RULEMAKING ISSUE
(Notation Vote)

August 26, 1994 SECY-94-225

For: The Commissioners

From: James M. Taylor
Executive Director for Operations

Subject: ISSUANCE OF PROPOSED RULEMAKING PACKAGE ON GI-23, "REACTOR COOLANT PUMP SEAL FAILURE"

Purpose: Obtain Commission approval of the staff's proposed resolution of GI-23 by rulemaking.

Issue:

The proposed rule would require that each pressurized-water reactor (PWR) licensee evaluate its plant for dependencies that may cause insufficient capacity and capability to ensure that the reactor core is cooled coincident with a loss of reactor coolant pump (RCP) seal cooling. A loss of RCP seal cooling could lead to a failure of the RCP seals during certain postulated off-normal events (i.e., station blackout, loss of essential service water, or loss of component cooling water). For significant dependencies found as a result of implementing the proposed rule, licensees would be required to either (1) take action to reduce the dependency so that reactor core and associated coolant systems will provide sufficient capacity and capability to ensure that the core is cooled or (2) demonstrate that the risk associated with RCP seal failures during the postulated off-normal conditions is sufficiently low such that further risk reduction measures to address the possible consequences of failures are not justified. The proposed amendments are intended (1) to address regulatory concerns arising from unresolved uncertainties regarding RCP seal integrity under the postulated off-normal conditions and the possible consequences of seal failure in the unlikely event of such circumstances and (2) to enhance the existing level of protection of public health and safety against the risk associated with such seal failures when the costs of implementing enhancement measures can be justified. The rulemaking package consisting of a Federal Register Notice with a statement of considerations (Enclosure A) and a regulatory analysis, draft NUREG-1483 (Enclosure B), is proposed to be issued for public comment.

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NOTE: TO BE MADE PUBLICLY AVAILABLE WHEN THE FINAL SRM IS MADE AVAILABLE

RD-8. Generic Items
Generic Issues

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EXECUTIVE SUMMARY

This report provides a regulatory analysis for the Nuclear Regulatory Commission's (NRC's) proposed resolution of Generic Issue 23 (GI-23), "Reactor Coolant Pump Seal Failure," through promulgation of a rule applicable to pressurized water reactors (PWRs).

Reactor coolant pump (RCP) seal failure refers to failure of the RCP seal assemblies designed to minimize reactor coolant leakage along the RCP shafts. Since leak rates resulting from the loss of RCP seal integrity may exceed the capability of the reactor coolant makeup system, the failure of the seals is a potential initiating event for small-break loss-of-coolant accidents (LOCAs). Appendix A to this document provides a summary of recent data on operational experience involving RCP seal leakage during normal operations, i.e. when core coolability was not at risk.

Based on experience and technical studies done on this subject, the NRC has determined that the RCP seals are important to safety. Seal failures associated with normal operation are dealt with by issuing Information Notice 93-61 (August 9, 1993) as a method to inform licensees of operational experience, thereby providing reasonable assurance that such problems will be avoided in future. The NRC has decided that a rule is needed for the resolution of the concerns regarding RCP seal failures during off-normal conditions involving loss of seal cooling i. e. during station blackout, or loss of component cooling water (CCW), or loss of service water (SW) without station blackout. The primary objective of the proposed rule is (1) to address regulatory concerns arising from unresolved uncertainties regarding reactor coolant pump seal integrity under the postulated off-normal conditions and the possible consequences of seal failure in the unlikely event of such circumstances, and (2) to enhance the existing level of protection of public health and safety against the risk associated with such seal failures where the costs of implementing enhancement measures can be justified. The options provided in the proposed rule are to evaluate plant-specific dependencies that may cause insufficient capacity and capability to ensure that the reactor core is cooled coincident with loss of reactor coolant pump (RCP) seal cooling which could lead to failure of seals during off-normal events of loss of seal cooling, and either (1) take action to reduce the dependency such that reactor core and associated coolant systems will provide sufficient capacity and capability to ensure that the core is cooled, or (2) demonstrate that the risk associated with reactor coolant pump seal failures during the postulated off-normal conditions is sufficiently low that further risk reduction measures to address their possible consequences are not justified.

One of these options, an alternate seal cooling system, was chosen as the reference system to calculate the cost/benefit ratio. No cost/benefit ratio is calculated for other options as the staff is required to calculate the cost/benefit ratios for only one of the alternatives offered in the rule. Cost/benefit calculations are based on the alternate seal cooling option, which is expected to be the highest cost option. Implementation of that option is calculated to result in a 75% reduction in the probability of seal failure. That is, core damage frequency (CDF)

from RCP seal failures are estimated to be reduced from 2E-05 to 6E-06 per reactor-year for PWRs (after round-off). Appendix B contains information comparing CDF from GI-23 studies with those of the three PWRs of NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants."

The evaluation of CDF used a seal failure model that estimated the probability of failure of individual RCP seal stages as a function of time and the resultant probability of core uncovery as a function of time. The staff recognizes that this model is complicated and has large uncertainties associated with it. The best-estimate cost/benefit ratio is computed to be $680 per person-rem. Comparison of the best-estimate cost/benefit ratio against a guideline cost/benefit ratio of $1000 per person-rem shows that the proposed resolution is cost effective. The cost/benefit analysis was based on a system that used an air-cooled diesel generator to power existing components to provide RCP seal cooling and other plant functions (e.g., reactor coolant makeup or high-pressure injection) during off-normal conditions.

This engineering approach avoids dealing with some of the uncertainties associated with the complicated seal model. The cost estimates have not considered any items used for implementation of the station blackout rule and hence are expected to be an over estimate of the cost.

Other less expensive means of core cooling or preventing seal failure may also be possible. One approach that uses the fire-water system is estimated to cost less than one-third of the reference system and is described in Appendix C of Reference 7.

The regulatory analysis provided in this report documents the rationale for the staff's decision-making on GI-23, including the choices made among the alternatives considered. The backfit analysis presented in Appendix C is a part of the regulatory analysis to document the staff's assessment that the proposed resolution of GI-23 to prevent RCP seal failures conforms with 10 CFR 50.109, the backfit rule. Hence, this backfit analysis envelopes all the options provided for in the proposed rule.

ACKNOWLEDGEMENTS

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ACRONYMS

AECL	Atomic Energy of Canada Limited
ASCO	Alternate seal cooling option
ATWS	Anticipated-Transient-Without-Scram
BNL	Brookhaven National Laboratory
BWR	Boiling water reactor
CCW	Component cooling water
CDF	Core damage frequency
CFR	Code of Federal Regulations
ECCS	Emergency core cooling system
ESW	Essential service water
GI	Generic Issue
gpm	Gallons per minute
IPE	Individual plant examination
IPEEE	Individual plant examination for external events
LOCA	Loss-of-coolant accident
LWR	Light-water reactors
NPRDS	Nuclear Plant Reliability Data System
NRC	Nuclear Regulatory Commission
NSSS	Nuclear steam supply system
PRA	Probabilistic risk assessment
PWR	Pressurized water reactor
RCP	Reactor coolant pump
SW	Service water
TMI	Three Mile Island
USI	Unresolved Safety Issue

1. STATEMENT OF THE PROBLEM

"Reactor coolant pump seal failure" refers to degradation of the seals that limit primary coolant leakage along the shafts of the reactor coolant pumps (RCPs). Generic Issue 23 (GI-23), "Reactor Coolant Pump Seal Failure," has primarily addressed the consequences of such seal failures in pressurized water reactors (PWRs). RCP primary and secondary seals limit the leakage of reactor coolant along the pump shaft and thereby into the containment. These seals, forming part of the reactor coolant pressure boundary, require cooling[1] during normal operation even while the reactor is in hot standby or hot shutdown. Without such cooling, both primary and secondary seals are susceptible to increased leakage once temperatures exceed design limits[2].

Analysis of seal failures and leakage data from operating events and tests (Refs. 1-4) indicates that leakage past pump seals may be of sufficient magnitude to constitute a small-break loss-of-coolant accident (LOCA). Appendix A to this document provides a summary of RCP seal leakage experience during normal operations, i.e. when core coolability was not at risk. A detailed discussion of RCP seal design and operation is provided in Section 2 of Reference 5. To resolve GI-23, the known root causes of seal failure were studied. The studies performed under GI-23 originally addressed concerns about RCP seal failures under normal operation and under off-normal conditions (resulting from loss of all seal cooling). The staff has now decided to exclude from GI-23 any action regarding seal failures during normal operation. Therefore, the resolution of GI-23 concentrates on seal failures that may result from loss-of-all-seal-cooling conditions. For such conditions, particularly station blackout with an associated loss of seal injection cooling, or a loss of component cooling water (CCW), or service water (SW) or both, the major concerns involve seal failures caused by performance instabilities at the primary seal faces related to coolant flashing and two-phase flow as well as adverse temperature effects on secondary seal elastomer materials. Current RCP secondary seal materials are susceptible to accelerated degradation when seal cooling is lost and seal temperatures approach normal reactor coolant system operating temperatures. Seal failures resulting in a small-break LOCA under station blackout or a loss of CCW or SW could lead to core damage if a concurrent loss of normal and emergency reactor coolant makeup capabilities occurs.

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[1]Seal cooling is normally accomplished through seal injection or a thermal barrier heat exchanger or both. For Westinghouse plants, the seal injection water is supplied from the chemical and volume control system with a portion flowing through the pump seals and the remainder flowing past the thermal barrier heat exchanger and into the reactor coolant system. The thermal barrier heat exchanger reduces the temperature of any reactor coolant leakage along the RCP pump shaft upstream of the RCP seals. This heat exchanger is cooled by the component cooling water system.

[2]RCP seals are generally designed to operate at less than 160°F (~70°C). The normal reactor coolant operating temperature is approximately 550°F (~290°C).

In the worst case under two-phase flow conditions, the potential exists for the hydraulic balance on the primary seal faces to be upset, causing the faces to fail in the open position, i.e., the position of maximum leakage. Seal failures of this severity could result in leak rates that exceed the capability of the makeup system. Primary system leaks exceeding normal plant makeup capability are considered LOCAs that can lead to core damage unless the coolant inventory of the reactor coolant system is maintained using the emergency core cooling system (ECCS). If station blackout conditions continue for a long period and seal integrity is lost, it will not be possible to maintain coolant inventory because of the inability to power the motor-driven charging and ECCS pumps. Extended loss of CCW/SW could have a similar effect because of the dependency of these pumps at some plants on CCW/SW for seal cooling.

To resolve this issue, the known root causes of seal failure were studied, and from this knowledge, six alternatives were considered as described in Section 3 of this document. These alternatives were then evaluated to determine their relative merits and to select a proposed resolution. Three alternatives were included in the proposed rule, while the other three alternatives were rejected.

Probabilistic risk assessment (PRA) analyses indicate that the overall probability of core damage from small breaks could be dominated by events such as RCP seal failures (Ref. 1). Reference 1 cites the impact of mechanical- and maintenance-induced failures of RCP seals on plant safety. It is concluded in Reference 1 that, for some PWRs, the annual core damage frequency (CDF) from RCP seal failures may be about 20% of the total CDF for all causes.

Table 1-1 shows the estimated CDF per reactor year attributed to RCP seal failure that indicated sufficient risk to initiate rulemaking. The CDF shown is composed of three parts, station blackout (CDF_{SBO}), loss of CCW independent of station blackout (CDF_{CCW}), and loss of SW independent of station blackout (CDF_{SW}). The value for CDF_{SBO} was determined using a pump seal leakage model developed by Atomic Energy of Canada Limited (AECL), a contractor to the NRC, in conjunction with station blackout frequencies and durations from Reference 6 (see Appendix A of Reference 7). Three time dependent plant blackout models were used. Numerical values from these models were used to compute frequency of core uncovery from seal LOCAs. Three models of core uncovery from RCP seal failures were used assuming; 1) standard Westinghouse O-rings with cooldown, 2) standard Westinghouse O-rings with no cooldown, 3) Westinghouse Improved O-rings with no cooldown. The CDF was estimated by combining plant blackout models and the core uncovery models. The best estimate case is the one with Westinghouse O-rings, operator initiated cooldown, and the best estimate core uncovery model.

Separate calculations (see Ref. 3) were done by Brookhaven National Laboratory to estimate the benefits gained through the provision of alternate seal cooling during other off-normal conditions (such as loss of CCW and loss of SW without station blackout). Consequence assumptions from Reference 8 and Reference 9 were used to determine the benefits (values) gained through reduction of RCP seal failures during off-normal conditions. The value of

CDF_{CCW} is taken from a sensitivity study (Ref. 3) performed on Midland after completing an evaluation of core damage sequences initiated by loss of seal cooling on Calvert Cliffs-1, Indian Point-3 and Midland-2. When compared to PRAs of several plants, this value is considered to be low. Use of a more representative value would increase the benefit obtained from the proposed resolution. The value of CDF_{SW} is taken from an independent study (Appendix F to Reference 10) performed for the total population of PWRs. It is developed by considering various RCP seal leak scenarios under loss of ESW with their potential for core uncovery. Seal LOCA initiating frequencies were combined with a conditional core damage probability. The RCP seal failure probabilities are based on the NUREG-1150 model (Ref. 9) which utilizes a time dependent leak rate after loss of seal cooling. If a more detailed probabilistic model (like one by AECL, NUREG/CR-5167) is used, then the likelihood of seal LOCA would be higher.

Table 1-1

Core Damage Frequency Per Reactor-Year Attributed to RCP Seal Failure

CDF_{SBO}	5.6E-06
CDF_{CCW}	6.0E-06
CDF_{SW}	1.2E-05
Total CDF	2.4E-05

The public health benefit (in person-rem) is calculated by the formula:

Public Health Benefit = CDF x ΔCDF x D x N x Y

where

- CDF = CDF of RCP seal failure per plant-year
- ΔCDF = Percentage reduction in CDF
- D = Dose expected from core-melt accident (person-rem)
- N = Number of plants
- Y = Average remaining plant life (years)

For a total CDF of 2.4E-05, the public health benefit is calculated to be 100,890 person-rem, using ΔCDF as 0.75, D as 3E+06, N as 76, and Y as 25. The value of D used here is a best-estimate value. The high value used in the cost/benefit analysis was 2E+07, and the low value was 5E+04.

2. OBJECTIVES OF THE PROPOSED RESOLUTION

The proposed resolution for GI-23 is in the form of a rule that applies to PWRs. The general objective of the proposed resolution is to reduce the risk of severe accidents associated with RCP seal failure by making RCP seal failure a significantly small contributor to total CDF. The wording of the proposed rule 10 CFR 50.68, "Loss of Integrity of Reactor Coolant Pump Seals," is:

(a) Applicability.
The requirements of this section apply to all applicants for and holders of construction permits and operating licenses for commercial pressurized-water nuclear power plants.

(b) Definitions.
"*Dependencies*" means factors that create common-cause failure mechanisms.

"*Postulated events*" mean station blackout, as defined in 10 CFR 50.2, for the specified duration as defined in 10 CFR 50.63; loss of component cooling water; and loss of essential service water.

(c) Requirements.

(1) Each licensee and applicant subject to this section shall evaluate its plant to determine if there are dependencies that may cause insufficient capacity and capability to ensure that the reactor core is cooled (such as by loss of emergency core cooling system function), coincident with loss of reactor coolant pump seal cooling that could lead to failure of those seals during postulated events.

(2) If the evaluation in paragraph (c)(1) of this section identifies such dependencies, the licensee and applicant must either:

(i) Demonstrate that it has taken action to reduce the dependency such that the reactor core and associated coolant systems will provide sufficient capacity and capability to ensure that the core is cooled; or

(ii) Demonstrate that the risk associated with reactor coolant pump seal failures during postulated events is sufficiently low such that further risk reduction is not justified.

(3) If specific seal leakage rates are relied upon in either the evaluations performed pursuant to paragraph (c)(1) of this section or the demonstration performed pursuant to paragraph (c)(2)(i) of this section, the evaluations and demonstrations must include or incorporate by reference test data on seal performance characteristics that are sufficient

to support the assumed failure probabilities or leakage rates. The tests must adequately account for the complex mechanical and fluidics conditions that the seals may experience during postulated events with loss of all seal cooling.

(4) Probabilistic methods may be utilized in the evaluations performed pursuant to paragraph (c)(1) of this section and the demonstration performed pursuant to paragraph (c)(2)(i) of this section.

(5) If a licensee chooses to demonstrate under paragraph (c)(2)(i) of this section that it has reduced a dependency by installing an alternate dedicated seal cooling system powered by an alternate ac power source (as defined in § 50.2), the demonstration must show that the alternate ac power source has sufficient capability to ensure adequate and timely seal cooling, such that seal integrity is maintained during postulated events.

The proposed rule would serve to either increase assurance of core cooling or reduce the probabilities of seal failure predicted (Ref. 7) upon loss of seal cooling, and is based on current RCP seal technology and performance characteristics.

