CERTIFIED BY:
Ivan Catton - 12/20/93

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ACRS-2902
PDR 3/25/94

ACRS DECAY HEAT REMOVAL SYSTEMS SUBCOMMITTEE MEETING MINUTES
PROPOSED RULE FOR RESOLUTION OF GI-23, RCP SEAL FAILURE
OCTOBER 5, 1993
BETHESDA, MARYLAND

PURPOSE:

The purpose of the meeting was for the Subcommittee to review the NRC staff's proposed rule to address resolution of GI-23, "Reactor Coolant Pump Seal Failure".

ATTENDEES:

Principal meeting attendees included the following:

ACRS
I. Catton, Chairman
J. Carroll, Member
P. Davis, Member
T. Kress, Member
D. Ward, Consultant

NRC
R. Baer
P. Kadambi
J. Jackson

Northeast Utilities
D. Dube
E. Perkins

A complete list of attendees is attached to the office copy of these Minutes.

MEETING HIGHLIGHTS, AGREEMENTS, AND REQUESTS

INTRODUCTION

Dr. Catton made some brief introductory remarks. He noted that this generic issue has been under review since 1983. He said that he understands that the proposed Rule is now focused on addressing seal failure for the cases of off-normal events and accidents. He also questioned some elements of the Rule and requested NRC staff response to same.

NRC-RES PRESENTATION

Issue Overview:

Dr. P. Kadambi (RES) began the staff's presentation by providing an overview of this issue and the proposed Rule. Key points noted by Dr. Kadambi included the following:

- GI-23 is considered a high-priority issue by the staff. A proposed Rule, performanced-based in approach, has been crafted that applies to PWR plants only and addresses off-normal conditions, only.

DESIGNATED ORIGINAL

Certified By

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• The basis of the staff's safety concern is the potential for the RCP seals to pop open, resulting in an unisolable LOCA. Such an event combined with a loss of ECC is considered a significant risk contributor.

• Given the above, the proposed Rule requires affected licensees to either ensure seal cooling or ensure core cooling given a seal failure. The Rule addresses accident prevention events, such as SBO and ATWS; thus, affected plants can continue to operate until the rule has been approved.

In response to Subcommittee questions, RES noted that little information exists relative to loss-of-seal-cooling events. Some events have occurred, but no major adverse consequences have been seen. In response to Dr. Catton, Dr. Kadambi said that no events have occurred that posed a threat to core cooling. Mr. Baer indicated that to threaten core cooling one needs a low-probability event precursor such as a station blackout.

Mr. Carroll expressed concern with the staff's "lowest common denominator" approach being used here, since the rule's technical bases rests on information obtained from Westinghouse (and two other RCP vendors' designs are being affected, based on the W information). He asked if the staff has obtained additional information from the other RCP vendors. Mr. Baer indicated that they had requested such information when an earlier version of the Rule was issued for public comment; no such information was provided.

Background:

Mr. J. Jackson provided information on the technical aspects of this issue. He noted that there are two RCP seal designs, hydrostatic (used by W), and hydrodynamic (used by the remaining RCP vendors). Figures 1-3 provide detail on the two designs and the seal arrangement for the W design. The proper functioning of RCP seals relies on use of a pressure balance approach (Figure 3); thus, all PWR plants are subject to a seal pop-open event.

The staff's safety concern is the potential for a SBLOCA resulting from RCP seal failure caused in turn by loss of both seal cooling and ECC function. As noted above, the principal precursor here is a SBO event. Mr. Jackson noted that studies performed by the French and British led them to install backup seal cooling systems on their plants.

Figures 4-5 summarize the technical work performed relative to this issue.

An event tree used by the staff to determine potential leakage rates from a seal failure event was discussed (Figure 6). This failure model was originally developed by W and was subsequently modified by the staff. The worse-case leakage rate shown (with an estimated 2.5% occurrence probability) is 480 gpm; the most probable leakage rates are 21 and 60 gpm, respectively.

During discussion of the above event tree, Mr. Jackson noted, in response to Mr. Ward, that each event path is independent of the others. Also, the staff assumes that for a LOSC (loss of seal cooling) event, the seals will see high temperatures (i.e., RCS water temperatures) within 10 minutes; thus, the seal failure probability is time dependent.

Staff Actions for Proposed Rule:

P. Kadambi discussed the recent staff actions leading to the proposed Rule. He noted that an earlier version of the proposed rule was issued for public comment in April, 1991. The staff solicited information from the public (via a set of questions) relative to obtaining their input in the crafting of a rule. The gist of the responses provided to NRC was that no new information was forthcoming, and that no licensee wanted new requirements; if new requirements were to be imposed, however, respondents indicated that the staff should promulgate a rule. In response to Dr. Catton, Dr. Kadambi said that this issue will be addressed for BWR plants by development of a separate generic issue, which will be subject to the prioritization process.

Following receipt of the above comments, CRGR instructed the staff to develop a rule and associated regulatory guide to address LOSC for off-normal events only and to be applied to PWRs only. Seal failure during normal operation was to be addressed by NRC generic communication vehicles.

