UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON D. C. 20555

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MEMORANDUM FOR: Stephen Hanauer, Technical Advisor, OEDO

FROM: Ashok Thadani, Reactor Systems Branch, DSS

7.1e

At the January 27th meeting on ATWS, you suggested that there was a need to assess the probability of ATWS events exceeding ATWS criteria, given the plants meet Status Reports' requirements. A suggestion was made that a working group be formed to conduct this study. In order to accomplish this, you suggested that the scram failure probability (including the control rod drives) be assumed as 10^{-4} and consideration be given to the percent of time significant parameters would have values which would result in exceeding acceptance criteria. As I stated at the meeting and continue to believe that the range of parameter values in BWRs have an insignificant effect on the results. The significant impact on consequences is from unavailability of various systems. Thus the probability of exceeding criteria for BWRs assuming Status Report fix is between 10^{-6} to 10^{-7} per reactor year. Figure 1 of the slides I handed out at the meeting (a copy attached) and never got an opportunity to discuss, shows sequences that would lead to unacceptable consequences if the design modifications assumed in NEDO-20626 (Automatic SLCS, Recirculation Pump Trip, and Main Feed Pump Trip) are used. However if the Status Report fix is applied, the following are some of the sequences that would probably exceed criteria.

$$TC\ C_1 = 10^{-7}$$

$$TC\ C_2 = 10^{-7}$$

$$TCU,\ (NFS) = 10^{-7}$$

where NFS is New Feed System $\sim 10^{-2}$

$$TC\left[(M_1^* + R + S + CC + \ldots . \right]$$

$$= TC\ (10^{-3})$$

$$= 10^{-7}$$

Where M_1^* = Safety Valve Fails to Open $\sim 10^{-4}$
R = RHR System Fails $\sim 10^{-4}$
S = Service Water System Fails $\sim 10^{-4}$
CC = Component Cooling System Fails $\sim 10^{-4}$

Contact:
A. Thadani, NRR
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While this is not an exhaustive list of sequences that would exceed criteria, it shows that with Status Report fix, the probability of unacceptable consequences have been reduced from 10^{-4} to about 10^{-6} to 10^{-7} in BWRs.

The thrust of your remarks at the meeting seemed to address the PWRs and in particular the moderator temperature coefficient (MTC) value used in the analyses. Over a year ago I had indeed constructed several event trees including the moderator temperature coefficient effects to assure that the staff requirements were not excessive. Enclosure two provides these event trees. The loss of offsite power was drawn separately to determine the effect of diesel failures on consequences. Conservatively one could go through the event trees and assume the sequences shown on page 3 of enclosure two result in unacceptable consequences since the analyses for these events have not been performed. However, the following few sequences would be realistically expected to exceed the criteria.

$$TC\ \overline{I_2 I_3} \equiv 10^{-6}\text{-}10^{-7} \sim 5 \times 10^{-7}$$

$$TC\ \ * I^* \equiv .5 \times 10^{-7}$$

$$TC\ F^* \lesssim .5 \times 10^{-7}$$

Where $\overline{I_2\ I_3}$, F*, G* indicate MTC value between 99 and 99.9%, complete failures of auxiliary feedwater and high pressure injection system respectively.

$$TC\ [\ R + S + CC + \ldots]$$

$$= TC\ \ (10^{-3})$$

$$\approx 10^{-7}$$

This sequence covers the variety of failures (such as RHR, Service Water, etc.) that would cause exceeding ATWS criteria.

Having looked at these few sequences one concludes, based on analysis and judgment, that even with the inclusion of the moderator temperature coefficient and with the assumption of Status Report Fix applied to PWR plants, the probability of exceeding the criteria has been reduced from 10^{-4} to about 10^{-6} to 10^{-7} in PWRs. The consequences are indeed more affected by parameter values in the PWRs than in the BWRs.