The proposed rule addresses the inherent coupling of RCP seal failure with off-normal conditions (such as loss of CCW/SW or station blackout) during which thermal barrier cooling and/or injection flow to the seals are lost. As noted in Reference 11, conservative assessments show the probability of seal failure to increase rapidly as the seal leakage temperature increases beyond prescribed operating limits. This temperature increase is an expected consequence whenever normal seal cooling mechanisms have been rendered ineffective. Without seal cooling, leakage increases, and in the worst case scenarios considered for regulatory purposes, it is assumed to reach a maximum value associated with total seal failure. Seal failure models (Ref. 7) used in the cost/benefit analysis are based on independent testing and evaluation of certain design characteristics and materials of the Westinghouse RCP seal design by AECL. This design was selected because (1) it represents the majority (53 of 76) of commercial PWRs and (2) most seal testing and analysis have involved Westinghouse pump seals. Because basic design similarities exist in all PWR RCP seals, the results of the cost/benefit analysis are generally applicable to all commercial PWRs in the United States. (This is discussed further in Reference 7.)

To prevent temperature-related failures of the RCP seals, the alternate seal cooling option incorporates provisions for RCP seal cooling during off-normal conditions. The cost/benefit analysis assumes meeting the intent of this option by (1) installing an alternate ac source to provide at least one mode of seal cooling (seal injection or thermal barrier cooling) to the RCP seals and (2) performing plant modifications to allow alternate cooling of the makeup pump from an existing plant water system for those plants that have a potential vulnerability to loss of seal cooling from conditions other than station blackout (i.e. loss of CCW/SW).

The costs associated with the ac source were separated from any costs associated with responses to the station blackout rule (10 CFR 50.63) to avoid double counting. Further details are provided in Appendix C of Reference 7.

3. EVALUATION

3.1 Proposed Resolution

Six alternatives (discussed in section 3.2) have been considered before formulating the proposed resolution. These alternatives encompass a broad range of options such as plant-specific analyses, provision of alternate seal cooling system, testing of seal assembly, replacement of seals by those having improved design, and installation of emergency backup seal.

For cost/benefit considerations one of the alternatives, the alternate seal cooling option (ASCO) was chosen. It was evaluated based on present worth costs, averted radiological exposure, and impacts on other requirements. The attributes used to calculate cost/benefit ratios are reduction in risk (public health benefit), all industry costs (for 76 PWRs), all NRC costs, and averted onsite property damage and occupational exposure associated with a core-melt accident. A summary of costs and benefits is presented in Table 3-1. More detailed cost/benefit information for the proposed resolution, including high- , low- , and best estimates, is presented in Reference 7. Cost/benefit calculations have been revised based on the more recent information available to the staff including public comments on GI-23 in 1991, and they are included in Reference 10. The cost includes the capital cost associated with purchase, installation, and quality assurance of a non-safety grade 1100 KW diesel generator along with piping and connections for a backup water supply system. The cost does not include analyzing the interface between safety grade systems and non-safety grade systems.

Table 3-1

Summary of Cost ($$10^6$) and Benefit (for 76 PWRs)

DESCRIPTION	ALTERNATE SEAL COOLING
INDUSTRY COST: **IMPLEMENTATION** **OPERATION**	 **$72.40** **$ 1.17**
NRC COST: **DEVELOPMENT** **IMPLEMENTATION** **OPERATION**	 **$ 2.88** **$ 0.29** **$ 2.62**
AVERTED PROPERTY COST:(onsite damage)	**-$10.4**
PUBLIC HEALTH BENEFIT: (person-rem)	**100,890**
OCCUPATIONAL EXPOSURE: **OPERATIONAL (Reduction in person-rem)** **ACCIDENTAL (Reduction in person-rem)**	 **NEGLIGIBLE** **706**
COST/BENEFIT: ($/person-rem)	**$ 680**

$$\text{Cost/Benefit} = \frac{(\text{industry cost} + \text{NRC cost} + \text{onsite property cost})}{(\text{benefit} + \text{occupational exposure reduction})}$$

3.1.1 Analysis of ASCO

The effect of ASCO on the frequency of seal failure is too complex to describe as a simple number. A brief summary of the complex event tree used to evaluate off-normal conditions is presented in Section 4.1.1. The details, including RCP seal failure rate estimates, are provided in Reference 5 and Appendix B of Reference 7. The ASCO is estimated to reduce the CDF/reactor-year from 2.4E-05 to 5.9E-06. The best-estimate cost/benefit ratio is 680 $/person-rem.

The best-estimate cost/benefit ratio is favorable, based on the $1,000/person-rem decision guideline of Reference 12. There is also considerable uncertainty in the cost/benefit analysis, mainly from plant-specific uncertainties involving station blackout probabilities and release

consequences. Uncertainties are also introduced in applying the seal failure model. Reference 7 includes more information on uncertainties. The justification for including ASCO in the proposed resolution includes factors in addition to cost/benefit considerations, and it is further discussed in Section 4.2 regarding a lower cost alternative.

3.1.2 CDF Attributed to RCP Seal Failure

Implementation of the proposed rule would increase assurance of core cooling, and would reduce the likelihood of seal failure thus reducing the CDF per reactor-year attributed to RCP seal failure. It is assumed that the reliability of the proposed alternate seal cooling system, which depends on the reliability of the entire modification, is 0.90/0.60/0.75 (high, low, and best estimates, respectively) for the calculation of the change in CDF. The total CDF would be reduced by 75% (best estimate) if ASCO is implemented. The results of implementation are shown in Table 3-2. The reduction in CDF from seal failure meets the staff's criterion relative to being a substantial increase in the protection of public health and safety.

Table 3-2

CDF Reduction from GI-23 Implementation

ITEM	CDF ATTRIBUTED TO RCP SEAL FAILURE BEFORE GI-23 IMPLEMENTATION	REDUCTION IN CDF FROM SEAL FAILURE		CDF ATTRIBUTED TO RCP SEAL FAILURE AFTER GI-23 IMPLEMENTATION
		PERCENT	Delta CDF	
ALTERNATE SEAL COOLING OPTION	2.4E-05	75%	1.8E-05	6E-06

3.2 Alternatives

Six alternatives for the proposed resolution were considered. The first three were determined to merit inclusion in the proposed resolution, while the last three were rejected. Preliminary evaluations showed that rejected alternatives involve too many uncertainties or are otherwise ineffective or incomplete in resolving GI-23 relative to the proposed rule.

3.2.1 Alternative 1

Alternative 1 is to evaluate plant-specific dependencies affecting RCP seal cooling such as might occur during the postulated events of station blackout (see 10 CFR 50.2), or loss of component cooling water, or loss of service water. The intent is either (1) assure that reactor core and associated coolant systems will provide sufficient capacity and capability to ensure that the core is cooled, or (2) demonstrate that the risk associated with reactor coolant pump seal failures during the postulated off-normal conditions is sufficiently low that further safety

enhancement measures to address their possible consequences are not justified.

3.2.2 Alternative 2

Alternative 2 involves provision of an alternate seal cooling system to ensure that adequate and timely seal cooling is restored in case of loss of cooling. Two examples of such a cooling system are given in Appendix C to Reference 7.

3.2.3 Alternative 3

Alternative 3 involves verification through tests of the performance of seal components during postulated events. Tests developed to meet certain prescribed pressure, temperature, and other conditions with loss of all modes of seal cooling may provide some basis for judgment on seal performance under postulated events. The NRC staff believes that the limited number of seal tests conducted by the industry has not adequately represented all the conditions that can occur during the loss-of-all-seal-cooling events. The following description supports the conclusion that many industry and National Laboratory tests are inadequate to serve as the sole basis for confidence in seal integrity during station blackout, loss of CCW, or loss of SW:

3.2.3.1 <u>50-Hour Station Blackout Test of the St. Lucie Production Seal Cartridge (Byron-Jackson Seal)</u>. Although leakage remained within normal limits, the vapor seal rotating ring cracked, O-rings were permanently compressed, and U-cups were permanently hardened with extrusion. Test conditions did not allow for shaft motion. Temperature and pressure did not allow the saturation at the seal inlet that would be seen under actual station blackout conditions. The seal cartridge was new (unused) and the test was of the seal cartridge only without a pump and did not follow actual station blackout conditions.

3.2.3.2 <u>30-Minute Loss-of-Seal-Cooling Test on San Onofre RCP While the Pump Was Operating (Byron-Jackson Seal)</u>. Pressure fluctuations were observed for the second- and third-stage seals. Vapor seal leakage indicated seal cartridge degradation, O-rings were permanently deformed, and U-cups were extruded up to 1/16 inch (16 mm) axially with seal faces showing signs of wear and heat checking. Although controlled leakage of 2 gallons per minute (gpm) and vapor seal leakage of 0.5 gpm (~0.12m^3/hr) were the maximum recorded, results from this type of test should not be extrapolated to longer times or to nonrotating loss-of-seal-cooling events such as station blackout. It is not clear that loss of seal cooling with the pump running is as severe as loss of cooling with a nonrotating pump, as in station blackout.

3.2.3.3 <u>30-Minute Loss-of-Seal-Cooling Test of Operating Boiler Recirculation Pump with 4.5-inch (~11.5-cm) -Diameter Shaft (Bingham International Test for San Onofre)</u>. The test was not run with an RCP seal but with a smaller (4.5-inch

or 11.5-cm -diameter shaft) boiler recirculation pump. The second- and third-stage seals exhibited bistable behavior (see Ref. 13, and section 3.2.3.2 above).

3.2.3.4 Secondary Seal Material Tests (O-Rings, Channel Seals, and U-Cups). Secondary seals currently used in RCPs failed under station blackout conditions (see Refs. 5, and 11).

3.2.3.5 Limited Tests on Seal Rings to Find Balance Ratio at which Seals Popped Open. Seal rings were tested applying a closing load to one of the seal rings and decreasing this load until seal popped open. Changing the closing load was equivalent to changing the closing balance ratio. (see Ref. 13). The major experimental uncertainty is the thermal distortion and the exact seal face convergence during the test.

3.2.3.6 Station Blackout Test of 7 inch (~18 cm) -Diameter Seal Assembly Typical of Westinghouse Pump Seals Used in European Nuclear Power Plants. This test was conducted in France in 1985.. There is no guarantee that, under station blackout conditions, the 7-inch (~18 cm) seal would behave like the 8-inch (~20 cm) seal typically used in the United States. The 7-inch (~18 cm) seal is significantly different in design from the 8 inch (~20 cm) seal with differences in O-rings and channel seal materials, seal ring thicknesses, mounting and support configurations, flow restriction downstream of the gap between seal rings, and the balance ratio of the second-stage seal. The test seal was in "as-new" condition when tested, whereas NRC research has demonstrated a potential for a second-stage seal to pop open if the seal faces have scratches or wear marks. Modeling of important leakoff systems with orifice plates may have provided excessive flow resistance and choked the flow artificially, thus limiting the leakage. The test procedure was a compromise between test objectives and the facility capabilities; therefore, the actual station blackout sequence was not accurately duplicated. The test was a seal test, not a pump-seal test. Pump shaft growth could drag seal faces open, yet no consideration was given to shaft movement under thermal expansion, either to introduce or to monitor it (Ref. 5, 13, 14, and 15).

3.2.3.7 Multiple In-Plant Loss-of-Seal-Cooling Events. These events were of short duration (mostly hot functional testing) and of undocumented reactor coolant system conditions. They generally did not run long enough to cause hydraulic instability. Many events were of 10 minutes or less.

3.2.3.8 Byron Jackson 9000 Seal Test. A report on the testing details has not been submitted for NRC review, and the number of plants actually using this seal model is not yet known.

Further discussion of the test option as an acceptable solution to the safety question is provided in section 4.1.2.

3.2.4 Alternative 4

Alternative 4 involves replacement of all secondary seals with seals fabricated from improved high-temperature elastomers (equivalent to those proposed by Westinghouse in Reference 2). This material improvement relates to the proposed resolution in that its primary objective is to reduce the failure probability and improve the performance of the RCP seals in the event of loss of seal cooling. The improved secondary seal materials are beneficial under high-temperature conditions. This alternative, while providing improved high-temperature performance of the secondary seals, does not preclude seal failures (especially face seal failures) in the event of loss of all seal cooling and two-phase flow through the seals. Analysis of the improved secondary seals, proposed by Westinghouse using the seal failure model developed by AECL, showed that the probability of seal failure is not fully eliminated under loss of cooling conditions because failure of primary face seals is still a strong possibility, and there are other seal failure modes, e.g., seal faces "popping open." Reference 7 provides a description of the complex event tree used to develop estimates of the probability of seal failure and core uncovery as a function of time. This tree shows that there are a number of RCP seal failure paths that will continue to exist even with "perfect" secondary seals.

3.2.5 Alternative 5

Alternative 5 involves the design and installation of an emergency backup seal on each RCP to preclude excessive seal leakage in the event of loss of seal cooling. This seal design would take advantage of and depend on a fixed shaft position (no rotation) and would limit RCP seal leakage to less than 3 gpm (~0.75 m^3/hr). Activation of the emergency seals in the event of loss of seal cooling would eliminate the need for continued seal injection or thermal barrier cooling as proposed in ASCO. This alternative is directed at reducing the risks associated with the probabilities of high seal failure whenever seal cooling is lost. Reference 7 contains a discussion of temperature-related failure probabilities.

Although this alternative would be effective in reducing the consequences of RCP seal failure, it was rejected because of the high degree of uncertainty associated with its development and installation costs. The scope and extent of modifications to existing RCP shafts and seal assemblies that would be required to accommodate the emergency seal are indeterminate at this time, and the potential problems associated with inadvertent actuation need to be examined. The development of such a seal should be encouraged, and any proposed designs should be given serious consideration.

3.2.6 Alternative 6

Alternative 6 is simply to take no regulatory actions. A no-action resolution was rejected because of the significant CDF associated with RCP seal LOCAs (see Table 1-1).

3.3 Impacts on Other Requirements

3.3.1 USI A-44, "Station Blackout"

During the resolution of unresolved safety issue (USI) A-44 on station blackout (Refs. 8 and 16) and in the supplementary information on 10 CFR 50.63 (53 FR 23218, June 21, 1988) it was explicitly recognized that the potential leakage through RCP seals would affect the ability of plants to cope with a blackout. The NRC staff determined that, in the context of performing the station blackout coping analyses required by 10 CFR 50.63 with the GI-23 resolution still pending, an RCP seal leakage rate of 25 gallons per minute (gpm) (~6 m^3/hr) per RCP for PWRs and 18 gpm (~5 m^3/hr) per recirculation pump for BWRs, could be reasonably assumed for analysis purposes, because those values (which are the expected seal leakage rates with no "pop open" seal failures) were considered the most likely value for a seal leakage rate under the postulated off-normal conditions. The staff reemphasized, in Generic Letter 91-07, "GI-23 and Its Possible Effect on Station Blackout" (May 2, 1991), the possible implications of the pending GI-23 resolution with respect to the continued validity of coping analyses that rely on assumption of the above mentioned seal leakage rate. Those assumed values are technically justifiable and would remain valid if it is demonstrated on the basis of assessments performed and/or actions taken under this rule that no seal failure will occur (i.e., acceptable test data is made available indicating that seals will maintain integrity without cooling, or that seal cooling is ensured by an alternate, dedicated seal cooling system). However, as noted above and from the information developed in the GI-23 effort to date, the staff has been unable to determine with confidence the probability or magnitude of seal leakage to be expected under such conditions. Conservative interpretation of the results of research sponsored by NRC and of industry work reviewed by NRC staff, as described above, with appropriate allowance for the significant uncertainties involved, leads the staff to conclude that the possibility of RCP seals "popping open" or secondary seals failing during a station blackout and causing a leak of more than 25 gpm cannot be precluded if cooling to the seals is lost for periods longer than about 10 minutes.

Ultimately, questions regarding the need to revise station blackout coping analyses will be determined based on the method chosen by a licensee to demonstrate compliance with this proposed rule. If a licensee chooses to present test data to demonstrate compliance with this rule, the seal leakage rates must be reflected consistently in the licensee's station blackout coping analysis as well (or be appropriately bounded by assumed leakage values). If a licensee chooses to provide alternate seal cooling and has assumed 25 gpm seal leak rate in the station blackout coping analysis the adequacy and timeliness of the alternate seal cooling system must be demonstrated. In further regard to the alternate seal cooling option, the proposed rule acknowledges that an alternate ac power source that some plants may be using to comply with 10 CFR 50.63 could provide the needed electrical power. Such an arrangement would be satisfactory as long as the alternate ac power source ensures adequacy and timeliness of seal cooling as demonstrated by a specific analysis and in a manner consistent with the coping analysis under 10 CFR 50.63.

Applicability to BWRs

To investigate the potential for RCP seal leakage and the safety consequences of such leakage, the amount of research and study, that has been performed for PWRs, has not been accomplished for BWRs for recirculation pump seals, because the safety significance of such work was not considered to be at a high enough level to merit the allocation of significant resources. However, recent information from the industry in response to NRC's request for public comment has caused the staff to reconsider this position, resulting in a view that additional staff action may be appropriate. This question has been addressed by the NRC's contractor Brookhaven National Laboratory in a technical report on a study performed for BWRs (Ref. 17) which indicates that further study in this area is justified. The staff intends to initiate an investigation into the safety significance of the BWR concerns while proceeding with resolution of the more significant safety concerns on PWRs through the proposed rule.

