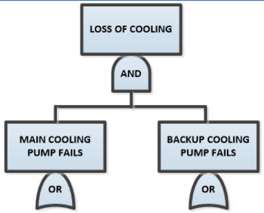
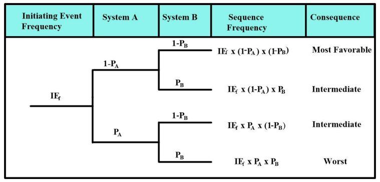
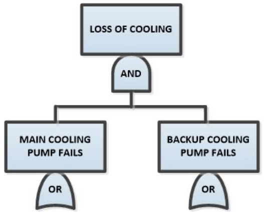


Session 4 -- Crane safety studies at nuclear power plants

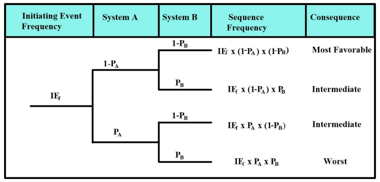


Present the use of fault tree and event tree analysis in crane safety studies

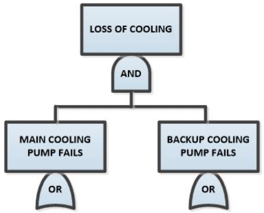
Howard Lambert
FTA Associates
2022



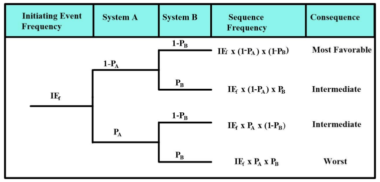
Crane safety studies at nuclear power plants



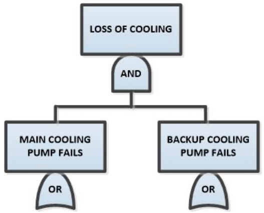
- Describe two reports
- NUREG-0612 “Control of Heavy Loads at Nuclear Power Plants” (July 1980)
- NUREG-1174 “A survey of Crane Operating Experience at US Nuclear Power Plants” from 1968 through 2002 (June 2003)



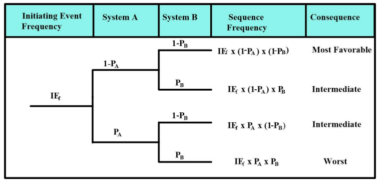
NUREG 0612



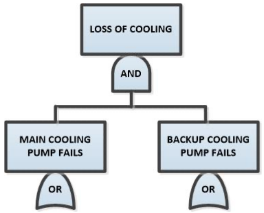
- The first Part of the presentation deals with the use of fault tree analysis to describe Load drop scenarios of heavy loads at Nuclear power Plants
- NUREG-0612 addresses controls for safe movement of heavy loads
  1. Safe load paths
  2. Procedures
  3. Crane operator training
  4. Special lifting devices
  5. Special lifting devices not specially designed
  6. Crane inspection and Maintenance



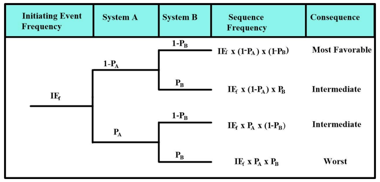
Accidental Drops of Heavy Loads Consequences



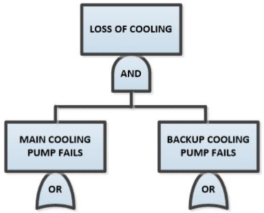
- Damage irradiated uranium fuel
- Cause critically accidents
- Damage safe shutdown equipment



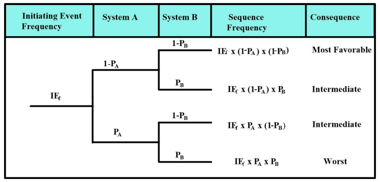
TECHNICAL APPROACH – FAULT TREE ANALYSIS



- Above the hook/below the hook
- Basic Events
- Human Error Events (e.g., Crane Operator Failure, Erroneous Test and Maintenance Actions)
- Equipment Failure (e.g., Structural Failure, Control System Failures Leading To Over speed)



STEPS IN STUDY (CONTINUED)

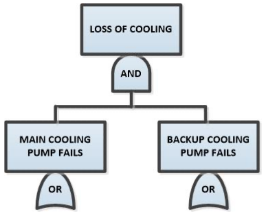


- Events identification and fault tree construction - - determination of all the ways the polar crane (bridge) system could fail:

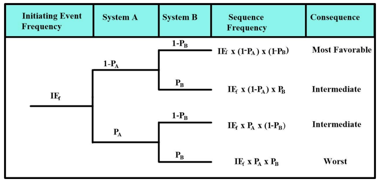
1. Structural failure while subjected to normal load conditions
2. Structural failure due to excessive load
    - i) Two-blocking event
    - ii) Load hang-up event

3. Over speed event - - loss of hoisting of lowering capability coupled with loss of brakes

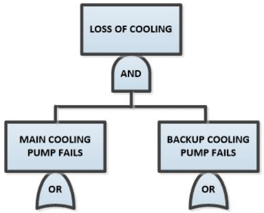
Two blocking event refers to continue to hoist past the limit switch position resulting stretching and breaking the wire rope resulting in a load drop



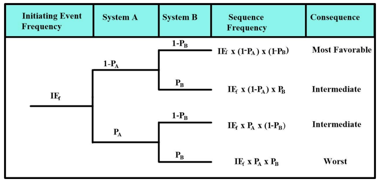
Steps continued

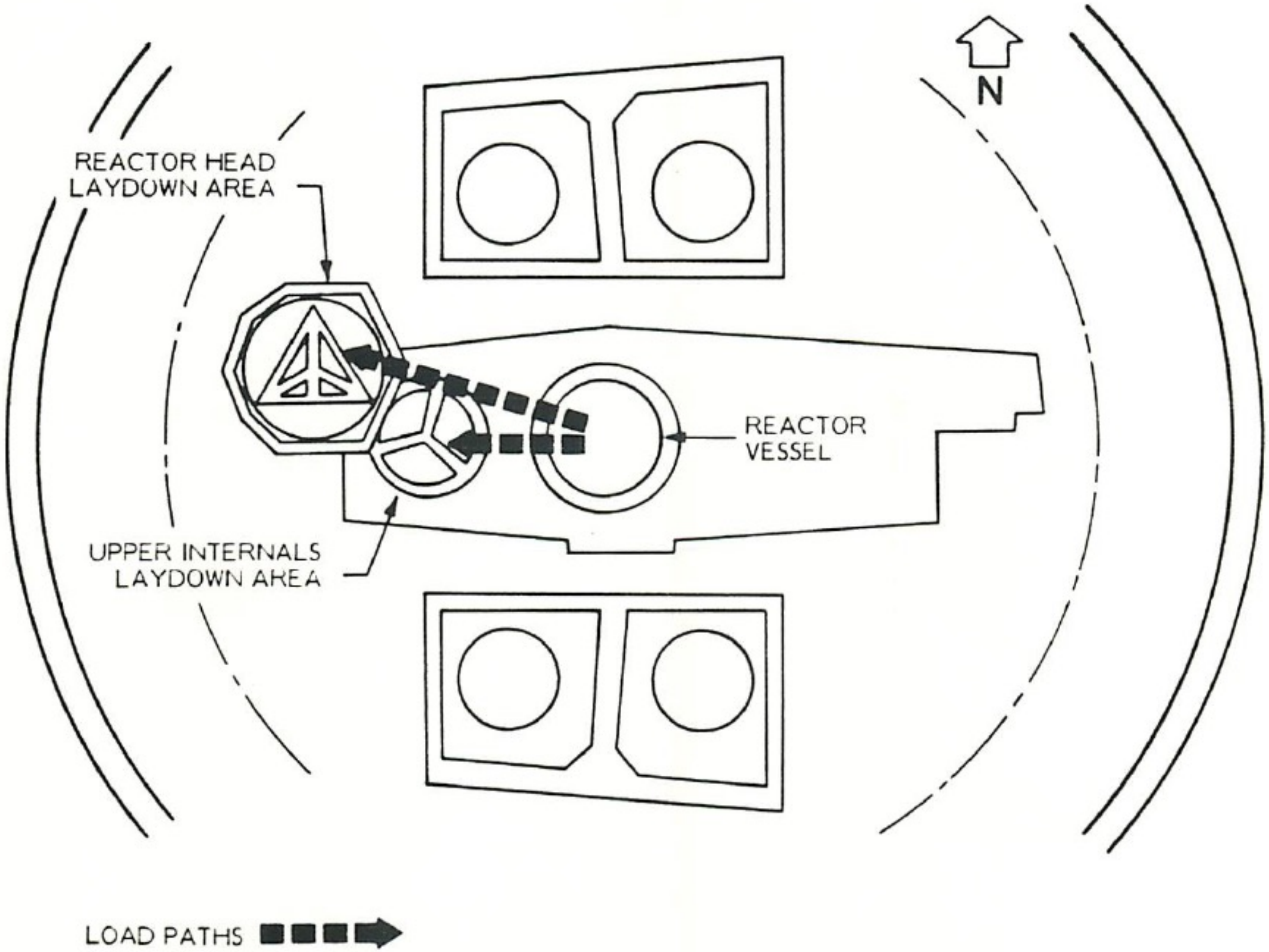


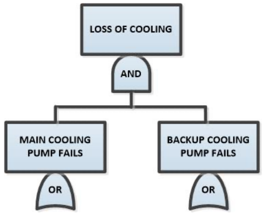
- Qualitative analysis
  - Find minimal cut sets and establish all single failure events leading to system failure
- Probabilistic analysis
  1. Find sources of data and determine applicability to nuclear power plants
  2. Compute probability of the Top Event (Load Drop)
  3. Probabilistically rank basic events and min cut sets (i.e., conduct a sensitivity analysis)
- Conclusions, recommendations and results.



