GE Nuclear Energy

James F. Klapproth
Manager, Engineering and Technology

Nuclear Services
General Electric Company
175 Curtner Avenue, MC 706, San Jose, CA 95125-1088
408 925-5434, Fax: 408 925-3837
james.klapproth@gene.ge.com

MFN 02-004
January 16, 2002

Document Control Desk
US Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Submittal of GE Non-Proprietary Document NEDO-32721 Revision 2, **Application Methodology for the General Electric Stacked-Disc ECCS Suction Strainer,** December 2001

Reference MFN 01-063, **Transmittal of Revision 2 of Proprietary Licensing Topical Report NEDC-32721P, "Application Methodology for GE Stacked Disk Suction Strainer",** October 30, 2001

GE submitted the referenced document, NEDC-32721P Revision 2, to the NRC on October 30, 2001. The enclosed document (1 copy), NEDO-32721, Revision 2, is the non-proprietary version of the reference.

Sincerely,

FOR Bradley J. Erbes

J.F. Klapproth, manager
Engineering and Technology
GE Nuclear Energy
(408) 925-5434
e-mail: james.klapproth@gene.ge.com

cc: J. Donoghue (NRC) w Attachments (1 copy + 1 CD)
T. McIntyre (GE) w/o Attachments

Attachment: NEDO-32721, Revision 2

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GE Nuclear Energy

NEDO-32721
Revision 2
Class I
December 2001
DRF 0000-0000-1367

LICENSING TOPICAL REPORT

APPLICATION METHODOLOGY for the General Electric Stacked Disk ECCS Suction Strainer

Prepared by:

T. A. Green
Sr. Technical Project Manager
F. J. Moody
Fellow, Thermal-Hydraulics
H. Choe
Plant Safety Analysis
J. Lynch
Principal Engineer, Technical Services
T. R. McIntyre
Manager — New Product Introduction & Special Projects

Approved By:

J. F. Klapproth, Manager
Engineering & Technology

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Manager — New Product Introduction & Special Projects

M. E. Harding for

Approved By:

J. F. Klapproth, Manager
Engineering & Technology

Important Notice Regarding Contents of this Report

Please Read Carefully

The purpose of this report is to document the application methodology for the General Electric Stacked Disk ECCS Suction Strainer. This report addresses hydraulic performance design methods and provides procedures for the calculation of hydraulic loads for new strainer installations. The use of this information for any purpose other than that for which it is intended, is not authorized; and with respect to any unauthorized use, GE makes no representation or warranty, express or implied, and assumes no liability (for example, no liability related to nuclear damage) as to the completeness, accuracy, or usefulness of the information contained in this document, or that its use may not infringe privately owned rights.

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ABSTRACT

The GE stacked-disk ECCS suction strainer utilizes disks whose internal radius and thickness vary over the height of the strainer. The selected variation in these parameters achieves an increased surface area compared to conventional strainers of comparable size, and this optimizes strainer performance by generating minimum head loss for any assumed debris loading in the smallest possible volume. This licensing topical report documents the application methodology for the General Electric stacked disk ECCS suction strainer, including (1) hydraulic performance design methods and (2) procedures for calculation of loads for new strainer installation that can be used in the structural analysis of the torus penetration(s), the strainer supports, and the strainer itself.

1.0 INTRODUCTION

The BWR Owners' Group (BWROG) has developed Utility Resolution Guidance [Ref. 1] to assist utilities in resolving the ECCS suction strainer plugging issue and, in particular to provide guidance to BWR operators in responding to NRC Bulletin 96-03 [Ref. 2].

Section 3.2.6.2.3 of the Utility Resolution Guidance documents the methodology for calculating the head loss across specific strainers tested by the BWROG after the limiting quantity of debris present on each strainer has been established. These calculation procedures are described in Appendices A and B of the alternate strainer test report [Ref. 3]. The alternate strainer test report also describes the basis for which the head loss correlations were developed and their application requirements.

The GE stacked-disk strainer design is based on a patented innovation that utilizes disks whose internal radius and thickness vary over the height of the strainer. The selected variation in these parameters achieves an increased surface area compared to conventional stacked-disk strainers of comparable size tested by the BWROG. This optimizes strainer performance by generating minimum head loss for any assumed debris loading in the smallest possible volume. GE has thoroughly tested the optimum stacked-disk strainer design at the EPRI NDE Center, and the resulting test data are included as Appendix A. This testing included evaluation of strainer performance for very high fibrous debris loadings. The hydraulic performance data correlation presented in Section 3.3 is based on earlier BWROG test data [Ref. 3], as well as the specific GE optimized strainer data (Appendix A). Section 3.5 describes the GE strainer sizing calculation methodology, and an example calculation is included in Section 3.6.

Section 4 of this Licensing Topical Report provides the calculation procedures to be followed to provide hydrodynamic load inputs to the structural analyses of the new strainers, the torus penetrations, and the strainer supports, if employed. The load calculation procedures are based on scaling of the previously calculated loads by applying scale factors that account for changes in size, geometry, and location of the new strainers. These scale factors are applicable for Mark I, II, and III containment designs.

2.0 DESCRIPTION OF GE STACKED-DISK STRAINER

The patented GE stacked-disk ECCS pump suction strainer is optimally designed to have minimum head loss and to accumulate a maximum quantity of debris, within a given volume. The strainer has a central core of varying radius such that the flow through the entire central region is maintained at constant velocity. The constant velocity core minimizes head loss where velocities are the greatest. A number of perforated disks of varying internal diameter and whose thickness may vary with radius surround the central core. Figure 2-1 is an isometric view of a typical GE stacked-disk strainer with a quarter segment removed to illustrate the internal design. The holes in each disk are sized to prevent a significant quantity of debris from passing into the strainer, but allow fluid to pass through the strainer. For BWR application, the strainer hole size will vary to assure that the design is compatible with specific containment spray nozzles and/or with the ECCS pump seal cooling flow orifices. The spacing between the disks is maintained constant at 1.75 inches. The outer diameter of the disks is typically constant, but can vary and still maintain the constant velocity core. The prototypical optimum stacked-disk strainer tested by GE is shown in Figure 2-2.

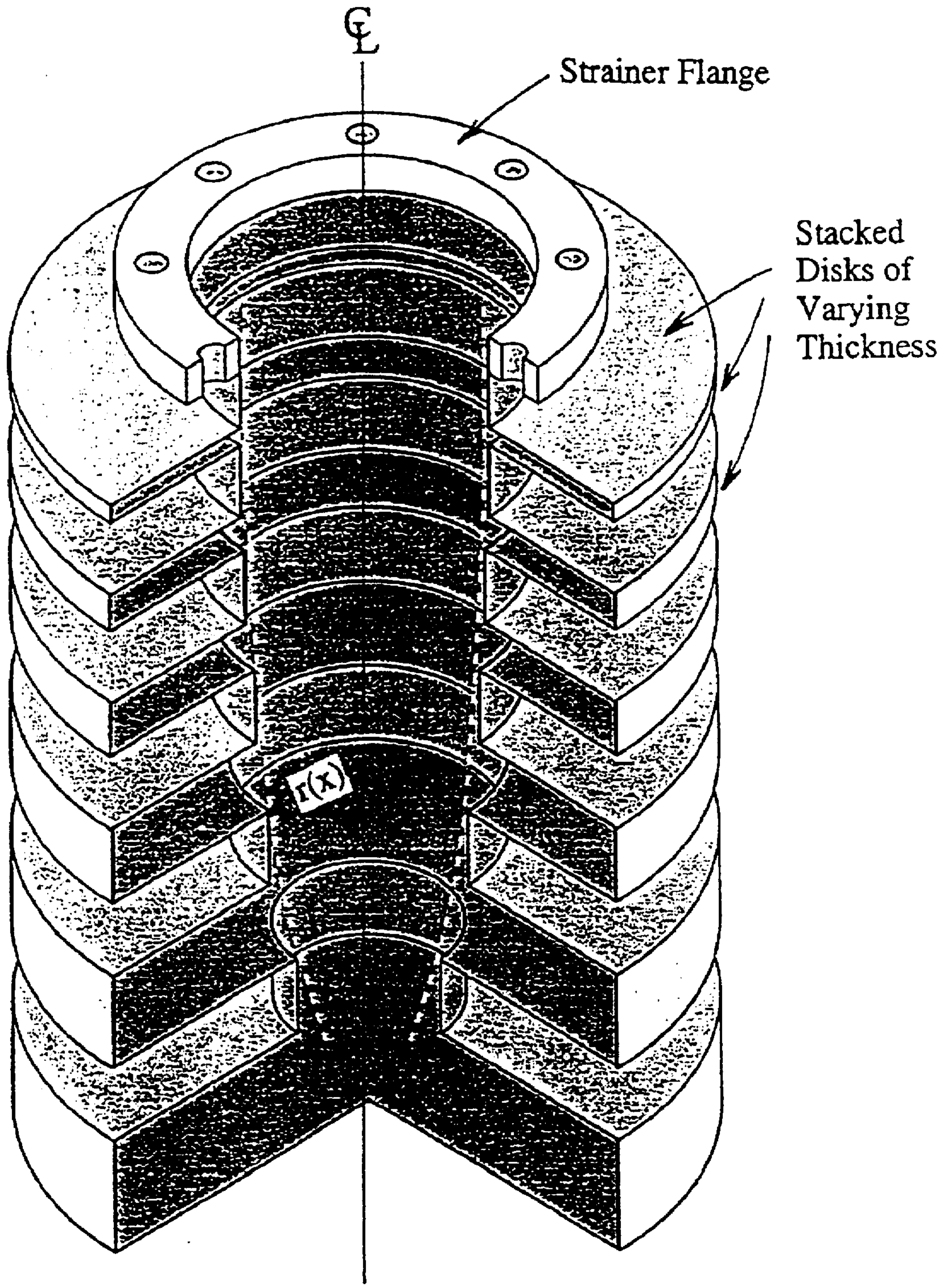

Figure 2.1. Typical GE Stacked-Disk Strainer with a Quarter Segment Removed to Illustrate the Internal Design