3.3.2 GI-65, Component Cooling Water System Failure

GI-65 has been subsumed into GI-23 because adoption of the proposed rule would virtually eliminate the risk of an RCP seal LOCA coincident with a CCW failure. CCW is generally required for cooling lubricating oil, bearings, and environmental systems associated with makeup and injection pumps and, therefore, may be implicated in a wide range of common cause failures. The NRC has judged that a sufficient basis would exist to resolve GI-65 if safe shutdown is assured in case of RCP seal cooling failure. Hence, GI-65 was subsumed into GI-23.

3.3.3 Three Mile Island (TMI) Actions II.K.2.16 & II.K.3.25

Following the TMI accident of 1979, the NRC examined the potential for a serious accident involving the failure of the RCP seals from a loss-of-offsite-power event. This led to the establishment of TMI Action Items II.K.2.16 and II.K.3.25 in NUREG-0737 (Ref. 18). TMI Action Items II.K.2.16 (for Babcock & Wilcox plants) and II.K.3.25 (for Combustion-Engineering, General Electric, and Westinghouse plants) require licensees to evaluate the integrity of their reactor coolant or recirculation pump seals for a period of 2 hours following a loss-of-offsite-power event. All PWR plants except Calvert Cliffs, Units 1 & 2, Haddam Neck, and Arkansas Nuclear One, Units 1 & 2, have limited the potential for seal failure by automatically loading the seal coolant injection pumps onto the emergency power bus and automatically starting the seal coolant injection pumps. This design was found acceptable. The remaining five units have been judged against the criterion that they should demonstrate the acceptability of operator action to reinstate seal cooling in time to assure seal integrity during an event caused by or resulting in a loss of offsite power. They have committed to manually load seal cooling in time based on plant-specific considerations. No additional actions are expected to result from issuance of the proposed rule.

3.3.4 GI-130, Essential Service Water System (ESW) System Failure at Multiplant Sites

The ESW system typically supports all the front-line safety systems required for safe shutdown. Generic Issue GI-130 was resolved by requesting licensees at 7 sites (14 plant units) to consider improvements to their ESW system reliability and installation of a dedicated RCP seal cooling system. The backfitting of improvements considered under GI-130 were subsumed by the expected resolution of GI-23 (see Generic Letter 91-13, "Request for Information Related to the Resolution of GI-130," September 19, 1991).

3.3.5 GI-153, "Loss of Essential Service Water (ESW) in LWRs"

During the evaluation of GI-130, described above, it was recognized that all plants appear to be somewhat susceptible to loss of ESW; a new generic issue, GI-153, "Loss of ESW in LWRs," was established regarding the vulnerability of ESW at all LWRs. A quantitative generic estimate of the CDF contribution from loss of ESW function leading to RCP seal failure to represent the full population of PWRs is shown in Appendix F to NUREG/CR-5918 (Reference 10). The results of this study are incorporated in the cost/benefit numbers from GI-23. This risk for the total population of PWRs has been estimated and an average value derived. This average value of 1.2E-05 has been taken into the cost/benefit calculations of GI-23, and the proposed resolution for GI-23 would reduce this portion of the risk. This issue has been resolved by the NRC staff by taking into account the expected improvements in ESW reliability through actions proposed in Generic Letter 89-13, "Service Water System Problems Affecting Safety-Related Equipment", and by actions arising from the rulemaking on GI-23.

3.3.6 GI-106, Piping and the Use of Highly Combustible Gases in Vital Areas

In resolving this generic issue the NRC concluded that hydrogen explosions in some vital areas could cause an RCP seal LOCA (NUREG-1364, "Regulatory Analysis for the Resolution of Generic Safety Issue 106: Piping and the Use of Highly Combustible Gases in Vital Areas" June 1993). The proposed rule for GI-23 is not expected to decrease the risk from hydrogen explosion. However, licensees responding to the Individual Plant Examination for External Events (IPEEE) programs under the Generic Letter 88-20, Supplement 4, "Individual Plant Examination of External Events for Severe Accident Vulnerabilities" (June 28, 1991) are expected to provide information that will enable the identification of any vulnerability from hydrogen explosion in their fire analyses.

3.3.7 Individual Plant Examination (IPE) and Individual Plant Examination for External Events Programs

Under these programs, plants will be searching for dependencies in their facilities with regard to the consequences of severe accidents. The guidance provided for these programs mentions RCP seal LOCA as a special event similar to a station blackout or anticipated transient without scram (ATWS). IPE reports submitted and evaluated by the staff to date appear to

confirm that RCP seal LOCA is one of the prominent contributors to the residual risk in the operating plants, i.e., the associated risk is a significant part of the remaining risk in plants in which adequate protection is already reasonably assured.

The NRC staff notes that, based on the available evidence, no undue public risk exists without the promulgation of the rule for RCP seals. The proposed rule would enhance safety by accident prevention and thereby reduce the likelihood of a core damage accident being caused by LOCA induced by RCP seal failure. Further enhancement in reducing the overall risk may also be achievable by additional improvements in severe accident management, given the assumption that core damage occurs, whether from seal failure or other causes (such as station blackout or other LOCA sequences). Therefore, the proposed rule should be viewed as being in the same accident prevention context as the ATWS rule (§10 CFR 50.62) and the station blackout rule (§10 CFR 50.63) in that it recognizes, as the other two rules recognize, multiple failure possibilities resulting from common cause effects that should be addressed. This concern has been recognized in the introduction to Appendix A to 10 CFR Part 50.

4. DECISION RATIONALE

The likelihood of core damage accidents from RCP seal failures has been evaluated by using both engineering evaluations and cost/benefit analyses. The engineering evaluation includes the study of the probability of RCP seal failure and the duration of possible loss-of-seal-cooling events. The cost/benefit studies focused on the timing and consequences of various accident sequences, identifying root cause and dominant factors for core damage from RCP seal failures. These studies indicate that RCP seal failures can be a significant contributor to the overall plant risk.

4.1 Engineering Evaluation

4.1.1 Loss of All Seal Cooling

The relationship between the loss of seal cooling and seal failure is not a precise engineering determination. A method for quantifying this relationship described in Reference 7 involved the development of a complex event tree. The event tree considered the likelihood of failures in individual seal stages as a function of time and displayed the consequences of various failure combinations. However, the quantification of this event tree requires knowledge of the time-dependent failure rate of each seal stage. Little hard data exist, so the quantification was based on the judgment of seal experts with the following considerations:

1. Hydraulic instability may occur, leading to the seal faces "popping open," if there is a sufficient loss of inlet subcooling or seal stage back pressure.

2. Although experimental measurements of the frictional forces exerted by degraded O-rings and channel seals were quite low during scaled component testing, the probability of RCP seal binding failures occurring during a real loss-of-cooling event is hard to assess since the seal face plate closing forces have not been measured under these conditions.

3. Extensive testing by NRC and Westinghouse of scaled O-rings and channel seal materials indicates that improved materials are available for 0-rings that would not fail under loss-of-cooling conditions and that, if channel seals fail as predicted, the backup O-rings would still perform their sealing function. However, limited tests on full-scale O-rings seem to support the theory that batch testing of the actual materials used in manufacturing each particular set of O-rings may be necessary to ensure their high-temperature characteristics. Additional uncertainty exists regarding the performance of secondary seal materials since there have been few events or tests of these components under actual loss-of-cooling conditions.

The complexity of the proposed seal failure event tree used by both AECL and Westinghouse to describe the potential failure modes of the Westinghouse seal illustrates the need for caution in relying on any decision based solely on this type of analysis. The failure event tree

has one success path that leads to a leakage rate of 21 gpm (~5 m^3/hr) per pump and 15 possible failure paths that lead to leakages ranging from 47 gpm (~11 m^3/hr) per pump to 480 gpm (~110 m^3/hr) per pump. Each of these paths involves the use of several assigned probabilities based on engineering judgment and speculation on the behavior of seals during a loss-of-cooling event based on the items listed above.

Another aspect of the problem is that the longer the loss of seal cooling persists, the greater is the likelihood that the seal will fail and the core will be uncovered. Moreover, when seal cooling is lost and if seal failure occurs, reestablishing cooling may not correct the seal failure. Major judgments in the duration of possible loss of seal cooling are:

(a) The station blackout rule (10 CFR 50.63) groups plants based on the length of time they are expected to have to cope with station blackout. There is some probability that a station blackout will actually last longer than the predicted time.

(b) The loss of seal cooling can be caused by the loss of CCW/SW, which may lead to longer times than those assumed for station blackout.

Providing an engineering solution to the loss-of-cooling seal failure problem, i.e., providing an alternative source of cooling that would be available during all other postulated loss-of-cooling events such as station blackout, would reduce the unknowns associated with all the above considerations. This solution also would ensure compatibility with the resolution of USI A-44. Therefore, the option of providing an alternate seal cooling system in the proposed rule has been used as the reference solution.

4.1.2 Seal System Integrity Testing

This option is included in the rule to ensure a sufficient basis in experimental data to assess the performance of the seals during postulated events such as station blackout, loss of CCW, or loss of SW. Experiments that test individual components separately have not provided sufficiently reliable data in the past. Testing must adequately model (or duplicate) the complex thermal and fluidics factors that prevail when cooling is lost. The results should enable the NRC staff to estimate the likelihood of "popping open", as well as the timing and magnitude of leakage if the seal "pops open", if assurance that the core is cooled depends on this factor. The NRC has identified the following factors which appear to be important to a representative test:

(a) Modeling of the multiple stages of the seal assembly, including the housing, the shaft, and the leakoff control piping and valves, under liquid and two-phase flow conditions.

(b) Appropriate consideration of the seal balance ratio (ratio between closing and opening forces), spring forces, shaft movement, wear on seal faces, and secondary seals (o-rings, u-cups, etc.)

(c) Temperature, pressure and flow conditions (with proper records thereof) over the wide range of possibilities characterizing loss of seal cooling, with the duration of the test accounting for the anticipated length of a station blackout.

The NRC is interested to receive in public comments suggestions regarding the parameters of a test program that would provide sufficiently reliable information in a cost effective manner so that a regulatory position which incorporates testing as an option may be based on definitive technical evidence. A test program conducted by PWR owners jointly, with appropriate NRC staff participation, appears to have considerable merit to implement practicably a technically adequate test option that is cost effective.

4.2 Cost/Benefit Considerations

The cost/benefit analysis shows that the implementation of ASCO will reduce seal failure probability in the event of loss of seal cooling. It is estimated that ASCO would reduce the current CDF from RCP seal failure by 75%. For a summary of cost and benefits for 76 PWRs, see Table 3-1. The averted radiological exposure to the public for 76 operating PWRs over an estimated average remaining lifetime of 25 years[3] is estimated to be about 100,890 person-rem.

The industry implementation cost for ASCO is estimated at $72.4 million ($953,000 per plant). The industry operating cost (present value) for the remaining life of the plant is estimated at $1.17 million ($15,400 per plant). The total industry cost for implementation and operation is therefore estimated to be $73.6 million (present value). However, the expected reduction in RCP seal failure as a result of the resolution is estimated to result in a substantial savings in averted onsite property costs of $10.4 million. (More information about the cost and benefit of GI-23 is given in References 7, and 10.)

The best-estimate cost/benefit ratio for ASCO is $680 per person-rem. Reference 12 suggests a cost/benefit of less than $1000/person-rem as a guideline for the adoption of resolution. Considering these guidelines, the proposed ASCO is justified based on the cost/benefit analysis. Reference 12 stipulates that the cost/benefit guideline of $1000/person-rem is given in 1983 dollars and should be corrected for inflation. However, since the NRC staff is actively considering the question of whether and in what manner the $1000/person-rem should be modified, the staff has decided to use the criterion in the unmodified form. Based on a 5% per year inflation rate, the projected guideline is approximately $1700/person-rem at the end of 1994.

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[3]Although not included in this regulatory analysis, anticipated license renewal (life extension) for many of these plants would further extend the remaining years of operation, resulting in even greater public health benefits.

For an alternative look at cost/benefit considerations, a different and less-expensive fix is examined in Appendix C of Reference 19. It is an independent seal cooling arrangement, generically applicable for a station blackout event. This fix is shown to be cost effective. In fact, accounting only for the benefit achieved from preventing seal failures during a station blackout event, the cost/benefit ratio is about $692/person-rem. If the benefits for loss of CCW/SW are considered, this system would be even more cost beneficial.

4.3 Consideration of NUREG-1150 Results

A comparison of CDFs from GI-23 with those from NUREG-1150 (Ref. 9) is presented in Appendix B.

4.4 Decision

Because of the above-mentioned considerations, it is recommended that the proposed rule be adopted. The analysis and determination that the proposed rule concerning RCP seal failure complies with the backfit rule, 10 CFR 50.109, are presented in Appendix C to this guide.

5. IMPLEMENTATION

5.1 Implementation of Rule to Resolve GI-23

The Commission expects that licensees and applicants will take the following actions in response to the proposed rule, "Loss of Integrity of Reactor Coolant Pump Seals.", and hence resolve GI-23. Terms used in the rule are meant to be consistent with the station blackout rule, 10 CFR 50.63. The staff recommends that PWR licensees notify the NRC, about what option of the rule they will adopt, along with the schedule for implementation.

5.1.1 Perform an evaluation:

Licensees would be required to perform an evaluation, if one has not already been performed under a program such as the IPE, to determine if factors exist at their plants that create common-cause failure mechanisms (dependencies) whereby an RCP seal LOCA can occur at the same time that reactor core cooling capability may be disabled. Coincident timing means that duration during the progress of events associated with a postulated event when the seal LOCA and lack of core cooling capability occur together. The starting and ending points for the failures in each of the systems may or may not coincide. For example, if a licensee shows that either seal cooling or core cooling is assured for the duration of the station blackout analysis under 10 CFR 50.63, no further action would be required by the proposed rule to address this postulated event. The response of the RCP seals to the loss of cooling should consider the "popping open" mode of failure as one of the possibilities. This evaluation need not be submitted to the NRC for review and approval, but should be held onsite and be available for NRC inspection. As currently constituted, the requirements under this proposed rule do not include regulatory controls on the procedures or hardware which a licensee may choose to rely upon to comply with Paragraph (c)(2)(i) of the proposed rule. Hence a licensee could make changes in these areas without giving NRC any notice of them.

5.1.2 Actions pursuant to dependencies identification:

If dependencies are identified, licensees may either take action to reduce them, or show that the risk of core damage is so low that any action to reduce them is not justified. The action to reduce dependencies can range over a number of possibilities, including providing alternative seal cooling or showing that sufficient and timely core cooling capability will be restored. The alternate seal cooling system need not be classified as safety-related, may be powered from any source available in the station blackout scenario, and need not satisfy the single failure criterion. These relaxed criteria are appropriate because the requirements constitute safety enhancement beyond the "adequate protection" standard of the regulations. However, the seal cooling system must have sufficient capacity and provide the cooling rapidly enough to meet the objective of maintaining seal integrity. A specific analysis is required to show that this objective is met; that analysis may be part of the above evaluation. Means of ensuring sufficient core cooling in the event of seal failure (e.g., enhancing the capacity and capability of existing core cooling systems) could be considered by licensees and

may be found acceptable. An assessment supporting the adequacy of the actions taken should be included in the evaluation above. Such an assessment that addresses specifically dependencies that could lead to loss of seal cooling and seal failure, appropriately models seal failure mechanisms, and clearly documents and supports assumptions would be acceptable for purposes of demonstrating compliance with this proposed rule. Specifically, in this regard, application by licensees of the methodology (in particular, the seal modelling) employed in the NUREG-1150 studies is acceptable to the staff, if properly applied.*

Alternatively, a licensee may conclude on the basis of an appropriate analysis that the likelihood of core damage resulting from loss of all seal cooling by some failure paths identified is so small that no action is warranted. In performing such analyses and making such judgements, the use of decision criteria similar to those used in the IPE for determining whether corrective actions were warranted would be appropriate and acceptable to the staff. As a practical bounding case in this regard, the staff would expect licensees to implement appropriate corrective or mitigative actions, to address identified dependencies that could lead to seal failure with resulting estimated core damage frequencies of about 2E-5.

The NRC recognizes that the risk associated with seal failure may vary widely among the existing plants, and that plant-specific and vendor-specific factors have an important bearing on seal behavior and on the actions that may be relied on for coping with a loss of seal integrity. The NRC has performed a generic study, including estimating costs and benefits as documented in the regulatory analysis, to conclude that the risk reduction requirements of this proposed rule are justified. However, the NRC recognizes that such a generic analysis may not apply accurately to every reactor licensee given that there are significant differences in plant design as well as significant uncertainties in the analysis. Accordingly, the proposed rule provides licensees with a great deal of flexibility for achieving compliance, by assuring RCP seal integrity, or reducing dependencies, or showing that the risk is sufficiently low. Flexibility also exists in determining the evaluation methods and selecting appropriate actions for addressing the seal failure concern in their facilities from the options provided in the proposed rule. This is a performance-oriented approach to rulemaking with risk being one of the criteria on which compliance will be determined. The approach is similar to that taken by licensees under the IPE program to address severe accident vulnerabilities at their facilities. Proper application of the IPE assessment approach could be an acceptable means of satisfying the provisions of this rule. An acceptable means for demonstrating compliance with the proposed rule is a demonstration by a suitable analysis that the risk associated with the postulated off-normal conditions is sufficiently low that further actions to improve protection of public health and safety against the possible consequences are not justified in view of the cost. A sufficiently low level of risk would be achieved if the core damage frequency from seal failure possibilities is about 1E-5. The NRC would like to receive public comment on this approach to rulemaking and the criterion for resolving the generic issue.