Provisions of Proposed Rule:

The current proposed Rule version requires that affected licensees:

- Ensure RCP seal integrity during postulated events (SBO, loss of CCW or SW), or ensure ECC capability if seal integrity is lost.

- Achieve seal integrity by either providing an alternate seal cooling system to provide adequate and timely (within 10 minutes of LOSC) seal cooling, or verify seal performance (given LOSC) by tests.

Mr. Carroll expressed concern that the testing requirements specified in the draft Regulatory Guide are so onerous that no licensee/vendor will elect this option. Dr. Kadambi said that the tests are designed to force the popping open mechanism for the seals, if, indeed, it is going to occur.

Results of both the regulatory analysis and the cost/benefit (C/B) analysis were shown (Figures 7-8). Results of the C/B support promulgation of the Rule, with a cost calculation result of $680/person-rem. Mr. Ward opined that the staff has hung justification of this Rule on a cost analysis that represents a close call, given the large uncertainties associated with this calculation.

During discussion of the above, Mr. Baer indicated that some plants (e.g., Zion) have already installed backup seal cooling capability, while others have added alternate AC power that could be used to power seal cooling equipment, given a LOSC event.

The staff also made the point that comparing the results of the IPE's received to date (CDF/RY for RCP seal failure) with the CDF for same calculated by RES shows similar results (Figure 9). The relationship of GI-23 to resolution of other generic issues was also noted (Figures 10-11).

Dr. Catton requested some discussion on the details of the proposed seal test program as specified in the draft Regulatory Guide. Mr. Jackson indicated that the goal of this test program is to show that the seals are hydrodynamically stable and will not pop open given a LOSC event. Mr. C. Ruger (BNL) seconded Mr. Jackson by indicating that the tests are designed to show that the seals will be stable for all operating conditions. The staff felt such testing was mandated by the W position that a pop-open event was not credible.

During the above discussion, Dr. Catton expressed concern with the staff's requirement that one must assume all RCP seals leak at the 480 gpm rate. He suggested that the probability of such an event is quite low.

Comments by Northeast Utilities (NU):

Mr. E. Perkins and Dr. D. Dube provided comments on the proposed rule. Two major points were noted: (1) many plant-specific design and operational considerations exist which decrease the perceived risk significance of RCP seal failure events, and, (2) RCP seal failure experience has been improving; actual LOSC events have not resulted in catastrophic seal failures.

Dr. Dube went on to show how plant features (existing or to be installed) at the NU Haddam Neck and Millstone Units render moot "classic" RCP seal failure events. Many of these plant features were, or are being, backfitted to these units by NU in response to other safety concerns (e.g., SBO Rule). Figures 12-15 provide details.

Dr. Dube indicated, in response to Subcommittee questions, that the NU plants, when fully configured as noted above, could meet the strictures of the proposed Rule, except for the "10-minute rule" concerning the initiation of back-up seal cooling.

Turning to NU's experiences with LOSC events, Dr. Dube indicated that three such events have occurred, one at the Haddam Neck plant, and, two at Millstone, Unit 2. None of these events resulted in gross leakage, even though two events involved LOSC for a number of hours (Figure 16).

Dr. Dube also noted that the CE Owners Group had collected data on a total of 71 LOSC events that occurred at CE plants (time span of data not given). He said that none of these events resulted in gross seal leakage, even though, as above, some incidents involved LOSC for many (8-10) hours. Mr. Baer asked Dr. Dube if the NRC could be provided this data.

In conclusion, Dr. Dube indicated that NU believes it can satisfy the intent of the proposed Rule, given the above noted modifications it either has or plans to install at its PWR plants. Mr. Perkins questioned the staff's assumption that a licensee can comply with this rule for a minimal cost of ~$1M/unit.

Comments by NUMARC Representative:

Mr. A. Marion (NUMARC) made some brief comments. He indicated that it appears to be an open question as to whether a rule is needed to close out this Generic Issue. He did volunteer to provide additional industry data regarding licensees' experience with LOSC events.

Mr. Marion noted that, in general, NUMARC prefers that NRC use rulemaking to address resolution of generic issues given the "due process" features that accompany such a regulatory vehicle. In response to Mr. Carroll (i.e., what should the staff do to resolve this issue), Mr. Marion declined to offer an opinion. He did state that he believes that NRC ought to review the IPE results vis-a-vis the threshold CDF value for requiring action to address potential safety issues, and see how this threshold approach would apply to resolution of GI-23. He also indicated that NRC does not seem to be giving sufficient credit for the mitigation potential of equipment installed to address the SBO Rule as it pertains to this

Generic Issue. Finally, Mr. Marion indicated that NUMARC will provide formal comment on the Rule when it is made available to him.

In response to Mr. Ward, Mr. Marion indicated that NUMARC does not believe that NRC has established a sound basis for promulgation of this Rule.

SUBCOMMITTEE DISCUSSION:

The Subcommittee briefly discussed the results of the day's presentations. Mr. Ward opined that the staff's arguments supporting the need for this Rule appear weak.

Review of this matter by the ACRS during its October 1993 Meeting was approved by the Subcommittee; Dr. Catton instructed the presenters regarding the scope and content of their presentations before the Committee.