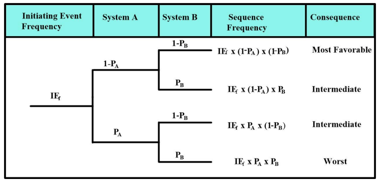
LOAD PATH FOR REACTOR HEAD AND UPPER INTERNALS REMOVAL PLAN VIEW

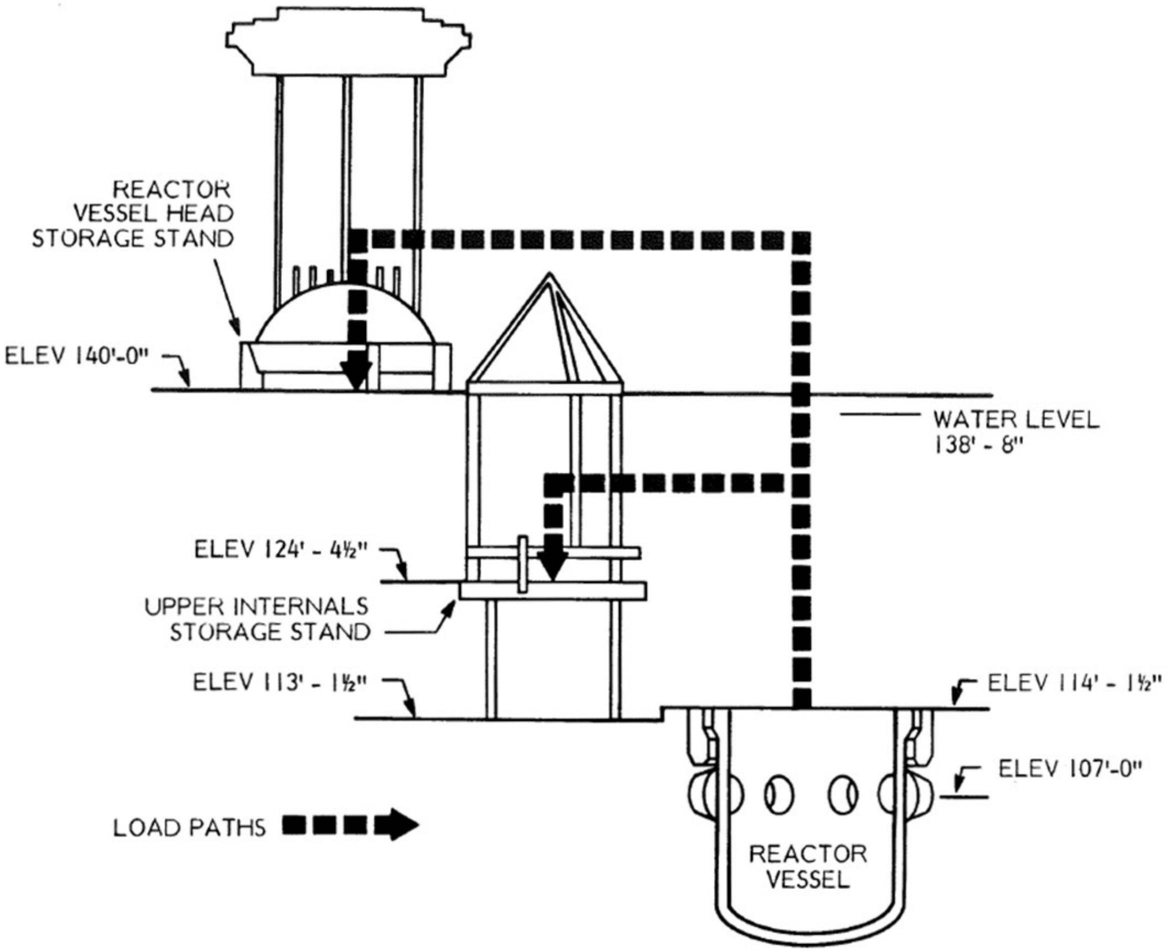


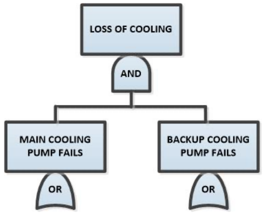




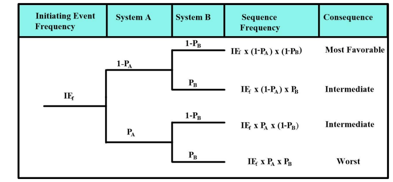
LOAD PATH FOR REACTOR HEAD AND UPPER INTERNALS REMOVAL ELEVATION VIEW

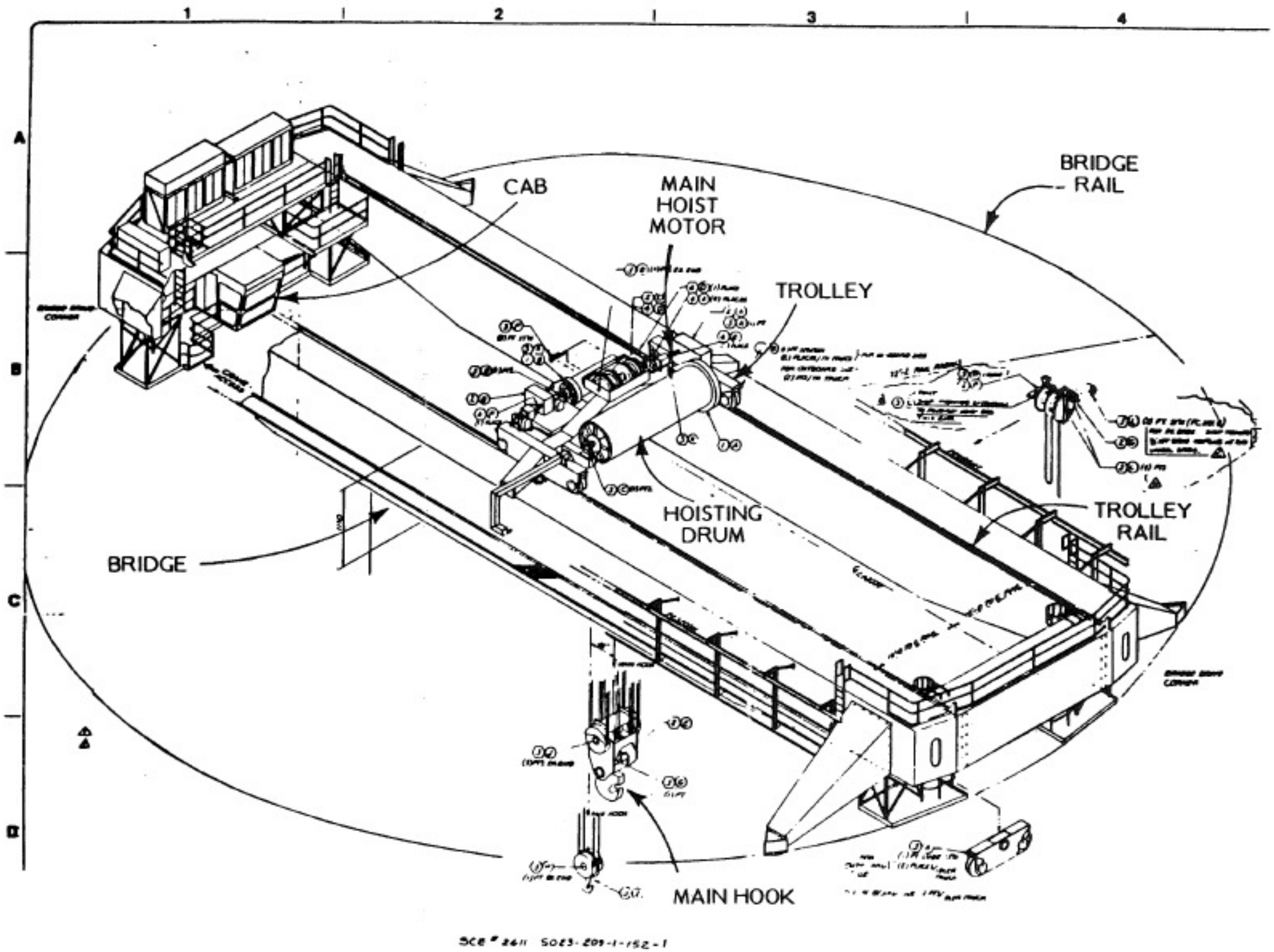


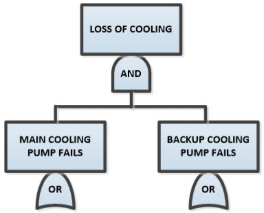



LOSS OF COOLING
AND
MAIN COOLING PUMP FAILS
BACKUP COOLING PUMP FAILS
OR
OR

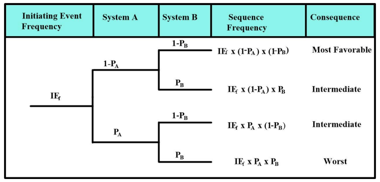
Polar Crane

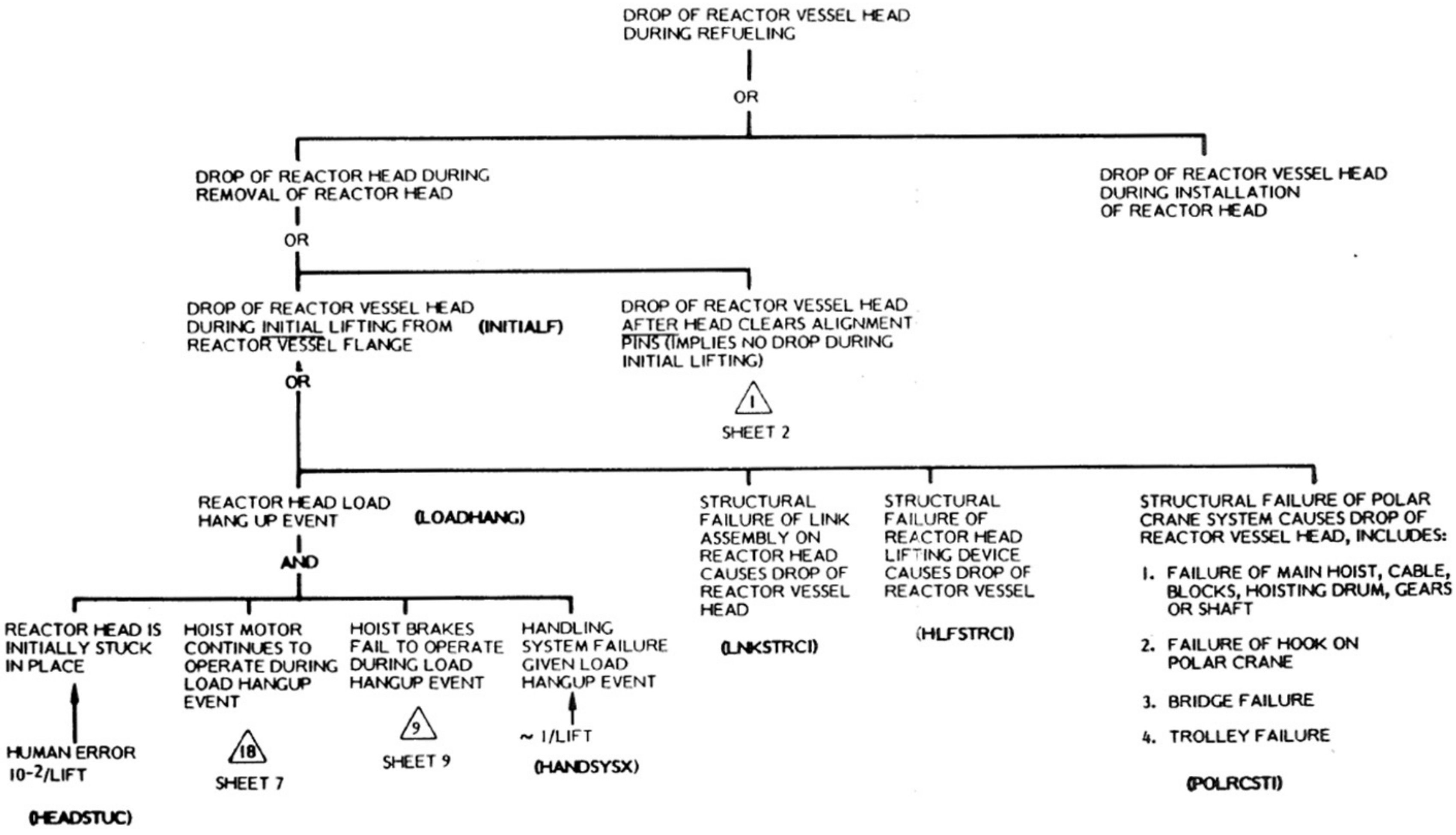

Initiating Event Frequency
System A
System B
Sequence Frequency
Consequence
Most Favorable
Intermediate
Intermediate
Worst

