Organisation and Operation of the IPSN crisis centre in case of accident in a French PWR

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I. INTRODUCTION

The French nuclear power plants consist of standardised pressurized water reactors. In view of the potential consequences of an accident in this type of installation, a national emergency management system has been created providing the capacity to implement the necessary countermeasures to protect nearby populations. The Institute for Nuclear Safety and Protection (IPSN), the technical support body of the French safety authority, has therefore devised and set in place an aid system which could, in the event of an emergency occurring in a French PWR, enable the predetermined objective to be attained.

The following description only relates to the first phase of an accident, i.e. the first few days after its occurrence; IPSN action in the post-accident phase is in this paper therefore excluded. In view of the national context and the missions entrusted to the IPSN in the field of reactor emergency management, the different aspects of its action are reviewed, showing their interaction and their overall coherence. Thus, issues relating to training, organisation and participation in exercises are described as they constitute the outward sign of the correct functioning of its action and make improvement possible by constant feedback of experience.

II. THE NATIONAL EMERGENCY MANAGEMENT SYSTEM

The French national emergency management system for PWRs involves the different governmental bodies with special responsibilities for nuclear safety, radiological protection and civil defence. Here we shall restrict ourselves to those relating to the IPSN's emergency centre.

The nuclear operating organisation - Electricité de France in the case of PWRs - remains, in an accident situation, responsible for the safety of its installation and its staff. Therefore two centres of decision-making exist at local level:

- the management of the damaged plant, which has the task of returning the installation to a safe state, to limit the release and to protect the staff;
- the prefecture of the administrative *département* in which the reactor is located, which has the task of protecting the population from the consequences of the accident. The prefect of the *département* involved constitutes the representative of the government and co-ordinates, as necessary, the action of other neighbouring prefectures affected.

The action specified in the emergency plans is then initiated, whether they are those of the on-site emergency plan within the installation or those laid down in the off-site emergency plan for the neighbouring populations.

Aid in decision-making is supplied at a national level by, on the one hand, an EDF emergency team and, on the other hand, emergency teams from the safety authority (DSIN), the radiological protection authority (DGS/OPRI) and the civil defence authority (DSC), all of which are located in Paris. These four teams described before are in constant liaison throughout a nuclear emergency.

At both national and local levels, technical emergency teams are formed to supply the necessary inputs to the decision-making bodies: that of the damaged installation to meet the needs of the manager of the plant, that of EDF at corporate level and that of the IPSN to advise the DSIN. These three teams are interlinked to enable the necessary technical dialogue to take place.

The main role of the IPSN is thus, in the PWR case, to advise the government authorities of any countermeasures to be put in place to protect the population, in view of the assessment of the potential hazards represented by the damaged installation. The current design of the French PWRs has led the IPSN to estimate that, in most accident situations, the dynamics of an accident would be relatively slow and no major releases would occur before some hours. Therefore, the IPSN's objectives in the event of an emergency in a nuclear facility will be:

- to assess the state of the installation and to monitor its development;
- on the basis of this assessment, to forecast the possible development of the accident and to estimate the associated consequences;
- in parallel, to estimate the consequences of the releases of radioactivity into the environment; this estimation being based on both the preceding assessments and on measurements which may have been taken in the environment;
- on the basis of the above, to inform the government authorities of the situation and the foreseeable potential consequences, notably by advising them about the countermeasures to take.

III. ORGANISATION OF THE IPSN CRISIS CENTER

In case of emergency, the IPSN's technical emergency centre comprises four units (see figure 1):

- a management unit (CD) with the task of co-ordinating the work of the two technical units, collating the results obtained and transmitting the necessary information recommendations to the safety authority. It is to be noted that a video conference facility therefore links the management unit to the DSIN emergency team;
- a secretariat unit (CS) with the task of dispatching the information received and transmitting the previously-validated advice and data obtained;
- two technical units, designated installation assessment unit (CEI) and radiological consequences unit (CCR) with the task of processing the information received and, more specifically, analysing it.

