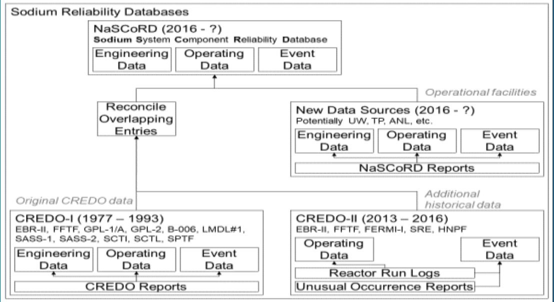
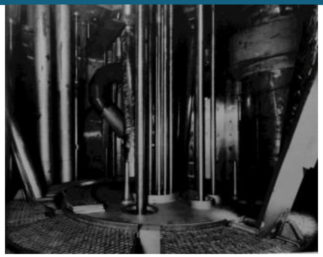
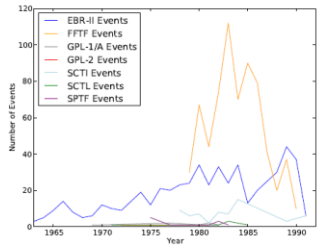
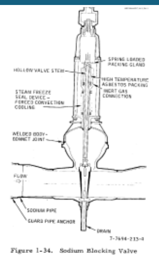
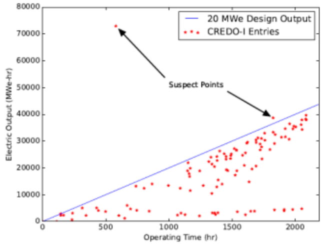
Sodium Valve Performance in the NaSCoRD Database











PRESENTED BY

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Motivation

Knowledge Management and Preservation

- US operational data from reactors and test loops was feared lost after ORNL lost control of the data in the mid-1990s.
- In 2016, JAEA transferred the "flat" version of the US portion of the Centralized Reliability Data Organization (CREDO) database.

Future test complex insights

- CREDO contains failure data and operational records from the FFTF and EBR-II reactors and the WARD and ETEC loops.
- New loops will use similar physical components to those used in the historical facilities and can learn from their experiences.

Probabilistic Risk Assessment (PRA) support

- CREDO data was used to support MONJU, PRISM, and EBR-II PRAs.
- This data can be a valuable resource to future SFR PRAs.

This paper is the first in a series of papers focusing on various components in the database

Outline

Overview of the NaSCoRD Database

- Database Overview
- Types of Components
- Data Quality Efforts

Focus on Sodium Valve Insights

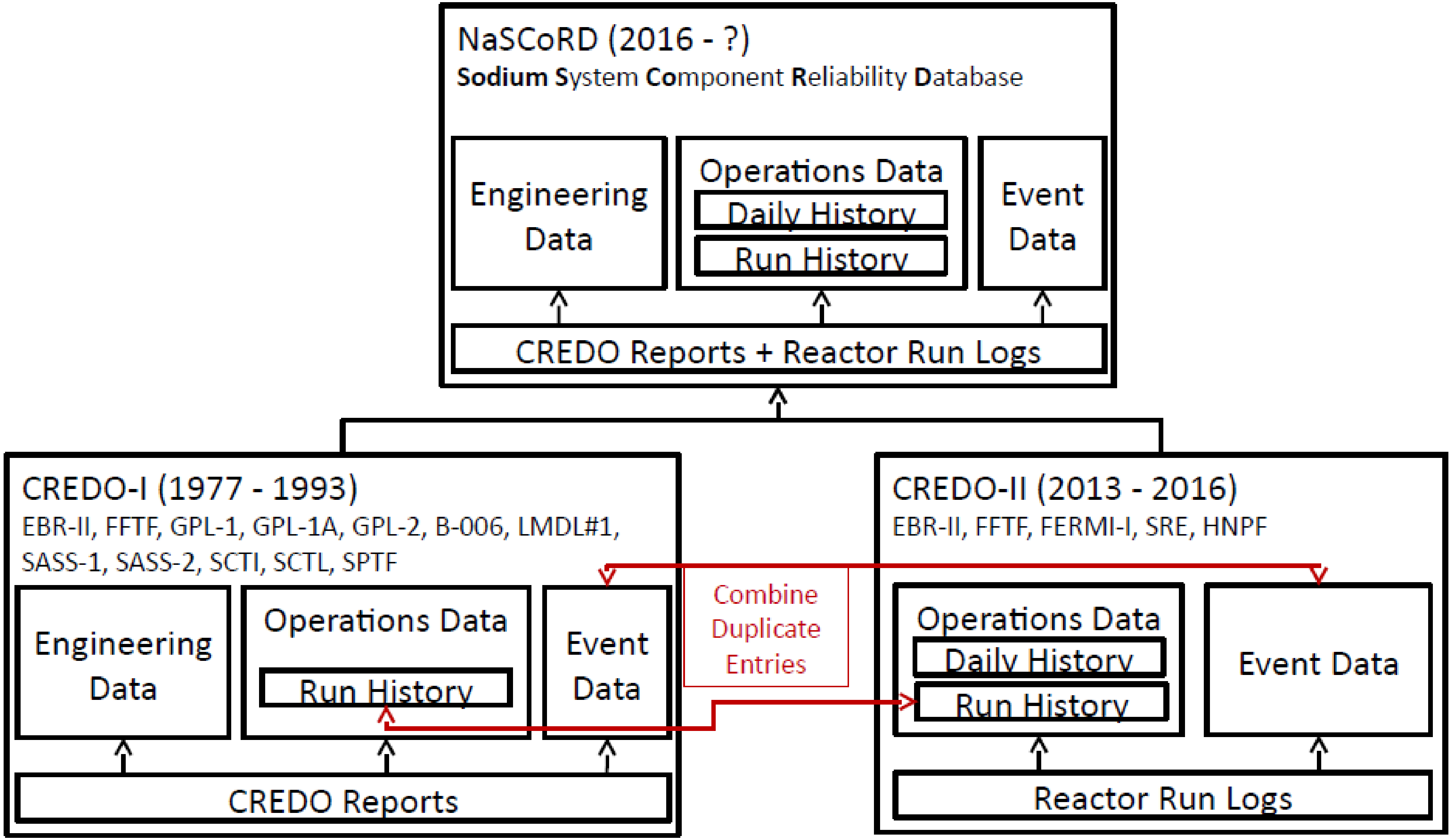
- Data Processing Method
- Prior Distribution
- Posterior Distribution