Thus for PWRs, one could extend the event trees by including other parameters such as power, Doppler Coefficient, gap size, auxiliary feedwater initiation time, etc. In most analyses expected values of these and other parameters have been assumed with the possible exception of power and for B&W reactors auxiliary feedwater initiation time (although recent B&W analyses have assumed a highly optimistic auxiliary feedwater actuation time). It is my judgment (and I thought others who concurred in our August 13, 1976 letter to the AIF agreed with this judgment) that the selection of parameters and the determination of their interactions, distributions, probability and consequence functions would require considerable research before such data could be incorporated into a probabilistic model. This could of course be our long range goal but in the interim the simple staff approach provides the desired degree of protection from ATWS events.

It is my belief that if there is a significant conservatism in the staff Status Report approach, it might well be the unreliability estimate of the control rod drive mechanisms (CRDM) although I do agree with you that CRDM unreliability lower than $10^{-4} \sim 10^{-5}$ cannot be demonstrated. I think the B&W approach (20 electrical failures, no mechanical failures; conclusion: $1/20 * 10^{-5}$ CRDM unreliability) is poor, at best. Recently we have been mired in arguments with GE over failure data, statistical methods, assumptions, etc., used in their estimates of the control rod drive mechanisms unavailability.

With this as background, if a working group is formed, the work function should also address the safety goal (could the goal be different for the first 100 reactors and future reactors), value impact, etc.? (enclosure 1 provides some preliminary thoughts on options, etc.)

If a semiprobabilistic study is initiated and if such a study cannot be completed in a couple of months what option would you recommend the staff follow in the interim?

A. Thadani

Ashok Thadani
Reactor Systems Branch
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cc: B. Rusche
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W. Minners
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ENCLOSURE 1

