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DIAGNOSIS AND PROGNOSIS OF THE SOURCE TERM BY THE FRENCH SAFETY INSTITUT DURING AN EMERGENCY ON A PWR

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ABSTRACT

The French approach for the diagnosis and the prognosis of the source term during an accident on a PWR is presented and the tools which have been developed to implement this approach at the Institute for Nuclear Protection and Safety (IPSN) are described.

In case of an accident in a nuclear installation, it is necessary to evaluate the situation and in particular to forecast its development in terms of release into the environment. In France, this information is elaborated by a national emergency organization and provided to the local government representative (the head of the Prefecture) who takes it into account in order to implement the decisions concerning the protection of the population.

The national emergency organization consists mainly in a decision-making level (the Emergency Managing Centers) and a think tank level (the Emergency Technical Centers of the utility - one located in the plant, the other in the Paris area - and of the IPSN).

The IPSN Emergency Technical Center (ETC) is organized round a management unit receiving analysis data from two working parties, one studying the situation within the damaged plant (Plant Assessment Unit) and the other concerned with assessing the radiological consequences of the accident (Radiological Consequence Unit).

1. The working frame of the Plant Assessment Unit.

This paper focusses on the work performed by the Plant Assessment Unit. During an emergency, the experts working in this Unit have to face the challenge of making, in real time, an operational synthesis of the available informations. In particular, they have to make the discrepancy between the essential and subordinate informations, detect the errors and raise the judicious questions at the right time. Finally, their synthesis aims at providing a diagnosis and a prognosis of the situation.

Although this synthesis is elaborated by the IPSN ETC on its own side, it is periodically confronted, through a phone conference network, with the diagnosis and the prognosis performed by the ETCs of the utility /1/. In order to structure the dialogue between the three ETCs, a think grid has been jointly designed (fig.1). According to that grid, the surveyed items are the following ones : the physical state of the safety barriers, the availability of the safety systems, the state of the safety functions and the margins to critical states.

This think grid provides a useful frame for the three ETCs, making the discussion more methodic, exhaustive and systematic. It enables them to clarify their divergences in the analysis of the situation.

After that discussion, every ETC writes a synthetic message which is transmitted to its corresponding Emergency Managing Team. Divergences in those messages are still possible, but their reasons are very likely already clarified.

The following paragraphs present the procedure followed by the IPSN Emergency Teams to use the think grid and answer its questions.

2. The first step : the qualitative approach.

In this step, the Emergency Teams are only interested in finding the position and the evolution of the representative point of the plant in the 3D space describing the physical state of the safety barriers (fig.2).

Only a limited number of physical states (from safe to degraded state) of the safety barriers is considered. The evolution from one state to an other corresponds to a step in the fission product release which should be discriminated by the plant instrumentation and gives an idea of the degree of severity of the accident.

The qualitative diagnosis is elaborated by monitoring a set of about 100 measurements. They are picked out among the several thousands which are transmitted from the affected plant to the IPSN ETC and received on the following IPSN terminals :

- the terminal connected to the plant Safety Panel Display System (SPDS),
- the terminal connected to the plant computer,
- or, better, the 'local treatment' terminal which allows every ETC to perform its own processing of a preselected set of 100 measurements.

The values of those measurements are compared to some thresholds and a rough diagnosis about the state of the safety barriers is issued.

The qualitative prognosis is based upon the observation of the procedures being followed by the operators and the study of the present and future availability of the safety systems. Use of PRA studies is made to identify those systems which are especially important in a given scenario to prevent core melt.

The informations necessary for the prognosis are provided to the Emergency Teams through the phone conference network, the previously quoted terminals and the *ALADIN* software (see 3.3).

3. The second step : the quantitative approach.

In this step, the Emergency Teams try to give some quantitative answers about the state of the safety functions (subcriticality, core cooling, confinement efficiency) and the margins to critical states. Such questions as the following ones are tackled :

- the size of the RCS break,
- the fraction of clad rupture and core melt,
- the localization and quantification of containment leakage,
- the quantification of hydrogen,
- the time before core uncovery, clad rupture, core melt,
- the released activity,
- ...

In order to answer those questions, some tools, developed in the frame of a project entitled SESAME, are available for the Emergency Teams.

In the origin, those tools consisted mainly of curves, tables, correlations and reports presenting operational synthesis of a given topic.

However, due to the difficulty to link those different elementary tools and to adjust them to specific situations, it was found progressively more efficient to commit the calculations to some softwares running on PC or work stations.

