ENCLOSURE 2

PROBABILISTIC RISK ASSESSMENT

OF THE

BIG ROCK POINT PLANT

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CONSUMERS POWER COMPANY AND SCIENCE APPLICATIONS, INC.

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STUDY PURPOSE

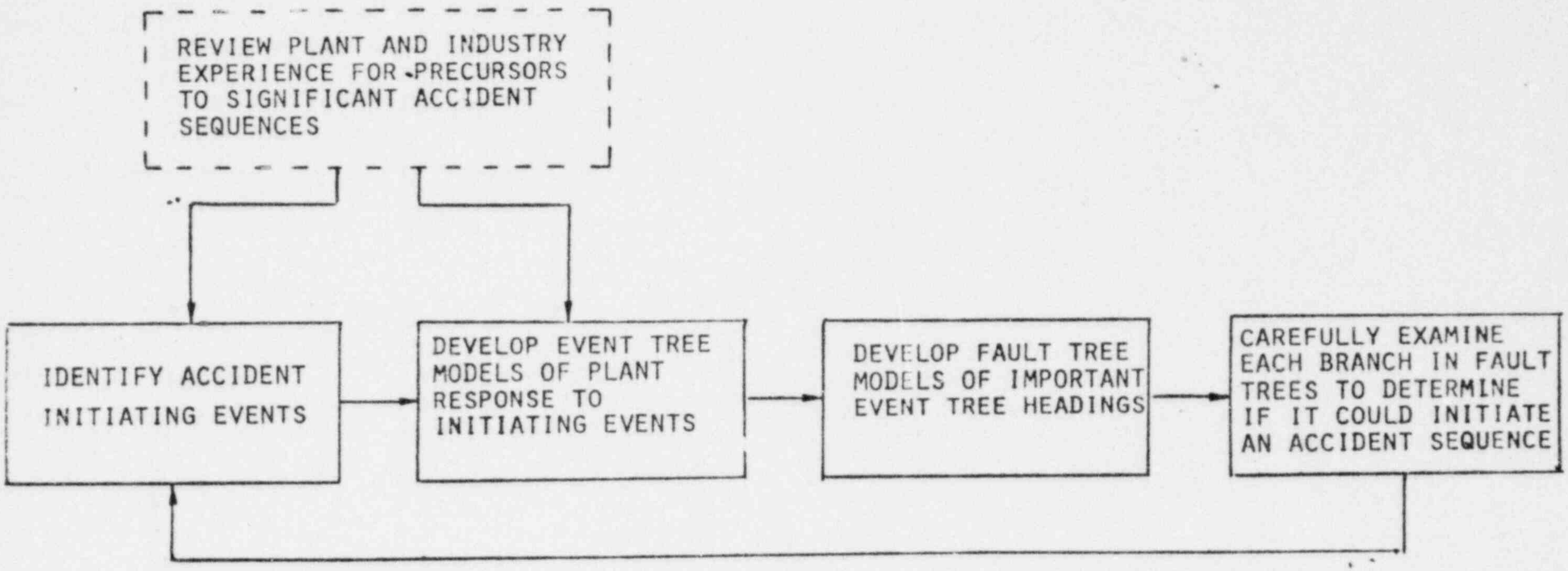
EMPLOY THE TECHNIQUES OF PROBABILISTIC RISK ASSESSMENT (PRA) TO SUPPORT THE CONTINUED SAFE OPERATION OF THE BIG ROCK POINT NUCLEAR PLANT

SCOPE OF STUDY

- COMPLETE BASELINE PRA
- SEQUENCE DEVELOPMENT AND PROBABILISTIC QUANTIFICATION
- IN-PLANT AND EX-PLANT CONSEQUENCES ANALYZED
- THOROUGH CONSIDERATION OF POTENTIAL PLANT MODIFICATIONS
- ON-GOING DEFINITION OF RISK MINIMIZATION PROGRAM

APPROACH EMPLOYED

- COMPLETE BASELINE PRA
  - INITIATOR SPECIFIC TO PLANT
  - ACCIDENT SEQUENCES (EVENT TREES AND FAULT TREES)
  - PLANT SPECIFIC DATA
  - IN-PLANT AND EX-PLANT CONSEQUENCES
- DIFFICULT ISSUES TREATED DIRECTLY
  - COMMON CAUSE FAILURES
  - INTERNAL EVENTS (E.G., FIRES AND HIGH ENERGY LINE BREAKS)
  - EXTERNAL EVENTS (E.G., SEISMIC AND WIND LOADINGS)
  - EQUIPMENT ENVIRONMENTAL QUALIFICATION
- INCLUDED IN SCOPE
  - UNIQUE APPROACHES TO ASSURING COMPLETENESS
  - FORMULATION AND INVESTIGATION OF EFFECT OF VARIOUS PLANT MODIFICATIONS
  - SIGNIFICANT CPCo PARTICIPATION
- EXCLUDED FROM SCOPE
  - SABOTAGE
  - DETAILED QUANTIFICATION OF PROBABILITY OF FAILURE TO SCRAM



