U. S. Nuclear Regulatory Commission Meeting with the Combustion Engineering Owner's Group Regarding Bulletin 2001-01

Meeting 2001-0760
Monday, August 27, 2001
1:00 p.m. - 3:00 p.m.

CEOG

Introduction

- Meeting objective
  - Present an Integrated Inspection Plan for the CEOG fleet, which
    - Provides information important to safety,
    - Addresses issues with performing 100% visual inspections
    - Provides inspections consistent with ALARA policies, and
    - Effectively and efficiently manages the issue

In accordance with the CEOG Charter this meeting is not intended to be a response to the Bulletin or make any commitments for CEOG members

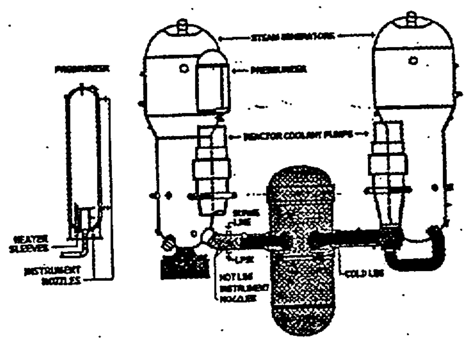
CEOG

Introduction

- Agenda
  - Overview of Alloy 600 Experience in CE Plants
  - CE Head Design
  - Insulation and Inspectability
  - Integrated Approach, Justification and Actions
  - Summary
  - Discussion & Feedback

Alloy 600 Experience in CE plants

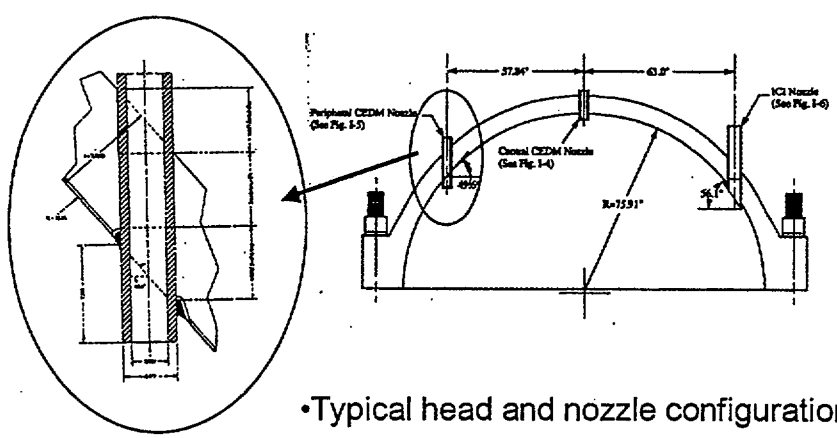
- The CEOG implemented Alloy 600 Programs to
  - assess the problem,
  - develop NDE,
  - develop repair & mitigation techniques
- CEOG plants have replaced, mitigated or have active replacement programs underway to eliminate Alloy 600 cracking



CE Head Design

- Low alloy, hemispherical heads
  - 48 to 102 penetrations
    - Counter-bored
- Alloy 600 nozzles
  - Machined finish on OD,
  - Interference fits (0 to 3 mils)
  - Attachment welded to the underside of head
    - Alloy 182 J-Groove weld
      - Small weld volume