The general organization of those softwares is presented on figure 3. They are of two types :

- expert systems operating on work stations,
- FORTRAN or PASCAL softwares, operating on PCs.

Their general features are the following ones :

- user-friendliness,
- flexibility (possible adaptation to various situations),
- fast execution (by means of simple models),

Contrary to the design approach, they use, to the maximum extent, realistic assumptions and physical laws. Systematic qualification is performed through comparison with reference codes and the results allow a better knowledge of their validity domain.

The softwares are described in the following paragraphs. They are roughly divided into three groups.

3.1. *Thermalhydraulics*

The "*BRECHEMETRE*" software makes an evaluation of the size of the RCS break by means of a mass balance on the primary circuit and a comparison with a critical flow correlation issued from the CATHARE code.

An other way to perform an estimation of the break size consists in comparing the evolution of the containment pressure with precalculated scenarios computed with ESCADRE for various break sizes. This is done with the "*SINBAD*" software which also includes correlations on the following topics :

- water and steam properties,
- correspondence between swell and collapsed levels,
- RCS break size and equilibrium pressure,
- critical flow,
- steam break or safety injection flows necessary for residual power removal,
- fraction of clad rupture versus pressure and temperature at the top of the core,
- time between core uncovery and clad rupture, core melt, bottom head failure or basemat penetration.

In the "*SCHEHERASADE*" software, the primary circuit is represented by a 0D capacity at saturation with a heat source (the core), a heat exchanger (the steam generators), an injection of subcooled liquid (the safety injection) and one or several breaks (the size of which is estimated according to the previous explanations). *SCHEHERASADE* calculates the evolution of the liquid inventory by means of mass and energy balances. A comparison with a critical liquid inventory (under which core uncovery is possible) gives an estimation of the delay before core uncovery.

3.2. *Fission product emission, transport and confinement*

"*ALIBABA*" is an expert system which provides an early diagnosis of containment leakage and identifies the position of the leakage. This diagnosis is elaborated from radioactivity measurements in the auxiliary buildings and from informations on the closure of the valves located on both sides of the pipes crossing the containment /2/.

In addition to thermalhydraulics, the "*SINBAD*" software includes some correlations and methods providing an estimation of :

- the core residual power,
- the core residual activity for all the volatile fission product families,
- the flow rate of the containment leakage.

The "*PERSAN*" software calculates the fission product release outside the installation for the accidents without containment bypass. For that purpose, *PERSAN* collects the data prepared by *ALADIN*, *SCHEHERASADE*, *ALIBABA* and *SINBAD* and performs the following calculations versus time :

- fission product released into and outside the primary circuit,
- fission product deposition inside the containment (with the possible influence of the spray system),
- distribution of the containment leakage between the atmosphere (direct leakage) and the auxiliary buildings,
- fission product filtration and deposition in the auxiliary buildings.

The "*RTGV*" software calculates the fission product release outside the installation for the accidents involving steam generator tube rupture without core degradation. The calculation is based upon mass and activity balances in the primary and secondary circuits.

3.3. Other Softwares

The "*HYDROMEL*" software studies the behaviour of hydrogen in the containment. It calculates the position of the containment atmosphere in the Shapiro diagram. If combustion is found possible, it calculates the maximum pressure and temperature to be expected. After combustion, it also evaluates the quantity of hydrogen remaining in the containment.

"*ALADIN*" is an expert system which gives informations about safety systems availability. Those informations are complementary to the ones provided by the SPDS. Two features of *ALADIN* can be more specifically used by the Plant Assessment Unit :

- a documentation function which presents a detailed description of the electrical supply of the systems through text or synoptics,
- a simulation function allowing the user to determine the origin or the consequences of a fault on an electrical supply or a component.

The margin to criticality is approximately evaluated with the "*CRAC*" software which performs a reactivity balance by taking into account the effects of the control rods, the moderator, boron, xenon and Doppler.

CONCLUSION

This methodology and the associated tools allow a more efficient work of the IPSN Emergency Teams. It presents the advantage to save their time for complementary verifications and comparison of strategies.

However some training must be provided to the teams to get them accustomed with the approach. This is done through both academic sessions and simulated emergency situations. During the academic sessions, the think grid, the hand tools and the softwares are presented and some specific exercices, focussed on one topic, are proposed. The simulated emergency situations consist of emergency drills performed together with the utility at least twice a year and deal with the overall situation of an accident on a PWR.

