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TRAINING IN MANAGEMENT AND ANALYSIS OF SEVERE ACCIDENTS

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TRAINING FOR OPERATORS AND PLANT MANAGEMENT

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INTRODUCTION

It is an evidence to say that training of nuclear power plants operating staff is something highly important for operational safety, either during normal operation or to be able to face incidental or accidental situations.

For many years, EDF has been making a lot of efforts to develop and to provide appropriate training to each of the different categories of personnel who participate in nuclear power plants operation and maintenance.

These efforts have led to a specific organization which involves both EDF's Nuclear and Fossil Generation Division and Personnel Division and which is in charge of the main following actions :

- elaboration of training plans (so-called "guide-plans") ;
- specification of training courses ;
- development of training methods, tools and material ;
- implementation of training ;
- organization of training experience to spotlight necessary a valuable improvements and modifications.

With regard to training related to incidents and accidents management, it is important, among others, to make the difference between training of personnel on shift (plant operating teams and safety engineers) and training of personnel who makes up the emergency response teams that would be called upon in the event of a nuclear accident.

Because of different origins, different backgrounds and especially different functions if an accident occurs on a unit, these two populations need completely different trainings.

In a very simplified manner personnel on shift has to operate the faulted unit by applying the appropriate emergency operating procedures or by performing the actions that decision making centers ask for. Members of emergency response teams have basically :

- to monitor the main safety parameters of the faulted unit ;
- to periodically make a diagnosis of the situation and a prognosis of its possible development (see previous presentations) ;
- to ask for complementary or ultimate actions if the situation is so degraded that emergency operating procedures are not sufficient to face it ;
- to supply information to Public Safety Authorities and to the media.

Moreover, for each of these two populations training has to be tailored to each of the sub-categories of personnel they include : on the one hand operators, shift supervisors, safety engineers and on the other hand, members of decision making centers or members of technical support centers.

The training that EDF provides to these two categories of personnel is presented separately in the following pages. In both cases, links between functions to be sustained and characteristics of the training are tried to be shown. In conclusion, general perspectives on training evolution in EDF are given.

1 - TRAINING FOR PERSONNEL ON SHIFT

1.1 - Operating teams

In plants in the 900 MWe series, the shift team, under the responsibility of the shift supervisor, is responsible for the operation of both units and the common facilities.

In plants in the 1300 MWe series, one shift team is assigned to each unit. The differences in design between the two series have meant that unit operation has been organised in two quite distinct manners : the number of functions and the definitions thereof remain the same but the number of personnel assigned to each function differs.

As an example, the shift team for two 900 MWe PWR units comprises :

. a shift supervisor, responsible at all times for unit operation, in normal operating conditions ;

. a deputy shift supervisor who assists the shift supervisor and is particularly responsible for all matters relating to blocking ;

. 4 operators, i.e. 2 per unit, who operate the units from the control rooms ;

. 4 operation technicians and 3 auxiliary operators (all of them also called field technicians) who are responsible for field operations (manual operations or decentralized controls) and inspection rounds in the units. They assist the operators. Certain operation technicians may be called on to work in the control room under the responsibility of an operator.

In the event of an incident or an accident occurring on its unit(s), the operating team has basically :

. to detect the occurrence of the event ;

. to call for the safety engineer ;

. to diagnose the event by using either alarm sheets or diagnosis diagram (DEC) or diagnosis procedure (AO) depending on the nature and the severity of the event ;

. to operate the plant by applying the appropriate procedure(s) :

- abnormal operating procedures ("I" procedures),
- emergency operating procedures ("A" procedures),
- beyond design basis procedures ("H" procedures),
- ultimate procedures ("U" procedures).

As it is done for all categories of personnel, the training provided to operating teams includes for main phases with a duration and content suitable to the profile and background of people concerned :

- Preliminary training, to familiarize new recruits with the EDF working environment and organization and to enhance awareness of safety, radiation protection, work organization, and quality assurance concerns.
- Basic technical training, to adapt new recruits and personnel transferred from conventional power plants to their new jobs. This training is theoretical and focused on understanding physical phenomena ; it provides a general view of the operation of a nuclear power plant unit, facilitates internal communication, and supplies a common language for everyone involved.
- Specific training that is, for operating teams, operation of the plant (mainly from the control room).
- Further training and retraining to maintain and enhance knowledge.

It is important to notice that in EDF, qualification personnel must be recognized by certification of each person's ability to perform the specified tasks and that this qualification is based on training, in addition to professional experience and expected ability to succeed in the position.

For operating teams, specific training, advanced training and retraining are provided on plant and in National Training Centers (see for example figure 1). The use of part-task simulators and full-scope simulators forms an important part of their training.

During the initial phase of operator training, these simulators help the trainees to better understand the physical phenomena at play in a plant unit under normal operating conditions. For learning how to handle possible incidents or accidents, they supplement the main training, provided at the nuclear power plant sites. The trainee operators come to take three different 10-day courses on full-scope simulators. The first course deals with reactor startup, particularly the phase concerning formation of the pressurizer bubble, load variations, and reactor shutdown. The second course familiarizes the trainees with operating incidents ; for this purpose, the instructor draws on a range of nearly 1 000 different incidents. The third course confronts the operator with out-of-limits conditions requiring the implementation of emergency procedures. An accident involving a steam generator tube failure is always included. The failures of electrical power sources are also taken into account.

The full-scope simulators also serve for annual operator retraining. They provide the possibility of placing an entire operating team in a realistic accident situation.

1.2 - Safety engineers

Since the beginning of the eighties, on each EDF's nuclear site there is a shift engineer, called safety engineer. In normal operating conditions, he ensures that the safety of the installations is kept at an acceptable level (for instance he verifies that technical specifications are correctly applied by the operating teams), and analyses potentially problematic events and significant incidents occurred on the plants.

In the event of an incident or an accident he is called for by the operating team of the faulted unit. As soon as he has come up in the control room, he has :

- to monitor the safety parameters ;
- if needed, to ask the team to perform complementary actions not already included in the emergency operating procedure they are applying (for instance isolation of a second ruptured steam generator in case of a steam generator tube rupture accident) ;
- if the situation is considerably degraded, to ask the team to apply an ultimate procedure (U1 or ECP7).

The training of safety engineers includes the training of operating teams (as described above).

Nota : At the present time about 50 % of safety engineers had in the past a position of shift supervisor.

Of course their training is much more deep and detailed with respect to safety bases, rules and principles. It covers different fields like :

- probabilistic safety assessments,
- fire security,
- periodic tests and technical specifications,
- quality concept and quality insurance,
- effluents, confinement,...

One of the aims of the training of safety engineers is to enable them to control any activity on the site which may have an impact on plants safety and to help operating teams in decision making and in self-training.

Finally training of safety engineers deals for an important part with the use of the permanent monitoring procedure SPI (SPE).

In the near future (1992-1993), shift supervisors will get more extended responsibilities for safety during normal operation and will receive the same training than the present safety engineers. For their part safety engineers might leave their on-shift position for an on-call position. However EDF has not yet taken any decision in that way.

1.3 - Training methods and tools

1.3.1 - General organization of training

The training of EDF's nuclear power plants personnel on-shift is defined in a set of guidelines (so-called "guide-plans") prepared at a National level. Plant managers use these guidelines to draft specific training plans comprising mardatory general actions and specific actions tailored to each person's knowledge and experience.

In liaison with training specialits and statutory organizations, they produce each year a Plant Training Plan as well as Individual Training Plans.

The Plant Training Plan is based on general orientations and requirements of the Nuclear and Fossil Generation Division. It defines the overall needs of the Plant for the next year. The Individual Training Plans comprises :

- essential training : related to the function and compulsory for qualification ;
- recommended training : not absolutely necessary but highly desirable ;
- desired training : desired by the employee and agreed by the management.

Depending on its nature, training is provided on plant or, most generally, in training centers.

EDF has a total of 19 occupational training centers managed by EDF's Personnel Division. Three of these centers are specialized in nuclear training and are equipped with simulators (see figure 2 and example given in appendix 1).

EDF's Nuclear and Fossil Generation Division itself has 15 smaller training facilities, all located near power plants. Lastly, in each plant, the supervisors normally in charge of managing the work teams provide customized training geared to local conditions.

1.3.2 - Teaching methods

The teaching method generally adopted is "participative", i.e., it involves constant dialogue between the instructor and the trainees, starting with the presentation of a real situation to be analyzed. The maximum number of trainees in a class is usually 12, but only 4 when the training is performed on plant equipment or on a simulator. Most instructors are experienced personnel from plant operating teams, who will subsequently return to their previous jobs, thus ensuring effective feedback of experience for everyone involved.

Extensive use is made of conventional audio-visual materials. Comprehensive teaching handbooks guide the instructors in their sessions and ensure consistency among the different decentralized training actions. Scale models of equipment and video cassettes are also employed.

Computer-aided teaching is always available in the power plants to maintain the knowledge of operating staff and the personnel in charge of PWR instrumentation and control maintenance. The equivalent of 500 hours of teaching is devoted to describing the plant systems, the operations, and the operating instructions, as well as to the analysis of routine operating incidents that have occurred in French or foreign power plants. Another package of approximately 50 hours duration provides basic information about automatic controls and deals with the instrumentation and control equipment. Other specific courses deal with radiation protection and valves.

1.3.3 - Simulators

The most impressive facilities used for training are the plant control simulators, which replicate nuclear power plant operational behaviour. They include :

- *3 simulators for teaching basic operating principles*, two for PWRs and one for gas-cooled reactors, developed by the French Atomic Energy Commission (CEA) for use in the early stages of learning plant operating techniques ;

- *22 function simulators*, which enable learning to understand certain main systems (for instance 8 simulators replicate the reactor chemical and volume control system) ;

- 9 full-scope PWR unit simulators (5 for 900 MWe class PWRs, 3 for 1300 MWe class PWRs and 1 for 1400 MWe class PWRs), installed at EDF's Bugey, Caen and Paluel training centers.

The main characteristics of these full-scope simulators are given in appendix 2.

In addition to these simulators, to improve the training of its personnel so as to better fit specific training needs, EDF has developd two other simulators.

The first one is a simulator for training operating personnel to deal with a steam generator tube rupture accident. It has been developed during the last three years. Series production is going on and all French nuclear power plants are being equipped with these simulators. An expert system called "Sepia" (Système d'Enseignement Par l'Intelligence Artificielle), developed by Framatome (the French reactors builder), is connected to each of these simulators. Sepia analyzes operator behaviour and makes appropriate observations to help optimize operating skills.

The second one is the SIPA simulator. This simulator is used to produce and study post-accident situations, thereby meeting two objectives :

- to improve the training given, to safety engineers in particular, in the field of thermohydraulic phenomena occurring during accidents ;

- to increase the possibilities for research, making it possible to validate the quality of design codes in an environment analogous to that of a power plant by applying operating procedures, thereby creating further possibilities for developing new design codes.

This simulator uses a powerful design code (CATHARE-SIMU) which makes it possible to operate the plant in real time when it is subjected to a great variety of accidents (eg primary system break of up to 12") ; pedagogical images are used to contain two-phase leaks into the primary system. At the present time, SIPA is under acceptance tests and begins to be operational for training purposes.

A paper describing the main characteristics of the SIPA simulator is given in appendix 3.

2 - TRAINING OF CRISIS CENTER MEMBERS

The emergency preparedness, the capacity of an organization to control *highly improbable situations* depends on members qualification and training, enhanced by various drills.