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* The staff is currently assessing the significance of an error in NUREG-1150 in the application of the model regarding timing of seal failure on loss of cooling.

5.1.3 Reliance on RCP Test Data:

The test option comes into play if a licensee wishes to rely on RCP seal characteristics that purport to prevent or preclude seal failure under the postulated events. The NRC does not propose the conduct of any specific test under this provision, but believes that licensees should be given the opportunity to develop a cost-effective test to address the concern involved. If the licensee's evaluation to show that a plant complies with this rule relies on claims that either the seal will not "pop open" or that a "popped open" seal will leak at a much lower rate than the maximum possible (for Westinghouse seals this is 480 gallons per minute), this must be based on appropriate test data and an acceptable interpretation of that data. The staff notes in this regard that such acceptable interpretation has not been provided in information submitted to NRC to date during the interaction with industry on GI-23. Accordingly, licensees are cautioned that simply relying on (or resubmitting) information that has already been provided to the NRC staff will not be sufficient for the NRC staff to reach a finding of compliance with the rule, unless a current engineering evaluation of that information is provided that acceptably addresses previous points of disagreement comprising additional technical justification for its acceptability in this context.

5.1.4 The use of probabilistic methods:

The NRC has always recognized the appropriate use of probabilistic methods, but this provision in the rule has the purpose of ensuring consistency and coherence in applying such methods when it is done under other commitments (such as the IPE and IPEEE) or requirements (such as under 10 CFR 52.47(a)(v)).

5.1.5 The use of alternate ac under station blackout rule:

The purpose of this provision (paragraph (c)(5) of the proposed rule) is to assure that licensees have the flexibility to use plant modifications undertaken under 10 CFR 50.63 to resolve GI-23. The specific analysis that demonstrates the adequacy of the alternate ac power source should be included in the evaluation discussed above. Also, as discussed above under the "The Station Blackout Rule", NRC would like to receive public comment on the coordination of actions to comply with this proposed rule and 10 CFR 50.63.

5.2 Schedule

A schedule will be developed after receipt and resolution of public comments for licensee's submittal for the implementation of the proposed rule.

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Appendix A

RCP Seal Leakage Experience

A survey of the data on reactor coolant pump (RCP) seal failures for existing nuclear power plants in the United States reported in NUREG/CR-4400 (Ref. A1) was performed by Brookhaven National Laboratory (BNL) using the following sources:

1. Nuclear Safety Information Center files
2. EG&G Licensee Event Report summaries (Ref. A2)
3. Nuclear power experience
4. Nuclear Plant Reliability Data System (NPRDS)
5. Data collected for prioritization of GI-23 (Ref. A3)

The data collected covered the period from July 1969 through May 1984 and included only mechanical- or maintenance-induced seal failures during plant operation.

A total of 173 RCP seal failures in pressurized water reactors (PWRs) were determined from the survey -- 46 for Westinghouse (W) plants with W pumps, 31 for Combustion Engineering (CE) plants with Byron Jackson (BJ) pumps, 28 for Babcock and Wilcox (B&W) plants with BJ pumps, 9 for B&W plants with older Bingham pumps with two-stage pump seals, and 4 for B&W plants with the newer Bingham pumps with three-stage pump seals. Considering seal failures of all magnitudes, the RCP seal failure rate was calculated to be 26.0 failures per million hours. Seal failures that resulted in a leak comparable to a small loss-of-coolant accident occurred at a rate of 1.3E-02/reactor-year.

A more recent limited data survey, using only NPRDS data from January 1984 to October 1987, was performed by BNL to determine whether seal failure rates had improved since 1984. The results indicated that W plants with W pumps showed some improvement in seal failure rate (about a 60% reduction). B&W plants with either BJ or Bingham seals experienced a more significant improvement, about an order of magnitude; while CE plants with BJ pumps had about the same seal failure rate for both periods.

In another recent study, the NRC staff reviewed the pump seal failure data in the NPRDS and the Sequence Coding and Search System (SCSS) for the period between January 1985 and March 1990. The failure rate for RCP seals was 11.9 failures per million hours. Comparison of the staff study results for the past 5 years with the data reported in NUREG/CR-4400 (Ref. A1) for the earlier time period indicates that the seal failure rate has decreased by roughly a factor of 2.

Some recent RCP seal leakage events in PWRs are shown in Table A-1 below. Although none of these failures resulted in the large leakage rates seen in some of the earlier events, seal failure still remains a generic problem.

REFERENCES FOR APPENDIX A

A1. M.A. Azarm, J.L. Boccio, and S. Mitra, "The Impact of Mechanical- and Maintenance-Induced Failures of Main Reactor Coolant Pump Seals on Plant Safety," NUREG/CR-4400 (BNL-NUREG-51928, Brookhaven National Laboratory), December 1985.

A2. W.H. Sullivan and J.P. Poloski, "Data Summaries of Licensee Event Reports of Pumps at U.S. Commercial Nuclear Power Plants," NUREG/CR-1205 (EGG-EA-5044, Idaho National Engineering Laboratory 9EG&G)), January 1980.

A3. NRC Memorandum from R. Riggs, Operating Experience Evaluation Branch, to E. Adensam, Acting Branch Chief, on Reactor Coolant Pump Seal Degradation Review, December 9, 1980.

Table A-1

RECENT REACTOR COOLANT PUMP SEAL LEAKAGE EVENTS IN PWRs

EVENT DATE	PLANT	< VENDOR > NSSS	SEAL	DESCRIPTION OF LEAKAGE EVENTS
AUG 1, 1988	ANO-2	CE	BJ	1st & 2nd SEAL STAGES FAILED. LEAKAGE 40 gpm (9 m^3/hr).
SEP 15, 1988	TMI-1	B&W	W	DAMAGED O-RING, 1st SEAL STAGE FAILED. LEAKAGE 9 gpm (2 m^3/hr).
NOV 9, 1988	WATERFORD 3	CE	BJ N9000	SEALS FAILED AFTER STARTUP. EXCESSIVE CLEARANCE BETWEEN SHAFT AND SEAL ASSEMBLY
DEC 5, 1988	PALISADES	CE	BJ	PUMP SEAL DID NOT "STAGE" ON STARTUP. REPLACED AT OUTAGE.
DEC 15, 1988	TMI-1	B&W	W	DAMAGED O-RING. SEAL LEAKAGE 8 gpm. W UNABLE TO ADVISE SOLUTION.
DEC 21, 1988	MAINE YANKEE	CE	BJ SU	DEGRADED SEAL PERFORMANCE. SEALS REPLACED WITH BJ N9000 SEAL.
MAR 3, 1989	PALO VERDE 3	CE	KSB	SEALS DAMAGED. LEAKAGE 2 gpm (0.5 m^3/hr).
JUN 16, 1989	KEWAUNEE	W	W	LOW SEAL LEAKOFF, 1st STAGE SEAL FAILED. REPLACED SEAL.
JUN 19, 1989	INDIAN POINT 2	W	W	LEAKAGE 14 gpm (3 m^3/hr), RC PRESSURE WAS LOWERED TO DECREASE LEAKRATE, SEAL REPLACED DURING OUTAGE.
NOV 7, 1989	MAINE YANKEE	CE	BJ SU	N9000 WAS EARLIER REPLACED BY SU TYPE, WHICH FAILED. PLANT SHUT DOWN.
JAN 20, 1990	WATERFORD 3	CE	BJ N9000	SEAL LEAK FOUND DURING SHUTDOWN WHILE CHECKING REACTOR COOLANT SYSTEM LEAKS.
JUL 2, 1990	ST. LUCIE 1	CE	BJ	1st & 2nd SEAL STAGES DETERIORATED. LEAKAGE 3 gpm (0.7 m^3/hr).
AUG 24, 1990	FORT CALHOUN	CE	BJ	INLET PRESSURE ON 2nd STAGE STEADILY DECREASED. PLANT SHUT DOWN. SEAL REPLACED

Appendix B

COMPARISON OF CORE DAMAGE FREQUENCY FROM GI-23 WITH RESULTS FROM NUREG-1150

Table B-1 presents a comparison of the core damage frequency (CDF) per reactor-year from Generic Issue 23 (GI-23) studies with the CDF of three pressurized water reactors (PWRs) of NUREG-1150 (Ref. B1): Surry, Sequoyah, and Zion. These three PWRs are Westinghouse plants that use Westinghouse reactor coolant pumps (RCPs) and pump seals. The RCP seal failure model used for NUREG-1150 plants was similar to that used in GI-23 risk assessment studies for loss-of-seal-cooling events. Both models contained multiple-path event trees that represented success/failure paths for a three-stage seal. These success/failure paths contained both secondary seal (O-ring, channel seal) failure modes and face seal hydraulic failure modes.

For the above mentioned three NUREG-1150 plants, the overall CDF from station blackout is fairly consistent for Surry and Sequoyah, and is somewhat lower for Zion. The CDF values from station blackout seal failures for Surry (8.6E-06) and Sequoyah (4.3E-06) are close to the GI-23 estimate (5.6E-06). The portions of CDF from station blackout that are caused by seal failure are proportionally consistent except for Zion, which has a very low contribution (ratio of $CDF_{SBO(Seals)}/CDF_{SBO}$ for Surry = 32%, Sequoyah = 37%, and Zion = 6%).

Zion has a very high contribution to total CDF from loss-of-seal-cooling conditions other than station Blackout, i.e., loss-of-coolant accidents (LOCAs) from seal failure caused by loss of component cooling water (CCW) and loss of service water (SW). Surry and Sequoyah have a very low contribution from these causes. For GI-23 the CDF from seal LOCA caused by the loss of CCW is somewhere between the very low values of Surry and Sequoyah and the high number for Zion. The Zion number indicates a significant contribution from CCW failure. Zion also shows an equally significant contribution from SW. It should be noted that the NUREG-1150 studies considered potential passive failures in the CCW and SW systems. For Zion, it was found that certain failures could not be isolated. This led to the high CDF values shown in Table B-1.

Table B-1, Core Damage Frequency (CDF) per Reactor-Year

COMPARISON	NUREG 1150			GI-23
SELECTED PLANTS	SURRY	SEQUOYAH	ZION	76 PWRs
TOTAL CDF (INTERNAL EVENTS)	4.00E-05	5.72E-05	3.40E-04	NOT CALCULATED
CDF FROM STATION BLACKOUT	2.72E-05	1.16E-05	6.50E-06	NOT CALCULATED
CDF FROM SEAL LOCA CAUSED BY STATION BLACKOUT	8.60E-06	4.32E-06	4.00E-07 (NOTE 1)	5.60E-06 (NOTE 2)
CDF FROM SEAL LOCA CAUSED BY LOSS OF CCW	NEGLIGIBLE (NOTE 3)	<1.0E-08 (NOTE 4)	1.47E-04 (NOTE 5)	6.00E-06 (NOTE 6)
CDF FROM SEAL LOCA CAUSED BY LOSS OF SW	NEGLIGIBLE (NOTE 7)	<1.0E-08 (NOTE 4)	1.46E-04 (NOTE 5)	1.20E-05 (NOTE 8)

Notes:

1. Zion has SW and CCW systems cross-connected between two units.

2. This value is taken from NUREG/CR-5167 (Ref. B2)

3. At Surry, RCP seal injection does not fail on loss of CCW; it was therefore determined to be insignificant as a separate initiator.

4. At Sequoyah, the frequency of loss of SW is assessed to be very low and not included as an initiating event. The CDF due to loss of CCW is assessed to be very low because high pressure injection and charging pumps are cooled by reliable SW.

5. This is driven by specific nonrecoverable passive failures.

6. This is derived from a sensitivity study NUREG/CR-4643 (Ref. B3) performed on one plant.

7. Surry has a very reliable (gravity fed from a canal) SW system that is assumed not to fail.

8. This is derived from an independent study (Appendix F to NUREG/CR-5918 (Ref. B4)) performed for the total population of PWRs.

Conclusion

The GI-23 CDF results for station blackout are in fairly good agreement with the NUREG-1150 results. As to the results for CCW, the GI-23 study has shown that seal LOCAs resulting from loss of CCW are very plant-specific because CCW designs and the resulting seal cooling dependencies vary widely. The NUREG-1150 results seem to support this conclusion. As a result of the possible wide variations in the benefits from a fix for CCW/SW, GI-23 pursued a fix that could solve all the dependencies (i.e., an Alternate seal cooling system) at a reasonable cost. The cost/benefit ratio was then calculated, assuming only a benefit of fixing the station blackout portion (see Appendix C to NUREG-1401 (Ref. B5)).

REFERENCES FOR APPENDIX B

B1. U.S. Nuclear Regulatory Commission, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," NUREG-1150, Vol. 1, December 1990.

B2. R.G. Neve and H.W. Heiselmann, "Cost/Benefit Analysis for Generic Issue 23: Reactor coolant Pump Seal Failure," NUREG/CR-5167 (SCIE-NRC-001-90, Scientech, Inc.) April 1991.

B3. S. Mitra, R. Baradaran, and R. Youngblood, "Evaluation of Core Damage Sequences Initiated by Loss of Reactor Coolant Pump Seal Cooling," NUREG/CR-4643 (BNL-NUREG-52003, Brookhaven National Laboratory), August 1986.

B4. C.J. Ruger and J.E. Jackson, "Analysis of Public Comments on Generic Issue 23, Reactor Coolant Pump Seal Failure," NUREG/CR-5918 (BNL-NUREG-52337, Brookhaven National Laboratory), (to be published).

B5. S.K. Shaukat, J.E. Jackson, and D.F. Thatcher, "Regulatory Analysis for Generic Issue 23: Reactor Coolant Pump Seal Failure," Draft Report for Comment, NUREG-1401, U.S. Nuclear Regulatory Commission, April 1991.

APPENDIX C

BACKFIT ANALYSIS FOR GENERIC ISSUE 23

1 INTRODUCTION

This appendix presents the backfit analysis for Generic Issue 23 (GI-23), "Reactor Coolant Pump Seal Failure," in accordance with Section 50.109, "Backfitting," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities." The technical findings for GI-23 are presented in NUREG/CR-4948 [1], and the cost/benefit analyses are presented in NUREG/CR-5167 [2]. The responses to public comments on a package reflecting "the staff's current understanding, findings, and potential recommendations for GI-23" are documented in NUREG/CR-5918 [3]. A revised cost/benefit analysis as a result of responding to the public comments is also included in NUREG/CR-5918. These studies indicate that reactor coolant pump (RCP) seal failures are significant contributors to the overall plant risk. As a consequence of these technical findings and based on the cost/benefit analyses performed on one of the options of the rule, i. e., the alternate seal cooling system, the NRC staff has prepared the backfit analysis as follows.

The estimated benefit from implementing the proposed rule would be a reduction in the core damage frequency (CDF) per reactor-year and a reduction in the associated risk of off-site radioactive releases caused by RCP seal failure. The risk reduction to the public for 76 operating pressurized water reactors (PWRs) over an estimated average lifetime of 25 years is estimated to be 101,000 person-rem (best-estimate numbers were used). Also the direct and indirect costs of implementation are justified in view of this increased protection.

The implementation cost per plant for licensees to comply with the proposed rule is estimated at $953,000. The industry's operating costs are estimated at $15450 per plant.

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1. C.J. Ruger and W.J. Luckas, Jr., "Technical Findings Related to Generic Issue 23: Reactor Coolant Pump Seal Failure," NUREG/CR-4948 (BNL-NUREG-52144, Brookhaven National Laboratory), March 1989.

2. R.G. Neve and H.W. Heiselmann, "Cost/Benefit Analysis for Generic Issue 23: Reactor coolant Pump Seal Failure," NUREG/CR-5167 (SCIE-NRC-001-90, Scientech, Inc.) April 1991.

3. C.J. Ruger and J.E. Jackson, "Analysis of Public Comments on Generic Issue 23, Reactor Coolant Pump Seal Failure," NUREG/CR-5918 (BNL-NUREG-52337; Brookhaven National Laboratory), (to be published).

Over the lifetime of the 76 plants, the best-estimate cost to industry is estimated to be $73.6 million (present value). However, the expected reduction in RCP seal failure is estimated to result in substantial net savings of $10.4 million in onsite property costs. Detailed cost/benefit worksheets are presented in Appendix F of NUREG/CR-5918.

