LOCA-LOOP Requirement
Proposed Agenda

9:00	Define the industry's expectations ■ what is the end point ■ what is the process	Adrian Heymer (NEI)
9:15	How do the BWRs fit into this end point and process	Terry Rieck (Exelon)
9:30	Update and discussion on LOOP data ■ definition of LOOP ■ LOOP data ■ conditional LOOP given LOCA data ■ Impact of degraded grid on LOOP probability	Frank Rahn (EPRI)
10:15	Break	
10:30	Update and discussion on LOCA data ■ IGSCC improvement factor ■ NUREG 5750 data evaluation	S. Visweswaren (GE)
11:00	Discussion on delayed LOOP affect on LOCA analysis for BWRs	Dan Pappone (GE)
11:15	Discussion on single failure ■ independent rule or part of LOCA/LOOP	TBD (NRC)
11:30	Schedule and future industry support activities	All
12:00	Adjourn	

GDC 35 – Enhancement End State -- LOOP-LOCA Task

- Issuance of an amendment to GDC 35

- Eliminate the requirement to analyze for a LOCA event coincident with, or followed by a loss of offsite power without assuming a single failure.

BWR LOCA/LOOP

Terry Rieck (Exelon)
Chairman BWROG RIR Option 3 Committee
NRC Presentation
October 17, 2001

LOCA/LOOP Option

- Drop the requirement that LOOP be postulated in larger, more unlikely design-basis LOCAs
- Consider LOOP for all other LOCAs
- Delayed LOOP evaluated as not needed under a risk-informed approach

Potential Safety Benefits

- Focus Industry and NRC on Risk-Significant SSCs
- Improved diesel generator reliability
  - slower start times
  - load sequencing based on more risk-significant scenarios
  - less challenging load sequencing
  - less challenging testing
- Improved ECCS equipment reliability
  - slower valve stroke times

Potential Burden Reduction

- Margin gain to LBLOCA ECCS criteria
  - peaking factors
  - power uprate
  - Relaxation in ESF equipment assumptions (e.g. valve stroke actuation times, pump flows)
- Relaxation in DG start times
- Relaxation in DG redundancy
- Relaxation in TS allowed outage times & surveillances for DGs, ECCS and other electrical equipment

Needed Technical Analysis

- LOCA frequencies
  - Factor in IGSCC mitigation
- Conditional LOOP probabilities
- Consequences of delayed LOOP
  - For break sizes not excluded
- Review risk implications of plant changes

Potential BWR Design Basis Changes

- LBLOCA (off-site power now available)
  - eliminate simultaneous LOOP
  - immediate ECCS pump start
- SBLOCA (assumes LOOP but relies on steam driven or diesel driven pumps)
  - DG start delayed
  - must evaluate delayed LOOP impact

GE Nuclear Energy

LOCA and LOOP Frequency

Presented to NRC Staff at Rockville, MD
Meeting: Potential Changes to 10CFR 50.46

by GE and BWROG
S. Visweswaran
October 17, 2001

Overview

- *Objective*
- *Introduction*
- *Acceptance Criterion*
- *LOCA Frequency*
- *LOOP frequency*
- *Combined LOCA and LOOP frequency*
- *Conclusions*

Objective

- *Evaluate if the combined probability of (liquid) loss-of-coolant-accident (LOCA) and a loss of offsite power (LOOP) is low enough to justify elimination of 10 CFR 50.46 requirement that reactors be designed for a coincident occurrence of both events.*

Introduction

- *Current regulations require the reactors be designed for a coincident occurrence of LOCA and LOOP*
- *This regulation requires in emergency diesel generators (DG) to start in a very short period causing undue wear-out of DGs in tests.*
- *Elimination of this requirement is being considered as part of Option 3*
- *SECY-01-0133 has estimated a low combined frequency of LOCA and LOOP*
  - *SECY uses the LOCA frequency from NUREG 5750. BWROG evaluation shows a lower value*
  - *SECY uses LOOP frequency from NUREG/CR-6538. EPRI evaluation shows a lower value.*
- *BWROG finds the coincident frequency is even lower than the SECY estimate*
- *Coincident frequency of LOCA and LOOP is negligible enough to justify elimination of the subject requirement.*