ADJOURNMENT

The meeting was adjourned at 5:05 pm.

FUTURE SUBCOMMITTEE ACTIONS ON THIS MATTER AND ITEMS FOR FOLLOW-UP

Future Subcommittee Actions:

At this time, no additional action by the Subcommittee is planned, pending future NRC staff action on the proposed Rule. [**Note**: Subsequent to this meeting, the ACRS reviewed the proposed Rule and in a October 14, 1993 letter to the EDO recommended that the Rule not be issued for public comment at this time.]

Follow-up Actions:

No specific follow-up actions were identified during this meeting.

BACKGROUND MATERIAL PROVIDED TO THE SUBCOMMITTEE FOR THIS MEETING

1. Memorandum, from C.J. Heltemes, RES, for J. E. Wilkins, ACRS, transmitting proposed Rule package for resolution of GI-23, "Reactor Coolant Pump Seal Failure", dated August 3, 1993.

2. Memorandum, S. Mays, ACRS Senior Fellow, to ACRS Members, "Generic Issue 23, Reactor Coolant Pump Seal Failure", dated September 14, 1993 (**Prepared for Internal Committee Use**).

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Note: Additional meeting details can be obtained from a transcript of this meeting available in the NRC Public Document Room, 2120 L St., NW, Washington DC 20006, (202) 634-3273, or can be purchased from Ann Riley and Associates, Ltd., 1612 K St., NW, Suite 300, Washington, DC, 20006, (202) 293-3950.

PRIMARY AND SECONDARY SEAL MATERIALS

PRIMARY SEALS

- HYDROSTATIC SEAL

  - NON-ROTATING SEAL RING AND RUNNER BOTH HAVE ALUMINUM OXIDE FACEPLATES CLAMPED TO 410 SS HOLDERS (WESTINGHOUSE FIRST STAGE SEAL DESIGN)

  - CLEARANCE IS APPROXIMATELY 0.00045"

  - FACEPLATES DO NOT TOUCH, BUT RIDE ON A FILM OF COOLANT (SEPARATION DOES NOT DEPEND ON PUMP ROTATION)

- HYDRODYNAMIC SEALS

  - NON-ROTATING SEAL RING HAS A CARBON-GRAPHITE FACEPLATE

  - RUNNER HAS A HARD FACE SUCH AS TITANIUM CARBIDE OR OTHER CARBIDE

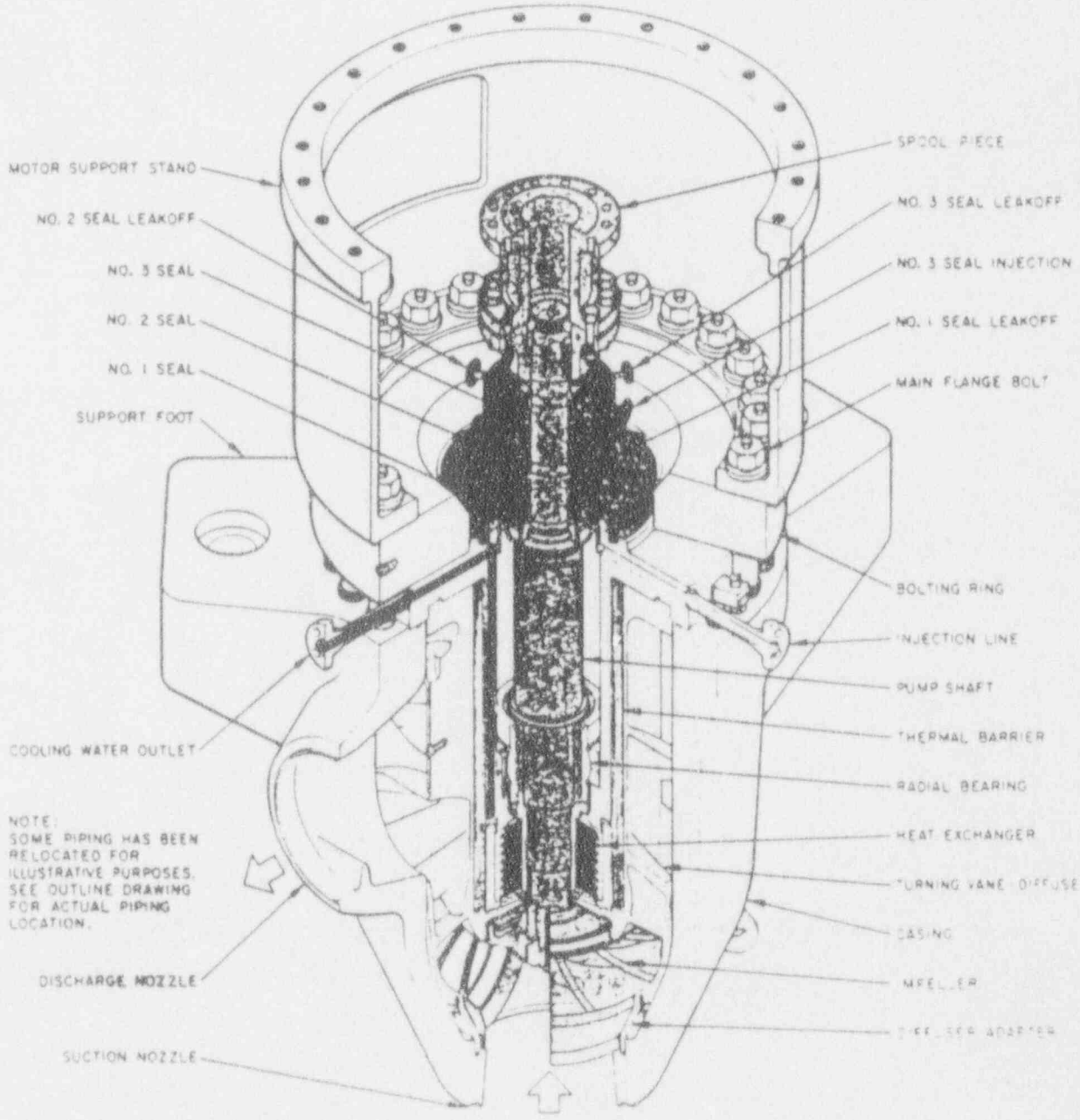
  - CLEARANCES ARE APPROXIMATELY 20 TO 40 μ