The best-estimate cost/benefit ratio is $680/person-rem. Although there is considerable uncertainty in the cost/benefit analysis because of uncertainties in core damage estimates resulting from seal failure assumptions, release consequence uncertainties, and various blackout probability models, the proposed rule is a means of showing that the risks of doing nothing is acceptably low, or of precluding common-cause temperature-related seal failures under loss-of-all-seal-cooling conditions and of ensuring compatibility with the resolution of USI A-44.

The referenced cost/benefit analysis assumes an average remaining plant life of 25 years. It does not take into account the potential for increased plant life as a result of plant license renewal. If it did, the cost/benefit ratio would decrease nearly linearly with the period of life extension. This decrease occurs because the benefit increases linearly with time and the major element of cost is the initial cost, which would be unchanged. Only the operating costs (both industry and NRC) would increase with time. For example, if the cost/benefit analysis assumed a 20-year license renewal extension in addition to the typical 25-year remaining life, the cost/benefit ratio would decrease from $680/person-rem to about $425/person-rem.

The quantitative cost/benefit analysis (NUREG/CR-5167) was one of the factors considered in evaluating the proposed resolution; however, other factors also played a part in the decision-making process. Probabilistic risk assessment (PRA) analyses indicate that the overall probability of core damage from postulated small breaks could be dominated by such events as RCP seal failures.

The conclusions of this backfit analysis are that a substantial increase in the protection of the public health and safety would be derived from backfitting the RCP seal improvements and that the backfit is justified in view of the favorable cost/benefit ratios. The following sections of this backfit analysis address the nine factors stipulated by 10 CFR 50.109(c) to be used in the determination of backfitting.

2 ANALYSIS OF 10 CFR 50.109(c) FACTORS

2.1 Objective

The objective of backfitting the proposed rule is to evaluate plant-specific dependencies that cause loss of cooling to reactor coolant pump (RCP) seals and could lead to failure of seals during postulated off-normal events, and either assure core cooling or demonstrate that the risk associated with reactor coolant pump seal failures is sufficiently low that further safety enhancement measures to address their possible consequences are

not justified, or to prevent loss of seal integrity.

2.2 Licensee Activity

To implement the backfit, each PWR licensee would need to provide a response as to how it intends to meet the objectives of the rule that contains various options for the concerns during off-normal plant conditions, i.e. station blackout, loss of component cooling water, or loss of service water.

2.3 Public Risk Reduction

Backfitting in accordance with the proposed rule would yield a reduction in public risk from the accidental off-site release of radioactive materials of 101,000 person-rem (best estimate) for 76 operating PWRs with an average remaining life of 25 years. Also CDF per reactor-year would be reduced by about 75% from 2.4E-05 to 6E-06.

2.4 Occupational Exposure

For 76 operating PWRs, the best-estimate total decrease in the radiological exposure of facility employees for the average remaining lifetime of the plants is estimated to be 700 person-rem because of fewer accidental exposures. The radiological operational exposure is negligible.

2.5 Installation and Operating Costs

2.5.1 Installation

Assuming all 76 operating PWRs include provisions for seal cooling during off-normal conditions, the best-estimate total cost (labor and capital) is $72.4 million ($953,000 per plant). This assumes meeting the intent of alternate seal cooling by (1) installing an independent power source to provide at least one mode of seal cooling (seal injection or thermal barrier cooling) to the RCP seals and (2) performing plant modifications to allow alternate cooling of the makeup pump from an existing plant water system for those plants that have a vulnerability to loss of seal cooling from conditions other than station blackout. No additional plant downtime is expected.

2.5.2 Operation

The best-estimate operating cost for the 76 operating PWRs is $1.2 million. This amount is essentially negligible in the overall total industry cost calculations.

The total industry cost is the sum of installation (implementation) and operating costs. and it is approximately $73.6 million.

2.6 Potential Safety Impact

The changes to the plant and the added operational complexity from implementation will have no adverse impact on plant safety. The RCP seal resolution is closely related to USI A-44, Station Blackout, and is compatible with the rule developed therein.

2.7 NRC Costs

2.7.1 Development

NRC costs for development of the proposed resolution are estimated at $2.88 million (best estimate) for 76 operating PWRs.

2.7.2 Implementation

NRC costs for implementation of the proposed resolution are estimated at $290,000 (best estimate) for 76 operating PWRs. This estimate assumes minimal resources for review of the licensee responses.

2.7.3 Operation

NRC inspection costs are estimated at $2.62 million (present value) for 76 PWRs over an average remaining lifetime of 25 years.

The total NRC costs are the sum of the development, implementation, and operating costs, estimated to be approximately $5.8 million.

2.8 Facility Differences

The proposed resolution is applicable to all PWR plants regardless of design or age.

2.9 Term of Requirement

The proposed rule is the final resolution of GI-23; it is not an interim measure.

ENCLOSURE A

[7590-01-P]

NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

RIN 3150-AE53

Loss of Integrity of Reactor Coolant Pump Seals

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The Nuclear Regulatory Commission (NRC) is proposing to amend its regulations to require each pressurized-water reactor (PWR) licensee to evaluate its plant for dependencies that may cause insufficient capacity and capability to ensure that the reactor core is cooled coincident with a loss of reactor coolant pump (RCP) seal cooling. A loss of RCP seal cooling could lead to a failure of the RCP seals during certain postulated off-normal events (i.e., station blackout, loss of essential service water, or loss of component cooling water). The proposed amendments are intended (1) to address regulatory concerns arising from unresolved uncertainties regarding RCP seal integrity under the postulated off-normal conditions and the possible consequences of seal failure in the unlikely event of such circumstances and (2) to enhance the existing level of protection of public health and safety against the risk associated with such seal failures when the costs of implementing enhancement measures can be justified.

DATE: Comment period expires __________, 1994. Comments received after this date will be considered if it is practical to do so, but the Commission

is able to assure consideration only for comments received on or before this date.

ADDRESSES: Mail written comments to: Secretary, U. S. Nuclear Regulatory Commission, Washington, DC 20555 (-0001), ATTN: Docketing And Service Branch.

Deliver comments to: 11555 Rockville Pike, Rockville, Maryland, between 7:45 a.m. and 4:15 p.m. Federal workdays.

Copies of comments received may be examined and copied for a fee at the NRC Public Document Room, 2120 L Street, NW. (Lower Level), Washington, DC.

FOR FURTHER INFORMATION CONTACT: Syed K. Shaukat, Division of Safety Issue Resolution, Office of Nuclear Regulatory Research, U. S. Nuclear Regulatory Commission, Washington, DC 20555, telephone: (301) 415-6592.

SUPPLEMENTARY INFORMATION:

Background

The reactor coolant pumps that circulate water through the primary coolant system of a light-water reactor contain shaft seals to limit the leakage of primary coolant along the pump shaft and into the leak-off collecting system. There are three major RCP seal designs in PWRs in the United States; Westinghouse (W), Byron Jackson (BJ), and Bingham International (BI) (formerly Bingham Willamette). Although the different pump manufacturers have variations among their designs, the general behavior of their seals is similar. The overall assembly is made up of three or four stages of face seals. High-pressure flow of cold water is either injected from an external

system or is taken from the primary coolant system, through a thermal barrier heat exchanger, into the seal assembly. Some designs incorporate both methods to cool the seals. The leakage flow (which is the actual flow through the seals) passes between the rotating seal ring (shaft mounted) and the nonrotating seal ring (mounted on the pump housing). This gap is the primary hydraulic seal of the device. Polymer secondary seals, which may include channel seals with O-rings, i.e., O-rings with backup rings, and U-cups, are used in the shaft seal assembly to accommodate relative axial motion. These secondary seals prevent leakage between the movable seal ring and the housing, but permit relative axial motion between the two. The gap between the seal rings is established by a balance of forces on the movable seal ring. Friction between the secondary seals and the seal ring tends to impede motion in either direction. The hydraulic pressure on the back side of the seal ring and the spring load tends to close the gap. During normal operation (single phase flow), the hydraulic seal is stable; that is, if the gap opens up for some reason, the pressure distribution over the seal faces changes. This decreases the overall pressure force that acts to separate the seal rings. Therefore, the gap will decrease. If the gap closes because of some perturbations, a greater pressure drop will occur at the inside diameter (ID) of the seal. This increases the force acting on the faces of the seal ring and the movable seal ring will be driven back with a resulting increase in the gap.

In the event of a station blackout, the power to seal injection pumps and to the pumps that provide cooling water to the thermal barrier heat exchanger would be lost. As a result hot water would enter the seal assembly. As this flow passes between the hydraulic seal faces, it would flash to the

relatively low pressure region at the ID of the seal assembly. The reduced fluid density would cause a higher pressure gradient near the ID of the gap and this would result in an increase in the distributed pressure, which would tend to open the seals. In the worst cases, this increase in pressure could cause the seal to become unstable and "pop open" (move to a maximum possible seal gap). A seal that has "popped open" could subject some components of the seal package to temperatures and pressures they might not be able to withstand. A fully open seal gap would allow a high flow of coolant to exit the primary coolant system.

By design, RCP seals rely on a continuous flow of water to perform their intended function. At some plants, part of this flow may be directed to the containment sump as part of the normal operations design. The water that exits the seal shaft under normal conditions is considered part of the identified leakage into containment allowable under technical specifications for each plant. The definition of seal integrity applicable to the rule takes account of the leakage flow provided for in the design. The seals differ from the other parts of the reactor coolant pressure boundary in that a certain amount of leakage is permitted through them at all times without violating the criteria in the regulations. Hence, seal integrity is seriously in question only if the leakage flow far exceeds this normal flow.

RCP seal failure and consequent excessive leakage can occur as a result of mechanical failures or from a loss of seal cooling. Causes such as excessive pump vibration, defective parts, contaminants in the flow through the seals, improper maintenance, faulty installation or assembly, secondary seal failure, or significant transient changes in the seal flow parameters contribute to mechanical failures. Seal failures have occurred in which the

loss of primary coolant to the containment was greater than the normal make-up capacity of the plant. In all of the seal failures that have occurred to date, however, emergency core cooling capability was available to replenish reactor coolant lost through seal leakage. The seal failures experienced have not resulted in a direct threat to the health and safety of the public, but this operating experience does point to the potential for seal failures resulting in a small loss-of-coolant accident (LOCA).

Seal integrity is totally lost if the seal "pops open." Estimates provided by some vendors and the NRC staff's independent assessment indicate that the maximum flow rate through seals that have "popped open" could far exceed the make-up capability available and hence could be categorized as a LOCA. (This type of seal failure has not been observed in the relevant operating experience to date.) A seal LOCA by itself may not constitute a threat to public health and safety if the emergency core cooling system (ECCS) is available to replenish reactor coolant lost through seal leakage and performs its intended functions, as has been the case in the instances of seal failure experienced to date. However, none of these incidents involved a complete loss of the component cooling water (CCW) system that provides cooling water to the seal cooling heat exchanger and, in some plants, the high pressure coolant injection pumps. The CCW system relies on the service water (SW) system for its cooling water and both rely on ac power. Therefore, on complete loss of CCW, the equivalent of a small-break LOCA could occur (if the RCP seal "popped open"), with no high-pressure coolant injection pumps available for reactor coolant system make-up. This sequence of events could lead to core melt.

Because significant uncertainties exist regarding the complex phenomena that determine seal behavior under off-normal conditions that result in prolonged loss of seal cooling, the generic studies of the issue were focused on trying to better understand and characterize seal behavior in such conditions, that is, to develop reliable estimates of seal failure probabilities and the probabilities associated with specific seal leakage rates under such severe off-normal conditions. This is the type of technical information needed to resolve the seal failure issue definitively.

The NRC solicited public comments (56 FR 16130, April 19, 1991) on its understandings, findings, and potential recommendations regarding GI-23 as outlined in Draft Regulatory Guide DG-1008, "Reactor Coolant Pump Seals." Several organizations from the industry provided their comments. These comments are addressed in NUREG/CR-5918, "Analysis of Public Comments on Generic Issue 23," In addition, the NRC has continued its interactions with industry representatives as opportunities presented themselves and has obtained some new insights into the issue. For example, the staff heard from the Combustion Engineering Owner's Group (CEOG) during meetings with the Advisory Committee on Reactor Safeguards (ACRS) in October 1993 and in a meeting with the staff in May 1994. Some information that had not been provided in the above solicitation for comments was made available, and the NRC is incorporating this information in the considerations for rulemaking. The NRC continues to seek whatever information is available to industry that may enable a better understanding of RCP seal performance under station blackout, or loss of CCW, or loss of SW conditions.

Objective

To examine the safety implications of this issue, the NRC assigned a high priority to the investigation of RCP seal failures (NUREG-0933, "A Prioritization of Generic Safety Issues," December 1983). The work on GI-23, "Reactor Coolant Pump Seal Failure," was authorized in October 1983. The NRC has pursued resolution of GI-23 while giving due consideration to information from other activities in the NRC's generic safety issue resolution program and the industry's continuing efforts to improve seal performance.

Initially, the purpose of GI-23 was to evaluate the adequacy of current licensing requirements relating to RCP seal integrity and to determine whether further NRC action is necessary to ensure that RCP seal failures do not pose an undue risk. The principal objectives initially were to determine the need to improve RCP seal reliability during normal operation and during station blackout, when seal cooling is lost. Examination and comparison in early GI-23 studies of current and past operating experience indicated that ongoing efforts by the industry to improve seal performance during normal operation were effective and RCP seal performance during normal operating conditions was steadily improving. As a result, in 1992, the NRC determined that the concerns regarding seal integrity during normal plant operation could be resolved by ensuring that information on RCP seal operating experience is made available to industry and encouraging continued efforts to maintain and further improve seal performance. Information Notice 93-61, "Excessive Reactor Coolant Leakage Following a Seal Failure in a Reactor Coolant Pump or Reactor Recirculation Pump," was issued on August 9, 1993, to all licensees toward this end. However, studies related to other generic issues, probabilistic studies performed at Indian Point and Zion, comparison studies

between the Westinghouse SNUPPS design and the British Sizewell-B plants, and recognition of actions taken by French and British plants to use steam-driven sources of seal cooling under station blackout conditions heightened the concerns regarding seal performance of domestic plants under off-normal conditions. Therefore, the focus of GI-23 was modified to concentrate on the consideration of possible effects of seal failure during a broader range of off-normal conditions, i.e., loss of essential SW and loss of CCW in addition to station blackout.

Operating Experience and Test Results

An NRC study based on RCP seal failures experienced at operating plants through 1984 showed that RCP seal failures, with leak rates equivalent to those of small-break LOCAs, had actually occurred at a frequency of about 1E-2 per reactor year, an order of magnitude greater than that estimated in WASH-1400. A subsequent limited-data survey using the Nuclear Plant Reliability Data System (NPRDS, an industry-sponsored data base) data from January 1984 to October 1987 indicated that W plants with W pumps showed some improvement in seal failure rate (about 60% reduction). B&W plants with either BJ or Bingham seals experienced a more significant improvement, about one order of magnitude; while Combustion Engineering (CE) plants with BJ pumps had about the same seal failure rate for both periods.

In a more recent study, the NRC reviewed the pump seal failure data in the NPRDS and the Sequence Coding and Search System (SCSS) for the period between January 1985 and March 1990. The failure rate for RCP seals was about 6E-3 per reactor year. None of the failures resulted in the large leakage rates seen in some of the earlier events, or appeared to show any evidence of

seals "popping open." Therefore, concerns about normal operation appear to have abated, and issuing Information Notice 93-61, and other such information notices as appropriate in the future, are expected to be sufficient NRC action.

The extensive reviews of operational events and tests on pump seals that the NRC has conducted are documented in the reports referred to in the regulatory analysis document and this Federal Register notice. The NRC is aware of a total of 75 loss-of-seal-cooling events and 38 tests that purport to simulate or study some aspects of loss-of-seal cooling. These have covered durations of loss of seal cooling from 2 minutes to 50 hours. Operational conditions have covered hot functional tests to full-power operation in PWRs. The challenges to the seals have varied because most PWRs have two modes of seal cooling, whereas others have only thermal barrier cooling. Having reviewed all the available information, the NRC finds that 49 operational events covering loss-of-seal-cooling durations from 30 minutes to 9 hours have some relevance to GI-23. Generally, however, the information available from this experience is of limited usefulness in contributing a detailed understanding of the "popping open" mode of seal failure. No "popping open" failures were observed in the operating experience considered, but regulatory concern is not completely allayed by this information because it does not provide convincing evidence that "popping open" during the off-normal events being considered can be precluded. Similarly, 36 tests were studied,of which 20 (covering loss of seal cooling durations from 30 minutes to 50 hours) were considered relevant to the "popping open" mode of seal failure. Sixteen laboratory tests and one prototypic test (the 1985 French test) did show "popping open" to occur; however, none of the tests definitively characterized

operational seals under loss of cooling conditions. Although these tests may tend to support the concern that operational seal failure under the postulated off-normal conditions is a possibility, they do not provide conclusive evidence that operational seal failure is expected under such conditions.