FLOW DIAGRAM OF ITERATIVE PROCESS TO ASSURE COMPLETENESS IN PRA ACCIDENT SEQUENCE DEFINITION

INITIATING EVENTS FOR BRP PRA

FOR WHICH EVENT TREES WERE DEVELOPED

INITIATING EVENT	FREQUENCY (YR^{-1})
TURBINE TRIP	1.4
LOSS OF MAIN CONDENSER	.06
SPURIOUS CLOSURE OF MSIV	.06
LOSS OF FEEDWATER	.16
LOSS OF OFFSITE POWER	.13
LOSS OF INSTRUMENT AIR	.06
SPURIOUS OPENING OF TURBINE BYPASS VALVE	.1
SPURIOUS OPENING OF RDS ISOLATION VALVE	1.2×10^{-3}
SPURIOUS CLOSURE OF BOTH RECIRCULATION LINE VALVES	2.1×10^{-3}
STUCK OPEN SAFETY VALVE	2.6×10^{-4}
INTERFACING LOCA	2.6×10^{-3}
HIGH ENERGY LINE BREAK IN RECIRCULATION PUMP ROOM	3.9×10^{-7}
HIGH ENERGY LINE BREAK IN PIPE TUNNEL	3.8×10^{-6}
SMALL LOCA	1.0×10^{-4}
MEDIUM LOCA	1.0×10^{-5}
LARGE LOCA	1.0×10^{-6}
SMALL STEAM LINE BREAK INSIDE CONTAINMENT	1.0×10^{-4}

INITIATING EVENTS FOR BRP PRA
FOR WHICH EVENT TREES WERE DEVELOPED
(CONTINUED)

INITIATING EVENT	FREQUENCY (YR^{-1})
MEDIUM STEAM LINE BREAK INSIDE CONTAINMENT	1.0×10^{-5}
LARGE STEAM LINE BREAK INSIDE CONTAINMENT	1.0×10^{-6}
SMALL STEAM LINE BREAK OUTSIDE CONTAINMENT	1.0×10^{-4}
MEDIUM STEAM LINE BREAK OUTSIDE CONTAINMENT	1.0×10^{-5}
LARGE STEAM LINE BREAK OUTSIDE CONTAINMENT	1.0×10^{-6}
FIRE IN CABLE PENETRATION ROOM INSIDE CONTAINMENT WHICH AFFECTS ALL CORE COOLING SYSTEMS	1.8×10^{-3}
FIRE IN CABLE SPREADING ROOM OUTSIDE CONTAINMENT WHICH AFFECTS ALL CORE COOLING SYSTEMS	9.0×10^{-4}
FIRE IN STATION POWER ROOM WHICH AFFECTS ALL CORE COOLING SYSTEMS	3.3×10^{-3}
FIRE IN CONTROL ROOM WHICH AFFECTS ALL CORE COOLING SYSTEMS	1.0×10^{-4}
LARGE EARTHQUAKE (0.16 PEAK $<$ GROUND ACCELERATION $<$ 0.45g) MEDIAN = .23g	1×10^{-5}
MEDIUM EARTHQUAKE (.053g $<$ PEAK GROUND ACCELERATION $\leq$ 0.16g) MEDIAN = .084g	1×10^{-4}
SMALL EARTHQUAKE (.016 $<$ PEAK GROUND ACCELERATION $\leq$ .053g) MEDIAN = .03g	1×10^{-3}
LOSS OF CONTROL ROOM HABITABILITY(9)	0.14

METHODOLOGY FOR DEFINING COMPONENT FAILURE RATES FOR THE BIG ROCK POINT PRA

- THE COMPONENT FAILURE RATE DATA WAS USED IN EVENT TREE AND FAULT TREE QUANTIFICATION
- DATA WAS TAKEN FROM BOTH PLANT SPECIFIC AND GENERIC DATA SOURCES
- PLANT SPECIFIC DATA WAS PREFERRED WHERE IT WAS AVAILABLE AND CONSIDERED APPROPRIATE
- DATA WAS INAPPROPRIATE WHEN THE NUMBER OF DEMANDS OR OPERATING HISTORY, WHICH WAS DEDUCED FROM THE PLANT RECORDS, WAS CONSIDERED TO BE NONREPRESENTATIVE (E.G., CONTROL VALVE DEMANDS)
- GENERIC DATA WAS USED WHERE PLANT SPECIFIC DATA WAS NOT AVAILABLE OR NOT APPROPRIATE

PLANT SPECIFIC DATA

- INFORMATION USED TO COMPILE PLANT SPECIFIC COMPONENT FAILURE RATES WAS DERIVED FROM PLANT RECORDS
- SOURCES OF INFORMATION INCLUDED:
  - PLANT MAINTENANCE RECORDS; WHICH PROVIDED A DESCRIPTION OF MAINTENANCE ACTIVITIES
  - CONTROL ROOM LOG BOOKS; THESE PROVIDE THE DAY-TO-DAY OPERATING HISTORY
  - SURVEILLANCE TESTS; PROCEDURES BY WHICH SAFETY RELATED COMPONENTS AND INSTRUMENTATION CAN BE TESTED AGAINST STANDARD OF NORMAL OPERATION
  - DOCUMENTS WHICH DESCRIBE UNUSUAL OR ABNORMAL EVENTS; E.G., LERs, ERs, DRs, ETC.