  - FACEPLATES ARE IN RUBBING CONTACT. A LUBRICATING FILM IS DEVELOPED THROUGH PUMP ROTATION.

SECONDARY SEALS

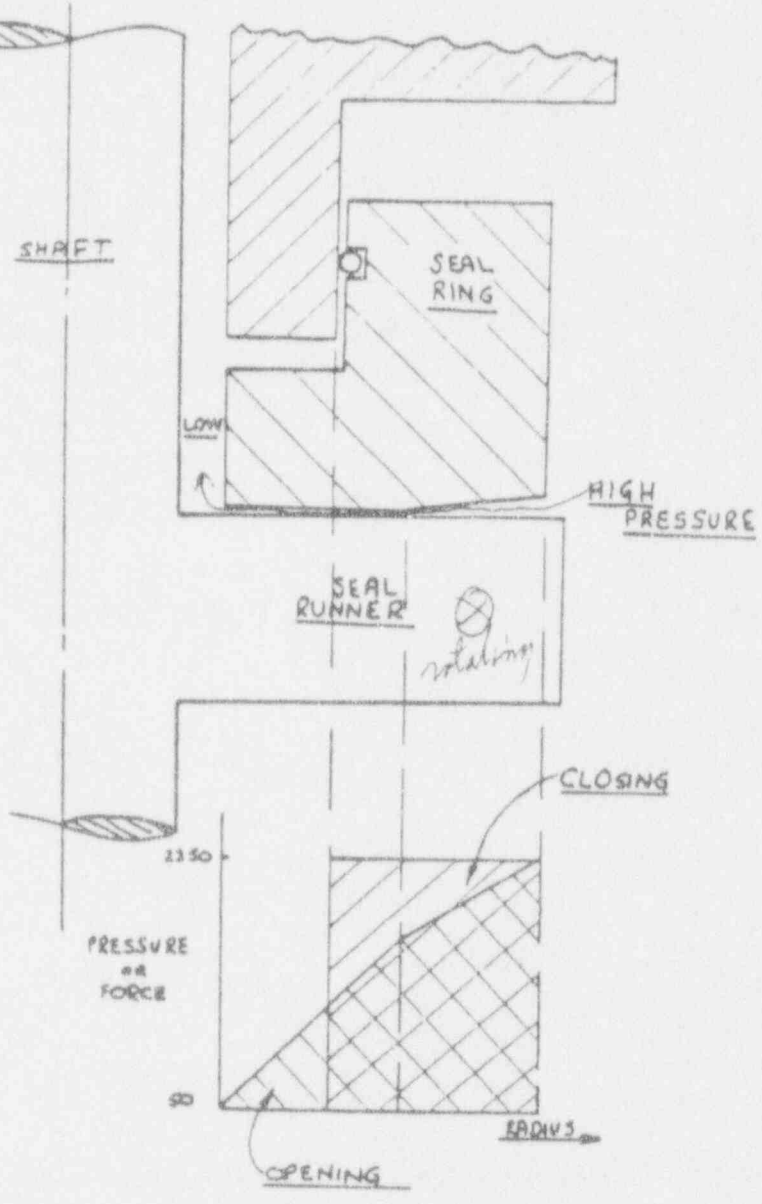
O-RINGS (Ethylene Propylene) CHANNEL SEAL (Teflon)