The NRC, Idaho National Engineering Laboratory (INEL), Atomic Energy of Canada Limited (AECL), Westinghouse, and the Westinghouse owners group (WOG) performed several studies of loss-of-seal cooling with different testing programs. W analyzed its RCP seal performance after a postulated station blackout and estimated the reactor coolant leakage through the pump seals (WCAP-10541, Rev. 2, "Reactor Coolant Pump Seal Performance Following a Loss of All ac Power," November 1986, a Westinghouse Proprietary Class 2 report, not publicly available). Based on studies done by the NRC, INEL (NUREG/CR-4077, "Reactor Coolant Pump Shaft Seal Behavior During Station Blackout," April 1985), AECL (NUREG/CR-4821, "Reactor Coolant Pump Shaft Seal Stability During Station Blackout," May 1987), and the WOG/AECL test report (SP-S-241, Proprietary report (1986) not publicly available), it was concluded that W standard O-rings might experience failures at gaps under temperature and pressure conditions expected during loss-of-seal cooling. W then developed a modified O-ring (of a different material) for use as a replacement for the present O-rings. The NRC understands that WOG may not recommend use of the modified W O-ring should GI-23 resolution recommend solutions that do not require such a change to be made. Energy Technology Engineering Center (ETEC) was contracted by the NRC to independently estimate leak rates from W seals under loss of all seal cooling conditions. ETEC results (NUREG/CR-4294, "Leak Rate Analysis of the Westinghouse Reactor Coolant Pump," July 1985) generally agree with W analysis, but both analyses were predicated on O-ring and channel

seal integrity. Local secondary seal leakage could invalidate the analysis based on primary leakage alone in various ways. For this reason, and for an independent review of W work, the NRC requested AECL to review the WOG report WCAP-10541, Rev. 2 (a Westinghouse Proprietary Class 2 report, not publicly available). This review (NUREG/CR-4906P, a report containing Westinghouse proprietary information not publicly available) raised the concern that the second stage seal may "pop open" under conditions that involve prolonged loss of seal cooling. This seal failure mechanism of seal faces "popping open," was not considered in any analyses previous to the AECL work.

There were several test programs carried out by the industry to validate seal performance, including full-scale 7-inch seal tests (in France, May 1985). The results from these tests, which were developed to meet certain prescribed pressure, temperature, and other conditions with loss of seal cooling, provide some additional bases for making judgments regarding seal performance under the off-normal conditions of interest. However, the NRC believes that this limited number of seal tests has not adequately represented all the conditions that can occur during loss-of-seal-cooling events and hence does not sufficiently address the concerns relating to RCP seal failure. More detailed discussions of these studies are presented in draft NUREG-1483, "Regulatory Analysis Supporting Proposed Rule on Reactor Coolant Pump Seals," and in NUREG/CR-4948, "Technical Findings Related to Generic Issue 23: Reactor Coolant Pump Seal Failure," (March 1989).

Evaluation of Significance

To assist in assessing the possible safety significance of this issue in terms of core damage frequency, AECL was retained as a subcontractor to

Scientech, Inc., NRC's contractor to provide the information on best-estimate failure models for the W RCP seal during station blackout. This information is documented in Appendix A to NUREG/CR-5167, "Cost/Benefit Analysis for Generic Issue 23: Reactor Coolant Pump Seal Failure" (April 1991). This appendix provides information about the probability of core-uncovery due to seal failure models with W standard (unqualified) O-rings, W modified (qualified) O-rings, and hypothetical not yet developed (improved) O-rings. This appendix also indicates that the probability of core uncovery is a time-dependent function, that also depends whether plant cooldown is employed or not.

The relationship between loss of seal cooling and seal failure is not a precise engineering determination, especially because no hard data exist to correlate seal failure in the "popping open" mode with the passage of time after the loss of seal cooling. Therefore, estimates of the associated probabilities are based on expert judgment considering that (1) seals are designed for continuous cooling, (2) hydraulic instability may result in seal faces "popping open," (3) frictional forces of secondary seals (O-ring, channel seals, and U-cups) may drag seal faces open, and (4) the failure of uncooled secondary seals may lead to additional leak paths. Such considerations were used in making the probabilistic assessments in some studies, for example, NUREG-1150, "Severe Accident risks: An Assessment for Five U.S. Nuclear Power Plants" (December 1990). Detailed information is provided in the regulatory analysis document and the reference documents listed therein. Insights gained from the overall study of this issue (including preliminary evaluation of individual plant examination results) indicate that the risk contribution from a loss of seal integrity could be on

the order of 20% of the total risk of core damage for some PWRs after taking into account the time dependent magnitude and likelihood of seal leakage using event-tree methodology and expert judgment.

The seal failure event trees become quite complex when considering failure of individual stages as a function of time. Any decision based on probabilistic risk assessment should be made cautiously because, to be reliable, the event trees must be interpreted correctly. For example, the failure event tree developed by W has one success path (which has been judged to be the most likely path) leading to leak rates of 21 gpm per pump and 15 other possible failure paths with leak rates from 47 to 480 gpm per pump. The longer the loss of seal cooling persists, the greater is the likelihood of seal failure. Expert judgment indicates that leakage from a seal failure caused by loss of cooling might not be corrected with restoration of seal cooling if the cooling is interrupted for a prolonged period. There is some indication from operating experience that seal damage could even be caused by such restoration of cooling, although no evidence has been reported that "popping open" is an expected mode of failure under such circumstances.

On the basis of its generic analysis of this issue, the NRC estimates that the core damage frequency from RCP seal failure before the implementation of the rule is about 2E-5, and about 6E-6 after the implementation of the rule (see draft NUREG-1483, "Regulatory Analysis Supporting Proposed Rule on Reactor Coolant Pump Seals"). These estimates are based on a summation of contributions from postulated seal failure during station blackout, loss of CCW, and loss of SW scenarios. Draft NUREG-1483 documents the NRC staff's studies of operational events and tests related to seal failures. The NRC

found the information from operational events to be of limited use to assess the safety concerns for the following reasons:

(1) Data about the events are sketchy, partly because most licensees do not classify the RCP seals as safety-related systems that must meet event reporting regulatory requirements.

(2) The data gathering from events do not appear to have considered the detailed fault tree analysis that represents the basis for the NRC safety concerns regarding the "popping open" mode of failure. A sound assessment of operational experience requires that post-event analyses be based on a seal model that is technically justified. Such a model has been developed by Westinghouse for their seals and has been substantially endorsed by the NRC, although the agreement does not extend to the probabilities associated with the "popping open" mode of failure. If this key feature of the failure model is not incorporated into a post-event analysis of a seal failure, the NRC finds it difficult to establish the direct relevance of that data.

(3) When the NRC evaluated all the available information, only a very few events (or tests) were found to be sufficiently characteristic of the concerns that arise from an extended loss of seal cooling.

Accordingly, the NRC's understanding of RCP seal behavior under conditions such as station blackout, loss of CCW, or loss of SW derives largely from interpretations (based on expert judgment) of seal test results

and generic analyses. Conservative interpretation of the information available to the NRC indicates that, if a loss of all seal cooling occurs, "popping open" of a seal becomes a potential concern within a short time. The NRC does not have experimental or analytical information to reliably predict when and under what circumstances a seal totally deprived of cooling may "pop open" or fail by any other mechanism. On the basis of a simplified thermal analysis and a review of vendor recommendations, the NRC determined that interruption of cooling for 10 minutes or less is not likely to create the high-temperature saturation conditions in the seal assembly that could cause the seals to "pop open." The increased temperatures would be expected, however, to cause seal leakage to increase considerably even if the seal does not "pop open"; and even if the loss of seal cooling is temporary and seal cooling is restored, damage could be considerable and irreversible such that restoration of seal cooling might not decrease leakage. Under some circumstances, restoring seal cooling may even cause seal damage.

Generic studies of the seal failure issue have provided improved qualitative understanding of seal behavior under off-normal conditions, but the information from these studies has not enabled development of reliable quantitative estimates of the probability of seal failure, or the probabilities associated with specific seal leakage rates, that are needed to resolve the seal failure issue definitively. The generic studies do not, therefore, provide a sufficient basis for direct imposition of new generic requirements for particular plant modifications. Regulatory concern persists in view of the possible severe consequences of seal failure during off-normal events that could also involve the loss of ECCS function.

The NRC has concluded, therefore, that the seal failure concern should be addressed further by licensees on a plant-specific basis in a manner consistent with the Commissions's Severe Accident Policy, i.e., licensees should evaluate their individual plants to identify dependencies that result in a loss of seal cooling and could lead to seal failure under station blackout, loss of CCW, or loss of SW conditions and either (1) assure that reactor core and associated coolant systems provide sufficient capacity and capability to ensure that the core is cooled under such conditions or (2) demonstrate that the risk associated with RCP seal failures during these postulated off-normal events is sufficiently low that further risk reduction measures to address their possible consequences are not justified.

Relationship to Existing Requirements and Generic Issues

The promulgation of this proposed rule will have implications for one existing regulatory requirement (10 CFR 50.63, the Station Blackout Rule) and several generic issues, some of which are currently being processed within the NRC's safety issue resolution program. Although a brief description of these implications is provided below, the regulatory analysis in draft NUREG-1483 contains a more complete treatment of the impacts.

The Station Blackout Rule

During the resolution of unresolved safety issue (USI) A-44, "Station blackout," and in the supplementary information section of the final rule that added 10 CFR 50.63 (53 FR 23218, June 21, 1988), it was explicitly recognized that the potential leakage through RCP seals would affect the ability of plants to cope with a blackout. The NRC staff determined that, in the context

of performing the station blackout coping analyses required by 10 CFR 50.63 with the GI-23 resolution still pending, an RCP seal leakage rate of 25 gallons per minute (gpm) per RCP for PWRs, and 18 gpm per recirculation pump for boiling water reactors (BWRs), could be reasonably assumed for analysis purposes, because those values (which are the expected seal leakage rates with no "pop open" seal failures) were considered the most likely value for a seal leakage rate under the postulated off-normal conditions. The staff reemphasized, in Generic Letter 91-07, "GI-23 and Its Possible Effect on Station Blackout" (May 2, 1991), the possible implications of the pending GI-23 resolution with respect to the continued validity of coping analyses that rely on an assumed 25/18 gpm seal leakage rate. Those assumed values are technically justifiable and would remain valid if it is demonstrated on the basis of assessments performed and/or actions taken under this rule that no seal failure will occur (i.e., acceptable test data is made available indicating that seals will maintain integrity without cooling, or that seal cooling is ensured by an alternate, dedicated seal cooling system). However, as noted above and from the information developed in the GI-23 effort to date, the NRC has been unable to determine with confidence the probability or magnitude of seal leakage to be expected under such conditions. Conservative interpretation of the results of research sponsored by NRC and of industry work reviewed by NRC staff, as described above, with appropriate allowance for the significant uncertainties involved, leads the NRC staff to conclude that the possibility of RCP seals "popping open" or secondary seals failing during a station blackout and causing a leak of more than 25 gpm cannot be precluded if cooling to the seals is lost for periods longer than about 10 minutes.

Ultimately, questions regarding the need to revise station blackout coping analyses will be determined based on the method chosen by a licensee to demonstrate compliance with this proposed rule. If a licensee chooses to present test data to demonstrate compliance with this rule, the seal leakage rates must be reflected consistently in the licensee's station blackout coping analysis as well (or be appropriately bounded by assumed leakage values). If a licensee chooses to provide alternate seal cooling and has assumed 25 gpm seal leak rate in the station blackout coping analysis the adequacy and timeliness of the alternate seal cooling system must be demonstrated. In further regard to the alternate seal cooling option, the proposed rule acknowledges that an alternate ac power source that some plants may be using to comply with 10 CFR 50.63 could provide the needed electrical power. Such an arrangement would be satisfactory as long as the alternate ac power source ensures adequacy and timeliness of seal cooling as demonstrated by a specific analysis and in a manner consistent with the coping analysis under 10 CFR 50.63. The NRC requests public comment on cost-effective means by which compliance with 10 CFR 50.63 can be assured while implementing the resolution of GI-23.

Applicability to BWRs

The amount of research and study that has been performed for PWRs has not been accomplished for BWRs for recirculation pump seals because the safety significance of such work was not considered to be at a high enough level to merit the allocation of significant resources. However, recent information from the industry in response to NRC's request for public comment has caused the staff to reconsider this position, resulting in a view that additional

staff action may be appropriate. This question has been addressed by the NRC's contractor Brookhaven National Laboratory (BNL) in BNL Report A-3806-4-93, Rev. 1, "Evaluation of Recirculation Pump Seal Failure in BWRs" (June 1993) which indicates that further study in this area is justified. The NRC staff intends to initiate an investigation into the safety significance of the BWR concerns while proceeding with resolution of the more significant safety concerns on PWRs through the proposed rule.

GI-65, Component Cooling Water System Failure

GI-65 has been subsumed into GI-23 because adoption of the proposed rule would virtually eliminate the risk of an RCP seal LOCA coincident with a CCW failure. CCW is generally required for cooling lubricating oil, bearings, and environmental systems associated with makeup and injection pumps and, therefore, may be implicated in a wide range of common cause failures. The NRC has judged that a sufficient basis would exist to resolve GI-65 if safe shutdown is assured in case of RCP seal cooling failure.

Three Mile Island (TMI) Actions II.K.2.16 & II.K.3.25

Following the TMI accident of 1979, the NRC imposed additional requirements on licensees to improve the level of safety in specific areas. NUREG-0737, "Clarification of TMI Action Plan Requirements" (November 1980) described these TMI actions that required licensees to consider the consequences of loss-of-offsite-power on RCP seals and take appropriate actions. No additional actions are expected to result from issuance of the proposed rule.

GI-130, Essential Service Water System (ESW) System Failure at Multiplant Sites

The ESW system typically supports all the front-line safety systems required for safe shutdown. Generic Issue GI-130 was resolved by requesting licensees at 7 sites (14 plant units) to consider improvements to their ESW system reliability and installation of a dedicated RCP seal cooling system. The backfitting of improvements considered under GI-130 were subsumed by the expected resolution of GI-23 (see Generic Letter 91-13, "Request for Information Related to the Resolution of GI-130," September 19, 1991).

GI-153, Loss of Essential Service Water in LWRs

Generic issue GI-153 has been resolved by the NRC by taking into account the expected improvements in ESW reliability through actions proposed in Generic Letter 89-13, "Service Water System Problems Affecting Safety-Related Equipment," and by actions arising from the rulemaking on GI-23.

GI-106, Piping and the Use of Highly Combustible Gases in Vital Areas

In resolving this generic issue the NRC concluded that hydrogen explosions in some vital areas could cause RCP seal LOCA (NUREG-1364, "Regulatory Analysis for the Resolution of Generic Safety Issue 106: Piping and the Use of Highly Combustible Gases in Vital Areas" June 1993). The proposed rule for GI-23 is not expected to decrease the risk from hydrogen explosion. However, licensees responding to the Individual Plant Examination for External Events (IPEEE) programs under the Generic Letter 88-20, Supplement 4, "Individual Plant Examination of External Events for Severe Accident Vulnerabilities" (June 28, 1991) are expected to provide information

that will enable the identification of any vulnerability from hydrogen explosion in their fire analyses.

Individual Plant Examination (IPE) and Individual Plant Examination for External Events Programs

Under these programs, plants will be searching for dependencies in their facilities with regard to the consequences of severe accidents. The guidance provided for these programs mentions RCP seal LOCA as a special event similar to a station blackout or anticipated transient without scram (ATWS). IPE reports submitted and evaluated by the staff to date appear to confirm that RCP seal LOCA is one of the prominent contributors to the residual risk in the operating plants, i.e., the associated risk is a significant part of the remaining risk in plants in which adequate protection is already reasonably assured.

Implementation of Rule to Resolve GI-23

The Commission expects that licensees and applicants will take the following actions in response to the proposed rule, and hence resolve GI-23. Terms used in the proposed rule are meant to be consistent with the station blackout rule, 10 CFR 50.63.

Perform an Evaluation

Licensees would be required to perform an evaluation, if one has not already been performed under a program such as the IPE, to determine whether factors exist at their plants that create common cause failure mechanisms (dependencies) whereby an RCP seal LOCA can occur at the same time that

reactor core cooling capability may be disabled. Coincident timing means that time during the progress of events associated with a postulated event when the seal LOCA and lack of core cooling capability occur together. The starting and ending points for the failures in each of the systems may or may not coincide. For example, if a licensee shows that either seal cooling or core cooling is ensured for the duration of the station blackout analysis under 10 CFR 50.63, no further action would be required by the proposed rule to address this postulated event. The response of the RCP seals to the loss of cooling should consider the "popping open" mode of failure as one of the possibilities. This evaluation need not be submitted to the NRC for review and approval, but should be held onsite and be available for NRC inspection. Currently, this proposed rule does not include regulatory controls on the procedures or hardware that a licensee may choose to rely upon to comply with § 50.68 (c)(2)(i) of the proposed rule. Hence, a licensee could make changes in these areas without giving NRC any notice of them.