GENERIC DATA

- SOURCES OF GENERIC DATA INCLUDED:
  - (1) WASH-1400, REACTOR SAFETY STUDY, AUGUST 1974
  - (2) GE-22A2589, RECOMMENDED COMPONENT FAILURE RATES, MAY 1974
  - (3) IEEE-50, COMPONENT RELIABILITY DATA, 1977
  - (4) CRNL-704, COMPONENT RELIABILITY DATA, DECEMBER 1971
  - (5) AI-67-TRD-15, RELIABILITY DATA COMPILATIONS, FEBRUARY 1968
  - (6) NUREG/CR-1363, DATA SUMMARIES OF LERs OF VALVES, JUNE 1980
  - (7) NUREG/CR-1205, DATA SUMMARIES OF LERs OF PUMPS, JANUARY 1980

- THE RECOMMENDED GENERIC VALUE, USED FOR A COMPONENT FAILURE RATE, WAS TAKEN FROM THE SOURCE MOST COMPATIBLE WITH THE TYPE AND MODE OF OPERATION OF THAT COMPONENT AT BIG ROCK POINT.

EXAMPLES OF COMPONENT FAILURE DATA
USED IN BIG ROCK POINT PRA

- EMERGENCY DIESEL GENERATOR (PLANT SPECIFIC)

FAILURE TO START - 12/669	$Q = 1.79 \times 10^{-2}/D$
FAILURE TO RUN - 7/355	$\lambda = 1.97 \times 10^{-2}/HR$

- MOTOR OPERATED VALVES (PLANT SPECIFIC)

FAILURE TO OPEN - 7/989	$Q = 7.07 \times 10^{-3}/D$
FAILURE TO CLOSE - 10/639	$Q = 1.56 \times 10^{-2}/D$
FAILURE TO REMAIN CLOSED -1/1254970	$\lambda = 8.81 \times 10^{-7}/HR$

- GENERIC VALUES FOR MOTOR OPERATED VALVES NOT USED IN ANALYSIS BUT SHOWN FOR COMPARISON

FAILURE TO OPEN	$Q = 1 \times 10^{-3}/D$
FAILURE TO CLOSE	$Q = 1 \times 10^{-3}/D$
FAILURE TO REMAIN CLOSED	$\lambda = 1.6 \times 10^{-7}/HR$

ESTIMATES OF HUMAN ERROR PROBABILITIES FOR BIG ROCK POINT

- o MANY OF THE BACKUP SYSTEMS FOR BRP SAFETY FUNCTIONS DEPEND ON OPERATOR ACTION
- o DETERMINING PROBABILITY OPERATOR WOULD PERFORM ACTIONS REQUIRED TO ALIGN BACKUP SYSTEMS
- o USED SWAIN AND GUTTMANN'S "HANDBOOK OF HUMAN RELIABILITY WITH EMPHASIS ON NUCLEAR POWER PLANT APPLICATIONS"
- o FACTORS WHICH DETERMINE HUMAN ERROR PROBABILITIES
  - EXPERIENCE
  - TRAINING
  - PROCEDURES
  - STRESS

IN-PLANT CONSEQUENCE ANALYSIS

- ASSESS POTENTIAL FOR CORE MELT
- DEFINE RANGE OF SEQUENCE CHARACTERISTICS (E.G., TIMING, CONTAINMENT CHALLENGE)
- EMPLOY RACAP TO CALCULATE RANGE OF RELEASES FOR VARIOUS CONTAINMENT STATES
- CATEGORIZE RELEASES BY SIMILARITY OF TIMING AND QUANTITY RELEASED

POTENTIAL CONTAINMENT FAILURE MODES

<u>SIGNIFICANT</u>

- + ENCLOSURE ISOLATION FAILURE
- + SHORT-TERM OVERPRESSURE FAILURE (ATWS)
- + PRIMARY SYSTEM ISOLATION FAILURE

<u>UNIMPORTANT</u>

- + LONG-TERM OVERPRESSURE FAILURE
- + HYDROGEN COMBUSTION
- + IN-VESSEL STEAM EXPLOSION
- + EX-VESSEL STEAM EXPLOSION
- + BASEMAT PENETRATION
- + NORMAL CONTAINMENT LEAKAGE

RISK MINIMIZING FACTORS

- o EXPERIENCED OPERATING STAFF
- o LOW RATIO OF POWER TO CONTAINMENT VOLUME (<0.2 SURRY)
- o LOW RADIONUCLIDE INVENTORY (~0.1 SURRY)
- o LOW POPULATION SITE

OUTPUTS OF STUDY

- DESCRIPTION OF RISK-CONTRIBUTING SEQUENCES
- SUMMARY OF PLANT OPERATING EXPERIENCE
- RISK EVALUATION OF RECOMMENDED DESIGN CHANGES
- QUANTITATIVE DESCRIPTION OF ACCIDENT PROCESS AND SOURCE TERMS
- COMPARISON OF HEALTH EFFECTS DISTRIBUTIONS CONSIDERING SITE POPULATION AND METEOROLOGY
- PLAN FOR PROGRAM TO DEPICT QUANTITATIVELY THE AGING PROCESS