Implementation of the on-site emergency response plan involves the setting-up of a decision making center, 3 operational control centers and an analysis and reflection center :

- the Management Control Center (MCC)
- the Local Control Center (LCC)
- the Health Physics Control Center (HPCC)
- the Logistic Control Center (LGCC)
- the Local Crisis Team (LCT).

In case of radiological accident, the EDF national organization involves implementation of a decision making center and a reflection center :

- the National Management Control Center (NMCC)
- the National Crisis Team (NCT).

Some people are well acquainted with the problems to be dealt with either by virtue of the post they hold or through their training and professional experience.

This is notably the case for the staff of the LCC (Local Control Center) in charge of managing the damaged unit in the control room. These engineers have the same training than the safety engineers.

The staff of the other control centers and crisis teams is entirely competent in the field of nuclear operations but it is necessary to familiarize a part of them with situations they may have to meet with, and, to train another part of them with the methodology carrying out in case of accident.

Three categories of functions to be trained have been identified :

- the accident specialists in charge of making periodically the diagnosis of the situation and the prognosis of its probable development and asking for complementary or ultimate actions in case of very severe situation ;

- the dose assessment specialists in charge of determining the quantity of released (or to be released) activities and its consequences around the site according to the meteorological conditions ;

- the staff of management control centers in charge of the relationship with the public authorities, the on-site protectives actions and the information of the media.

Beyond the initial and continue training, the drills test the capacity of the organization to control a severe accident and to mitigate its consequences. Finally, the drills contribute to all emergency organization members qualification and training (on-shift and on-call people).

2.1 - Accident specialists

The accident specialists are members of the national and local crisis teams.

The national crisis team comprises four accident specialists out of nine persons. The rest of this team comprises a manager, a logistic technician, several specialists in the fields of containment, release and radiological assessments.

The local crisis team includes two accidents specialists out of four persons team.

These two teams have together :

- to give to local and national management control centers technical informations about the situation and its probable evolution,
- to realize periodically a diagnosis and a prognosis,
- to provide advises to the local control center about the long term behaviour of the damaged unit.

In order to carry out these missions, two fields of knowledges are necessary.

Firstly, these specialists must have a good knowledge of reactor operation and systems, emergency operating procedures. It is very often the case because of the background and the job of these engineers.

On the other hand, the severe accident intervention guide and the diagnosis and prognosis method for severe accident situation require a specific training.

Secondly, these categories of people have the capability of using the computer aids. The facilities of the national and local technical support centers include a safety panel terminal (KPS system) and a centralized information processing workstation (KIT system).

2.2 - Dose assessment specialists

The dose assessement specialists compose the Health Physics Control Center (HPCC) and a part of the National Crisis Team (NTC).

On-site, the Health Physics Control Center is in charge of centralization and interpretation of radiological and meteorological measurements. With these informations, it determines the diagnosis of the situation : the quantity of radioactive material released and according to the meteorological situation, the whole-body dose and the thyroid dose. This center also evaluates the prognosis, the forecasting of radioactive material released by means of precalculated dose for various core features and status conditions.

At headquarter, the dose assessment specialists of the National Crisis Team carry out the same work in the field of prognosis and check that the local evaluations are adequate.

Theses teams have to use different tools :

- graph calculation chart, nomograms or hand calculations,
- rapid dose assessment model micro-computer,
- centralized information processing workstation.

2.3 - Management control centers staff

On-site, the management control center is run by the plant management and his staff (around seven persons).

The National Control Center is led by the Senior Vice-President of Nuclear and Fossil Generation Division and his staff (around four persons).

Each of these two centers have their own responsabilities. The plant manager or his representative is in charge of the on-site decisions, maintaining or restoring the safety status of the damaged unit, protection of employees, and finally information of the local authorities and of the local media.

The national management control center is in charge of the national relationships.

Besides the manager qualification, the members of these two centers have the capability of understanding the technical informations provided by the operational center and the crisis teams. In order to inform the media, a spokeman is included in these centers but different people may be invited to speak with the media.

The heads of the national crisis team are put in the same category of qualifications.

2.4 - Training methods and tools

The training methods and tools have three purposes :

- to complete the knowlegde,
- to suggest a work methodology,
- to train and to coach the members.

Four training methods are used for performing these purposes : simulators, class room courses, information meetings and drills.

2.4.1 - Simulators

National courses are implemented in the training centers ; theses courses cover the accident management and the use of crisis centers facilities :

- The accident management information consists of several days of training with alternance of theoretical courses and use of full-scope simulator ; this information is given to the management control center staff.

- The safety panel and the centralized information processing are implemented like in the control room, in each crisis center. It is possible with these workstations to obtain all informations about the damaged unit ; but, for using these terminals, some training is required. It is the reason for which a special course, using a full-scope simulator, deals with this aspect. This course is provided to local and national crisis teams.

- Besides, the Framatome simulator, which has been designed for accident analysis, is used for training the national crisis team to specific accident.

2.4.2 - Classroom courses

The dose assessment specialists use in case of radiological accident, specific tools like calculation chart, monograms... A specific course involving all materials has been realized by the training centers in order to familiarize and to coach this kind of specialists.

The leaders of the site management control center have to familiarize with the problems that they will have to deal with. For this purpose, they attend a training course which describes the drills feedback, the dose assessment method and which simulates an accident with the different management control centers actions.

The leaders of the management control center and the spokeman attend a training course with journalists. They have to write some press releases according to an accident scenario, and to brief the simulated press. They are recorded with videocamera in order to assess the performances and to improve their press briefings.

2.4.3. - Technical information meetings

Some technical information meetings are organized for the national crisis team.

As an illustration, the following topics are covered :

- Severe accident intervention guide,
- Diagnosis and prognosis approach,
- Tool to evaluate reactor coolant system leakage rate,
- Tools to evaluate releases during the first period of an accident.

2.4.4 - Drills and exercices

The drills play a dual role. They test the capacity of the organization to control an emergency situation and they contribute to staff training and coaching.

Because of the number of people and the diversity of tasks involved, the different aspects of the organization must be tested separately before full-scope simulations are attemped. These considerations have led to the implementation of different categories of drills and exercises, organized at local or/and national levels.

At the local level, on- site, there are two main categories of exercises. The first covers mobilization drills which include two subgroups :

- Drills related to setting up the organization out of working hours, which provide a mean for checking the efficiency of the system installed for alerting staff at home and for assessing the time required for these preparation,
- Drills related to gathering plant personnel during working hours and possibly during refueling shutdowns. Such exercises consist in evacuating part of the plant, such as the reactor building or the nuclear auxiliary building, and gathering the personnel at predetermined assembly points. If necessary, all or part of the personnel are evacuated offsite. These drills enable on-site alarm networks to be tested and provide a mean for assessing time requirement for assembly of the personnel and the efficiency of the evacuation arrangements.

The second category of exercises concerns technical drills the aim of which is to test the efficiency of organization response to an accident situation. They are based on simulation of an accident affecting all or part of the crisis organization. There is a wide range of these drills. Their use depend on how the various constituents of the accident scenario are proportioned. This category includes both drills that may be limited to a single control center and those involving the entire organization.

At the local level, at least one drill of each type is performed yearly at each nuclear site ; a drill in setting up the emergency response plan, a drill in evacuating the controlled area, a personnel assembly exercise, and a technical drill requiring the participation of the entire site crisis organization. Futhermore, exercises in implementation of the public emergency response plan are organized at the initiative of the prefect.

At the national level, mobilization and technical drills are organized. EDF organizes technical drills involving the crisis organization of the nuclear site and the EDF national crisis organization. For these interactive drills, full-scope simulators are used. The local control center and local crisis team are transferred to the training center, telecom-linked to the control centers at the site concerned. The situations simulated are complex and cumulate several incidents and accidents, such as a nonisolable secondary pipe break, a steam generator tube rupture, and electrical power losses. Simulators are a mean for placing the team responsible for controlling the accident in situations close to real conditions. The aim is to restore the unit to a safe condition, with minimum release to the environment, while fully accomplishing all other aspects of the operator's task, including assessment of radiological consequences and communication of plant data. Each site participates in this type of drills every two years, which means that seven or eight drills have to be organized yearly.

The Safety Authority organizes two exercices per year involving the crisis organization of the operating utility (according to the procedures described) and the Safety Authority. These exercices usually take place in two successive stages. The first interactive stage is implemented by means of a simulator. The second stage is based on a predetermined scenario comprising a large number of failures designed to induce deteriorated situations. The purpose of the second stage is to assess the capability of the crisis team when dealing with sequences aimed at preventing core meltdown and limiting release to the environment. It is also used to test the efficiency of the team responsible for assessment of the radiological consequences.

Finally, the General Secretary of the Interministerial Committee for Nuclear Security organizes an exercise about every three years requiring the participation of the whole crisis organization of EDF and the public authorities. The scenario is based on a highly improbable situation leading inescapably to an extremely deteriorated condition and is intended to test the response of those in charge of protection of the environment and the security of the population. With a view to ensuring the efficiency of the information system, reporters may be associated with the exercise. The last full-scope exercise of that kind took place on june 14, 1990.

3 - SOME ECONOMICAL ELEMENTS

At the present time, the manpower in Nuclear and Fossil Generation Division is about 25 000 employees.

In 1990, as it already was in the previous years, about 7 % of total work hours was dedicated to training.

This corresponds to about 22 % of total wages and to about 40 kF/employee.

The current price of a full-scope simulator varies from 50 MF to approximately 80 MF depending on its specific features.

CONCLUSION

Over the last years, EDF has made a major effort to generate the necessary abilities for operating its nuclear power plants. The EDF's training system has broadly contributed to the succesful implementation of the French nuclear program.

The ultimate goal of training is professional competence, aimed at optimizing the quality and safety of plants and plants operation. This is consequently an area of constant development, drawing on the steady progresses achieved in all fields, wether they are technical or methodological. This is particularly the case with regard to accident management.

The extent of the effort and investment in training undertaken by EDF will not decrease in the future : improvement of operational safety will always be pertinent and a prime concern in EDF.

