Arizona Nuclear Power Project

DOCUMENT NUMBER

13-NC-EC-201

TITLE/DESCRIPTION

Title: Human Reliability Analysis Calculation for Recovery of Essential Chillers, including manual restart of the chillers, following Flow Transmitter Isolation.

Description: This risk analysis uses the Human Cognitive Reliability model for an HRA of a manual restart of the Ess. Chillers. The event is similar to the event described in SPEER 88-01-007 except that an accident situation is assumed.

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1.0 PURPOSE

To supplement the calculations performed on 13-NC-EC-200, Ref. 1, calculate the human reliability probability for recovery of the Essential Chiller following an incident as described in EER-88-EC-018 and SPEER 88-01-007 (Ref. 2). The initial calculation assumed a restart of the chillers was possible using only operations personnel.

This calculation will determine a probability curve, including error bounds, for recovery of one essential chiller using a maintenance technician to perform a manual restart. The calculation will use "best estimate" time approximations for maintenance actions as described in Reference 5, and conservative assumptions regarding plant conditions. This calculation resulted from Nuclear Engineering calculations that showed if the chilled water pump continues to run following a chiller failure, an automatic restart may not be successful. Given an automatic start failure, a manual start by maintenance personnel is required.

2.0 SUMMARY

A probability curve for operator/maintenance response to recover/restore the essential chiller was calculated (see 5.2). The 95% confidence time as calculated is:

Median time = 320 mins
Error Factor = 2.4

3.0 ASSUMPTIONS

3.1 The Essential Chiller demand is assumed to occur due to a large LOCA. Although this is not the most probable event, it is the limiting transient with relation to time available for operator action (due to maximum loading and maximum room heat-up during the LOCA), and with relation to operator stress.

3.2 Only one technician is assumed to be performing the actions required. Credit for multiple technicians is not taken.

3.3 Where two (2) technicians are available, the most qualified technician on shift is assumed to perform the action.

3.4 Although procedural steps guiding the operators to troubleshoot the chiller, are available and used (see Ref. 1), the actions required for a manual restart of the chiller are not directly in a procedure. A knowledge based response is therefore assumed.

4.0 INPUT DATA

4.1 HCR Model

Per Ref. 1, the Human Cognitive Reliability (HCR) model for a knowledge based action during a large LOCA is:

$$p(t) = \exp - \left[\frac{\left(T/T_{1/2}\right) - 0.5}{0.791}\right]^{0.8}$$

where $T_{1/2}$ = nominal time taken by a crew for the performance of a task.

= $T_{1/2}$ (estimated) * (1 + .28); adjustment for high stress during a large LOCA (See Table 3-4, Ref. 4)

4.2 Time Delay

Ref. 1 calculations assume a 15-minute time delay for control room response to a loss of Essential chillers. An additional 15 minute delay is assumed for CR operator action to contact the maintenance personnel. The 30-minute total delay gives a revised base formula of:

$$p(t) = \exp - \left[\frac{\left(\frac{T-30}{T_{1/2}}\right) - 0.5}{0.791}\right]^{0.8}$$; t and $T_{1/2}$ in minutes.

4.3 Maintenance Technician Response

During the nine (9) day period as described by Ref. 2, there was an "around the clock" coverage of HVAC technicians. The qualifications and experience of the technicians on call varied from shift-to-shift and from day-to-day. For this reason, the technicians were grouped, by the maintenance department, as far as their past experience and abilities, especially with relation to a manual restart of the chillers. The justification and documentation of this grouping is provided in References 5 and 6. The three (3) groups of technicians available are defined as "Expert," "Trained," and "Novice".

Based on these classifications, assumptions 3.2/3.3, and the shift schedule during the nine (9) day incident, a shift coverage distribution can be derived. The resulting percentages for shift coverage by each of the groups is:

P_e = Percentage of nine (9) days an expert technician was available.
= 0.62

P_T = Percentage of nine (9) days a trained technician was available.
= 0.28

P_N = Percentage of nine (9) days a novice technician was available.
= 0.10

The "best guess" time response for each group as provided by Ref. 6 is:

$T_{1/2}$ (Expert) = 38 minutes

$T_{1/2}$ (Trained) = 86 minutes

$T_{1/2}$ (Novice) = 91 minutes

5.0 CALCULATION AND RESULTS

5.1 Formula Derivation

There were three (3) Methods considered for the derivation of the Human Error Probability (HEP) considered. These are:

1) Derive an average response time using the data in 4.3 above and substitute this average into the formula in 4.2 above. This would yield a single term formula. It was felt this would not be accurate for large time periods.