SUMMARY OF DOMINANT SEQUENCES

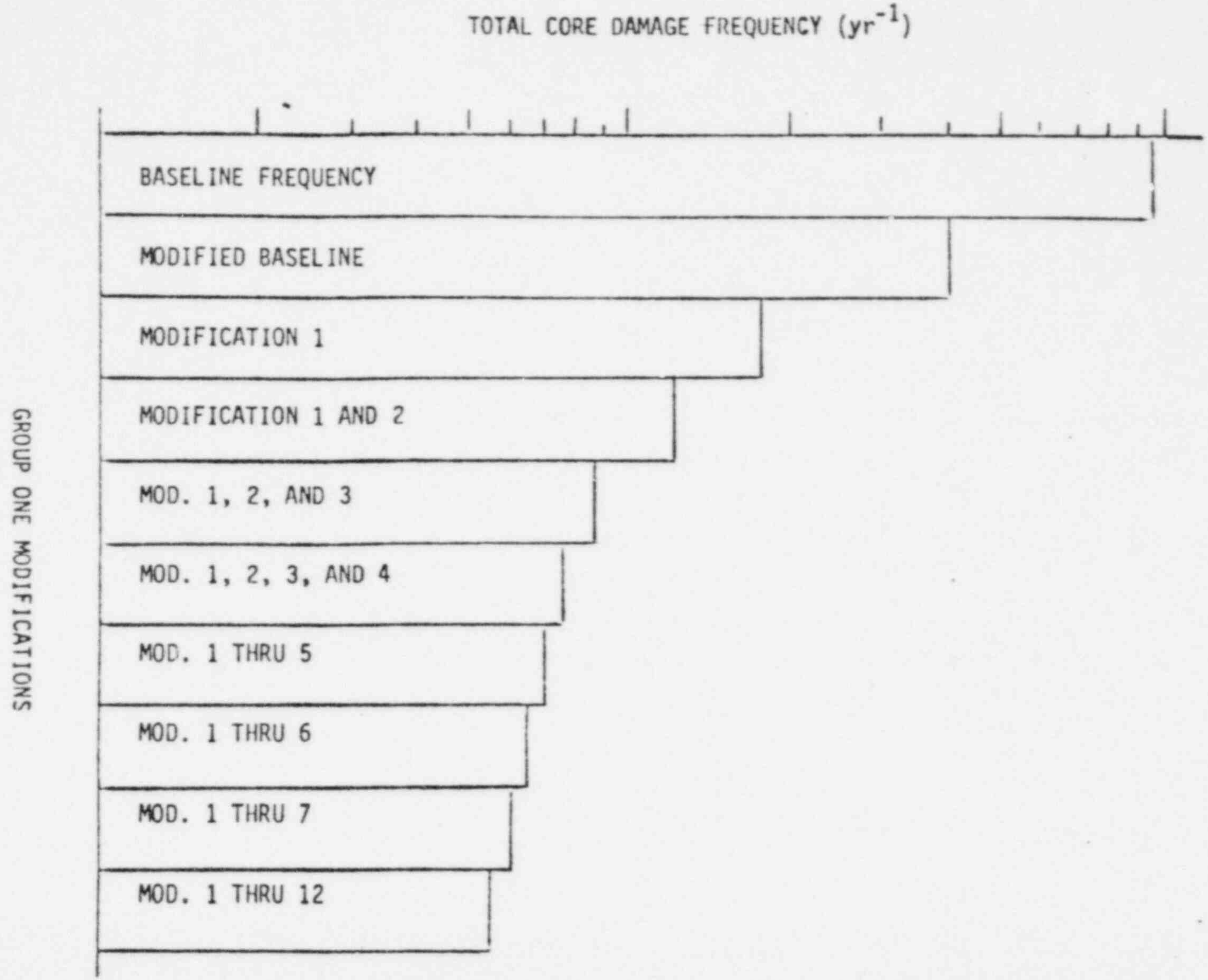
SEQUENCE CLASS (NO. OF SEQUENCES)	PERCENTAGE CONTRIBUTION TO CORE DAMAGE
TURBINE TRIP (3)	0.08
LOSS OF FEEDWATER (1)	0.04
LOSS OF MAIN CONDENSER (6)	0.38
LOSS OF OFFSITE POWER (15)	4.57
LOCA (5)	4.37
STEAM LINE BREAK INSIDE CONTAINMENT (3)	11.18
LOSS OF INSTRUMENT AIR (6)	3.35
SPURIOUS CLOSURE OF MSIV (4)	0.33
SPURIOUS OPENING OF TURBINE BYPASS VALVE (5)	7.22
ATWS (18)	4.78
SPURIOUS OPENING OF RDS ISOLATION VALVE (2)	1.73
HIGH ENERGY LINE BREAK (2)	0.15
INTERFACING LOCA (2)	8.84
FIRE (6)	23.37
STUCK, OPEN SAFETY (8)	29.47
TOTAL (86 SEQUENCES)	~100.