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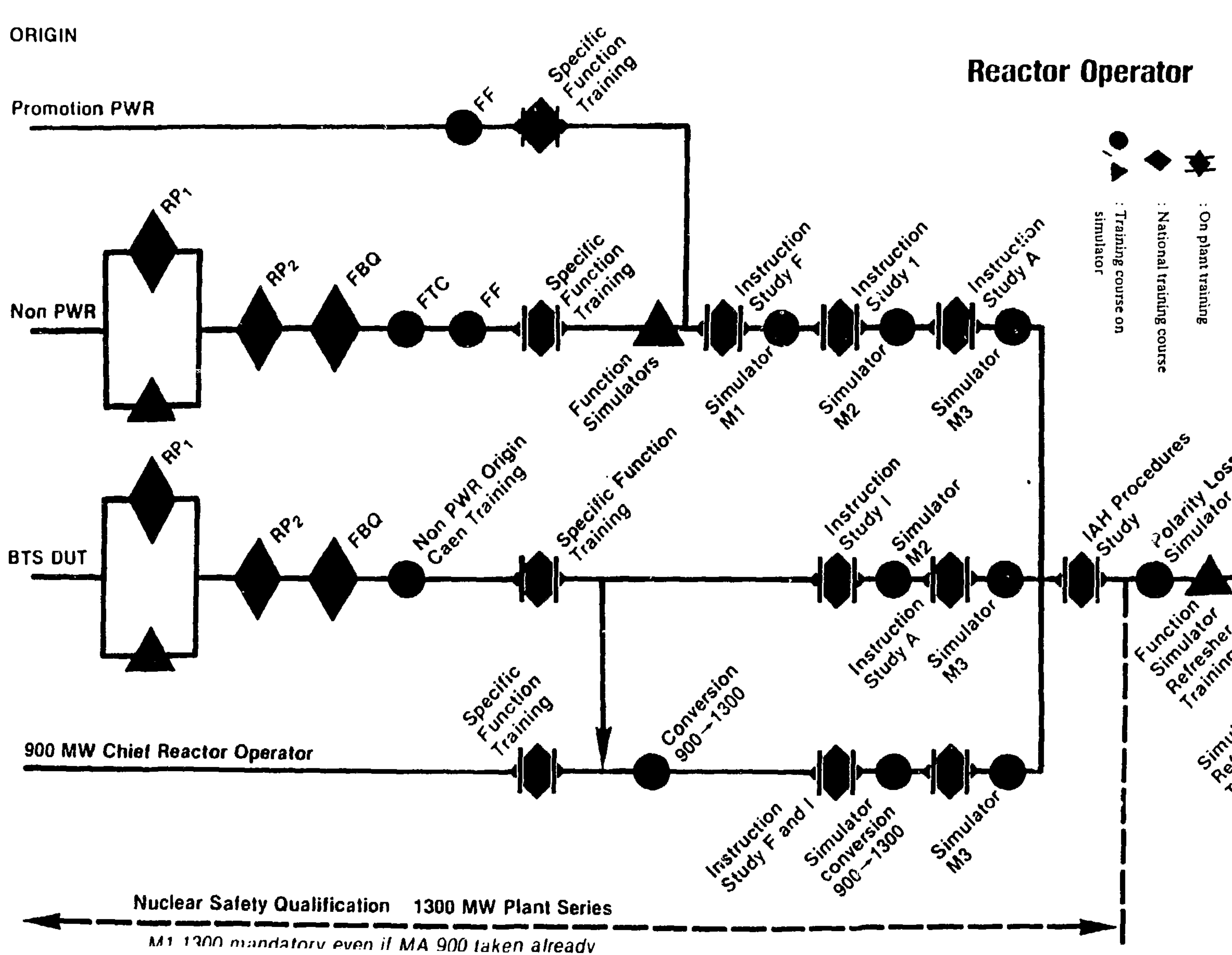


Figure 1
Guideline for reactor operator training

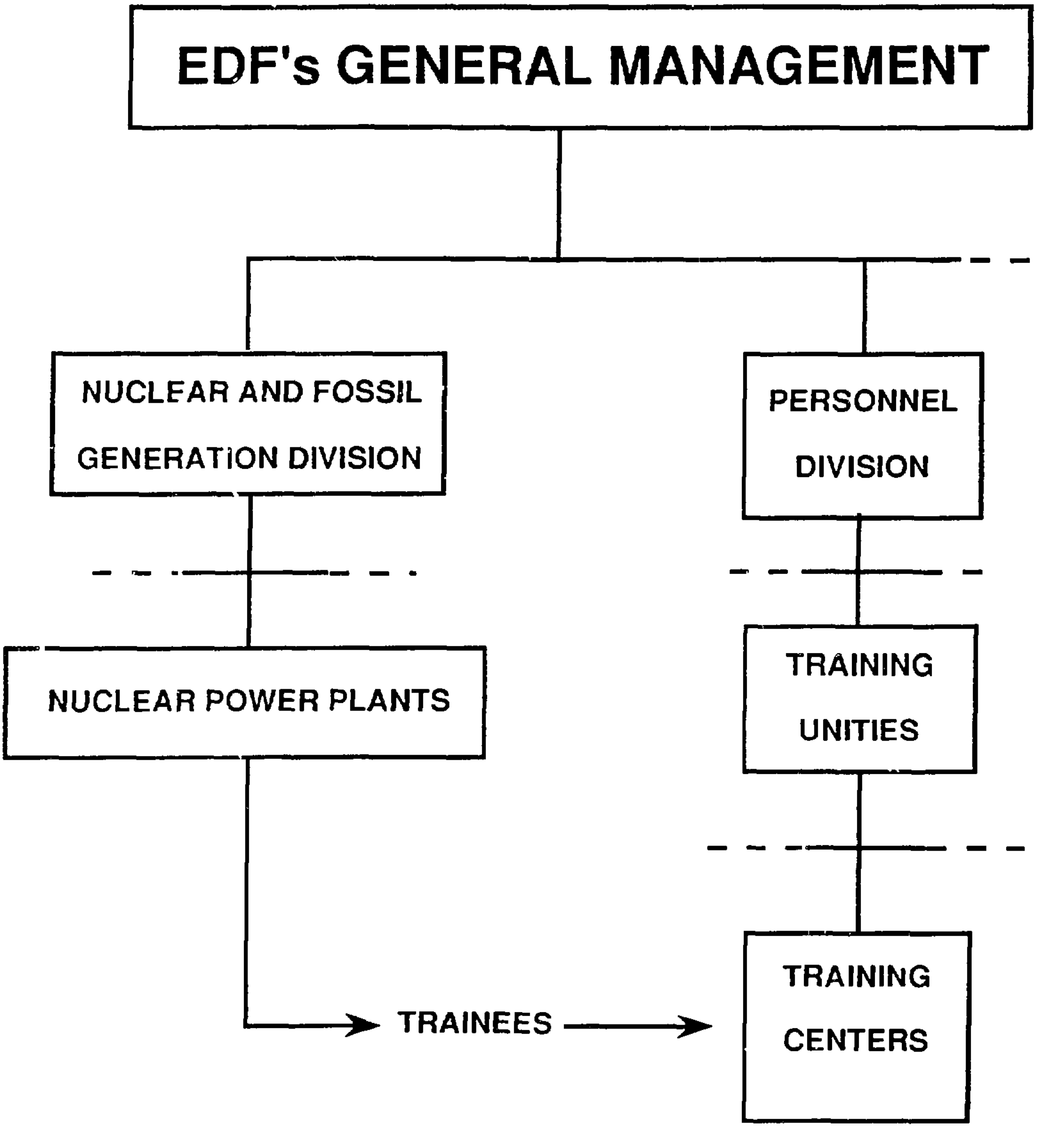


FIGURE 2

GENERAL ORGANIZATION OF TRAINING IN EDF

A P P E N D I X 1

The Bugey Training Center

It was decided to build the Bugey training center in 1974. The center was opened in 1978. Its purpose is to give both a theoretical and an on-the-job training to the people who operate P.W.R. plants.

It used to be the only nuclear training center. However two centres have been giving the same training in Caen and in Paluel since 1983.

The expansion of the center has been similar to that of the French Nuclear Programme. When it was created, the Bugey center employed 20 people and was equipped with one full scope simulator. Now, 120 people work in the Bugey training center. Moreover 5 full scope simulators and 3 function simulators are in operation.

Every year, 800 people come to the Bugey center to get a technical training and 1,400 people come and train on full scope simulators. This represents an 18,000 men.day training.

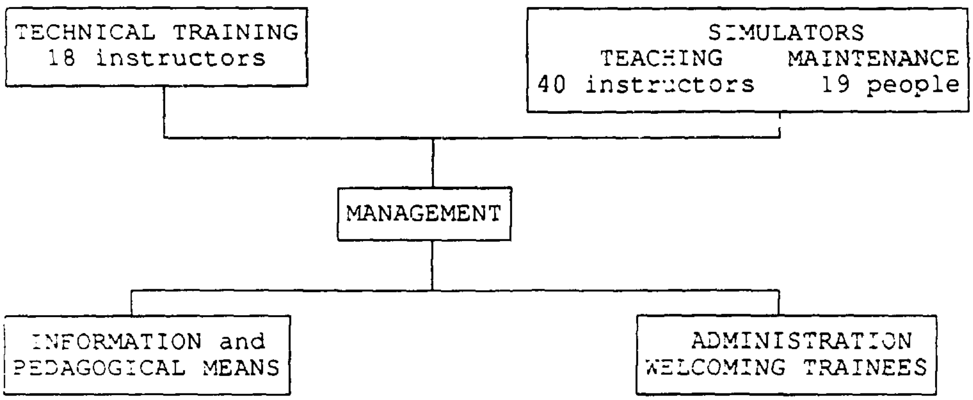
The training is intended not only for nuclear plant staff but also for people from the Construction division, the Engineering and Research division, the Energy Distribution division and from the French Atomic Energy Authority.

Until 1988, we played a part in the training of the staff of the Belgian Doel and Tihange nuclear plants.

The first team of the Koeberg South African plant was trained in our center.

Moreover we have been taking part in the training of operators and instructors from the Uljine Korean nuclear plant.

Organization chart of the Bugey Training Center



A P P E N D I X 2

Main characteristics of full-scope simulators

A. FULL-SCOPE SIMULATOR

A simulator is first of all a perfect replica of a nuclear plant control room. An operator training on a simulator should get the same perception as if he was in his own control room. Each of his actions has a direct effect on the workings of the system and reacts on indicators, recorders and mimic boards.

A simulator is made up of the following sets :

The control room

Like its real counterpart, the control room includes:

* **the control desk**. It includes the controls and the information that enable the operator to check up the most important parameters and to do the most common operating acts.

* **the rear board**. It includes in the first place the controls of the various auxiliaries that are used less often or are considered as less important and in the second place all the engineered safeguard systems of the facilities.

* **the back up panel**. It is not part of the control room as such and it is to be found apart. It includes all the controls needed to bring the unit back to a safe state when the control room is out of order.

The computers

To make this simulated control room work, the simulator is provided with a set of computers powerful enough to react, in real time and thanks to an elaborate mathematical modelling, like a real control room.

The interface

An interface is to_be found between the computers and the control room. First, it converts digital information from the computers into either analogical or on off information in the control room. Secondly and conversely, it enables the computer to take into account the information and actions asked by the operator in the ontrol room.

The instructor's desk

To be able to control the work done by the trainees in the control room or on the back up panel, the instructor can use another desk which is slighly behind the control room. Thanks to this desk, the instructor can control the parameters that are being studied and cause malfunctions or incidents. Several teaching methods can be used :

* **Starting the exercice.** The simulator is put automatically in a predetermined condition that is chosen amongst several others such as full capacity, cool shutdown, hot layup, limited capacity and so on.

* **Causing malfunctions.** The instructor has got a list of malfunctions such as clear and determined malfunctions or shift of parameters. He will choose some of them and will submit them to the trainees. There are different ways of causing malfunctions. For instance, malfunctions can occur at a particular moment or at a specific level of power during loading.

* **Stopping time.** The instructor can bring the facilities to a standstill at any time, i.e. he can stop the time so as to explain a particular phenomenon before carrying on the simulation.

* **Coming back on a sequence.** To make comments on a particular point, it is possible to go ten minutes back and have the extract played again. However the instructor does not intervene in that particular case.

* **Slow/accelerated motion.** It is possible to have a sequence played again but four times more slowly than in real time. It is also possible to have the film played eight times quicker so as to pass quickly over a part that has been well understood.

* **Local operations.** To reproduce at best the atmosphere in a real control room, the operator has to think about the orders he is going to give to auxiliary operators or to the people working on the facilities, for instance concerning a valve operation uncontrolled from the control room. In that case, the instructor operates with the instructor's desk. If the operator forgets something, the simulator takes into account the wrong position of the valve in question and the consequences appear in the control room (defective output for instance).

