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SENSITIVITY OF RISK PARAMETERS TO HUMAN ERRORS FOR A PWR*

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Sensitivities of the risk parameters, emergency safety system unavailabilities, accident sequence probabilities, release category probabilities and core melt probability were investigated for changes in the human error rates within the general methodological framework of the Reactor Safety Study[(1)] for a Pressurized Water Reactor (PWR). Impact of individual human errors were assessed both in terms of their structural importance to core melt and reliability importance on core melt probability.

The Human Error Sensitivity Assessment of a PWR (HESAP) computer code was written for the purpose of this study. The code employed point estimate approach and ignored the smoothing technique applied in RSS.[(1)] It computed the point estimates for the system unavailabilities from the median values of the component failure rates and proceeded in terms of point values to obtain the point estimates for the accident sequence probabilities, core melt probability, and release category probabilities. The sensitivity measure used was the ratio of the top event probability before and after the perturbation of the constituent events.

As shown in Figure 1, core melt probability per reactor year shows significant increase with the increase in the human error rates, but does not show similar decrease with the decrease in the human error rates due to the dominance of the hardware failures. When the Minimum Human Error Rate (M.H.E.R.) used is increased to 10^{-3}, the base case human error rates start

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dominating the hardware failure rates contributing to the same event and the core melt probability shows much more sensitivity. By measuring the impact of different generic classes of human errors it was observed that test and maintenance type of errors are more important than operator errors in the determination of core melt probability; so are pre-accident errors compared to post accident errors, omission type of errors compared to commission type of errors and all non control room errors together compared to all control room errors.

Figure 2 shows that the human errors have more impact on the high consequence side. Release Categories (RC) 1, 3, and 4, as defined in RSS, show much larger sensitivities compared to that of Categories 5, 6, and 7. It is also observed that Release Category 7 dominates at all points in its contribution to core melt probability, but with reduced relative contribution at higher human error rates.

A qualitative analysis of the structural importance of the individual human errors was performed. Structurally important human errors were ranked according to their reliability importance on core melt probability, as shown in Table 1. The reliability importance of a human error with respect to core melt probability is the difference in the expected values of core melt probability given that the human error in question did occur and did not occur.

In conclusion, it could be said that the opportunity for reduction in core melt probability by reducing the human error rates without simultaneous reduction of hardware failure rates is limited. But core melt probability shows significant increase due to the increase in the human error rates. More importantly most of the dominant accident sequences show signficiant increase in their probabilities and many of the emergency safety systems show large sensitivity to human errors. This effort now allows the evaluation of new error rate data along with proposed changes in the man machine interface.

1. "Reactor Safety Study, An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants." WASH-1400, NUREG-75/014, U.S. Nuclear Regulatory Commission (October 1975).