TYPES OF MODIFICATIONS BEING CONSIDERED

- PROCEDURAL CHANGES
- EXPANDED USE OF EXISTING FEATURES
- MODIFICATIONS TO REDUCE HUMAN ERROR PROBABILITY
- EXPANDED EQUIPMENT QUALIFICATION
- PHYSICAL DESIGN MODIFICATIONS

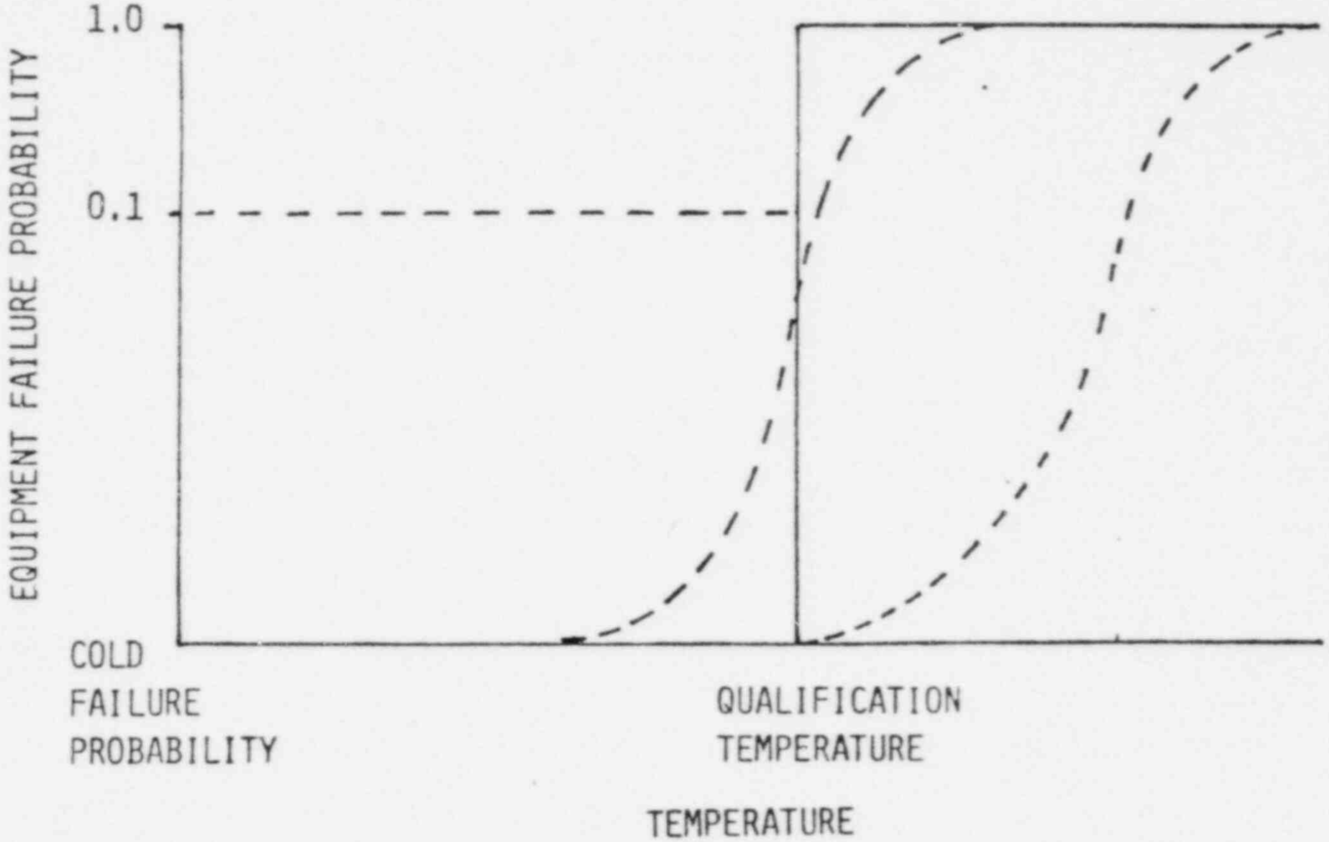
LIST OF RISK OUTLIERS AND SEQUENCE CLASSES AFFECTED

SEQUENCE CLASSES	TURBINE TRIP	LOSS OF FEEDWATER	LOSS OF MAIN CONDENSER	LOSS OF OFFSITE POWER	LOCA	STEAM LINE BREAK INSIDE CONTAINMENT	LOSS OF INSTRUMENT AIR	SPURIOUS CLOSURE OF MSIV	SPURIOUS OPENING OF TURBINE BYPASS VALVE	ATWS	SPURIOUS OPENING OF RDS ISOLATION VALVE	HIGH ENERGY LINE BREAK	INTERFACING LOCA	FIRE	STUCK OPEN SAFETY VALVE
EMERGENCY CONDENSER MAKEUP	X		X	X			X	X	X						X
ENVIRONMENTAL QUALIFICATION	X	X	X	X	X	X	X	X	X	X	X		X		X
LIMITED FW DURING ATWS										X					
MSIV BACKUP VALVE FAILURE				X											
POST INCIDENT SYSTEM RELIABILITY	X	X	X	X	X	X	X	X	X		X		X		X
RDS/CS RELIABILITY	X		X	X	X	X	X	X	X		X		X		X
STANDBY DIESEL RELIABILITY				X											
INSTRUMENT AIR SYSTEM REPAIR							X								
LEAKING RDS VALVES											X				
SINGLE VALVE ISOLATION OF PRIMARY SYSTEM													X		
PROXIMITY OF SAFETY SYSTEM PIPING TO HIGH ENERGY LINES												X			
CONCENTRATION OF SAFETY SYSTEM ELECTRICAL CABLES IN SINGLE LOCATIONS														X	
LATE AUTOMATIC ISOLATION OF MAIN STEAM LINE ON LOSS OF COOLANT									X						
SECONDARY SYSTEM INSTABILITIES		X		X						X	X				



