ENCLOSURE 1

MFN 05-126

GE 26A6586, Revision 0
Active Strainer Maximum Concentration Methodology

Non-Proprietary Information

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NOMENCLATURE

V_s	Volume of the strainer control volume
V_p	Volume of water in the plant containment pool or test facility tank
M_s	Mass of debris in the control volume
M_p	Mass of debris in the plant containment pool or test facility tank
M_b	Cumulative mass of debris bypassed
M_o	Mass of debris present in the containment pool or test facility tank at time t=0
$\dot{M}_p$	Rate of change of mass in the containment pool or test facility tank
$\dot{M}_s$	Mass accumulation rate in strainer control volume
$\dot{M}_b$	Mass flow rate of bypassed debris
Q	Flow rate of water through the Active Strainer
C	Concentration defined as mass of debris per unit volume of water.
C_o	Concentration in the containment pool or test facility tank at time t=0
η	Bypass fraction
i	Subscript denotes a reference to a particular debris species
plant	Subscript denotes a reference to a plant-specific quantity
test	Subscript denotes a reference to a test-specific quantity

1 SCOPE

This report describes the methodology and design bases developed for specifying debris loads (the amount of debris) required for scaled model testing the debris-laden performance of the GE Containment Sump Active Strainers.

2 DESCRIPTION

2.1 Maximum Concentration Methodology

This report establishes and justifies the bases for the Maximum Concentration Methodology. The methodology develops the algorithms necessary to justify scaled testing of the Active Containment Sump Strainer, an alternative to full scale, full debris load testing in a full scale PWR containment facility. The algorithms transform in-plant post-LOCA flow and debris conditions surrounding the in-plant strainer to scaled test conditions in a test tank containing a sub-scale strainer.

Debris load is defined as a concentration, or:

$$Concentration = \frac{MassDebris}{Volume}$$

[[

]] The concentration reaches a maximum value some time after system flow and debris transport are initiated.

The objective of this work is to conservatively bound the maximum concentration around the strainer in the containment pool. [[

]]

Once the maximum concentration of debris around the plant full-scale strainer is defined, the amount of debris to be used during scaled model testing (in less than full-scale test facilities) can also be determined.

The methodology can be used for any sized strainer and debris mixture.

This report also gives a general overview of the GE Containment Sump Active Strainer and the overall approach used for scaled testing. This information is provided to supplement the overall understanding of the Active Strainer and the context in which the Maximum Concentration Methodology is necessary.

2.2 Active Strainer Description

The Active Strainer consists of a motor driven plow and comb that sweep over a perforated plate. Fluid enters a location at the periphery of the plow-swept area and is projected radially outward by centrifugal action. [[

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The other components shown in Figure 2-1 serve the following functions:

[[

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2.2.1 *Determination of Size for the Active Strainer*

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2.2.2 *Determination of the Rotation Rate of the Plow and Comb*

[[

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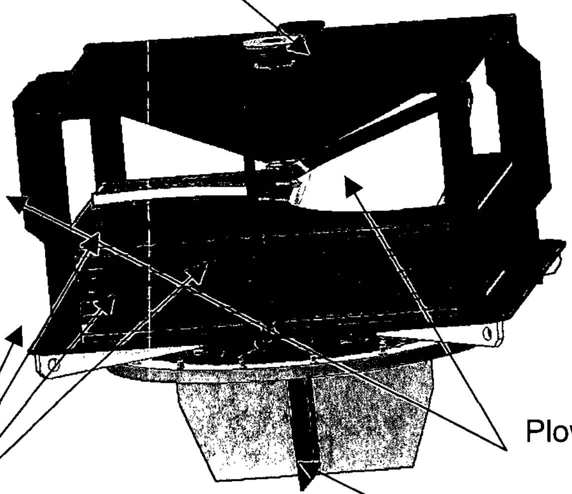

Figure 2-1 Active Strainer Assembly

2.3 Scaling Approach For Active Strainer Testing

Because a scale model of the strainer will be tested, it is important to establish scaling laws so that the test results can be extrapolated to the prototype strainer with confidence. The scale model laws developed by F. J. Moody [1] will be used for this purpose.

Two types of scaling have been considered: geometric scaling, where all linear dimensions are reduced by the same factor; and segment scaling, which would only represent that part of the strainer inside some radius less than full size. Scale-up laws can be obtained for predicting full size performance from a geometrically similar test. [[

]]

The following table summarizes the characteristics of the test strainer compared to the full-scale strainer. The characteristics are given for both segment and geometric scaling bases. Here, S is the constant scaling factor between the full-scale strainer and the test strainer. For a typical full-scale strainer size of 4 ft, the scaling factor S is 2, assuming a 2 ft test strainer.