FIG. 1



CUTAWAY VIEW OF PUMP

F16.2



CONTROLLED LEAKAGE SHAFT SEAL

FIG-3

SUMMARY OF TECHNICAL WORK

INEL/AECL	● SCALE TESTING OF SECONDARY SEALS, NUREG-4077
	● HYDRAULIC STABILITY OF SEALS
	● CONDUCTED FRICTION TESTS, NUREG/CR-4821
AECL	● REPORT ON FRENCH SEAL TEST, NUREG/CR-4907P
	● REVIEW OF WCAP 10541, REV. 2, NUREG/CR-4906P
ETEC	● LEAKAGE ANALYSIS OF WESTIHGHOUSE SEAL, NUREG/CR-4294
BNL	● INDUSTRY SURVEY ON SEAL FAILURE FREQUENCY
	● CORE MELT FREQUENCY ESTIMATES
	● CHARACTERIZED SEAL FAILURE MECHANISMS DURING NORMAL OPERATION, NUREG/CR-4400
	● INDUSTRY SURVEY OF INSTRUMENTATION AND OPERATING PROCEDURES, NUREG/CR-4544

FIG 4

SUMMARY OF TECHNICAL WORK - (CONT'D)

BNL (Continued)

- RISK ASSESSMENT OF LOSS OF CCW INDUCED SEAL FAILURE, NUREG/CR-4643
- TECHNICAL FINDINGS REPORT, NUREG/CR-4948

SCI ENTECH

- COST/BENEFIT ANALYSIS, NUREG/CR-5167

WESTINGHOUSE

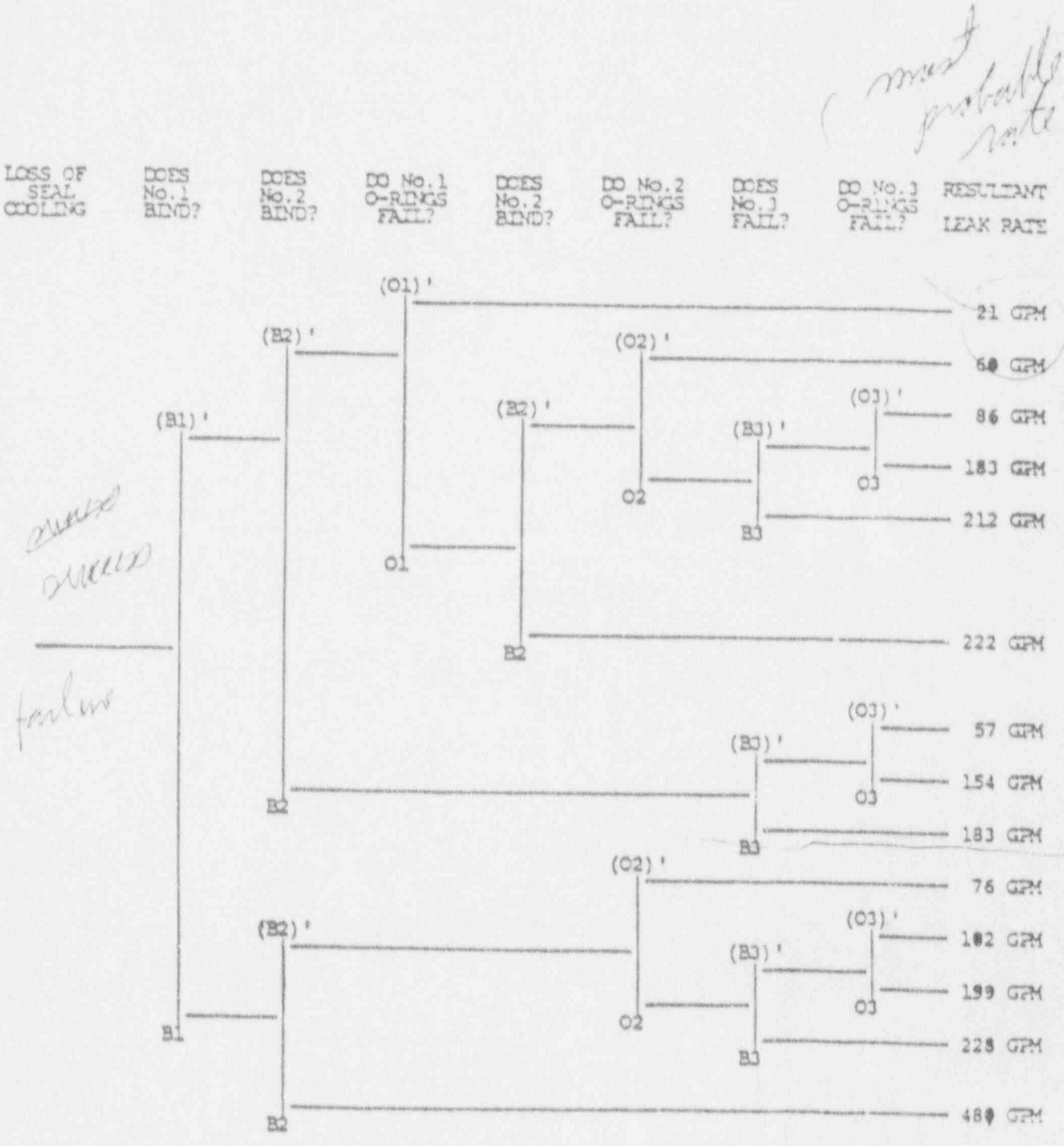
- SCALE TESTING OF SECONDARY SEALS
- ANALYSIS OF W SEAL FOR STATION BLACKOUT, WCAP 10541, REV. 2
- FRENCH 7" SEAL TEST

OTHER PUMP MANUFACTURERS

- B J SEAL TESTS (ST. LUCIE AND N-9000)
- BINGHAM SEAL TEST (4 1/2" BWR RECIRCULATING PUMP)

MEETINGS WITH ALL NSSS VENDORS AND PUMP MANUFACTURERS

F16.5



RCP seal leakage following loss of all seal cooling.