BWR ATWS RISK

BWR RPS UNRELIABILITY

WASH-1400		WASH-1270
UPPER BOUND	MEDIAN	95% CONFIDENCE
4.6×10^{-5}	1.3×10^{-5}	1.0×10^{-4}

ANTICIPATED TRANSIENT FREQUENCY

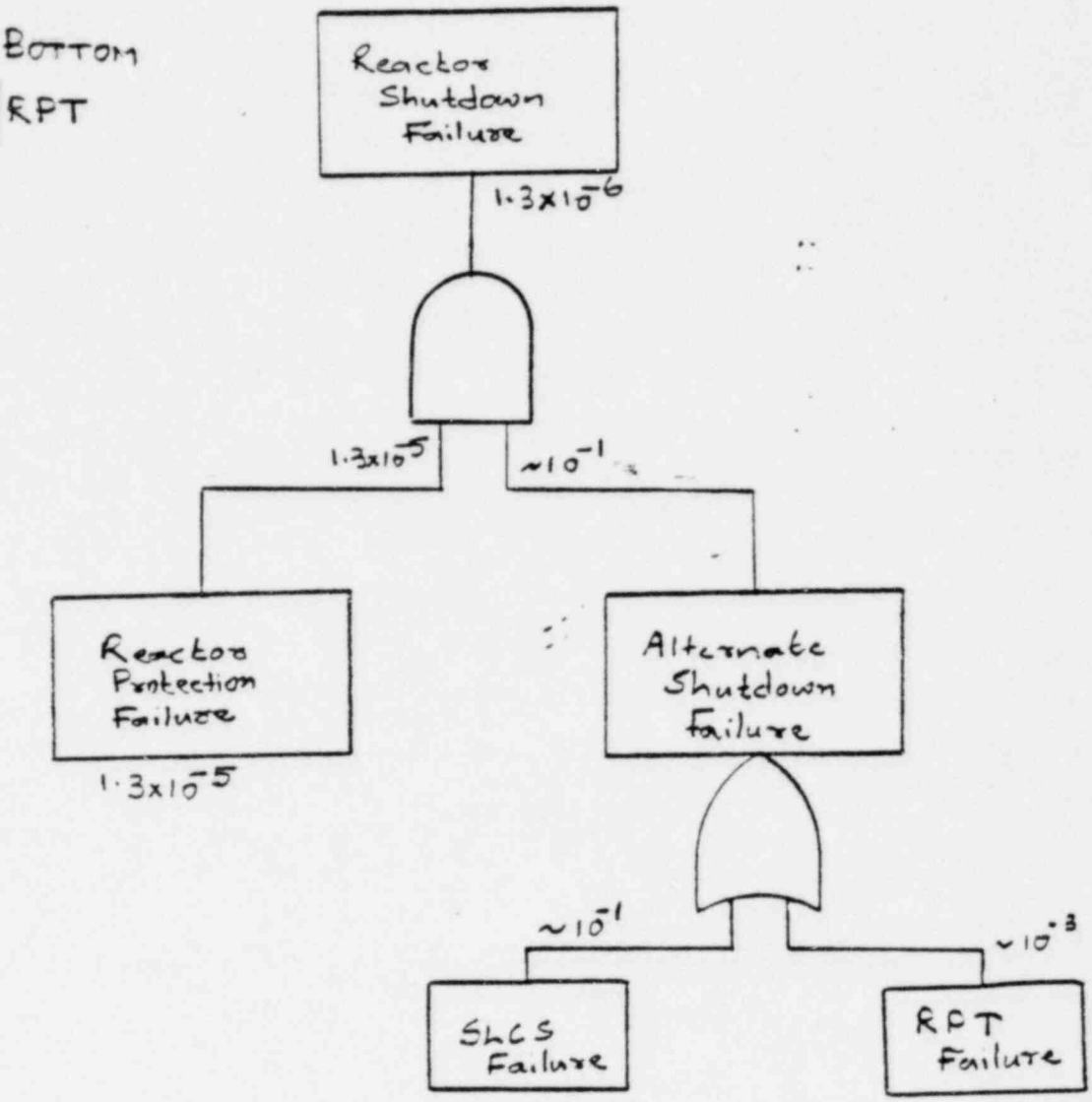
WASH-1400	WASH-1270
10 PER PLANT YEAR	1 PER PLANT YEAR

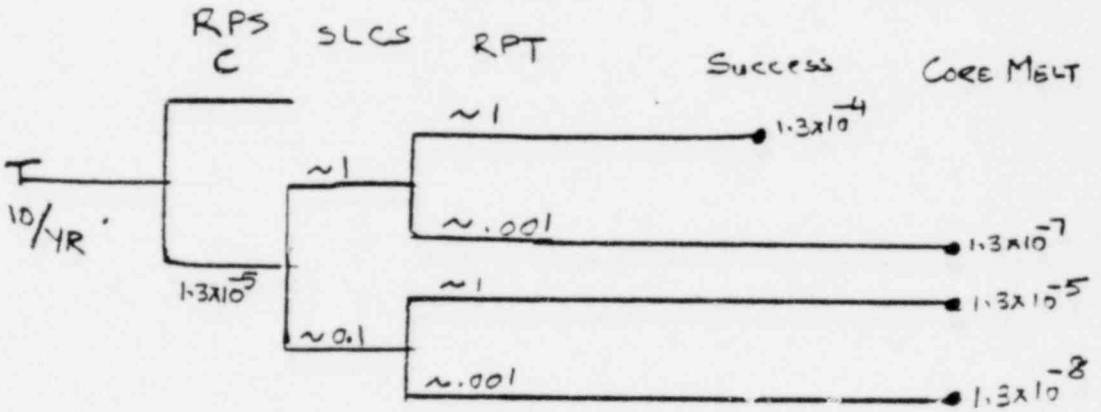
ATWS PROBABILITY

WASH-1400	WASH-1270
(MEDIAN)	
1.3×10^{-4}	1.0×10^{-4}

WASH-1400 STUDIES

PEACH BOTTOM
W/RPT





PROBABILITY OF CORE MELT

PLANTS W/RPT	1.3×10^{-5}
PLANTS W/O RPT	1.3×10^{-4}

CONTAINMENT FAILURE MODES

$\alpha \equiv$ CONTAINMENT OVERPRESSURE, CORE MELT, STEAM EXPLOSION, MISSILES TO ATMOSPHERE

$\sim 10^{-2}$

$\gamma \equiv$ CONTAINMENT OVERPRESSURE, CORE MELT (BLOWOUT PANELS BLOWN PROVIDING LEAKAGE PATH)