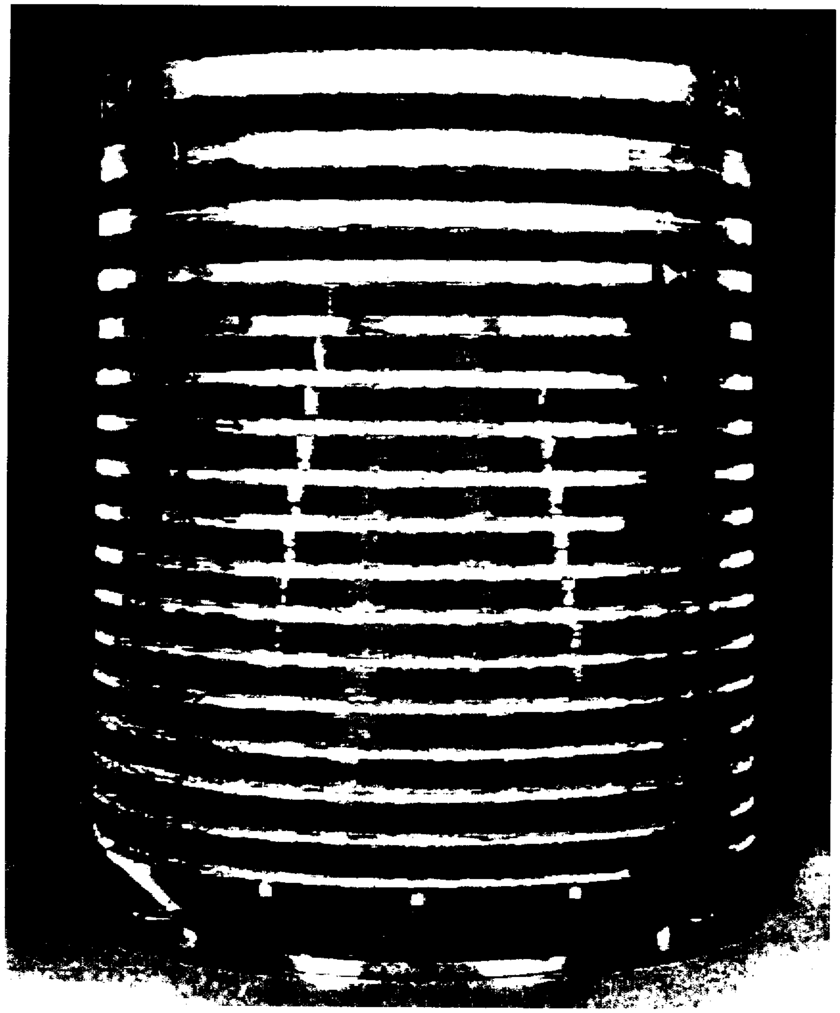

Figure 2-2. Protypical GE Stacked Disk Strainer

3.0 HYDRAULIC DESIGN METHODOLOGY

3.1 Overview of Hydraulic Design Methodology – Basic Principles

The methodology used for hydraulic design of the GE stacked-disk suction strainer is described in this section. This methodology is employed to calculate the strainer head loss and the detailed shape of the strainer such as the number of the disks, the thickness and the radii of the disks, and the overall size of the strainer (outer diameter and length). The head loss calculation includes the head losses without debris (clean head loss) and with debris. The head loss with debris considers the effects of the fiber debris and the corrosion products first. Then effects of other miscellaneous debris are considered in terms of a bump-up factor as outlined in Appendix A of Reference 3. The detailed sizing calculation estimates the perforated plate area based on the total debris load, and then determines the inner radius and thickness of each disk assuming an estimated outer diameter. If the strainer dimensions do not meet the design requirements, the same calculation may be repeated for a different outer diameter. The head loss calculation and the sizing calculation are iterated until all design requirements are met.

Sections 3.2, 3.3, and 3.4 describe the details on the head loss calculation. Section 3.2 describes the hydraulic testing performed on the GE prototype strainer, including the clean head loss as well as the debris head loss. Section 3.3 describes the test data correlations developed from the GE prototype hydraulic testing, as well as the BWROG testing of the 60-point star strainer and the stacked-disk strainer No. 2. Section 3.4 describes the bump-up factor calculation procedure for miscellaneous debris.

Section 3.5 describes the basic fluid mechanics and the equations used for the strainer sizing. Section 3.6 provides an example strainer sizing calculation that also includes the head loss calculation.

For the head loss correlation, the following head loss equation is used:

$$\Delta h = K_h \cdot \frac{\mu U t}{\rho g d^2}$$

where

Δh = the head loss in ft
K_h = the dimensionless head loss coefficient
μ. = the dynamic viscosity in lbm/ft-sec
U = the approach velocity in ft/sec, defined as

$$U = \frac{Q}{\pi D L}$$

Q = the pump flow rate applied to the strainer in ft^3/sec
D = the outer diameter of the strainer in ft
L = the active length of the strainer in ft

t = the fiber bed thickness in ft, defined as

$$t = \frac{M_f}{\rho_f \cdot \pi DL}$$

M_f = mass of fiber debris in lbm
ρ_f = uncompressed density of the fiber debris in lbm/ft^3

ρ = the density of the water in lbm/ft^3
g = the gravitational acceleration, 32.2 ft/sec^2
d = the interfiber distance in ft

The definitions of these terms and symbols are consistent with Reference 3.

3.2 Hydraulic Test

A prototype GE strainer was fabricated with the hydraulic design optimized as described in Section 3.5 and with proper internal structural supports so that the strainer can withstand the postulated hydrodynamic loads. A hydraulic test was performed on the GE prototype strainer to:

- Ascertain the head loss performance of the GE strainer design compared with other designs available in the industry.

- Evaluate strainer debris load conditions not addressed in Reference 3, in particular the high fiber load conditions and the performance with Tempmat fiber insulation.

The applicable test data from Reference 3, along with the GE prototype test data, are used in developing the design correlation for the GE strainers.

Appendix A provides the descriptions of the GE prototype strainer, the test facility, the test procedures, and the test data obtained. Table 3-1 is the test matrix.

3.3 Correlation of Test Data

The main focus of this section is to obtain an appropriate correlation for K_h. Appendix B of Reference 4 provides an overview of available literature related to the head loss data, and also a sound theoretical model. The testing and the modeling work in Reference 4 are applicable to flat perforated plate geometries, and, therefore, some phenomena that could exist in complex suction strainer configurations are not addressed. Reference 3 provides test data for a variety of strainer designs, for which the test data has been empirically correlated.

Table 3.1. Test Matrix for GE Prototype Stacked-Disk Strainer Testing

Test ID	Flow, gpm	M_f, lbm	M_c, lbm	RMI, ft^2	Remarks
GE1	2500 -10,000				Clean head loss
GE2	2500 -10,000	25	100		Performance comparison
GE3	2500 - 10,000	50	100		Performance comparison
GE4	2500 - 10,000			640	Performance comparison
GE6	1250 - 3750	100 - 600			High fiber Load
GE7	2500 - 7500	17 - 100	85 - 500		$M_c/M_f = 5$
GE8	2500 - 4000	118.5 - 237	32 - 64		TempMat
GE9	2500 - 10,000 5000	25 - 75 75	125 - 375 375	160 - 480 640	M_c/M_f =5 RMI/Mf = 6.4 ft^2/lbm Additional RMI
GE10	5000	50	1568		High M_c/M_f

The strainer head loss can theoretically be calculated by the Darcy equation for porous media for the given strainer geometry and debris loading profile. This problem is, however, not easily solvable because it is difficult to define the debris load profile and the corrosion-to-fiber mass ratio (M_c/M_f) profile in a complex geometry in a three-dimensional flow field. Therefore, the following more practical approach has been employed:

From the review of References 3 and 4, it is found that K_h is expected to be a primary function of the following four parameters for a given strainer design:

The following procedure is used to define the GE optimum stacked-disk strainer geometry:

1. Determine U_p/U_c. The total perforated area, A_s, is estimated considering the total debris to be collected by the strainer. The pump suction flange inner radius is given as part of the existing conditions for the each plant, and wb is determined as part of the strainer design. The strainer outer diameter, R, is determined based on the strainer envelope requirements. Equation 8 is used to calculate U_p/U_c.

   To calculate the head loss from RMI debris, the methodology described in Reference 3 shall be employed. The BWROG test results showed that RMI has a negligible or very small effect on overall strainer head loss when a substantial quantity of fibrous debris is present.

2. Calculate r; from Equation 7. Start from r_L and sequentially calculate r_i. Adjust U_p/U_c slightly until r_0 shows a reasonable value.

3. Use the minimum allowable disk thickness (e.g., 3/8 or 0.4 inch) to calculate (U_p/U_d); for each disk using Equation 9 where (U_d/U_c); remains below 1.0. When (U_d/U_c); exceeds 1.0, set the value of (U_d/U_c); equal to 1.0 and calculate t; for each disk using Equation 9.

4. Calculate other design parameters such as the strainer length (L), and the total perforated plate area (A_s) based on the calculation of r_i and t_i.

3.6 Example Strainer Size Calculation

The head loss correlations and the strainer sizing methodology developed above are programmed into an EXCEL spreadsheet. The strainer design input parameters include:

- NPSH available for the ECCS suction strainer
- Suppression pool temperature at which the above NPSH is calculated
- Debris loads - fiber debris, sludge, RMI, and other miscellaneous debris
- Pump flow rate
- Suction flange inner diameter and the maximum outside diameter of the strainer

Based on these inputs, an approximate strainer size is determined and the calculation is iterated between the head loss and strainer sizing until all the design requirements are met. After the finalized strainer design is selected, detailed geometric information is produced as an output for the hardware designer. This design information includes:

- Strainer D (outside diameter) and L (active length)
- Number of disks
- The thickness and the inner radius of each disk
- The total perforated plate area
- Other miscellaneous geometric details

An example calculation is provided in Appendix C.

