Westinghouse Non-Proprietary Class 3

WCAP-17100-NP
Revision 1

February 2010

PRA Model for the Westinghouse Shut Down Seal

Page Change Markups December 2010

LEGAL NOTICE

This report was prepared as an account of work performed by Westinghouse Electric Company LLC. Neither Westinghouse Electric Company LLC, nor any person acting on its behalf:

A. Makes any warranty or representation, express or implied including the warranties of fitness for a particular purpose or merchantability, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

COPYRIGHT NOTICE

DISTRIBUTION NOTICE

This report was prepared for the PWR Owners Group. This Distribution Notice is intended to establish guidance for access to this information. This report (including proprietary and non-proprietary versions) is not to be provided to any individual or organization outside of the PWR Owners Group program participants without prior written approval of the PWR Owners Group Program Management Office. However, prior written approval is not required for program participants to provide copies of Class 3 Non Proprietary reports to third parties that are supporting implementation at their plant, and for submittals to the NRC.

Therefore, the 1710 psig limitation on O-ring survivability is considered to be no longer applicable since O-rings from the first batch are no longer in service.

O-rings for the SDS will all be manufactured from the latest third batch of O-ring material. However, as discussed later in this report, there are only a very limited number of O-rings that would be exposed to the high pressure differentials resulting from actuation of the SDS and in most cases, the extrusion gaps are predicted to close due to thermal expansion of the contiguous components. The one that will have an extrusion gap was tested using the process for the existing RCP O-rings. Details are found in Section 3.2.4 of this report.

1.2.3.4.5. Postulated Seal Failures

The WOG2000 PRA model in WCAP-15603-A for RCP seal behavior under a loss of all seal cooling event has four basic scenarios. In the first scenario, all of the seal stages perform as designed limiting RCS inventory loss through the seal package to 21 gpm per RCP. This was assigned a probability of occurrence of 0.79. The second scenario assumes that the No. 1 seal would "bind" in an open position in spite of the closing forces on the back side of the No. 1 seal and, assuming that the No. 2 seal closed as designed, results in an RCS inventory loss of 76 gpm per RCP. This was assigned a probability of occurrence of 0.01. The third scenario assumes that the No. 1 seal behaved as designed, but that the No. 2 seal would "pop" open and result in an RCS inventory loss of 182 gpm per pump. This was assigned a probability of occurrence of 0.1975. The fourth scenario assumes that the No. 1 seal "binds" open and the No. 2 seal "pops" open resulting in an RCS inventory loss of 480 gpm per pump. This was assigned a probability of 0.0025. The conservatisms in the WOG2000 PRA model are discussed in WCAP-16396-NP.

1.2.3.4.6. Operator Actions

The generic emergency response to the loss of all AC power instructs plant operators to use natural circulation cooldown of the RCS to cool the RCP seals following restoration of AC power if the RCP seals had been exposed to hot RCS fluid, rather than restoring seal injection or TBHx cooling. This is applicable to all plants with Westinghouse seals, regardless of O-ring material. This strategy acknowledges the uncertainty associated with the seal response to a cold thermal shock and the benefits of a decrease in RCS inventory loss as the seal leak rate decreases with decreasing RCS pressure and temperature. There is also a concern with restoration of TBHx cooling resulting in the potential loss of the CCW system integrity due to water hammer, which could result in the loss of mitigating capability for the event. The concern with restoration of seal injection was the potential for seal damage due to cold thermal shock which could increase the seal leakage rate to containment.

[

Deleted: February

]a,c

As described in WCAP-16396-NP, there are several instances in which seal cooling has been restored following a loss of all RCP seal cooling. In each of these instances, no damage to the RCP seals that results in high levels of RCS inventory loss have been observed. However, because the restoration of RCP seal cooling has not been fully analyzed, Westinghouse recommends in Technical bulletin TB-04-22, Revision 1, that cooling of the seals should be done by RCS natural circulation cooldown if the seal temperature exceeded the shut down limit specified in the RCP Instruction Book (typically 225°F to 235°F) rather than re-establishing seal injection. Westinghouse further recommends that following a loss of all seal cooling event, the affected RCPs be stopped immediately or at least before the seal and bearing temperatures begin to rise.