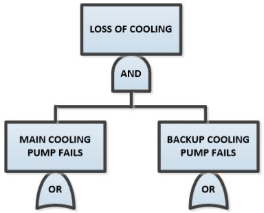

1
2
3
4
A
B
C
D
CAB
MAIN HOIST MOTOR
BRIDGE RAIL
TROLLEY
HOISTING DRUM
TROLLEY RAIL
BRIDGE
MAIN HOOK



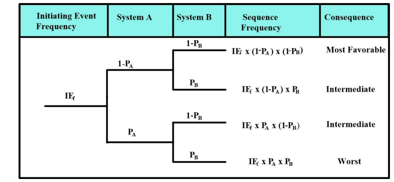
Fault Tree Top Event – Sheet 1

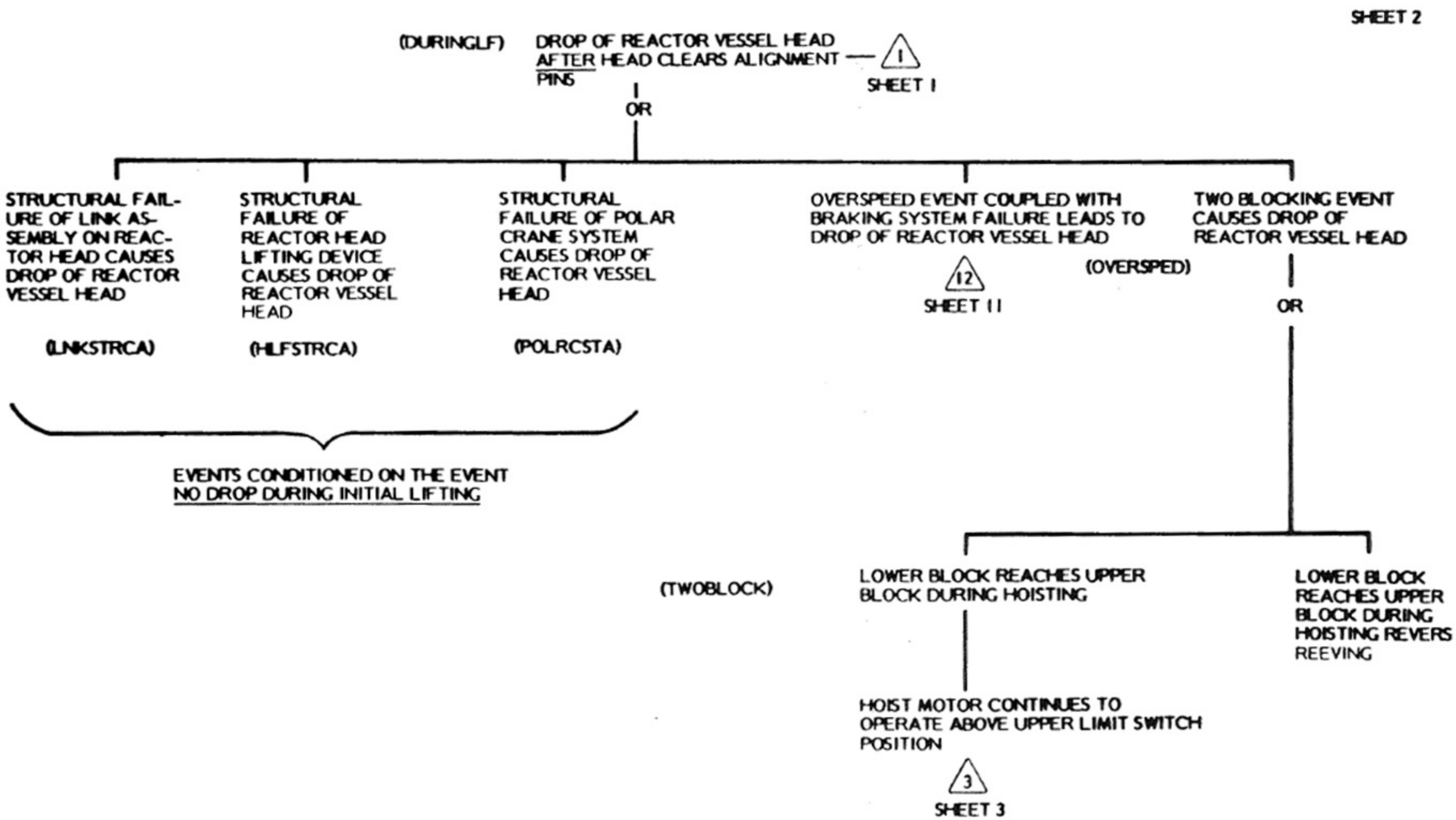


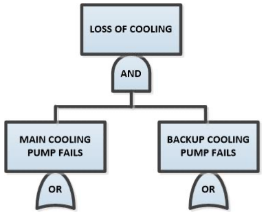




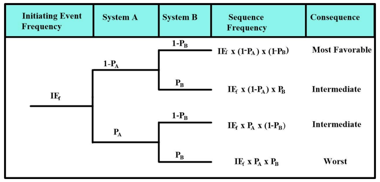
Fault Tree Top Event – Sheet 2







Qualitative Evaluation



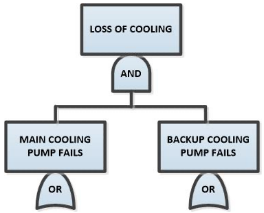
DESCRIPTOR EVENTS

- STRUCTURAL FAILURE DURING INITIAL LIFT
- STRUCTURAL FAILURE AFTER INITIAL LIFTING
- DROP OF HEAD DURING INITIAL LIFTING
- REACTOR HEAD LOAD HANGUP EVENT
- OVERSPEED EVENT
- TWO-BLOCKING EVENT

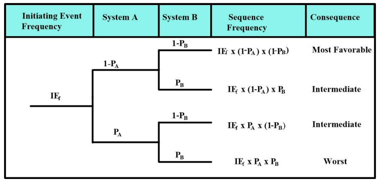
MIN CUT SETS

A TABLE OF THE NUMBER OF MIN CUT SETS VERSUS ORDER IS GIVEN BELOW:

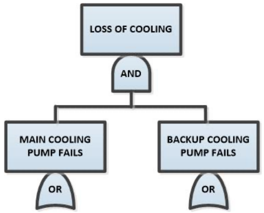
ORDER	1	2	3	4	5	6
NO. OF MIN CUT SETS	6	0	2	178	94	8



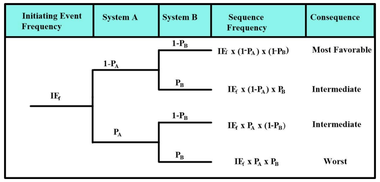
PROBABILISTIC ANALYSIS



- Assigning probabilistic data to the basic events
- Computing the probability of the top event (i.e., Probability of reactor head/upper internals drop during refueling)
- Determining the most important basic events and min cuts sets that contribute to the load drop event (i.e., conduct an importance analysis).



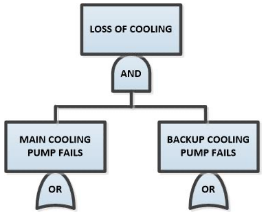
Structural Reliability



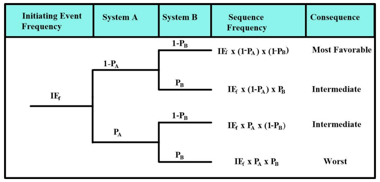
- After initial lift, it was assumed that as many 10 structural elements are in series

- It was assumed that each element is stressed to the maximum allowable stress limit

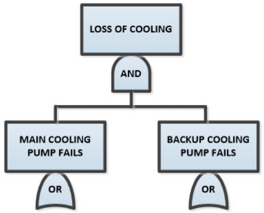
- Mean probabilities are given below:
  - During lifting of the head (after initial lift), no binding 3.0 E-7/lift
  - Same as above with binding 1.0E-4/lift
  - During lifting the upper internals (after initial lift) insignificant



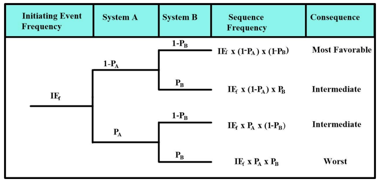
PROBABILISTIC DATA FOR BASIC EVENTS



- Human error
- Equipment failure
- Structural failures
  - Structural failure of the polar crane system
  - Structural failure of the reactor head lifting device
  - Structural failure of the link assembly on the reactor vessel
  - Crane failure
  - Rigging



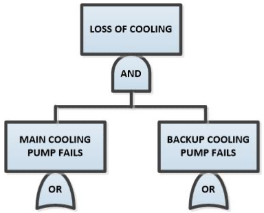
Causes of Crane Accidents
United States Department of Navy



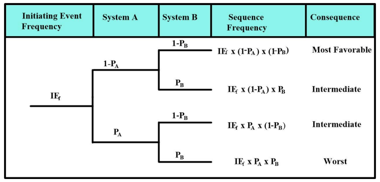
Cause Category	(1) Number of load drop events reported	(2) Upper* bound estimate	Estimated** mean probability
1. Crane failure	10	20	1.7×10^{-5}/lift
2. Crane operator failure	30	60	5.1×10^{-5}/lift
3. Rigging failure	3	6	5.1×10^{-6}/lift
Total	43	86	7.4×10^{-5}/lift

* Assumes only one-half of the events are reported.

** Calculated as the average of columns (1) and (2) divided by the estimated mean number of lifts, 8.75×10^5.



Human Error Probabilities

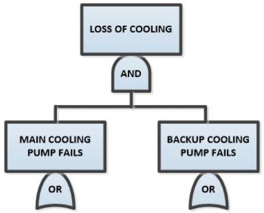


- GENERALLY
  10^{-2}/event
- EXCEPTIONS

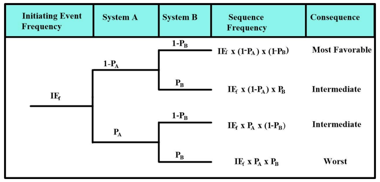
  (1) Continue to hoist to upper limit switch position = 10^{-3}/event

  (2) Conditional probability for emergency stop during

  - Two Blocking = 1
  - Load Hangup = 1
  - Overspeed = 0.1



Equipment Failure Probabilities



EQUIPMENT FAILURE

- BEING UNAVILABLE AT THE TIME OF THE DEMAND (e.g., OPEN OR SHORT CIRCUIT IN A CONTROL CIRCUIT)
- FAILURE TO CHANGE STATE UPON DEMAND (e.g., RELAY CONTACTS FAILING TO OPEN, BRAKES FAIL-ING TO OPERATE).

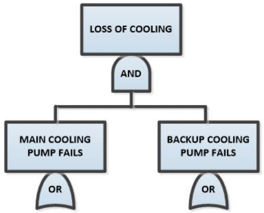
UNANNOUNCED FAILURES

- DYNAMIC BRAKE RESISTOR
- OVERSPEED SWITCHES

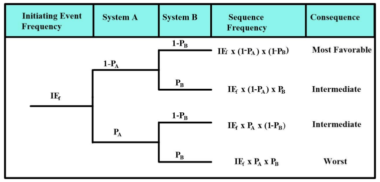
$\lambda\theta/2$

λ = failure rate

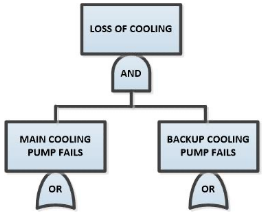
θ = plant life, 30 years



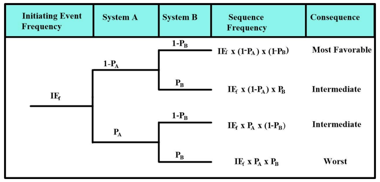
Reactor Head Probability drop per lift



	Mean (90% confidence interval)	
	Best Estimate	Conservative
With Initial Lift	2.0×10^{-5} (1.5×10^{-5}, 2.1×10^{-4})	3.6×10^{-5} (2.7×10^{-5}, 3.1×10^{-4})
Without Initial Lift	3.8×10^{-6} (1.7×10^{-6}, 4.4×10^{-5})	6.5×10^{-6} (3.0×10^{-6}, 6.5×10^{-5})

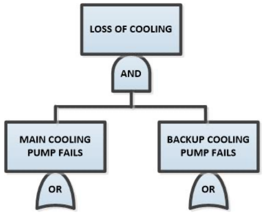


Basic event importances

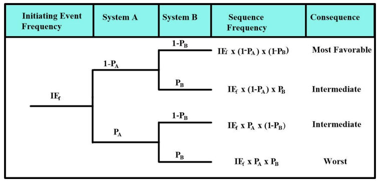


LIMITING SYSTEM UNAVAILIBILITY= 0.19569E-04

RANK	BASIC EVENT	IMPORTANCE	PROBABILITY	ERROR FACTOR	DISTRIBUTION	BASIC EVENT DESCRIPTION
1	INITIALF	0.807	1.00	0.000	CONSTANT	** DROP OF HEAD DURING INITIAL LIFTING **
2	POLRSCSI	0.434	0.850E-05	10.0	LOGNORML	STRUCTURAL FAILURE OF POLAR CRANE SYSTEM
3	DURINGLF	0.138	1.00	0.000	CONSTANT	** STRUCTUAL FAILURE AFTER INITIAL LIFTING **
4	HLFSTRCI	0.133	0.260E-05	10.0	LOGNORML	STRUCTURAL FAILURE REACTOR HEAD LIFTING DEVICE
4	LNKSTRCI	0.133	0.260E-05	10.0	LOGNORML	STRUCTURAL FAILURE OF LINK ASSEMBLY ON HEAD
5	LOADHANG	0.107	1.00	0.000	CONSTANT	** REACTOR HEAD LOAD HANGUP EVENT **
5	HANDSYSX	0.107	1.00	0.000	CONSTANT	HANDLING SYSTEM FAILURE
5	HEADSTUC	0.107	0.100E-01	10.0	LOGNORML	REACTOR HEAD IS INITIALLY STUCK IN PLACE
5	ESTOPOPL	0.107	1.00	0.000	CONSTANT	OPERATOR FAILS TO PRESS EMERGENCY STOP
5	HOISTOPL	0.107	0.100E-01	10.0	LOGNORML	OPERATOR FAILS TO PLACE HOIST LEVER IN OFF POSIT
6	POLRSCTA	0.869E-01	0.170E-05	10.0	LOGNORML	STRUCTURAL FAILURE OF POLAR CRANE SYSTEM
7	ZEROADHI	0.772E-01	0.100E-01	10.0	LOGNORML	ZERO ADJUSTMENT SET HIGH
7	STPTHI	0.772E-01	0.100E-01	10.0	LOGNORML	SET POINT ADJUSTMENT TOO HIGH
8	TWOBLOCK	0.547E-01	1.00	0.000	CONSTANT	** TWO BLOCKING EVENT **
8	ESTOPOP2	0.547E-01	1.00	0.000	CONSTANT	OPERATOR FAILS TO PRESS EMERGENCY STOP
8	HOISTOP2	0.546E-01	0.100E-01	10.0	LOGNORML	OPERATOR FAILS TO PLACE HOIST LEVER IN OFF POSIT
9	LSHCLOSE	0.536E-01	0.500E-02	2.00	LOGNORML	LIMIT SWITCH CONTACTS FAIL TO OPEN
10	HLFSTRCA	0.256E-01	0.500E-06	10.0	LOGNORML	STRUCTURAL FAILURE REACTOR HEAD LIFTING DEVICE
10	LNKSTRCA	0.256E-01	0.500E-06	10.0	LOGNORML	STRUCTURAL FAILURE OF LINK ASSEMBLY ON HEAD
11	COMPHI	0.116E-02	0.150E-03	10.0	LOGNORML	COMPARATOR OUTPUT CURRENT HIGH
11	WHTSTONE	0.116E-02	0.150E-03	10.0	LOGNORML	WHEATSTONE BRIDGE FAILURE LOW
11	OUTDRLOW	0.116E-02	0.150E-03	10.0	LOGNORML	OUTPUT DRIVER FAILS LOW
11	ABINPTLO	0.116E-02	0.150E-03	10.0	LOGNORML	OUTPUT OF BISTABLE INPUT AMP FAILS LOW
11	ASTPTHI	0.116E-02	0.150E-03	10.0	LOGNORML	SET POINT AMP FAILS HIGH
12	LSCLOSED	0.108E-02	0.100E-03	3.00	LOGNORML	LS CONTACTS FAIL TO OPEN
13	HCLOSED	0.772E-03	0.100E-03	3.00	LOGNORML	HOIST CONTACTS,H, FAIL TO OPEN
13	HIRELAY	0.772E-03	0.100E-03	3.00	LOGNORML	HIGH LIMIT RELAY CONTACTS FAIL TO OPEN
14	MHCLOSED	0.162E-03	0.100E-04	3.00	LOGNORML	MH CONTACTS FAIL TO OPEN
15	OVERSPED	0.864E-04	1.00	0.000	CONSTANT	** OVERSPEED EVENT **
15	DYBRRES	0.864E-04	0.410	2.00	LOGNORML	DYNAMIC BRAKE RESISTOR FAILS OPEN CCT
16	HB12-13C	0.660E-04	0.100E 00	10.0	LOGNORML	HB CONTACTS 12-13 FAIL TO OPEN
16	HB11-12C	0.660E-04	0.100E-03	3.00	LOGNORML	HB CONTACTS 11-12 FAIL TO OPEN
17	MENSENLO	0.386E-04	0.500E-05	10.0	LOGNORML	MAIN HOIST SENSOR FAILURE LOW
18	FDSTRCCT	0.374E-04	0.150E-03	10.0	LOGNORML	FAILURE OF FIELD STRENGHTING CCT
18	193X730	0.374E-04	0.150E-03	10.0	LOGNORML	DRIVER 193X730 DEFECTIVE
19	HBRAKE1	0.191E-04	0.170E-04	10.0	LOGNORML	HOIST BRAKE #1 FAILS TO OPERATE
19	HBRAKE2	0.191E-04	0.100E 00	10.0	LOGNORML	HOIST BRAKE #2 FAILS TO OPERATE
20	RUNTIMER	0.105E-04	0.100E-03	3.00	LOGNORML	RUN TIMER CONTACTS FAIL TO OPEN
21	ACPOWER	0.713E-05	0.200E-03	3.00	LOGNORML	LOSS OF AC POWER
22	HMOTOR	0.249E-05	0.100E-04	3.00	LOGNORML	LOSS OF HOISTING MOTOR
23	ESCLOSED	0.228E-05	0.100E-04	3.00	LOGNORML	ES CONTACTS FAIL TO OPEN
24	ESTOPCLO	0.162E-05	0.100E-04	3.00	LOGNORML	EMERGENCY STOP SWITCH CONTACTS FAIL TO OPEN
25	HOISTOPO	0.132E-05	0.100E-01	10.0	LOGNORML	OPERATOR FAILS TO PLACE HOIST LEVER IN OFF POSIT



