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RAPPORT DAS N° 166 e

INTRODUCTION OF ACCIDENTAL PROCEDURES IN THE EVENT TREES OF THE 900MW PWR PRA

G. BARS*, M. CHAMP*, J.M. LANORE*, R. POCHARD*

ANS-ENS. International topical meeting on probalistic safety methods and applications
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CEA/IPSN - FRANCE

INTRODUCTION

In France a PRA is presently in progress in the Safety Assessment Department of CEA for a standardized 900 MW PWR plant.

The objective of this PRA is to establish a model of the risk related to a standard plant, with a basic data set. This model will then be used to calculate risk variations, in order to provide to the safety authorities an aid for making decision in case of problems which can be stated in term of relative or differential risk assessments.

This PRA uses mainly the existing methods and knowledge, but however some specific investigations are performed, related to the objectives and to the French situation.

In particular, due to the important attention given in France to the procedures in the frame of reactor safety, a feature of the PRA is an introduction nearly systematic of the emergency procedures in the Event Trees.

Indeed, the French safety approach for severe accidents management is the implementation of a set of special emergency procedures which identify the optimal actions even for out of design situations. So by accounting for these procedures (correctly or incorrectly applied) an important set of operator actions can be included in the PRA. This approach implies the introduction of the notion of procedure failure at the level of the Event Trees. (3) (4) (6).

Quantification of the corresponding probabilities leads to several problems as physical efficiency of the procedures, systems availability (including instrumentation), and human behaviour.

Among these problems the physics of the sequence is a primary question, both to state the efficiency of the procedure to prevent a core damage, and to assess the allowable time for the operator actions. So a set of thermohydraulic studies was initiated for various accident sequences and procedures. We present here the example of the small LOCA Event Trees and the studies related to the introduction of procedure actions in case of HPSI failure. The results illustrate the interest of the approach and its significant impact on the PRA.

PROBABILISTIC ANALYSIS OF THE SMALL LOCA

Small LOCA event trees

For small LOCA, four event trees have been drawn :

- S_1 : small LOCA (2" $< \emptyset <$ 6")
- S_2 : very small LOCA (3/8" $< \emptyset <$ 2")
- S_3 : stuck open PORV
- S_4 : stuck open safety valve

This distinction between S_1-S_4 and S_2-S_3 is a consequence of the introduction of the procedures which involve different systems during the long term cooling. As an example fig.9 shows the S_2 event tree.

Procedures introduced in the event trees

Three procedures actions (X, Y, Z) have been introduced in these event trees (fig.9)

- X corresponds to the feed and bleed action (issued from H2 procedure). This procedure is used for the case of a total loss of feed water.

- Z corresponds to the long term cooling actions after LOCA (issued from the long term aspect of the A1.1 procedure).

- Y corresponds to a short term core cooling with the steam generators (short term actions of A1 and U1 procedures). (5).

The present studies are related to the Y actions in case of small LOCAs without HPIS. These actions are detailed below.

Y Actions

On the S.I. signal, the operator has to enter into the AO procedure. This procedure is designed for orientating the operator into the suitable accidental procedure. In case of a primary break, the AO tests orientate the operator into the A1.1 (small breaks) or A1.2 (large breaks) procedure. The main action of these procedures consists in cooling the primary circuit with a temperature velocity of 56°C/h with the atmosphere relief valves of the steam generators.

Besides that, the shift technical advisor (STA) has to perform a continuous post accidental supervision. It consists in a functional safety system monitoring on the one hand and in a NSSS physical state analysis on the other hand. On a functional or state criterion he may decide the entering in U1 (in case of HPSI failure U1 will be applied). In that case, the operator has to perform the important actions :

- A maximal cooling through the steam generators.

- If the preceeding action shows to be not efficient enough (state criterion) opening the pressurizer valves.

These actions are subordinated to the thermohydraulical state of the reactor coolant system and to the availability of the safety systems to be operated.

THERMOHYDRAULICS CALCULATIONS

Investigations Undertaken

The general problem is the efficiency of the Y actions in case of small LOCA without HPSI. So first calculations have been performed without operator action. Then other calculations where initiated including Y actions for answering the following questions :

- o Is this action efficient to prevent core meltdown for the 900 MW type reactors ?
- o If this action shows to be efficient to prevent core meltdown, will it be enough to prevent damage ?
- o Within how many minutes should the operator act to prevent core uncovery or meltdown ?

Studies have been conducted for two break sizes : 1.5 and 3", located in a steam generator channel head (cold leg).

The code used is Relap 4 mod 6 which has been assessed on a large set of analytical and global facilities.