B. SIMULATOR INITIAL QUALITY

1 . THE CONTRACT

The construction specification show the principles and characteristics of the process simulation :

* the simulated field, that is to say the whole of the elementary systems and of the different operating situation ,

* the components and the phenomena that have to be calculated and not reproduced by repetition ,

* elements and phenomena that have to be considered as reference states (initialization) ,

* technical and bibliographic references..

As aconsequence of those specifications, the constructor must conceive an actual and accurately calculated simulation. He has got nothing but the characteristics of the components and of the fundamental physical data, especially in the field of neutronics and thermohydrolics.

He does not know the results of the actual tests or of the calculations for nuclear plant conception.

This situation guarantes to Electricité de France a full scope simulation and the means to check it during the validation phase.

2 . TECHNICAL REFERENCES

Electricité de France gives the constructor the data concerning the elementary systems to be simulated wich contain most of the technical references:

* role of the installation ,

* conception principles ,

* detailed description, nomenclature and characteristics of the components ,

* operating conditions ,

* instrumentation and control logical diagrams ,

* mechanical diagrams ,

* safety analysis ,

* bibliographic references.

3 . ACCURACY AND TOLERANCE

The performances expected from the simulation are specified in terms of maximum limit of the gap between the theoretical or actual value and the value calculated in identical conditions.

In continuous operating conditions set values must be accurate to ± 0.5 %. There should not be a difference of more than 1 % between the other parameters and the theoretical values.

In normal transient conditions the gaps must be inferior to 10 % and the tolerance on the time elapsed between the beginning of a transient ana the apparition of a parameter extremum is 20 % .

In exeptional transient conditions the gaps must be inferior to 20 % of the variation of the considered value. The tolerance on time being the same as for normal transients.

In all simulated transients, the curves must be identical to the ones noted on plant recorders.

4 . EXAMPLE : HOUSE LOAD OPERATION AT FULL POWER ON A 900 MWe CP 2 SIMULATOR

<u>Document of reference</u> : calculation of the manual house load operation at SAINT LAURENT B1 after comparing the BABEL code with an actual test carried out in this nuclear power plant.

<u>Test on identification of house load operation at full power</u>

<u>Aims</u> : compare the evolution of the main parameters given by the simulator along with the BABEL model data. Those data being themselves recalculated by the SEPTEN (1)from the results of the actual test carried out in the plant.

<u>Results</u> : the most significant recording of this test concern nuclear power and the position of the control rods, the inlet and outlet primary water temperature, the pressuriser level and pressure and the steam generator level.

<u>Conclusion</u> : during this important transient (so far as neutronics and thermohydrolics are concerned) the simulation is close to reality.

(1) SEPTEN = Nuclear and Thermal Engineering of the construction group of EDF

C. SIMULATORS EVOLUTION

1 . CAUSES OF THE EVOLUTION

Full scope simulators are paired with standardized reference units. Simulation must therefor evolve along with the modifications carried out in nuclear plants, so long as those modifications are in connection with the simulated field or the control room hardware itself.

But there also other causes of evolution, such as :

* the extension of the specifications concerning training on simulators, as for example taking into account the transfer of gaseous wasters by ventilation after a radio active incident in the confinement building,

* improvement of certain simulation models by incorporating technical progress made by constructors or the Nuclear and Thermal Engineering of EDF, as for example the generalization of a bi-phasis modelization,

* operation feed back and specific operation requirements,

* simulation anomalies recorded during the training sessions.

2 . ORGANISATION OF SIMULATORS MODIFICATIONS QUALITY ASSURANCE

So as to maintain and guarantee full scope simulators required quality level, Electricité de France has set up an organization that relies on the responsability of the different partners, on internal control and on the application of the quality organization handbook principles concerning simulator maintenance and training activities.

A commission of experts from the Administration Representative Standing groupe, check periodically theoretical and practical staff training conditions. After studying the surveys carried out by the Institute for health physics and nuclear safety (from the Atomic Energy Commission), the Standing Group express their recommandations to Electricité de France.

* **Nuclear training centres** paly permanently an active party in the evolution of the simulators and act as supplier to the Thermal Generating Division. Maintenance teams work according to a convention passed with the Thermal Generating Division. They act on thr authority of the T.G.D. for the following missions :

- participating to the reception of the simulators,

- correcting simulation anomalies with regard to the construction specifications,

- carrying minor modifications connected with the evolution of the reference units, which do not deeply affect the model,

- following up the integration of more important modifications entrusted to the constructor of the simulators,

- general surveys and propositions about simulators evolution according to the demands put forward by the instructors and to the remarks made by the trainees,

- preventive maintenance of the equipment,

- administration of reference documentation about simulators coming from corresponding units.

* **The constructor** has his own quality organization and guarantees that the training equipment (delivered or modified is in accordance with the contract passed with Electricité de France.

* **The Thermal Generating Division** is a customer of the training centres. A technical group in charge of simulation follow up, gathers twice a year with the T.G.D. and training centres representatives.

This group:

- analyses afterwards the work continuously carried out by training centres,

- analyses the surveys and requests about evolution put forward by training centres,

- decides on important interventions that have to be done and appoints responsible bodies.

The Thermal Generating Division internal nuclear inspection checks on quality organization in training centres.

D. THE S3C SIMULATOR

1. NEW CONTROL ROOMS

Over the past few years, it became obvious that the human factor had become more and more important in the way nuclear plants are operated. This led people to improve constantly the man/machine interface. The first consequence is the increasing use of ergonomics. The second consequence is the emergence of new and more complex processes demanding the use of computers in order to provide operators with elaborate information.

This is why the French Electricity Board decided to equip the new N4 units with fully computerized control rooms.

Such an organization of the control room demands new means of communication and new procedures. This is why it seemed important for us to create a simulator reproducing this new kind of control room.

The **new control room includes** :

- A **mural mimic board** giving an overall view of the unit.
- An **auxiliary panel**. It provides the control room with enough conventional means to ensure safety in the unit in the event of a computer breakdown.
- 3 **computerized desks** (2 operator workstations and one shift supervisor/safety engineer workstation).

  Each workstation includes :

  * 3 full graphic screens to visualize operation images
  * 3 semi graphic screens for alarms
  * Dialogue means :
    - 3 touch sensitive and monochrome screens
    - 2 keyboards for operating dialogues
    - 1 alpha digital keyboard
    - 1 tracker ball

2 . THE SIMULATOR

Aims

The S3C simulator was created to

- make sure that a P.W.R. unit can be operated from a computerized control room in normal, incidental or accidental conditions.

- define and elaborate the means of acquisition and control of the alphadigital and graphic data needed for such an operating system.

Structure

To avoid being forced to develop new patterns, it was decided to create the simulator in a computer room representing a unit "P.W.R.-1 300 MWe".

The computer (called SP) performs manual actions and deals with control and instrumentation of a unit "P.W.R.-1 300 MWe". It gives and receives from the computer (SC) the data coming from the control room. The SC computer fulfills the operators' job and processes data.

Creation

Three stages were necessary for the simulator to become operative :

First stage : judging operation in normal and accidental conditions.

Second stage : judging operation in normal, incidental and accidental conditions when computerized procedures are required. This stage took place in the first half of 1989.

Third stage : using the simulator to train operators from N4 units.

A P P E N D I X 3

The SIPA simulator

SIPA, A REAL TIME SYSTEM FOR POST-ACCIDENT TRAINING AND STUDIES

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The SIPA simulator, now under development, is designed to study in real time PWR behaviour under normal and accidental conditions. The commissioning of the version for EDF, called SIPA 1, and of the CEA version called SIPA 2 is planned in 1991. Its objectives are Shift Safety Advisors training, studies and safety analysis. Its software workshop will allow flexibility and portability. Most of the models are developed using code generators. The primary circuit is described by CATHARE-SIMU, a speeded-up version of the French advanced code CATHARE. It will be completed by about 35 connected systems developed by THOMSON-CSF and SEMA-GROUP. The computational power will be supplied by a CRAY processor that will be linked to a "training network" and an "engineering network" constituted of some independent workstations.

(keywords: Nuclear engineering, computer systems, thermal-hydraulics, real time simulation, interactivity)

1. INTRODUCTION

The French nuclear power plant programme has developed the PWR units since the seventies. Up to now 54 units have been placed into commercial operation. They represent a total power of 54 000 MWe.

There is only one architect-engineer and only one utility in France which are EDF, and only one group of manufacturers, mainly constituted with FRAMATOME, ALSTHOM, CEGELEC ... This organization has allowed a large standardization because all the units in operation or under construction belong to only 6 series, including the 900 MWe pre-series.

The unit number has permitted the development of a large research programme realized by EDF and CEA which includes codes like CATHARE* or experimental test loops like BETHSY**. The realization of SIPA benefits from 15 years of French efforts in the domain of reactor safety and training simulators (with the support of THOMSON-CSF Simulators Division).

* CATHARE : a Code for Analysis of Thermal-Hydraulics during an accident and for Reactor Safety Evaluation.

** BETHSY : the French integral test facility for PWR safety studies.

SIPA, designed for nuclear accidents, will be applied first of all in 1991 to the twenty eight 900 MWe/CP units and to the twenty 1300 MWe/P4 units.

2. OBJECTIVES OF SIPA

SIPA (in French : SImulateur Post-Accidentel) is an acronym chosen in 1981 for a real time "simulator" designed to study the behaviour of a PWR during normal operation, incidental and accidental conditions. Then, the notion of simulator has developed to an advanced multipurpose calculating system, essentially adaptable and evolutionary. That is the tool which is now under development.

It will be operated by EDF and CEA. The three main purposes of the use of SIPA are described below.

a) Training of the EDF/SPT (Nuclear and Fossil Generation Division) SSA (Shift Safety Advisors)

The training of the SSA (in French : ISR : *Ingénieur de Sûreté et Radioprotection*) and operating staffs during execution of crisis drills needs to well understand what could physically happen during incidental and accidental transients. To achieve this objective, the "simulator" must run in real time, have the best physical relevance and a clear visualization of the physical phenomena, mainly two-phase flow.

b) Studies for EDF/SEPTEN (Design Department for Thermal and Nuclear Projects)

The EDF/SEPTEN design studies require large scale reproduction of operating points and scenarios, Quality Assurance for models and data-packages, interactive capability for procedure finalization, availability of resources developed by specialists which can be used by engineers with a more general technical background and cooperative working practices for simulator configuration, creation of new models, simulation performances and result analysis.

c) Safety analysis for CEA/IPSN (Protection and Nuclear Safety Institute)

The safety analysis requirements include the actual safety analysis (analysis of the reactor systems, procedures, design basis accidents, probabilistic safety analysis, real incidents studies, reactor tests ...) the preparation and the execution of safety drills and the training of analyst engineers. The simulator has been decided in accordance with the French safety authority, the Central Service for the Safety of Nuclear Installations for which IPSN is a technical support.

3. THE SOFTWARE WORKSHOP AGLAE

SIPA simulator will be more than the representation of only one plant, it is a calculating system provided to model "à la carte" a PWR, a test loop or only a part of an installation. This is achieved through the use of a software workshop, called AGLAE (in french : Atelier de Génie Logiciel Adapté aux Etudes).

a) Objectives of the workshop

The main objectives of the software workshop in order to involve the flexibility of the SIPA tool are the modularity, the ability of extension of the models and the portability.

The modularity allows the replacement of any part of a model to put a more or less sophisticated description of a system or another, slightly different during a parametric study. For example, it will be possible to replace a single phase Residual Heat Removal System by a two-phase model, or during a study to test the profile and the location of different elements in a system.