Actions Pursuant to Dependencies Identified

If dependencies are identified, licensees may either take action to reduce them or show that the risk of core damage is so low that any action to reduce them is not justified. The actions to reduce dependencies can range over a number of possibilities, including providing alternative seal cooling or showing that sufficient and timely core cooling capability will be restored. The alternate seal cooling system need not be classified as safety-related, may be powered from any source available in the station blackout scenario, and need not satisfy the single-failure criterion. These relaxed criteria are appropriate because the requirements constitute safety

enhancement beyond the "adequate protection" standard of the regulations. However, the seal cooling system must have sufficient capacity and provide the cooling rapidly enough to meet the objective of maintaining seal integrity. A specific analysis is required to show that this objective is met. This analysis may be part of the above evaluation. Various means of ensuring sufficient core cooling in the event of seal failure (e.g., enhancing the capacity and capability of existing core cooling systems) could be considered by licensees and may be found acceptable. An assessment supporting the adequacy of the actions taken should be included in the evaluation. An assessment that specifically addresses dependencies that could lead to loss of seal cooling and seal failure, appropriately models seal failure mechanisms, and clearly documents and supports assumptions would be acceptable for demonstrating compliance with this proposed rule. Specifically, licensees may apply the methodology (in particular, the seal modeling) employed in the NUREG-1150 studies, if it is properly applied.[1]

Alternatively, on the basis of an appropriate analysis a licensee may conclude that the likelihood of core damage resulting from loss of all seal cooling by some failure paths identified is so small that no action is warranted. In performing such analyses and making such judgments, decision criteria similar to those used in the IPE for determining whether corrective

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[1] The staff is currently assessing the significance of an error in NUREG-1150 in the application of the model regarding timing of seal failure on loss of cooling.

actions were warranted would be appropriate and acceptable to the staff. As a practical bounding case in this regard, the NRC would expect licensees to consider appropriate corrective or mitigative actions and to address identified dependencies that could lead to seal failure with a distribution of resulting core damage frequencies estimated to have a mean value in the range E-5 to E-4. The NRC expects that implementation of corrective or mitigative actions would be justified if the mean value is estimated to be greater than E-4. Such decision-making criteria are consistent with guidelines currently used by the NRC for regulatory analyses.

The NRC recognizes that the risk associated with seal failure may vary widely among the existing plants, and that plant-specific and vendor-specific factors have an important bearing on seal behavior and on the actions that may be relied on for coping with a loss of seal integrity. The NRC has performed a generic study, including estimating costs and benefits as documented in the regulatory analysis, to conclude that the risk reduction requirements of this proposed rule are justified. However, the NRC recognizes that such a generic analysis may not apply accurately to every reactor licensee given that there are significant differences in plant design as well as significant uncertainties in the analysis.

Accordingly, the proposed rule provides licensees with a great deal of flexibility for achieving compliance by assuring RCP seal integrity, or reducing dependencies (for example, by providing high pressure safety injection pump cooling using a non-safety grade system), or showing that the risk is sufficiently low. Flexibility also exists in determining the evaluation methods and selecting appropriate actions for addressing the seal failure concern in their facilities from the options provided in the proposed

rule. This is a performance-oriented approach to rulemaking with risk being one of the criteria on which compliance will be determined. The approach is similar to that taken by licensees under the IPE program to address severe accident vulnerabilities at their facilities. Proper application of the IPE assessment approach could be an acceptable means of satisfying the provisions of this rule. An acceptable means for demonstrating compliance with the proposed rule is a demonstration by a suitable analysis that the risk associated with the postulated off-normal conditions is sufficiently low that further actions to improve protection of public health and safety against the possible consequences are not justified in view of the cost. A sufficiently low level of risk would be achieved if the mean value of the distribution of core damage frequencies from seal failure possibilities with assurance of containment integrity has a mean value less than E-5. The NRC would like to receive public comment on this approach to rulemaking and the criterion for resolving the generic issue.

Reliance on RCP Test Data

The test option comes into play if a licensee wishes to rely on RCP seal characteristics that purport to prevent or preclude seal failure under the postulated events. The NRC does not propose the conduct of any specific test under this provision, but believes that licensees should be given the opportunity to develop a cost-effective test to address the concern involved. If the licensee's evaluation to show that a plant complies with this rule relies on claims that either the seal will not "pop open" or that a "popped open" seal will leak at a much lower rate than the maximum possible (for Westinghouse seals this is 480 gallons per minute), appropriate test data must be provided along with an acceptable interpretation of that data. The NRC

notes that such acceptable interpretation has not been provided in information submitted to the NRC to date during the interaction with industry on GI-23. Accordingly, licensees are cautioned that simply relying on (or resubmitting) information that has already been provided to the NRC will not be sufficient for the NRC staff to reach a finding of compliance with the rule, unless a current engineering evaluation of that information is provided that includes additional technical justification for its acceptability in this context and acceptably addresses previous points of disagreement.

Experiments that test individual components separately have not provided sufficiently reliable data in the past. The test option included in this rule is intended to ensure a reliable basis for assessing the performance of the seals under loss-of-seal-cooling conditions. Such testing must adequately model (or duplicate) the complex thermal and fluidics factors that prevail when cooling is lost. The results should enable the NRC to estimate the likelihood of "popping open," as well as the timing and magnitude of leakage if the seal "pops open," if assurance that the core is cooled depends on this factor. The NRC has identified the following factors that appear to be important to a representative test:

(1) Modeling of the multiple stages of the seal assembly, including the housing, the shaft, and the leakoff control piping and valves, under liquid and two-phase flow conditions.

(2) Appropriate consideration of the seal balance ratio (ratio between closing and opening forces), spring forces, shaft movement, wear on seal faces, and secondary seals (O-rings, U-cups, etc.).

(3) Temperature, pressure, and flow conditions (with proper records thereof) over the wide range of possibilities characterizing loss of seal cooling, with the duration of the test accounting for the anticipated length of a station blackout.

The modeling approach employed in NUREG-1150 (subject to correction of the error identified above) appears to adequately address or reflect all these factors and to be acceptable for use in developing a seal test program. Thus, on the basis of information currently available to the NRC, a test program that considers the failure modes in the event trees developed for the NUREG-1150 probabilistic analysis would be considered to be adequate.

The NRC is interested in receiving suggestions regarding the parameters of a test program that would provide sufficiently reliable information in a cost-effective manner leading to a regulatory position that incorporates, as an option, testing that is based on definitive technical evidence. A test program jointly conducted by PWR owners, with appropriate NRC participation, appears to have considerable merit to implement a technically adequate test option that is cost effective.

The Use of Probabilistic Methods

The NRC has always recognized the benefits of using probabilistic methods. Accordingly, this provision in the proposed rule affords licensees with discretion to utilize probabilistic methods in the evaluation of dependencies. If licensees choose to use probabilistic methods, the NRC expects licensees to ensure consistency and coherence in applying such methods

under other commitments (such as the IPE and IPEEE) or requirements (such as under 10 CFR 52.47(a)(v)).

The Use of Alternate ac Under the Station Blackout Rule

The purpose of this provision (in § 50.68 (c)(5) of this proposed rule) is to ensure that licensees have the flexibility to use plant modifications undertaken under 10 CFR 50.63 to resolve GI-23. The specific analysis that demonstrates the adequacy of the alternate ac power source should be included in the evaluation discussed above. Also, as discussed above under the "The Station Blackout Rule," NRC would like to receive public comments on the coordination of actions to comply with this proposed rule and 10 CFR 50.63.

The NRC is also interested in receiving comments on the procedures and criteria to be applied to demonstrate the risk associated with low probability events such as RCP seal failure during postulated events. The NRC would also like to receive comments on the cost estimates that form the basis for the justification for the proposed rule as described in the regulatory analysis document and the references therein.

The NRC notes that, based on the available evidence, no undue risk to the public exists without the promulgation of the rule for RCP seals. Actions taken under the proposed rule could enhance safety by preventing accidents and thereby reduce the likelihood of a core damage accident being caused by a LOCA induced by RCP seal failure. Further enhancement in reducing the overall risk may also be achievable by additional improvements in severe accident management, given the assumption that core damage occurs, whether from seal failure or other causes (such as station blackout or other LOCA sequences). Therefore, the proposed rule should be viewed in the same accident prevention

context as the ATWS rule (10 CFR 50.62) and the station blackout rule (10 CFR 50.63) in that it recognizes, as the other two rules recognize, multiple failure possibilities resulting from common cause effects that should be addressed. This concern has been recognized in the introduction to Appendix A to 10 CFR Part 50.

Questions for the Public

The discussion above provided a comprehensive overview of the bases for the scope and content of the proposed rule and identified a number of policy and technical issues. The Commission requests comments on the specific questions below to aid in the resolution of these issues.

1. What evidence exists that each type of seal will not "pop open" or otherwise limit leakage under the postulated conditions (i.e., station blackout, loss of CCW, loss of SW)?

2. If this proposed rule becomes final in substantially the same form, what criteria should apply to coordinate the actions under this rule and under 10 CFR 50.63?

3. What alternatives exist to the consideration of risk as a criterion for establishing compliance given the highly diverse designs of the currently operating PWR plants and the systems that support proper RCP seal functioning?

4. What regulatory controls should be placed on actions (e.g., installation of an alternate RCP seal cooling system) that a licensee chooses to rely upon to show compliance with § 50.68 (c)(2)(i) of the proposed rule?

4.1 Should the proposed rule require the licensee to include a description in the Final safety Analysis report (FSAR) of any procedures and/or hardware relied upon to demonstrate compliance with § 50.68 (c)(2)(i), so that licensee-initiated changes to the description of the procedures and/or hardware are controlled by 10 CFR 50.59?

4.2 Should the proposed rule require the licensee to have any changes to procedures and/or hardware that are relied upon to demonstrate compliance with § 50.68 (c)(2)(i) reviewed by a management review committee, in order to determine whether the effectiveness of the procedures or hardware upon risk has been reduced (similar to 10 CFR 50.54(q))?

4.3 Once a licensee has determined the need for and implemented procedures and/or hardware to demonstrate compliance with § 50.68 (c)(2)(i), should the licensee be free to change its determination, and/or to change the procedures and/or hardware without notice to the NRC (either prior to the change or after the change)?

5. Is additional guidance needed in the statement of considerations with respect to either risk assessment regarding RCP seal failures during postulated events or the assessment of RCP seal leakage rate to support a licensee's evaluation?

Availability of Documents

Copies of NRC documents cited here, including generic issue (GI) notices, are available for inspection and copying for a fee at the NRC Public Document Room (PDR) at 2120 L street NW. (Lower Level), Washington, DC. BNL Report No. BNL-A-3806-4-93, Revision 1, is also available at the PDR. Telephone (202) 634-3273; fax (202) 634-3343.

Copies of Wash-1400 and NUREGs 0933, CR-4077, CR-4400, CR-4294, CR-4821, CR-4948, CR-5167, and CR-5918 may be purchased from the Superintendent of Documents, U.S. Government Printing Office Mail Stop SSOP, Washington, DC 20402-9328 (telephone (202)512-2249 or (202)512-2171)); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161.

Requests for single copies of draft NRC documents should be made in writing to the U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Distribution and Mail Services Section. Requests for drafts will be filled as long as supplies last. Copies of drafts are also available for inspection or copying for a fee from the NRC Public Document Room (PDR) at 2120 L Street NW. (Lower Level), Washington, DC; telephone (202) 634-3273; fax (202) 634-3343.

Criminal Penalties

For purposes of section 223 of the Atomic Energy Act (AEA), the Commission proposes to issue the proposed rule under one or more of sections 161b, 161i, or 161o of the AEA. Willful violations of the rule would be subject to criminal enforcement.

Finding of No Significant Environmental Impact: Availability

The Commission has determined under the National Environmental Policy Act of 1969, as amended, and the Commission's regulations in Subpart A of 10 CFR Part 51, that this rule, if adopted, would be a Federal action improving the quality of the human environment, and does not degrade the environment in any way. Therefore, the Commission concludes that there will be no significant impact on the environment from this proposed rule. This discussion constitutes the environmental assessment and finding of no significant impact for this proposed rule; a separate assessment has not been prepared.

Paperwork Reduction Act Statement

This proposed rule amends information collection requirements that are subject to the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 et seq.). This rule has been submitted to the Office of Management and Budget (OMB) for review and approval of the information collection requirements.

The public reporting burden for this collection of information is estimated to average 100 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send

comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to the Information and Records Management Branch, Mail Stop T-6F33, U. S. Nuclear Regulatory Commission, Washington, DC 20555, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202, (3150-0011), Office of Management and Budget, Washington, DC 20503.

Regulatory Analysis

The Commission has prepared a draft regulatory analysis that examines the costs and benefits of the alternatives considered. This analysis is presented in draft NUREG-1483, "Regulatory Analysis Supporting Proposed Rule on Reactor Coolant Pump Seals," and is available for inspection in the NRC Public Document Room, 2120 L Street, NW. (Lower Level), Washington, DC. Single copies of the analysis may be obtained from Syed K. Shaukat, Division of Safety Issue Resolution, Office of Nuclear Regulatory Research, U. S. Nuclear Regulatory Commission, Washington, DC 20555, Telephone: (301) 415-6592.

Regulatory Flexibility Certification

In accordance with the Regulatory Flexibility Act of 1980 (5 U.S.C. 605(b)), the Commission certifies that, if promulgated, this rule will not have a significant economic impact on a substantial number of small entities. This proposed rule affects only the licensing and operation of nuclear power plants. The companies that own these plants do not fall within the scope of the definition of "small entities" set forth in the Regulatory Flexibility Act

or the Small Business Size Standards set out in regulations issued by the Small Business Administration at 13 CFR Part 121.

Backfit Analysis

As required by 10 CFR 50.109, the Commission has completed a backfit analysis for the proposed rule. The Commission has determined, based on this analysis, that the actions taken to comply with the requirements of this proposed rule will provide a substantial increase in protection to public health and safety at a justifiable cost. The backfit analysis on which this determination is based is included in Appendix C to draft NUREG-1483, "Regulatory Analysis Supporting Proposed Rule on Reactor Coolant Pump Seals."

List of Subjects In 10 CFR Part 50

Antitrust, Classified information, Criminal penalties, Fire protection, Intergovernmental relations, Nuclear power plants and reactors, Radiation protection, Reactor siting criteria, Reporting and recordkeeping requirements.

For the reasons set out in the preamble and under the authority of the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended and 5 U.S.C. 553, the NRC is proposing to adopt the following amendment to 10 CFR Part 50.

PART 50 - DOMESTIC LICENSING OF PRODUCTION AND UTILIZATION FACILITIES

1. The authority citation for Part 50 continues to read as follows:

AUTHORITY: Secs. 102, 103, 104, 105, 161, 182, 183, 186, 189, 68 Stat. 936, 937, 938, 948, 953, 954, 955, 956, as amended, sec. 234, 83 Stat. 1244, as amended (42 U.S.C. 2132, 2133, 2134, 2135, 2201, 2232, 2233, 2236, 2239, 2282); secs. 201, as amended, 202, 206, 88 Stat. 1242, as amended, 1244, 1246 (42 U.S.C. 5841, 5842, 5846).

Section 50.7 also issued under Pub. L. 95-601, sec. 10, 92 Stat. 2951 (42 U.S.C. 5851). Section 50.10 also issued under secs. 101, 185, 68 Stat. 955, as amended (42 U.S.C. 2131, 2235); sec. 102, Pub. L. 91-190, 83 Stat. 853 (42 U.S.C. 4332). Sections 50.13, 50.54(dd), and 50.103 also issued under sec. 108, 68 Stat. 939, as amended (42 U.S.C. 2138). Sections 50.23. 50.35, 50.55, and 50.56 also issued under sec. 185, 68 Stat. 955 (42 U.S.C. 2235). Sections 50.33a, 50.55a and Appendix Q also issued under sec. 102, Pub. L. 91-190, 83 Stat. 853 (42 U.S.C. 4332). Sections 50.34 and 50.54 also issued under sec. 204, 88 Stat. 1245 (42 U.S.C. 5844). Sections 50.58, 50.91, and 50.92 also issued under Pub. L. 97-415, 96 Stat. 2073 (42 U.S.C. 2239). Section 50.78 also issued under sec. 122, 68 Stat. 939 (42 U.S.C. 2152). Sections 50.80-50.81 also issued under sec. 184, 68 Stat. 954, as amended (42 U.S.C. 2234). Appendix F also issued under sec. 187, 68 Stat. 955 (42 U.S.C. 2237).

2. § 50.8 Paragraph (b) is revised to read as follows: OMB approval.

* * * * *

(b) The approved information collection requirements contained in this part appear in §§ 50.30, 50.33, 50.33a, 50.34, 50.34a, 50.35, 50.36, 50.36a, 50.48, 50.49, 50.54, 50.55, 50.55a, 50.59, 50.60, 50.61, 50.63, 50.64, 50.65, 50.68, 50.71, 50.72, 50.73, 50.75, 50.80, 50.82, 50.90, 50.91, 50.120, and Appendices A, B, E, G, H, I, J, K, M, N, O, Q, and R.

3. A new § 50.68 is added to read as follows:

§ 50.68 Loss of integrity of reactor coolant pump seals.

(a) Applicability. The requirements of this section apply to all applicants for and holders of construction permits and operating licenses for commercial pressurized-water nuclear power plants.

(b) Definitions. "*Dependencies*" means factors that create common-cause failure mechanisms.