FIG. 6

SUMMARY OF REGULATORY ANALYSIS

CORE DAMAGE FREQUENCY (CDF)
COMPARED WITH THOSE OF NUREG-1150 PWRs

COMPARISON	NUREG-1150			GI-23
Selected Plants	Surry	Sequoyah	Zion	76 PWRs
Total CDF (Internal Events)	4.0 E-05	5.7 E-05	3.4 E-04	Not calculated
CDF from Station Blackout	2.7 E-05	1.2 E-05	6.5 E-06	Not calculated
CDF from seal LOCA (Station Blackout)	8.6 E-06	4.3 E-06	4.0 E-07	2.8 E-04 (HIGH)* 5.6 E-06 (BEST)* 1.8 E-07 (LOW)*
CDF from seal LOCA (Loss of CCW)	Negligib.	< 1.0 E-08	1.5 E-04	1.3 E-04 (HIGH)** 6.0 E-06 (BEST)**
CDF from seal LOCA (Loss of SW)	Negligib.	< 1.0 E-08	1.5 E-04	1.2 E-05 ***
TOTAL RISK OF CORE DAMAGE				2.36 E-05 (BEST)

IMPLEMENTATION OF THE PROPOSED RULE
WOULD REDUCE THIS RISK BY 75% TO 5.9 E-06

* Value taken from NUREG/CR-5167, Appendix A & B.

** Value taken from NUREG/CR-4643.

*** Value taken from NUREG/CR-5918, Appendix F.

FIG. 7

COST/BENEFIT ANALYSIS

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

DESCRIPTION	ALTERNATE SEAL COOLING
INDUSTRY COST:	
IMPLEMENTATION	$72.4
OPERATION	$ 1.2
NRC COST:	
DEVELOPMENT	$ 2.9
IMPLEMENTATION	$ 0.3
OPERATION	$ 2.6
AVERTED PROPERTY COST:(onsite damage)	-$10.4
PUBLIC HEALTH BENEFIT: (person-rem)	100,890
OCCUPATIONAL EXPOSURE:	
OPERATIONAL (Reduction in person-rem)	NEGLIGIBLE
ACCIDENTAL (Reduction in person-rem)	706
COST/BENEFIT: ($/person-rem)	$ 680

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

F16-8

RCP SEALS FAILURE - PWR PLANTS
IPE DATABASE (09/28/93)

PLANT NAME	RCP SEALS FAILURE CDF PER RY	TOTAL PLANT CDF PER RY	PERCENT OF TOTAL CDF
ARKANSAS NUCLEAR 1	3.85E-06	4.67E-05	8.25%
ARKANSAS NUCLEAR 2	1.03E-06	3.40E-05	3.03%
BEAVER VALLEY 2	8.19E-05	1.92E-04	42.64%
CATAWBA 1&2	2.98E-05	4.40E-05	67.80%
D.C. COOK 1&2	1.19E-05	6.26E-05	19.02%
DIABLO CANYON 1&2	1.86E-05	8.80E-05	21.17%
H.B. ROBINSON (HIGH)	1.35E-04	3.20E-04	42.30%
HADDAM NECK	3.67E-05	1.90E-04	19.31%
INDIAN POINT 2	4.29E-07	3.13E-05	1.37%
KEWAUNEE	5.86E-06	6.65E-05	8.82%
MAINE YANKEE	9.51E-07	7.40E-05	1.29%
MCGUIRE	1.19E-05	4.00E-05	29.75%
PALO VERDE 1, 2, & 3	1.30E-06	9.00E-05	1.45%
POINT BEACH 1&2	1.98E-05	1.15E-04	17.22%
SAN ONOFRE 2&3 (LOW)	1.36E-07	3.00E-05	0.45%
SEABROOK	3.15E-05	6.70E-05	46.95%
WATTS BAR 1&2	1.33E-04	3.30E-04	40.40%
ZION 1&2	2.04E-07	4.00E-06	5.10%
MEAN VALUE	2.91E-05	1.01E-04	20.91%

FIG.