RESULTS

Transients without Operator Action

Case of the 3" break. The computation without operator intervention shows that the core is severely damaged (clads rupture), but not melt. The clads temperature remains relatively high ($\geq$ 800°C) during a long time ($\simeq$ 1h). The coolable geometry is preserved.

Case of the 1.5" break. This break represents the class of small breaks (between 3/8 and 2" in the spectrum). It has always been considered as leading to a core melt if there is no HPIS and without operator intervention. This transient is characterized by a water deficit with a strong coupling between primary and secondary pressure, due to the residual power removal, because the break is too small for doing it by itself.

The calculation without action confirms this fact.

Calculations with Operator Action

Mitigating actions of the Al procedures. The first step in improving the effectiveness of the operators actions was to calculate the effect of a cooling velocity of 56°C/h under small LOCAs conditions with concurent HPIS failure. Informations existed indicating that a full opening of the atmosphere dump valves (ADVs) could be not necessary to save the core (1). For this reason, it was decided to first test the effectiveness of the normal LOCA procedures in depressurizing the reactor down to the LPIS head before significant core damage.

The delay of operator action was assumed 20 minutes.

Case of the 3" break. The main results are summarized on the figures 1, 3, 5 and 7.

- A short core uncovery occurs between 1000 seconds and 1250 seconds after the break.
- After 1250 seconds the accumulators begin to empty.
- The clad temperatures do not exceed 700°K.

- The low pressure injection system becomes effective 3200 seconds after the break occurence.

- There is no severe core damage to be expected.

Case of the 1.5" break. The main results are summarized on the figures 2, 4, 6 and 8.

- The accumulators begin to emply 2870 seconds after the break occurence.

- At 3000 seconds a very short core uncovery (100 seconds) occurs upon a height of 20 cm.

- The clads temperatures are not affected by this core uncovery

- At 5470 seconds, the low pressure injection system becomes effective.

Assessment of the Effectiveness of the Ul Procedure for the S_2D Sequence

Upon occurence of a small LOCA with coincident failure of the high pressure injection system, the decision to open manually full scale all the ADVs would be taken using the Ul procedure. Given the preceeding results, the problem of the effectiveness of the Ul procedure for the case of the S_2D sequence can be stated as the evaluation of the allowable delay for operator action.

Figure 7 shows that the benefit of using the Ul procedure would not be very important for the case of the 3" break since the ADVs have to be nearly full open to achieve a 56°C/h cooling velocity.

Concerning the case of the 1.5" break, the benefit could show to be interesting in terms of delay for operator action. This point is still under investigation.

Impact on the PRA Results

The failure probability of the Y action appears as a multiplying factor for the S_2D sequence. Now the results of the thermohydraulics calculations indicate that the time available for the operator is at least 20 minutes. In such a situation the probability of human error is mainly due to a failure in diagnosis and decision making. To assess a probability for this type of problem, a common approach is to use a time reliability curve.

For instance for using the values given in NUREG/CR-1278 (2), the failure probability for an allowed delay of 20 minutes is .1 (screening value) or .01 (nominal value). So a rough estimation indicates that the probability of the S_2D sequence will be at least reduced by a factor 10 to 100.

CONCLUSIONS

- A cooldown velocity of 56°C/h is sufficient to prevent significant core damage when operated within 20 minutes after occurence of a small LOCA with coincident failure of the HPIS.
- Further investigations are required to assess the influence of break location and the possibilities of a stronger action on the ADVs (in terms of delay for operator action).

The effect of these results on the PRA are obvious since they reduce significantly the probability of the important S_2D sequence.

Similar studies are in progress for several other operator actions, from which similar effects are expected. So we can say that the introduction of procedures in the event trees provides very interesting insights on accident sequences progress and mitigation, and will have an important impact on the PRA results.

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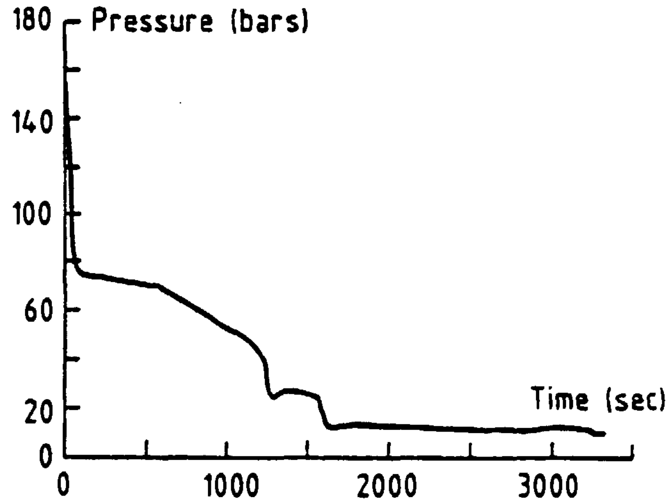