Path Forward

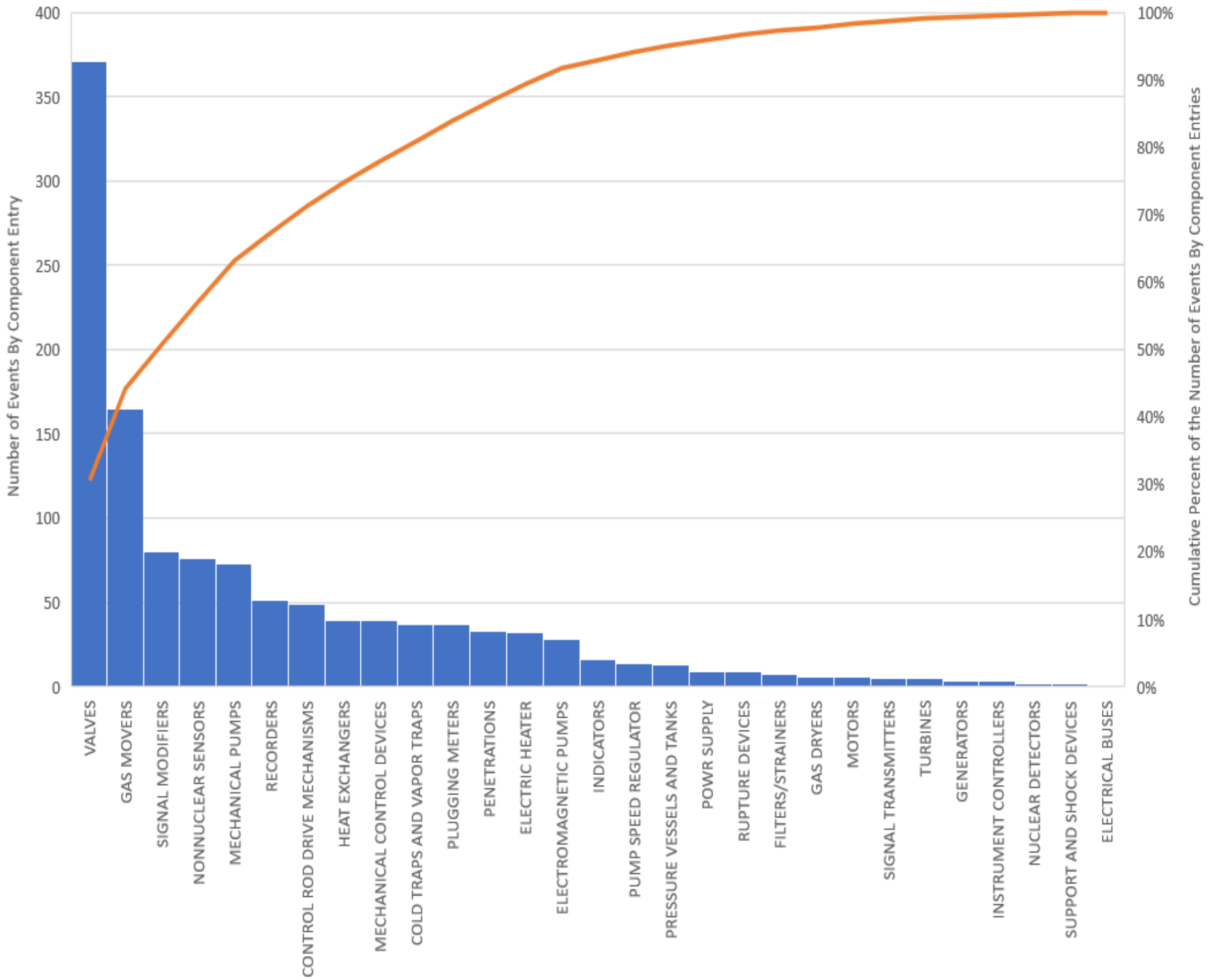
- Temperature Dependency
- Other Components (e.g., Pump, Pipes, and I&C)
- Requesting Access