FIG-9

RELATIONSHIP TO OTHER SAFETY ISSUES

- USI A-44, STATION BLACKOUT

- GI-65, COMPONENT COOLING WATER SYSTEM FAILURE

- TMI ACTION II.K.2.16 & II.K.3.25, LOSS OF OFF-SITE POWER

- GI-130, ESW SYSTEM FAILURE AT MULTI-PLANT SITES

- GI-153, LOSS OF ESSENTIAL SERVICE WATER IN LWRs

FIG. 10

RELATIONSHIP TO OTHER SAFETY ISSUES (CONTINUED)

- GI-106, PIPING AND THE USE OF HIGHLY COMBUSTIBLE GASES IN VITAL AREAS

- GI-57, EFFECTS OF FIRE PROTECTION SYSTEM ACTUATION ON SAFETY-RELATED EQUIPMENT

- INDIVIDUAL PLANT EXAMINATION (IPE) AND INDIVIDUAL PLANT EXAMINATION FOR EXTERNAL EVENTS (IPEEE) PROGRAMS

F16-11

HADDAM NECK PLANT: NO ECCS PUMP ROOM COOLING NEEDED, AIR-COOLED HPSI AND LPSI PUMPS, CHARGING PUMP AUXILIARY LUBE OIL COOLER AND POSITIVE DISPLACEMENT CHARGING PUMP