4.0 CALCULATION OF LOADS FOR NEW STRAINER APPLICATIONS

4.1 Purpose and Overview

4.1.1 Process Overview

This section provides methods for calculation of suppression pool hydrodynamic loads on the new strainer installation that are to be used as input to the structural analysis of the suppression pool penetrations, the strainer attachment, and the strainer itself.

Hydrodynamic loads on structures submerged within suppression pools, caused by postulated Loss of Coolant Accidents (LOCA) and Safety Relief Valve (SRV) actuations have been extensively studied, and load definition methodologies have previously been approved by the NRC (e.g. Ref. 10). The purpose of this approach is to provide a simple and straightforward process for load definition of the new strainers such that all of the margin inherent in the original strainer load definitions is maintained.

4.1.2 Definitions and Nomenclature

For consistency with previous load definitions, the GE methodology for ECCS Suction Strainer submerged structure loading uses the relationships:

$$F_A(t) = \rho V_a \frac{a}{g_0}$$

and

$$F_V(t) = C_D A \rho \frac{U^2}{2g_0}$$

for the acceleration and standard drag loads, respectively, where:

$F_A(t)$ = the acceleration drag force as a function of time (lbf)

ρ = the density of water (lbm/ft^3)

V_a = the "acceleration drag volume" (ft^3)

a = the local acceleration of the flow field surrounding the submerged structure (ft/sec^2)

$F_V(t)$ = the velocity drag force as a function of time (lbf)

C_D = the velocity drag coefficient (dimensionless)

A = the cross sectional area of the structure in the direction of the flow (ft^2)

U = the local velocity of the flow field surrounding the submerged structure (ft/sec)

g_0 = Newton's constant (32.2 lbm-ft/lbf-sec^2)

5.0 SUMMARY

This Licensing Topical Report documents the application methodology for the General Electric optimum stacked-disk ECCS suction strainer.

Section 3.0 documents the hydraulic design methodology employed. Applicable test data has been compiled and an empirical design correlation for the GE optimum stacked-disk strainer has been developed. This design correlation considers the methodology described in NUREG/CR-6224 [Ref. 4] and includes the mass of corrosion products to mass of fiber ratio, Reynolds number based on the local velocity across the perforated plate surfaces and the fiber diameter of the insulation, a flow rate factor (bed compaction factor), and the bed thickness to strainer diameter ratio. It has been demonstrated that the correlation between the design methods and the test data is realistic and conservative.

Section 4.0 provides methods for calculation of submerged structure loads for the new strainer installation that can be used in the structural analysis of the torus penetrations, the new strainers, and the strainer supports, if applicable. The load calculation procedures involve the development of scale factors that modify the original strainer loads to account for changes in size, geometry, porosity and location of the new strainers.

6.0 REFERENCES

1. NEDO-32686, Revision 0, "Utility Resolution Guidance for ECCS Suction Strainer Blockage", November 1996.

2. NRC Bulletin 96-03, "Potential Plugging of ECCS Suction Strainers by Debris in BWRs", May 6, 1996.

3. Continuum Dynamics Inc. Report 95-09, Revision 4, "Testing of Alternate Strainers With Insulation Fiber and Other Debris", November 1996.

4. NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCH Generated Debris", October 1995.

5. H. Schlicting, "Boundary Layer Theory", McGraw-Hill; 1968.

6. GE Report NEDO-21888 Rev 2, "Mark I Program Load Definition Report", November 1981.

7. Vectra Report 0084-00242-002, "Cooper Strainer Evaluation", March 26, 1996.

8. SMA Report Number 12101.05-8001, "Combining Harmonic Amplitudes for Mark I Post Chug Responses", August 1982.

9. SMA Report Number SMA-12101.04-R003D, "Response Factors Appropriate for Use with CO Harmonic Response Combination Design Rules", March 1982.

10. NUREG-0661, "Safety Evaluation Report for the Mark I Containment Program", July 1980.

11. NPP Report, "Cooper Plant-Unique Analysis Report for the Mark I Containment Program, Rev 0.", April 1984.

12. GENE E22-00100-10, "ECCS Suction Strainer Hydrodynamic Mass and Acceleration Drag Volume Study – Perforated and Solid Cylinder Tests

13. D.B. Osgood, "Oscillating Flow about Perforated Cylinders", U.S. Naval Postgraduate School, September, 2000

14. Glenn L Martin Wind Tunnel Test Report DLMWT Test 1663, "ECCS Suction Strainer Test", March 18, 1998

Appendix A

"General Electric Company Stacked Disk Strainer Report" (CDI Report, December 1996)

General Electric Company

Stacked Disk Strainer Data Report

Revision 0

December 1996

Prepared by
Continuum Dynamics, Inc.
P.O. Box 3073
Princeton, New Jersey 08543

Project Manager

Andrew E. Kaufman

Authors
Andrew E. Kaufman
Robert W. Diertl
Richard G. Louderback

Prepared for
GE Nuclear Energy
General Electric Company
175 Curtner Avenue
San Jose, California 95125

ABSTRACT

A General Electric Company (GE) stacked disk strainer was tested under a variety of debris and flow conditions in the Boiling Water Reactor Owners' Group (BWROG) test facility at the EPRI facility in Charlotte, North Carolina. This report documents the head loss results from the tests conducted in October and November 1996.

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1. INTRODUCTION

In the event of a Loss of Coolant Accident (LOCA) in a Boiling Water Reactor (BWR) nuclear power plant, insulation installed on piping can reach the wetwell which supplies water to the Emergency Core Cooling System (ECCS). This insulation combined with corrosion products and other debris can migrate and block strainers installed on suction lines supplying the ECCS pumps. An alternate suction strainer design, the GE stacked disk strainer, was provided by the General Electric Company to evaluate its performance under different flow and debris loads. From October into November 1996, Continuum Dynamics, Inc. conducted a series of tests on this strainer. Tests were conducted at the Electric Power Research Institute (EPRI) Non Destructive Evaluation Center in Charlotte, North Carolina.

Testing was conducted following the Plan for Testing GE Strainer, Revision 1, 31 October 1996 (Ref. 1). Test procedures and materials essentially duplicated BWROG procedures and materials for strainer testing (Refs. 2 and 3).

2. TEST FACILITY

A schematic of the test facility is shown in Figure 2-1. The strainer was mounted horizontally to a 24 inch tee in a nominally 50,000 gallon vessel. Two centrifugal pumps capable of producing 10,000 GPM were used to provide system flow controlled by valves on the pump outlets. The flow returned to the vessel through a venturi and then through a pipe whose exit was centered in the vessel and directed down toward the floor. This pipe orientation prevented material from settling on the vessel floor.

Instrumentation

A schematic illustrating the instrument locations is shown in Figure 2-2. The head loss across the strainer and debris bed is measured by a Rosemount 1151 smart differential pressure transmitter that is connected to the blind flange of the strainer tee. The flow rate is measured by the venturi in the return leg of the piping and another a Rosemount 1151 smart differential pressure transmitter. The outputs of these transmitters were connected through Sensotec GMA displays and amplifiers (0.2% accuracy) to a computer controlled DATAQ DI-220 12 bit data acquisition system. Test debris was weighed on an Ohaus model DS10L scale and water temperature was measured with a thermometer. Table 2-1 lists the instruments used in the test program.

Table 2-1. Instrument List

Symbol	Instrument	Range	Accuracy	Comment
DP1	Differential Pressure Transmitter	0-650 inches of water	+/-1 inch of water	Strainer head loss.
DP3	Differential Pressure Transmitter	0-250 inches of water	+/-0.4 inches of water	Used with venturi (+/- 300 GPM accuracy)
A/D	Data Acquisition	0.5 volts	+/-0.025%	Record pressure and flow data.
T1	Thermometer	25-120 degrees F	+/-3 degrees F	Water temperature commercial grade.
B1	Balance	0-100 pounds	+/-0.5 pounds	Weight debris commercial grade.

Strainer

A photograph of the GE stacked disk strainer is shown in Figure 2-3.

Debris Materials

The test materials used in the program were supplied by the manufacturer or were supplied by utilities participating in the program. See the tables and plots in Appendix A for the materials used in the tests.

Summary of Test Procedures

The test procedures duplicated the test procedures used in the BWROG strainer tests. The procedures are summarized below.

The main test procedure defines the steps necessary to perform one complete test for measuring strainer head loss. The main steps in this procedure include system start up, material addition, data acquisition, flow rate control, and test termination. Data acquisition is started before the pumps are turned on and material is added to the vessel after the flow rate has been established. The time of material introduction is recorded. The amount of material added is determined by the test matrix.

During a test the flow rate is maintained at a nearly constant value determined by the test matrix, unless the strainer maximum pressure drop is reached or the maximum pump flow is achieved. After the strainer head loss has reached approximately steady state, the flow rate can be adjusted down and up (a flow sweep) to obtain head loss at different flow rates. A nun is terminated when the strainer head loss reaches approximately steady state or a determined value of head loss has been achieved (after conducting any required flow sweeps). After test termination, a backup copy of the digitally recorded data is made and the ending water temperature is taken.

Daily procedures are followed to check the differential pressure transducers and data acquisition system. Differential pressure cell zeros and known water height readings are taken and compared to the transducer output. The output of the data acquisition system is also checked to insure it is operating correctly and that the instruments are correctly connected. Periodic confidence checks on the scales and thermometer are also conducted as required.