Acceptance Criterion

- *Appropriate criterion would be the one identified for "Rare Initiators"*
- *Collective frequency of all rare initiators should be <1 E-5 per year*
- *Expected frequency of rare Initiator of a specific type should be 'demonstrably' < 1E-6 per year*

LOCA Frequency per NUREG 5750

- *BWR LOCA frequency is evaluated based on operating experience of 710 calendar years*
- *Large LOCA frequency is taken to be breaks in pipes of sizes 5 inches or more in diameter. (Some PRAs also include breaks in 4 inch diameter pipes as large LOCA)*
- *The crack frequency estimate is based on 34 through-wall cracks in large pipes in 710 calendar years*
- *There is a conditional probability that the cracks will lead to a break.*
- *All cracks are based on inter-granular stress corrosion cracking (IGSCC) mechanism*
- *However, all operating USBWR plants have implemented IGSCC countermeasures. Therefore, the crack frequency based on operating history has to be adjusted before using for predicting future crack rates*

LOCA Frequency per NUREG 5750

LOCA Frequency = $(F_{TW})(P_{R/TW})(IGSCC_{BWR\text{-}only})$

where,

F_{TW} = Frequency of through-wall cracks in primary (un-isolatable) piping
= (Number of through-wall cracks/number of calendar years of operating experience)

$P_{R/TW}$ = Mean probability of rupture given a through-wall crack
= 2.5/(nominal pipe diameter in mm), for pipe diameters from 1 to 10 inches (from 25 to 250 mm)
= 0.01, for pipe diameters greater than 10 inches (250 mm)

$IGSCC_{BWR\text{-}only}$ = IGSCC FOI (Factor of improvement), for BWRs only = 1/20=0.05

BWROG Evaluation of IGSCC FOI

- *IGSCC Factor of Improvement (FOI) of 20 was the improvement goal for the improved IGSSC resistant materials that were tested*
- *Test conditions were quite aggressive (not typical of plant conditions) to shorten the test time to a reasonable value*
  - *High loads, cycling and 8 ppm oxygen environment*
- *FOI for Nuclear Grade and low carbon stainless steel materials ranged from 30 to 70*
  - *Smaller FOI for cases where high loads eliminated beneficial effects of residual stresses due to induction heating stress improvement (IHSI) or heat sink welding (HSW)*
  - *Some cases FOI lower due to termination of test due to time constraint*
- *With the introduction of hydrogen water chemistry or noble metal chemical addition (NMCA) at most BWR plants, calculated FOI are expected to be higher since crack growth phase will be now longer*

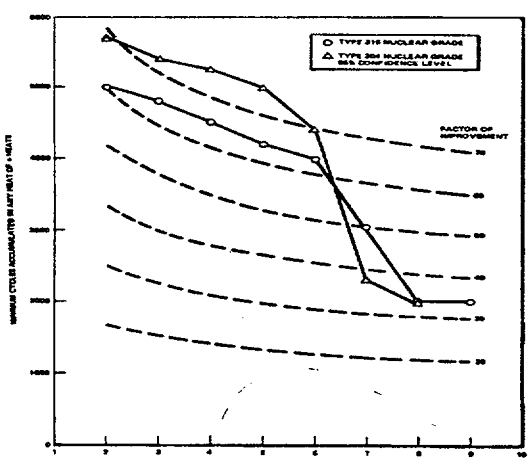
BWROG Evaluation of IGSCC FOI (Cont'd)

- ***Field leakage frequency estimate in NUREG-5750 based on data up to 1997 implies a FOI of 33***
  - ***FOI is expected to be better than 33 if data up to now are considered since no leakage incident(s) between 1997 and now***

An IGSCC FOI of at least 33 is Justified

SV-9

BWROG Evaluation of IGSCC FOI (Cont'd)