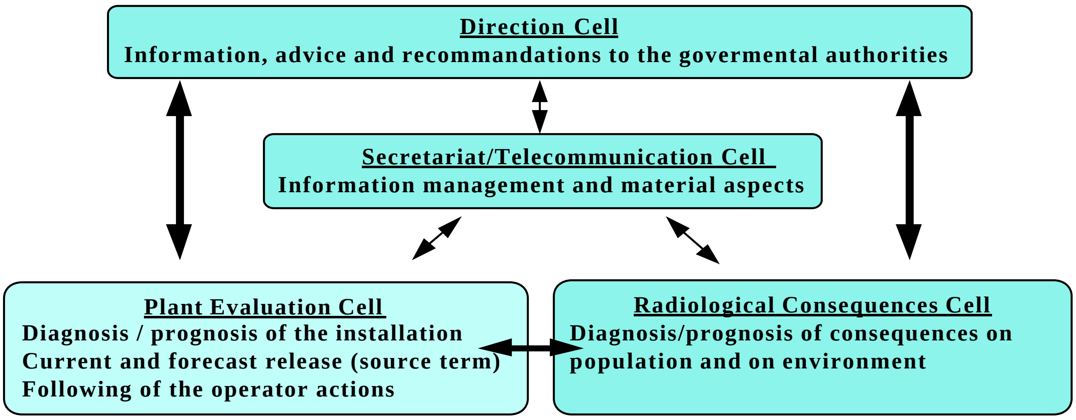

Figure 1: Organisation of the IPSN emergency centre

For the PWRs, the CEI consists of nine staff: a co-ordinator, a technical secretary, the delegate for the plant involved, two audioconference workers, a data processing worker and three specialists (operations, thermal hydraulics and containment) using aid support system for their assessment. This unit is linked to the other technical emergency teams by an audioconference system making it possible to periodically assess the situation from a technical point of view. The CEI is responsible for the evaluation of source term and should verify that the operator takes proper steps to limit the releases into the environment.

The CCR consists of six staff: a co-ordinator, a deputy, a technical secretary, a co-ordinator of liaison outside the unit and two staff in charge of making estimates with a computer system. Links are in place between the unit and the staff of the French meteorological authority, the OPRI and the EDF technical emergency teams. The CCR should supply the estimation of consequences and interpret measurements made in the environment after releases.

IV. THE METHODOLOGY AND TOOLS OF THE IPSN

A so-called 3D/3P approach (triple diagnostic/triple prognostic), developed in collaboration with the operating organisation has been adopted. Sole the basic principles are described hereafter. This method is intended to indicate the options available to the emergency teams and to serve as a basis for the technical dialogue between the different players during an emergency. The approach is a deterministic one and is based on the concept of defence in depth. The state of the installation is evaluated throughout the accident with special reference to the three barriers, successively considering their physical state, the state of the functions guaranteeing their integrity and finally the state of the systems available to monitor these functions. The first stage is determination of the type of accident, which makes it possible to obtain an initial estimate of on-going and of foreseeable releases into the environment. On the basis of this diagnostic, a prognostic of the development of the state of the safety functions is made, essentially by determining the current and foreseeable availability of the associated engineered safety features. Change in the state of the safety barriers then governs the evaluation of the eventual radioactive releases. Application of the technique ends with filling in a special synopsis sheet describing the current and eventual state of the barriers and safety functions, as well as the associated releases. This will be used as a basis for discussions between the IPSN and EDF during the accident.

This process is assisted by two computer systems: the SESAME system designed to provide answers to questions concerning the installation and another named CONRAD designed to calculate the radiological consequences in the environment.

IV.1 Description of the SESAME system

The tools described below were developed with a view to assisting expert appraisal. They are in no case intended to replace the expert, who remains fully responsible for his own assessment. It is therefore necessary for him to properly understand the scope of validity of the various tools he may be required to use and to maintain a critical attitude concerning the results produced.