"*Postulated events*" mean station blackout, as defined in 10 CFR 50.2, for the specified duration as defined in 10 CFR 50.63; loss of component cooling water; and loss of essential service water.

(c) Requirements. (1) Each licensee and applicant subject to this section shall evaluate its plant to determine if there are dependencies that may cause insufficient capacity and capability to ensure that the reactor core is cooled (such as by loss of

emergency core cooling system function), coincident with loss of reactor coolant pump seal cooling that could lead to failure of those seals during postulated events.

(2) If the evaluation in paragraph (c)(1) of this section identifies such dependencies, the licensee and applicant must either:

(i) Demonstrate that it has taken action to reduce the dependency such that the reactor core and associated coolant systems will provide sufficient capacity and capability to ensure that the core is cooled; or

(ii) Demonstrate that the risk associated with reactor coolant pump seal failures during postulated events is sufficiently low such that further risk reduction is not justified.

(3) If specific seal leakage rates are relied upon in either the evaluations performed pursuant to paragraph (c)(1) of this section or the demonstration performed pursuant to paragraph (c)(2)(i) of this section, the evaluations and demonstrations must include or incorporate by reference test data on seal performance characteristics that are sufficient to support the assumed failure probabilities or leakage rates. The tests must adequately account for the complex

mechanical and fluidics conditions that the seals may experience during postulated events with loss of all seal cooling.

(4) Probabilistic methods may be utilized in the evaluations performed pursuant to paragraph (c)(1) of this section and the demonstration performed pursuant to paragraph (c)(2)(i) of this section.

(5) If a licensee chooses to demonstrate under paragraph (c)(2)(i) of this section that it has reduced a dependency by installing an alternate seal cooling system powered by an alternate ac power source (as defined in § 50.2), the demonstration must show that the alternate ac power source has sufficient capability to ensure adequate and timely seal cooling, such that seal integrity is maintained during postulated events.

(d) Implementation. Current licensees must complete the analyses and demonstrations required by this section and implement any hardware and procedural changes necessary for compliance with the requirements of this section, within two refueling outages after [Insert Date of Final Rule Publication].

Dated at Rockville, Maryland, this ______ day of ____________, 199 .

For the Nuclear Regulatory Commission.

Samuel J. Chilk,
Secretary of the Commission.

ENCLOSURE B

NUREG-1483

REGULATORY ANALYSIS SUPPORTING PROPOSED RULE ON REACTOR COOLANT PUMP SEALS

Draft Report for Comment

Manuscript Completed: June 1994
Date Published:

S. K. Shaukat

Division of Safety Issue Resolution
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ABSTRACT

This report presents the regulatory and backfit analyses for Generic Issue 23 (GI-23), "Reactor Coolant Pump Seal Failure." The cost/benefit analysis is based on a proposed resolution that includes provisions for alternate seal cooling during off-normal plant conditions involving loss of all seal cooling (such as station blackout or loss of component cooling water or loss of service water). Other means of obtaining a cost-effective enhancement of safety (such as by removing common cause failures that might challenge core coolability) are expected to be enveloped by this analysis. Research, technical data, and other analyses supporting the resolution of this issue are described and summarized.

Background:

The staff assigned a high priority to the investigation of RCP seal failures in November 1982 and identified the generic issue for resolution as GI-23 in October 1983. These actions, which were taken on the basis of operational data at that time, indicated a relatively high likelihood of seal failure if the seals were not properly operated and maintained. The main concern regarding seal failure was that leakage of reactor coolant could occur at levels higher than the capacity of the make-up system, hence causing a loss-of-coolant accident (LOCA). The staff's studies have shown that a loss of seal cooling is the most likely mechanism by which an otherwise properly maintained seal might lose integrity by "popping open". The staff has found that the causes for loss of seal cooling occurred as important components in several other generic issues, i.e., USI A-44, "Station Blackout"; GI-65, "Component Cooling Water System Failure"; and GI-153, "Loss of Essential Service Water in LWRs."

Ever since this issue emerged, the staff has interacted extensively with nuclear industry representatives to keep them apprised of our concerns. The attention paid to RCP seals, by both NRC and the industry, has resulted in improved seal performance during normal operations. Operational data shows fewer seal failures in recent years. Thus, this proposed rulemaking does not include actions on normal operating conditions. GI-23 concentrates on the possible effects of seal failure during a range of off-normal conditions such as station blackout, loss of essential service water, and loss of component cooling water.

On April 19, 1991, the staff published for comment a Federal Register Notice (56 FR 16130) on the current understandings, findings, and potential recommendations regarding GI-23, together with a draft Regulatory Guide, DG-1008, "Reactor Coolant Pump Seals." In addition, the staff made presentations to the Committee to Review Generic Requirements (CRGR) and the Advisory Committee on Reactor Safeguards (ACRS). Appropriate guidance and comments from these sources have been incorporated in the enclosed rulemaking package.

Discussion:

The proposed amendment to 10 CFR Part 50, Section 50.68, "Loss of Integrity of Reactor Coolant Pump Seals," would be applicable to all pressurized water reactors. It has been formulated using a performance-oriented approach to regulation, with risk explicitly identified as a criterion to achieve compliance. The performance-oriented approach used for this rule is based on explicitly defining the safety objective in terms of defense-in-depth principles, prevention and mitigation. Prevention is addressed by increasing the level of assurance that the seals are unlikely to fail (using either alternative seal cooling or through testing), if it can be done in a cost effective manner. Mitigation is addressed by ensuring that there is sufficient capacity and capability to cool the core even if a seal failure is predicted.

The risk assessment actions under this rule are expected to result from an effort similar to that which licensees have pursued under the individual plant examination (IPE) program. A licensee may conclude on the basis of such an analysis that the likelihood of the loss of all seal cooling is so small that no action is warranted. Such an assessment that specifically addresses dependencies that could lead to loss of seal cooling and seal failure, that appropriately models seal failure mechanisms, and that clearly documents and supports assumptions would be acceptable for demonstrating compliance with this proposed rule. The staff would expect licensees to consider corrective or mitigative actions only if dependencies that could lead to seal failure result in a distribution of estimated core damage frequencies with a mean value in the range of E-5 to E-4. If the mean core damage frequency from seal failure scenarios is lower than E-5 (with reasonable assurance of containment integrity), no additional risk reduction would be required; if it is higher than E-4, the staff would expect the licensee to promptly identify corrective or mitigative actions (along with a schedule) to be implemented. This approach is consistent with the staff proposals in the regulatory analysis guidelines that have been published for public comment.

The staff believes that the PWRs currently operating provide adequate protection to the public health and safety without implementing the actions proposed in the rule. The proposed rule is intended as a safety enhancement whose implementation costs are justified in view of the potential for increased protection in a manner consistent with the Backfit Rule, 10 CFR 50.109. There are two existing rules that were promulgated to resolve major safety issues (the ATWS rule, 10 CFR 50.62 and the SBO rule, 10 CFR 50.63) which fall into the same category as this proposed rule and which are being subjected to an effectiveness review under the staff's ongoing PRA Implementation Plan. The staff intends to coordinate the activities to resolve public comments and to review the effectiveness of the above mentioned regulations to assure consistency and coherence of regulatory responses.

The parameters that have governed the staff review of licensee actions under the SBO rule have included a best-estimate assumption for seal leakage under loss of all seal cooling. That is, it was assumed that PWR seals would not "pop open" under station blackout conditions, and that the thermal-hydraulic conditions would lead to a leakage flow through the seals of 25 gpm. Similarly, it was assumed that the recirculation pump seals of BWRs would leak at 18 gpm under station blackout conditions. As information became available under GI-23 the staff continued to evaluate the merits of these assumptions, and industry was kept informed through generic communications of those findings that could affect their analyses under station blackout. For example, the staff issued Generic Letter 91-07, "GI-23 and Its Possible Effect on Station Blackout" on May 2, 1991, to reiterate that the coping analysis under 10 CFR 50.63 could be affected by GI-23 findings. While implementation of the proposed rule will resolve GI-23 for PWRs, including the issue of seal leakage during station blackout, resolution of GI-23 for BWRs is being pursued as a separate matter by the staff. This is because the staff has not established that the safety concern for BWRs rises to the same level as that for PWRs, and relevant information provided by industry is still under staff evaluation.

The staff has prepared a generic assessment of the costs and safety benefits of implementing hardware and procedural measures that would likely be implemented by a licensee under this proposed rule in order to demonstrate compliance with Section (c)(2)(i) of the rule. This generic assessment is contained in the regulatory analysis for the proposed rule (Enclosure B). Although the staff's generic assessment showed that the cost/benefit ratio (also known as impact/value ratio expressed as dollars per person-rem) for implementing remedial measures would meet current NRC acceptance guidelines for backfits constituting a cost-justified safety enhancement, the margins in the cost/benefit ratio are such that there is insufficient confidence that the criteria would be met for every PWR that implements such remedial measures. In other words, when the uncertainties associated with the likelihood of seal leakage upon loss of cooling and the cost uncertainties of remedial measures are considered, a backfit may be justified for specific plants and not justified for some others. Generally speaking, there is no legal requirement in rulemaking that the perceived benefits of a proposed regulatory requirement apply to every member of the affected class. It is normally sufficient that there is a reasonable basis for imposing the requirement on the affected class. Thus, the Commission may, by rulemaking require all licensees of a specific class to implement remedial actions addressing a matter that the Commission has generically determined represents a problem for that class of reactor licensees, even though the Commission would not be able to show that every one of the licensees in that class would actually achieve significant, cost-effective risk reduction. Moreover, by providing in 10 CFR 50.12 a generally applicable procedure for any member of a class affected by a Commission rule to request an exemption from the rule based upon "special circumstances," the Commission has provided a regulatory mechanism whereby any licensee may request relief from a generic regulatory requirement. The staff therefore believes that a rule requiring all PWRs to institute remedial measures to address RCP seal vulnerabilities could be justified despite the uncertainty in the regulatory analyses.

Alternatively, the staff could continue to defer rulemaking, conduct further research, and perform plant-specific analyses in order to develop a rule that would more specifically identify the subset of plants that would see a clear and significant reduction in risk from RCP seal failure if remedial measures are imposed. However, this would be a resource-intensive task for the staff and would result in further delay in addressing the potential vulnerabilities that are the subject of GI-23.

The staff has developed a proposed RCP seal rule that is performance-based. Licensees would be able to demonstrate that no further actions to address RCP seal vulnerabilities are necessary on the basis that the risk of core damage attributable to such vulnerabilities is sufficiently low that further action is not justified. Thus, the proposed RCP seal rule places upon the licensee the burden of demonstrating that remedial actions are not necessary. This is a departure from existing rulemaking approaches whereby the NRC determines that remedial actions are necessary, a regulatory standard is promulgated, and licensees are given flexibility (in a performance-based regime) to demonstrate how the regulatory standard will be met. The staff believes that such a regulatory approach is justified for RCP seal vulnerabilities in view of the

narrow margin in the cost-benefit ratio for remedial measures. Furthermore, licensees have the best understanding of the design and operational characteristics of their plants and therefore are in the best position to perform individual, plant-specific risk analyses of RCP seal cooling vulnerabilities. The staff also notes that licensees are already performing risk analyses of their plants under the IPE and individual plant examination for external events (IPEEE) generic letters, and that application of these methodologies to address RCP seal cooling vulnerabilities would be a natural extension. The staff has pointed out in the statement of considerations for the proposed rule that such analyses may be performed (as some licensees have already done) using the methodology employed in the NUREG-1150 studies. For these reasons, the proposed rule has been structured to permit a licensee to comply with this rule by performing analyses showing that the risk of RCP seal failure is sufficiently low such that further remedial actions to address RCP seal cooling vulnerabilities are not justified.

The enclosed proposed rule presents the basis for the staff's positions and indicates the specific areas in which public comment is sought. Feedback from this rulemaking effort is expected to indicate to the staff whether broader application of the risk-based approach in safety regulation is feasible and desirable. The staff recognizes that the effort to review probabilistic analyses performed by licensees, who choose to comply with the proposed rule by showing that the risk from dependencies is sufficiently low, could strain the applicable NRC resources. The staff will continue to develop options to perform resource-effective reviews of licensees' evaluations while the proposed rule is receiving public comment. Such options are likely to include selective detailed review of some plants on the basis of insights from the IPE program, or of those plants whose licensees ignored the "popping open" mode of seal failure in their evaluations, while at the same time determining that no actions pursuant to this proposed rule are justified. The staff believes that this proposed rule could be viewed as a test vehicle to support broader application and increased reliance on risk-based regulation to meet the agency's mission.

Resources:

The resources to conduct the proposed rule are included in the current five-year plan. The resources to implement the rule cannot be estimated at this time, but will be provided with the final rule.

Coordination:

The Office of General Counsel has no legal objection. The Advisory Committee on Reactor Safeguards considered this issue at their 412th meeting in August 1994, and decided against further review of the package prior to issuance for public comment.

Recommendation: That the Commission:

(1) Approve the publication of the proposed rule for public comment (Enclosure A).

(2) Certify that this rule, if adopted, would not have a significant economic impact on a substantial number of small entities in order to satisfy the requirements of the Regulatory Flexibility Act (5 U.S.C. 605(b)).

(3) Note:

(a) That a regulatory analysis (draft NUREG-1483) has been prepared for this rulemaking action (Enclosure B).

(b) That the proposed rule contains an environmental assessment that indicates a finding of no significant impact for this proposed rule.

(c) That the Subcommittee on Clean Air and Nuclear Regulation of the Senate Committee on Environment and Public Works, the Subcommittee on Energy and Power of the House Committee on Energy and Commerce, and the Subcommittee on Energy and Mineral Resources of House Committee on Natural Resources will be informed of this rulemaking action (Enclosure C).

(d) That the proposed rule would amend information collection requirements subject to the Paperwork Reduction Act. These requirements will be submitted to the Office of Management and Budget for review and approval.

(e) That the Chief Counsel for Advocacy of the Small Business Administration will be informed of the certification and the reasons for it as required by the Regulatory Flexibility Act.

(f) That a public announcement will be issued (Enclosure D).

(g) That a copy of the proposed rule will be distributed to all affected licensees and other interested persons.

James M. Taylor
Executive Director
for Operations

Enclosures:
A. Federal Register Notice
B. Regulatory Analysis
C. Draft Congressional Letters
D. Draft Public Announcement

Commissioners' comments or consent should be provided directly to the Office of the Secretary by COB Tuesday, September 13, 1994.

Commission Staff Office comments, if any, should be submitted to the Commissioners NLT Tuesday, September 6, 1994, with an information copy to the Office of the Secretary. If the paper is of such a nature that it requires additional review and comment, the Commissioners and the Secretariat should be apprised of when comments may be expected.

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

The Honorable Philip R. Sharp, Chairman
Subcommittee on Energy and Power
Committee on Energy and Commerce
United States House of representatives
Washington D.C. 20515

Dear Mr. Chairman:

The Nuclear Regulatory Commission is sending the enclosed proposed amendment to 10 CFR Part 50 to the Office of Federal Register for publication. The amendment, if adopted, would add a provision that would require pressurized light water reactor licensees to assure reactor coolant pump seal integrity during postulated events; or assure sufficient emergency core cooling capability even if seal integrity is lost.

The Commission is issuing the proposed rule for public comment.

Sincerely,

Dennis K. Rathbun, Director
Office of Congressional Affairs

Enclosure: As stated

cc: Representative Michael Bilirakis

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

The Honorable Richard H. Lehman, Chairman
Subcommittee on Energy and Mineral Resources
Committee on Natural Resources
United States House of representatives
Washington D.C. 20515

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Sincerely,

Dennis K. Rathbun, Director
Office of Congressional Affairs

Enclosure: As stated

cc: Representative Barbara Vucanovich

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

The Honorable Bob Graham, Chairman
Subcommittee on Nuclear Regulation
Committee on Environment and Public Works
United States Senate
Washington D.C. 20510

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The Commission is issuing the proposed rule for public comment.

Sincerely,

Dennis K. Rathbun, Director
Office of Congressional Affairs

Enclosure: As stated

cc: Senator Alan K. Simpson

ENCLOSURE D

DRAFT PUBLIC ANNOUNCEMENT

NRC PROPOSES TO REVISE REQUIREMENTS REGARDING REACTOR COOLANT PUMP SEAL FAILURE

The Nuclear Regulatory Commission is proposing to amend its regulations to require each pressurized-water reactor licensee to evaluate its plant for dependencies pertaining to reactor coolant pump seal failure during postulated events, i.e. station blackout, loss of essential service water, or loss of component cooling water. The dependencies of concern are those that may cause insufficient capacity and capability to ensure that the reactor core is cooled coincident with loss of reactor coolant pump seal cooling. The NRC has found that loss of seal cooling could lead to failure of seals.

If the above type of dependencies are identified, the licensee must take action to reduce it or demonstrate that the risk associated with the dependency is sufficiently low, as indicated in the Federal Register notice published on ______________ ___, 199___. The NRC is seeking public comment on various technical and policy issues described in the Federal Register notice.

The period for public comment ends on ______________ ___, 199___.