2) Use the time estimates in 4.3 above (adjusted for stress) and derive a three (3) term formula for the HEP. This formula would depend highly on the estimates provided and would be very sensitive to errors in these estimates.

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3) Use the recommended distribution for operator response as defined in Ref. 4 to derive an average response time. This would then be used as input to a three (3) term equation where the response time for each group of technician is estimates using the HCR model.

Statistically, method 3 was considered the most accurate and was therefore used. Additionally, the results were found to be more conservative than methods one and two. This conservation will be discussed later. The average time response is derived as:

$T_{1/2}$ (nominal) = $T_{1/2}/(1+K_1)$; K_1 is from Table 3-4, Ref. 4

$T_{1/2}$ (~~monimal~~ nominal QWH 9-30-88 ccl) = $\dfrac{T_{1/2}\text{ (Expert)}}{(1 - 0.22)}$ for expert time estimation

= $\dfrac{T_{1/2}\text{ (Trained)}}{(1 + 0.0)}$ for trained time estimation

= $\dfrac{T_{1/2}\text{ (Novice)}}{(1 + 0.44)}$ for novice time estimation

The average of these yields the average estimated response time:

$$T_{1/2}\ (\text{ave}) = 1/3 \left(\frac{38}{0.78} + 86 + \frac{91}{1.44} \right) \text{minutes}$$

$$= 66 \text{ minutes}$$

The estimated response times for each technician group are:

$T_{1/2}$ (expert) = 66 minutes * (1-0.22)
= 52 minutes

$T_{1/2}$ (trained) = 66 minutes

$T_{1/2}$ (novice) = 66 (1 + 0.44) minutes
= 95 minutes

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Adjusting for stress (see 4.1) yields:

$T_{1/2}$ (expert) $=$ 52 * (1 + 0.28) minutes
$=$ 67 minutes

$T_{1/2}$ (trained) $=$ 66 * (1 + 0.28) minutes
84 minutes

$T_{1/2}$ (novice) $=$ 95 minutes * (1 + 0.28)
$=$ 122 minutes

Using these time response estimations, the formula in 4.1, and the shift coverage percentages in 4.3 the following HEP is derived.

$$P(t) = P_e * P(t)_{expert} + P_t * P(t)_{trained} + P_n * P(t)_{novice}$$

where:

$$P(t)_{expert} = \exp - \left[\frac{\left(\frac{t-30}{67}\right) - 0.5}{0.791} \right]^{0.8}$$

$$P(t)_{trained} = \exp - \left[\frac{\left(\frac{t-30}{84}\right) - 0.5}{0.791} \right]^{0.8}$$

$$p(t)_{novice} = \exp - \left[\frac{\left(\frac{t-30}{122}\right) - 0.5}{0.791} \right]^{0.8}$$

$$P(t) = 0.62 * \exp - \left[\frac{\left(\frac{t-30}{67}\right) - 0.5}{0.791} \right]^{0.8} + 0.28*$$

$$\exp - \left[\frac{\left(\frac{t-30}{84}\right) - 0.5}{0.791} \right]^{0.8} + 0.10 \exp - \left[\frac{\left(\frac{t-30}{122}\right) - 0.5}{0.791} \right]^{0.8}$$

5.2 Calculation of P(t)

The above formula yields:

t	P(t)
0	1.0
60 min	1.0
120 min	0.42
180 min	0.20
240 min	0.11
300 min	0.06
320 min	0.05
360 min	0.03
420 min	0.02
480 min	0.01

5.3 Comparison With Other Methods

It is felt that the complexity of the event and the actions required cannot be accurately modeled by Ref. 3, as are most HRA results for the PVNGS PRA. However, Ref 3, (SWAIN), can be used for a rough estimate as follows:

- actions are required for start including installing 2 jumpers and throttling 2 valves

failure to install jumpers = 2 x 0.003 (Table 13-3 #13)
= 0.006

failure to throttle valves = 2 x 0.003 (Table 14-1, #2)
= 0.006

HEP = 2 x 0.006 = 0.012
= Failure to perform LOCAL action

For novice technicians add HEP = 0.04
failure to recall 4 items (Table 15-1, #2)

- For diagnosis HEP use Figure 12-3. Use nominal for trained and expert, use upperbound for novice. Diagnosis time is equal to total time minus estimated completion time (not including stress).

- For stress of local actions add stress factors = 2 for expert, trained and four (4) for novice.