TOTAL CORE DAMAGE FREQUENCY (yr^{-1})
GROUP ONE MODIFICATIONS
BASELINE FREQUENCY
MODIFIED BASELINE
MODIFICATION 1
MODIFICATION 1 AND 2
MOD. 1, 2, AND 3
MOD. 1, 2, 3, AND 4
MOD. 1 THRU 5
MOD. 1 THRU 6
MOD. 1 THRU 7
MOD. 1 THRU 12

FRAGILITY CURVE FOR EQUIPMENT ENVIRONMENTAL QUALIFICATION



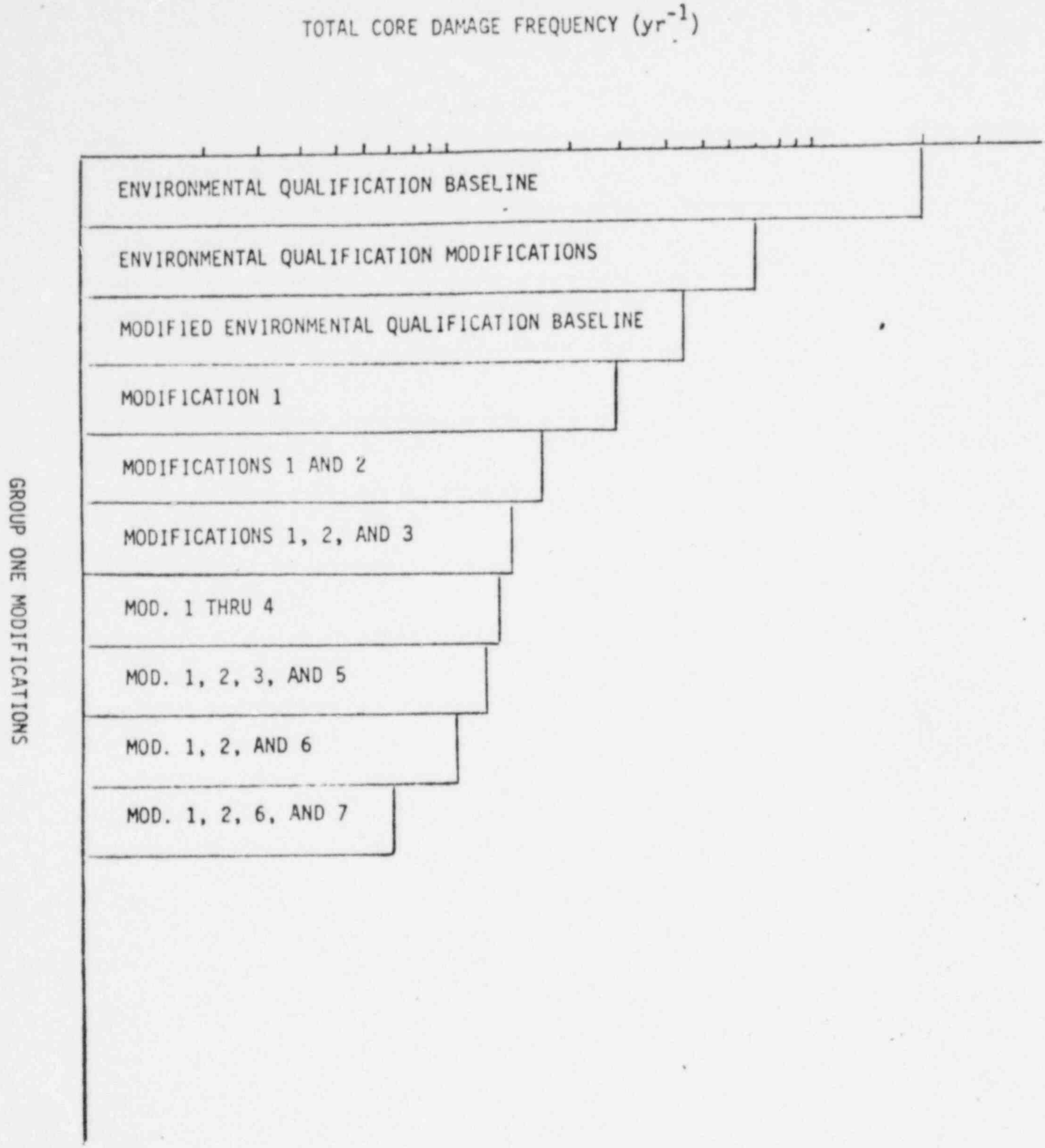

TOTAL CORE DAMAGE FREQUENCY (yr^{-1})
GROUP ONE MODIFICATIONS
ENVIRONMENTAL QUALIFICATION BASELINE
ENVIRONMENTAL QUALIFICATION MODIFICATIONS
MODIFIED ENVIRONMENTAL QUALIFICATION BASELINE
MODIFICATION 1
MODIFICATIONS 1 AND 2
MODIFICATIONS 1, 2, AND 3
MOD. 1 THRU 4
MOD. 1, 2, 3, AND 5
MOD. 1, 2, AND 6
MOD. 1, 2, 6, AND 7

