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Accident Management for PWRs
in France and Germany

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CONTENT

1. Introduction

2. Objectives and Significance of Accident Management

3. Relation between Accident Management and Emergency Planning

4. Accident Management Measures

5. General Approach for Development and Implementation of Accident Management

6. Comparison of Approaches

7. Further Work

1. INTRODUCTION

The results of risk analyses, research and particularly the two severe accidents in the nuclear power plants TMI-2 and Chemobyl let to a worldwide re-examination of all aspects dealing with the capability to cope with severe accidents. Strategies have been developed or are under development providing actions that can be taken to prevent severe accidents or to mitigate their consequences. Those strategies are investigated and discussed using the term "accident management".

The purpose of this report is to present the respective views in France and Germany and to point out differences and commonalities of the approaches. This report also includes proposals for further work.

2. OBJECTIVES AND SIGNIFICANCE OF ACCIDENT MANAGEMENT

The general safety objective for the operation of a nuclear power plant is to prevent the release of significant amounts of radioactive material into the environment. The achievement of this goal requires that important safety functions are adequately assured throughout normal and accidental situations. The maintenance of the safety functions is normally supplied through use of safety systems that are automatically activated. The basis for designing the safety systems are postulated accidents which are well defined in their courses. These design basis accidents are defined in such a way that each of them is representative of a group of similar events; they constitute the representative loads for these groups of events for purposes of plant design. The efficiency and reliability of the safety systems to cope with these design basis accidents have to be demonstrated in detail during the licensing procedure. The design of the safety systems is focused on the prevention of core damage and the ensuring of the containment retention capability.

Irrespective of the precautions described above the consequences of complex failures of human or material origin, which have not been taken into account explicitly when designing the plant (events beyond the design basis, severe accidents), were and are still investigated within the scope of safety studies and reactor research in order to extend the "defence in depth" concept. Strategies to cope with those events have been developed, implementing a limited number of new systems and using in a flexible way existing systems, both safety systems and operational systems. This concept is named "accident management" and can be defined as follows:

"Accident management" includes all measures to prevent core damage and retain the core within the reactor vessel, maintain containment integrity and minimize off-site releases.

This definition includes a distinction between *prevention* and *mitigation* aspects:

(1) *Prevention* considers measures to avoid damage to the reactor core. Due to the relatively slow development from an initiating event to major core degradation there is in principle the possibility for the plant personnel to identify and diagnose the status of the plant and to restore safety related functions, e. g. by reactivating safety or operational or additional systems. These measures are considered to have priority over measures with mitigative character.

(2) *Mitigation* considers measures to control and minimize the consequences of core melt sequences. If measures to maintain sufficient core cooling and decay heat removal fail, core melt will start progressively. Even in this case measures to control and minimize the consequences can be initiated. The final goal is to avoid an uncontrolled and large release of fission products into the environment. This can be achieved by maintaining the integrity of the containment and by limiting release rates.

3. RELATION BETWEEN ACCIDENT MANAGEMENT AND EMERGENCY PLANNING

The link between accident management and emergency planning is developed in France and Germany; one of the major aims of accident management is to limit the consequences of severe accidents to the environment and minimize counter-measures which would have to be taken in the frame of emergency planning.

The crisis organisation in both countries is set up in the frame of emergency planning to protect the installations and the environment; an essential feature of this organisation is a coherent flow of information to provide the teams concerned with the data necessary for diagnosis and prognosis.

French point of view

In France, the crisis organisation is based on three emergency plans:

- the on-site emergency plan (in French: Plan d'Urgence Interne PUI), which is directed by the head of the nuclear installation concerned.
- the off-site emergency plan (in French: Plan Particulier d'Intervention PPI), which is directed by the civil authorities, i. e. the prefect of the département concerned, and the objective of which is to protect the population from the radiological effects of the accident.
- the post-accidental emergency plan (in French: Plan d'Action Post-Accidentel PPA), which is also directed by the prefect and whose objective is to allow the return to a normal life in the area affected by the accident.

There are two essential links between these emergency plans and accident management.

Firstly, the emergency plans are founded upon technical bases, whose most important point is the taking into account of a reference source term called S3.