Table 2-1 Active Strainer Scaling Approaches

Parameter	Full-Scale Strainer	Test Strainer (Segment Scaling)	Test Strainer (Geometrical Scaling)
Strainer Radius	R	[[	
Strainer Area	πR^2		]]
Distance Between Top Perforated Plate and Missile Shield	[[		]]
Perforated Plate Hole Size	X	[[	
Flow rate through Strainer	Q		
Approach Velocity of Water to Strainer	U		
Plow and Comb Angular Velocity	Ω		
Plow and Comb Tip Velocity			
Perforated Plate Pressure Drop	ΔP		]]

[[

]] Both types of tests will be performed, as the only differences in the testing will be the approach velocities and rotational speeds.

3 MAXIMUM CONCENTRATION METHODOLOGY DESIGN

3.1 Conservation of Mass

3.1.1 Generic Model

The Maximum Concentration Model is based on the conservation of the mass of debris. Consider the sketch shown in Figure 3-1.

$\dot{M}$ Represents mass flow rate with units of mass per unit time.

$$\dot{M} = FlowRate\ Concentraton = Q \cdot \frac{M}{V} \quad (1)$$

[[

]]

Figure 3-1 Generic Control Volume Diagram

[[

]]

From the conservation of mass then,

$$\dot{M}_{stored} = \dot{M}_{in} - \dot{M}_{out} \quad (2)$$

Assuming that $\dot{M}_{in}$ and $\dot{M}_{out}$ are known, the mass accumulation rate in the control volume $\dot{M}_{stored}$ can be determined.

3.1.2 Conservation of Mass Applied to the Active Strainer

The same conservation of mass model can be applied to the Active Strainer in a containment pool. The model is sketched in Figure 3-2.

[[

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Figure 3-2 Control Volume Diagram for the Active Strainer in a Containment Pool

There is a containment pool with a volume of water V_p and a mass of debris M_p. Around the strainer is the control volume with volume, V_s, which contains a mass of debris M_s. [[

]]

The volumetric flow rate through the control volume and strainer is designated as Q.

Following Equation 2 and the conservation of mass for the containment pool,

$$\dot{M}_s = -\dot{M}_p - \dot{M}_b \qquad (3)$$

Assuming that $\dot{M}_p$ and $\dot{M}_b$ are known, the mass accumulation rate in the control volume, $\dot{M}_s$ can be determined. [[

]]

[[

]] This methodology considers each species of debris separately. [[

]]

Therefore, Equation 3 can be written for each species, denoted by the subscript *i*.

$$\dot{M}_{s,i} = -\dot{M}_{p,i} - \dot{M}_{b,i} \tag{4}$$

The concentration in the control volume is as follows:

$$Concentraton_i = \frac{M_{s,i}}{V_{s,i}} \tag{5}$$

Equation 4 is the basis for the Maximum Concentration Methodology. This methodology, in short, determines this maximum concentration, for debris species *i*, that occurs in the control volume V_s at the plant. By selecting the maximum value of $M_{s,i}$, the maximum concentration in the control volume containing the strainer can be determined, following Equation 5. [[

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[[ ]]

Note that Figure 3-2 is representative of the plant containment as well as the test pool. Accordingly, the variables change when applied to a different environment. Because this report discusses the scaling of concentrations from the plant to a scaled test pool, it is important to carefully note the subscripts of the different variables, $V_{s,i}$ in particular.

3.1.3 Determination of Variables

3.1.3.1 Containment Pool Variables V_p and $M_{p,i}$

As mentioned earlier, the volume of the containment pool is V_p. [[

]]

Unlike the other variables, V_p is not debris-specific and therefore does not have the subscript *i*.

[[

]]

The mass of the debris $M_{p,i}$ is the debris present in the pool that is eventually transported with the flow to the strainer(s). [[

]]

3.1.3.2 Control Volume Variables $V_{s,i}$ and $M_{s,i}$

The control volume, $V_{s,i}$, is the region in which debris concentrates around the strainer. [[

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[[

]].

The mass $M_{s,i}$ will be determined by solving the differential equation in Equation 4. The solution to this equation is discussed in Appendix 20.

