickness (in)	-	2.5000
Input Surf Area Reduct (sq ft)	-	3.12
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	432.71
Circumscribed Area (sq ft)	-	165.98
Total Gap Volume (cu ft)	-	72.81

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	98.40	206.64	1.00	1.00
Sludge		336.00	1.00	.50
Dirt/Dust		37.00	1.00	.50
Rust Flakes		21.70	1.00	1.00
Paint Chips		356.00	.00	1.00
Cal Sil		51.00	.00	1.00

Rev.	Orig.	Date	Chkd.	Date
1	PMM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

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Other	43.00	1.00	.50

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	98.40	206.64	2.10		
Fiber (micro)	1.17	206.64	177.00	.270E-04	148148.10
Sludge	.52	168.00	324.00	.328E-04	182882.20
Dirt/Dust	.15	18.50	120.00	.328E-04	182882.20
Rust Flakes	.07	21.70	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.12	21.50	185.00	.328E-04	182882.20
Ave Particles	.86	229.70	268.38		170479.70
Ave Debris					158720.30

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.30	.058	2.729	2.729	.021

Deposition Flag = transition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .053

Rev.	Orig.	Date	Chkd.	Date
1	PM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

13-Mar-98
16:42:37
Strainer Head Loss Calculation for Vermont-Yankee - Case: 3d-with_100%_Nukon

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	173.00
Strainer Flow Rate (gpm)	-	4600.00
Total Flow Rate (gpm)	-	4600.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	1.000
Fluid Density (lb/cu-ft)	-	60.73
Fluid Viscosity (lb/ft/sec)	-	.246E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	144.50
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	24.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	20
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	5.5000
Max Debris Thickness (in)	-	2.5000
Input Surf Area Reduct (sq ft)	-	3.12
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	432.71
Circumscribed Area (sq ft)	-	165.98
Total Gap Volume (cu ft)	-	72.81

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	98.30	206.43	1.00	1.00
Sludge		336.00	1.00	.50
Dirt/Dust		37.00	1.00	.50
Rust Flakes		21.70	1.00	1.00
Paint Chips		356.00	.00	1.00
Cal Sil		51.00	.00	1.00
Other		43.00	1.00	.50

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	98.30	206.43	2.10		
Fiber (micro)	1.17	206.43	177.00	.270E-04	148148.10
Sludge	.52	168.00	324.00	.328E-04	182882.20
Dirt/Dust	.15	18.50	120.00	.328E-04	182882.20

Rev.	Orig.	Date	Chkd.	Date
1	PVM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006 **Sht.** 63 **of** 86

DE&S Duke Engineering & Services

Rust Flakes	.07	21.70	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.12	21.50	185.00	.328E-04	182882.20
Ave Particles	.86	229.70	268.38		170479.70
Ave Debris					158726.50

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.32	.062	2.726	2.726	.021

Deposition Flag = transition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .057

Rev.	Orig.	Date	Chkd.	Date
1	PHM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

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31-Jul-98
11:20:27

Strainer Head Loss Calculation for Vermont-Yankee - Case: 4

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	173.00
Strainer Flow Rate (gpm)	-	3700.00
Total Flow Rate (gpm)	-	7400.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	.500
Fluid Density (lb/cu-ft)	-	60.73
Fluid Viscosity (lb/ft/sec)	-	.246E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	119.00
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	19
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	4.5000
Max Debris Thickness (in)	-	2.0000
Input Surf Area Reduct (sq ft)	-	2.55
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	404.32
Circumscribed Area (sq ft)	-	142.98
Total Gap Volume (cu ft)	-	56.44

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	16.72	40.13	1.00	1.00
Sludge		546.00	1.00	.50
Dirt/Dust		61.00	1.00	.50
Rust Flakes		35.30	1.00	1.00
Paint Chips		.00	.00	.00
Cal Sil		.00	.00	.00
Other		70.00	1.00	.50

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	8.36	20.06	2.40		
Fiber (micro)	.11	20.06	180.00	.233E-04	171673.80
Sludge	.42	136.50	324.00	.328E-04	182882.20
Dirt/Dust	.13	15.25	120.00	.328E-04	182882.20

Rev.	Orig.	Date	Chkd.	Date
1	PYM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006 **Sht.** 65 **of** 86

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Rust Flakes	.05	17.65	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.09	17.50	185.00	.328E-04	182882.20
Ave Particles	.70	186.90	267.98		170503.00
Ave Debris					172644.40