To show these tools in the context of their utilisation, two sets of accident sequences are considered hereafter, a loss of coolant accident (LOCA) and a steam generator tube rupture (SGTR). These two sets of accident sequences make it possible to demonstrate the performance of these tools, even though they remain applicable to other situations. The description of the evaluation tools is preceded by a summary of the data acquisition system, which plays a major role as the quality of the work carried out by the technical emergency response centre greatly depends upon it.

A. Reception and processing of data

Before any evaluation can take place the data must be acquired. This is done by a data processing system capable of transmitting one hundred analogue readings per minute, via an EDF network, between any PWR unit and the emergency response centres of the IPSN and EDF. The values transmitted are the readings recorded by the sensors at the accident-stricken site.

A program called ACQUISITION has been developed to utilise these data. It receives the readings transmitted and stores them in a database accessible to all members of the corresponding emergency response team. It applies the conventions adopted for representing unavailable readings and generates a statement of availability for all the sensors over time that the different specialists can read. During these operations, it is possible to evaluate the validity of the values transmitted by means of on-screen forms describing the sensor involved (its measurement range, its accuracy and its location).

In the event of unavailability of the data link, the ACQUISITION program enables pre-formatted messages to be entered for some fifty readings. These messages are faxed by the accident-stricken plant every fifteen minutes. If this mode of transmission of the data also fails, it is envisaged to use simpler messages which can be exchanged by phone with the accident-stricken plant. These messages are then keyed-in using the ACQUISITION program. A degree of redundancy in the transit of data is thus provided.

B. Use of the SESAME system in the event of a loss of coolant accident (LOCA)

The figure 2 represents the utilisation of the different tools in case of a LOCA accident occurring on a French PWR.