3.1.3.3 Bypass Variable $M_{b,i}$

$M_{b,i}$ is the mass of debris bypassed. Because the mass of debris bypassed is a debris-specific quantity, it is has a subscript, *i*. [[

]]

[1] [[

]]

3.2 Maximum Concentration Methodology

Employing the conservation of mass model described in the previous section, it is necessary to solve Equation 4 to determine the maximum concentration in the control volume surrounding the strainer.

In order to solve Equation 4 for $\dot{M}_{s,i}$, $\dot{M}_{p,i}$ and $\dot{M}_{b,i}$ must first be determined.

3.2.1 Determination of $\dot{M}_{p,i}$, the Mass Flow Rate Entering the Control Volume

[[

]] Once the water level of the RWST reaches a predetermined value, suction is drawn from the containment pool at the flow rate Q. The mass of debris in the containment pool outside of the control volume decreases over time because the ECCS flow rate pulls the debris into the control volume surrounding the strainer.

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At any time after the start of the pumps, the mass of debris in the containment at any time, t, is given by:

[[

]]

The rate of change of debris in the containment pool is

[[

[[

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]]

The rate at which debris enters the control volume is equal to the rate at which mass decreases in the containment pool. [[

]]

[[

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3.2.2 Determination of $\dot{M}_{b,i}$, the Mass Flow Rate Bypassed by the Active Strainer

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Bypass is directly proportional to the concentration surrounding the strainer in the control volume for the same reasons cited above]]

Therefore, the mass flow rate of debris bypassed is given by the following expression:

[[

]]

The bypass fraction is determined experimentally and is discussed in Appendix 10.

3.2.3 Determination of $\dot{M}_{s,i}$, the Mass Accumulation Rate of Debris in the Control Volume

The rate of change of the debris mass in the control volume surrounding the strainer can be expressed using Equations 4, 8, 9 and 10.

[[

]]

Equation 12 gives an expression for the mass present in the control volume for a full-scale strainer in a typical PWR.

The concentration in the control volume for a full-scale strainer in a typical PWR follows Equations 10 and 12:

[[

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[[

]]

At some intermediate time $C_{s,i}$ is a maximum, which determines the concentration of debris present in the control volume for the full size strainer in the PWR plant application.

Comparing the time varying concentration in the control volume to the original pool concentration prior to the start of recirculation provides insight as to how the concentration changes. This comparison, or normalization, is as follows:

$$\frac{C_{s,i}}{C_{0,i}} = \frac{M_{s,i}/V_{s,i}}{M_{0,i}/V_p} \tag{14}$$

[[

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3.2.4 Applying the Maximum Concentration to the Scaled Strainer

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]] The following discusses how to achieve the same concentration in the scaled test facility as in the actual PWR plant.

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[[

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Note that the mass determined by Equation 18 is different from the mass determined in Equation 12. Equation 12 gives the mass that challenges the full-scale strainer at a maximum concentration. Equation 18 determines the mass required to challenge the scaled test strainer at a maximum concentration.

The maximum concentration is replicated during testing by introducing the maximum mass of debris, calculated by Equation 18, to the scaled test strainer within its control volume. [[

]]

A sample calculation of the maximum concentration and mass required for maximum concentration testing is given in the following section.

4 SAMPLE CALCULATION OF THE MASS OF DEBRIS REQUIRED FOR MAXIMUM CONCENTRATION TESTING

This section contains a sample calculation that determines the debris required for performing a maximum concentration test.

The defining equations are Equation 13 and 17. For the purpose of clarity in this example, the subscript "s" has been modified to refer to the control volume in either the plant or in the test pool.

[[

]]

It is necessary to first specify all of the variables:

Table 4-1 Variables for a Sample Maximum Concentration Calculation

Parameter	Value
Q –ECCS Suction Flow Rate	5000 gpm = 11.14 ft^3/s
V_p – Containment Pool Volume	400,000 gallons = 53,475.94 ft^3
$V_{s,plant}$ – Control Volume for the Full-Scale Strainer*	[[
$V_{s,test}$ – Control Volume for the Scaled Strainer*	
η_{Fiber}	
$\eta_{Particulate}$	]]
$M_{o,Fiber}$	4088.40 lbm
$M_{o,Particulate}$	659.3

[[

]]

Once all of the variables are specified, the maximum concentration and mass required can be determined. These values can be solved for directly from Equations 13 and 17. The derivation for the maximum concentration and mass required for testing for the fiber load is contained in Appendix 30.

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4.1 Numerical Approach

Equation 13 can be plotted by choosing an arbitrary time step. The resultant plot is shown below:

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Figure 4-1 Absolute Concentration $C_{s,i,pool}$ in the Containment Pool Control Volume vs. Time

As shown here, the concentration in the control volume reaches a maximum. [[

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After determining the peak concentration in the control volume, the mass required to perform the maximum concentration test is determined by Equation 17.