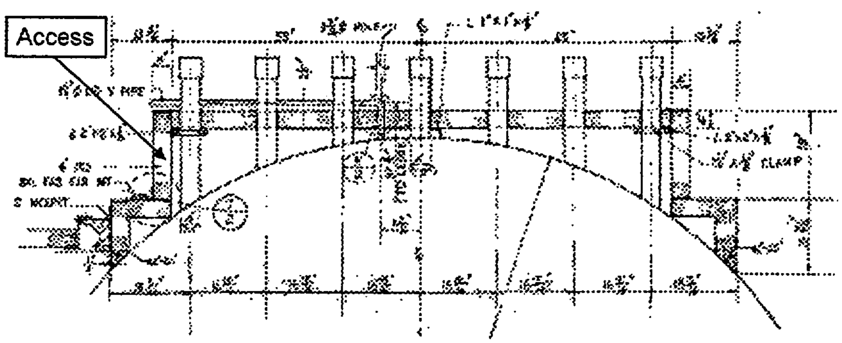
CE Head Design



- Typical head and nozzle configuration

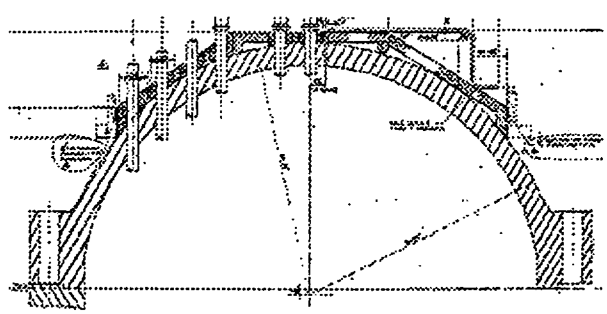
Insulation Configuration and Inspectability

- Typical Westinghouse and B&W CRDM designs
  - Constant elevation
  - Good access
  - Vertical side panels



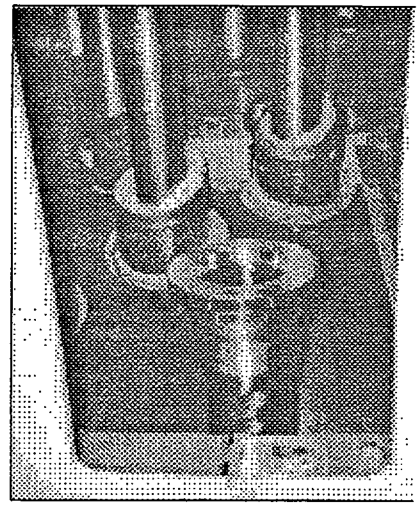
Insulation Configuration and Inspectability

- Most CE CEDMs are a constant distance from head
  - Typical insulation configuration
    - Installed during erection
    - Close proximity to CEDM housings
    - Conforms to the contour of the head
    - Contacts the head



Insulation Configuration and Inspectability

- Panels and collars restrict access to VHPs
- Head disassembly or destructive removal required
- Shroud inhibits access at some plants



CEOG 9

Insulation Configuration and Inspectability

- Performing bare metal visual inspections requires rigorous planning
  - Destructive insulation removal and/or upper head disassembly
  - Asbestos handling and occupational protection issues
  - Insulation removal = Large dose burden
  - Potential issues
    - Mag-jack and electrical cable damage
    - RV pressure boundary damage
    - Large outage extension

CEOG 10

Insulation Configuration and Inspectability

- New insulation design issues
  - Consider all NRC requirements
    - GL 85-22 & RG 1.82 sump transport concerns
  - Facilitate future inspections
  - Procurement and manufacturing lead-time
  - Insulation efficiency
    - Mag-jack cooling issues
  - Heat loading in containment

CEOG 11

Insulation Configuration and Inspectability

- Potential dose/schedule impact of an expedited Visual Inspection
  - Exceeds typical values in EPRI Report 2001-50 (6 m-rem / 2 days)

Plant	Dose (Rem)	Time to remove/replace insulation	Coil Stack Removal Required	Preparation Cost (not including dose)	Notes
A	>18.4	16+ days	No		74 RVHP's. Actual data from destructive removal in 1989.
B	~75	2000+ Man-Hrs	Yes	$0.5M to $2M, assuming no extension of the outage	97 RVHP's. Assumes destructive removal, with shroud lift.
C	~64	2000+ Man-Hrs	Yes	$0.5M to $2M, assuming no extension of the outage	102 RVHP's. Assumes destructive removal, with shroud lift.

Estimates will vary due to differences in insulation design and configuration, and also due to the configuration of head area equipment, such as the shroud, number of housings, cabling, etc.