Mean Probabilities of Various Load Drop Scenarios per Lift (Best Estimate Case)

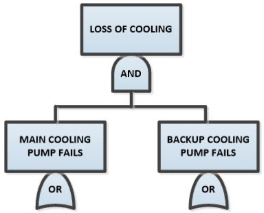


MEAN PROBABILITIES OF VARIOUS LOAD DROP SCENARIOS PER LIFT*
(BEST ESTIMATE CASE)

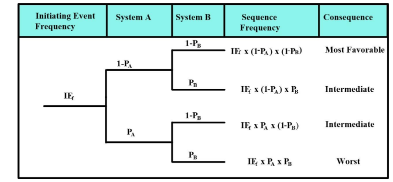
Load Drop Scenario	Mean Probability
• Drop of head during initial lift	1.6×10^{-5}
• Structural failure during initial lift	1.4×10^{-5}**
• Structural failure after initial lift	2.7×10^{-6}
• Reactor head load hangup event	2.1×10^{-6}
• Two-blocking event	1.1×10^{-6}
• Overspeed event	1.7×10^{-9}

*Because there are common min cut sets to the above scenarios, the probability of their sum exceeds the Top Event probability.

**Includes the sum of importances of the following basic events: POLRSCI, HLFSTRCI, and LNKSTRCI in Table 4.

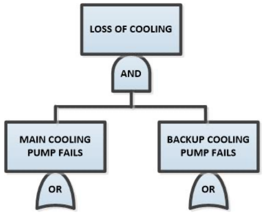


Ranking of Most Important Min Cut Sets

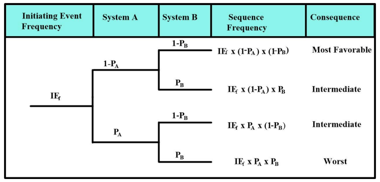



```
LIMITING SYSTEM UNAVAILABILITY= 0.196E-04
RANK  IMPORTANCE

   1 0.434E 00   CUT SET        1
       BASIC EVENT      PROBABILITY        ERROR FACTOR DISTRIBUTION  BASIC EVENT DESCRIPTION
       INITIALF         0.100E 01            0.000     CONSTANT   **  DROP OF HEAD DURING INITIAL LIFTING **
       POLRSCSI         0.850E-05            10.0      LOGNORML   STRUCTURAL FAILURE OF POLAR CRANE SYSTEM

   2 0.133E 00   CUT SET        5
       BASIC EVENT      PROBABILITY        ERROR FACTOR DISTRIBUTION  BASIC EVENT DESCRIPTION
       HLFSTRCI         0.260E-05            10.0      LOGNORML   STRUCTURAL FAILURE REACTOR HEAD LIFTING DEVICE
       INITIALF         0.100E 01            0.000     CONSTANT   **  DROP OF HEAD DURING INITIAL LIFTING **

   2 0.133E 00   CUT SET        4
       BASIC EVENT      PROBABILITY        ERROR FACTOR DISTRIBUTION  BASIC EVENT DESCRIPTION
       INITIALF         0.100E 01            0.000     CONSTANT   **  DROP OF HEAD DURING INITIAL LIFTING **
       LNKSTRCI         0.260E-05            10.0      LOGNORML   STRUCTURAL FAILURE OF LINK ASSEMBLY ON HEAD

   3 0.869E-01   CUT SET        2
       BASIC EVENT      PROBABILITY        ERROR FACTOR DISTRIBUTION  BASIC EVENT DESCRIPTION
       DURINGLF         0.100E 01            0.000     CONSTANT   ** STRUCTUAL FAILURE AFTER INITIAL LIFTING **
       POLRSCTA         0.170E-05            10.0      LOGNORML   STRUCTURAL FAILURE OF POLAR CRANE SYSTEM

   4 0.511E-01   CUT SET      268
       BASIC EVENT      PROBABILITY        ERROR FACTOR DISTRIBUTION  BASIC EVENT DESCRIPTION
       ESTOPOPL         0.100E 01            0.000     CONSTANT   OPERATOR FAILS TO PRESS EMERGENCY STOP
       HANDSYSX         0.100E 01            0.000     CONSTANT   HANDLING SYSTEM FAILURE
       HEADSTUC         0.100E-01            10.0      LOGNORML   REACTOR HEAD IS INITIALLY STUCK IN PLACE
       HOISTOPL         0.100E-01            10.0      LOGNORML   OPERATOR FAILS TO PLACE HOIST LEVER IN OFF POSIT
       INITIALF         0.100E 01            0.000     CONSTANT   **  DROP OF HEAD DURING INITIAL LIFTING **
       LOADHANG         0.100E 01            0.000     CONSTANT   **  REACTOR HEAD LOAD HANGUP EVENT  **
       ZEROADHI         0.100E-01            10.0      LOGNORML   ZERO ADJUSTMENT SET HIGH †
```

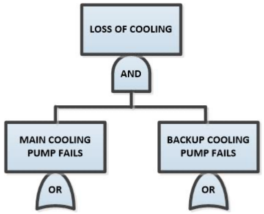
† Calibration Error in Load Sensing Circuit



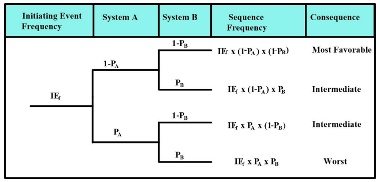
Recommendations



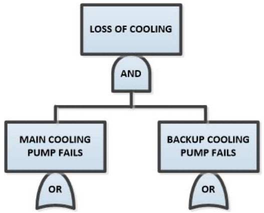
RECOMMENDATIONS	STUDY
• MORE RELIABLE LOAD SENSING CIRCUIT LESS SUSCEPTIBLE TO CALIBRATION ERRORS	(1)
• SHORTEN EXPOSURE TIME OF LOAD OVER OPEN REACTOR VESSEL	(1)
• SECOND OPERATOR	(1)
• SECOND LIMIT SWITCH	(2)
• OVERSPEED SWITCH	(3)



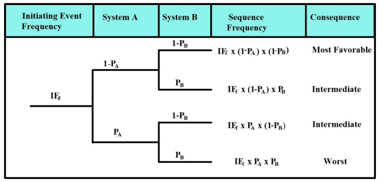
NUREG-1174

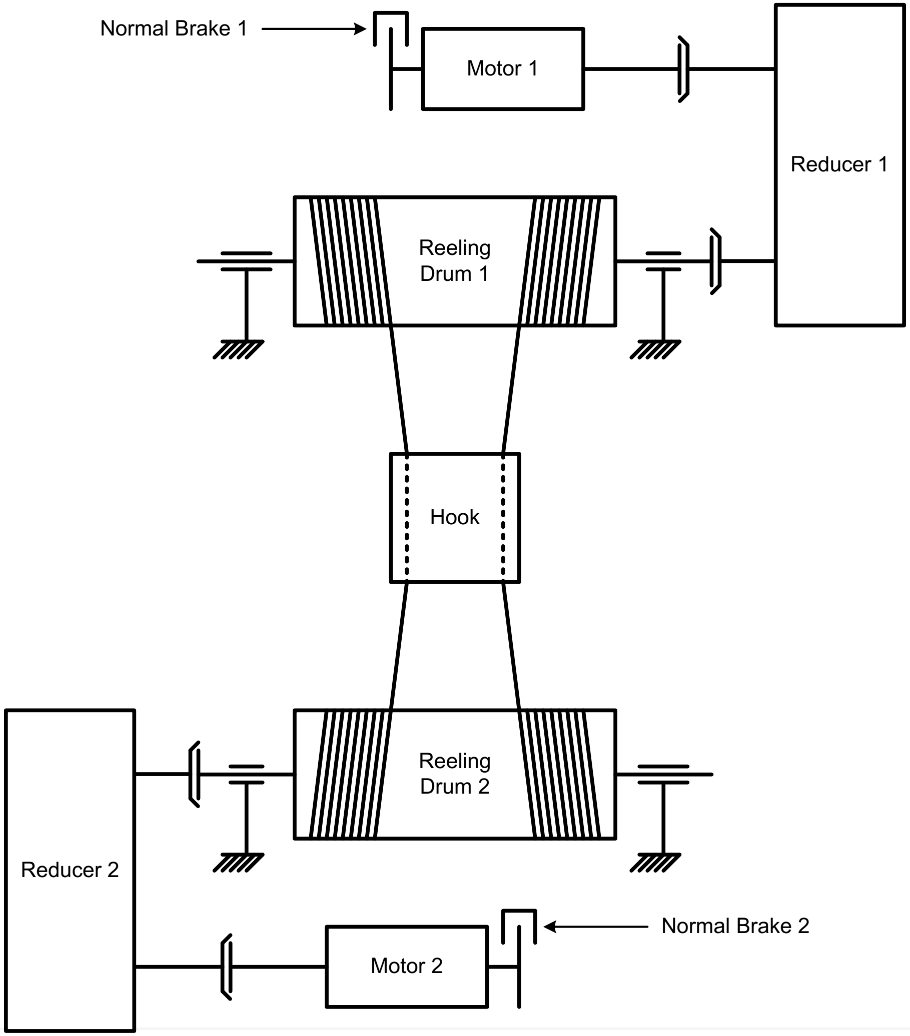


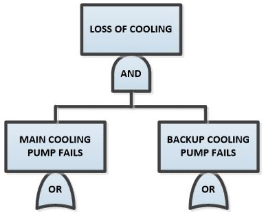
- “A survey of Crane Operating Experience at US Nuclear Power Plants” from 1968 through 2002 (June 2003)
- response to a candidate generic issue 186, "Potential Risk and Consequences of Heavy Load Drops in Nuclear Power Plants,"
- Finding of phase 2 NUREG 0612 report
  - Installation of a single failure proof crane not cost effective
  - Further action was not required to reduce the risk associated with heavy load drops
- Determine the likelihood and significance of heavy load drops
- Trend analysis