Overview of the NaSCoRD Database

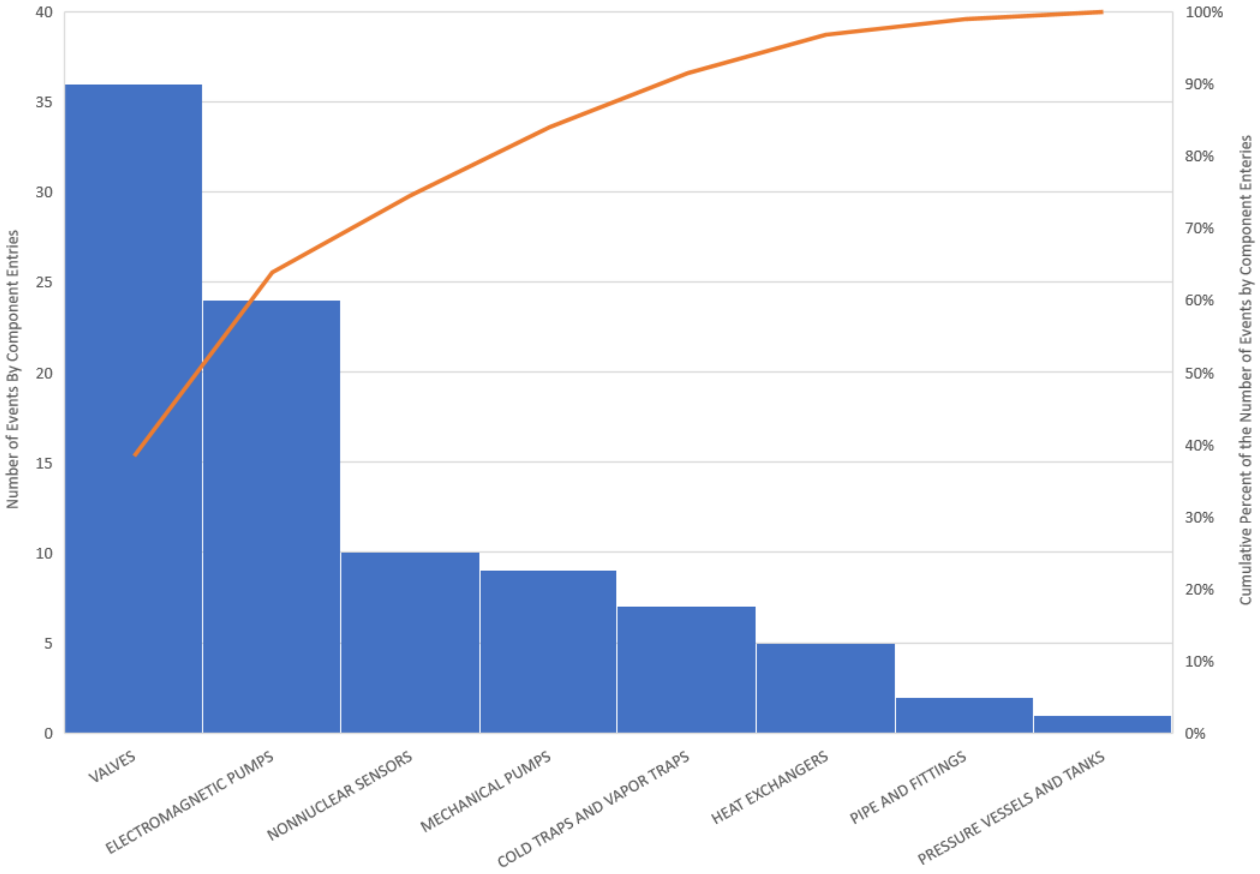
Basic Structure of the NaSCoRD Database



Number of Events Recorded in NaSCoRD



Reactor

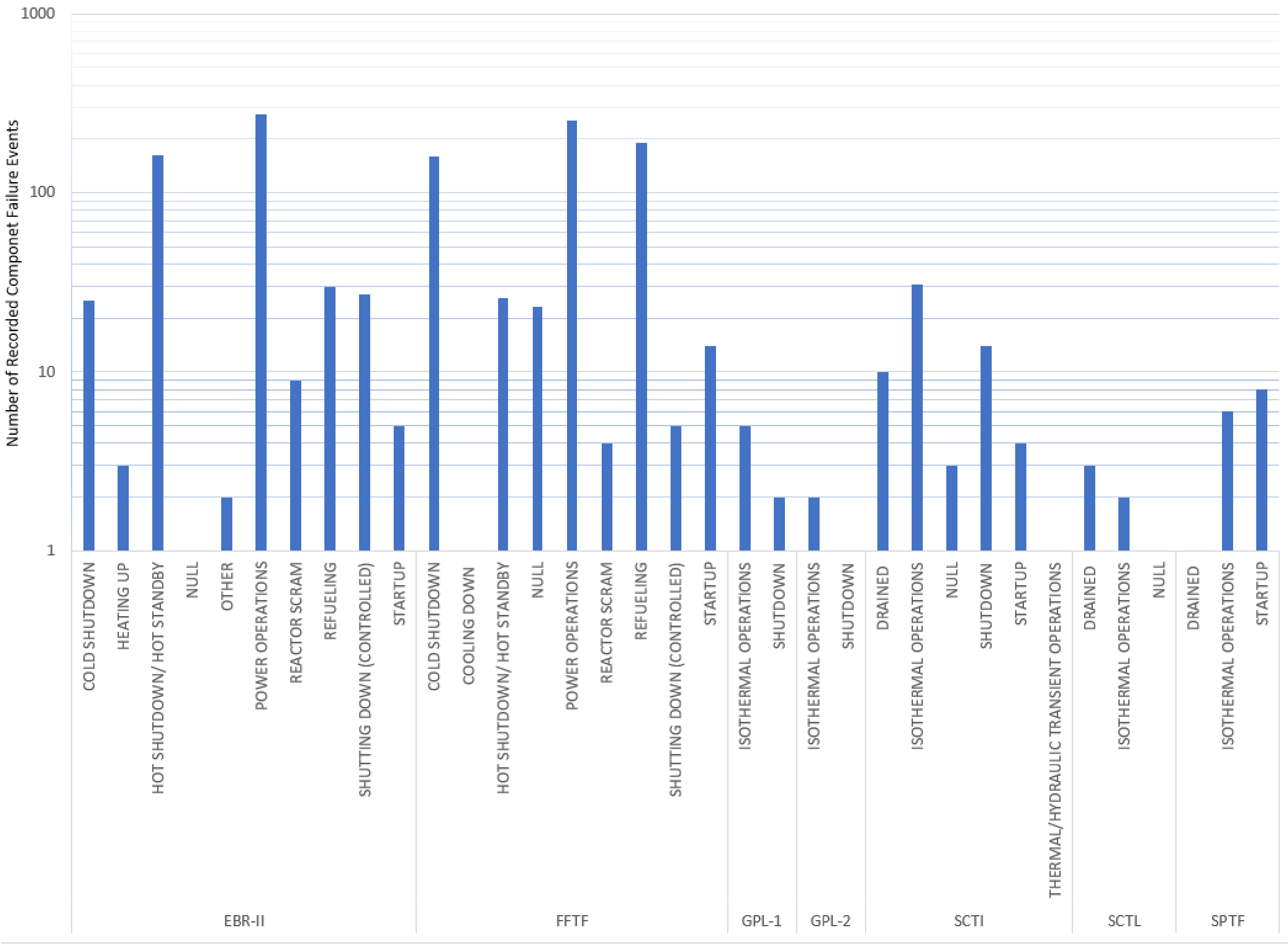


Test Loop

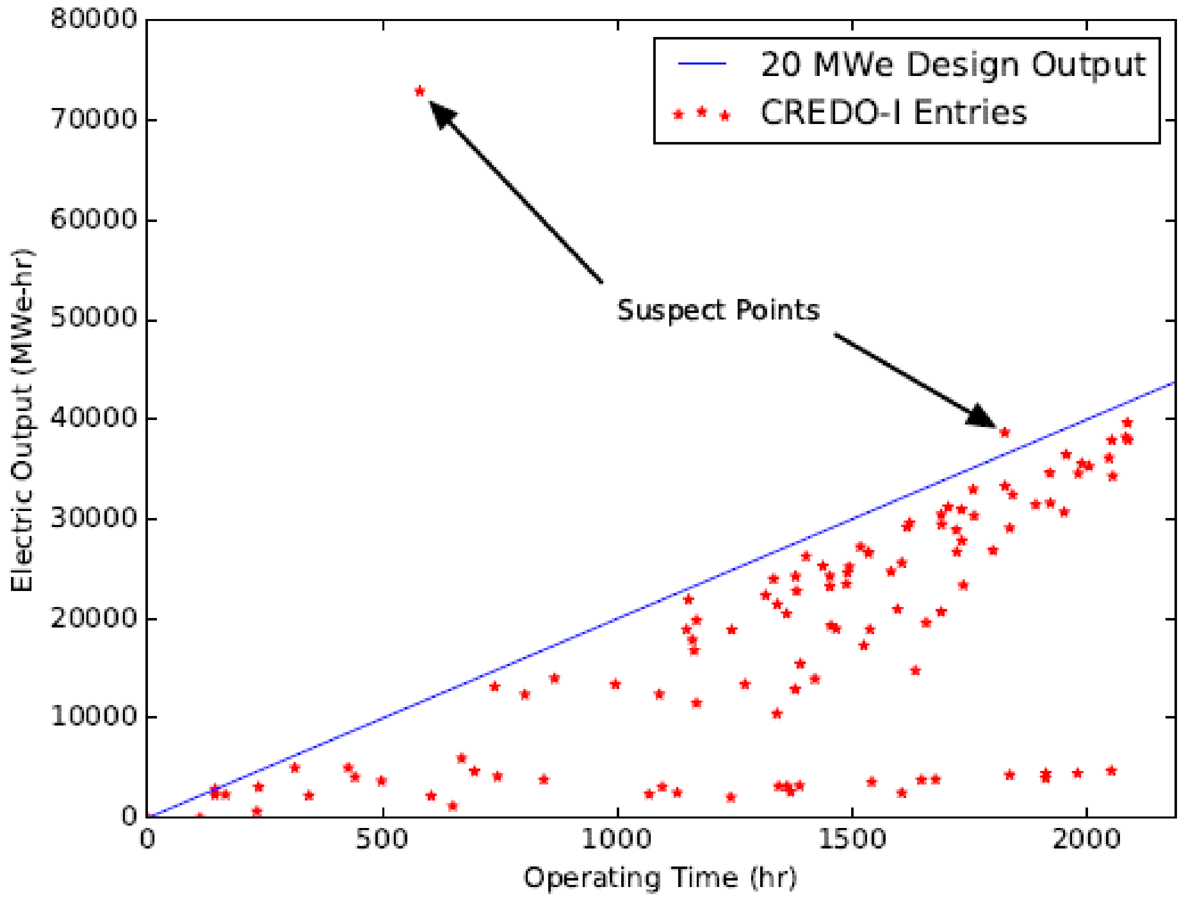
NaSCoRD Provides a Rich and Multifaceted Database

The NaSCoRD database records:

- State of the system or facility (operational, standby, maintenance, …)
- Component Descriptions, Operating Conditions, Design Levels
- Human interactions with components
- Links to additional records (if still available)



Some Data Quality Issues Remain



EBR-II

Original data collection efforts occurred in the early days of PRA

- Failure boundaries were not always well defined
- Data was passed back and forth from ORNL and JAEA
- Data quality issues remain but should be resolvable when NaSCoRD is combined with other data sources.

Focus on Sodium Valve Insights

EG&G Insights

EG&G (INEL) took an initial attempted at evaluating failure probabilities for sodium components in the early 1990s.

- CREDO data was examined but was not used exclusively in their recommendations
- EG&G suggested changes to the CREDO data given current best practices.
- This report was used as our primary source for a diffuse informed prior