The modularity leads naturally to the extension of the possibilities of the simulator.

This extension will be of three kinds : models, codes allowing the generation of other models and data-packages.

The need for new models to complete and improve the representation will be confirmed as the use of the simulator grows. For example, a neutronic three dimensional code could be added directly. Some ideas are envisaged now for the second step as mentioned in a later paragraph.

Large codes allow the generation of new system modelling. That is the case of LEGO, a very modular circuit description code and especially CATHARE 2, the newest version of the French advanced thermal-hydraulic code.

New data-packages will permit the study of new kinds of PWR with a design not too far from the existing one and experimental test loops. This implies on the one hand the adaptation of some circuits as aforesaid for the modularity and on the other hand the creation of the specific data-package adapted to the model.

In order to establish the possibility of including new models or codes without any adaptation, it has been necessary to write "SIPA standards".

They concern the languages used (FORTRAN, C, ADA ...), the variables characteristics, the identification (particularly names of routines, COMMON, etc.), the connections between modules or between software and man-machine interface system.

Another aim of the SIPA software including the organization of the whole tool is the portability on any kind of computing machines. To achieve this objective, the languages will be used in their most standard version as mentioned above. The standard tools (data bank, CAD, graphic software, ...) have been chosen under those used on most of the available work-stations, the operating system is UNIX and the different parts communicate with a standard protocol (TCP/IP).

All these conditions must be used in order to favour the development of the SIPA system according to the fut e needs of training, studies and safety analysis and the implementation of the software on most of the present and future hardware, taking into account the replacement of the computers or the development of a SIPA version for another customer than EDF or CEA.

b) Structure of the workshop

The simulator as a computing system will be made up of a certain number of modules (for example elementary systems). Each module will have several versions (more or less sophisticated, corresponding to different designs ...). To each version will be associated a data-package, a set of graphics (schematic drawings, curves ...) and a lot of activable failures.

The task of the AGLAE workshop is to allow the engineer to constitute an idiosyncratic representation of the plant. First of all, he choses the elementary modules which are linked together by the connection points. He has then to complete with the characteristics and the initial values of the variables in order to get the steady state conditions. The data are stored in a data-bank. Then he establishes the man-machine interface connections in order to generate operator actions and failures, get and display the results.

The structure of the workshop has been designed to manage the elements, the simulations constituted from these elements depending on whether they are either official and qualified models or private and test models.

c) Automatic code generators

Most of the models will be developed using code generators. This concerns the thermal hydraulic calculations (HYTHERNET generator) and the control models (CONTRONET generator).

After the analysis by the engineer, the circuit to be designed is seized by a computer aided design software and communicated to the automatic generation tools which deliver the source code in a standard FORTRAN language.

All connections of a model with other models or the man-machine interface will be set, as well as modifiable parameters and failures which will be activable during simulation.

4. MODELLING OF THE PLANT

For the first step of the project, two series of reactors will be described, the 900 MWe (3 loops) and 1300 MWe (4 loops) units.

In further steps, other representations of reactors will be available.

The first step of SIPA simulator contains the modelling of a PWR including the primary and secondary circuits and all the systems needed to describe the behaviour of the plant during an accident until the fuel becomes damaged.

a) CATHARE-SIMU

The reactor coolant system and the secondary system, until the steam header are described by CATHARE-SIMU, a speeded-up version of the French advanced thermal-hydraulic computer code CATHARE which has been developed by EDF and CEA, adapted to real time calculations and simulations uses, and with the same physical relevance.

It must be pointed out that CATHARE-SIMU uses the same physical laws and correlations as CATHARE with only some minor simplifications. This was considered the only way to be sure to maintain the level of physical relevance of CATHARE.

Since CATHARE-SIMU, like CATHARE, uses a numerical scheme with variable time step, two ways have been used to reduce the computing time:

- reduction of the time needed for an iteration,

- avoidance of short time steps.

The main modifications are the following :

- minor modifications in the equations : energy balance is written in the secondary form, momentum equations are written for the sum and difference of phases,

- suppression of ESOPE high level language (ESOPE is used in CATHARE to give full flexibility in circuit configuration),

- optimization of programming,

- limitation of nodalization (133 nodes for the reactor coolant system representation),

- suppression of all non physical discontinuities of variables and derivatives for a better convergence of the Newton's method (tables for water/steam properties replaced by polynomial approximations),

- optimization of treatment of "out-of-range" variables (e.g. iterations where void fraction becomes greater than one or lower than zero),

- modification of convergence criteria,

- improvements in the numerical analysis.

CATHARE-SIMU has been validated referring to CATHARE on 35 transient calculations. The validation of CATHARE itself, which is continuing at present, based on hundreds of transient calculations, has been supported up to now by a large experimental programme including results of the test loops LOBI, LOFT, ROSA 4, PKL and more recently BETHSY. The validation of CATHARE-SIMU have been performed in order to test not only the physical relevance of the modelling, but also the reliability of the computation.

b) Modelling of the 900 MWe and 1300 MWe units

SIPA includes also about 35 connected systems, particularly :

- the systems related to the primary circuit, as chemical and volume control, residual heat removal, reactor boron and water make-up, rod control, steam generator blowdown system ....,

- the secondary circuit with normal and emergency feedwater, turbine by-pass systems and a simplified model of the turbine-generator,

- the safeguard systems as safety injection, containment spray and emergency systems ....,

- the protection system,

- the instrumentation and the control needed for the application of the procedures,

- the actual plant unit status logging and safety panels systems,

- a simplified representation of the power distribution (6,6 kV and 380 V) in order to simulate loss of power, emergency supply ....,

- a modelling of the containment allowing to get temperature, pressure and, in the sump, level and temperature.

c) Physical domain

The physical range of situations goes from reactor in cold shutdown state with closed and degazed vessel (solid state) to normal full power operation and accidental conditions.

For the primary circuit, the physical representation is that of CATHARE-SIMU. The two-phase flow thermal-hydraulic calculations are made with a six equation model with homogeneous, stratified and counter-current two-phase flow, uncovering and reflood of the core.

It contains also the calculations of the amount of boron and of activity.

The physical domain contains particularly :

- breaks up to 12 inches in every point of the primary circuit in one or several loops (LOCA),

- steam pipe breaks,

- secondary feedwater pipe breaks,

- steam generator tubes ruptures (SGTR) up to 120 tubes in one or several steam generators,

- combination of SGTR with primary or secondary break,

- anticipated transients with or without trip.

All these accidents may be simulated in any condition of the reactor. Up to 9 breaks may simultaneously happen and any failure can be added to this accidental situation.

5. SIPA NETWORKS

a) Man-machine interface system

The man-machine interface system must be designed for all the uses of SIPA, that are training, studies and safety analysis.

For the training of SSA, it is not necessary to have the representation of an actual reactor control room, because the SSA during a possible accident has not to make any operation as the operators have to do. The task of SSA is, essentially to watch the most important parameters and if necessary to decide of the application of the ultimate procedure U1, which function is to prevent core degradation using an evaluation based on the core cooling states under accident conditions.

The SSA must have a well knowledge of the physical phenomena occurring during a transient or an accident to understand what would happen during a real crisis. The training of SSA must insist on the well understanding of the behaviour of the plant to help them to evolve "from the reflex to the reflexion". So, the man-machine interface must clearly illustrate this behaviour.

The trainee engineer needs all the control actions placed at operator's disposal and the instructor needs the possibility of introducing failures at any time during the simulation.

For studies and safety analyses, the way to use this tool is similar and the requirements for the man-machine interface are the same.

For these objectives the interactivity and the userfriendliness are very important improvements with respect to existing tools, particularly batch computer codes.

In these cases, the engineer has to analyze the behaviour of the plant during the studied transient. He must have the status of a system and the evolution versus time of the main parameters in front of his eyes and he has to introduce failures and operator actions at any time. Otherwise, when the transient is not longer interesting, he lets the calculation come back to an intermediate restart initialization and run again the calculation on another scenario.

In order to achieve all the objectives of training, studies and safety analyses, the man-machine interface is constituted of workstations using graphics software. They are able to display the outputs in the dynamic graphics format that is most meaningful for interpretation and interactive response. It is possible to have schematic drawings of systems, graph types like curves or bar graphes and texts (alarms of example). The graphical objects change in real time along the simulation and it is possible to intervene directly on some elements (for example on schematic drawings, in using menus and introducing commands, failures, etc.).

For training, the visualization of the thermal hydraulic behaviour, particularly two-phase flow, is displayed by a "pedagogic system" in real time. It represents a schematic drawing of the primary circuit including its elements (core, vessel, pipes, pumps, pressurizer, steam generators, etc). The values of the parameters are refreshed every second but the pictures like a cartoon, are refreshed each 0.1 second. They represent in every element of the circuit the status of the flow. For the two-phase flow, it includes the homogeneous flow using bubbles growing with the void fraction and moving function of the flow rate, the co- and counter-current stratified two-phase flow, the rise of steam bubbles in vessel and secondary side of steam generators, etc. The level of temperature of the fuel is represented by colors from light red for cold conditions to dark red for the hottest. Global picture displays the boron concentration. The "pedagogic system" is designed in order to illustrate in the most meaningful manner the thermal-hydraulic phenomena of the reactor.

b) Computing network

The schematic diagram of the SIPA network is represented on the figure below.

The SIPA simulator is designed to run in real time. This means that the calculations of the transient must run at the same speed as the possible real transient occurring in the plant.

This requirement determines the computational power needed.

The major part of the computing time is used by CATHARE-SIMU. The nominal time-step is 500 ms and it needs 100 ms as a minimum on a processor of CRAY X-MP.

The other parts of software (connected systems, control ...) need only a small part of the total computing time.

For all these reasons, it has been decided to use one processor of a CRAY "Super Computer". This computer which is not a strictly dedicated computer will be located in a computing center on another site than the simulator.

The link between the remote super-computer and the simulator will be a fast line (1 Mbit/s).

It realizes an ETHERNET deport using TCP/IP protocol. Another line of 64 kbits/s is provided for the batch use.

Taking into account the anticipated progress of the ratio computational power/price, it could be possible to replace later the remote Super Computer by a local computer, like a mini super computer.

On the site of the simulator, the line will arrive to the "scheduler computer" which will manage the communications between the simulator and the Super Computer and the time steps during the simulation.

A workstation SUN-SPARC 4-370 has been chosen for this function.

The "scheduler computer" is connected with:

- the "training network" which gathers all the hardware needed for the SSA training in the control room. This network will also be used in studies and safety analysis, particularly during simulations for which it is useful to have all the hardware available. This network contains :

. the "principal operating desk" made up of four workstations SUN SPARC 4-60 GX. On their displays will be set the schematic drawings, graphs, alarm texts. For all purposes, the management of the simulation including failures and operator actions is carried out from this desk. A server SUN SPARC 4-390, is used as data bank for the graphics,

. the "pedagogic system" constituted of two workstations SUN SPARC 4-60 GX which has been described above in the man-machine interface and another station which is dedicated to the instructor in order to introduce failures and other administrative actions,

. the "KIT, KPS, TCI network" linked by a conventional part interface. It is a replica of some systems existing in the plants : the safety panel and plant unit status logging system. It is used for training because SSA have to do with the same materials in the plants and during studies and safety analysis for giving complementary information to those provided by the "principal operating desk". The hardware is exactly the same as in the plants, i.e. Bull computers. This network is linked to the National Crisis Center to perform crisis drills.