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.19	.020	.248	.209	.115

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .020

Rev.	Orig.	Date	Chkd.	Date
1	PMM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006 Sht. 66 of 86

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31-Jul-98
11:25:41

Strainer Head Loss Calculation for Vermont-Yankee - Case: 5a

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	164.00
Strainer Flow Rate (gpm)	-	7100.00
Total Flow Rate (gpm)	-	14200.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	.500
Fluid Density (lb/cu-ft)	-	60.92
Fluid Viscosity (lb/ft/sec)	-	.262E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	119.00
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	19
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	4.5000
Max Debris Thickness (in)	-	2.0000
Input Surf Area Reduct (sq ft)	-	2.55
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	404.32
Circumscribed Area (sq ft)	-	142.98
Total Gap Volume (cu ft)	-	56.44

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	16.72	40.13	1.00	1.00
Sludge		366.00	1.00	.50
Dirt/Dust		41.00	1.00	.50
Rust Flakes		23.70	1.00	1.00
Paint Chips		.00	.00	.00
Cal Sil		.00	.00	.00
Other		47.00	1.00	.50

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	8.36	20.06	2.40		
Fiber (micro)	.11	20.06	180.00	.233E-04	171673.80
Sludge	.28	91.50	324.00	.328E-04	182882.20
Dirt/Dust	.09	10.25	120.00	.328E-04	182882.20

Rev.	Orig.	Date	Chkd.	Date
1	PKM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006 **Sht.** 67 **of** 86

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Rust Flakes	.04	11.85	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.06	11.75	185.00	.328E-04	182882.20
Ave Particles	.47	125.35	267.89		170493.80
Ave Debris					172576.50

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.25	.039	.248	.192	.090

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .039

Rev.	Orig.	Date	Chkd.	Date
1	PWM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

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31-Jul-98
11:29:12

Strainer Head Loss Calculation for Vermont-Yankee - Case: 5b

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	170.00
Strainer Flow Rate (gpm)	-	7100.00
Total Flow Rate (gpm)	-	14200.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	.500
Fluid Density (lb/cu-ft)	-	60.80
Fluid Viscosity (lb/ft/sec)	-	.251E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	119.00
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	19
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	4.5000
Max Debris Thickness (in)	-	2.0000
Input Surf Area Reduct (sq ft)	-	2.55
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	404.32
Circumscribed Area (sq ft)	-	142.98
Total Gap Volume (cu ft)	-	56.44

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	16.72	40.13	1.00	1.00
Sludge		497.00	1.00	.50
Dirt/Dust		55.00	1.00	.50
Rust Flakes		32.20	1.00	1.00
Paint Chips		.00	.00	.00
Cal Sil		.00	.00	.00
Other		64.00	1.00	.50

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	8.36	20.06	2.40		
Fiber (micro)	.11	20.06	180.00	.233E-04	171673.80
Sludge	.38	124.25	324.00	.328E-04	182882.20
Dirt/Dust	.11	13.75	120.00	.328E-04	182882.20

Rev.	Orig.	Date	Chkd.	Date
1	PVM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006

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Rust Flakes	.05	16.10	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.09	16.00	185.00	.328E-04	182882.20
Ave Particles	.63	170.10	268.19		170464.90
Ave Debris					172604.50

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.42	.039	.248	.156	.142

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .039

Rev.	Orig.	Date	Chkd.	Date
1	PMM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

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31-Jul-98
11:37:32

Strainer Head Loss Calculation for Vermont-Yankee - Case: 6a

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	164.00
Strainer Flow Rate (gpm)	-	4600.00
Total Flow Rate (gpm)	-	4600.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	1.000
Fluid Density (lb/cu-ft)	-	60.92
Fluid Viscosity (lb/ft/sec)	-	.262E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	144.50
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	24.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	20
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	5.5000
Max Debris Thickness (in)	-	2.5000
Input Surf Area Reduct (sq ft)	-	3.12
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	432.71
Circumscribed Area (sq ft)	-	165.98
Total Gap Volume (cu ft)	-	72.81

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	9.00	21.60	1.00	1.00
Sludge		156.00	1.00	.50
Dirt/Dust		18.00	1.00	.50
Rust Flakes		10.10	1.00	1.00
Paint Chips		.00	.00	.00
Cal Sil		.00	.00	.00
Other		20.00	1.00	.50