FIGURE   QUALITATIVE COMPARISON OF BIG ROCK POINT RISK WITH DECISION RULES PROPOSED IN NUREG-0739

LIMITS ON OCCURRENCE OF HAZARD STATE				
	DECISION RULE ON MEAN FREQUENCY			
HAZARD STATE	GOAL LEVEL	UPPER LIMIT	BIG ROCK POINT PRE-MOD. STATUS	BIG ROCK POINT POTENTIAL POST MOD. STATUS
SIGNIFICANT CORE DAMAGE	$<3x10^{-4}$/RY	$<1x10^{-3}$/RY	BELOW GOAL	BELOW GOAL
LARGE SCALE FUEL MELT (LSFM)	$<1x10^{-4}$/RY	$<5x10^{-4}$/RY	ABOVE LIMIT	BELOW GOAL
LARGE SCALE UNCONTROLLED RELEASE FROM CONTAINMENT [GIVEN LSFM] (1)	<0.01	<0.1	ABOVE LIMIT	BETWEEN GOAL AND LIMIT FOR MOST SEQUENCES (1)

(1) THIS DECISION SEEMS TO BE ARBITRARY, OPEN TO INTERPRETATION, AND LIKELY UNACCEPTABLE BECAUSE IT IS SO STRONGLY RELATED TO THE SEQUENCE CHARACTERISTICS AND INDEPENDENT OF THE SEQUENCE PROBABILITY.

FIGURE QUALITATIVE COMPARISON OF BIG ROCK POINT RISK WITH DECISION RULES PROPOSED IN NUREG-0739

LIMITS ON RISK TO MOST EXPOSED INDIVIDUAL (1)

PROBABILITY GOAL	DECISION RULE ON MEAN FREQUENCY PER SITE-YEAR: GOAL LEVEL	DECISION RULE ON MEAN FREQUENCY PER SITE-YEAR: UPPER LIMIT	BIG ROCK POINT PRE-MOD. STATUS	BIG ROCK POINT POTENTIAL POST-MOD. STATUS
INDIVIDUAL PROBABILITY OF DELAYED CANCER DEATH (MOST EXPOSED PERSON)	$<5x10^{-6}$/SITE-YEAR	$<2.5x10^{-5}$/SITE-YEAR		
PROBABILITY OF EARLY DEATH (MOST EXPOSED PERSON)	$<1x10^{-6}$/SITE-YEAR	$<5x10^{-6}$/SITE-YEAR	BELOW GOAL	BELOW GOAL

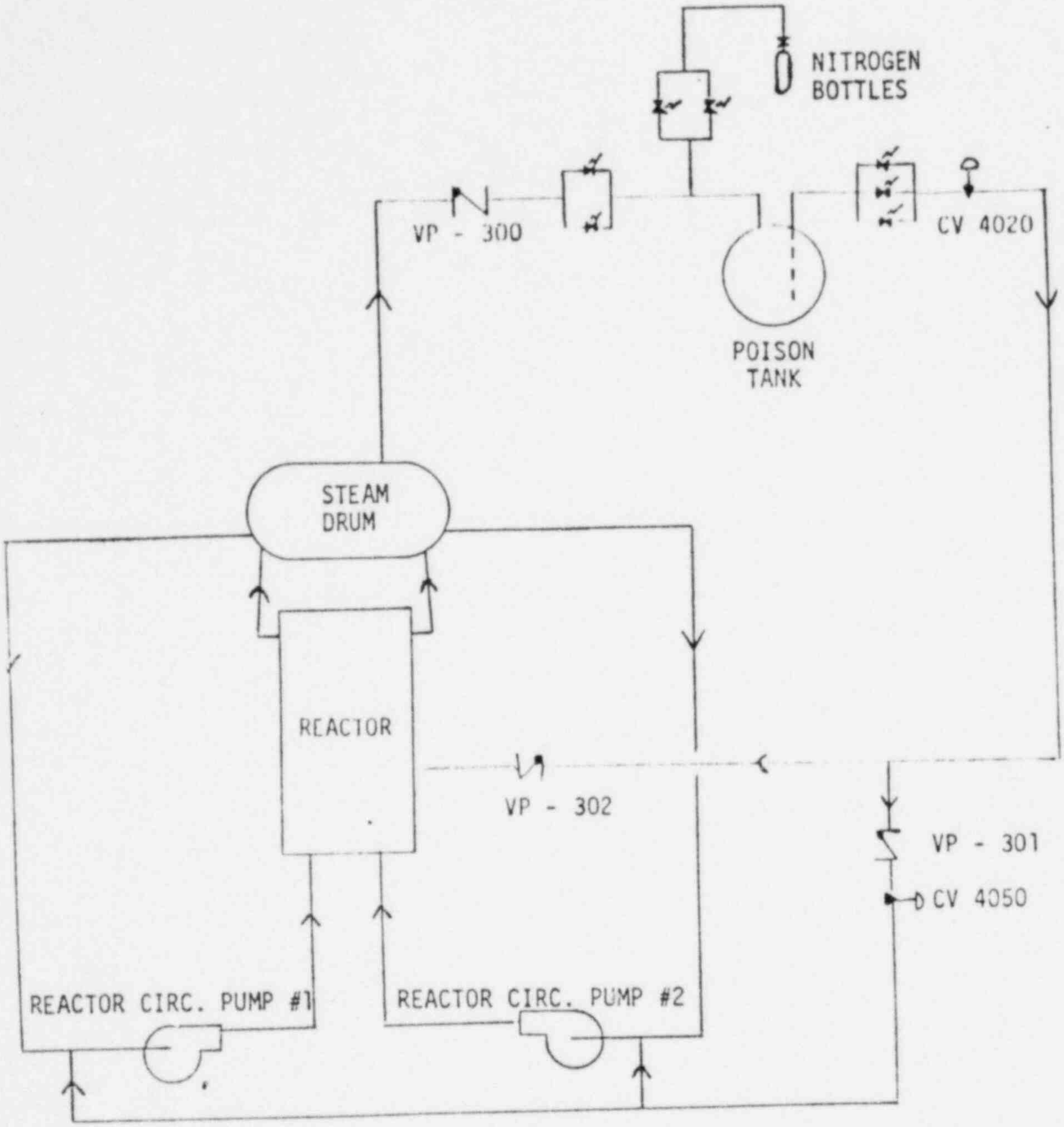
(1) DECISION RULES ON MEAN FREQUENCY PER LARGE SCALE FUEL MELT HAVE NOT YET BEEN ESTIMATED.