[[

]]

4.2 Discussion of Bypass

While the plot of $C_{s,i,pool}$ gives the actual concentration of fiber and particulate debris in the control volume, the normalized concentration plot, as shown below, provides additional insight. Through the normalized concentration plot it is possible to compare the concentration of the control volume to the original concentration of the overall containment pool. [[
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Figure 4-2 Normalized Concentration in the Control Volume C_s vs. Time

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Figure 4-3 Normalized Bypass Flow Rate vs. Time

Note that the scale on this chart is logarithmic and normalized.

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Figure 4-4 Normalized Cumulative Amount of Debris Bypassed vs. Time

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]], observation has shown that large or dense pieces of debris typically settle to the bottom of the pool, once swept away from the plow and comb. Therefore, if debris settles to the bottom of the pool, it will not be bypassed.

[[

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5 SENSITIVITY STUDIES

This methodology contains two different variables that can only be determined through testing: [[ ]] Therefore, the sensitivity of the results of the methodology must be evaluated, with respect to these two variables.

As shown earlier, the normalized concentration of debris in the control volume is governed by the Equation 15.

[[

]]

The normalized concentration of debris in the control volume is used for this study because it makes the results insensitive to the absolute mass of debris, $M_{o,l}$, thus allowing for clear comparisons to be made without considering some plant-specific conditions and differences.

5.1 <u>Sensitivity of the Normalized C_s to V_s</u>

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[[

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Figure 5-1 Normalized Concentration of Fiber in the V_s for Varying Control Volume Radii

As similar plot for particulate debris is shown the below. The main difference between the plots is the bypass fraction η.

[[

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Figure 5-2 Normalized Concentration of Particulate in V_s for Varying Control Volume Radii

[[

]]

Table 5-1 Comparisons for Varying Control Volume Radii

Effective V_s Radius	[[			
Volume of V_s				
Maximum Normalized Concentration				
Time at which the Maximum Concentration Occurs				
Time of Maximum Concentration/Volume of V_s				]]

These results are consistent with Equation 15. [[
]]

[[

]]

5.2 Sensitivity of the Normalized C_S to η

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[[

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Figure 5-3 Normalized Concentration in V_s for Various Bypass Fractions η

[[

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Table 5-2 Comparison for Different Bypass Fractions η

Eta	[[									
$C_{s,max}$										
T_{max} (s)										
$\Delta C_{s,max}$										]]

[[

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[[

]]

APPENDIX 10: DETERMINATION OF BYPASS FRACTION η_l

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Conservation of Mass

Consider the sketch below:

[[

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Figure 10-1 Control Volume Diagram for Bypass Testing

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APPENDIX 20: DERIVATION OF THE MASS ACCUMULATION RATE IN THE CONTROL VOLUME (EQUATION 11)

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[[

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APPENDIX 30: ANALYTICAL DETERMINATION OF M_S AND C_S

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APPENDIX 40: DERIVATION OF THE NORMALIZED CUMULATIVE AMOUNT OF DEBRIS BYPASSED

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ACKNOWLEDGEMENTS

1. Dr. F.J. Moody
2. Continuum Dynamics, Incorporated

ENCLOSURE 3

MFN 05-126

Affidavit

General Electric Company

AFFIDAVIT

I, **George B. Stramback,** state as follows:

(1) I am Manager, Regulatory Services, General Electric Company ("GE") and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in the GE design bases document 26A6586-P, *Active Strainer Maximum Concentration Methodology,* Revision 0, (GE Nuclear Energy Proprietary Information), dated October 11, 2005. The proprietary information is delineated by a double underline inside double square brackets. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation{3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner, GE relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by General Electric's competitors without license from General Electric constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future General Electric customer-funded development plans and programs, resulting in potential products to General Electric;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a., and (4)b, above.

(5) To address 10 CFR 2.390 (b) (4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GE, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GE, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within GE is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GE are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it contains detailed debris concentration methodology developed under GE's Program for evaluation of active and passive solutions for the PWR suction strainer blockage issue. The development of these PWR methodologies was achieved at a significant cost to GE, on the order of a few million dollars.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GE asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GE's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GE's

comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GE.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GE's competitive advantage will be lost if its competitors are able to use the results of the GE experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GE would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GE of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 2nd day of November 2005.

George B. Stramback
George B. Stramback
General Electric Company