CEOG 12

Insulation Configuration and Inspectability

- Summary of CE Insulation Configurations
- Some Westinghouse plants have similar configurations

	Design and Fabrication					
					Insulation	
Unit Name	NSSS Design	Nozzle Material Supplier	Head Fabricator	NRC Susceptibility Ranking	Type	Restricts Visual Inspectability
ANO 2	CE	SS/H	CE	Moderate	Reflective Contoured	Yes
Calvert Cliffs 1	CE	H	CE	Moderate	Reflective Contoured	Yes
Calvert Cliffs 2	CE	H	CE	Moderate	Blanket Contoured	No
Fort Calhoun	CE	H	CE	Moderate	Reflective Stepped	No
Millstone 2	CE	H	CE	Moderate	Encapsulated Contoured	Yes
Palisades	CE	H	CE	Low	Blanket Contoured	No
Palo Verde 1	CE	SS	CE	Moderate	Encapsulated Contoured	Yes
Palo Verde 2	CE	SS	CE	Moderate	Reflective Contoured	Yes
Palo Verde 3	CE	SS	CE	Moderate	Reflective Contoured	Yes
San Onofre 2	CE	SS/H	CE	Moderate	Encapsulated Contoured	Yes
San Onofre 3	CE	SS/H	CE	Moderate	Encapsulated Contoured	Yes
St. Lucie 1	CE	H	CE	Moderate	Encapsulated Contoured	Yes
St. Lucie 2	CE	SS/H	CE	Moderate	Encapsulated Contoured	Yes
Waterford 3	CE	SS/H	CE	Moderate	Reflective Contoured	Yes
Point Beach 2	W	H/B	BW/CE	Moderate	Block Contoured	Yes
Indian Point 3	W	H	CE	Moderate	Block Contoured	Yes
Kewaunee	W	H/B	BW/CE	Moderate	Block Contoured	Yes
Indian Point 2	W	H	CE	Moderate	Encapsulated Contoured	Yes

Integrated Approach

- Most CEOG plants are planning inspections at the next outage

Moderately Susceptible Plants	Inspection Type	Extent of Inspection at Next Refueling Outage	Date
1	TBD		Fall 01
2	VT	6 Penetrations	Fall 01
3	VT	Essentially 100%	Spring 02
4	TBD		Spring 02
5	VT	Essentially 100%	Spring 02
6	Surface or Volumetric	Up to 25% within the outage window	Spring 02
7	Volumetric or VT (if vol. unavailable)	Essentially 100% Essentially 100%	Spring 02
8	TBD		Spring 02
9	VT	Essentially 100%	Fall 02
10	VT	Essentially 100%	Fall 02
11	TBD		Fall 02
12	Volumetric or VT (if vol. unavailable)	Essentially 100% Essentially 100%	Spring 03
13	VT, or Volumetric	Essentially 100% Essentially 100%	Spring 03

This table based is based on a recent informal poll of the CEOG plants. Actual plans will be set forth in individual responses to Bulletin 2001-01

Integrated Approach

- Limited deferral of the visual inspection is appropriate for certain plants
  - Time to develop and refine inspection and removal/repair tooling
  - Time to study optimal removal strategies
  - Time to engineer insulation replacement
  - Reduced dose for insulation removal
  - Minimize outage impact
  - Allows ALARA efficient inspections

CEOG 15

Justification of Approach

- Minimal risk for 1 cycle deferral
- Immediate inspection would result in hardship for plants with restrictive designs
  - Inconsistent with ALARA policies
  - Dose and schedule in excess of expectations when bulletin was drafted
- Most plants are inspecting per the Bulletin
  - Integrated program will provide necessary information

CEOG 16

Justification - First

- All plants are greater than seven (7) EFPYs from ONS3
- Most plants in last half of top 45 ranking
- 13 plants are moderately susceptible
- 1 plant is low susceptibility