~ 1

TC - α 1.3×10^{-7}

TC - γ 1.3×10^{-5}

TOTAL RISK	2×10^{-5}
ATWS RISK	1.3×10^{-5}
ATWS FRACTIONS	65%

FOR PLANTS WITHOUT RPT, ATWS RISK ~100%

RSB ESTIMATES USING WASH-1270 & WASH-1400

ATWS $\equiv$ TC $\equiv$ 10^{-4} WASH-1270

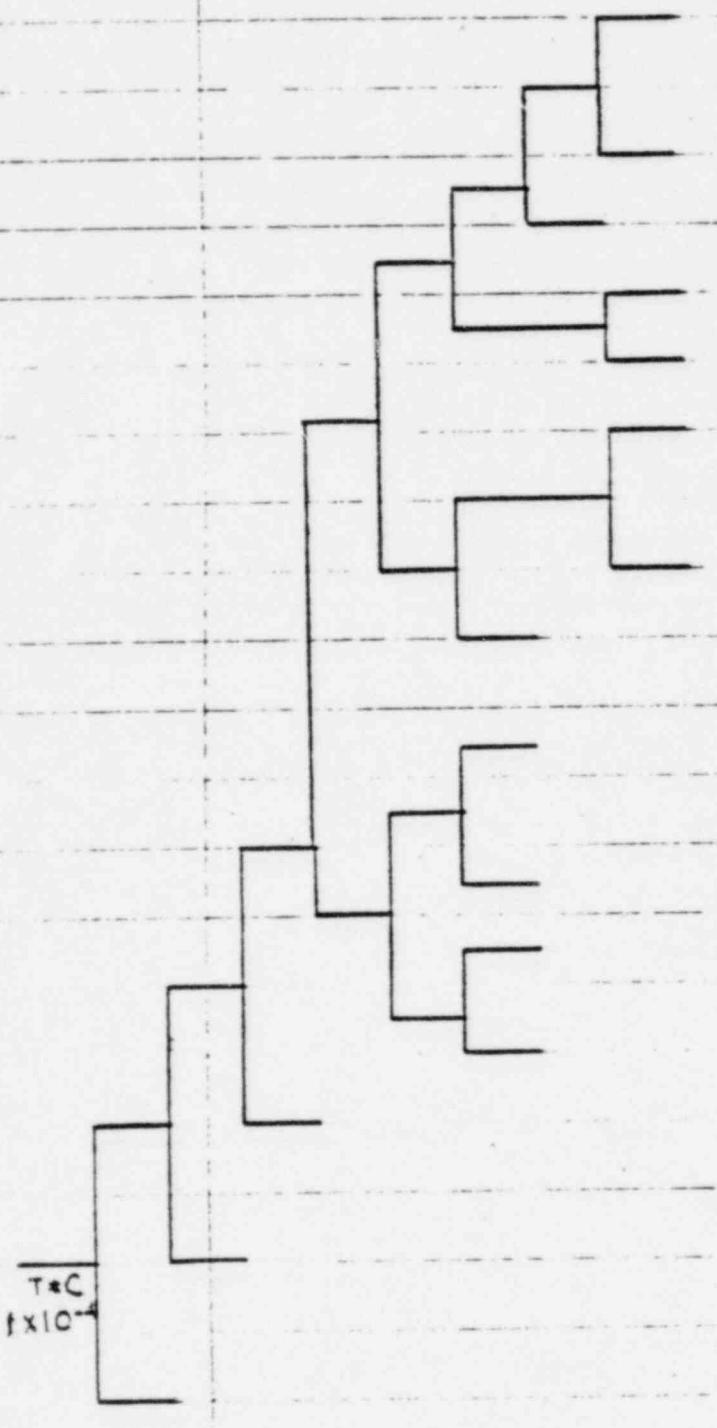
ASSUMPTION : (1) SLCS MANUALLY INITIATED AT TEN MINUTES
(2) RECIRCULATION PUMPS TRIPPED