Source term S3 can be shortly characterized as follows:

- delay before important release: one day after beginning of the accident.
- no direct leak path to environment (i.e, filtration before release).
- level of radioactive release: a few thousandths of core inventory for iodine and cesium.
- release time: from 24 to 48 h after beginning of the accident.

These characteristics make it possible to take measures (sheltering, evacuation, iodine tablets) for protection of population, which appears satisfactory with regard to CIPR 40 recommendations.

Thus by accident management everything is done to ensure radioactive release characteristics less severe than those of S3 source term (this is, for example, the objective of the U procedures).

Secondly, the methods used in accident management take into account the necessity for the civil authorities to have a minimal delay (approximately 12 hours) for practical application of measures concerning the protection of the population. This explains that:

- ultimate accident management procedures tend to delay as much as possible irreversible events such as, for example, loss of containment integrity;
- prognosis on the evolution of the accident situation and its consequences for the environment is an important task for the crisis teams.

German Point of View

In case of an emergency an adequate flow of information from the plant to the concerned authorities is required. The operator of a nuclear power plant has to inform the authority responsible for emergency preparedness when certain alarm levels are exceeded. There are two alarm levels specified:

- **pre-alert for off-site emergency response** should be given in case of a plant hazard state in the nuclear facility so early that the effect on the environment is nil or at least negligible with regard to the alert criteria. However, on the basis of the plant conditions it cannot be excluded that an emergency response will be required.
- **alert for off-site emergency response** is given if in case of an accident in a nuclear facility a dangerous release of radioactive materials to the environment was determined or is foreseeable.

Currently specific alert criteria are established. On this basis plant operators give recommendations to the authorities regarding pre-alert or alert depending on plant parameters. In addition criteria are defined regarding emissions and immissions. Accident management has the potential to limit those consequences of a severe accident which require emergency response measures to the nearer environment of the plant site. The need for evacuation can be minimized.

4. ACCIDENT MANAGEMENT MEASURES

4.1 Accident management procedures

To implement accident management measures it is necessary to develop specific procedures for the control room staff and respective guidance for the crisis teams.

Accident management procedures extend the safety-function-oriented approach into the area of design basis accidents. With this approach a broad range of conceivable failure combinations can be covered with a reasonably small number of procedures. As in the design range, preventive measures are given priority over mitigative measures. Their objective is to maintain core cooling in order to prevent core meltdown or at least to interrupt the core degradation process in time.

4.1.1 Structure of accident management procedures in Germany

The accident management procedures in Germany will be a part of a dedicated accident management manual, separated from the operating manual.

The accident management manual will contain a decision tree which will make it easy to choose measures corresponding to different plant states. This decision tree is oriented on safety functions.

The accident management manual only deals with measures to cope with phenomena in the beyond-design-basis range. It is a supplement to the safety-function-oriented (or state-oriented) section of the operating manual and thus is mainly structured on a safety-function-oriented basis.The aim is to provide accident management measures for all safety objectives; here, a restriction to the most efficient and most simple measures is advisable, to keep the manual easy to handle.

Some accident management measures are event-oriented and apply to specific scenarios. An example for this is the necessary reconnection to the grid after a large-scale failure of the general electricity supply.

The accident management manual only contains those regulations that are vital for the performance of the specified measures. It does not include regulations concerning the organisation of the technically responsible crisis team as these are already laid down in other manuals. The regulations vary between the utilities.

4.1.2 Structure of accident management procedures in France

The French accident management approach, as defined below, is made up of two levels. The first one concerns operating modes applied in the control room by the operators and the safety engineer, using appropriate emergency operating procedures. The second one deals with the accident management by the crisis team, on site and on the national level, based in principle on a specific document, the Guide for Severe Accident Management (GIAG).

a) Emergency Operating Procedure in Case of Beyond-Design-Basis Accident

The main characteristic of this emergency operating procedure's set is to propose to the operators a continuous response between prevention and mitigation actions in case of beyond design basis accident.