SV-10

Mean Probability of Rupture Given a Thru-Wall Crack

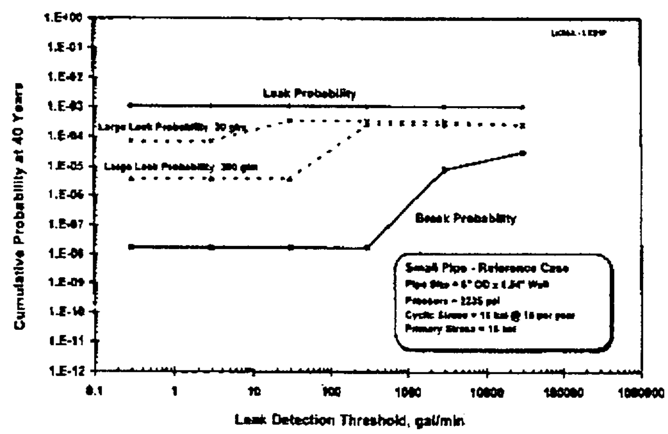
- *Quantitative fracture mechanics evaluations indicate lower $P_{R/TW}$ value than the value of 1E-2 assumed in NUREG/5750*
- *Simonen, et al paper indicates a $P_{R/TW}$ value in the range of 1E-4*
  - *Most BWRs can detect a change of 1 gpm in unidentified leakage*
  - *Duane Arnold plant was scrammed when unidentified leakage reached 3 gpm*
- *NUREG/CR-4792 implies a $P_{R/TW}$ value of 1E-2, but it is very conservative since it does not consider in-service inspection (ISI) or the IGSCC mitigation measures*
  - *$P_{R/TW}$ value is expected to be at least one order of magnitude lower when credit for ISI and mitigation measures is taken*

Mean Probability of Rupture Given a Thru-Wall Crack (cont'd)

- *NUREG/CR-6004 showed a wide variation in the calculated rupture probability due to SSE at a given leakage rate*
  - *$P_{R/TW}$ varied from 5E-2 to 5E-7 for BWR cases*
  - *Analysis implicitly assumes probability of safe shutdown earthquake (SSE) occurrence as 1.0*
  - *If SSE probability is included, the high end number is expected to be considerably less than 1E-3*

The value for medium and large pipes is $\leq$ 1E-3

Mean Probability of Rupture Given a Thru-Wall Crack (cont'd)



SV-13

LOCA Frequency: NUREG 5750 Vs BWROG Value

- *LOCA Frequency =* $(F_{TW})(P_{R/TW})(IGSCC_{BWR\text{-}only})$
- *NUREG 5750 Value = (34/710)(0.01)(1/20)*
  = 2.4 E-5 per year
- *BWROG Value = (34/710)(0.001)(1/33)*
  = 1.5E-6 per year

SV-14

LOOP Frequency per EPRI

- *NUREG/CR-6598 estimates probability of LOOP following plant trip and ECCS actuation to be 6.0E-2 for BWRs and 1.4E-2 for PWRs based on certain events*
- *EPRI has evaluated the same events identified in NUREG and has concluded only one event event in 2735 is relevant. This yields a best estimate of 3.7E-4 for both BWRs and PWRs*
- *EPRI identifies 5 other events where availability of offsite power was briefly in doubt*
- *GE has used the EPRI data to model the LOOP frequency. Assumed 6 events out of 2735 to obtain the best estimate probability and uncertainty parameters*
  - *Best estimate of probability of LOOP following plant trip and ECCS actuation is 2.2E-3*

Expected Combined LOCA + LOOP Frequency

- *Expected frequency of LOCA : 1.5 E-6 per year*
- *Probability of LOOP following LOCA: 2.2E-3*
- *Expected Combined LOCA + LOOP frequency: 3.3 E-9 per year*
- *This is significantly less than the acceptance criterion of 1E-6 per year*
- *LOCA + LOOP frequency for Medium LOCA is also < 1.0E-6 per year*