Also associated with each main test procedure is a material preparation procedure which defines how much material is to be added to the vessel. This procedure defines the methods to identify and quantify the materials to be used for each test. All material used in the program is identified by a unique number.

Data is stored on disk as voltages from the differential pressure transducers. Using the calibration curves for each instrument, the voltages are converted to engineering units (either inches of water or gallons per minute). The clean head loss as a function of flow rate is subtracted from each head loss data point to obtain the head loss across the debris bed. The data is plotted in Appendix A as a function of time along with tabulated approximate steady state values.

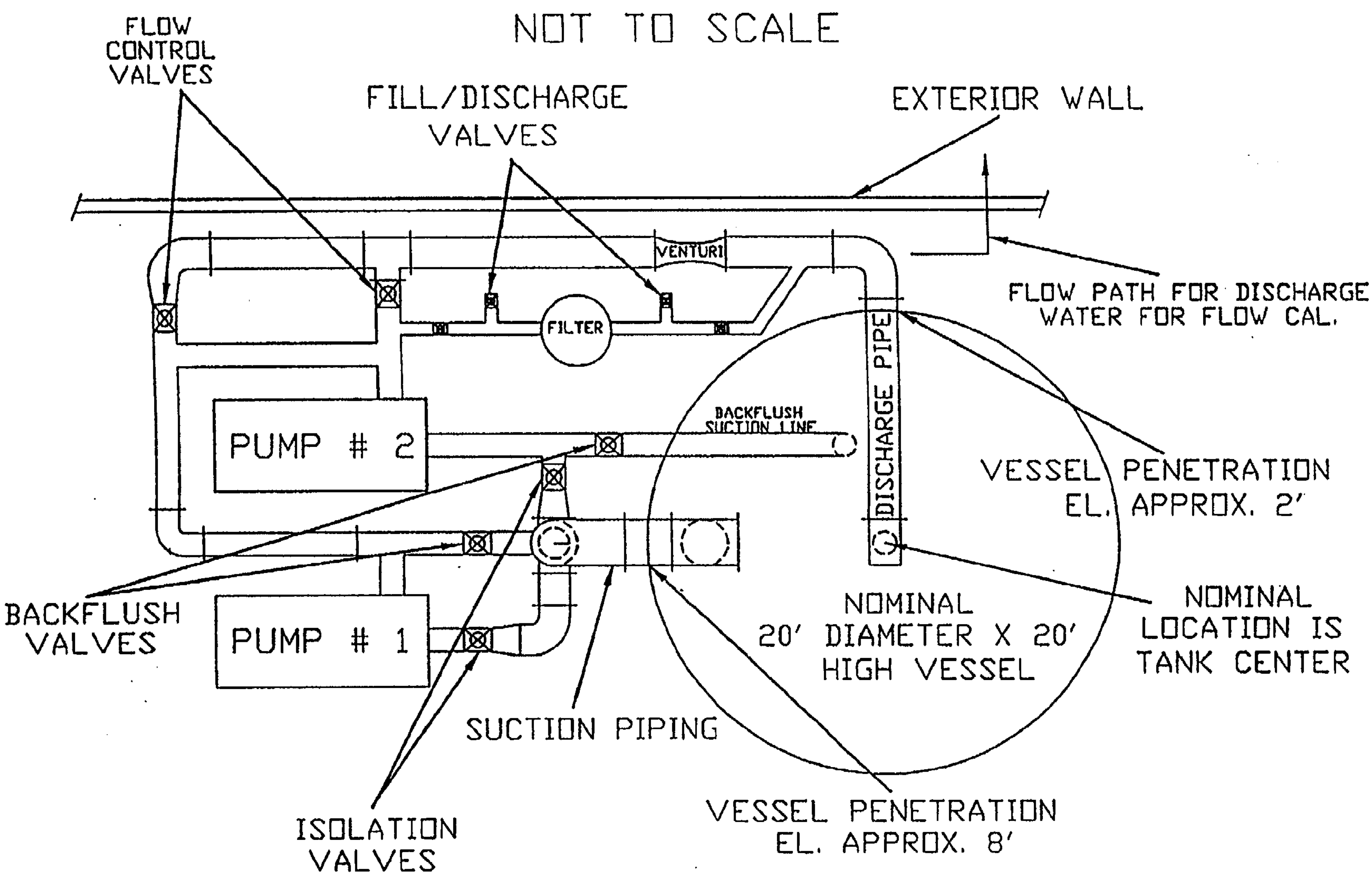

Figure 2-1. Schematic of test facility

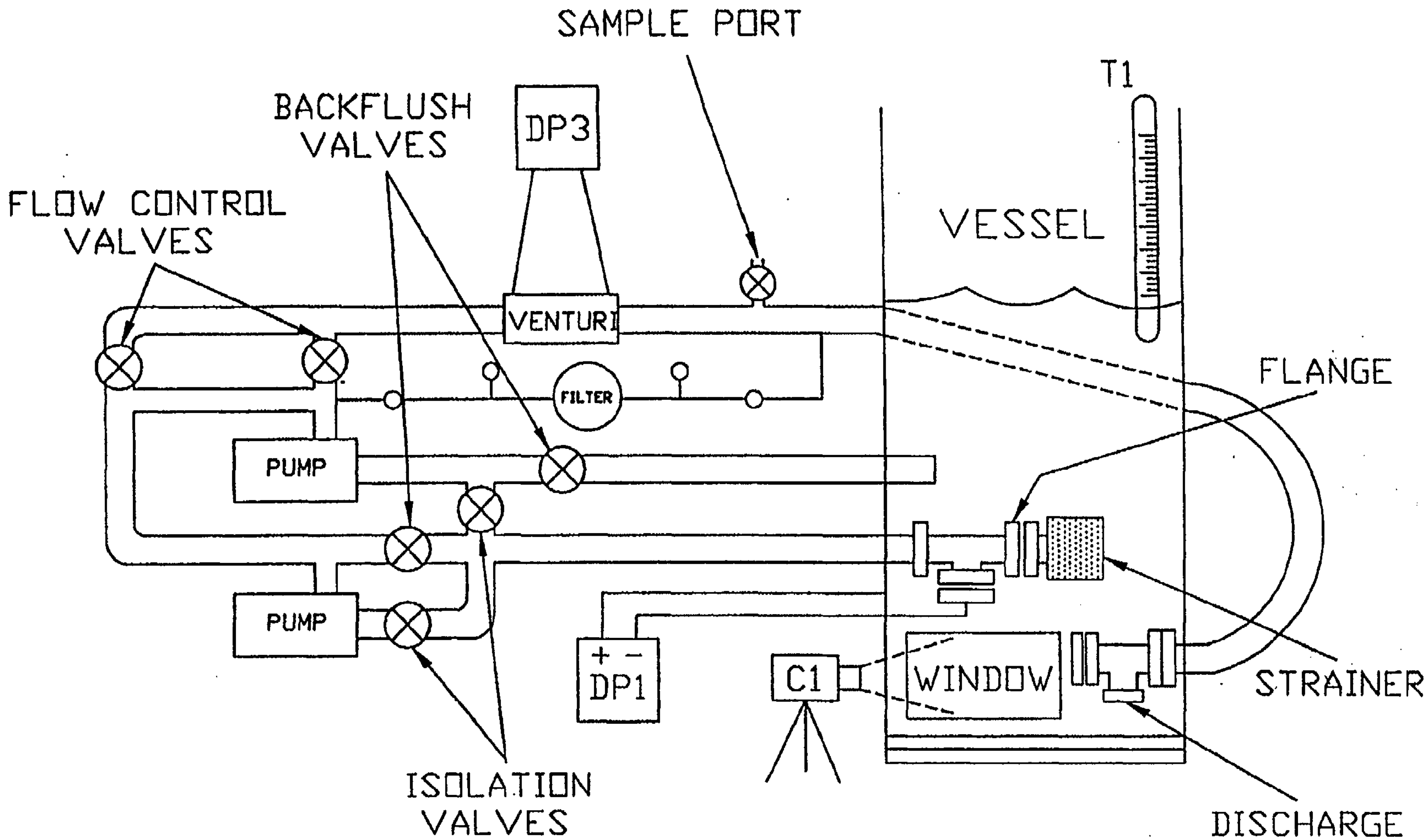

Figure 2-2. Schematic of instrument locations.