CONSEQUENCES: CORE UNCOVERS
DAMAGING VIBRATIONS IN THE POOL
CORE MELT

WASH-1400 DID NOT CONSIDER CONTAINMENT OVERTEMPERATURE OVER-PRESSURE FAILURE MODE

IMPLICATIONS: EVEN WITH AUTOMATIC RPT, NEED TO UPGRADE SLCS TO REDUCE PROBABILITY OF UNACCEPTABLE CONSEQUENCES

FIGURE 1 - GE EVENT TREE (using NEDO-20626 Fix)



EVENT	PROBABILITY	CONSEQUENCES
TCP	1×10^{-5} (1 VLV.) 1×10^{-6} (2 VLVS.)	Unacceptable
TCM_2	1×10^{-8}	—
TCM_1	1×10^{-6}	Acceptable
TCM_1P	1×10^{-7}	Unacceptable
TCU_2	$1. \times 10^{-5}$	"
TCU_2P	$1. \times 10^{-6}$	Unacceptable
TCU_2M_1	$1. \times 10^{-7}$	—
TCU_1	1×10^{-5}	Unacceptable
TCU_1M_1	1×10^{-7}	—
TCU_1U_2	$1. \times 10^{-6}$	Unknown*
$TCU_1U_2M_1$	1×10^{-8}	N/A
TCC_2	$< 10^{-7}$	N/A
TCC_1	$< 10^{-7}$	N/A
TCF_1	$< 10^{-7}$	N/A

UNACCEPTABLE CONSEQUENCES PROBABILITIES

BWR 4 & 5

PLANT MODIFICATIONS	UNACCEPTABLE CONSEQUENCE PROBABILITY
NONE	10^{-4}
RPT	10^{-4}
RPT, SLCS	10^{-5}
RPT, SLCS, HPCI	$10^{-5} - 10^{-6}$
RPT, SLCS, HPCI, RHR	$10^{-6} - 10^{-7}$
ARSS (ASSUMING 10^{-5} UNRELIABILITY FOR THE DRIVES)	10^{-5}

BWR 6

PLANT MODIFICATIONS	UNACCEPTABLE CONSEQUENCE PROBABILITY
NONE	10^{-4}
RPT	10^{-4}
RPT, SLCS	$10^{-5} - 10^{-6}$ (DUE TO HPCS)
RPT, SLCS, HPCS	$10^{-6} - 10^{-7}$
ARSS	10^{-5}

OPTIONS:

1. CRD UNRELIABILITY 10^{-5}

   A. ATWS SAFETY GOAL FOR FIRST 100 REACTORS 10^{-6}

      IMPACT:

      RPS - ELECTRICAL MODS.
      NO SINGLE FAILURES FOR PWRS
      LIMITED SINGLE FAILURES FOR BWRS
      SMALL COST TO FIX PWRS < $1 M
      REDUCED COST TO FIX BWRS

   B. ATWS SAFETY GOAL FOR STANDARD PLANTS (FUTURE) 10^{-7}

      IMPACT:

      STATUS REPORT REQUIREMENTS

2. CRD UNRELIABILITY 10^{-4}

   WHETHER THE SAFETY GOAL IS 10^{-6} OR 10^{-7}
   STATUS REPORT FIXES WOULD BE INDICATED

3. CRD UNRELIABILITY 10^{-6}

A. ATWS SAFETY GOAL FOR FIRST 100 REACTORS 10^{-6}

IMPACT:

SIMILAR TO (A) OF OPTION 1 EXCEPT
CONSIDERABLE COST REDUCTION FOR BWRS

B. STANDARD PLANTS SAFETY GOAL 10^{-7}

IMPACT:

SIMILAR TO (A) OF OPTION 1 WITH
SIGNIFICANT UPGRADING OF THE RPS

RECOMMEND:

OPTION # 1

A. CONSISTENT WITH OUR PHILOSOPHY 10^{-3}/UNACCEPTABLE CONSEQUENCES

B. DOES NOT DISAGREE WITH RSS RISKS

C. DIFFICULT, IF NOT IMPOSSIBLE, TO DEMONSTRATE CRD UNRELIABILITY LESS THAN 10^{-5}

D. ASSURES FUTURE NUCLEAR RISK TO BE A FRACTION OF OTHER RISKS

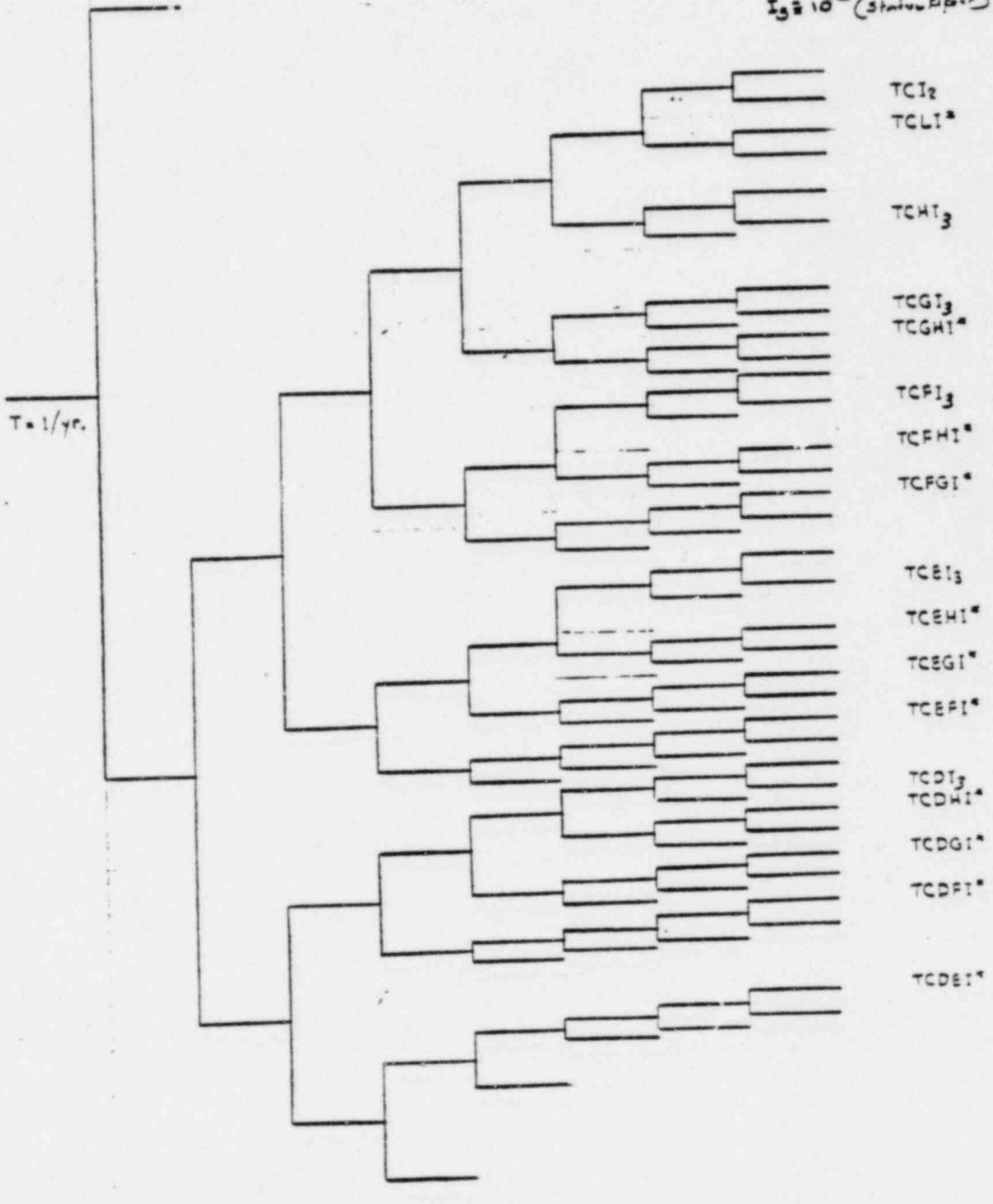
ENCLOSURE 2

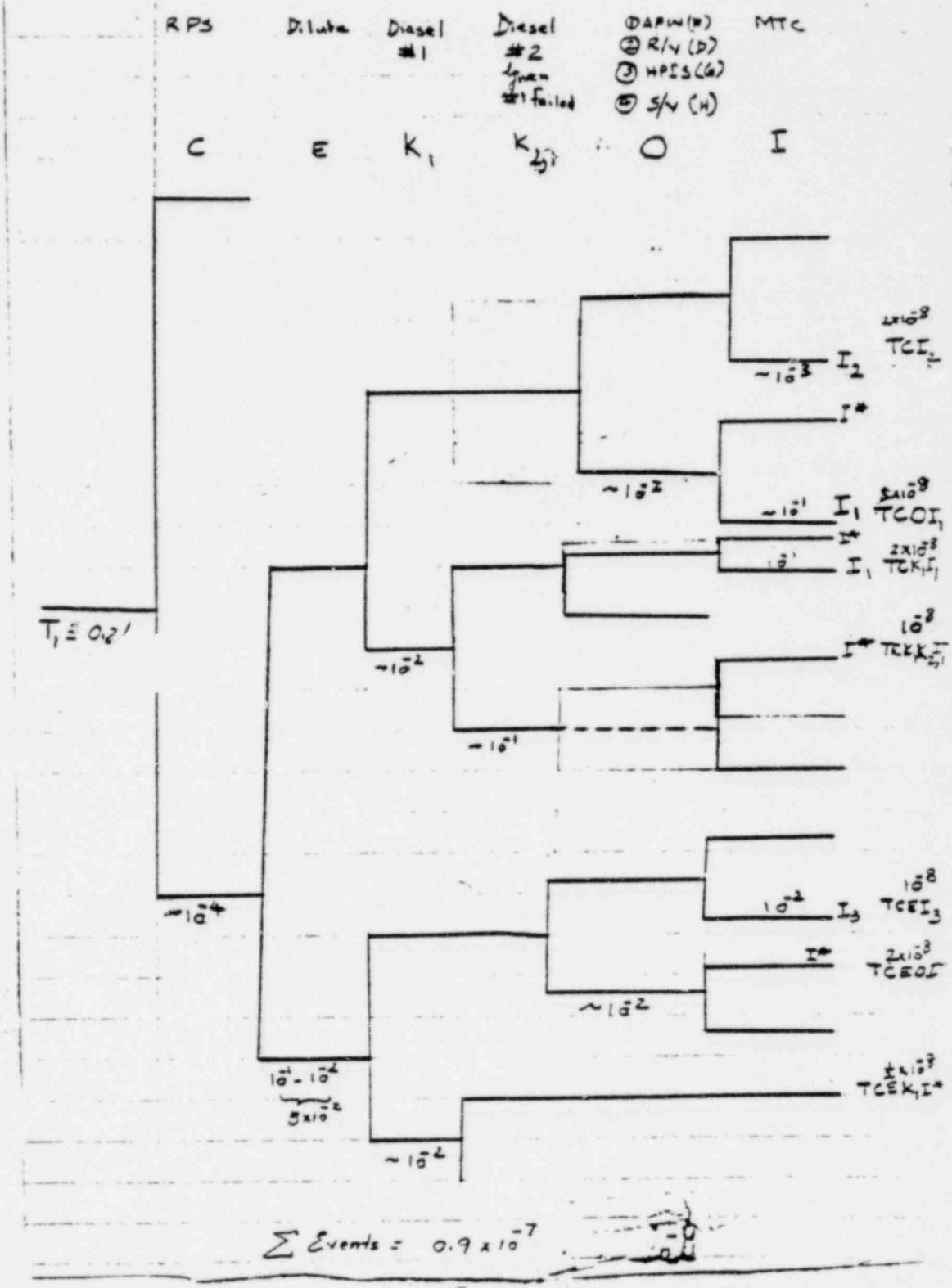
(1)