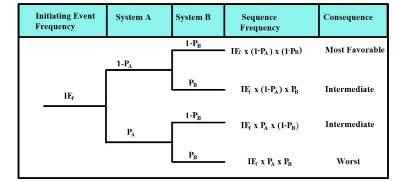
Single Failure Proof Crane

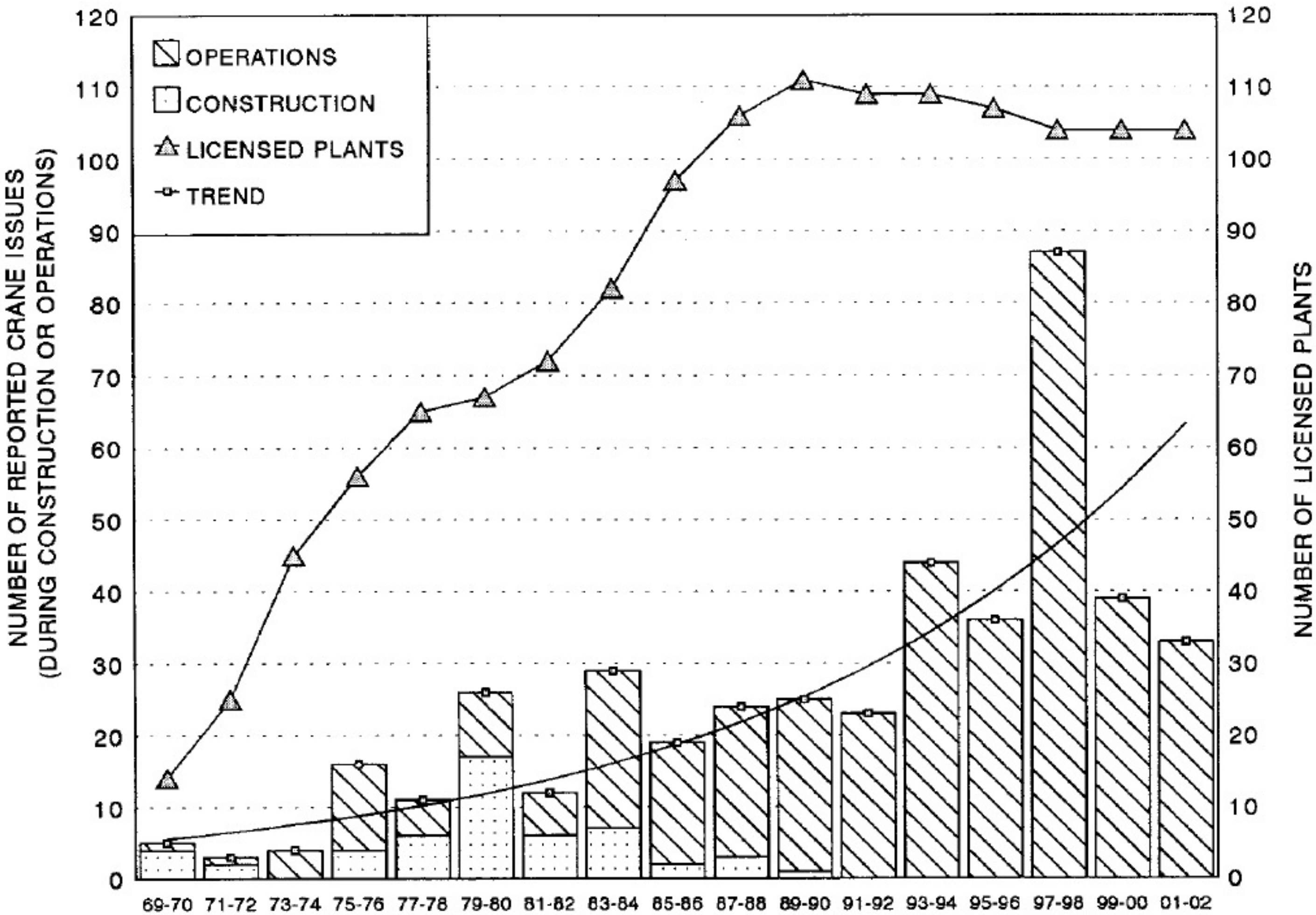


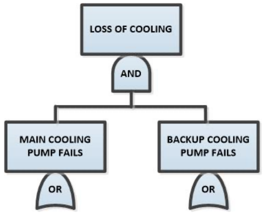




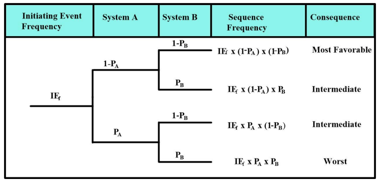
Reported Crane issues at US Nuclear Power Plants

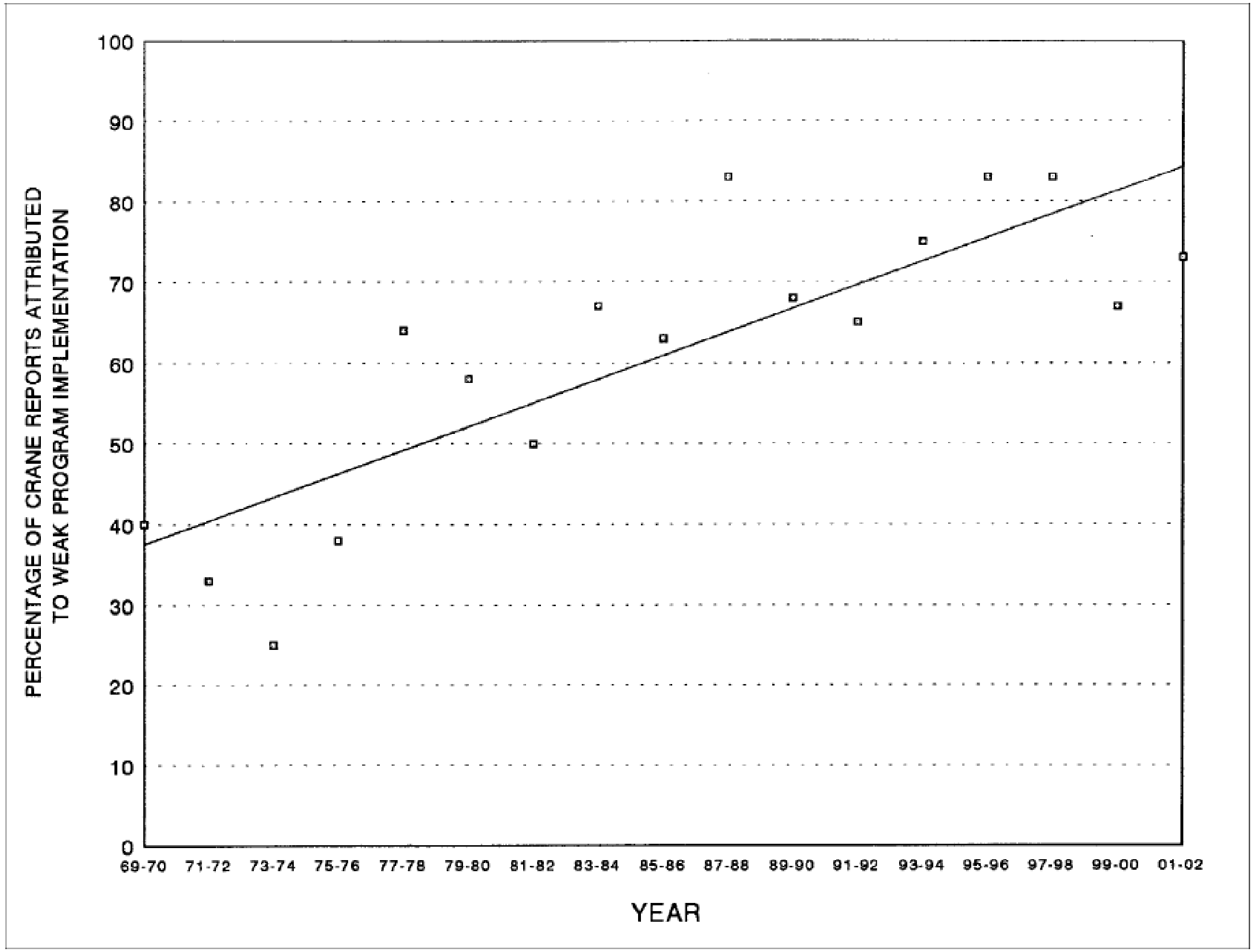


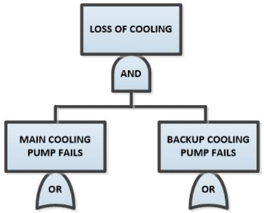




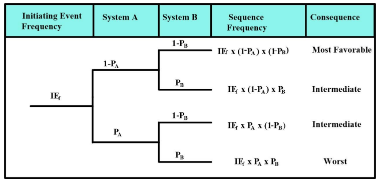
Trend in crane issues due to poor performance