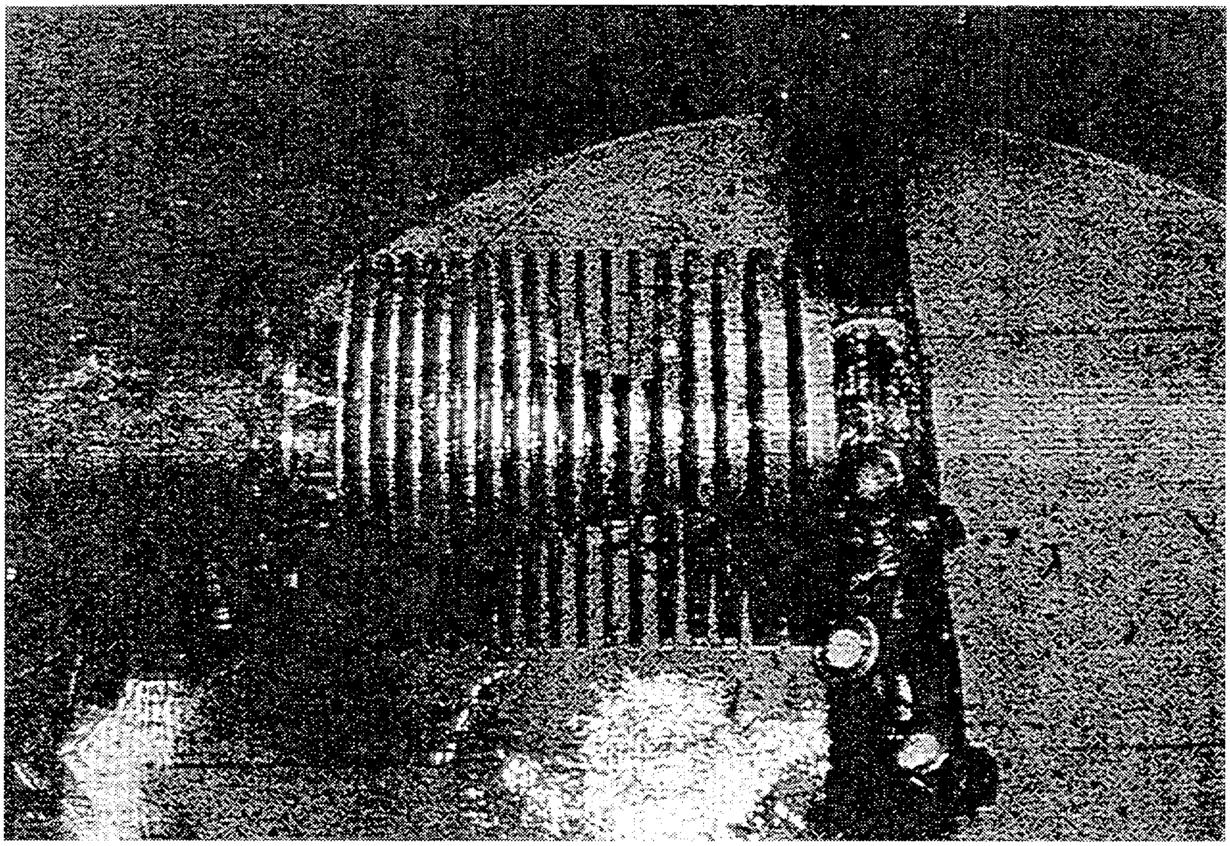

Figure 2-3. Photograph of stacked disk strainer.

3. TEST DATA

Tabular data collected from the test program is included in Appendix A. The tables contain specific information about each test including run number, run date, flow rates tested, mass/amount of materials, the average water temperature and the steady state differential pressure across the strainer (head loss) for that condition. All of the tabulated head loss values represent the head loss across the debris bed. The head loss of the clean strainer has been subtracted (except for the baseline, clean strainer case).

Plots for each of the runs are also included in Appendix A. The plots show the strainer differential pressure and the corresponding flow rate as a function of time. Material addition times and other run specific notes are indicated on the plots. The strainer differential pressure represents the head loss across the debris bed only, "dean" head loss has been subtracted out.

The data contained in the tables and the plots in the Appendix have been verified according to C.D.I. Quality Assurance procedures. Notes for each run are also provided.

4. QUALITY ASSURANCE

All quality related test activities were performed in accordance with the Continuum Dynamics, Inc. Quality Assurance Manual, Revision 12 (Ref. 4). Quality related activities are those which are directly related to the planning, execution and objectives of the tests. Supporting activities such as test apparatus design, fabrication and assembly are not controlled by the C.D.I. Quality Assurance Manual. C.D.L's Quality Assurance Program provides for compliance with the reporting requirements of 10 CFR Part 21. All instrument certification and calibration, test procedures, data reduction procedures and test results will be contained in a Design Record File which (upon completion) will be kept on file at C.D.I. offices.

5. REFERENCES

1. Continuum Dynamics, Inc., Plan for Testing GE Strainer, Revision 1, 31 October 1996.

2. Continuum Dynamics, Inc., DRF-G-118, "Full Scale Strainer Head Loss Testing with Fibrous Insulation and Corrosion Products + Other Debris," July 1996.

3. Continuum Dynamics, Inc., DRF-R-124, "Strainer Testing with Fibrous Insulation & Corrosion Products," December 1996.

4. Continuum Dynamics, Inc., Quality Assurance Manual, Revision 12, October 1996.

A. TEST RESULTS AND DATA PLOTS

The test results and plots of head loss across the debris bed and flow rate are shown for the respective tests. For all runs, except GE1, the clean head loss is subtracted from the total measured head loss to provide the head loss across the debris bed. Head loss is measured in inches of water and flow rate is measured in gallons per minute (GPM).

The following test data is included in this report:

Run GE1

Run GE2

Run GE3

Run GE4

Run GE6

Run GE7

Run GE8

Run GE9

Run GE10.

Appendix B

"Fast Panel Analysis of Strainer Designs" (CDI Technical Memo No. 97-03, January 1997)

C.D.I. TECHNICAL MEMORANDUM NO. 97-03

FAST PANEL ANALYSIS OF STRAINER DESIGNS

Rev. 0

Prepared by

Milton E. Teske
Alexander H. Boschitsch

CONTINUUM DYNAMICS, INC.
P. O. BOX 3073
PRINCETON, NEW JERSEY 08543

Prepared under Purchase Order No. 52897003805 for

GE NUCLEAR ENERGY
GENERAL ELECTRIC COMPANY
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95125

Approved by

Alan B. Bilanin

Alan J. Bilanin

February 1997

SUMMARY

A fast panel analysis is used to: (1) predict the hydrodynamic mass coefficients of three GE optimal stacked disk strainer designs placed in an inviscid flow field, and (2) compare these predicted values with predicted mass coefficients for solid cylinders of the same corresponding dimensions.

THEORY

A boundary element analysis developed for nonlifting potential flow is employed to calculate the virtual mass of a closed body. The panel analysis proceeds by first discretizing the surface of the closed body into a collection of constant-strength boundary elements (panels), and then adjusting the individual strengths of the panels so that the superposition of the ambient flow and the flow induced by the panels has zero normal component at every panel centroid. The velocity induced by a panel with constant source strength σ_i is given by:

$$u_i(R) = \sigma_i \int_{A_i} \frac{R-\rho}{r^3}\, dA, \quad r = \left| R - \rho \right| \tag{1}$$

where A; is the panel area, R is the evaluation point and p is a point on the panel surface. For sufficiently distant observation points, the integral in Eq (1) can be approximated by:

$$u_i(R) = \sigma_i \; A_i \frac{R - \rho_c}{r_c^3} \tag{2}$$

where ρ_c; is the panel centroid. The non-penetration condition is imposed by requiring for all panels, i=1 to N, that:

$$2\pi\sigma_i + \hat{n}_i \cdot \left(u_\infty + \sum_{j \neq i} u_j\,(R_i) \right) = 0 \tag{3}$$

The set of equations represented in Eq (3) comprises an N-body problem where each panel interacts with all other panels. The characteristic $O(N^2)$ computational complexity associated with such problems is reduced to O(NlogN) by invoking multipole-based fast summation procedures applied to Eq (2). This fast velocity calculation is embedded within a GMRES iteration sequence to invert Eq (3) for σ_i. Complete details of the fast panel scheme are given in Ref. 1.

Once the panel strengths are known, the panel-induced potential is determined using:

$$\phi(R) = -\sum_{i=1}^{N} \sigma_i \int_{A_i} \frac{1}{r}\, dA \tag{4}$$

The negative sign reflects preference for the convention:

$$U(R) = +\nabla_R \phi(R) \tag{5}$$

The pressure is given by:

$$P = -\rho \frac{\partial \phi}{\partial t} \tag{6}$$

and the time-varying potential by:

$$\phi(R,t) = \beta(t)\, \phi_0(R) \tag{7}$$

where ϕ_0 is the potential associated with a steady-state flow with unit magnitude ambient velocity (note that from Eqs (3) and (4) the panel strengths and hence potential scale linearly with velocity magnitude). Consequently, to compute the virtual mass it suffices to know the surface potential under steady state conditions. Specifically, Eq (4) is evaluated at every panel centroid. Once again, fast summation methods are employed to reduced computation time. Virtual mass coefficients are obtained by summing:

$$m = -\int_s P\hat{n}\, dA = +\rho\beta\,(t)\int_s \phi_0(R)\hat{n}\, dA \cong +\rho\beta(t)\sum_{i=1}^{N} \phi_0(R_i)\hat{n}(R_i)\hat{n}_i\ A_i \tag{8}$$

Equation (8) accounts only for the panel-induced potential. The contribution from the free stream potential $\phi_0 = u_\infty \cdot R$ is:

$$m_\infty = +\rho\beta(t) \cdot \int_s \hat{n}(R \cdot u_\infty)\, dA = +\rho\beta(t)\ Vu_\infty \tag{9}$$

where V is the volume of the immersed body.

DISCUSSION

Important design values for the GE optimal stacked disk strainer are its hydrodynamic mass coefficients for coaxial flow impinging on the strainer, and for flow normal to the axis of revolution of the strainer. As illustrated in Figure 1 by the velocities $U_1(t)$ and $U_2(t)$, respectively, these flow components create an apparent mass to the strainer, and therefore augment its actual mass in any loads analysis. By definition, the hydrodynamic mass coefficient C_h multiplies the strainer mass defined by the mass enclosed in a solid cylinder of radius R and length L to give the strainer hydrodynamic mass, while the virtual mass coefficient Cm multiplies the strainer volume defined by the volume enclosed in a solid cylinder of radius R and length L to give the strainer acceleration drag volume.