Conclusion

- *For Large LOCA, with BWROG estimate of LOCA frequency and EPRI's estimate for LOOP frequency, the expected frequency of LOCA + LOOP is 3.3 E-9 per year*
- *This is significantly below the acceptance criterion of 1E-6 per year*
- *For Medium LOCA also, the LOCA+LOOP frequency is <1.0E-6 per year*
- *Since values are "demonstrably' smaller than the acceptance criterion for frequency of a single rare initiator, we recommend elimination of the regulation*

Discussion of LOOP Frequency and Degraded Grid Data

FRANK J. RAHN
JOHN GAERTNER

EPRI

Potential Changes to 10CFR 50.46 Meeting
NRC White Flint North
October 17, 2001

1 EPRI

Update of EPRI Report 1000158 Losses of Off-Site Power at US Nuclear Plants - Through 2000

2 EPRI

Single Year LOOP Events while at-power -per generating unit year

Year	# of Events	Total Unit Calendar Years	Losses per Gen. Unit Year
2000	1	103	0.01
1999	2	103	0.02
1998	3	103.2	0.03
1997	4	106.4	0.04
1996	5	108.0	0.05
1995	2	107.2	0.02
1994	0	107.0	0

* because there are few LOOP events per year while on-line, and each adds 0.01 to the loss probability, the year to year experience will vary and can be be significantly impacted by the number of severe storms in a given year

3

EPRI

Loss of all Off-Site Power experience for Year 2000

-for events that occurred while at-power

- There was one LOOP event at U.S. nuclear plants during the year 2000 while the plant was on-line
  - It occurred at Diablo Canyon 1 on 05/15/2000
  - The safety busses were without power for over 33 hours
  - The cause of the loss was an indoor 12 kV bus connection failure and fire
  - The plant tripped from 100% power and the 3 EDGs started and loaded
- All other LOOP-related events that occurred in year 2000 were either partial losses of off-site power or occurred while the plant was in an outage

4

EPRI

Longer term average of LOOP events while at-power -per generating unit year

AVERAGE FOR DESIGNATED RANGE OF YEARS

Range of years	Duration of LOOP	# of Events	Total Unit Calendar Years	Losses per Gen. Unit Year
5 years (1996-2000)	Longer than 30 Minutes	15	523.6	0.029
	Less than 30 Minutes	0		---
	Total	15		0.029
10 Years (1991-2001)	Longer than 30 Minutes	29	1060.4	0.027
	Less than 30 Minutes	6		0.006
	Total	35		0.033

EPRI

Loss of all Off-Site Power experience for Year 2000 -for events that occurred while off-line

- There were 3 LOOP events while the plant was off-line during the year 2000
- These occurred at
  - Brunswick 1 on 03/03/2000
  - Farley 1 on 04/09/2000
  - Davis Besse 1 on 04/22/2000

EPRI

Loss of all Off-Site Power experience for Year 2000
-for events that occurred while off-line

In the following 3 events, the plants were in a condition and configuration, and had activities underway, that would not be permitted when at power

- Brunswick 1 on 03/03/2000
  - Unit was in 6th day of a refueling outage
  - During relay trip testing, a switch positioning error resulted in a LOOP
  - The EDGs started and loaded. Off-site power was restarted after 9:09 hours while the operators investigated the situation, but could have been restored much sooner if needed.
- Farley 1 on 04/09/2000
  - Reactor was defueled
  - The protection relay was activated during panel cleaning and de-energized a bus
  - An EDG started and loaded. Off-site power was restored after 19 min.
- Davis Besse 1 on 04/22/2000
  - Reactor was defueled
  - The inservice startup transformer tripped-off when a technician opened the case of a mis-identified relay during bus transfer tests
  - The EDGs started and loaded. Off-site power was restored after 10 min.