Fig. 1 3" break

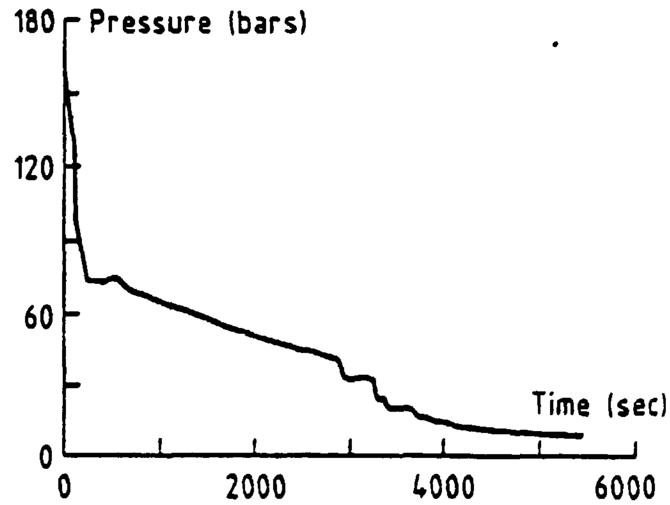


Fig. 2 1.5" break

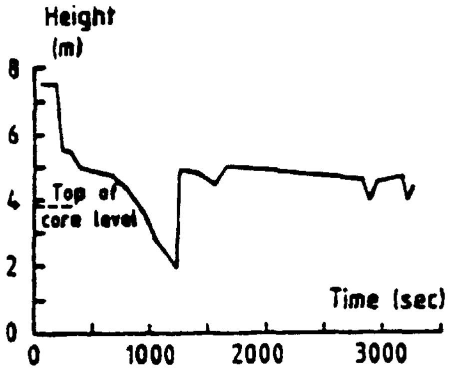


Fig. 3 3" break

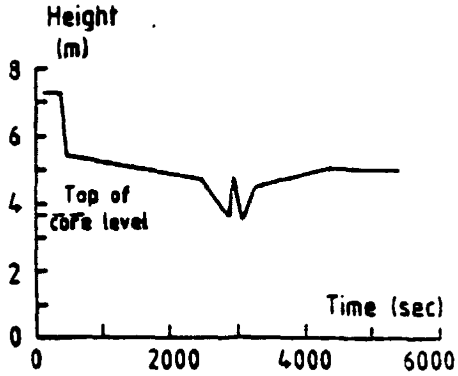


Fig. 4 1.5" break

WATER LEVEL

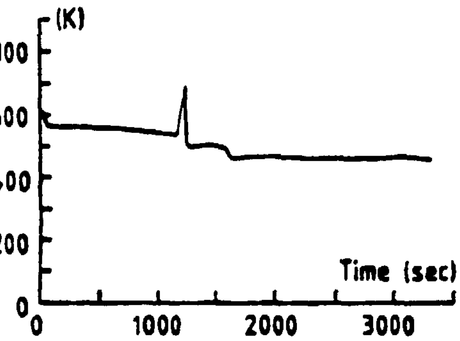


Fig. 5 3" break

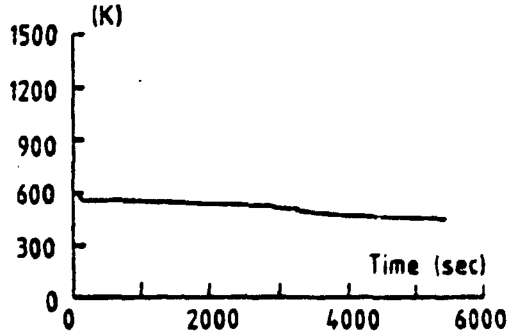


Fig. 6 1.5" break

CLAD TEMPERATURE

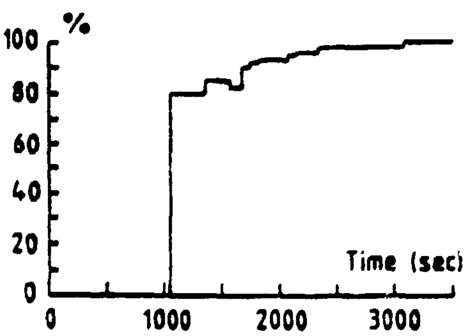


Fig. 7 3" break

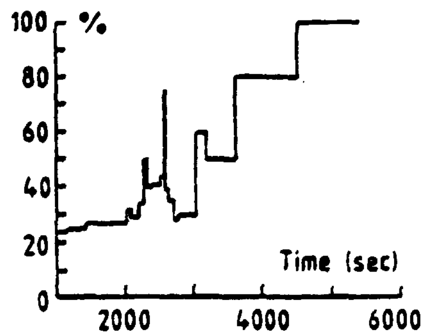