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	9.00	21.60	2.40		
Fiber (micro)	.12	21.60	180.00	.233E-04	171673.80
Sludge	.24	78.00	324.00	.328E-04	182882.20
Dirt/Dust	.08	9.00	120.00	.328E-04	182882.20

Rev.	Orig.	Date	Chkd.	Date
1	PVM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006

DE&S
Duke Engineering & Services

Rust Flakes	.03	10.10	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.05	10.00	185.00	.328E-04	182882.20
Ave Particles	.40	107.10	267.10		170560.40
Ave Debris					172576.10

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.10	.024	.250	.250	.058

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .024

Rev.	Orig.	Date	Chkd.	Date
1	[signature]	8/6/98	[signature]	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

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31-Jul-98
12:21:19

Strainer Head Loss Calculation for Vermont-Yankee - Case: 6b

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	173.00
Strainer Flow Rate (gpm)	-	4000.00
Total Flow Rate (gpm)	-	4000.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	1.000
Fluid Density (lb/cu-ft)	-	60.73
Fluid Viscosity (lb/ft/sec)	-	.246E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	144.50
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	24.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	20
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	5.5000
Max Debris Thickness (in)	-	2.5000
Input Surf Area Reduct (sq ft)	-	3.12
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	432.71
Circumscribed Area (sq ft)	-	165.98
Total Gap Volume (cu ft)	-	72.81

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	9.00	21.60	1.00	1.00
Sludge		322.00	1.00	.50
Dirt/Dust		36.00	1.00	.50
Rust Flakes		20.80	1.00	1.00
Paint Chips		.00	.00	.00
Cal Sil		.00	.00	.00
Other		42.00	1.00	.50

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	9.00	21.60	2.40		
Fiber (micro)	.12	21.60	180.00	.233E-04	171673.80
Sludge	.50	161.00	324.00	.328E-04	182882.20
Dirt/Dust	.15	18.00	120.00	.328E-04	182882.20

Rev.	Orig.	Date	Chkd.	Date
1	PYM	8/6/98	TS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006

DE&S Duke Engineering & Services

Rust Flakes	.06	20.80	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.11	21.00	185.00	.328E-04	182882.20
Ave Particles	.82	220.80	267.76		170543.50
Ave Debris					172685.60

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.24	.021	.250	.193	.135

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .021

Rev.	Orig.	Date	Chkd.	Date
1	PHM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
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DE&S
Duke Engineering & Services

31-Jul-98
12:25:58

Strainer Head Loss Calculation for Vermont-Yankee - Case: 6c

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	173.00
Strainer Flow Rate (gpm)	-	4300.00
Total Flow Rate (gpm)	-	4300.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	1.000
Fluid Density (lb/cu-ft)	-	60.73
Fluid Viscosity (lb/ft/sec)	-	.246E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	144.50
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	24.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	20
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	5.5000
Max Debris Thickness (in)	-	2.5000
Input Surf Area Reduct (sq ft)	-	3.12
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	432.71
Circumscribed Area (sq ft)	-	165.98
Total Gap Volume (cu ft)	-	72.81

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	9.00	21.60	1.00	1.00
Sludge		336.00	1.00	.50
Dirt/Dust		37.00	1.00	.50
Rust Flakes		21.70	1.00	1.00
Paint Chips		.00	.00	.00
Cal Sil		.00	.00	.00
Other		43.00	1.00	.50

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	9.00	21.60	2.40		
Fiber (micro)	.12	21.60	180.00	.233E-04	171673.80
Sludge	.52	168.00	324.00	.328E-04	182882.20
Dirt/Dust	.15	18.50	120.00	.328E-04	182882.20

Rev.	Orig.	Date	Chkd.	Date
1	PMM	8/6/98	FB	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006

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Rust Flakes	.07	21.70	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.12	21.50	185.00	.328E-04	182882.20
Ave Particles	.86	229.70	268.38		170479.70
Ave Debris					172644.30

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.30	.022	.250	.179	.151

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .022

Rev.	Orig.	Date	Chkd.	Date
1	PJM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
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Project No.: A346
Calc. No.: DC-A34600.006

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31-Jul-98
12:29:32

Strainer Head Loss Calculation for Vermont-Yankee - Case: 6d

Time Into the Transient (sec) - 0.