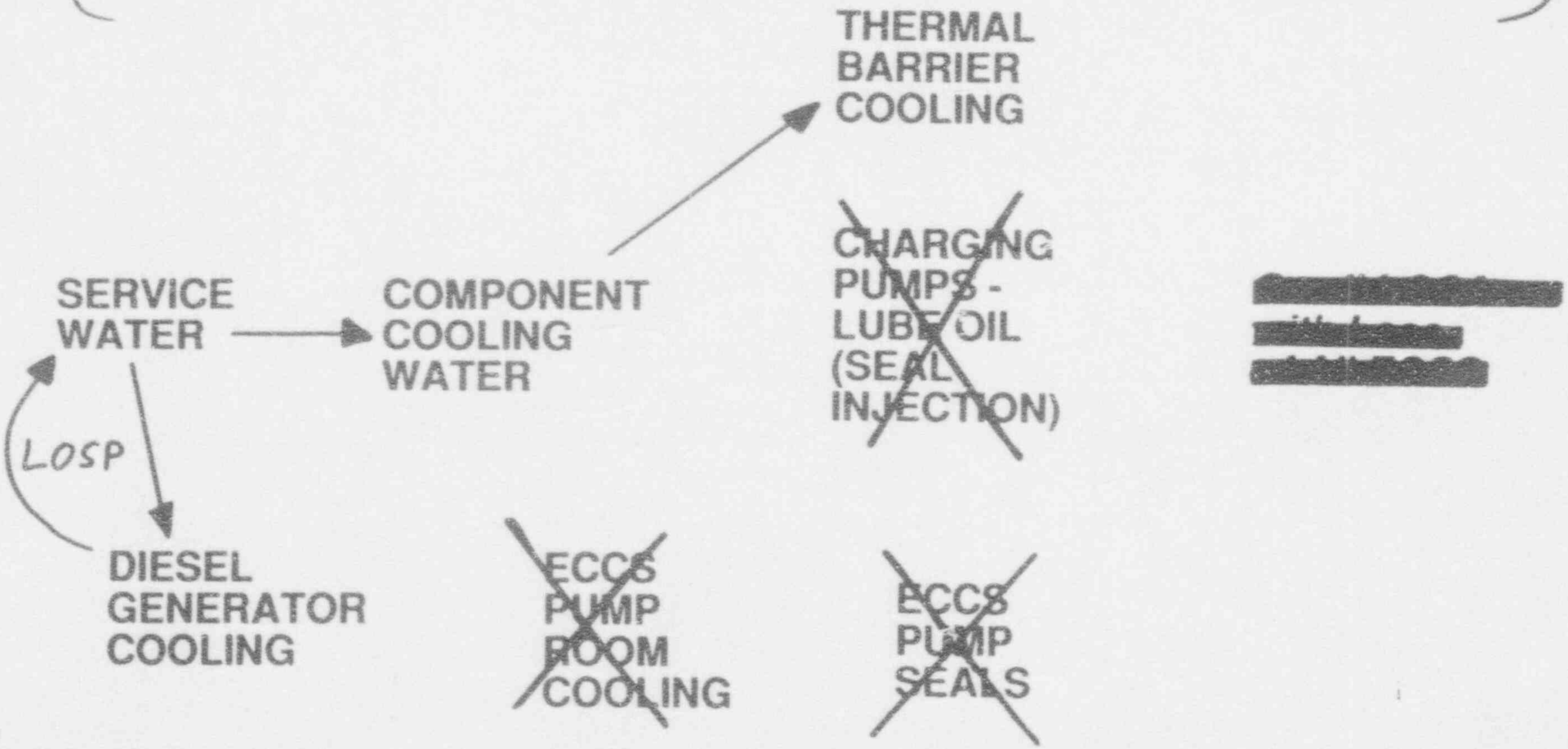


FIG. 12

MILLSTONE UNIT 3 : PROCEDURE FOR LOSS OF ALL SERVICE WATER, AND AIR-COOLED S.B.O. DIESEL GENERATOR

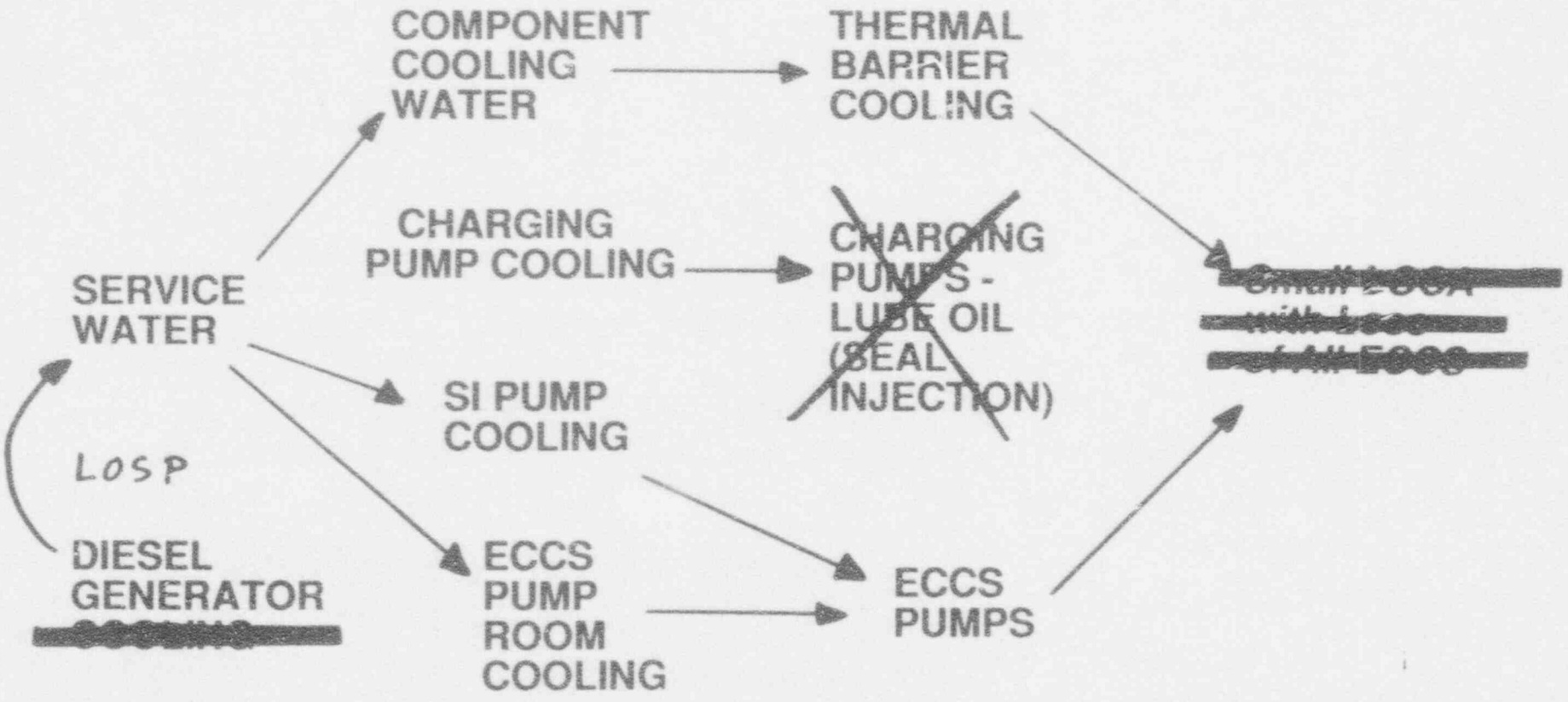


FIG. 13

Additional Features

- **Haddam Neck Plant**

  - Loop isolation valves with emergency AC power. Procedure for isolating RCP with failed seal.

  - Procedure for aligning service water to CCW loads for loss of CCW events (assuming small isolable line break, or loss of all 3 CCW pumps, but no major CCW pipe break).

  - Purchase of 1750 kw air-cooled diesel-generator.

- **Millstone Unit 3**

  - Loop isolation valves with normal AC power.

FIG. 14

MILLSTONE UNIT 2 FEATURES

PREVENTION OF RCP SEAL FAILURE

- Byron Jackson pumps
- Three full-pressure seals mounted in series and fourth low-pressure back-up seal designed to withstand operating system pressure with pumps stopped.
- Unit 1 to Unit 2 electrical cross-tie (4 emergency power supplies)

Per NUREG/CR-4400:

" Combustion Engineering plants with Byron Jackson pumps have experienced no large leakages" through 1985.

Per NUREG-1401, there have been some recent seal failures in CE plants with BJ seals, but none classified as small LOCAs.

LOSS OF SEAL COOLING EXPERIENCES

HADDAM NECK PLANT

- Loss of all RCP seal cooling for 30 minutes during loss of offsite power event 7/15/69 (no automatic loading of CCW and charging pumps).

  First and second stage seals in No. 4 RCP failed. No. 4 RCP experienced 15 GPM leakage.

MILLSTONE UNIT 2

- RBCCW isolated to 'D' RCP seal assembly for 9 hrs on 11/15/84 while in hot standby (530 F).

  No gross RCP seal leakage. Seal operated normally for two months until refueling outage.

- RBCCW isolated to 'B' RCP on 11/16/84 in hot standby (530 F) for 5 hrs. First stage seal failed, and second stage was degraded.

  No gross RCP seal leakage. Seal operated satisfactorily for two months until refueling outage.

91-91d