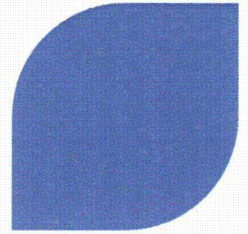


Small Break Loss of Coolant Accident - MOX

NRC Meeting
Rockville, MD
December 10, 2012

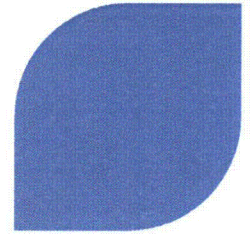


Agenda



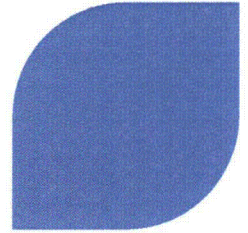
- ▶ **Objectives**
- ▶ **MOX project goals: Small Break Loss of Coolant Accident (SBLOCA) methodology**
- ▶ **Overview of the UO₂-based SBLOCA analysis methodology**
 - ◆ EMF-2328PA Revision 0
 - ◆ EMF-2328P Revision 0 Supplement 1
- ▶ **Overview of the MOX SBLOCA topical report**
 - ◆ EMF-2328 Revision 1
- ▶ **Summary**
- ▶ **Next Steps**

Objectives



- ▶ **Summarize current SBLOCA methodology**
- ▶ **Summarize SBLOCA MOX methodology approach**
 - ◆ Decay heat
 - ◆ Fuel rod modeling
- ▶ **Obtain NRC feedback on SBLOCA MOX topical report content**
 - ◆ Applicability of retained models and methods
 - ◆ Acceptability of approach for MOX related changes
- ▶ **Obtain NRC feedback on schedule**

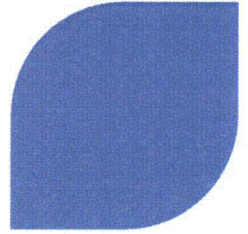
MOX Project Goals



► NRC approval of SBLOCA MOX topical report

- ◆ Pre-submittal meeting (strategy and scope) - today
- ◆ Pre-submittal meeting (content) – 3rd quarter 2014
- ◆ Topical submittal to NRC – 4th Quarter 2014
- ◆ Post-submittal meeting – 1st Quarter 2015
- ◆ Additional Meetings/Technical Audits as needed
- ◆ Requested NRC approval – 4th Quarter 2016

SBLOCA Overview



► Five phases:

◆ Forced flow

- Single phase break flow, slow-steady depressurization approaching steam generator (SG) pressure
- In contrast, a LBLOCA has a rapid and very chaotic depressurization

◆ Natural circulation

- Ends when the system evolves to a two-phase state and natural circulation by density differences can no longer be sustained

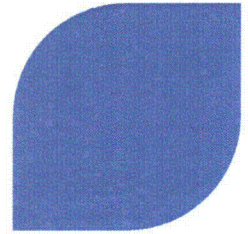
◆ System drain down and loop seal clearing

◆ Boil-off

◆ Core recovery

- Begins when ECCS injection reaching the vessel matches the boil-off rate

Overview of Current SBLOCA Methods - EMF-2328 Revision 0



▶ Reviewed by the NRC – SER dated March 2001

▶ Appendix K- based analysis approach

▶ Computer codes

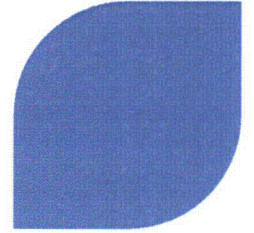
◆ RODEX2

- Provides initial fuel rod conditions to S-RELAP5
 - Burnup-dependent effects

◆ S-RELAP5

- Evolved from ANF-RELAP code
- Calculates overall thermal-hydraulic response
- Principal computer code used for the analysis of the SBLOCA event
- RODEX2 module within S-RELAP5
 - Power-dependent effects

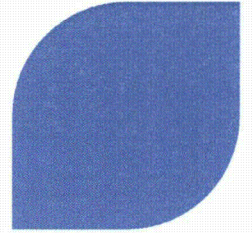
Overview of Current SBLOCA Methods - EMF-2328 Revision 0 (continued)



► Benchmarks

- 2-D Flow Tests
- Semiscale S-UT-8
- LOFT LP-SB-3
- UPTF-A5RUN11E
- BETHSY Test 9.1b