7 EPRI

Comparison of EPRI LOOP/LOCA Results with SECY 01-133

8 EPRI

NRC's SECY 01-133 Analysis

- SECY 01-133's analysis based on 1997 report, NUREG/CR-6538
- EPRI believes NUREG/CR-6538 significantly overstates P(LOOP|LOCA)

9

EPRI

NUREG/CR-6538 METHODOLOGY

- NUREG/CR-6538 recognizes that in US LWR operating history, no LOCAs followed by immediate LOOP have occurred
- The report assumes that:
  - TRIP-LOOP and ECCS ACTUATION-LOOP events are surrogates for LOCA-LOOP events
- Reviewed LERs for period 1984-93
- Identified 12 LERs describing trips or ECCS actuations followed by 'LOOP'

10

EPRI

TRIP-LOOP AND ECCS-LOOP EVENTS SHOULD BE COMBINED

- NUREG/CR-6538 estimates dominated by few ECCS actuations
- Assumption that starting of EDGs = LOOP is probably not correct
- NUREG/CR-6538 added P (LOOP|TRIP) and P(LOOP|ECCS) to estimate P(LOOP|LOCA)
- Events should be aggregated not added
  - Trip and ECCS actuations and
  - BWR and PWR events
  - Combined total of such events was 2735

11 EPRI

EPRI's interpretation of LERs analyzed in NUREG/CR-6538

- 1986 ROBINSON 2 event was a LOOP
- 5 other events involved complicated sequences where availability of offsite power was briefly lost
- In 6 other events power remained available at all times at a minimum of one safety bus
  - EPRI does not characterize these events as LOOPs

12 EPRI

EPRI recommendation for probability of LOOP given a LOCA

- **Upper bound**

  6 events / 2735 events = 2.2 E-3

- **Lower bound**

  1 event / 2735 events = 3.7 E-4

- **EPRI's best estimate is:**

  3.7E-4 < P(LOOP given LOCA) < 2.2E-3

13 EPRI

IMPACT OF DEGRADED GRID ON LOOP EVENTS

Perspective

14 EPRI

Industry and NRC Concerns

- **Heightened awareness over potential transmission voltage instability and offsite power supplies due to:**
  - **Increased power transfers between regions**
  - **Lack of transmission capacity**

15

EPRI

Recent Industry Steps Taken to Address Concerns

- **INPO SOER 99-1**
- **Transmission Control Agreements**
  - **Impact of potential & subsequent loss of large generator**
  - **Load shed priorities**
- **Equipment upgrades and procedural changes to increase operating flexibility**
  - **Operational impact and measures to monitor for and address double sequencing, fast transfer problems, and voltage margin for starting large loads**

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EPRI

INPO SOER 99-1

- INPO Issued SOER 99-1 to ensure:
  - communications with grid operators are robust
  - operators know how to respond to grid disturbances
  - design assumptions and trip set points are valid
  - plant switchyard equipment is adequately maintained
- Industry Response
  - Revised procedures (e.g., surveillance, instrumentation inaccuracy, communication with transmission providers)
  - Upgraded system studies (e.g., dynamic studies, generator reactive capability, energy management systems, etc.)
  - Plant upgrades (e.g., load tap transformers, additional capacitor banks, FACTS devices, etc.)

17 EPRI

Conclusions

- 2000 LOOP experience consistent with 10-year average of 0.03 losses per generating year
- EPRI analysis of the data referenced in SECY 01-133 yield more than a order of magnitude lower estimates of P(LOOP given a LOCA)
- Recent experience with degraded transmission grid environment suggest that INPO recommendations and ISO/RTO protocols to protect nuclear units are working (both for voltage support and LOOP)

18 EPRI

GE Nuclear Energy

Delayed LOOP Effect on LOCA Analysis

Presented to NRC Staff at Rockville, MD

by GE and BWROG
Dan Pappone
October 17, 2001

Overview

- Purpose
- Introduction
- Basic BWR break spectrum response
- Time period when D/G power is required
- LOCA analysis methods for delayed LOOP
- Conclusions

