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CEA-DAS--418 RAPPORT DAS N° 418

INTERACTION BETWEEN THERMAL/HYDRAULICS, HUMAN FACTORS AND SYSTEM ANALYSIS FOR ASSESSIN FEED AND BLEED RISK BENEFITS

J.M. LANORE, J.L. CARON*
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International SNS/ENS/ANS topical meeting
on probabilistic safety assessment
and risk management
(Zurich, 30 août-4 septembre 1987)

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INTRODUCTION

For probabilistic analysis of accident sequences, thermal/hydraulics, human factors and systems operation problems are frequently closely interrelated. This presentation will discuss a typical example which illustrates this interrelation : total loss of feedwater flow. It will present thermal/hydraulic analyses performed, how the T/H analyses are related to human factors and systems operation, and how, based on this, the failure probability of the feed and bleed cooling mode was evaluated.

This analysis was part of the probabilistic safety analysis conducted for French 900 MWe plants by the French Atomic Energy Commission (CEA).

2 - DESCRIPTION OF ACCIDENT SEQUENCE

The consequence of total loss of feedwater is steam generator dryout which is annunciated by a specific alarm. The operator is cued to use an H procedure, in this case procedure H_2.

The initiating event, total loss of feedwater, implies total failure or inoperability of both the main and auxiliary feedwater systems :

The key actions required by procedure H_2 are :

- recovery of a feedwater system
- or, opening of pressurizer pressure relief valves to remove residual heat and initiation of safety injection in the feed and bleed configuration.

Failure of the SI feed and bleed configuration may result from :

- failure of the operator to diagnose the accident or to accomplish requisite actions timeously,
- or, equipment failure(s) in the pressurizer relief or safety injection systems.

These events are, however, interrelated because :

1) the time limits for operator action imposed to prevent unacceptable consequences depend on the plant operating mode at the time of the initiating event and also on operability of systems required by the procedure. For example, the greater the pressurizer relief capacity, the longer the time limit provided before actuation of pressurizer relief is required.
2) the requisite system performance depends on the time at which operator action occurs.

3) some causes of feedwater system failures also affect other systems which are required to mitigate feedwater system failures.

In order to evaluate the probability of different accident sequences leading to success or failure of procedure H_2, all of these interrelationships should be considered.

3 - DEFINITION OF EVENT SEQUENCES

Thermal/hydraulics analyses have been performed taking into account the variation of the following three parameters :

- Initial plant status at the moment of total loss of feedwater. This status is, for instance, dependent on time between loss of normal feedwater and loss of auxiliary feedwater,
- Availability of pressurizer relief valves and high head safety injection subsystem,
- Time at which the operator implements procedure H_2.

These analyses were used to assess the time limits depending on initial plant status and system availability, with respect to operator action in order to prevent core uncovery.

The different configurations that can lead to the success or failure of procedure H_2 have been identified and represented on event-trees. Two examples are illustrated on figures 1 and 2.

4 - HUMAN FACTOR ANALYSIS

Actions for which we have evaluated failure probabilities are recovery of a feedwater system and initiation of the feed and bleed cooling configuration.

For the first action, the contribution of the human factor is negligible compared with that of equipment.

On the other hand, the human factor is very important for the second action. This action can be broken down as follows :

step 1 - Detection of abnormal event
step 2 - Diagnosis
step 3 - Decision-making
step 4 - Action

The failure probability during steps 1 and 4 is considered negligible compared with that during steps 2 and 3.

Steps 2 and 3 have been analyzed using the Swain model (Ref.1). This model gives the failure probability of a cognitive action (diagnosis and decision-making) as a function of the time available to perform it.

These probabilities apply to a team of operators and must be weighted as a function of actual accident conditions. In particular, a multiplication factor has been introduced to take into account operator reluctance to deliberately initiate a primary break.

Given the importance of human intervention in these situations, an additional assessment was carried out for a specific case Ref. 2. This assessment used a different approach (SHARP's method and HCR model).

It confirmed the results obtained using the first approach.

5 - RESULTS

7 sub-initiators have been identified given the various potential causes of loss of feedwater.

On the basis of these sub-initiators and initial plant conditions at the time of the accident, 23 different total loss of feedwater situations have been identified.

An event-tree was developped and the failure probability of procedure H_2 quantified for each situation.

This was done by combining system reliability analyses and human factor studies.

The benefits provided by procedure H_2 were then assessed for each situation.