The HEP for each is:

HEP (expert) = Diagnosis (@ t - 38) + 2* 0.012

HEP (trained) = Diagnosis (@ t - 86) + 2* 0.012

HEP (novice) = Diagnosis UB (@ t - ~~86~~ 91 GLN 9-30-88) + 4* (0.012 + 0.04)

$P(t) = P_e$ * HEP (expert) + P_T*HEP (trained) + P_N*HEP (novice)

Using figure 12-3 for diagnosis:

t	P(t)	HCR P(t)
60	0.5	1.0
120	0.06	0.42
240	0.04	0.11
360	0.0~~2~~3 GLN 9-30-88	0.03

The results above are similar, with the HCR model providing the more conservative results.

5.4 Uncertainty in the Analysis

The uncertainty in the analysis can be calculated from the upper and lower bound estimates.

LOWER BOUND

Assume: 1) $T_{1/2}$ = $T_{1/2}$ (expert; no stress); i.e., best technician

2) No time delay

3) Rule based action curve from Ref. 4

This yields:

$$P(t) = \exp - \left[\frac{\left(\frac{t}{52}\right) - 0.6}{0.601} \right]^{0.9}$$

the 95% confidence time equals

$$t = 52* ((-\text{Ln } 0.05)^{1.11}\ 0.601 + 0.6)$$

$= 137$ mins

UPPER BOUND

Assume: 1) $T_{1/2} = T_{1/2}$ (novice; stress; conservative estimate) i.e., worst technician (see Ref. 6)

$= 150$ minutes * 1.28

$= 192$ minutes

2) Time delay increase to 90 mins; i.e., no maintenance tech. called until chiller trips (see Ref. 1)

3) Knowledge based action curve.

$$P(t) = \exp - \left[\frac{\left(\frac{t - 90}{192}\right) - 0.5}{0.791} \right]^{0.8}$$

The 95% confidence time equals

$$t = (192 * ((-\text{Ln } 0.05)^{1/0.8} * 0.791 + 0.5)) + 90$$

$= 785$ mins

ERROR FACTOR

$$EF = \sqrt{\text{upperbound/lower bound}}$$

$$= \sqrt{785/137}$$

$$EF = 2.4$$

Conclusion

Typical PRA values range from EF = 3 to an EF = 100. With an EF = 2.4, the result is shown to be below this range and is considered acceptable.

5.5 Conservatisms in the Analysis

Conservatisms

1) HRA stress levels are based on high stress. Most EC chiller demands would not be at these high stress levels.

2) For long time periods, as is being analyzed. for the 95% confidence time, additional expert technicians and the EC system engineers would be called out to assist. Assuming a 90 minute delay to call and a maximum 90 minute driving time, within 180 minutes these personnel would be available. Additionally, approximately 1/3 of the time (day shift), this extra personnel would be available immediately.

3) The HCR averaging method used to derive the resulting formula in 5.1 yields slightly conservative results. This is due to the $T_{1/2}$ (expert) derived by this method (55 minutes, no stress) is larger than the original $T_{1/2}$ (expert) estimated (38 minutes). Since 62% of the time experts are available, this $T_{1/2}$ dominates the calculations. A solution using the original estimated $T_{1/2}$ values yields lower P(t) estimates.

Non Conservatisms

1) The time estimates assumes that the technicians are in their office at the time of the incident. Occasionally technicians may be elsewhere onsite causing longer transit times.

2) The manipulations required for a manual start would in most non-accident situations require a work order. Under accident situations, this requirement would be presumably waived by the shift supervisor. Therefore, time estimates would be longer during non-accident situations due to paperwork requirements. Note that during non-accident situations more time is available for a restart due to smaller heat loads etc.

6.0 REFERENCES

1) D. W. Henneke, "HRA - Chiller Recovery Calculation," June 9, 1988 13-NC-EC-200.

2) "Essential Chilled Water System Rendered Inoperable Due to Isolation of Flow Transmitters on Both LOOPS," SPEER-88-01-007 June 1988.

3) A. D. Swain, H. E. Guttman, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," NUREG/CR-1278 August 1983.

4) G. W. Hannaman, A. J. Spurgin, Y. D. Lukic, "Human Cognitive Reliability Model for PRA Analysis," NUS-4531, December 1984.

5) R. E. Buzzard; "Operator Response Time to Both Essential Chiller Inoperable," ANPP Internal Memo 217-00100-JTP/REB, September 21 1988.

6) C. Clapper, P. L. Brandjes, G. W. Sowers, "Essential Chiller Restoration for LER 88-017 Supplemental Response", ANPP Internal Letter 226-00199-GWS/WMS/GC, September 28, 1988.

7) G. W. Hannaman, A. J. Spurgin, Y. D. Lukic, "A Model for Assessing Human Cognitive Reliability in PRA Studies," IEE Human Factors Conference, Monterey, CA, June 1985.