FLOW CONDITIONS:

Temperature (Deg F)	-	173.00
Strainer Flow Rate (gpm)	-	4600.00
Total Flow Rate (gpm)	-	4600.00
Suppression Pool Volume (cu-ft)	-	68000.
Debris Removed from Pool (frac)	-	1.000
Debris Deposited on Strainer (frac)	-	1.000
Fluid Density (lb/cu-ft)	-	60.73
Fluid Viscosity (lb/ft/sec)	-	.246E-03

STRAINER PARAMETERS:

Strainer Type	-	3
Length (in)	-	144.50
Strainer Diameter - Disk (in)	-	47.00
Strainer Diameter - Gaps (in)	-	26.00
Inlet Pipe Diameter (in)	-	24.00
Outlet Pipe Diameter (in)	-	24.00
Inner Cylinder Perforation Switch	-	1
Number of Disks	-	20
Disk Thickness (in)	-	2.0000
Gap Thickness (in)	-	5.5000
Max Debris Thickness (in)	-	2.5000
Input Surf Area Reduct (sq ft)	-	3.12
Input Circ Area Reduct (sq ft)	-	.00
Input Gap Vol Reduct (cu ft)	-	.00
Full Surface Area (sq ft)	-	432.71
Circumscribed Area (sq ft)	-	165.98
Total Gap Volume (cu ft)	-	72.81

SUPPRESSION POOL DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	FSP	FDB
Fiber	9.00	21.60	1.00	1.00
Sludge		336.00	1.00	.50
Dirt/Dust		37.00	1.00	.50
Rust Flakes		21.70	1.00	1.00
Paint Chips		.00	.00	.00
Cal Sil		.00	.00	.00
Other		43.00	1.00	.50

STRAINER DEBRIS PARAMETERS:

	Volume (cu ft)	Mass (lb)	Density (lb/cu-ft)	Size (ft)	SV (ft**-1)
Fiber (macro)	9.00	21.60	2.40		
Fiber (micro)	.12	21.60	180.00	.233E-04	171673.80
Sludge	.52	168.00	324.00	.328E-04	182882.20
Dirt/Dust	.15	18.50	120.00	.328E-04	182882.20

Rev.	Orig.	Date	Chkd.	Date
1	[signature]	8/6/98	[signature]	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006 **Sht.** 77 **of** 86

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Rust Flakes	.07	21.70	324.00	.820E-04	24390.24
Paint Chips	.00	.00	94.00	.125E-03	16000.00
Cal Sil	.00	.00	62.00	.328E-02	1828.82
Other	.12	21.50	185.00	.328E-04	182882.20
Ave Particles	.86	229.70	268.38		170479.70
Ave Debris					172644.30

Maximum Bed Solidity - .200
Compression Factor - 1.00

HEAD LOSS SUMMARY:

Head Loss (ft water)	Velocity (ft/sec)	dto (in)	dt (in)	solidity (frac)
.34	.024	.250	.171	.158

Deposition Flag = linear deposition

DEBRIS SURFACE CONDITIONS:
Approach Velocity (ft/s) - .024

Rev.	Orig.	Date	Chkd.	Date
1	PYM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006

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ATTACHMENT B: BLOCKAGE 2.5 OUTPUT FILES

Rev.	Orig.	Date	Chkd.	Date
1	[signature]	8/6/98	[signature]	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
Calc. No.: DC-A34600.006 Sht. 79 of 86

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Run:     VY                                           (VY01.BLK     )
Plant:   'Settling 01'
Version: BLOCKAGE 2.5

Debris Volumes Input by User
NUREG/CR-6224 Correlation

**********************************************************************
**********************************************************************
**********************************************************************