Name		Susceptibility	EFPYs to ONS 3
Oconee 3	B&W		0.0
Waterford 3	CE	Moderate	7.8
Calvert Cliffs 1	CE	Moderate	9.8
Calvert Cliffs 2	CE	Moderate	10.2
St. Lucie 1	CE	Moderate	10.3
San Onofre 2	CE	Moderate	10.7
San Onofre 3	CE	Moderate	10.8
St. Lucie 2	CE	Moderate	11.3
Millstone 2	CE	Moderate	14.3
Palo Verde 1	CE	Moderate	17.0
ANO 2	CE	Moderate	17.4
Palo Verde 3	CE	Moderate	17.5
Palo Verde 2	CE	Moderate	17.7
Fort Calhoun	CE	Moderate	17.9
Palisades	CE	Low	39.6

Justification - Second

- Visual and volumetric inspections performed to date for CE plants have not detected any leaking penetrations
  - Millstone
    - 1997, ECT 100%, shallow indications on 1 CEDM
  - San Onofre 2/3
    - Last 5 cycles, VT ~34% of penetrations, no leakage
  - Palisades
    - 1995, VT 100%, clean head, no leakage
    - 1995, ECT 8 ICIs, no indications
  - Waterford
    - 1997, VT 20%, no leakage
  - Calvert Cliffs
    - 2001, VT 8 ICI nozzles, no leakage
    - 1997, ECT Head Vent, no indications
  - St. Lucie 1
    - 2001, VT 2 CEDMs, no leakage

Justification - Third

- Most plants are planning to inspect per the Bulletin
- Near term outages are most affected by the timing of the Bulletin

Moderately Susceptible Plants	Inspection Type	Extent of Inspection at Next Refueling Outage	Next Scheduled Outage
1	TBD	TBD	Fall 01
2	VT	6 Penetrations Min.	Fall 01
3	VT	Essentially 100%	Spring 02
4	TBD	TBD	Spring 02
5	VT	Essentially 100%	Spring 02
6	Surface or Volumetric	Up to 25% within the outage window	Spring 02
7	Volumetric or VT (if vol. unavailable)	Essentially 100%	Spring 02
8	TBD	TBD	Spring 02
9	VT	Essentially 100%	Fall 02
10	VT	Essentially 100%	Fall 02
11	TBD	TBD	Fall 02
12	Volumetric or VT (if vol. unavailable)	Essentially 100%	Spring 03
13	VT, or Volumetric	Essentially 100%	Spring 03

This table based is based on a recent informal poll of the CEOG plants. Actual plans will be set forth in individual responses to Bulletin 2001-01

Justification - Fourth

- Cumulative results of the Integrated Inspection Program
  - Total CEOG penetrations in the moderate risk category = 1144

Outage Season	Fall 01	Spring 02	Fall 02	Spring 03
Penetrations inspected *	6	378	126	278
Cumulative Penetrations inspected *	6	384	510	788

* Data is pending final commitments from individual licenses

Justification - Fifth

- For plants deferring inspections, there is adequate time to properly design new insulation
  - Significantly reduce dose
  - More efficient and effective
  - Reduce the risk of extended outages
  - Allows the development of more effective long term plans
  - Improves the efficiency, effectiveness and accuracy of future inspections

CEOG 21

Justification - Sixth

- A qualitative review of the potential risk due to delaying the inspection shows that any increase in CDF is very small
  - Details available in handout

CEOG 22

Justification - Seventh

- Bulletin requirements allow some Moderately Susceptible plants to not inspect until late 2002 or early 2003
  - Based on the inspection schedules recently referenced in EPRI MRP-48
    - 8 plants have Fall 2001 outages
    - 13 plants have Spring 2002 outages
    - 9 plants have Fall 2002 outages
    - 4 plants have Spring 2003 outages

CEOG 23

Range of Proposed Actions

- Different plants are considering some or all of the following supplemental actions (see individual plant responses for actual commitments to the Bulletin)
  - Effective 100% visual/volumetric inspection during the next scheduled refueling outage following the completion of planning;
  - Report any penetration exposed during the current outage as part of the insulation removal/redesign planning;
  - Monitor the results of all industry inspections for potential impact on the decision to postpone short-term visual inspections;
  - Walkdown and document insulation configuration, and
  - Submit summary plans and schedules for penetration inspection program