Deleted: February

3.1.1.4 Piston Ring

On the majority of Westinghouse RCPs in the U.S. (Model 93A), the shaft adjacent to the insert has a sleeve used as a spacer (No. 1 Runner Retaining Sleeve). The SDS will be sealing on this sleeve rather than the shaft. The piston ring for this pump model can be a [

] [a,c] In the other RCP models (93, 93A-1, and 100), there is no sleeve. The SDS will seal directly on the shaft. [

] [a,c]

The term shaft will be used henceforth to describe the cylindrical surface on which the SDS seals, but in most cases the actual surface will be a sleeve.

[

] [a,c]

3.1.1.5 Wave Spring

The wave spring is located between the Modified No. 1 insert and the piston ring. Its purpose is to provide a slight pressure on the piston ring and polymer ring to prevent movement during normal plant operation. [

] [a,c]

3.1.1.6 Retaining Ring

The retaining ring is coated and lapped to a fine finish to minimize friction between it and the polymer ring to tolerate a short period of shaft coast down rotation. [

] [a,c]

3.1.1.7 Modified No. 1 Insert

The advantage of modifying the No. 1 Insert for the Shut Down Seal housing is two-fold. One is that this is a replacement part, so retrofitting a pump with this seal only requires replacing the existing Insert with a modified one. Secondly, modifying the Insert can be done before opening the pump for access. Installation of the modified Insert, with the SDS already installed prior to shipment to the plant in order to minimize the potential for

Deleted: February

3.1.2.6 Reliability

The reliability requirements for the SDS are based on assuring that the failure to activate and limit leakage is not a dominant failure mode in the PRA and that the reliability is maximized for risk-informed applications such as MSPI. The ability of the SDS to meet the reliability goals has been demonstrated through testing and analysis of the SDS. The reliability goals include:

- Very low potential for inadvertent actuation during normal operation to ensure that the initiating event frequency for inadvertent actuation does not contribute to the PRA initiating event frequencies, as well as for plant asset management considerations.
- Passive activation at a No. 1 seal leak-off temperature of 250°F to 290°F to ensure sufficient time for the operators to trip the RCP motors using existing procedures and guidance and to ensure that significant RCS inventory loss through the RCP seals does not occur prior to activation of the SDS.
- Less than 1 gpm leakage following activation to eliminate the need for immediate manual operator actions to restore RCS makeup for Appendix R fire scenarios and station blackout scenarios.

The target level of reliability for the Shut Down Seal that is demonstrated through testing and analysis is: [

]^{a,c}

3.1.2.7 Service Life

Currently the service life-limiting component in the RCP seal package is the high-temperature O-ring. Currently its service life is qualified for 6 years. However, an investigation is underway to extend that qualification to 9 years. The SDS will meet or exceed this new life limitation.

3.1.2.8 Material Selection

[

Deleted: February

] a,b,c

3.2.2.4 Crud Tester

An important consideration in the SDS design is the SDS endurance and corrosion resistance. A crud test machine was developed as shown in Figure 3-6. [

] a,b,c

a,b,c

Figure 3-6 Westinghouse Dynamic Crud Testing Machine

3.2.3 Test Results

3.2.3.1 Sealing Endurance Tests

The most challenging requirement the SDS must meet is the endurance test. Withstanding 570°F and 2350 psia for 24 hours leaking less than 1 gpm must be demonstrated to meet the design specification. [

Deleted: February

[ ] a,b,c

3.2.3.1.1. Test Results

Using the static testing machine, the SDS seal was tested repeatedly at full pressure and various temperatures. [

] a,b,c

Table 3-3 Table of Tests on SDS in Static Test Machine

a,b,c

[

Deleted: February

] a,b,c

3.2.3.1.2.2. Failure to Remain Sealed for Event Duration

[

Deleted: February

[–] a,b,c

Table 3-4 Hour-Interval Leakage from Shut Down Seal

[ ] a,b,c

Deleted: February

[

Table 3-6 Table of Survivabilities for SDS from Weibull Analysis			

] a,b,c

[

]

] a,b,c

3.2.3.2 Polymer Ring Extrusion

As described previously, the polymer ring is held in place between the metal piston ring and the metal retaining ring. When the SDS is actuated, the piston ring closes against the pump shaft to create a high pressure area behind the polymer ring which causes the polymer to flow in against the shaft providing a leak-tight seal. Since the retaining ring does not move and a small gap remains between the retaining ring and the shaft, the

Deleted: February

Table 3-7 Polymer Ring Extrusion after High Temperature Testing

[

a,b,c

[

] a,b,c

Table 3-8 Regression Analysis of Polymer Extrusion Data

[

a,b,c

Deleted: February


a,b,c

Figure 3-8 Regression Analysis Results for Polymer Extrusion

[

] a,b,c

3.2.3.2.1. Polymer Rin Radiation Testing

Two sets of tests were conducted with irradiated polymer rings: 1) sealing tests in the Static Tester, and 2) physical properties tests.