Table 2. Mechanical component (sodium working fluid) recommended failure rates

MECHANICAL COMPONENT (SODIUM WORKING FLUID) FAILURE RATE COMPARISON

		SOURCES																	
		RECOMMENDED (A)			LMEC			LYON			PIPING SURVEY			CRBRP-4			GEFR 00554		
COMPONENTS	COMPONENT TYPE / FAILURE MODES	MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES
VALVES	MANUAL																		
	FAIL TO OPEN/CLOSE	3.0E-04 /D	5		-			2.0E-07 \H (B) OR 1.0E-06 \H (B)		1 2	-			-			-		
	PLUG	5.0E-08 /H	10		-			(C)			-			1.0E-07 /H	10	1	-		
	INTERNAL LEAKAGE	5.0E-08 /H	10		-			(C)			-			1.0E-07 /H	10	1	-		
	INTERNAL RUPTURE	1.0E-08 /H	10	0	-			(C)			-			-			-		
	EXTERNAL LEAKAGE	3.0E-07 /H	10		2.8E-06 /H		1	(C)			-			1.0E-08 /H	10		5.5E-08 /H OR 4.4E-08 /H		1 2
	EXTERNAL RUPTURE	1.0E-08 /H	10	0	-			-			-			-			7.0E-14 /H		3
	MOTOR-OPERATED																		
	FAIL TO OPEN/CLOSE	1.0E-03 /D	5		1.2E-04 /H (B)		2	1.0E-05 \H (B)		3	-			-			-		
	SPURIOUS OPERATION	5.0E-07 /H	10		(C)			(C)			-			-			-		
	PLUG	5.0E-08 /H	10	0	(C)			(C)			-			-			-		
	INTERNAL LEAKAGE	5.0E-07 /H	10		(C)			(C)			-			-			-		
	INTERNAL RUPTURE	5.0E-08 /H	10	0	(C)			(C)			-			-			-		
	EXTERNAL LEAKAGE	5.0E-07 /H	10		2.8E-06 /H		1	(C)			-			-			-		
	EXTERNAL RUPTURE	5.0E-08 /H	10	0	-			-			-			-			-		
	PNEUMATIC/HYDRAULIC																		
	FAIL TO OPEN/CLOSE	3.0E-03 /D	5		1.2E-04 /H (B)		2	-			-			1.0E-03 /D	10		3.1E-04 /D		4
	SPURIOUS OPERATION	3.0E-07 /H	10		(C)			-			-			1.0E-07 /H (B)	10	1	-		
	PLUG	3.0E-08 /H	10	0	(C)			-			-			(C)			-		
	INTERNAL LEAKAGE	1.0E-07 /H	10		(C)			-			-			(C)			-		
	INTERNAL RUPTURE	3.0E-08 /H	10	0	(C)			-			-			(C)			-		
	EXTERNAL LEAKAGE	1.0E-06 /H	10		2.8E-06 /H		1	-			-			1.0E-08 /H	10		3.3E-07 /H		5
	EXTERNAL RUPTURE	3.0E-08 /H	10	0	-			-			-			-			3.3E-08 /H		6
	SOLENOID																		
	FAIL TO OPEN/CLOSE	3.0E-03 /D	5	1	1.2E-04 /H (B)			-			-			-			-		
	SPURIOUS OPERATION	3.0E-07 /H	10	1	(C)			-			-			-			-		
	PLUG	3.0E-08 /H	10	1,0	(C)			-			-			-			-		
	INTERNAL LEAKAGE	1.0E-07 /H	10	1	(C)			-			-			-			-		
	INTERNAL RUPTURE	3.0E-08 /H	10	1,0	(C)			-			-			-			-		
	EXTERNAL LEAKAGE	1.0E-06 /H	10	1	2.8E-06 /H			-			-			-			-		
	EXTERNAL RUPTURE	3.0E-08 /H	10	1,0	-			-			-			-			-		
	CHECK																		
	FAIL TO OPEN	1.0E-04 /D	5	0	-			-			-			-			-		
	PLUG	5.0E-07 /H	10	0	-			-			-			6.1E-08 /H	10		-		
	FAIL TO CLOSE	1.0E-04 /D	5	0	-			-			-			-			-		
	INTERNAL LEAKAGE	5.0E-07 /H	10	0	-			-			-			-			-		
	INTERNAL RUPTURE	5.0E-07 /H	10	0	-			-			-			-			-		
	EXTERNAL LEAKAGE	5.0E-07 /H	10	0	-			-			-			5.7E-08 /H	10		5.7E-06 /H		7
	EXTERNAL RUPTURE	5.0E-07 /H	10	0	-			-			-			-			7.0E-15 /H		8
	RUPTURE DISC																		
	FAIL TO OPEN	5.0E-07 /H	10	0	-			-			-			-			-		
	PREMATURE OPENING	1.0E-05 /H	10		3.1E-04 /H			-			-			-			5.0E-07 /H OR 1.3E-06 /H		9 10

EGG-SSRE-8875

GENERIC COMPONENT FAILURE DATA BASE

FOR LIGHT WATER AND LIQUID SODIUM REACTOR PRAs

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February 1990

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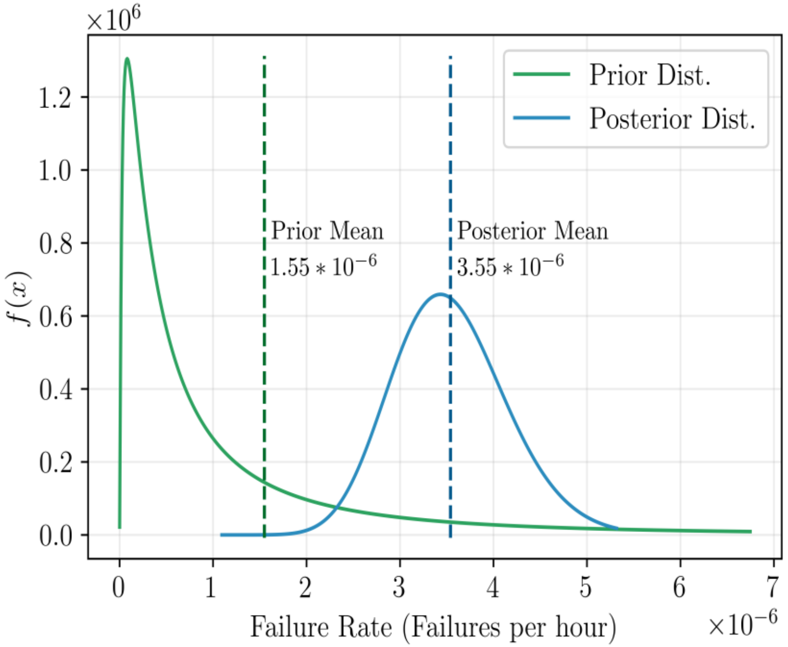
Prepared for the
U.S. Department of Energy
Idaho Operations Office
Under DOE Contract No. DE-AC07-76ID01570