- the "engineering network" constituted with the "engineering server" and some independent workstations. The server, a SUN SPARC 4-390, contains the data bank with the workshop software of the simulator, the models of the plant, the data-packages and the results of the simulations. Each workstation SUN SPARC 4-60 GX as in the "training network" can be used to prepare a simulation, to make some calculations but with only one display, to submit batches and to post-process the results.

Remote operating stations on the nuclear plant sites are envisaged in the future. They would be used for local personal training and be linked to the "training network".

6. DEVELOPMENT OF THE SIMULATOR

In the status of the realization of the simulator, one can distinguish the CATHARE-SIMU code previously developed, the first step under development and the second step the content of which has been defined and the realization started a few months ago.

CATHARE-SIMU has been developed by an EDF and CEA/IPSN team with the participation of THOMSON-CSF engineers. Up to now, it has also been used for batch calculations.

The first step of SIPA contains the following parts :

- all the elements designed for administration and management of SIPA, assembly and connection of the models, not only for the configurations planned for this step, but also software of AGLAE workshop in order to allow new models, codes and data-packages for the next steps,

- the three loops (900 MWe) and four loops (1300 MWe) plant configurations needed for the SSA training and the other purposes.

- the computing network and the hardware necessary to develop at least the two first steps.

The development of the software of the first step is achieved by THOMSON-CSF with the exception of the "KIT, KPS, TCI network" realized by SEMA-GROUP FRANCE.

The elements planned for the second step will complete the first one by means of :

- complementary physical descriptions as three dimensional neutronic calculation or detailed component cooling system,

- data-packages related to other plants series (N4, REP 2000 ...) or test loops (BETHSY),

- codes (CATHARE 2, LEGO),

- complementary pre and post-processing tools.

The second step has to be developed in collaboration with EDF and CEA/IPSN.

Two simulators will be installed, one called SIPA 1 for EDF (SPT and SEPTEN), the other for CEA/IPSN called SIPA 2.

SIPA 1 will be located on the site of EDF/SEPTEN near Lyon. It will run on a CRAY Super Computer of the computing center of EDF/DER, near Paris. It will be used for both training and studies and will be connected to the National Crisis Center for running crisis drills.

SIPA 2 will be installed in the Nuclear Research Center of Fontenay-aux-Roses and run on a CRAY Super Computer of the Nuclear Center of Saclay, both located near Paris. It will comprise the same elements as SIPA 1, without some specific devices dedicated to SSA training and without automatic code generators. It will be used for safety analysis and analyst engineer training and will be connected to the Technical Crisis Center of IPSN to run crisis drills.

The commissioning of both simulators is planned in 1991.

To date, commissioning of the software workshop is planned in july 1990. The pedagogic system runs, linked to CATHARE-SIMU. The test operating platform is in operation and the KKT network connection is planned in july 1990.

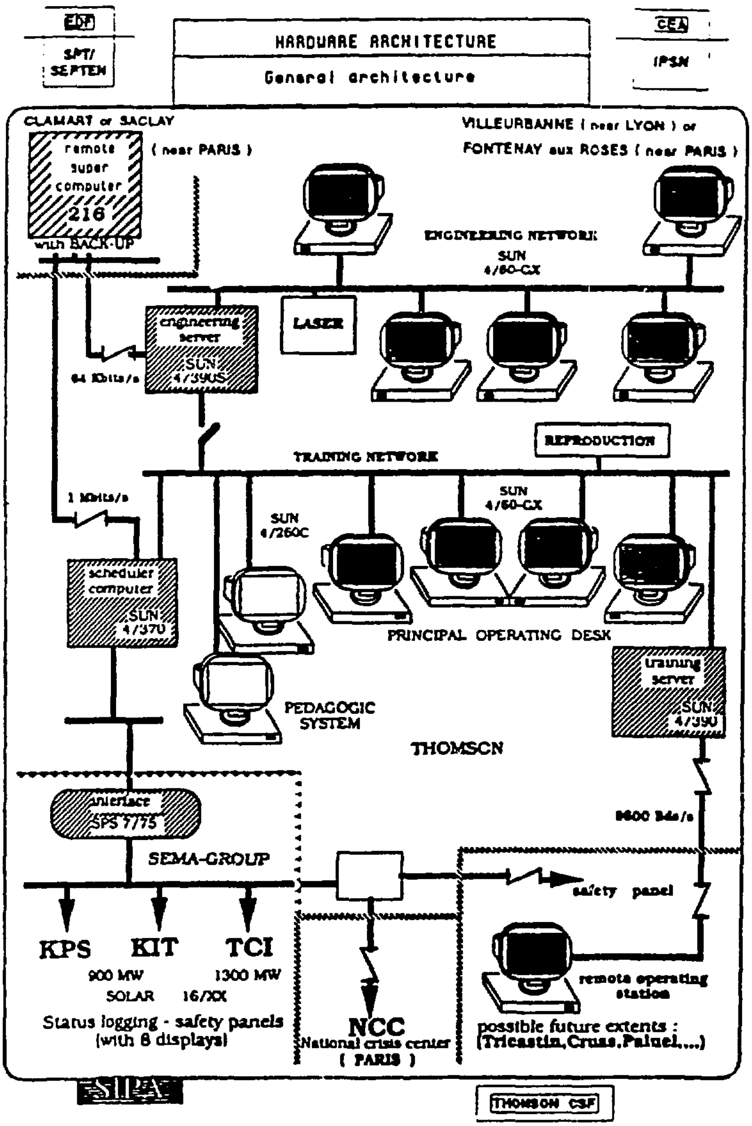
7. CONCLUSION

SIPA will be more than one simulator. It will be a computing system able to generate simulators adapted to any facilities (PWR or other type plant or test loops).

In addition to the advantages such as interactivity and results display of a simulator in comparison with other tools for the studies, it profits by a validated advanced thermal-hydraulic code. Its modularity and flexibility will allow it to be developed later. The software and data-packages of reactors and loops described will be adapted to the future needs of training, studies and safety analysis.

Its portability will make easier its

implementation on other computers in the future for SIPA 1 and SIPA 2 or for other customers than EDF and CEA/IPSN.



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Transparencies copies

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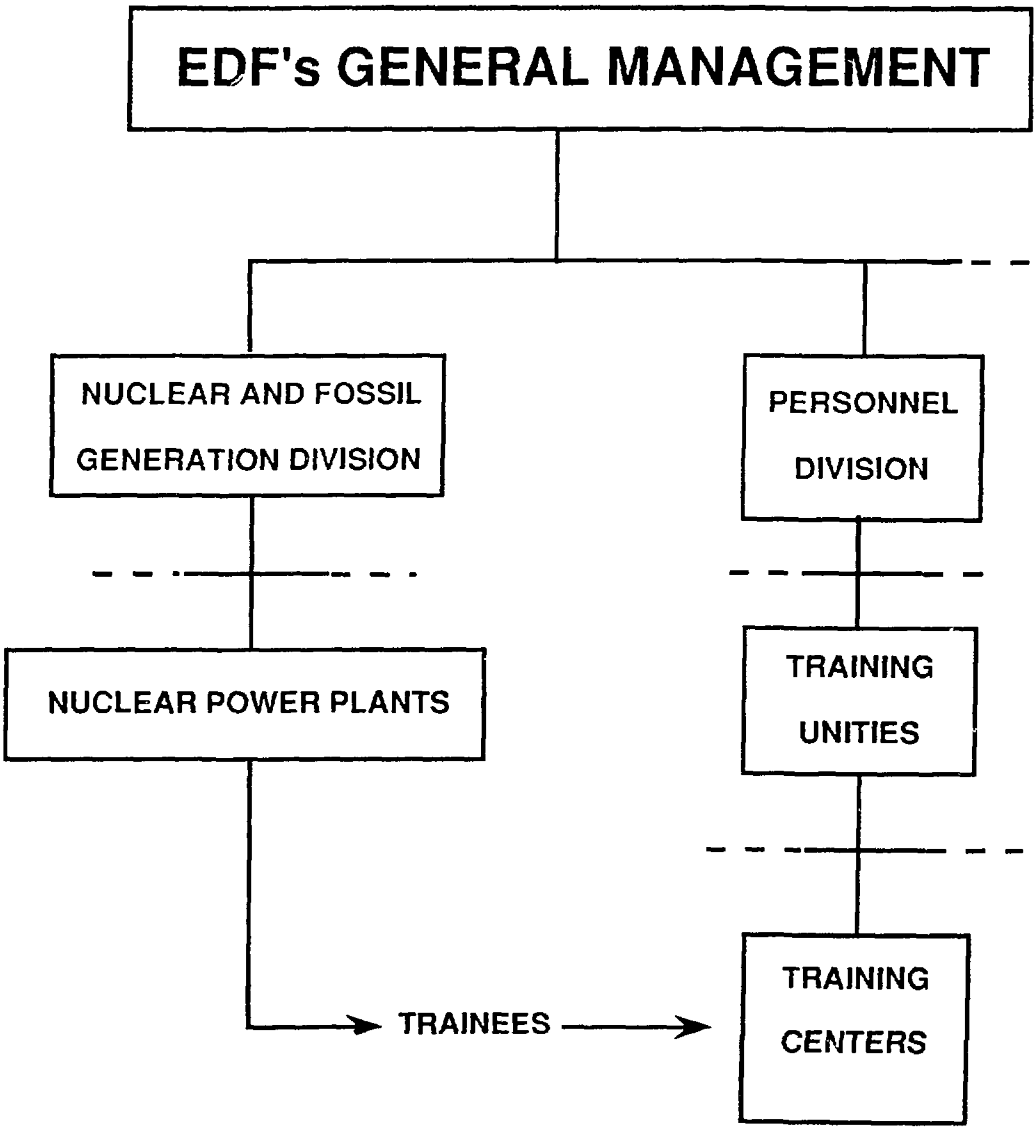

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  ./ 1 DEPUTY SHIFT SUPERVISOR (DSS)

  ./ 4 OPERATORS (OP), 2 PER UNIT

  ./ 4 OPERATION TECHNICIANS

  ./ 3 AUXILIARY OPERATORS

  (4 operation technicians + 3 auxiliary operators:) 7 "FIELD TECHNICIANS"

Note : The above-mentioned numbers of people do not take into account the additional personnel needed (and available) to face vacancies, illnesses, training, transfers...

TRAINING FOR OPERATING TEAMS (2)

- OPERATING TEAMS IN THE 1300 MWe PLANTS SERIES (SEPARATE UNITS)

  ./ 1 SHIFT SUPERVISOR (SS)

  ./ 1 DEPUTY SHIFT SUPERVISOR (DSS)

  ./ 2 OPERATORS (OP)

  ./ 5 FIELD TECHNICIANS

Note : The above-mentioned numbers of people do not take into account the additional personnel needed (and available) to face vacancies, illnesses, training transfers,...