FIGURE QUALITATIVE COMPARISON OF BIG ROCK POINT RISK WITH DECISION RULES PROPOSED IN NUREG-0739

SOCIETAL HEALTH RISK LIMITS				
	DECISION RULES			BIG ROCK POINT
			BIG ROCK POINT	POTENTIAL POST-
MEASURE OF RISK	GOAL LEVEL	UPPER LIMIT	PRE-MOD. STATUS	MOD. STATUS
EXPECTED VALUE OF DELAYED CANCER DEATHS	<2 PER 10^{10} KWh	<10 PER 10^{10} KWh	BELOW GOAL	BELOW GOAL
EXPECTED FREQUENCY OF EARLY DEATHS (RAISED TO THE 1.2 POWER)	<0.4 PER 10^{10} KWh	<2 PER 10^{10} KWh	BELOW GOAL	BELOW GOAL

Time Available to Operator
to Inject Liquid Poison
Preventing RDS

Transient	Time	
Low Level Transients Loss of feedwater and transients involving opening of the turbine bypass valve	Auto RCPT Manual RCPT @ 60s. No RCPT	RDS cannot be prevented
High Pressure Transients without Feedwater Loss of offsite power transients	Auto RCPT Manual RCPT @ 60s. No RCPT	RDS cannot be prevented
High Pressure Transients with Feedwater from Hotwell Loss of main condenser and turbine trip transients without bypass	Auto RCPT	180 s.
	Manual Rcpt @ 60s.	120 s.
	No RCPT	0 s.



LIQUID POISON SYSTEM

FLOW DIAGRAM

Modification	Loss of Condenser		Loss of Offsite Power		Misc. Scrams		Total Core Damage Frequency for ATWS	
1. Restrict Reject Line (Prevent FW trip on TBPV opening)	1.2×10^{-5}	NC	3.5×10^{-6}	NC	1.7×10^{-7}	NC	4.6×10^{-5}	2.5×10^{-5}
2. Load Rejection Capability		NC		3.5×10^{-7}		NC		2.0×10^{-5}
3. Evironmentally qualify LPS		6.1×10^{-6}		NC		NC		3.9×10^{-5}
4. Automatic LPS		6.1×10^{-6}		NC		NC		3.8×10^{-5}
5. Auto RCPT & Env Qual LPS		3.3×10^{-6}		NC		NC		3.5×10^{-5}
6. Restrict Reject Line Environ. Qual LPS		6.1×10^{-6}		NC		NC		1.8×10^{-5}
Restrict Reject Line Env Qual LPS Makeup from CDST		1.0×10^{-6}		NC		NC		1.1×10^{-5}
[illegible]. Restrict Reject Line Env Qual LPS Makeup from CDST Auto RCPT		1.1×10^{-7}		NC		NC		1.0×10^{-5}
9. Restrict Rej Line Auto LPS Makeup from CDST Auto RCPT		1.9×10^{-8}		NC		NC		9.8×10^{-6}

APPROACH TO EVALUATING
UTILITY OF CONTAINMENT SHIELD WALL

- FIRST DEFINE IMPORTANT ACCIDENT SEQUENCES
- ASSESS SPECTRUM OF ACCIDENTS LEADING TO SOURCE TERMS IN CONTAINMENT
- DEFINE MAGNITUDE OF POTENTIAL RADIONUCLIDE SOURCES TO CONTAINMENT FOR VARIOUS SEQUENCES (MELT AND NON-MELT)
- CONSIDER CORRECTIVE ACTION ROLE OF OPERATOR IN SEQUENCES
- ASSESS LOCATIONS REQUIRING OPERATOR PRESENCE (FOR INFORMATION GATHERING OR LOCAL ACTIONS)
- ASSESS THE ADEQUACY OF ASSUMPTIONS ON OPERATOR ACTION DURING SEQUENCES
- ASSESS POTENTIAL CONSERVATISMS IN OPERATOR ACTION ASSUMPTIONS
- ASSESS ACTIONS PREVENTED BY PRESENCE OF SOURCE TERM