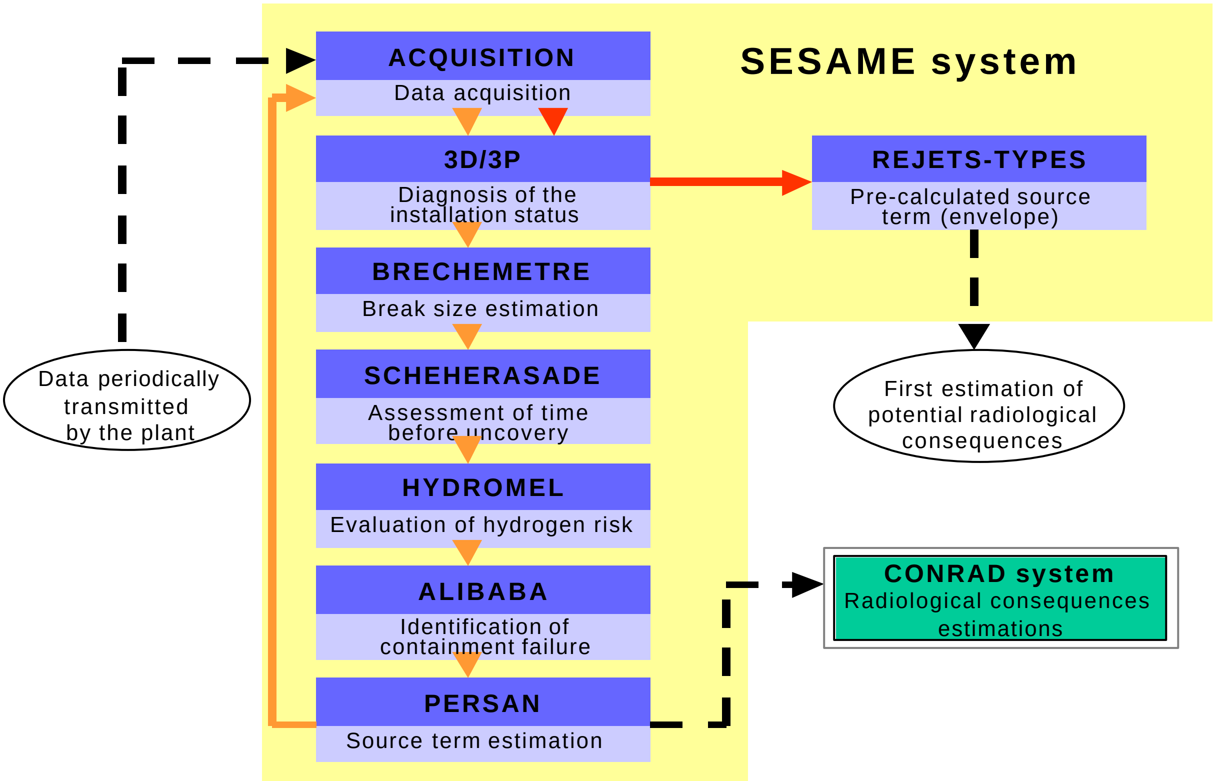

Figure 2: Utilisation of the SESAME system in case of LOCA accident on a French PWR

Basic diagnosis and monitoring of the situation require making a comparison between the readings transmitted by the installation with correlations or typical values. This task is performed with the assistance of the 3D/3P program. The «initial diagnosis» function of this tool proposes a selection of reference data and readings making it possible to rapidly determine the type of accident.

In a case of a LOCA, the expert first checks the state of the first barrier by comparing the temperatures measured at the core outlet with temperature thresholds signifying degradation of fuel (cladding failure or core meltdown). The presence of activity within the containment, while enabling him to confirm his diagnosis concerning the first barrier, also enables him to issue an opinion on the second barrier (primary break located in reactor building). He can verify this diagnosis by requesting display of the trends of other parameters such as the pressure and temperature within the reactor building. The various stack activity readings enable him to form an initial opinion on the state of the third barrier.

This material enables the expert to select, using the REJETS-TYPES program, a pre-determined accident scenario using the following parameters: reactor type, operation of spraying in the containment and core and containment degradation states. This stage enables the emergency response team to rapidly provide a first evaluation of radioactive releases outside the installation.

Once the presence of a primary break is diagnosed, the size of the break is evaluated using the BRECHEMETRE program. Two modes of evaluation are available:

– the first, based on variation of the water level in the pressurizer, gives the leak rate by means of a primary system mass balance. Comparison of the rate with critical flow correlations then gives the cross-sectional area of the break diagnosed by the experts. This model has been qualified using the CATHARE thermohydraulic computer code and a version of it on the SIPA simulator to take into account the effect of the reactor protection systems,
– the second, which is less precise, is based on comparison of the pressure peak measured in the containment at the moment of appearance of the break with standard pressure peaks for a spectrum of known break sizes and given cooling conditions. The standard pressure peaks were obtained by calculation using the PAREO design code (developed by EDF) and verified with the JERICHO code of the ESCADRE system (a set of severe PWR accident computer codes developed by the IPSN).

The diagnosis of a primary break immediately leads the experts to pose questions concerning the eventual state of the «water inventory» safety function which determines the states of the «fuel» barrier. To provide assistance in evaluating the risk of uncovering of the core and, when applicable, the time available before the onset of uncovering, the SCHEHERASADE program is available to the expert. This program uses mass and energy balances as a basis and applies hypotheses concerning the size and location of the break, as well as the cooling induced by the action taken by the operators. Assessment of the time available before degradation of the core (failure of cladding or meltdown of the core) is made using correlations derived from studies carried out with the VULCAIN reference code of the ESCADRE system.

In the event of a severe accident, it is necessary to evaluate the risk of combustion of the hydrogen present in the containment. On the basis of the temperature and pressure conditions in the containment, and hypotheses concerning the degree of degradation of the fuel, the HYDROMEL program provides the composition of the containment atmosphere, indicates whether there is a risk of combustion and provides, when applicable, the maximum pressure and temperature liable to be reached during combustion. HYDROMEL was qualified using the JERICHO code of the ESCADRE system.