TRAINING FOR OPERATING TEAMS (3)

- IF AN INCIDENT OR AN ACCIDENT OCCURS ON A UNIT, THE OPERATING TEAM HAS BASICALLY

  ./ TO DETECT THE OCCURRENCE OF THE EVENT (OP - IN MOST CASES OBVIOUS)

  ./ TO CALL FOR THE SAFETY ENGINEER (OP OR SS)

  ./ TO DIAGNOSE THE EVENT (OP AND SS)

    - ALARM SHEETS
    - DIAGNOSIS DIAGRAM (DEC)
    - DIAGNOSIS PROCEDURE (AO - LOI)

  AND TO SELECT THE APPROPRIATE PROCEDURE

  ./ DEPENDING ON THE NATURE AND ESPECIALLY THE SEVERITY OF THE ACCIDENT TO ALERT PLANT MANAGERS AND TO INITIATE THE MOBILIZATION OF EDF'S CRISIS ORGANIZATION (SS)

TRAINING FOR OPERATING TEAMS (4)

- TO OPERATE THE FAULTED UNIT BY APPLYING THE APPROPRIATE PROCEDURE(S) (WHOLE TEAM)

  ./ ABNORMAL PROCEDURES (I)

  ./ EMERGENCY PROCEDURES (A)

  ./ BEYOND DESIGN BASIS PROCEDURES (H)

  ./ ULTIMATE PROCEDURES (U)

  ./ STATE ORIENTED PROCEDURES (ECP - ECS)

- IF NEEDED TO PERFORM COMPLEMENTARY ACTIONS THAT EITHER SAFETY ENGINEER OR DECISION MAKING CENTERS ASK FOR

- TO OPERATE THE UNAFFECTED UNIT (900 MWe PLANTS SERIES)

TRAINING FOR OPERATING TEAMS (5)

- TRAINING IS DIVIDED INTO FOR MAIN PHASES

./ PRELIMINARY TRAINING ./ BASIC TECHNICAL TRAINING ./ SPECIFIC TRAINING	INITIAL TRAINING

./ ADVANCED TRAINING AND PERIODICAL RETRAINING

- EACH OF THESE PHASES HAS A DURATION AND A CONTENT ADAPTED TO THE PROFILE AND BACKGROUND OF PEOPLE CONCERNED

TRAINING FOR OPERATING TEAMS (6)

- **PRELIMINARY TRAINING**

  ./ TO FAMILIARIZE TRAINEES WITH THEIR WORKING ENVIRONMENT

  ./ GENERAL CONSIDERATIONS ON NUCLEAR SAFETY, RADIATION PROTECTION, WORK ORGANIZATION AND QUALITY INSURANCE

  ./ ESSENTIALLY CLASSROOM COURSES

  ./ TRAINING PROVIDED ON-PLANT AND THROUGH NATIONAL COURSES

TRAINING FOR OPERATING TEAMS (7)

- **BASIC TECHNICAL TRAINING**

  ./ TO ADAPT PEOPLE TO THEIR NEW JOB

  ./ THEORETICAL TRAINING FOCUSED ON

  - UNDERSTANDING OF PHYSICAL PHENOMENA (THERMOHYDRAULICS, NEUTRONICS,...)

  - GENERAL CONSIDERATIONS ON PLANT EQUIPMENT, SYSTEMS DESIGN AND OPERATION, REACTOR AND PLANT OPERATION

  ./ CLASSROOMS COURSES AND USE OF FUNCTION SIMULATORS (REACTOR CONTROL, TURBOGENERATOR, REACTOR CHEMICAL AND VOLUMETRIC CONTROL SYSTEM) AND FULL-SCOPE SIMULATORS[1]

  ./ TRAINING PROVIDED THROUGH NATIONAL COURSES MAINLY IN NATIONAL TRAINING CENTERS

  ./ DURATION : FROM 2 OR 3 WEEKS TO MORE THAN 15 WEEKS

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(1) ESSENTIALLY TO ILLUSTRATE PHYSICAL PHENOMENA

TRAINING FOR OPERATING TEAMS (8)

- SPECIFIC TRAINING (OPERATORS, SHIFT SUPERVISORS)

  ./ THEORETICAL AND PRACTICAL TRAINING TO PLANT OPERATION

  - NORMAL OPERATION
  - INCIDENTS
  - ACCIDENTS

  ./ TRAINING PROVIDED ON-PLANT AND IN NATIONAL TRAINING CENTERS (NATIONAL COURSES)

  ./ CLASSROOM COURSES AND USE OF FULL-SCOPE SIMULATORS

  ./ 3 MAIN 10-DAYS COURSES ON FULL-SCOPE SIMULATORS

  ./ FIRST 10-DAYS COURSE : NORMAL OPERATION

  - REACTOR/PLANT STARTUP, LOAD VARIATIONS, REACTOR/PLANT SHUTDOWN
  - INTERACTIONS BETWEEN SYSTEMS
  - LOGIC AND ANALOGIC INSTRUMENTATION AND CONTROL
  - USE OF G, F, S PROCEDURES

TRAINING FOR OPERATING TEAMS (9)

- **SECOND 10-DAYS COURSE : INCIDENTS**

  ./ MINOR INCIDENTS, LOAD TRANSIENTS, TURBINE TRIP, REACTOR TRIP

  ./ USE OF ALARM SHEETS AND SOME ABNORMAL PROCEDURES

- **THIRD 10-DAYS COURSE : ACCIDENTS**

  ./ SMALL AND LARGE LOCAs, STEAM GENERATOR TUBE RUPTURE, STEAMLINE BREAKS,... SWITCH TO EMERGENCY SHUTDOWN PANEL,...

  ./ USE OF DIAGNOSIS DIAGRAM (DEC) AND DIAGNOSIS PROCEDURE (AO - LOI)

  ./ USE OF ABNORMAL AND EMERGENCY PROCEDURES (I, A, H, ECP)

TRAINING FOR OPERATING TEAMS (10)

- ADVANCED TRAINING AND PERIODICAL RETRAINING

  ./ TO MAINTAIN AND ENHANCE KNOWLEDGE AS WELL AS PRACTICAL TRAINING

  ./ ADVANCED TRAINING

  - MAINLY DEALS WITH LOSSES OF ELECTRICAL SOURCES (DC AND AC POWER) AND COMPLEX SITUATIONS (CONCURRENT FAILURES AND/OR ACCIDENTS)

  - CLASSROOM COURSES AND USE OF FULL-SCOPE SIMULATORS

  ./ PERIODIC RETRAINING

  - ALL KINDS OF EMERGENCY SITUATIONS

  - AT LEAST ONE 5 DAYS REFRESHER COURSE ON SIMULATOR PER YEAR

  - RETRAINING OR "IN SITUATION" TRAINING (WHOLE TEAM)

TRAINING FOR SAFETY ENGINEERS (1)

- ON EACH EDF'S NUCLEAR SITE ONE SHIFT ENGINEER (CALLED SAFETY ENGINEER) SPECIALIST IN NUCLEAR SAFETY, QUALITY INSURANCE AND RADIATION PROTECTION

- DURING NORMAL OPERATION

  ./ ASSISTANCE TO OPERATIONAL PERSONNEL FOR ANY KIND OF PROBLEMS RELATED TO SAFETY - QUALITY INSURANCE

  ./ VERIFICATION THAT PLANTS SAFETY IS ALWAYS KEPT AT AN ACCEPTABLE LEVEL

  ./ ANALYSIS OF POTENTIALLY PROBLEMATIC EVENTS (PRECURSORS) AND SIGNIFICANT INCIDENTS

TRAINING FOR SAFETY ENGINEERS (2)

- IN THE EVENT OF AN INCIDENT OR AN ACCIDENT (REACTOR TRIP OR MORE SEVERE) THE ON-SHIFT SAFETY ENGINEER IS CALLED FOR BY THE OPERATING TEAM OF THE FAULTED UNIT AND HE APPLIES THE PERMANENT MONITORING PROCEDURE SPI (SPE)

  ./ MONITORING OF SAFETY PARAMETERS

  ./ IF NEEDED, REQUEST(S) FOR COMPLEMENTARY ACTIONS OR APPLICATION OF ULTIMATE PROCEDURE U1 (ECP7)

TRAINING FOR SAFETY ENGINEERS (3)

- TRAINING FOR SAFETY ENGINEERS INCLUDES TRAINING FOR OPERATING TEAMS

- MUCH MORE DEEP AND DETAILED WITH RESPECT TO SAFETY BASES, RULES AND PRINCIPLES

- COVERS MANY DIFFERENT FIELDS

  ./ QUALITY CONCEPT AND QUALITY INSURANCE

  ./ PROBABILISTIC SAFETY ASSESSMENTS

  ./ TECHNICAL SPECIFICATIONS

  ./ PERIODIC TESTS

  ./ FIRE SECURITY

  ./ EVENTS ANALYSIS METHODS

  ./ ...

TRAINING FOR SAFETY ENGINEERS (4)

- FOR AN IMPORTANT PART DEVOTED TO THE USE OF THE SPI (SPE) PROCEDURE :

  - ./ OBJECTIVES AND CONTENT OF THE SPI PROCEDURE
  - ./ RELEVANT THEORETICAL AND TECHNICAL BACKGROUND
  - ./ PRACTICAL USE OF THE SPI PROCEDURE AND CORRESPONDING COMPUTATIONAL AIDS (SAFETY PANEL,...)

- SPECIFIC TRAINING FOR SAFETY ENGINEERS PROVIDED IN NUCLEAR TRAINING CENTERS (NATIONAL COURSES)

- CLASSROOM COURSES AND USE OF FULL-SCOPE SIMULATORS

- DURATION DEPENDING ON THE ORIGIN OF SAFETY ENGINEERS

  - ./ STARTING ENGINEERS : 18 MONTHS ALTERNATIVELY ON-PLANT AND IN NATIONAL TRAINING CENTERS

  - ./ EXPERIENCED SHIFT SUPERVISORS : 7 WEEKS IN NUCLEAR TRAINING CENTERS

TRAINING METHODS AND TOOLS (1)