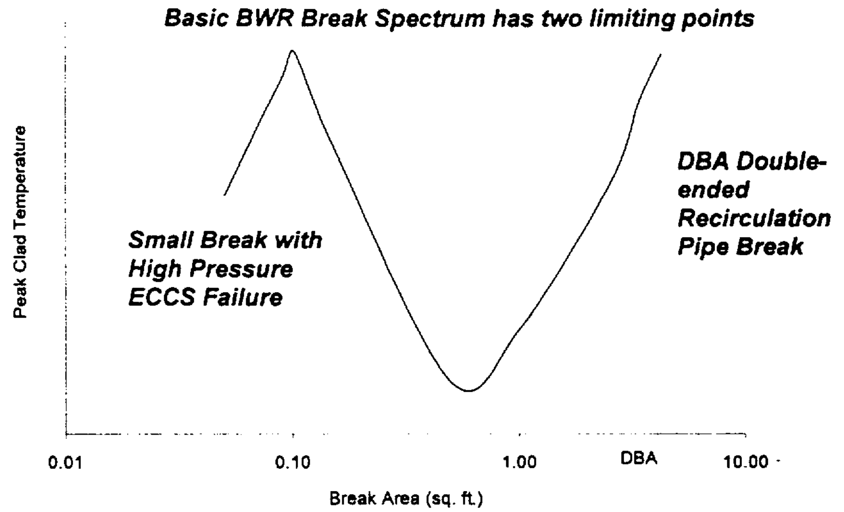
Purpose

- *Determine impact of delayed LOOP on LOCA analysis results*
- *Use RIR approach to address delayed LOOP*

Introduction

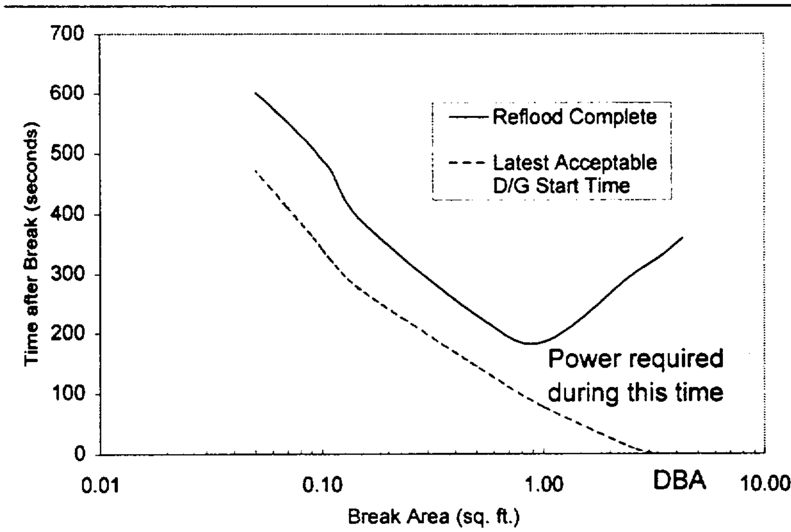
- *Current regulations require the reactors be designed for a combined occurrence of LOCA and LOOP*
- *Large Break LOCA requires rapid diesel start to assure adequate core cooling*
- *Uninterrupted power is required during core reflooding phase*
- *Delayed LOOP can interfere with bus loading sequence and delay or interrupt ECCS injection*

Basic BWR Break Spectrum Response



DCP-5

Time Period when D/G Power is Required



DCP-6

Time Period When D/G Power is Required

- *Using current 50.46 models and evaluation basis:*
  - *Large break LOCA has little or no margin available to accommodate delayed LOOP during first 6-7 minutes of event*
  - *Margin to accommodate delayed LOOP increases as break size decreases*
  - *Small break LOCA requires uninterrupted power for 3 minute duration*
    - *Time when power is required is a function of break size*
- *Core is quenched when reflooding is complete – margin is available after reflooding to accommodate a late delayed LOOP*

LOCA Analysis Methods for Delayed LOOP

- *Use RIR approach to eliminate delayed LOOP for LOCA analysis*
- *LOCA plus delayed LOOP not probable for >0.1 ft^2 break size*
  - *Break size not probable*
- *<0.1 ft^2 break size*
  - *5+ minutes available to accommodate delayed LOOP*
  - *Delayed LOOP expected to occur in first few seconds to 1 minute*
- *Delayed LOOP does not impact LOCA analysis when using RIR approach*

Conclusion

Delayed LOOP does not have to be considered under RIR approach