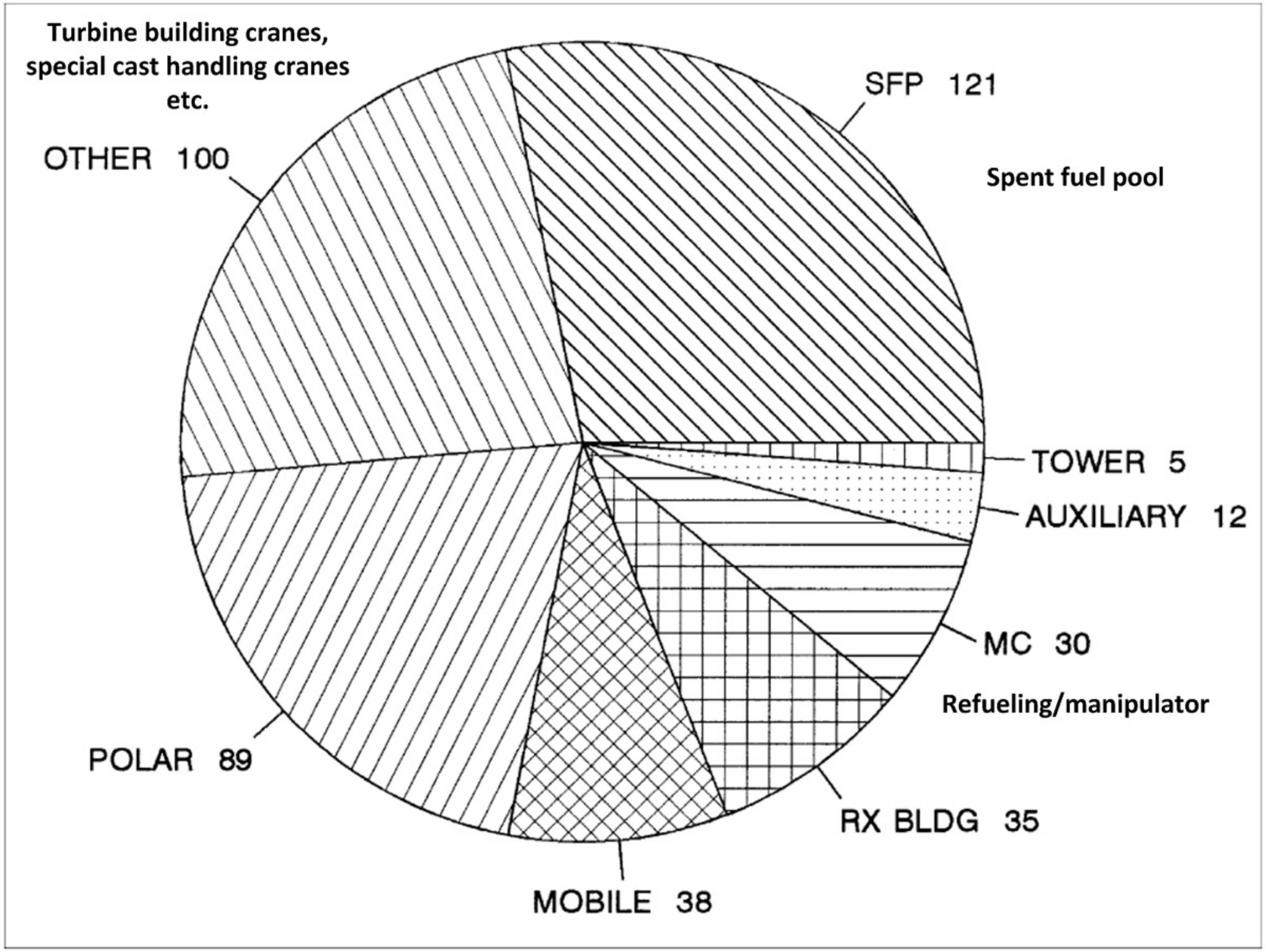


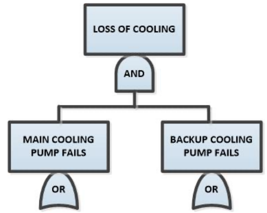




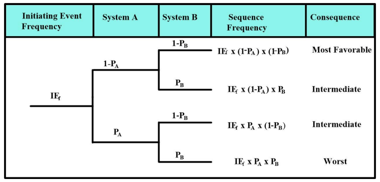
Crane issue distribution by crane type

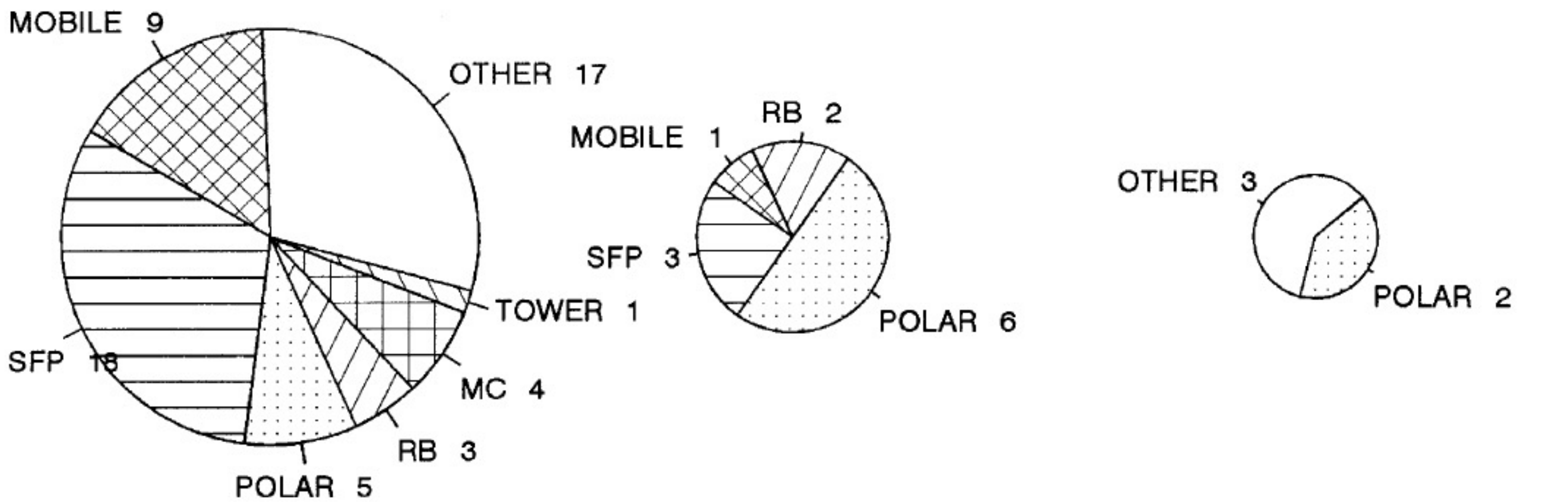




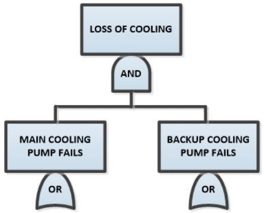


Crane types involved in load drops, load slips and crane component drops

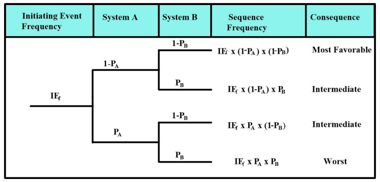


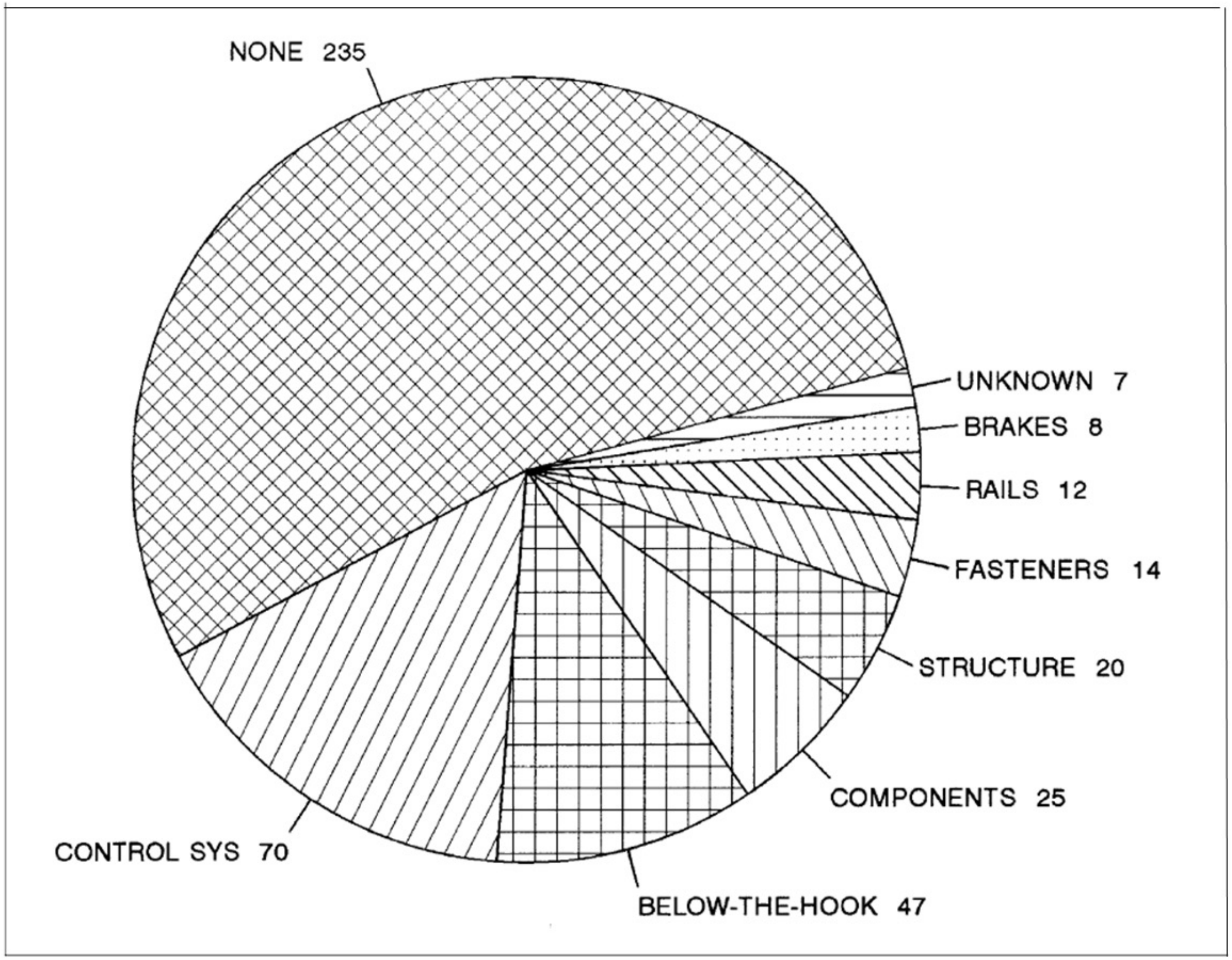


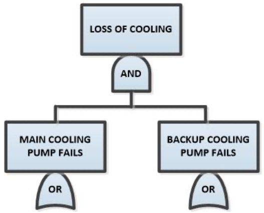
LOAD DROP LOAD SLIP CRANE COMPONENT DROP



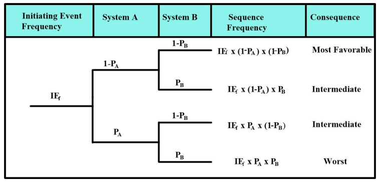
Crane events due to hardware deficiencies