   1  VOLUME-1   Diam.: 22.0   Loc: L

**********************************************************************
**********************************************************************
**********************************************************************
```

Initial As-Fabricated Volume Data (ft3)

TYPE	ORIGIN	CLASS	DENSITY	DEBRIS	TRANSPORT	FRACTION
NK	TG	F	2.40	209.00	209.00	1.000
RF	DW	P	324.00	0.15	0.15	1.000
DD	DW	P	156.00	1.00	1.00	1.000
SD	WW	P	324.00	2.38	2.38	1.000
Total				212.53	212.53	

CLASS	DEBRIS	TRANSPORT	FRACTION
Fibrous	209.00	209.00	1.000
Metallic	0.00	0.00	0.000
Particle	3.53	3.53	1.000
Ignore	0.00	0.00	0.000
Total	212.53	212.53	

Time Dependent Results for Weld: VOLUME-1

Time = 10000.0 sec, (166.667 min), (2.7778 hr)

ECCS DATA   Pool Temperature: 122.7 F   Total ECCS Flow: 18800.0 GPM

Pump Flow Rates (GPM)

No.	Module	Total	Pump 1	Pump 2
1	Loop1	18800.	14200.	4600.

Clean Strainer NPSH Margin (ft-water)   Change Due to Temp: 2.81

No.	Module	Pump 1	Pump 2
1	Loop1	97.19	97.19

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Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1	Pump 2
1	Loop1	95.73	95.73

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Loop1	167.972	0.000	0.899	0.000	403.13	0.00	249.4	0.0

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Loop1	2.4	0.5	277.5	0.5	2.4	0.5	55.5	0.5

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Loop1	175.0	0.5	277.5	0.5	1.7E+05	0.0E+00	1.7E+05	0.0E+00

		Mass Ratios		Thickness (in)			Head Loss (ft)		
No.	Module	M/F	P/F	Theo.	Actual	Metal	Fib&Prt	Metal	Total
1	Loop1	0.00E+00	6.19E-01	4.03	4.55	0.00	1.5	0.0	1.5

DEBRIS VOLUME DISTRIBUTION DATA   Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	209.002	0.196	2.88E-06	40.833	0.000	167.972
	Group	1	0.431	0.725		0.097	*******	0.512
	Group	2	0.149	0.161		0.079	*******	0.166
	Group	3	0.110	0.077		0.087	*******	0.116
	Group	4	0.081	0.029		0.093	*******	0.078
	Group	5	0.060	0.007		0.096	*******	0.051
	Group	6	0.044	0.001		0.094	*******	0.032
	Group	7	0.033	0.000		0.088	*******	0.019
	Group	8	0.024	0.000		0.078	*******	0.011
	Group	9	0.018	0.000		0.066	*******	0.006
	Group	10	0.013	0.000		0.054	*******	0.003
	Group	11	0.010	0.000		0.042	*******	0.002
	Group	12	0.027	0.000		0.127	*******	0.003
2	Rust F	RF	0.154	0.000	0.00E+00	0.142	0.000	0.012
	Group	1	1.000	*******		1.000	*******	1.000
3	Dirt/D	DD	1.000	0.000	1.03E-09	0.509	0.242	0.249
	Group	1	1.000	1.000		1.000	1.000	1.000

Rev.	Orig.	Date	Chkd.	Date
1	PMM	8/6/98	FS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation
Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.
Project No.: A346
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4	Sludge	SD	0.000	0.003	4.56E-08	1.211	0.528	0.638
	Group 1		*******	0.743		0.025	0.339	0.448
	Group 2		*******	0.106		0.013	0.072	0.090
	Group 3		*******	0.081		0.022	0.080	0.095
	Group 4		*******	0.047		0.037	0.086	0.095
	Group 5		*******	0.018		0.056	0.088	0.087
	Group 6		*******	0.004		0.080	0.085	0.071
	Group 7		*******	0.000		0.104	0.075	0.051
	Group 8		*******	0.000		0.122	0.061	0.032
	Group 9		*******	0.000		0.130	0.046	0.017
	Group 10		*******	0.000		0.125	0.031	0.008
	Group 11		*******	0.000		0.107	0.019	0.004
	Group 12		*******	0.000		0.180	0.018	0.002

DEBRIS VOLUME RATE DATA

No.	Type	ID	DW Tran. (ft3/s)	Suspended Pool (ft3/s)	Settled Floor (ft3/s)	Retain System (ft3/s)	Deposited Strainer (ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	9.84E-06	0.00E+00	1.21E-04