EVENT TREE EXCLUDING LOOP

RPS	Valve	Dilute	AFW	HPIS	S/V	LOOP	MTC
C	D	E	F	G	H	L	I
10^{-4}	10^{-2}	10^{-1}-10^{-2}	10^{-2}	10^{-2}	10^{-2}	10^{-3}	

$\Gamma^{\infty} \equiv 0.5$ (Expected Value)
$I_1 \equiv 10^{1}$ (90% value)
$I_2 \equiv 10^{-3}$ (99.9% ")
$I_3 \equiv 10^{-4}$ (Station Blackout)




RPS
Dilute
Diesel #1
Diesel #2 given #1 failed
DAFW(M) ② R/V (D) ③ HPIS(G) ⑤ S/V (H)
MTC
C
E
K_1
K_{2j}
O
I
$T_1 \equiv 0.2$ /
$\sim 10^{-4}$
$10^{-1} - 10^{-2}$
5×10^{-2}
$\sim 10^{-2}$
$\sim 10^{-2}$
10^{-1}
$\sim 10^{-2}$
$\sim 10^{-3}$
I_2
2×10^{-8} TCI_2
I^*
$\sim 10^{-2}$
$\sim 10^{-1}$
I_1
5×10^{-8} $TCOI_1$
I^*
10^{-1}
I_1
2×10^{-8} TCK_1I_1
10^{-8} $TCK_1K_{2j}I^*$
10^{-2}
I_3
10^{-8} $TCEI_3$
I^*
2×10^{-8} $TCEOI^*$
$\pm 2 \times 10^{-7}$ $TCEK_1I^*$
$\sum$ Events $= 0.9 \times 10^{-7}$

TRANSIENT

TCI_2 — 10^{-7}

$TCLI^*$ — $.5\times10^{-7}$

$TCHI_3$ — 10^{-8}

$TCGI_3$ — 10^{-8}

$TCGHI^*$ — $.5\times10^{-8}$

$TCFI_3$ — 10^{-8}

$TCFHI^*$ — $.5\times10^{-8}$

$TCFGI^*$ — $.5\times10^{-8}$

$TCEI_3$ — $.5\times10^{-7}$

$TCEHI^*$ — 2.5×10^{-8}

$TCEGI^*$ — 2.5×10^{-8}

$TCEFI^*$ — 2.5×10^{-8}

$TCDI_3$ — 10^{-8}

$TCDHI^*$ — $.5\times10^{-8}$

$TCDGI^*$ — $.5\times10^{-8}$

$TCDFI^*$ — $.5\times10^{-8}$

$TCDEI^*$ — 2.5×10^{-8}

$TCELI^*$ — $.25\times10^{-8}$

LOOP(T_1)

T_1CI_2 — 2×10^{-8}

T_1COI_1 — 8×10^{-8}

$T_1CK_1K_{2,1}I^*$ — 10^{-8}

T_1CEI_3 — 10^{-8}

T_1CEOI^* — 2×10^{-8}

$T_1CEK_1I^*$ — $.5\times10^{-8}$

$$\sum \text{Events} = 5.15\times10^{-7}$$

Power > 90%, Probability ~ .75

Overall Probability ~ 3.8×10^{-7}

Of course this list is not exhaustive and not all sequences exceed criteria.

ATWS DISTRIBUTION LIST

March 14, 1977

NOTE TO: Distribution

As per 3/9 ATWS meeting, the attachment provides Minners', Easterling's, and Thadani's comments.

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H. Krug	R. Vollmer
S. Levine	I. Wall
W. Minners	S. Weiss
R. Minogue	G. Wrobel

Comments by Frank Cherny on ATWS vs. Use of Faulted Stress Limit are attached at the end of this report.

Dupe

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