SBLOCA EMF-2328 Revision 0 Supplement 1



► EMF-2328 Revision 0 Supplement 1

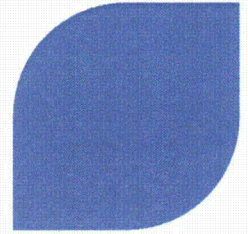
◆ Changes

- Spectrum of break sizes
- Core bypass modeling
- Reactivity feedback
- Delayed RCP trip
- Biasing of input parameters
- Loop seal clearing
- Break in attached piping
- Core nodalization

◆ Post-submittal meeting with NRC in November, 2012

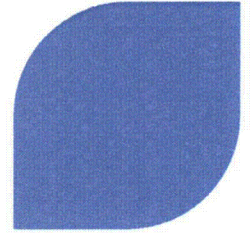
◆ Dates to be determined for RAls and Draft SER

Base for SBLOCA MOX Topical Report



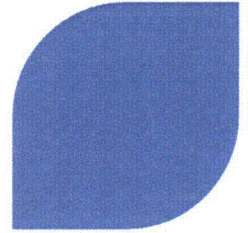
- ▶ **SBLOCA MOX Topical starting basis:**
 - ◆ EMF-2328PA Revision 0
 - ◆ EMF-2328P Revision 0 Supplement 1
- ▶ **Replaces RODEX-2 fuel rod models with GALILEO**
 - ◆ Addresses past issues regarding treatment for thermal conductivity degradation
 - ◆ Includes explicit models for addressing MOX fuel rods
- ▶ **Incorporates MOX Decay Heat**

Start of Proprietary Information



► **Start of proprietary meeting**

SBLOCA EMF-2328 Revision 0 Supplement 1



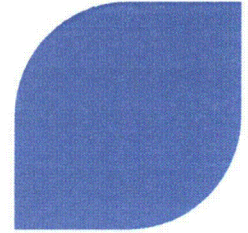
► EMF-2328 Revision 0 Supplement 1

◆ Changes



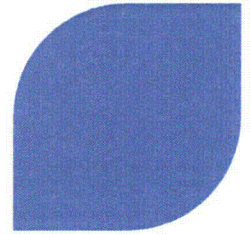
- ◆ Post-submittal meeting with NRC in November, 2012
- ◆ Dates to be determined for RAls and Draft SER

Base for SBLOCA MOX Topical Report



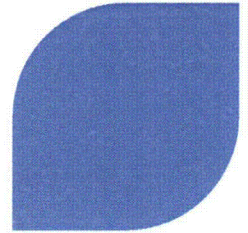
- ▶ **SBLOCA MOX Topical starting basis:**
 - ◆ EMF-2328PA Revision 0
 - ◆ EMF-2328P Revision 0 Supplement 1
- ▶ **Methodology critical features include**
 - ◆ Moody critical break flow
 - ◆ Complete boiling curve (Treated per reflood sections of App. K)
 - ◆ Return to nucleate boiling permitted
 - ◆ Treatment of loop seal clearing
 - ◆ Pump suction piping elevations
 - ◆ System volume distribution and water traps
 - ◆ Break in attached piping
 - ◆ RC pump trip studies
 - ◆ Core mixture level calculation

Items to be Addressed for SBLOCA MOX Analyses



- ▶ Fuel rod addressed by use of GALILEO models:
 - ◆ Stored energy
 - Higher energy within the MOX pellet will affect cladding temperatures early in the SBLOCA transient
 - ◆ Gap conductance
 - Changes in MOX fission gas release and composition
- ▶ Decay heat
 - ◆ MOX fuel will have a different decay heat curve which will be addressed
- ▶ Core specific MOX effects will be addressed
 - ◆ Examples include reduction in delayed neutron fraction, scram worth, and kinetics feedback mechanisms.
 - ◆ Addressed by use of ARCADIA code system to provide kinetics data

SBLOCA MOX Topical Report



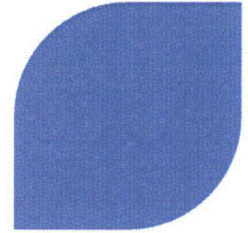
► Update methodology to reflect use of:

◆ GALILEO

- Replaces RODEX2
- Provides initial fuel rod conditions to S-RELAP5 (addresses initial stored energy and gap conductance change for MOX)
- Accounts for increased He production and fission gas release in MOX as well as material impacts