2	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	Dirt/D	DD	0.00E+00	0.00E+00	3.17E-08	5.42E-09	3.25E-08
4	Sludge	SD	0.00E+00	0.00E+00	1.71E-07	2.39E-07	1.43E-06

Time = 20000.0 sec, (333.333 min), (5.5556 hr)

ECCS DATA Pool Temperature: 140.5 F Total ECCS Flow: 18800.0 GPM

Pump Flow Rates (GPM)

No.	Module	Total	Pump 1	Pump 2
1	Loop1	18800.	14200.	4600.

Clean Strainer NPSH Margin (ft-water) Change Due to Temp: 5.22

No.	Module	Pump 1	Pump 2
1	Loop1	94.78	94.78

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1	Pump 2
1	Loop1	93.53	93.53

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Loop1	168.147	0.000	0.901	0.000	403.55	0.00	250.2	0.0

Fabricated Densities (lbm/ft3) Rubble Densities (lbm/ft3)

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No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Loop1	2.4	0.5	277.6	0.5	2.4	0.5	55.6	0.5

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Loop1	175.0	0.5	277.6	0.5	1.7E+05	0.0E+00	1.7E+05	0.0E+00

		Mass Ratios		Thickness (in)			Head Loss (ft)		
No.	Module	M/F	P/F	Theo.	Actual	Metal	Fib&Prt	Metal	Total
1	Loop1	0.00E+00	6.20E-01	4.04	4.85	0.00	1.2	0.0	1.2

DEBRIS VOLUME DISTRIBUTION DATA   Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	209.002	0.000	3.92E-09	40.847	0.000	168.147
	Group	1	0.431	0.837		0.097	*******	0.512
	Group	2	0.149	0.119		0.079	*******	0.166
	Group	3	0.110	0.037		0.087	*******	0.116
	Group	4	0.081	0.007		0.093	*******	0.078
	Group	5	0.060	0.001		0.096	*******	0.051
	Group	6	0.044	0.000		0.094	*******	0.032
	Group	7	0.033	0.000		0.088	*******	0.019
	Group	8	0.024	0.000		0.078	*******	0.011
	Group	9	0.018	0.000		0.066	*******	0.006
	Group	10	0.013	0.000		0.054	*******	0.003
	Group	11	0.010	0.000		0.042	*******	0.002
	Group	12	0.027	0.000		0.127	*******	0.003
2	Rust F	RF	0.154	0.000	0.00E+00	0.142	0.000	0.012
	Group	1	1.000	*******		1.000	*******	1.000
3	Dirt/D	DD	1.000	0.000	5.20E-14	0.509	0.242	0.249
	Group	1	1.000	1.000		1.000	1.000	1.000
4	Sludge	SD	0.000	0.000	1.33E-10	1.211	0.529	0.640
	Group	1	*******	0.868		0.025	0.339	0.450
	Group	2	*******	0.079		0.013	0.072	0.090
	Group	3	*******	0.039		0.022	0.080	0.095
	Group	4	*******	0.012		0.037	0.086	0.095
	Group	5	*******	0.001		0.056	0.088	0.086
	Group	6	*******	0.000		0.080	0.084	0.071
	Group	7	*******	0.000		0.104	0.075	0.051
	Group	8	*******	0.000		0.122	0.061	0.032
	Group	9	*******	0.000		0.130	0.045	0.017
	Group	10	*******	0.000		0.125	0.031	0.008
	Group	11	*******	0.000		0.107	0.019	0.004
	Group	12	*******	0.000		0.180	0.018	0.002

Rev.	Orig.	Date	Chkd.	Date
1	PHM	8/6/98	FS	8/6/98

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DEBRIS VOLUME RATE DATA

No.	Type	ID	DW Tran. (ft3/s)	Suspended Pool (ft3/s)	Settled Floor (ft3/s)	Retain System (ft3/s)	Deposited Strainer (ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	1.05E-08	0.00E+00	1.64E-07
2	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	Dirt/D	DD	0.00E+00	0.00E+00	1.59E-12	2.73E-13	1.64E-12
4	Sludge	SD	0.00E+00	0.00E+00	3.48E-10	6.94E-10	4.16E-09

Time = 21600.0 sec, (360.000 min), (6.0000 hr)

ECCS DATA Pool Temperature: 143.3 F Total ECCS Flow: 18800.0 GPM

Pump Flow Rates (GPM)

No.	Module	Total	Pump 1	Pump 2
1	Loop1	18800.	14200.	4600.

Clean Strainer NPSH Margin (ft-water) Change Due to Temp: 5.71

No.	Module	Pump 1	Pump 2
