

GSI-191: Analysis of Recovery Options

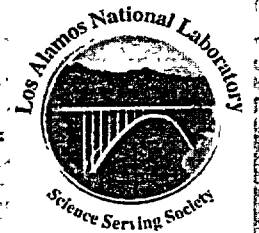
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ATTACHMENT 6



Probabilistic Risk Analysis Group
Decision Applications Division

p. 1





Basic Assumptions

- **Accident sequences as in NUREG/CR-6771**
 - Quantified recovery actions
 - Event tree and fault tree analysis
 - Human Reliability Analysis (ASEP)
- **Modeled after a typical PWR cooling system**
- **Cooling must be maintained for 24 hours**
- **Results given in technical letter LA-UR-02-7562**





Recovery Options

- **Continue ECCS Recirculation Cooling**
 - Recirculation pumps continue operation despite loss of NPSH
 - Actions are taken to restore NPSH and reestablish ECCS recirculation cooling
- **Switch to injection cooling with alternate source of water**





Continued Operation of ECCS Pumps

- **Pumps may operate with loss of NPSH**
- **Failure probability**
 - No data available – engineering judgment
 - LLOCA – 0.8
 - MLOCA – 0.5
 - SLOCA – 0.4 (Open PORV, LOFW)
- **Testing should be done to see if this is a viable recovery option**





Restore Recirculation Cooling

- **Operator must diagnose need**
 - Recognize symptoms of recirculation loss
 - Instruments must alert operator
- **Operator must act to restore recirculation**
 - Adjust flows
 - Use backflush system (if available)
- **Pumps must continue operating after recovery**





Continued ECCS Recirculation

- **Failure probability**
 - LLOCA – 0.46
 - MLOCA – 0.16
 - SLOCA – 0.025 (Open PORV, LOFW)
- **Driven by**
 - 1. Pump failure with loss of NPSH
 - 2. Operator failures





Human Reliability Analysis (HRA)

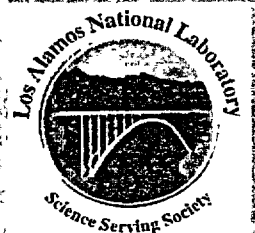
- **Based on Accident Sequence Evaluation Program (ASEP) methodology (NUREG/CR-4772)**
- **ASEP used to provide screening values for postulated diagnosis and post-accident actions**
- **Judgments were made regarding time available for operator actions and corresponding stress levels**
- **Some credit given for HRA recovery factors (RFs)**





Reestablish Injection

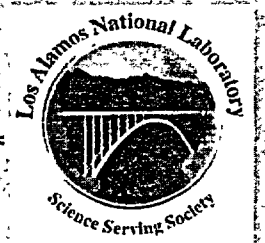
- **Operator must diagnose need to switch**
- **Switch must be successful**
 - Operator executes change
 - ECCS components operate
- **RWST must be refilled**
 - Spent fuel pool
 - Mixing water and boric acid from CVCS
 - Alternate RWST where available
 - Large LOCA – time for one of three methods





Reestablish Injection Cooling

- **Failure probability**
 - LLOCA – 0.87
 - MLOCA – 0.37
 - SLOCA – 0.045 (Open PORV, LOFW)
- **Driven by**
 - Operator failure – high stress, short time





CDF Associated with LOCA Events

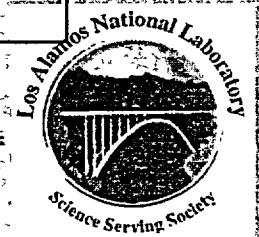
- **Traditional initiating event frequencies:**
 - Debris effects – 138 factor increase from no debris
 - With recovery – 19 factor increase from no debris
- **Leak before break initiating event frequencies**
 - Debris effects – 45 factor increase from no debris
 - With recovery – 2 factor increase from no debris
- **Increase warrants plant-specific studies**