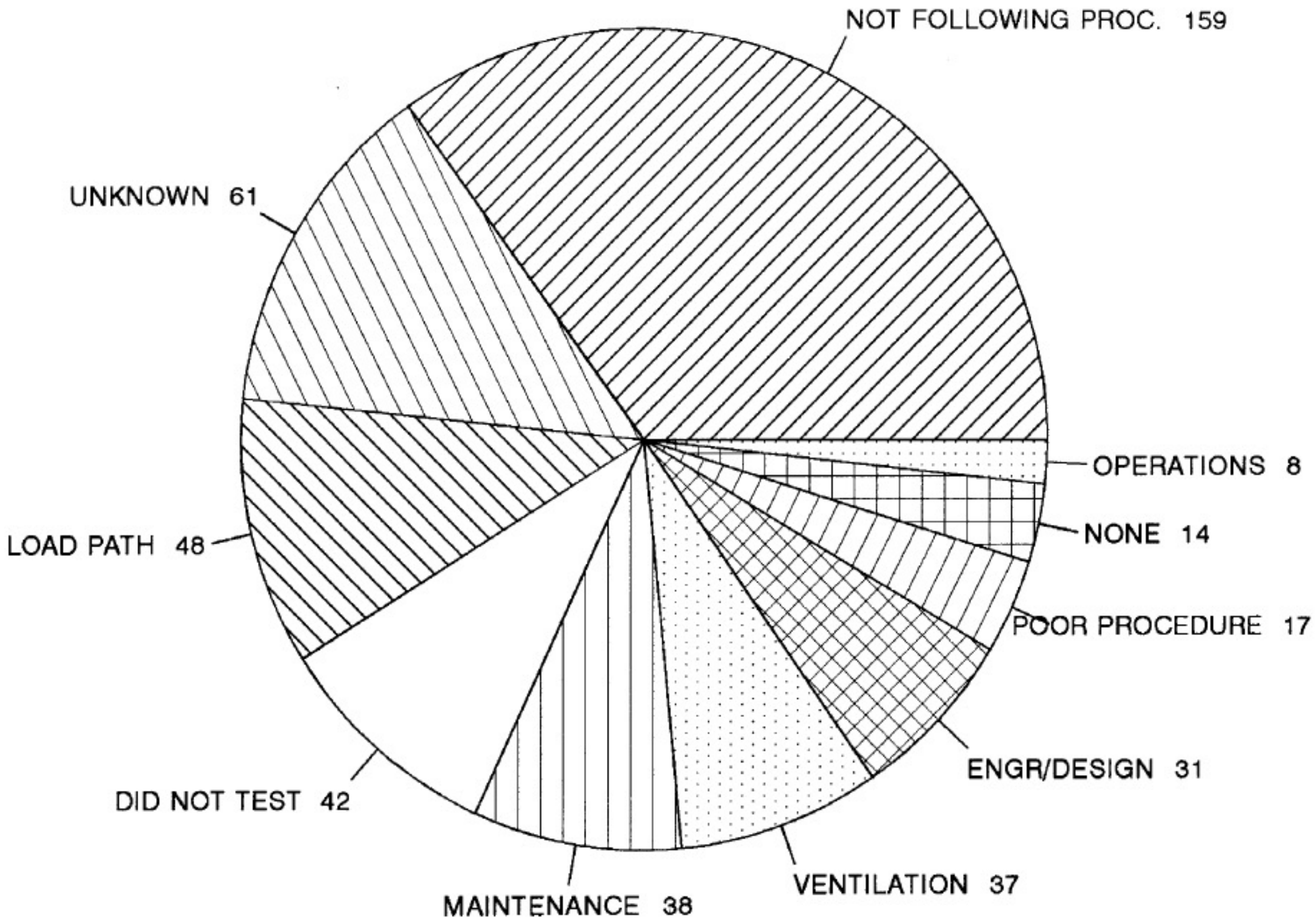


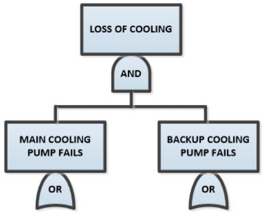




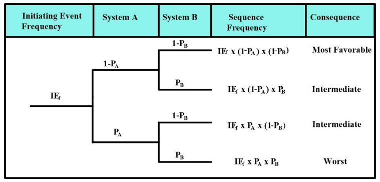
Principal reasons for crane events

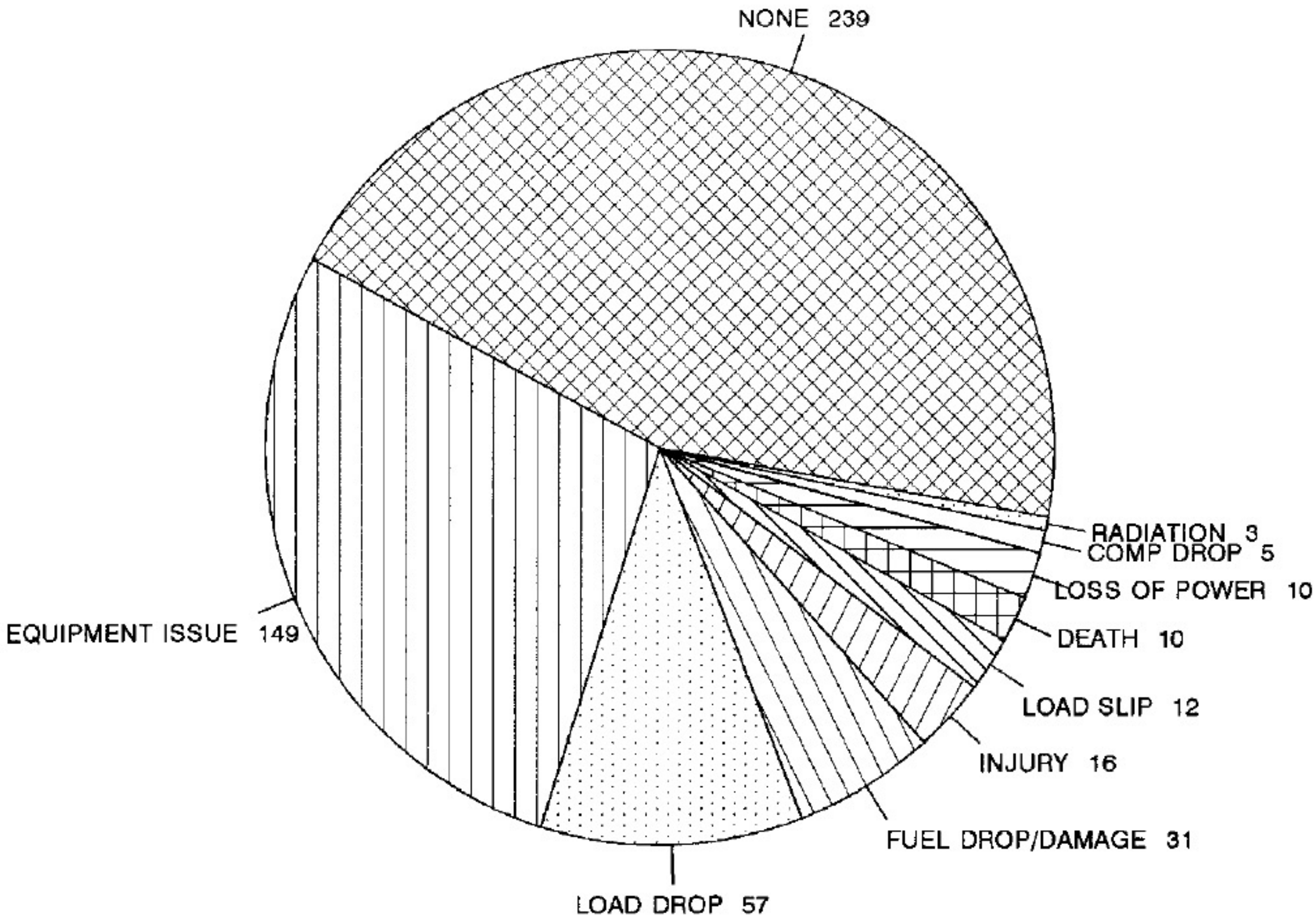


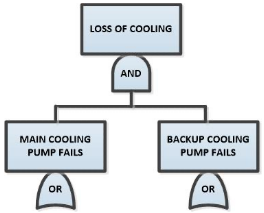




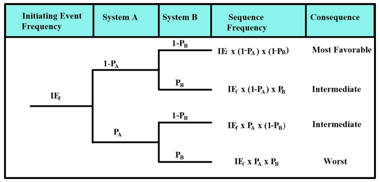
Safety Effect of crane events

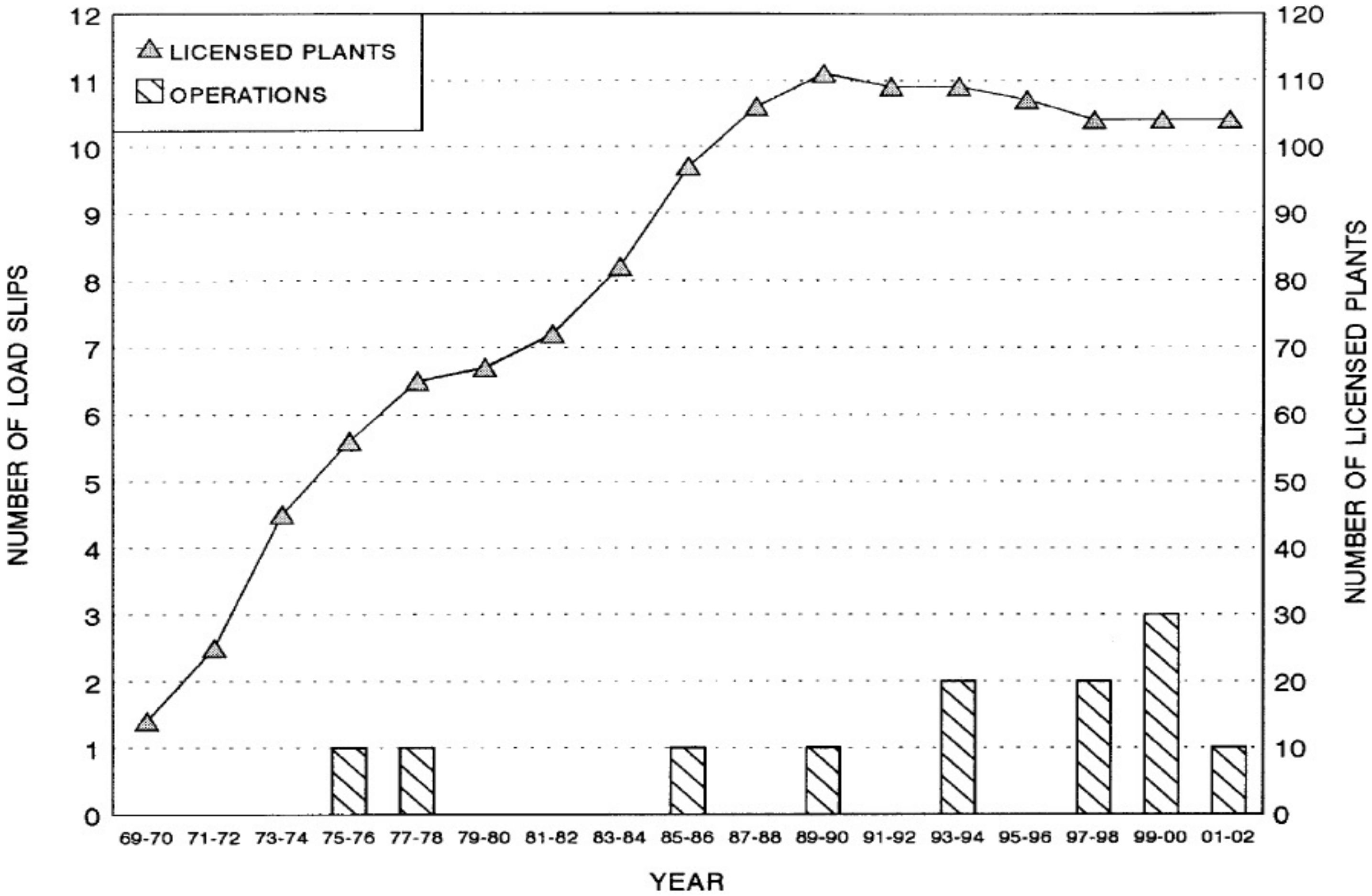






Load Slip distribution

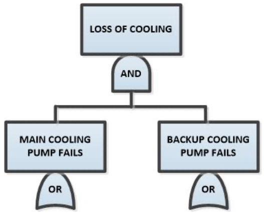




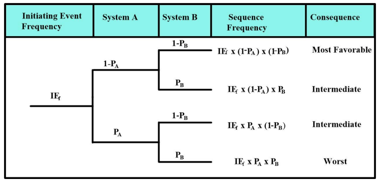
12 Load slips --- causes

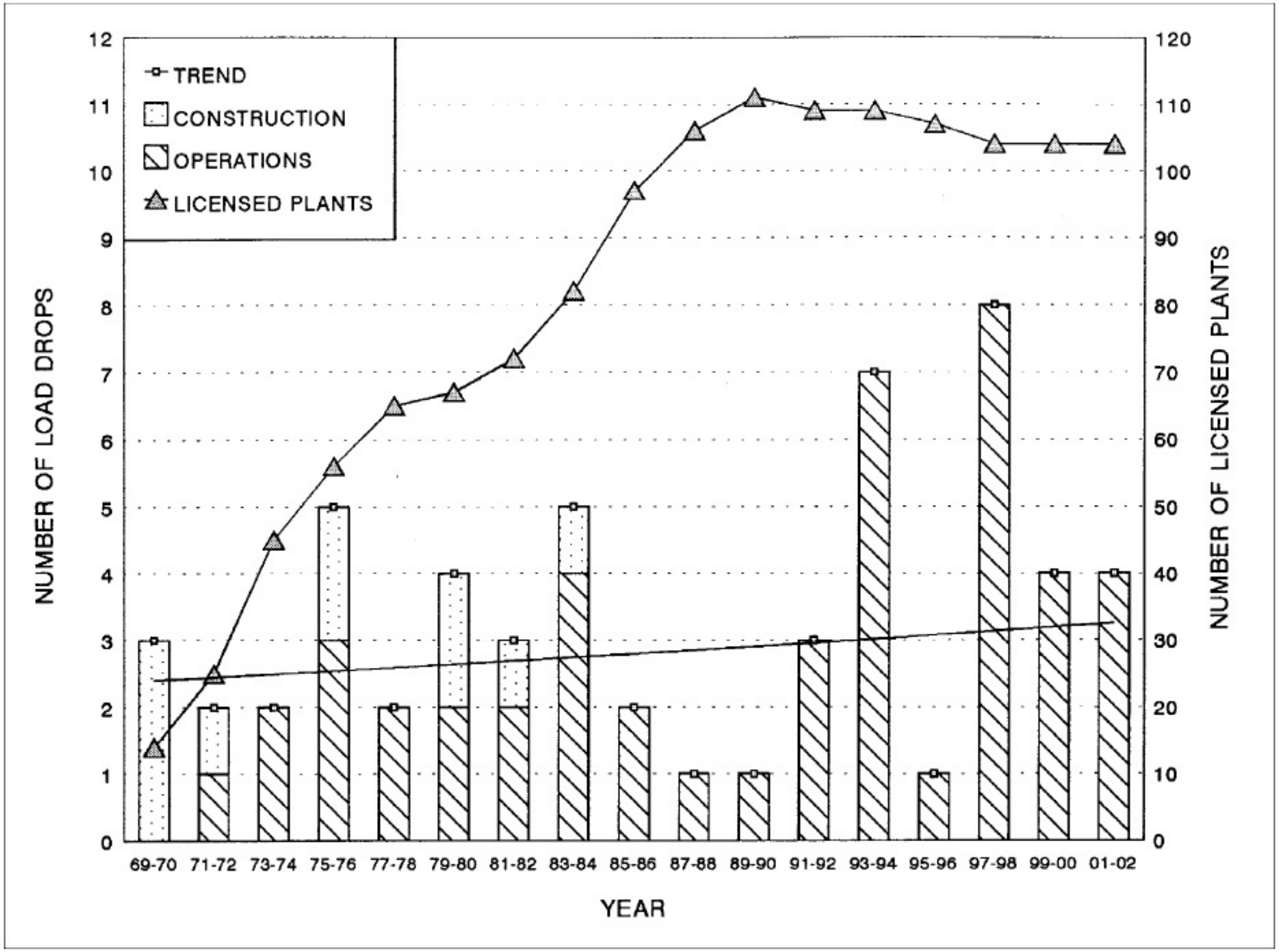
1. Below the hook
2. Control systems
3. Operations and engineering