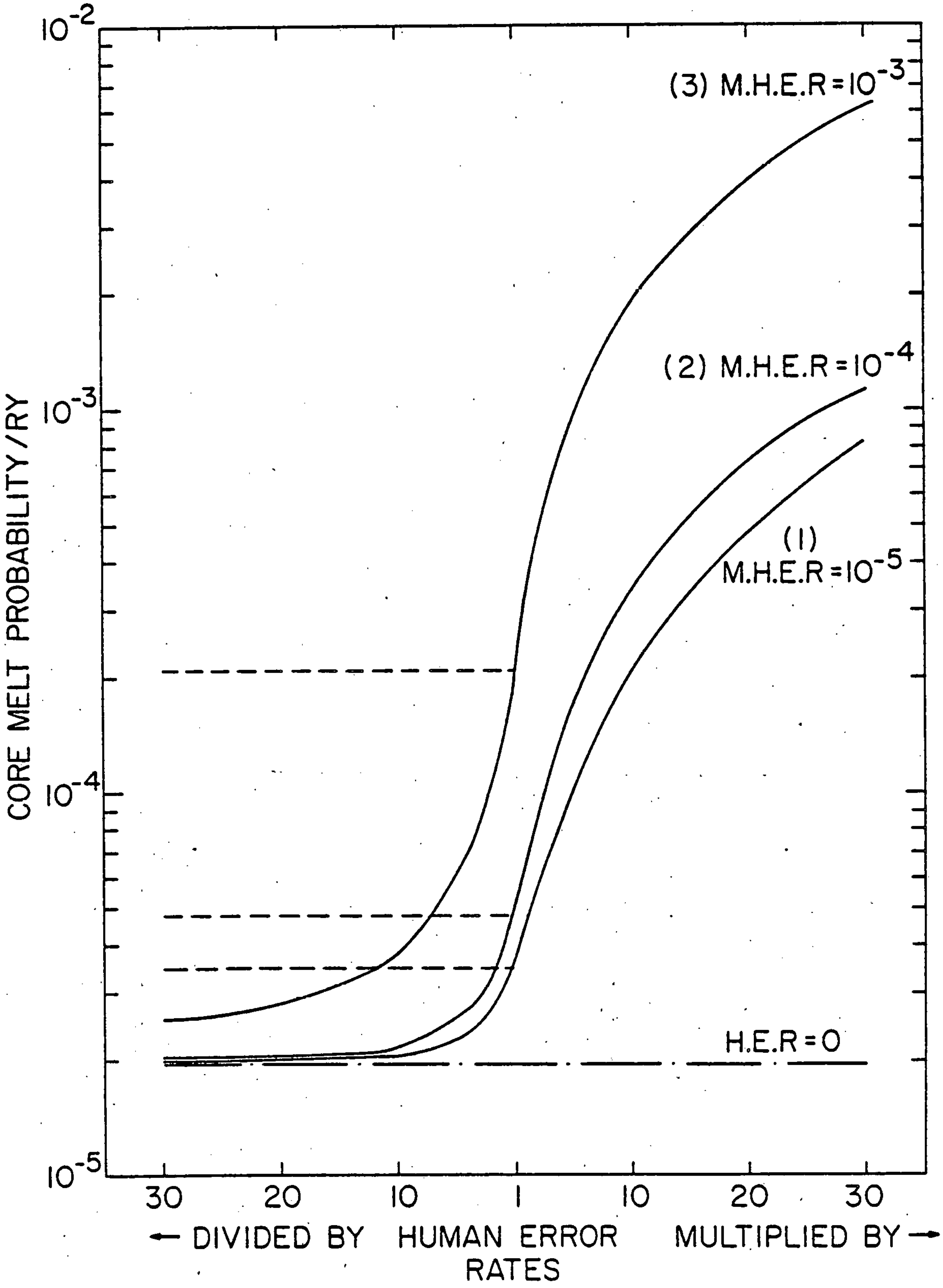

Fig. 1. Changes in core melt probability due to changes in all the human error rates.