Basic Approach – Bayesian Updating

Prior

$$EG\&G: \; p(\lambda|\sigma^2,\mu) = \frac{1}{\lambda\sqrt{2\pi\sigma^2}} \exp\left(\frac{-(\ln\lambda-\mu)^2}{2\sigma^2}\right) \; for\ \lambda > 0$$

$$Noninformative: \; p(\lambda|\alpha=0,\beta=0) = \frac{\beta^\alpha \lambda^{\alpha-1} e^{-\beta\lambda}}{\Gamma(\alpha)} = \lambda^{-1} \; for\ \lambda > 0$$



Likelihood – NaSCoRD Data

$$f\left(\underline{y} \,\middle|\, \lambda\right) = \prod_{i=1}^{n}\left(\frac{1}{\lambda}\exp\left(\frac{y_i}{\lambda}\right)\right)\prod_{j=1}^{m}\left(\exp\left(\frac{y_j}{\lambda}\right)\right) \; for\ \lambda, y_i, y_j > 0$$

Posterior – Calculated via Bayesian Updating

$$p(\lambda\,|\,\underline{y}) \propto f\left(\underline{y}\,\middle|\,\lambda\right) p(\lambda)$$

Impact of EG&G Revised Failure Modes on the Results

SNL has updated NaSCoRD's reported failure modes based upon EG&G's recommendations.

- Did these changes significantly impact the final results?
- Was there enough data to overwhelm and EG&G recommendations?

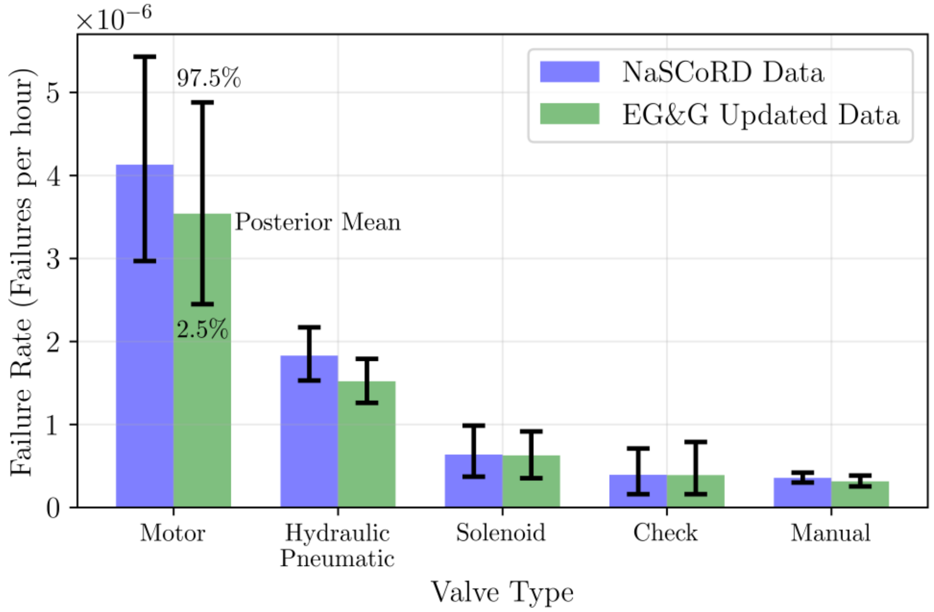


Table A-1. (continued)

No.	Event	Failure Mode	Revised Failure Mode	Include?
23.	FF800083	SPURIOUS	NOMOVE	YES
24.	FF800035	NOMOVE		YES
25.	FF850058	ABNORMOP		NO
26.	SL730003	NOMOVE		YES
27.	SL770007	LEAK(small)		YES
28.	SG770001	LEAK(small)		YES
29.	SG770006	ABNORMOP	NOMOVE	YES
30.	SG770007	ABNORMOP	NOMOVE	YES
31.	SG770008	ABNORMOP	NOMOVE	YES