In parallel, often as a consequence of training sessions or emergency drills, the approach is improved. In the future, more automatic help for diagnosis and prognosis of the accident situations will be available (with larger use of expert systems).

REFERENCES.

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/2/ P.PEPIN, C.CHAULIAC, M.LIBMANN, J.M.MARTINEZ. Early localization of containment leakage during an accident. (Second international conference on containment design and operation. TORONTO, October 1990).

FIGURE 1 THINK GRID

	DIAGNOSIS			PROGNOSIS	
	SYSTEM AVAILABILITY	STATE OF SAFETY FUNCTIONS	STATE OF SAFETY BARRIERS	SYSTEM AVAILABILITY	STATE OF SAFETY FUNCTIONS
SUB-CRITICALITY			FUEL		
RESIDUAL POWER REMOVAL			RCS		
CONFINEMENT			CONTAINMENT		

FIGURE 2: PHYSICAL STATE OF THE SAFETY BARRIERS

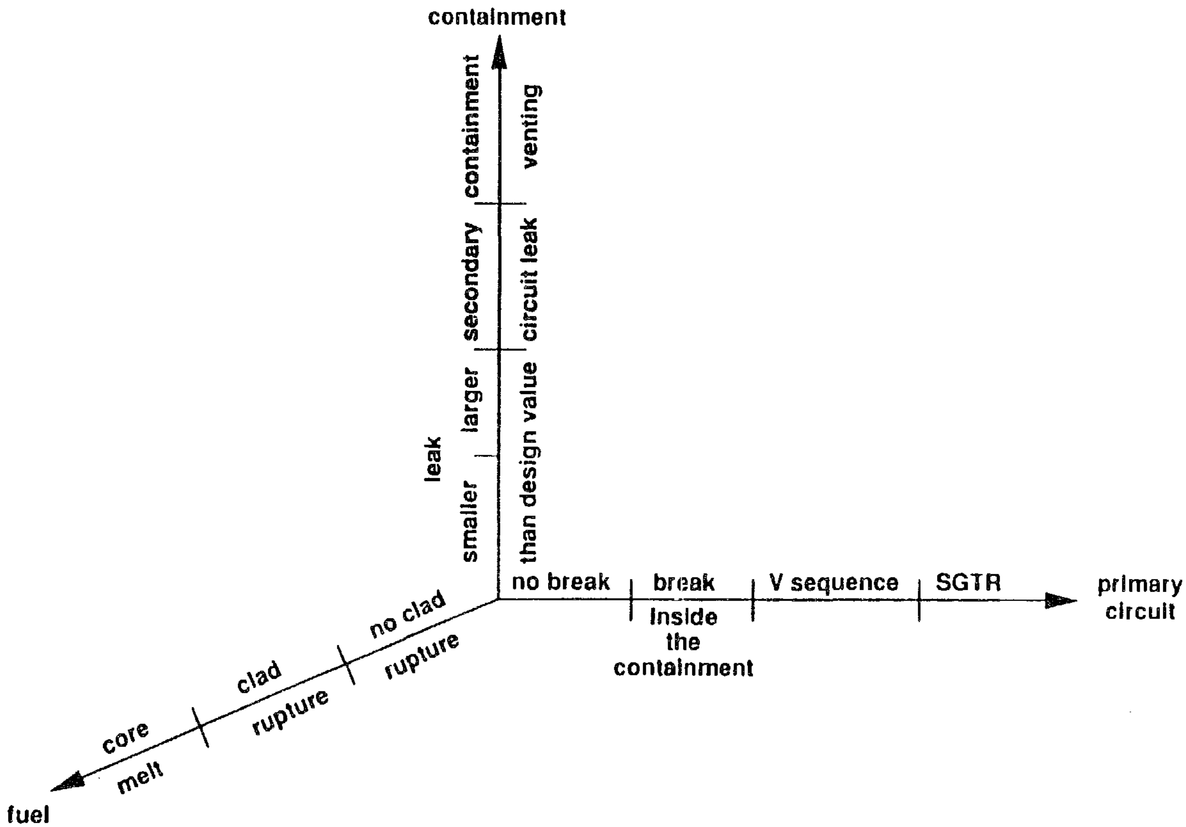

FIGURE 3

THE SESAME PROJECT

ORGANIZATION OF THE SOFTWARES USED BY THE PLANT ASSESSMENT UNIT