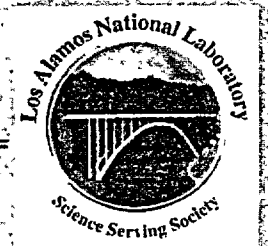
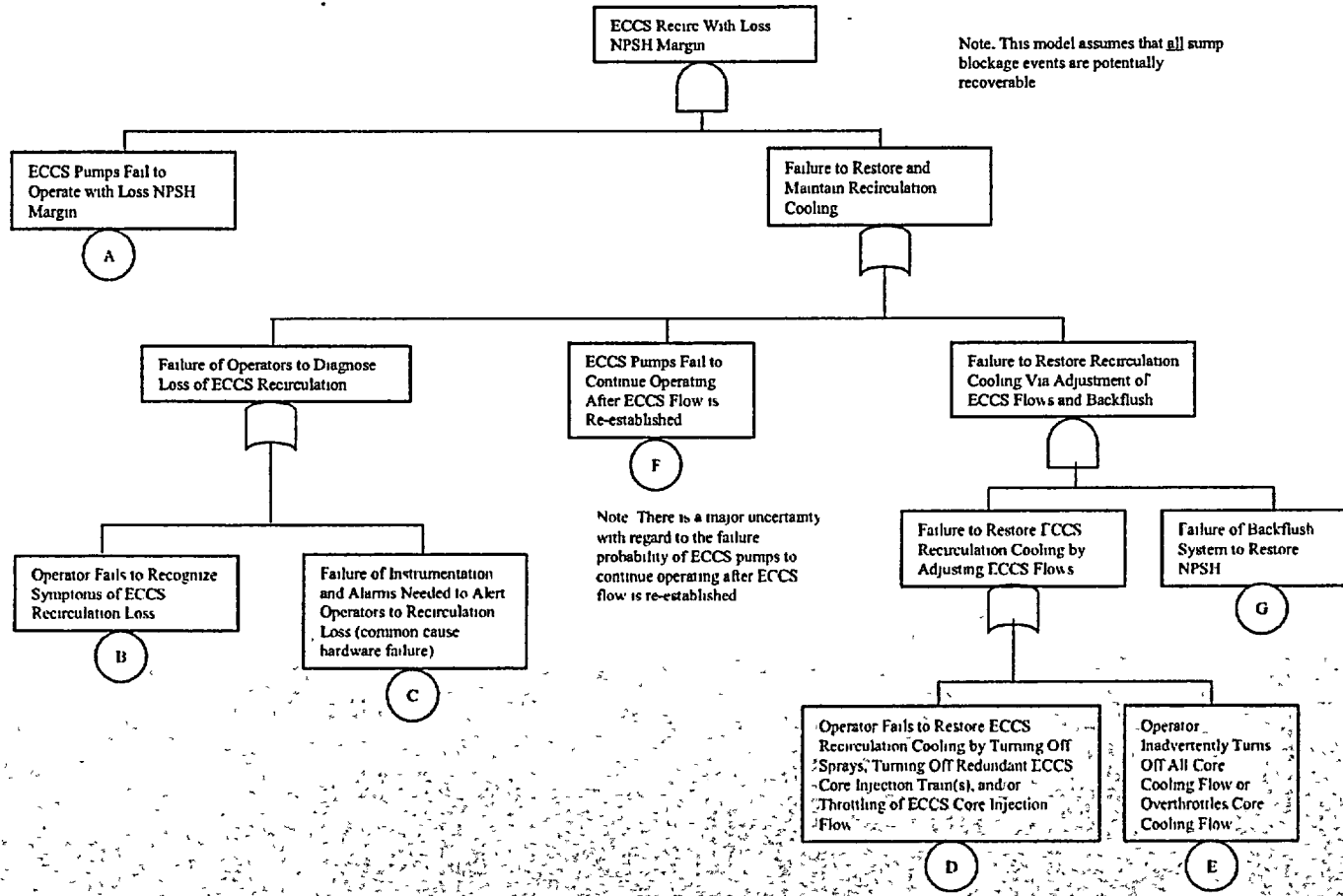
Sample Event Tree - LLOCA

Large LOCA >6 inch	ECCS Inject. LLOCA	Containment Spray Injection	ECCS Recirc LLOCA	Containment Spray Recirculation	Avoid Loss ECCS Recirc. NPSH Margin Due to Debris	ECCS Recirc With Loss NPSH Margin	Recover from Loss of ECCS Recirc Due to Debris	#	End State Names	
LLOCA	ECCS_INJ_L	SPRAY_INJ	ECCS_RECIRC_L	SPRAY_RECIRC	DEBRIS_OK_L	RECIRC_NPSHM_L	REC_DEBRIS_L			Sub-Atm
Assumptions in NUREG/CR-6771 apply								1	ok	ok
								2a	ok	ok
								2b	ok	ok
								2c	cd	cd
								3	ok	cd
								4a	ok	cd
								4b	ok	cd
								4c	cd	cd
								5	cd	cd
								6	ok	cd
								7a	ok	cd
								7b	ok	cd
								7c	cd	cd
								8	cd	cd
								9	cd	cd





Fault Tree – ECCS Recirc.





Fault Tree – ECCS injection