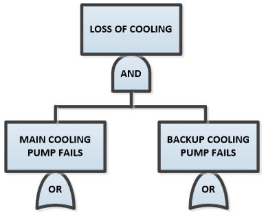
Six load slips involved a polar crane



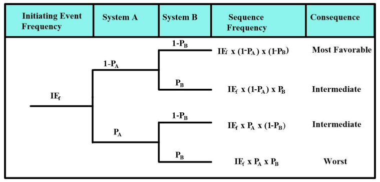
Load Drop Distribution

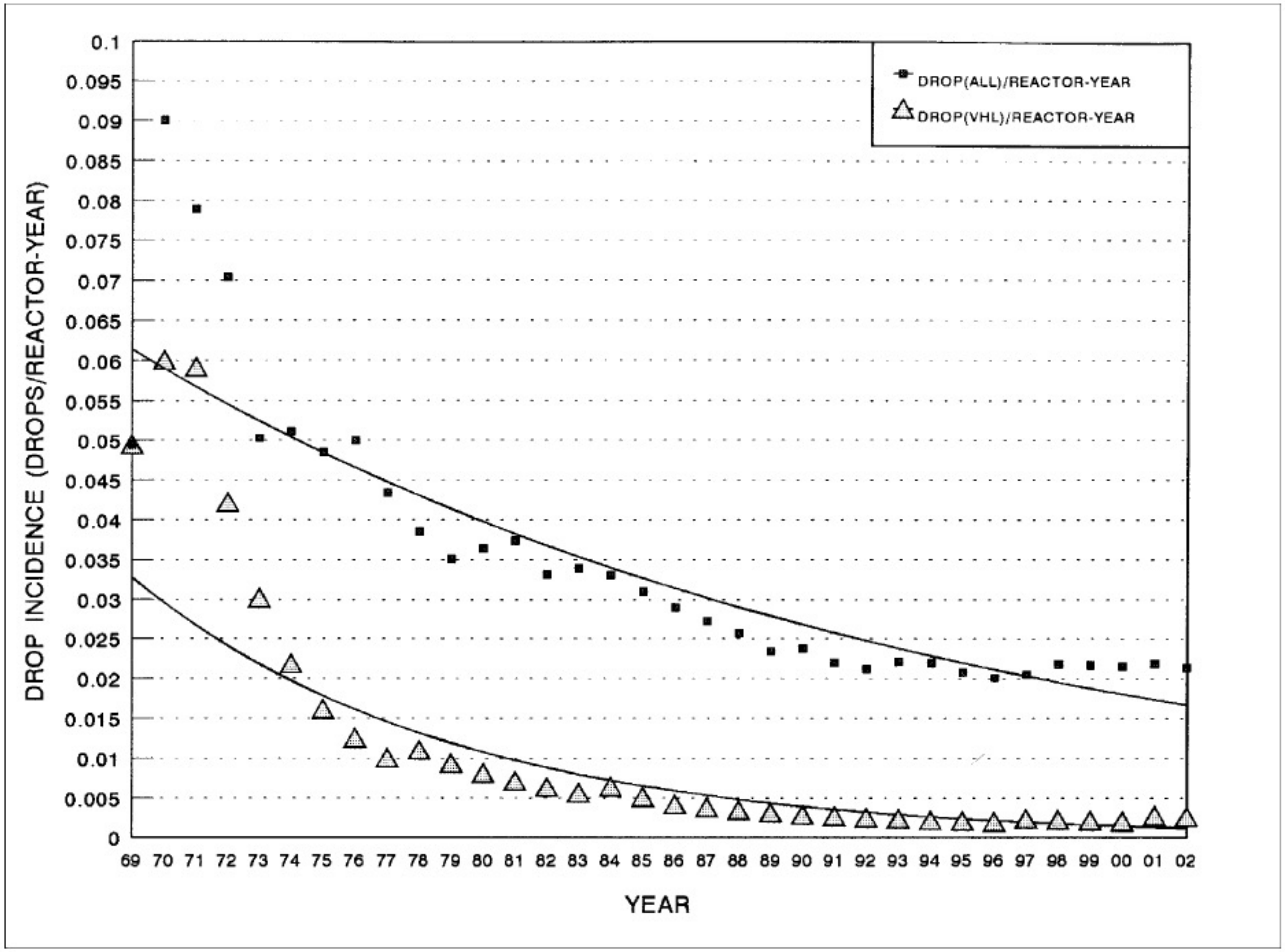


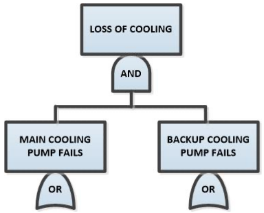




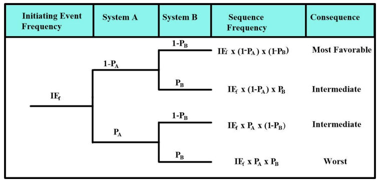
Load Drop Incidence Rate



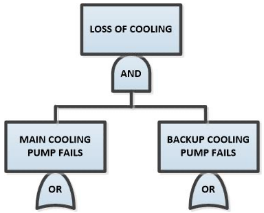




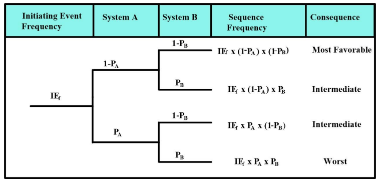
Basis of Probability Assignment for load drop event tree

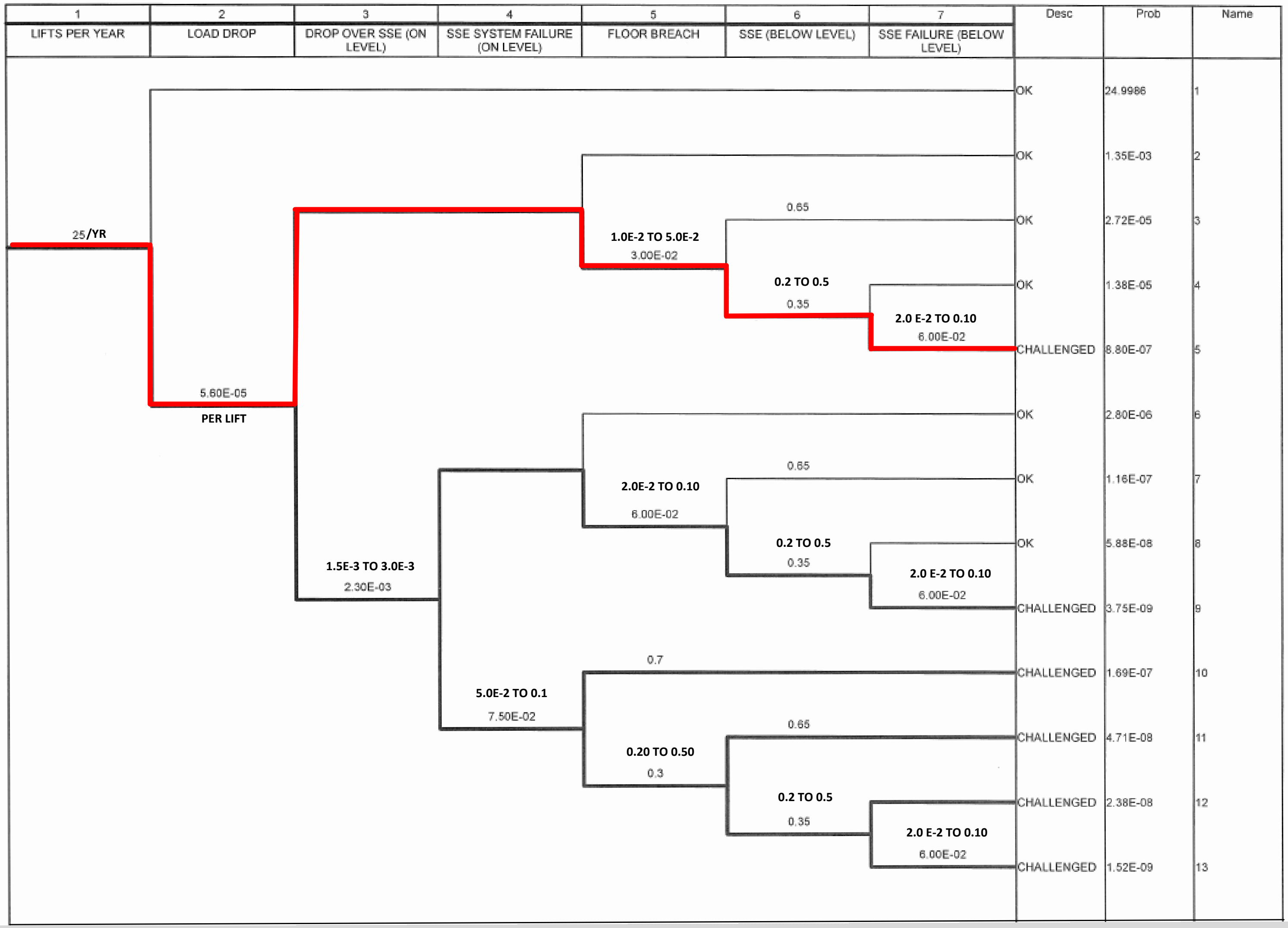


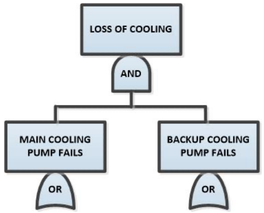
Node	Description	Basis	Probability Estimation
1	Number of very heavy Loads per reactor year	54000 Lifts since 1980 -- 2300 reactor years 54000/2300	25 per year
2	Load Drop	Three load drops since 1980 did not occur near SSE – All Rigging Failures 3/54000 drops/lift	5.6E-05 drops/lift
3	Drop Over SSE* (on level)	Failure to follow procedures 159 occurrences 159/54000 reduce by factor of 2 since all load drops are not caused by following procedures 159/54000 x .5 median (1.5E-3 3.0E-3)	2.3E-03
4	SSE System Failure (on level)	5 to 10 per cent median (0.05,0.10) Failure to follow procedures, common mode effects	7.5E-02
5	Floor Breach first branch	1 to 5 per cent median (0.01 0.05) Failure to follow procedures, common mode effects	3.0E-02
5	Floor Breach second branch	2 to 10 per cent median (0.02 0.10) Failure to follow procedures, common mode effects	6.0E-02
5	Floor Breach third branch	10 to 50 per cent median (0.10 0.50) Failure to follow procedures, common mode effects	0.30
6	SSE (Below Level)	20 to 50 per cent include controlling electrical, instrumentation or mechanical fluid systems	0.35
7	SSE Failure (Below Level)	48 Load path violations none resulted in SSE system failure assume double of probability reported in NUREG 0612 – 2 to 10%	6.0E-02



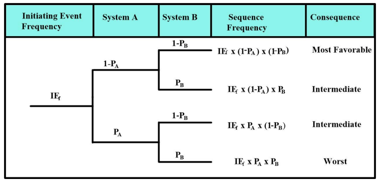
Load Drop Event Tree





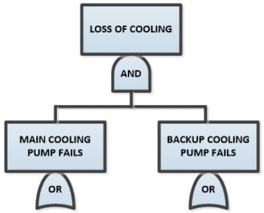


Potential Consequences of very heavy load drops

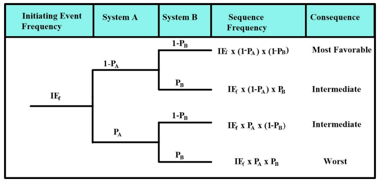


Endstate	Accident Frequency per Reactor Year[1]	Plant Consequence	Plant Status
1	No load drop path	None. No load drop occurs.	OK
2	1.4E-03 (mean)	Load drop occurs, but does not result in any train or system damage.	OK
3	2.8E-06 to 3.5E-05	Load drop occurs, resulting in a floor breach, but does not result in a SSE train or system damage.	OK
4	2.8E-05 to 3.5E-05	Load drop occurs, resulting in a floor breach, and one SSE train disabled	OK
5	1.4E-07 to 3.5E-06	Load drops occurs, resulting in a floor breach, and one SSE system disabled.	Plant is challenged.[2]
6	2.1E-06 to 4.2E-06	Load drop occurs, resulting in one SSE train being disabled. No floor breach or other damage to SSE.	**OK**
7	8.4E-09 to 2.1E-07	Load drop occurs, resulting in one SSE train being disabled. A floor breach occurs, but no other SSE damage occurs.	OK
8	8.4E-09 to 2.1E-07	Load drop occurs, resulting in one train disabled, a floor breach and one additional SSE train disabled in another system (both systems remain intact).	OK
9	4.2E-10 to 2.1E-08	Load drop occurs, resulting in one SSE train disabled, a floor breach, and one SSE system disabled.	Plant is challenged.
10	1.1E-07 to 4.2E-07	Load drop occurs, resulting in one SSE system disabled with no floor breach.	Plant is challenged.
11	2.1E-09 to 1.1E-07	Load drop occurs, resulting in one SSE system disabled, a floor breach, but no other train or system damage.	Plant is challenged.
12	2.1E-09 to 1.1E-07	Load drop occurs, resulting in one SSE system disabled, a floor breach, and one other SSE train damaged.	Plant is challenged.
13	1.1E-10 to 1.1E-08	Load drop occurs, resulting in two systems disabled, including a floor breach.	Plant is challenged.

[1]Assumes an average of 25 very heavy loads per reactor year.
[2]A condition where at least one SSE system has been disabled because of a load drop.



Comments



- Study concluded that BWRs are more susceptible to load drops than PWRs because most operations for BWR occur in the reactor building – loads are above safety equipment
- NUREG-1174 was an important reference document for the Yucca Mountain project
- Another reference document
  - Joseph Martore and H. E. Lambert, Heavy Loads Probabilistic Safety Assessment, TENERA LP and FTA Associates, Submitted to the National Science Foundation, August 1988.