CEOG 24

Summary

- CEOG plants have performed visual and volumetric inspections and found no leakage
- Some CE designed plants have a restrictive insulation configuration
  - Precludes an uncomplicated, visual inspection of VHP penetrations
- The impact of an expedited inspection without adequate planning will significantly increase dose and schedule
  - Without corresponding increase in safety
- Moderate Susceptibility Category CEOG plants are 7.8 to 17.9 EFPYs from Oconee 3

Summary (cont.)

- A significant number CEOG plants will inspect at the next refueling outage
  - The integrated results will provide information to the NRC regarding the CEOG fleet
- A qualitative review of the potential risk shows that any increase in CDF due to the deferral is small
- The Bulletin's requirements already allow several plants in the moderate susceptibility category to not inspect until early 2003

Summary (cont.)

- CEOG planning to continue to address Alloy 600 issues and is initiating a Strategic Plan for the long-term resolution of VHP issues
  - Methods for the prediction of crack susceptibility and initiation;
  - Methods for leakage and crack detection;
  - Methods for crack repair;
  - Methods for mitigation and prevention, and
  - Feasibility assessment for complete head replacement

Conclusion

- CEOG integrated approach is responsive to the Bulletin at a reduced dose

Discussion & Questions

CEOG

Risk Impact of Postponing CRDM Nozzle Inspection for One Cycle

David Finnicum

August 2001

Potential Initiating Events and Mitigation

- Postponing the CRDM nozzle inspection for one cycle might increase the probability of nozzle leak.
  - Postulated that CRM leak might lead to a CEA Ejection event
  - Dominant risk impact of CEA Ejection event is the attendant small Loss of Coolant Accident (LOCA) in the reactor head area

- Regarding potential impact on plant risk, we consider:
  - the increased likelihood of a leakage event,
  - the likelihood that a leakage event would lead to a CEA ejection event with the increased likelihood of a LOCA that would lead to significant fuel damage and release of radioactivity.

The potential increase in core damage frequency (CDF) can be estimated as follows:

$$\Delta CDF_{LOCA} = \Delta F_{CRDM\ LOCA} \times P_{Core\ Melt|CRDM\ LOCA}$$

Where:

- $\Delta F_{CRDM\ LOCA}$ = the increase in frequency of CRDM LOCA,
- $P_{Core\ Melt|CRDM\ LOCA}$ = the conditional probability that a CEA Ejection LOCA event will lead to significant core damage.

RG 1.174 defines an acceptably small increase in CDF

- The estimated increase in CDF can be compared with the criteria in Regulatory Guide 1.174.
  - acceptably small increase in CDF is less than 1.0E-6 per year. This criterion is intended to apply to permanent changes to the plant licensing basis. For a condition like the Alloy 600 inspection deferral issue where the proposed condition would be limited to one cycle, it would be reasonable to permit a somewhat higher increase in CDF.
  - A full risk assessment to quantify the change in CDF has not been performed. However, we believe that any increase in CDF is very small and well in line with the criteria of RG 1.174. The following discussion addresses each of the basic elements of the above risk equation.

Increase in Frequency of Leakage

Specifically,

$$\eta = \left[\frac{\sum_{i}^{N} t_i^{\beta}}{r} \right]^{1/\beta},$$

where:

t_i = age (EFPY, adjusted to 600 F head temperature using an Arrenius life-temperature adjustment) of the ith plant,