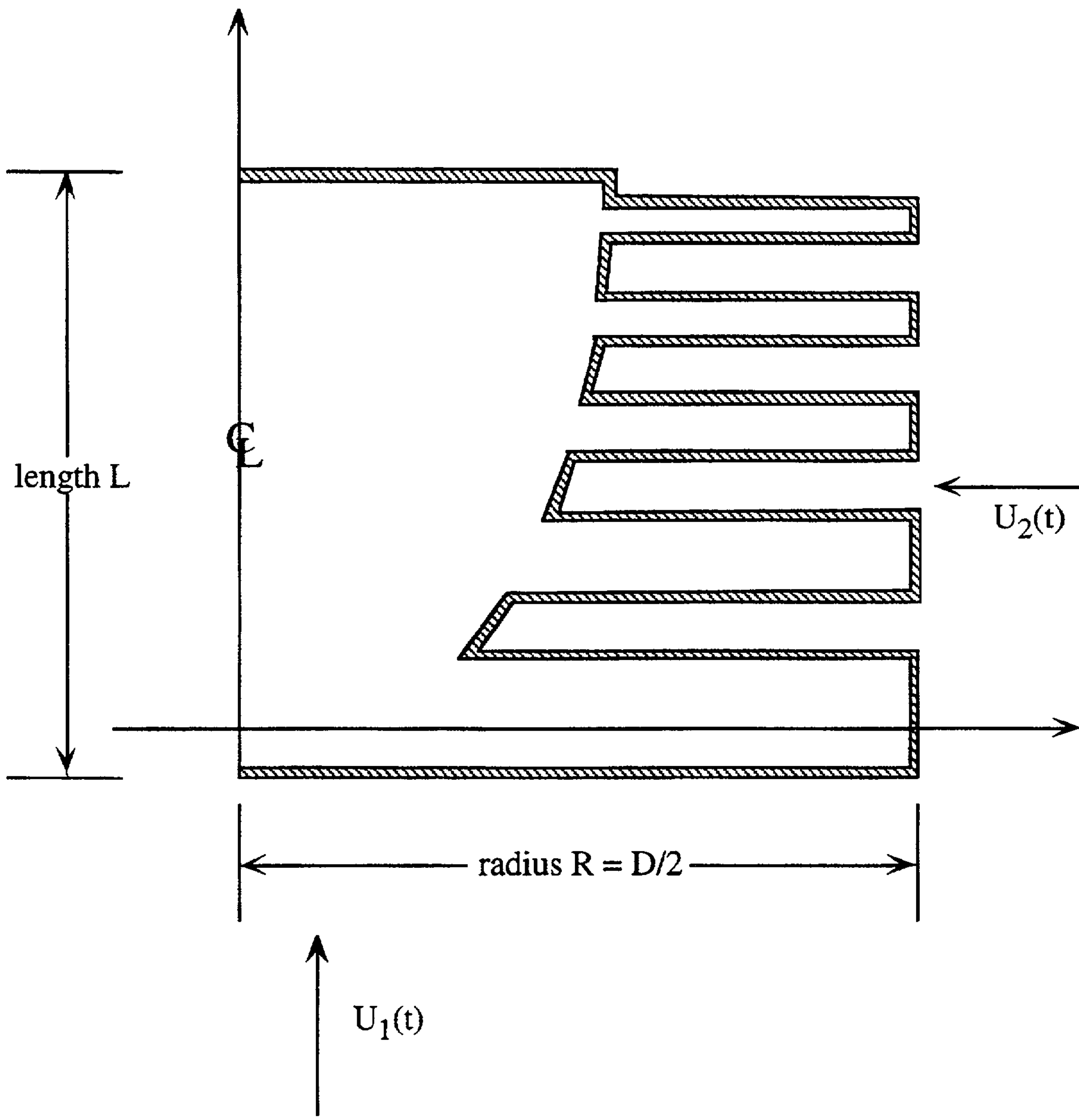

Figure 1. Optimal stacked disk strainer geometry. The strainer has a diameter of D and length of L, with an assumed longitudinal velocity of $U_1(t)$ and crossflow velocity of $U_2(t)$.

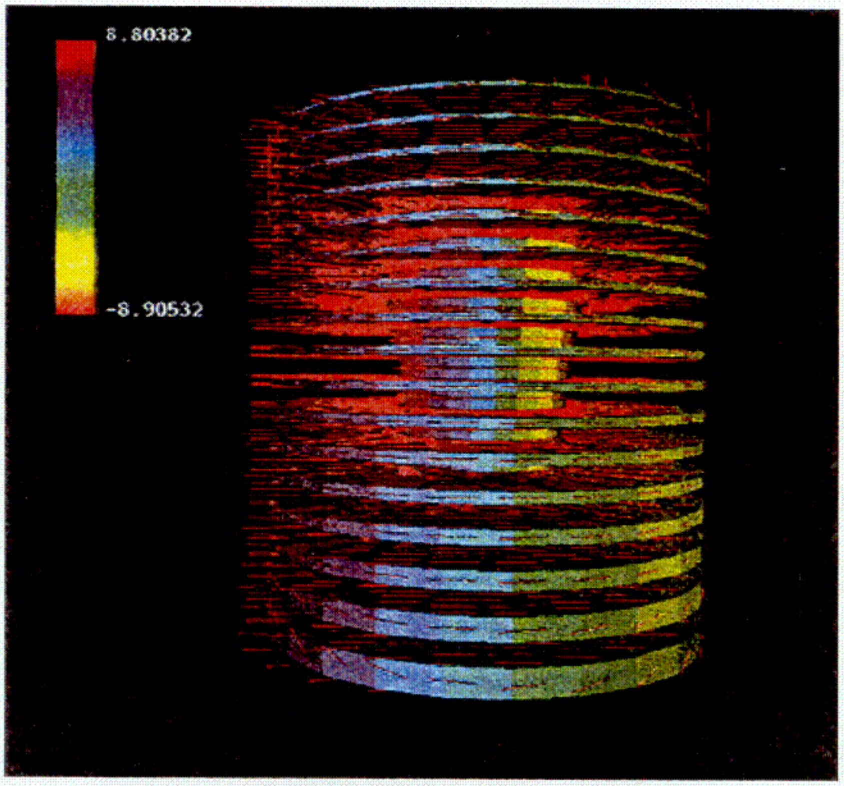

Figure 2. **Typical flow field around a stacked strainer for an assumed crossflow velocity of $U_2(t)$. Normalized velocity vectors are shown by red arrows; normalized pressure levels on the surface of the strainer are given by the color scale in the upper left hand corner of the figure.**

C01

Table 1. Assumed geometry for the fast-panel inviscid analysis of several stacked disk strainer designs.

D/L	0.6	0.89	1.2
Radius (in)	17.9	21.4	31.4
Length (in)	60.0	48.0	52.6
Number of Plates	20	17	19
Volume (ft^3)	17.52	17.50	33.21
Cylindrical Fraction	0.501	0.438	0.352

REFERENCES

1. Boschitsch, A. H., T. B. Curbishley, T. R. Quackenbush and M. E. Teske. 1996. A Fast Panel Method for Potential Flows about Complex Geometries. Paper No. A96-0024. 34th AIAA Aerospace Sciences Meeting and Exhibit: Reno, NV.

2. Boschitsch, A. H. and T. R. Quackenbush. 1996. Fast Panel Analysis (FPA) (Mod 0.0) User Manual. Technical Memorandum No. 96-20. Continuum Dynamics, Inc: Princeton, NJ.

3. Moody, F. J. 1997. Hydrodynamic Loads on CDI Strainer Design. General Electric Company: San Jose, CA.

4. Lamb, H. 1879. Hydrodynamics: Treatise on the Mathematical Theory of the Motion of Fluids. Dover Publications: New York, NY.

5. 1981. Mark I Containment Program Load Definition Report. NEDO-21888. General Electric Company: San Jose, CA. Table 4.3.4-1 (Revision 2).

Appendix C

Example Output of Strainer Size Calculation

Inputs for ECCS Suction Strainer Design

Plant: Design/Load Case: Calculation Date:	**Example** **Example LTR Calcs.** **3/19/97**
System	**RHR**
# of Pumps	
Rated Pump Flow (gpm)	
# of Strainers	
# of Strainers (CS Sizing)	
# of Strainers (RHR Sizing)	
Strainer Flowrate (gpm)	9349
Load Factor	1
Blockage Area (ft^2)	0
Total Headloss Limit (ft.)	5.26
Strainer Inside Radius (in.)	11.625
Strainer	**RHR**
Strainer Outside Radius (in.)	22
Nominal Flange Size	20
# of Flange Bolt Holes	20
# of Ribs	10
# of "Half" Ribs	0
"Half" Rib Length	0
Rib Width (in)	2
Rib Thickness (in)	0.38
Pool Temperature (F)	130
Volume of Fiber, Vf (ft^3)	10.04
Fiber Type	Nukon
Fiber Diameter (ft)	2.33E-05
Fiber Spacing (ft)	1.56E-04
Fiber Density, rho	2.4
Crud Mass (lb)	145.5
Misc. debris Loads (lb)	
Paint	133.3
Rust	13.2
Sand	0
Dirt/Dust	39.7
Zinc	0
Ca. Si	1.09
RMI Type	2.5 mil SS
Area of RMI Foil (ft^2)	0
US for RMI type	0.39
Kt for RMI Type	0.014
Kp for RMI Type	4.9