- SPECIFIC ORGANIZATION INVOLVING BOTH EDF'S NUCLEAR AND FOSSIL GENERATION DIVISION AND PERSONNEL DIVISION

- TRAINING FOR PERSONNEL ON-SHIFT DEFINED IN A SET OF GUIDELINES ("GUIDE-PLANS") PREPARED AT A NATIONAL LEVEL

- ONCE A YEAR PLANT MANAGERS PRODUCE

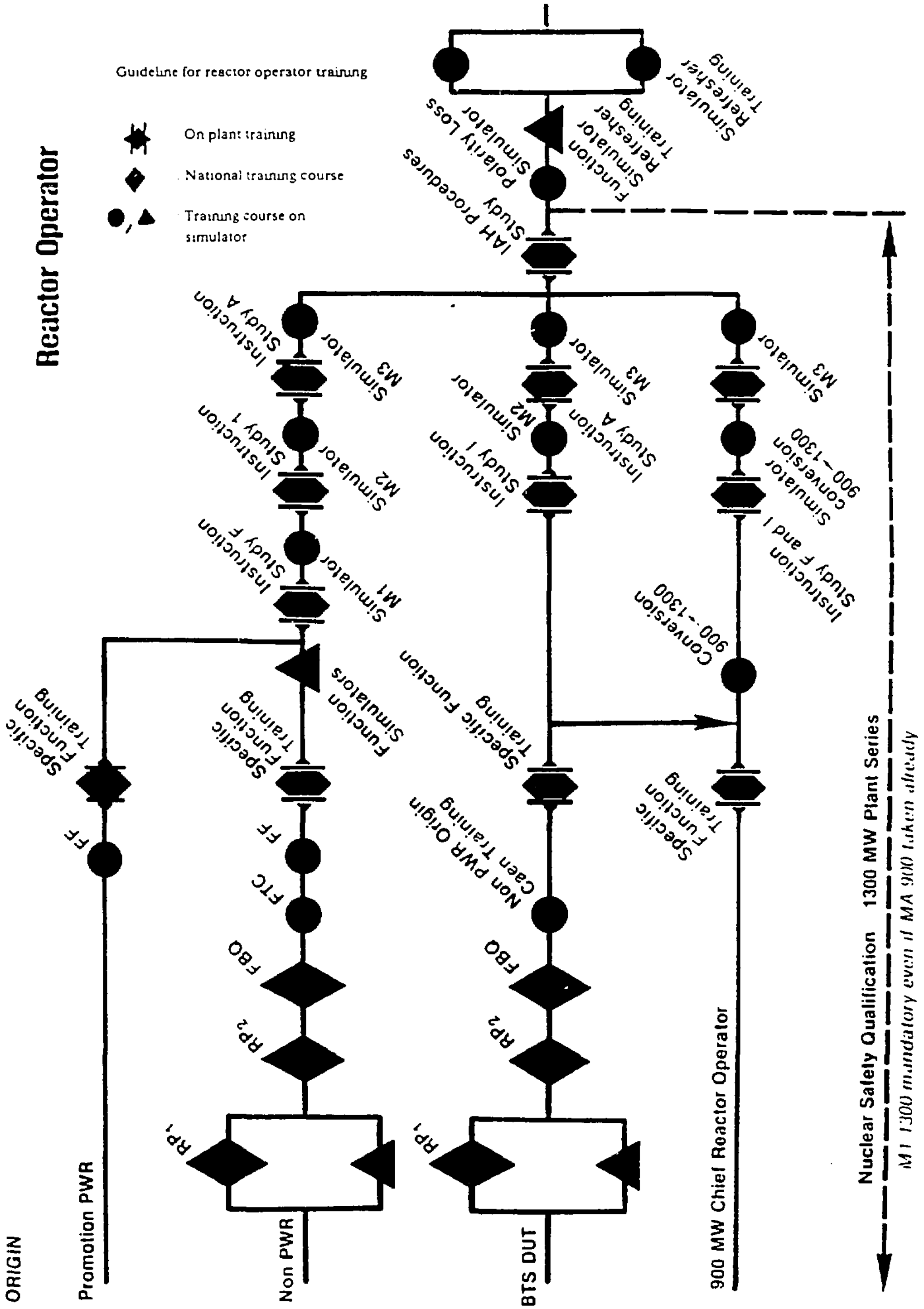
  ./ PLANT TRAINING PLANS

  ./ INDIVIDUAL TRAINING PLANS (ESSENTIAL/ RECOMMENDED/ DESIRED TRAINING)

- 19 TRAINING CENTERS MANAGED BY EDF'S PERSONNEL DIVISION (3 MAIN CENTERS SPECIALIZED IN NUCLEAR TRAINING)

- 15 TRAINING FACILITIES MANAGED BY EDF'S NUCLEAR AND FOSSIL GENERATION DIVISION

TRAINING METHODS AND TOOLS (2)



TRAINING METHODS AND TOOLS (3)

- TEACHING METHODS GENERALLY PARTICIPATIVE

- SMALL GROUPS OF TRAINEES : USUALLY 12, ONLY 4 WHEN USE OF FULL-SCOPE SIMULATORS

- EXTENSIVE USE OF CONVENTIONAL AUDIO-VISUAL MATERIALS

- COMPUTER-AIDED TEACHING AVAILABLE IN NPPs

TRAINING METHODS AND TOOLS (4)

- 3 SIMULATORS FOR TEACHING BASIC OPERATING PRINCIPLES

- 22 FUNCTION SIMULATORS

  ./ REACTOR CHEMICAL AND VOLUME CONTROL SYSTEM (8)
  ./ TURBOGENERATOR (7)
  ./ REACTOR CONTROL (7)

- 9 FULL-SCOPE SIMULATORS

  ./ 900 MWe PLANTS (5)
  ./ 1300 MWe PLANTS (3)
  ./ 1400 MWe PLANT (1)

- ON-PLANT SIMULATORS TO TRAIN PERSONNEL TO DEAL WITH STEAM GENERATOR TUBE RUPTURE (SEPIA)

- SIPA SIMULATOR UNDER DEVELOPMENT (CATHARE-SIMU CODE)

  ./ ADVANCED TRAINING
  ./ ACCIDENT STUDIES AND PROCEDURES DEVELOPMENT

ON-CALL PERSONNELS

TYPES	CENTERS	MISSIONS
ACCIDENTS SPECIALISTS	. Local Crisis Team . National Crisis Team	. DIAGNOSIS and PROGNOSIS . LONG TERM BEHAVIOR . MCC INFORMATION
DOSE ASSESSMENT SPECIALIST	. Health Physic Control Center . National Crisis Center	. RADIOACTIVE MATERIAL RELEASED EVALUATION . DOSE ASSESSMENT OFF-SITE AND ON-SITE . MCC INFORMATION
STAFF	. Management Control Center . National Management Control Center	. COORDINATION . DECISION - MAKING PEOPLES . INFORMATION AND LIAISON WITH OFF-SITE AUTHORITIES . MEDIAS INFORMATION

TRAINING

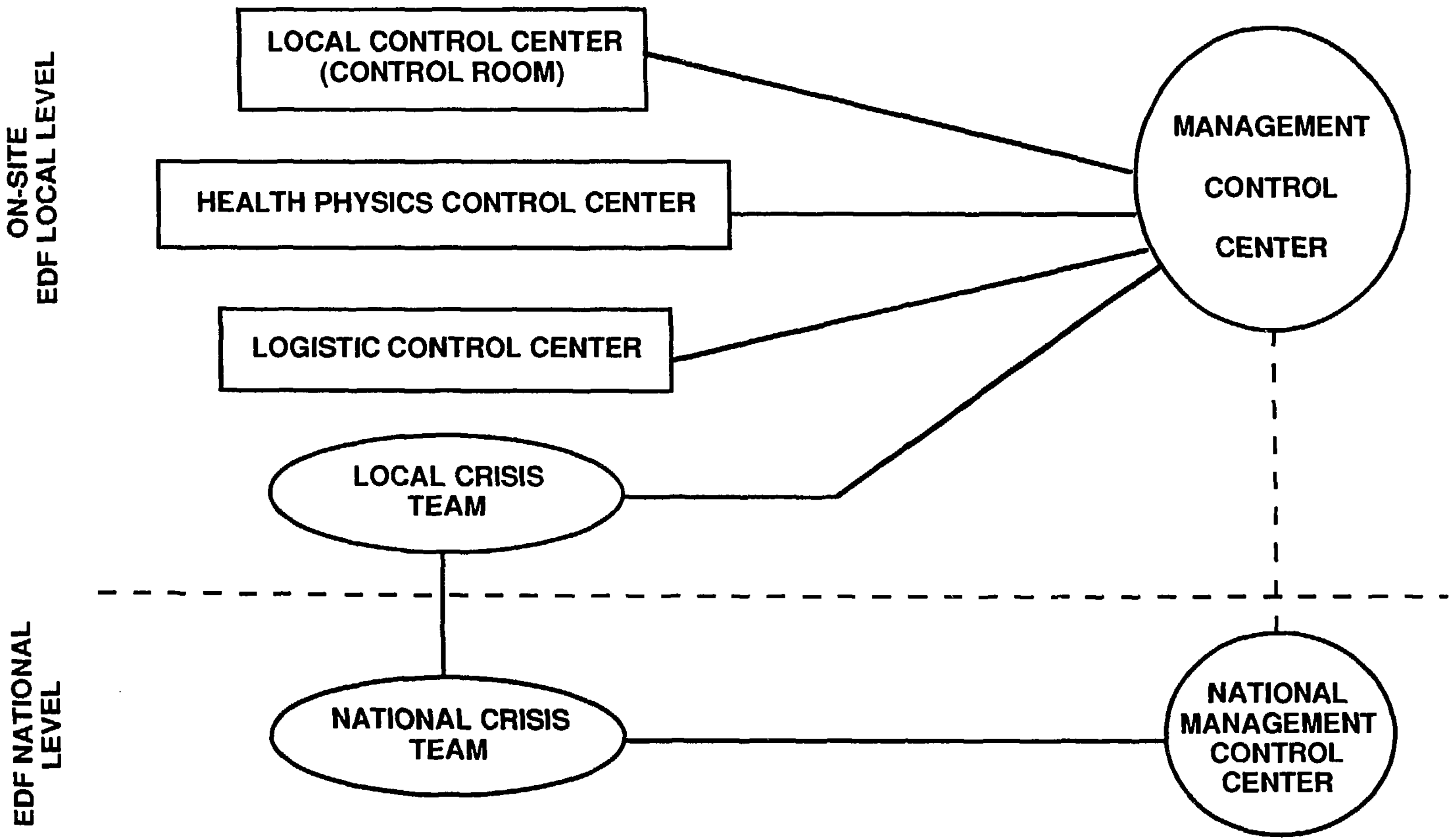
	TRAINING	TOOLS
ACCIDENTS SPECIALISTS	. ACCIDENT MANAGEMENT INFORMATION(*) . SAFETY PANEL AND CENTRALIZED INFORMATION PROCESSING(*) . SPECIFICS ACCIDENTS . SPECIFIC METHODS	. FULL SCOPE SIMULATOR . FULL SCOPE SIMULATOR . FRAMATOME SIMULATOR . MEETING WITH SPECIALISTS
DOSE ASSESSMENT SPECIALISTS	. DOSE ASSESSMENT METHODS(*) . SPECIFIC METHODS	. DOSE ASSESSMENT COURSES IN TRAINING CENTERS . MEETING WITH SPECIALISTS
STAFF	. ACCIDENT MANAGEMENT INFORMATION(*) . LEADER MANAGEMENT CONTROL CENTER COURSE . MEDIAS COMMUNICATION COURSE	. FULL SCOPE SIMULATOR . TRAINING WITH EMERGENCY SPECIALISTS . TRAINING WITH JOURNALISTS AND VIDEO CAMERA

(*) NATIONAL COURSES

DRILLS / EXERCICES

LOCAL LEVEL	. MOBILIZATION DRILLS . GROUPING PLANT PERSONNEL DRILLS . TECHNICALS DRILLS . ON-SITE AND OFF-SITE EXERCICES	1/YEARS/SITE 1/YEARS/SITE 1/YEARS/SITE ACCORDING TO AUTHORITIES
NATIONAL LEVEL	. MOBILIZATION DRILLS	2/YEARS/TEAM
LOCAL AND NATIONAL LEVEL	. NATIONAL EDF ORGANIZATION AND ON-SITE ERP DRILLS . EDF AND SAFETY AUTHORITY EXERCICES . EDF AND WHOLE MINISTRIES EXERCICES	1/ 2 YEARS/SITE 2/YEARS 1/ 3 YEARS

CRISIS CENTERS MEMBERS



SOME ECONOMICAL ELEMENTS

- EDF'S NUCLEAR AND FOSSIL GENERATION DIVISION MANPOWER

  ABOUT 25 000 EMPLOYEES

- IN 1990, 7 % OF TOTAL WORK HOURS DEDICATED TO TRAINING

  ./ 22 % OF TOTAL WAGES

  ./ 40 kF / EMPLOYEE

- CURRENT PRICE OF A FULL-SCOPE SIMULATOR : 50 - 80 MF

CONCLUSION

- IN THE PAST, EDF'S TRAINING SYSTEM BROADLY CONTRIBUTED TO THE SUCCESS OF THE FRENCH NUCLEAR PROGRAM

- TRAINING FUNDAMENTAL TO MAINTAIN AND IMPROVE OPERATIONAL SAFETY

- ALWAYS PERTINENT AND A PRIME CONCERN IN EDF