◆ S-RELAP5

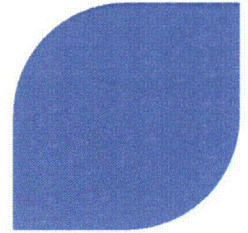
- GALILEO module within S-RELAP5



► MOX Decay Heat Modeling

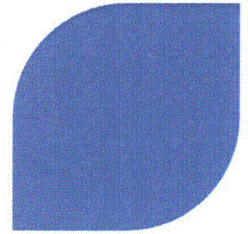
- ◆ Based on the ORIGEN computer module in the SCALE5 code system
 - Follows NUREG/CR-6972, “Validation of SCALE5 Decay Heat Predictions...”
- ◆ Benchmarked to UO_2 measured data supporting the 1979 ANSI/ANS-5.1 Licensing Standard
 - Will achieve equal or higher 95/95 uncertainties than that used for UO_2 small break LOCA.
 - Benchmarking to incorporate 2005 ANSI/ANS-5.1 database as well as separate measurements of PuO_2 data.
- ◆ Will be consolidated into a bounding small-break LOCA decay heat model for safety analysis.

SBLOCA MOX Topical Report



- ▶ **Converge RLBLOCA and SBLOCA S-RELAP5 models.**
 - ◆ Incorporating the RLBLOCA S-RELAP5 reactor vessel model into the SBLOCA model
- ▶ **Provide sample problem calculations: W4, W3, and CE**
- ▶ **Restructure submittal to reflect guidance of RG 1.203 (EMDAP)**

SBLOCA MOX Topical Report (cont.)



► Assessment base

◆ Retains Original Benchmarks

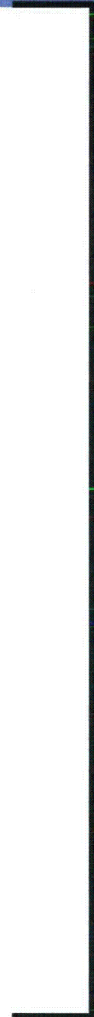
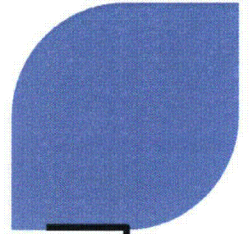
- BETHSY Test 9.1b
- UPTF TRAM A5

◆ Replaces other previous benchmarks with:

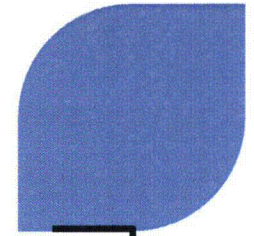
- ROSA 5%
- LOFT L5-1
- LOFT L3-6
- BETHSY Test 6.2 TC

◆ Revised assessment database provides better validation against critical SBLOCA phenomena

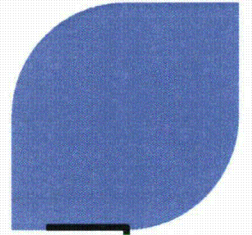
Assessment Base



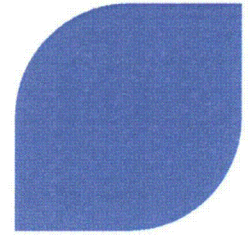
Assessment Base (cont.)



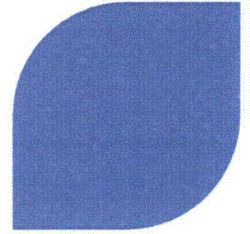
Assessment Base (cont.)



Evaluation Model Development and Assessment Process (EMDAP)



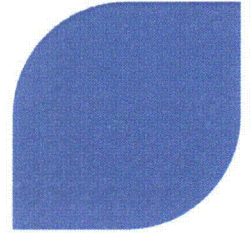
- ▶ **Regulatory requirements**
- ▶ **Scenario identification**
- ▶ **Evaluation model requirements**
 - ◆ Phenomena Identification and Ranking Table (PIRT)
- ▶ **Assessment data base summary**
 - ◆ Scaling analysis
- ▶ **Evaluation model description**
- ▶ **Assessment results**
- ▶ **Evaluation model implementation**
 - ◆ Sample problem
- ▶ **Quality assurance program**
 - ◆ Configuration control, peer reviews



▶ SBLOCA topical report content

- ◆ EMDAP
- ◆ GALILEO
- ◆ PIRT
- ◆ **S-RELAP5 code development**
 - MOX decay heat
- ◆ **Benchmarks**
 - LOFT L5-1, L3-6
 - BETHSY 6.2 TC, 9.1b
 - ROSA 5%
 - UPTF TRAM A5
- ◆ **Sample problems**

Next Steps



- ▶ **Pre-submittal meeting - 3rd Quarter 2014**
- ▶ **Topical report submittal – 4th Quarter 2014**
- ▶ **Post-submittal meeting – 1st Quarter 2015**
- ▶ **NRC SER - 4th Quarter 2016**