Example		RHR						Example LTR Calcs			
			ECCS Suction Strainer Sizing Calculation								
				(Hydraulic Resistance Formulation – Stack by Stack Method)							
	R =	22	inch		External Radius of the strainer (in.)						
	r(L) =	11.625	inch		Inside radius of ECCS suction strainer flange (in)						
	t(L) =	0.4	inch		Maximum inside disk thickness (in)						
	l,gap =	1.75	inch		Length of gap between disks (in)						
	t,w =	0.12	inch		Thickness of Perforated Plate (11 gauge) (in)						
	t,f =	0.2	inch		Allowance for flow blockage at corner of spacers/disk (in.)						
	b =	5.25	inch		length blocking the circumference of the inner radius of the						
	wb =	10.5	sq. inch		area blocking the central flow						
	ro =	2.7518	inch								
	U/Uc =	0.0068									
	Ud/Uc <	1									
	U/Ud >	0.0068									
	-0.00995										
Stack No.	f	r (in)	t (in)	A (in^2)	L (in.)	U/Ud	Ud/Uc	Uc/Uc	Qi/Qt, 1	Ai/At	Qi/Qt,2
1	-0.00011	3.137	1.400	3006	3.390	0.007	1.000	0.143	0.049	0.049	0.049
2	-0.00027	4.038	0.992	2986	6.372	0.007	1.000	0.184	0.049	0.049	0.049
3	-0.00056	4.763	0.798	2952	9.160	0.007	1.000	0.217	0.048	0.048	0.048
4	-0.00068	5.385	0.680	2917	11.830	0.007	1.000	0.245	0.048	0.048	0.048
5	-0.00073	5.936	0.598	2883	14.418	0.007	1.000	0.270	0.047	0.047	0.047
6	-0.00074	6.434	0.537	2848	16.945	0.007	1.000	0.292	0.047	0.047	0.047
7	-0.00073	6.890	0.490	2813	19.425	0.007	1.000	0.313	0.046	0.046	0.046
8	-0.00071	7.313	0.452	2779	21.867	0.007	1.000	0.332	0.046	0.046	0.046
9	-0.00067	7.709	0.420	2745	24.276	0.007	1.000	0.350	0.045	0.045	0.045
10	-0.00063	8.080	0.400	2711	26.666	0.007	0.982	0.361	0.044	0.044	0.044
11	-0.00059	8.431	0.400	2677	29.056	0.007	0.924	0.354	0.044	0.044	0.044
12	-0.00055	8.763	0.400	2644	31.446	0.008	0.873	0.348	0.043	0.043	0.043
13	-0.0005	9.080	0.400	2611	33.836	0.008	0.827	0.341	0.043	0.043	0.043
14	-0.00046	9.382	0.400	2578	36.226	0.009	0.787	0.336	0.042	0.042	0.042
15	-0.00041	9.671	0.400	2546	38.616	0.009	0.751	0.330	0.042	0.042	0.042
16	-0.00036	9.948	0.400	2514	41.006	0.009	0.718	0.325	0.041	0.041	0.041
17	-0.00031	10.214	0.400	2482	43.396	0.0010	0.688	0.319	0.041	0.041	0.041
18	-0.00027	10.470	0.400	2451	45.78	0.010	0.660	0.314	0.040	0.040	0.040
19	-0.00022	10.717	0.400	2420	48.176	0.011	0.635	0.309	0.040	0.040	0.040
20	-0.00018	10.956	0.400	2389	50.566	0.011	0.611	0.304	0.039	0.039	0.039
21	-0.00013	11.186	0.400	2359	52.956	0.012	0.589	0.299	0.039	0.039	0.039
22	-8.6E-05	11.409	0.400	2329	55.346	0.012	0.568	0.295	0.038	0.038	0.038
23	-4.3E-05	11.625	0.400	2299	55.986	0.012	0.549	0.290	0.038	0.038	0.038

Example	RHR			Example LTR Calcs		3/19/97
	Head Loss Calculation					
Debris Load:				RMI Summary:		
Mf =	24.10	lb		RMI Type	2.5 mil SS	
	Mx/Mf			Us for RMI Type	0.39	
Crud (Mc/Mf)	6.04			Kt for RMI Type	0.01	
Paint Chip	5.53			Kp for RMI Type	4.90	
Rust	0.55			tmax	0.87	
Sand	0.00			ta, use if >tp	0.00	
Dirt/C. Dust	1.65			tp	0.87	
Zinc	0.00			Dh	0.66	ft
Ca. Silicate	0.05					
Q	9349					
D	44					
L	55.00					
Ac	52.80	ft^2		Surface Area of Cylinder w/Strainer L&D		
Ac, corr	52.80	ft^2				
U	0.39	ft/sec		Flow Velocity for pi*DL (ft/sec)		
U1	0.29	ft/sec		Flow Velocity for pi*Dl + front and back surface (ft/sec)		
nu	5.43E-06	ft^2/sec				
Re,d	11.332					
t	0.19			Fiber thickness of cylindrical strainer (ft) = Vf *LF/Ac		
t/D	0.0519	ft				
Fq	1.000					
Ft	0.500					
Re,df	1.262					
Kh	1.037					
Dh	0.54					
Kbu	2.14					
				Clean Head Loss		
Dh,t	1.15 ft			Q(cu.ft/sec)	20.83	cuft/s
Clean Headloss +	1.83 ft			Flange head (ft)	1649	20" Diameter of suction line
Total Headloss =	2.99 ft	←		Str. Head(ft)	0.775	24" Inner diameter of strainer
RMI Headloss	0.66 ft	←		Str. Loss	1.736	ft
Headloss Limit	5.26 ft	←	+	Flange Loss	0.096	ft
Margin	2.27 ft			Total Clean =	1.832	ft

Example	RHR					Example LTR Calcs.			
	Outputs Based on Hydraulic Sizing Methodology – Fiber Loading								
Step	Characteristic					Variable		Value	Units
1	Outside Diameter					D	=	44.00	in
2	Strainer Active Length					L	=	55.00	in
3	Circumscribed Area					Ac	=	52.80	sq. ft.
4	Strainer Blockage					B	=	0.00	sq. ft.
5	Corrected Area					Ac,cor	=	52.80	sq. ft.
6	Flowrate					Q	=	9349	gpm
7	Load FActor					LF	=	1.00	
8	Total NSPH Limit					NPSH,D	=	5.26	ft.
9	Pool Temperature					T	=	130	F
10	Kinematic Viscosity					nu	=	0.00	lb-s-ft/slugs
11	total Volume of Fiber					Vf,t	=	10.04	cu.ft.
12	Volume of Fiber/Strainer					Vf	=	10.04	cu.ft.
13	Density of Fiber					rho,f	=	2.40	lbm/cu.ft.
14	Interfiber Spacing					d	=	0.00	ft.
15	Mass of Fiber/Strainer					Mf	=	24.10	lbm.
16	Total Mass of Corrosion Sludge					Ms,t	=	145.50	lbm.
17	Total Mass of Dirt/Dust					Md,t	=	39.70	lbm.
18	Total Mass of Corrosion Products					Mc,t	=	185.20	lbm.
19	Total Mc,t per Strainer					Mc,t	=	185.20	lbm.
20	Ratio of Corr. Prod/Fiber					Mc/Mf	=	6.04	
21	Strainer Approach Velocity					U	=	0.39	ft./sec.
22	Reynolds Number					Re	=	11.33	
23	Fiber Thickness					t	=	0.19	ft.
24	Ratio of Fiber Thickness/Dia.					t/D	=	0.05	
25	Nondim. Headloss, Kh					Kh	=	1.04	
26	GE Strainer Headloss					Dh	=	0.54	ft.
27	Bump Up Factor					Kbu	=	2.14	ft.
27		Paint Chips	Mx/Mf	=	5.53	Mx	=	133.30	lbm
		Rust	Mx/Mf	=	0.55	Mx	=	13.20	lbm.
		Sand	Mx/Mf	=	0.00	Mx	=	0.00	lbm.
		Dirt/Dust	Mx/Mf	=	1.65	Mx	=	39.70	lbm.
		Zinc	Mx/Mf	=	0.00	Mx	=	0.00	lbm.
		Ca.Si.	Mx/Mf	=	0.05	Mx	=	1.09	lbm.
28	Corrected Head Loss					Dh,cor	=	1.15	ft.
29	Clean Head Loss					Dh,cln	=	1.83	ft.
30	Total Head Loss					Dh,t	=	2.99	ft.
31	NPSH Margin Left					M	=	2.27	ft.

Example	RHR	Example LTR Calcs. 3/19/97

Parts List

Flange Size	20
# of Flange Bolt Holes	20
# of Ribs	10
Disk Sets	23

	Parts	Number of Unique Parts	Number of Parts	Part Number	
				First	Last
1	Bolt	1	20		1
2	Flange	1	1		2
3	Flange Lug	1	2		3
4	Top Support	1	1		4
5	Lifting Pipe	1	1		5
5	Compression Plate	1	10		6
6	Rib	1	10		7
7	Perforated Disk	46	46	8	53
8	Outer Disk Support Ring	23	23	54	76
9	Spacer (Inner Ring)	23	23	77	99
10	Internal Finger	23	230	100	122
	TOTALS	122	367		

Example	RHR	Example LTR Calcs.	3/19/97

PERFORATED DISK

Material: 304L or 304 SST
Thickness: 0.1198 in.
Hole/Spacing Dia. 0.12 x 0.19 spacing