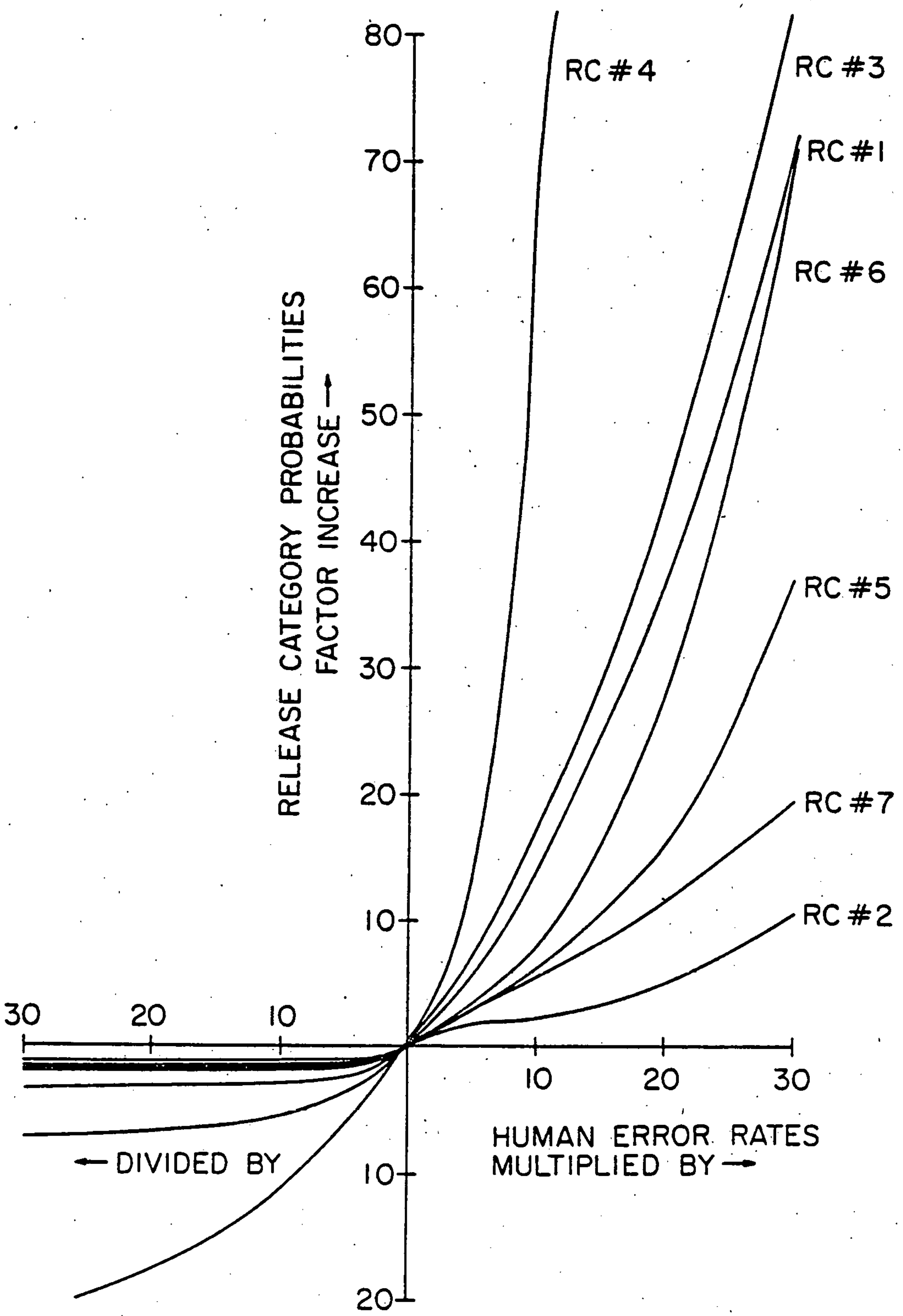

Fig. 2. Sensitivity of release category probabilities to changes in all the human error rates.

TABLE 1

RANKING OF INDIVIDUAL HUMAN ERRORS FROM RSS

IN TERMS OF RELIABILITY IMPORTANCE TO CORE MELT PROBABILITY

RANK	DESCRIPTION OF THE HUMAN ERROR	RELIABILITY IMPORTANCE
1	Repetitive human errors on three sets of logic train comparator, or bistable amplifiers that feed the Reactor Protection System	1.21 E-1
2	NO pairs of manual valves inadvertently left closed after pump test in Auxiliary Feedwater System	2.10 E-2
3	Six NO manual valves inside containment which allow flow to steam generator inadvertently left closed	2.10 E-2
4	Valves in charging pump cooling seal to intermediate seal heat exchanger closed by operator, NO	2.59 E-3
5	Charging pump service water discharge valve 1-SW-129 closed by operator, NO	2.59 E-3
6	Manual valve CS-25 in Low Pressure Injection System in closed position	1.40 E-3
7	Common mode miscalibration of comparators in Safety Injection Control System	1.34 E-3
8	All 8 heat exchanger air vent left closed in Containment Heat Removal System	1.30 E-3
9	High boron concentration not detected due to sampling error in batching tank	1.30 E-3
10	Boric acid concentration evaporation in boric acid tank not detected	1.30 E-3

NO: normally open.
NC: normally closed.