Sealing Tests:

[

Deleted: February

]a,c

Physical Properties Tests:

[

Deleted: ¶

]a,c

3.2.3.3 Actuation Testing

Several series of actuation tests have been completed to assure the reliable actuation of the SDS as described below.

3.2.3.3.1. Retracting Tests

[

Deleted: February

] a,b,c

Table 3-9 Maximum Force Data for Thermal Actuator Pistons

a,b,c

Deleted: February

3.2.3.4 Seal Assembly Actuation

A series of tests were performed in the static tester with complete SDS assemblies to verify the reliability of activation to initiate sealing. [

] a,b,c

Table 3-10 Actuation Tests of SDS Assembly in the Static Tester

[a,b,c]

The results of these tests show no failures [

] a,b,c

3.2.3.5 Oven Testing

After having proven that the whole SDS assembly reliably retracts and seals in the static tester, simple oven tests were performed to increase the statistical confidence interval predicting the reliability of the retracting actuator to retract the spacer from between the piston ring ends. [

] a,b,c

Deleted: February

] a,b,c

3.2.3.6 Radiation Testing

[

] a,b,c The purpose of the radiation test program was to determine if exposure to the radiation expected over the seal lifetime would impact the performance [

] a,b,c

The total lifetime dose of 200,000 rads was determined by reference to previous testing of elastomeric components used in the RCP No. 1 seal. This evaluation was previously done by Westinghouse and is documented in WCAP-10541. The evaluation concluded that a total dose of 150,000 rads would result from an exposure to a typical seal component lifetime of 54 months (4.5 years). For the actuator testing program, the dose was increased to 200,000 rads to match the current RCP seal lifetime of 72 months (6 years) and later to 350,000 rads for an extended 9-year RCP seal life that is currently being investigated.

Deleted: February

] [a,b,c]

3.2.3.10 Lateral Movement Tests

The same thermal issues that may cause an axial displacement of the sealing surface relative to the SDS may also cause lateral displacements. This could result from bending of the RCP shaft caused by asymmetric heating.

[

] [a,b,c]

3.2.3.11 Shaft Rotation

The SDS is designed to deploy on a non-rotating shaft. For the station blackout event the RCPs will automatically trip on loss of AC power and the shaft will have stopped rotating by the time the SDS activates. For all other total loss of RCP seal cooling events, the operator is required to trip the RCPs to achieve a non-rotating shaft condition when the SDS is passively actuated. There are three unique situations that can result in the SDS deploying on a rotating shaft: 1) the shaft is slowly rotating such as during the

Deleted: February

[

]a,c

Deleted: February

]^{a,b,c}

3.2.3.11.7. Operator Response Margin

It is typical for a plant to have one or more alarms to alert the operator for a loss of CCW to the RCP and one or more alarms for a loss of seal injection to an RCP. However, the alarm language and the process parameter that causes the alarm can be different from

Deleted: February

The outcomes for each path in the Figure 3-12 event tree were determined as follows:

[

] [a,c]

3.3.2 PRA Model Failure Probabilities

The split fractions assigned to the event tree nodes are supported by the statistical results of the testing program for the SDS that are described in this report.

[

] [a,b,c]

Deleted: February

The PRA model does not need to be modified to account for inadvertent actuation of the SDS. As discussed in Section 3.2.3.11, inadvertent actuation of the SDS onto a rotating shaft at 1200 RPM in the absence of a loss of RCP seal cooling would not cause the SDS polymer to constrict against the shaft / sleeve and the operators would have sufficient feedback to diagnose the condition and bring the plant to an orderly shutdown without damage to any other components. Thus, inadvertent actuation would not cause a plant trip or any other initiating event normally considered in the PRA. In addition, the inadvertent actuation of the SDS is extremely unlikely. Therefore, the PRA model does not need to be modified to account for inadvertent actuation of the SDS.

3.3.3 Simplified PRA Model

The event tree shown in Figure 3-13 was developed to illustrate the elements of successful actuation of the SDS to limit RCS leakage to very low levels. The detailed model shown in Figure 3-13 was not intended to be implemented into plant specific PRA models.

a,c

Figure 3-13 SDS Leakage Probabilities

Rather it was intended that a very simple event tree or fault tree would be implemented directly in preceding the existing RCP seal model that asks two questions:

Does the SDS actuate and effectively seal on the pump shaft?