Item No.	Disk No.	Location	Qty.	Outer Dia	Tol	Inner Dia	Tolerance	
							Minus	Plus
8	1	Top	1	43.75	+/- 0.02	6.25	0.01	0.02
9	1	Bot	1	43.785	+/- 0.02	6.03	0.01	0.02
10	2	Top	1	43.75	+/- 0.02	6.27	0.01	0.02
11	2	Bot	1	43.75	+/- 0.02	7.84	0.01	0.02
12	3	Top	1	43.75	+/- 0.02	8.08	0.01	0.02
13	3	Bot	1	43.75	+/- 0.02	9.29	0.01	0.02
14	4	Top	1	43.75	+/- 0.02	9.53	0.01	0.02
15	4	Bot	1	43.75	+/- 0.02	10.53	0.01	0.02
16	5	Top	1	43.75	+/- 0.02	10.77	0.01	0.02
17	5	Bot	1	43.75	+/- 0.02	11.63	0.01	0.02
18	6	Top	1	43.75	+/- 0.02	11.87	0.01	0.02
19	6	Bot	1	43.75	+/- 0.02	12.63	0.01	0.02
20	7	Top	1	43.75	+/- 0.02	12.87	0.01	0.02
21	7	Bot	1	43.75	+/- 0.02	13.54	0.01	0.02
22	8	Top	1	43.75	+/- 0.02	13.78	0.01	0.02
23	8	Bot	1	43.75	+/- 0.02	14.39	0.01	0.02
24	9	Top	1	43.75	+/- 0.02	14.63	0.01	0.02
25	9	Bot	1	43.75	+/- 0.02	15.18	0.01	0.02
26	10	Top	1	43.75	+/- 0.02	15.42	0.01	0.02
27	10	Bot	1	43.75	+/- 0.02	15.92	0.01	0.02
28	11	Top	1	43.75	+/- 0.02	16.16	0.01	0.02
29	11	Bot	1	43.75	+/- 0.02	16.62	0.01	0.02
30	12	Top	1	43.75	+/- 0.02	16.86	0.01	0.02
31	12	Bot	1	43.75	+/- 0.02	17.29	0.01	0.02
32	13	Top	1	43.75	+/- 0.02	17.53	0.01	0.02
33	13	Bot	1	43.75	+/- 0.02	17.92	0.01	0.02
34	14	Top	1	43.75	+/- 0.02	18.16	0.01	0.02
35	14	Bot	1	43.75	+/- 0.02	18.52	0.01	0.02
36	15	Top	1	43.75	+/- 0.02	18.76	0.01	0.02
37	15	Bot	1	43.75	+/- 0.02	19.10	0.01	0.02
38	16	Top	1	43.75	+/- 0.02	19.34	0.01	0.02
39	16	Bot	1	43.75	+/- 0.02	19.66	0.01	0.02
40	17	Top	1	43.75	+/- 0.02	1990	0.01	0.02
41	17	Bot	1	43.75	+/- 0.02	20.19	0.01	0.02
42	18	Top	1	43.75	+/- 0.02	20.43	0.01	0.02
43	18	Bot	1	43.75	+/- 0.02	20.70	0.01	0.02
44	19	Top	1	43.75	+/- 0.02	20.94	0.01	0.02
45	19	Bot	1	43.75	+/- 0.02	21.19	0.01	0.02
46	20	Top	1	43.75	+/- 0.02	21.43	0.01	0.02
47	20	Bot	1	43.75	+/- 0.02	21.67	0.01	0.02
48	21	Top	1	43.75	+/- 0.02	21.91	0.01	0.02

49	21	Top	1	43.75	+/- 0.02	22.13	0.01	0.02
50	22	Bot	1	43.75	+/- 0.02	22.37	0.01	0.02
51	22	Top	1	43.75	+/- 0.02	22.58	0.01	0.02
52	23	Bot	1	43.75	+/- 0.02	22.82	0.01	0.02
53	23	Top	1	43.75	+/- 0.02	23.01	0.01	0.02

Example	RHR	Example LTR Calcs.	3/19/97

DISK SUPPORT RING

Material: 304L or 304 SST
Thickness: 0.25 inch (stock)

Item No.	Disk No.	Qty	Outer Dia	Tolerance		Depth	Tol	Thickness
				Minus	Plus			
54	1	1	44.00	0.06	0.00	1.38	+/- 0.02	0.25 STK
55	2	1	44.00	0.06	0.00	0.97	+/- 0.02	0.25 STK
56	3	1	44.00	0.06	0.00	0.78	+/- 0.02	0.25 STK
57	4	1	44.00	0.06	0.00	0.66	+/- 0.02	0.25 STK
58	5	1	44.00	0.06	0.00	0.58	+/- 0.02	0.25 STK
59	6	1	44.00	0.06	0.00	0.52	+/- 0.02	0.25 STK
60	7	1	44.00	0.06	0.00	0.47	+/- 0.02	0.25 STK
61	8	1	44.00	0.06	0.00	0.43	+/- 0.02	0.25 STK
62	9	1	44.00	0.06	0.00	0.40	+/- 0.02	0.25 STK
63	10	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
64	11	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
65	12	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
66	13	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
67	14	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
68	15	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
69	16	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
70	17	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
71	18	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
72	19	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
73	20	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
74	21	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
75	22	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK
76	23	1	44.00	0.06	0.00	0.38	+/- 0.02	0.25 STK

Example	RHR	Example LTR Calcs.	3/19/97

SPACER (PERFORATED METAL)

Material: 304 SST
Thickness: 0.1198 in.
Hole/Spacing Dia. 0.12 x 0.19 spacing

Item No.	Disk No.	Qty	Inner Dia	Tolerance	Depth	Tol
77	1	1	6.27	+/- 0.02	1.75	+/-0.02
78	2	1	8.08	+/- 0.02	1.75	+/-0.02
79	3	1	9.53	+/- 0.02	1.75	+/-0.02
80	4	1	10.77	+/- 0.02	1.75	+/-0.02
81	5	1	11.87	+/- 0.02	1.75	+/-0.02
82	6	1	12.87	+/- 0.02	1.75	+/-0.02
83	7	1	13.78	+/- 0.02	1.75	+/-0.02
84	8	1	14.63	+/- 0.02	1.75	+/-0.02
85	9	1	15.42	+/- 0.02	1.75	+/-0.02
86	10	1	16.16	+/- 0.02	1.75	+/-0.02
87	11	1	16.86	+/- 0.02	1.75	+/-0.02
88	12	1	17.53	+/- 0.02	1.75	+/-0.02
89	13	1	18.16	+/- 0.02	1.75	+/-0.02
90	14	1	18.76	+/- 0.02	1.75	+/-0.02
91	15	1	19.34	+/- 0.02	1.75	+/-0.02
92	16	1	19.90	+/- 0.02	1.75	+/-0.02
93	17	1	20.43	+/- 0.02	1.75	+/-0.02
94	18	1	20.94	+/- 0.02	1.75	+/-0.02
95	19	1	21.43	+/- 0.02	1.75	+/-0.02
96	20	1	21.91	+/- 0.02	1.75	+/-0.02
97	21	1	22.37	+/- 0.02	1.75	+/-0.02
98	22	1	22.82	+/- 0.02	1.75	+/-0.02
99	23	1	23.25	+/- 0.02	3.06	+/-0.02

Example	RHR	Example LTR Calcs.	3/19/97

INTERNAL FINGER

Material: 304 SST
Thickness: 0.25 inch (stock)

Item No.	Disk No.	Qty	Length	Tol	Depth	Tol	Thickness
100	1	10	20.11	+/- 0.10	1.40	+/- 0.02	0.25 STK
101	2	10	19.21	+/- 0.10	0.99	+/- 0.02	0.25 STK
102	3	10	18.49	+/- 0.10	0.80	+/- 0.02	0.25 STK
103	4	10	17.87	+/- 0.10	0.60	+/- 0.02	0.25 STK
104	5	10	17.31	+/- 0.10	0.54	+/- 0.02	0.25 STK
105	6	10	1682	+/- 0.10	0.49	+/- 0.02	0.25 STK
106	7	10	16.36	+/- 0.10	0.45	+/- 0.02	0.25 STK
107	8	10	15.94	+/- 0.10	0.42	+/- 0.02	0.25 STK
108	9	10	15.54	+/- 0.10	0.40	+/- 0.02	0.25 STK
109	10	10	15.17	+/- 0.10	0.40	+/- 0.02	0.25 STK
110	11	10	14.82	+/- 0.10	0.40	+/- 0.02	0.25 STK
111	12	10	14.49	+/- 0.10	0.40	+/- 0.02	0.25 STK
112	13	10	14.17	+/- 0.10	0.40	+/- 0.02	0.25 STK
113	14	10	13.87	+/- 0.10	0.40	+/- 0.02	0.25 STK
114	15	10	13.58	+/- 0.10	0.40	+/- 0.02	0.25 STK
115	16	10	13.30	+/- 0.10	0.40	+/- 0.02	0.25 STK
116	17	10	13.04	+/- 0.10	0.40	+/- 0.02	0.25 STK
117	18	10	12.78	+/- 0.10	0.40	+/- 0.02	0.25 STK
118	19	10	12.53	+/- 0.10	0.40	+/- 0.02	0.25 STK
119	20	10	12.29	+/- 0.10	0.40	+/- 0.02	0.25 STK
120	21	10	12.06	+/- 0.10	0.40	+/- 0.02	0.25 STK
121	22	10	11.84	+/- 0.10	0.40	+/- 0.02	0.25 STK
122	23	10	11.63	+/- 0.10	0.40	+/- 0.02	0.25 STK

Example	RHR	Example LTR Calcs.	3/19/97

RIB

Material: XM-19 SST
Thickness: 0.38 (stock)
L-offset (base): 3.50 in.

Item No.	Length	Tol	Depth	Tol
1	61.24	+/- 0.15	10.49	+/- 0.15
2	57.85	+/- 0.15	8.49	+/- 0.15
3	54.86	+/- 0.15	7.59	+/- 0.15
4	52.08	+/- 0.15	6.86	+/- 0.15
5	49.41	+/- 0.15	6.24	+/- 0.15
6	46.82	+/- 0.15	5.69	+/- 0.15
7	44.29	+/- 0.15	5.19	+/- 0.15
8	41.81	+/- 0.15	4.73	+/- 0.15
9	39.37	+/- 0.15	4.31	+/- 0.15
10	36.96	+/- 0.15	3.92	+/- 0.15
11	34.57	+/- 0.15	3.55	+/- 0.15
12	32.18	+/- 0.15	3.19	+/- 0.15
13	29.79	+/- 0.15	2.86	+/- 0.15
14	27.40	+/- 0.15	2.55	+/- 0.15
15	25.01	+/- 0.15	2.24	+/- 0.15
16	22.62	+/- 0.15	1.95	+/- 0.15
17	20.23	+/- 0.15	1.68	+/- 0.15
18	17.84	+/- 0.15	1.41	+/- 0.15
19	15.45	+/- 0.15	1.15	+/- 0.15
20	13.06	+/- 0.15	0.91	+/- 0.15
21	10.67	+/- 0.15	0.67	+/- 0.15
22	8.28	+/- 0.15	0.44	+/- 0.15
23	5.89	+/- 0.15	0.22	+/-0-.15