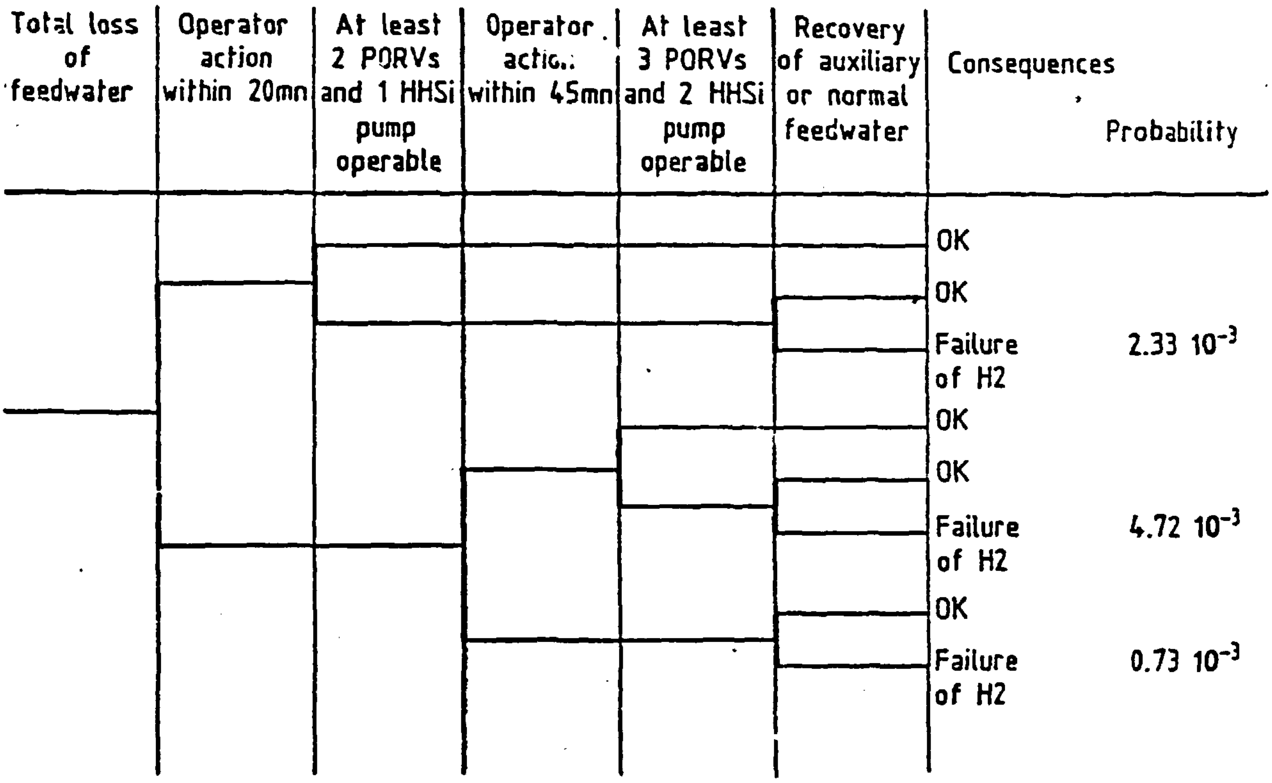
This benefit varies from a factor of 4 to 1000 depending on the case of interest.

Lumping the situations together, the overall failure probability of procedure H_2 has been estimated at 7×10^{-3} and the benefit provided by procedure H_2 at 140.

Reference document 1 - Hand Book of human reliability analysis
A.D. SWAIN - H.E. GUTTMANN
NUREG/CR-1218

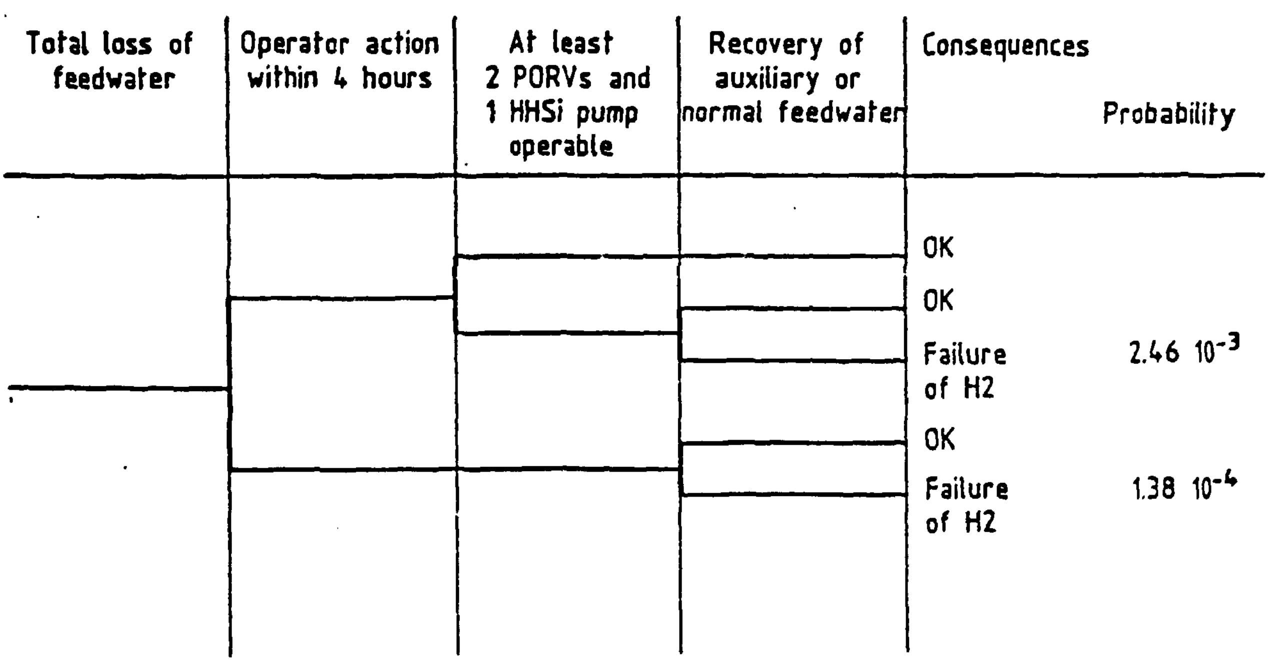
Reference document 2 - Quantification of H_2 procedure for a standard 900 MWe PWR pl Human reliability analysis
Y. LUKIC - A.J. SPURGIN
C.W. HANNAMAN - NUS 48.32

Fig. 1 - LOSS OF AUXILIARY FEEDWATER LESS THAN HOUR AFTER LOSS OF NORMAL FEEDWATER



Failure probability of H2 procedure : $7.8\ 10^{-3}$
Benefit : 129

Fig. 2 - LOSS OF AUXILIARY FEEDWATER FROM 1 TO 5 HOURS AFTER LOSS OF NORMAL FEEDWATER



Failure probability of H2 procedure : $2.6\ 10^{-3}$
Benefit : 385

Novembre 1987

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