1	Loop1	94.29	94.29

Fouled Strainer NPSH Margin (ft-water)

No.	Module	Pump 1	Pump 2
1	Loop1	93.07	93.07

STRAINER DEPOSITION DATA

		Volumes (ft3)				Masses (lbm)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Loop1	168.147	0.000	0.901	0.000	403.55	0.00	250.2	0.0

		Fabricated Densities (lbm/ft3)				Rubble Densities (lbm/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Loop1	2.4	0.5	277.6	0.5	2.4	0.5	55.6	0.5

		Material Densities (lbm/ft3)				Sp. Surface Areas (ft2/ft3)			
No.	Module	Fiber	Metal	Part.	Ignore	Fiber	Metal	Part.	Ignore
1	Loop1	175.0	0.5	277.6	0.5	1.7E+05	0.0E+00	1.7E+05	0.0E+00

		Mass Ratios		Thickness (in)			Head Loss (ft)		
No.	Module	M/F	P/F	Theo.	Actual	Metal	Fib&Prt	Metal	Total
1	Loop1	0.00E+00	6.20E-01	4.04	4.89	0.00	1.2	0.0	1.2

Rev.	Orig.	Date	Chkd.	Date
1	[signature]	8/6/98	[signature]	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006

DEBRIS VOLUME DISTRIBUTION DATA Transport Completion: 1.0000

No.	Type	ID	DW Tran. (ft3)	Suspend Pool (ft3)	Pool Conc. (ft3/ft3)	Settled Floor (ft3)	Retain System (ft3)	Deposited Strainer (ft3)
1	Nukon	NK	209.002	0.000	1.37E-09	40.847	0.000	168.147
	Group	1	0.431	0.849		0.097	*******	0.512
	Group	2	0.149	0.112		0.079	*******	0.166
	Group	3	0.110	0.033		0.087	*******	0.116
	Group	4	0.081	0.005		0.093	*******	0.078
	Group	5	0.060	0.000		0.096	*******	0.051
	Group	6	0.044	0.000		0.094	*******	0.032
	Group	7	0.033	0.000		0.088	*******	0.019
	Group	8	0.024	0.000		0.078	*******	0.011
	Group	9	0.018	0.000		0.066	*******	0.006
	Group	10	0.013	0.000		0.054	*******	0.003
	Group	11	0.010	0.000		0.042	*******	0.002
	Group	12	0.027	0.000		0.127	*******	0.003
2	Rust F	RF	0.154	0.000	0.00E+00	0.142	0.000	0.012
	Group	1	1.000	*******		1.000	*******	1.000
3	Dirt/D	DD	1.000	0.000	1.07E-14	0.509	0.242	0.249
	Group	1	1.000	1.000		1.000	1.000	1.000
4	Sludge	SD	0.000	0.000	5.26E-11	1.211	0.529	0.640
	Group	1	*******	0.880		0.025	0.339	0.450
	Group	2	*******	0.075		0.013	0.072	0.090
	Group	3	*******	0.035		0.022	0.080	0.095
	Group	4	*******	0.009		0.037	0.086	0.095
	Group	5	*******	0.001		0.056	0.088	0.086
	Group	6	*******	0.000		0.080	0.084	0.071
	Group	7	*******	0.000		0.104	0.075	0.051
	Group	8	*******	0.000		0.122	0.061	0.032
	Group	9	*******	0.000		0.130	0.045	0.017
	Group	10	*******	0.000		0.125	0.031	0.008
	Group	11	*******	0.000		0.107	0.019	0.004
	Group	12	*******	0.000		0.180	0.018	0.002

DEBRIS VOLUME RATE DATA

No.	Type	ID	DW Tran.	Suspended Pool	Settled Floor	Retain System	Deposited Strainer

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			(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)	(ft3/s)
1	Nukon	NK	0.00E+00	0.00E+00	3.58E-09	0.00E+00	5.76E-08
2	Rust F	RF	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	Dirt/D	DD	0.00E+00	0.00E+00	3.27E-13	5.59E-14	3.36E-13
4	Sludge	SD	0.00E+00	0.00E+00	1.34E-10	2.76E-10	1.65E-09

SUMMARY INFORMATION FOR WELD: VOLUME-1

Head Loss and NPSH Data (ft-water)

No.	Module	Max Head loss	Minimum Fouled Strainer NPSH Margin Pump 1	Pump 2
1	Loop1	1.54	93.07	93.07

Times Where Pump NPSH Margin Lost (sec)

No.	Module	Pump 1	Pump 2
1	Loop1	********	********

Rev.	Orig.	Date	Chkd.	Date
1	PXM	8/6/98	TS	8/6/98

Client/Project: Vermont Yankee Nuclear Power Corporation

Title: Vermont Yankee ECCS Suction Strainer Head Loss Performance Assessment. RHR and CS Debris Head Loss Calculations.

Project No.: A346

Calc. No.: DC-A34600.006