The EG&G estimates are fairly reflective of the NaSCoRD Dataset

Valve	Failure Mode	EG&G Prior Mean	Evidence (Hours, Failures)	Posterior Mean	95% Probability Interval
Check	External Leakage	5.0E-07	(7.7E06, 2)	2.5E-07	(7.1E-08, 5.3E-07)
	Internal Leakage	5.0E-07	(7.7E06, 1)	1.5E-07	(3.4E-08, 4.3E-07)
	Plug	5.0E-07	(7.7E06, 0)	5.8E-08	(3.4E-09, 2.1E-07)
	Total	1.5E-06	(7.7E06, 3)	3.9E-07	(1.6E-07, 7.9E-07)
Hydraulic/ Pneumatic	External Leakage	1.0E-06	(1.6E07, 12)	7.0E-07	(5.4E-07, 8.7E-07)
	Internal Leakage	1.0E-07	(1.6E07, 1)	2.3E-07	(1.4E-07, 3.8E-07)
	Plug	3.0E-08	(1.6E07, 0)	6.0E-09	(3.9E-10, 1.4E-08)
	Spurious Operation	3.0E-07	(1.6E07, 6)	1.1E-07	(4.3E-08, 1.9E-07)
	Total	1.4E-06	(1.6E07, 21)	1.5E-06	(1.3E-06, 1.8E-06)
Manual	External Leakage	3.0E-07	(2.4E07, 3)	1.1E-07	(7.4E-08, 1.4E-07)
	Internal Leakage	5.0E-08	(2.4E07, 2)	5.9E-08	(3.6E-08, 8.2E-08)
	Plug	5.0E-08	(2.4E07, 2)	4.9E-08	(3.3E-08, 6.9E-08)
	Total	4.0E-07	(2.4E07, 9)	3.1E-07	(2.5E-07, 3.9E-07)
Motor	External Leakage	5.0E-07	(7.4E06, 2)	1.3E-07	(2.4E-08, 4.6E-07)
	Internal Leakage	5.0E-07	(7.4E06, 4)	4.8E-07	(1.8E-07, 9.4E-07)
	Plug	5.0E-08	(7.4E06, 1)	5.8E-08	(8.2E-09, 2.1E-07)
	Spurious Operation	5.0E-07	(7.4E06, 3)	1.4E-07	(1.2E-08, 4.3E-07)
	Total	1.6E-06	(7.4E06, 24)	3.5E-06	(2.5E-06, 4.9E-06)
Solenoid	External Leakage	1.0E-06	(4.7E06, 0)	6.0E-08	(2.7E-09, 1.9E-07)
	Internal Leakage	1.0E-07	(4.7E06, 2)	2.7E-07	(1.2E-07, 4.4E-07)
	Plug	3.0E-08	(4.7E06, 1)	4.3E-08	(1.6E-09, 1.2E-07)
	Spurious Operation	3.0E-07	(4.7E06, 0)	3.2E-08	(3.2E-09, 1.1E-07)
	Total	1.4E-06	(4.7E06, 3)	6.3E-07	(3.5E-07, 9.1E-07)

Impacts of Prior Information on the Results were Minimal but Increased when Examining Failure Modes

The reduced total amount of data in the NaSCoRD data when compared to the CREDO data forces caution when looking at specific categories since there is a greater potential for insufficient failure data.

- In many of the valve type and failure mode combinations there were categories that had few to no recorded failure events.
- The estimated rates were predictably sensitive to the choice of prior.
- The biggest impacts of the prior distribution occur when there were less than two observed events in a valve type and failure mode combination.
- The choice of prior dominated the posterior in nine instances. Most of the combinations were in the check valve and solenoid valve categories because there were one or fewer recorded failure events.

When studying specific failure modes, it is recommended that the analyst considers how many failures are present. A small number of failures may affect the reliability of the data.

Wrapping Up

Requesting Access to the NaSCoRD Database

NaSCoRD is access controlled

- To request access, go to www.sandia.gov/nascord
- DOE and SNL approvals are required before access is granted.
- NaSCoRD access is provided to external users via Microsoft SQL HTML reports.

Conclusions

The posterior failure rates for sodium fast reactor valves produced in this analysis were consistent with failure rates produced from the CREDO data prior to 1990.

- Many factors were tested that could have potentially changed inferences regarding the valve failure rates such as prior assumptions and cleaning recommendations from SNL and EG&G.
- Despite these differences, the inferred failure rates were consistent for each valve type and even the different failure modes within each valve type.
- This suggests that the current NaSCoRD data is robust not only to different reasonable prior assumptions but also slight changes due to data cleaning.
- The information lost due to the absence of the JAEA data does not seem to have changed the conclusions regarding average valve failure rates.

Prior assumptions had a greater impact when subdividing valve failure rates such as for specific failure modes within specific valve types.

- Certain subdivisions of data do not have enough observed failure data to overwhelm a diffuse prior distribution.
- Conclusions based off such data will not be as robust to different prior distributions.