Finally, the ongoing and potential releases of fission products, which depend on the state of the third barrier are estimated. For 900 MWe PWRs, the IPSN has developed an expert system called ALIBABA which, on the basis of containment isolation reports and activity readings in the different rooms and in the ventilation ducts, can be used to detect any leak paths. The extension of the validity range of ALIBABA to 1300 and 1450 MWe reactors is under development.

To complete this diagnosis of the state of the containment, it is necessary to describe the transfer of fission products within the installation and to compare the activity thus calculated with that measured in the accident-stricken installation. This calculation of the transfer of fission products is made using the PERSAN program. This covers four families of fission products: noble gases, iodines, caesiums and telluriums. For iodines, it makes allowance for the different physical and chemical forms (aerosols, molecular iodine and organic iodine). The fission product behaviour laws are derived from parametric studies conducted by the IPSN. The PERSAN program can also handle the prognosis side by entering hypotheses such as the eventual state of the fuel, the containment and certain system such as ventilation and containment spraying. It has been qualified using accident sequences covered with the ESCADRE system codes.

C. Use of the SESAME system in the event of a steam generator tube rupture (SGTR)

The initial diagnosis made with the assistance of the 3D/3P and REJETS-TYPES programs is essentially based on observation of the results of activity readings in the blowdown lines of the steam generators and the uncondensables extracted from the condenser. Evolution of pressures in the different steam generators and the reactor coolant system is of course used to confirm the diagnosis.

The number of tubes ruptured is evaluated using the BRECHEMETRE software. Conversely to the LOCA case, only evaluation based on variation of the water level in the pressurizer is available. Here, the mass balance principle is maintained, only the correlations used to obtain the size of the break from the flow rate at the break being different. Qualification was also carried out using the CATHARE code.
In the event of a SGTR, the «thermohydraulic» and «fission product transfer» aspects are closely linked. Thus, the experts in charge of handling the «thermohydraulic» and «containment» parts evaluate, in close collaboration, the release of fission products into the environment using the «RTGV» program. On the basis of, on the one hand, the thermohydraulic conditions determined from the readings transmitted by the accident-stricken unit and, on the other hand, hypotheses such the number of tubes ruptured, the RTGV program draws up mass and activity balances. It thus calculates the primary activity peak due to the transient, the transfer of fission products from the primary system to the secondary system, and the transfer of fission products from the secondary system to the environment. The thermohydraulic part was qualified with the SIPA version of the CATHARE code while the «fission product transfer» part was qualified using the steam generator tube rupture studies made using the AXEL code.

IV.2 DESCRIPTION OF THE CONRAD SYSTEM

The system CONRAD is mainly oriented to the prediction of the radiological consequences in the early phase of the accident for the short term counter-measures.

It is composed of a set of tools permitting the calculation of the concentrations in the air and on the ground, the doses and dose rates due to the release in the air of radionuclides. It includes :

- A database containing the characteristics of approximately 700 radioisotopes,

- A set of atmospheric dispersion methods, covering different spatial scales,

- A module for the calculation of doses by plume irradiation, contamination by inhalation to different organs and irradiation due to deposition,

- A geographic information system allowing the presentation of the results (curves of isoconcentration, isodoses,..) on maps.

The system can treat either isotopes or families of isotopes (noble gases, iodines, tellures,...) corresponding to the composition of a PWR core for different cooling times and burn-up.

The system runs on the computer network of the CTC; a simplified version of the system runs also on PC micro-computers. An automatic transmission of the results of SESAME into the CONRAD system has been established and permits direct calculations.

Figure 3: CONRAD utilisation in the IPSN emergency centre

Simple methods, adapted to the objectives and the needs of the early phase of a crisis situation, have been retained in the system CONRAD. They are all based on the Gaussian puff model using the Doury's standard deviations and, in the near future, the model recently developed in the framework of the French-German commission (DFK). They take into account the dry and wet deposition on the ground, the depletion of the pollutant and the radioactive decay. Different tools are used for local or long range predictions.