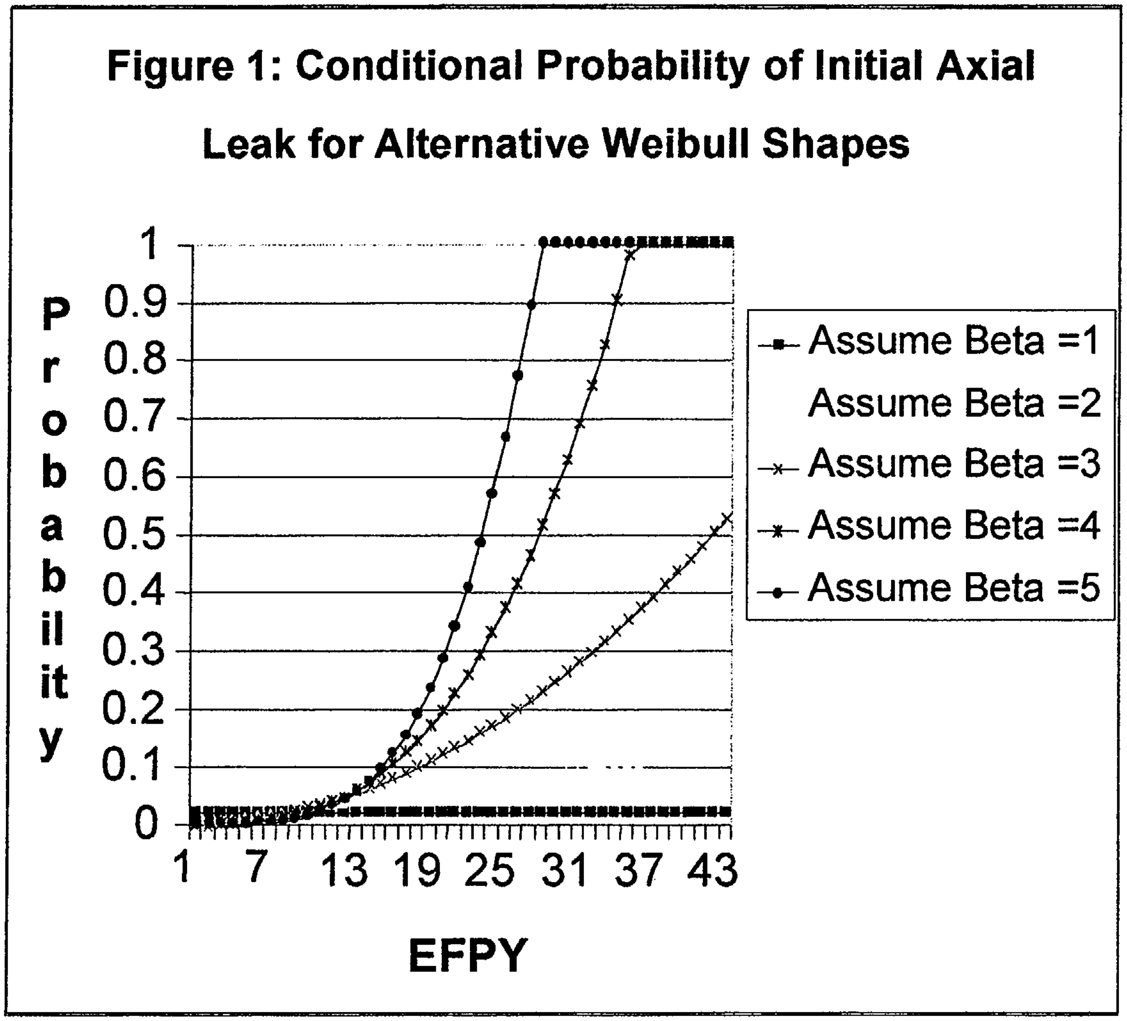
N = number of plants,

r = number of leaks (15),

η = scale parameter to be estimated (measured in units of t and known as the "characteristic life"),

β = shape parameter (whose value is assumed for this exercise).