[

Deleted: February

] [a,c]

Is the reactor coolant pump tripped within the operator response margin?

For a station blackout event, the response to this question is always true because AC power is lost to the RCPs as the initiating event. For all other sequences, a human error probability needs to be determined for the operator action to trip the pump so that the SDS is actuated on a stopped or slowly rotating shaft. The cues for the operator action and the typical times available to trip the pump motors can be found in Section 3.2.3.11.7 of this report. As discussed earlier, alternate methods to determine a more realistic time available for RCP trip can also be used. [

] [a,c]

3.3.4 Discussion of Uncertainties

The ASME/ANS PRA Standard (Reference 8) requires that the model uncertainties be identified and characterized so that they may be investigated further for risk-informed decision making. In some instances below, additional testing is referred to that which would substantially decrease identified uncertainties in the SDS PRA model. It is expected that the additional test information will have no impact on the SDS PRA model presented in this section of the report.

The model uncertainties that can affect the performance of the Shut Down Seal are identified as:

[

] [a,b,c]

Deleted: February

Westinghouse Electric Company
Nuclear Services
1000 Westinghouse Drive
Cranberry Township, Pennsylvania 16066
USA

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

Direct tel: (412) 374-4643
Direct fax: (724) 720-0754
e-mail: greshaja@westinghouse.com
Proj letter:

CAW-11-3084

January 20, 2011

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: WCAP-17100-P, Revision 1 Mark-up (Proprietary)

Reference: PWROG Letter OG-11-30 from Melvin L. Arey to the Document Control Desk, dated January 20, 2011

The proprietary information for which withholding is being requested in the above-referenced report is further identified in Affidavit CAW-11-3084 signed by the owner of the proprietary information, Westinghouse Electric Company LLC. The affidavit, which accompanies this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR Section 2.390 of the Commission's regulations.

Accordingly, this letter authorizes the utilization of the accompanying affidavit by Pressurized Water Reactor Owners Group (PWROG).

Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference this letter, CAW-11-3084, and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, Suite 428, 1000 Westinghouse Drive, Cranberry Township, Pennsylvania 16066.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Enclosures

CAW-11-3084

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF BUTLER:

Before me, the undersigned authority, personally appeared J. A. Gresham, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Sworn to and subscribed before me
this 20th day of January 2011

Renee' Giampole
Notary Public

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Renee Giampole, Notary Public
Penn Township, Westmoreland County
My Commission Expires September 25, 2013

(1) I am Manager, Regulatory Compliance and Plant Licensing in Nuclear Services, Westinghouse Electric Company LLC (Westinghouse), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse Application for Withholding Proprietary Information from Public Disclosure accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use 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 a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390; it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in "WCAP-17100-P, Revision 1 Mark-up, 'PRA Model for the Westinghouse Shut Down Seal'" (Proprietary), dated December 2010, for submittal to the Commission, being transmitted by Westinghouse letter, OG-11-30 letter and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse for the Pressurized Water Reactors Owners Group is expected to be applicable in other licensee submittals in response to certain NRC requirements for justification of models

describing the behavior of the Westinghouse Shut Down Seal in risk-informed regulatory applications and deterministic licensing basis analyses.

This information is part of that which will enable Westinghouse or Pressurized Water Reactors Owners Group participants in this program to:

(a) Develop plant specific Probabilistic Risk Assessment and deterministic models to describe the behavior of the Westinghouse Shut Down Seal for postulated plant events that result in a loss of all RCP seal cooling.

(b) Expeditiously modify risk-informed regulatory applications and gain any required NRC approval of those changes.

(c) Expeditiously modify licensing basis analyses and gain any required NRC approvals of those changes.

Further this information has substantial commercial value as follows:

(a) Plants will install the Shut Down Seal for its benefits in risk-informed applications and licensing analyses. Westinghouse plans to sell the risk assessment and licensing basis models as the basis for installing the Shut Down Seal.

(b) Westinghouse can sell support and defense of the results and conclusions of the subject WCAP.

(c) The information requested to be withheld reveals the distinguishing aspects of a new technology and methodology which was developed by Westinghouse.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide a product that provides similar benefits for and licensing defense services for commercial power reactors without commensurate expenses. Also, public

disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

COPYRIGHT NOTICE