A. Local Scale

For the consequences at local scale (several km around the site), two main methods have been developed.

A.1 Operational Graphs

During the early phase of the accident, the main objective is to determine the zones where short-term countermeasures have to be taken. Both a prediction of the source term and the forecast of the local weather are required[1]. In the context of such a situation, characterised by large uncertainties in the input data, a simple tool, named ABAQUES, consisting of pre-calculated graphs, giving values of atmospheric and surface transfer coefficients, has been adopted.

These graphs permit the calculation of the doses and dose rates as a function of time. They are drawn for several classes of meteorological conditions (combining the atmospheric stability, the wind velocity, and precipitations) and are suitable for gases or aerosols.

They take into account the uncertainty on the forecast of the local wind direction. For simple sites (without significant topographic effect), this uncertainty has been estimated to be ± 15°. In fact, later studies conducted by the French meteorological office have shown that it may be higher: the tests performed on some of the French nuclear sites have shown that the prediction could be done with an uncertainty of ± 30° with a confidence level lower than 70 percent on rather complex terrains. Therefore, specific adaptations of the graphs for such sites (complex terrain) have been brought. They consist in an increase of the angle of the sector which may be reached by the plume. This increase has been evaluated, site by site, according to studies performed on the site itself or to the expert judgement.

A.2 Gaussian Puff Model SIROCCO

The second method consists in a Gaussian puff model, called SIROCCO. The code used in the short scale is named SIROCCO-CD. All types of release kinetics and of meteorological conditions, eventually varying in time during the release, can be taken into account. The doses and dose rates, at different instants during and after the plume passage, then calculated by CALDOS on a grid of some hundred to thousand points around the site, permitting the drawing of isocurves.

B. Long Range Transportation

For regional and long distances, the version SIROCCO-LD of the Gaussian puff model has been developed. In this model, the puffs travel along trajectories considered as the locations of the mass centres of pollution. The trajectories are derived from the forecast or the analysed wind field calculated by the French Meteorological Office. The time interval between two trajectories is one hour. The concentrations and doses are computed, for each point of a grid of maximum 160 x 160 points. A version with a smaller mesh size for regional problem is also available.

C. Doses estimations

The impact on the population and on the environment of the atmospheric dispersion results (volume activities and deposition) is calculated with the code CALDOS, which evaluate the

[1] The weather forecast is given by the French Meteorological Office in the framework of an agreement with IPSN.

doses by external irradiation due to the plume and the deposition, as well as doses by inhalation for different populations. Dose coefficients are selected from ICRP71 or Federal Guidance.

V. TRAINING AND EXERCISES

The IPSN does not consider it necessary to form permanent teams of emergency specialists totally detached from other IPSN activities. Staff composing the teams are thus chosen from among all the IPSN's experts. They regularly undergo training in emergency situation management and participate in exercises organised by the government authorities, representing the best hands-on training.

In view of the specialities of each of the units, special sessions derived from a common basis are organised on the following items:
- phenomenology of severe accidents;
- context of an emergency;
- understanding of the missions, techniques and tools (paper and computer) available;
- hands-on experience.

Some one hundred IPSN staff have undergone such training and are ready to deal with an emergency situation on a PWR.

The entire system set in place by the IPSN to tackle an accident situation in a PWR, as well as those constituted by its actions described in the first section, has been regularly tested during exercises. These exercises are organised by the government authorities and involve the PWR plants 6 to 8 times. The latter are jointly prepared by IPSN and EDF specialists. The scenarios are established in view of the objective set, the resources and organisational structures involved, as well as the planned durations, on the basis of the results obtained with the computer codes - CATHARE or CATHARE/SIMU as well as ESCADRE - developed in France.

Two or three years after setting this structure in place within the IPSN, training sessions and exercises which have been organised have proved the overall consistency of the arrangements and their adequacy in terms of the objectives set. This system is continually improved (organisation, methodology, tools) taking advantage of feedback of the emergency exercises and could also be enhanced by applied to other nuclear installations.