Figure 1 - Probability of Leakage



Referring to Figure 1

- The temperature-adjusted plant age data are from Dominion Engineering. The estimated scale parameter along with the assumed shape parameter allow the calculation of a conditional probability of failure (aka "hazard rate," or failure rate) for various assumed values of the shape parameter (denoted as "Beta" in Figure 1) across the range of a typical plant's life.
- An assumed Beta of 1 gives the constant ("random") failure rate model typically used in PRA-type studies. The failure rate (about 2% per EFPY), or the probability of a leak initiating in the indicated year, is constant regardless of plant age. This is <u>not</u> typical for stress corrosion cracking. A Beta of 2 is the Rayleigh or "proportional (to age) growth model" in which the failure rate is proportional to plant age. Beta values of 3, 4, and 5 represent progressively more aggressive corrosion progress.
- Note that for plants under the age of about 12 EFPY (at 600F), the failure rate can appear constant and small regardless of the underlying model. As the plant ages, however, the failure rate can "take off." Equivalently, plants below a certain age may not need to do something now but older plants might need to take immediate action. Similarly, plants operating with a head temperature above or below the reference value of 600F will have their projected failure rate curve shifted up or down according to the Arrenius adjustment equation.

CRDM Nozzle Failure Rate

Nominal Failure Rate is 1.12E-5 pipe breaks per reactor year

- EPRI TR-102266 “Pipe Failure Study Update,” April 1993, provides a failure rate estimate for PWR Reactor Coolant System piping with inside diameters between 2 and 6 inches as being 1.70E-11 failures per hour (i.e., 1.5E-7 per year) per length of pipe.
- A typical PWR has approximately 75 CRDM nozzles, each of which can conservatively be represented as a “length of pipe.” Therefore, the random failure rate for the full set of CRDMs can be estimated as 75 x 1.5E-7 = 1.12E-5 pipe breaks per year.
- This is a small fraction of the total small break LOCA frequency which is typically about 1.0E-3 breaks per year.

Small break LOCA frequency would only increase by about 10%

- Even if the unreliability of the CRDM nozzles were to increase by a factor of 10, the CRDM contribution to the overall small LOCA frequency would only be 1.12E-4. Thus, the small break LOCA frequency would only increase by about 10%

CEA Ejection Event

- CEA Ejection events are included within design basis of all CEOG PWRs.
- CEA Ejection Event analyzed as a reactivity insertion event
- The Design Basis analyses show the CEA Ejection event is accommodated with no significant core damage.
- CEOG plants normally operate in an All Rods Out (ARO) mode which substantially reduces the chance of a positive reactivity insertion due to a CEA being ejected from the core
- Since the early 1970s, NRC and industry have performed PRAs for PWRs. All known initiating events, including CEA Ejection were evaluated for potential for contributing to risk. In most if not all PRAs, CEA Ejection was determined not to be a significant initiating event. The consequences are not substantially different from other small LOCA.
- The average value of the conditional CDF for CEOG plants, given that a small break LOCA occurs, is 2.15E-3.

CRDM Nozzle Leak (Small LOCA) Contribution to Core Damage Frequency

- Random failure rate for the full set of CRDM nozzles estimated to be **1.12E-5** pipe breaks per year
- Average Conditional CDF given a small LOCA is estimated to be **2.15E-3** for CEOG plants,
- Nominal $CDF_{CRDM\ Small\ LOCA}$ is about:

$$CDF_{CRDM\ Small\ LOCA} = 1.12E\text{-}5 \text{ pipe breaks/year} \times 2.15E\text{-}3 \text{ Core Melts/ pipe break}$$

$$= 2.4E\text{-}8 \text{ per year}$$

- Based on Figure 1, CRDM nozzle unreliability can be conservatively estimated to increase by less than a factor of ten for CEOG plants. Thus, the increase in the small LOCA frequency ($\Delta F_{CRDM\ Leak}$) would be 10 x 1.12E-5 = 1.12E-4 /yr, and the increase in CDF (ΔCDF_{LOCA}) would be 10 x 2.4E-8 = 2.4E-7/yr.
- For a typical PWR, with a total CDF of about 1.0E-5 per year, an increase of 2.4E-7 per year represents a 2.4% increase in total CDF. RG 1.174 defines an increase in CDF of less than 1.0E-6 as being a "very small" increase.