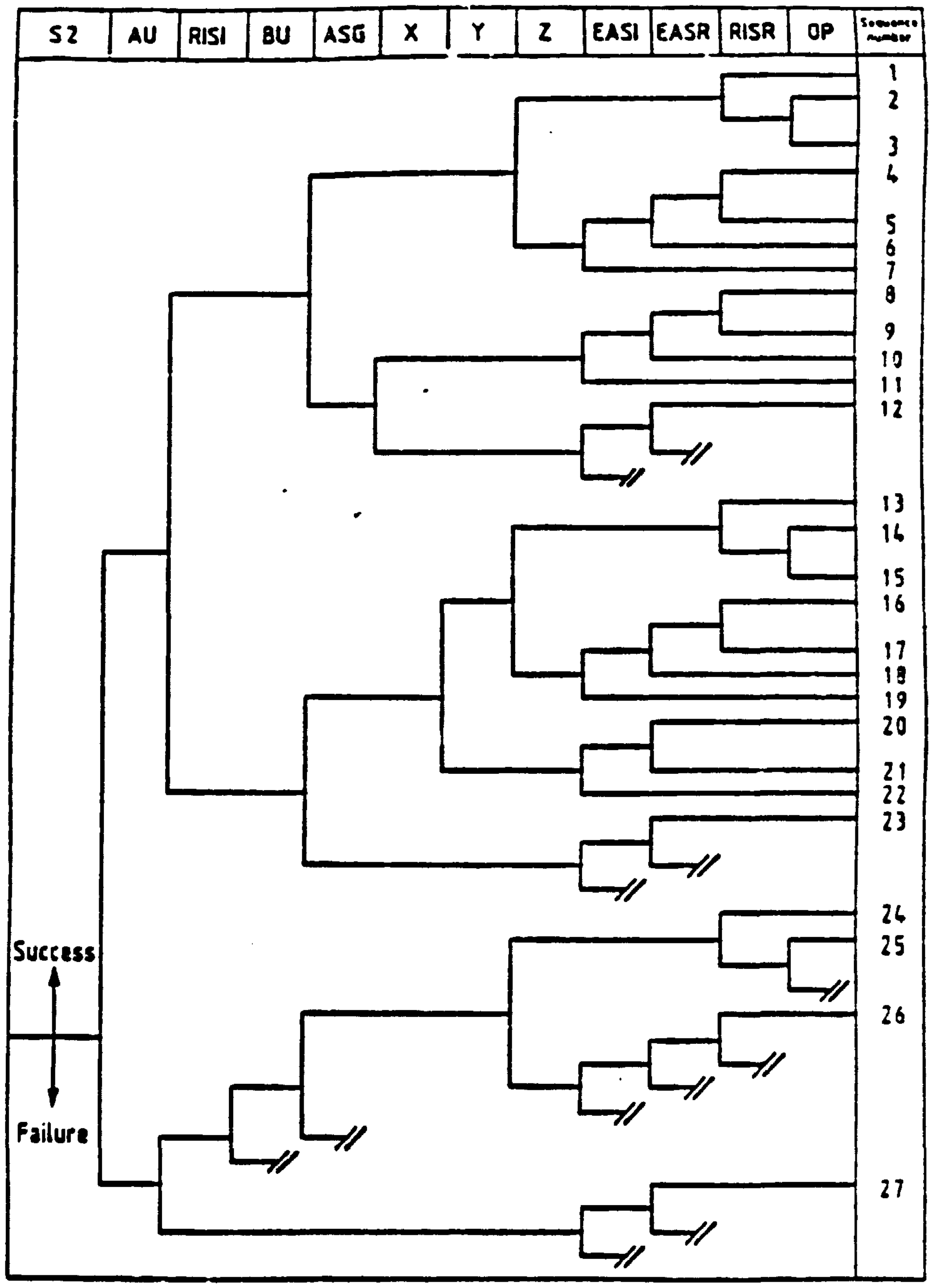


Fig. 8 1.5" break

PERCENTAGE OF ADVs OPENING



AU Reactor Protection System
RISI High Pressure Injection System
BU Emergency Borification
ASG Auxiliary Feed Water System
X X actions
Y Y actions

Z Z actions
EASI Containment Spray Injection System
EASR Containment Spra· Recirculation System
RISR High Pressure Recirculation System
OP Manual Operation of Containment Spray System

Juillet 1985

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