To start with, the operating feedback experience and the first results of reliability studies lead to take into account a complementary field of operation, corresponding to identified beyond design basis accidents. These new considered configurations result principally from the loss of frequently actuated redundant systems. Response to these accidents is provided on the one hand, when necessary, with additional means of mitigating and on the other hand within specific event-oriented operating procedures, called H procedures, worked out to cover such accidents:

H1 operating procedure dealing with total loss of heat sink or of the systems ensuring heat transfer to it,

H2 operating procedure dealing with total loss of steam generator feedwater,

H3 operating procedure dealing with total loss of emergency power supply,

H4 operating procedure dealing with total loss of low pressure safety injection or containment spray systems,

H5 operating procedure dealing with floods exceeding the reference level.

Secondly, always within the framework of the core meltdown prevention, a new type of emergency operating procedures, so-called SPI/U1, would be implemented in order to cover the event-oriented procedure insufficiencies in case of complex events (multiple equipment failures, combined or not with operator errors, progressive degradations,...). Both form part of the state-oriented approach which is based on the characterization of every possible cooling state of the core and on the systems availability enquiring at the given moment. The first one, SPI, is committed to the safety engineer. It is a continuous after-accident monitoring procedure which permits continuous updating of the initial diagnosis and possibly, in case of insufficiency of the current emergency operating procedure, the retirement of this procedure by the operators and the adoption for applying of the U1 ultimate operating procedure, which is then used as a "back-marker" for event-oriented procedures. The aim of the U1 procedure is to prevent, limit or delay damage of the core and its radiological consequences, depending on the seriousness of the situation and the level of resources remaining available.

By another way, allowances for hypothetical severe accidents which are still called "operating conditions not deemed to be plausible" (i.e. very low occurrence probability events) in the French regulations are covered by "ultimate procedures". These need either particular operating procedures or management measures involving special preventive means taking into account the risks of a hypothetical severe accident (core meltdown involving rupture of the reactor vessel). Dispositions have been taken to preserve the monitoring of the safety function "containment" compatible with a good efficiency for the measure decided upon in the emergency plans.

Actions to be implemented by the operators in case of core meltdown are described, as far as NSSS is concerned, in the late phase of the U1 procedure. Entry into this procedure can only be decided by the safety engineer, according to SPI criteria. The other ultimate procedures or arrangements are described later.

Remark: Emergency operating procedures dealing with design basis accidents, which are still for the greatest part event-oriented procedures, will be progressively changed into state-oriented emergency operating procedures. These new procedures will include some H procedures, but accident management principles will not be affected. The continuity of the response will be improved even further.

b) Guide for Severe Accident Management

The second part of the accident management measures in France concerns the support to the operating crews brought by the local and national crisis teams. Indeed, in case of a severe accident, emergency management teams are constituted on site but also in national centers in order to bring expert assessments to the operators in the control room. Experts' reflection is then supported by a specific document, the Guide for Severe Accident Management (GIAG). This document is not an emergency operating procedure but rather a guidance allowing to handle the available information and to manage the simultaneous actuation of the different ultimate procedures or other actions according to the particularism of the situation.

The GIAG's objective is to define beforehand the specific actions that should be undertaken to assume the best possible confinement of radioactive products, as far as possible in order to:

- avoid or minimize outside release,
- save time for emergency action plans implementation,
- bring back the plant to a more controlable state.

The GIAG'S design principles result from the following assumptions:

- present available instrumentation is not sufficient for state-oriented procedures in case of severe accident management, so the GIAG's strategy is defined from a system/actions grid,
- choice of action takes into account the current phenomenology knowledge, but studies are still in progress.

The GIAG presents for each proposed action a justification by a set of arguments based on technical studies in order to notify the experts the different advantages and disadvantages of their choices according to the equipment availability and the environmental conditions.

4.2 Examples of Accident Management Measures

4.2.1 France

The so-called "ultimate procedures" were introduced in France after 1980; their general goal is to limit the potential consequences of a severe accident by restoring and reinforcing the role of the main containment building as the last barrier against the potential escape of fission products into the environment.

As different possible failure modes were considered, there are different ultimate procedures, already cited in this report:

- U2 = restoration of the containment leaktightness
- U3 = implementation of complementary mobile devices to prevent long-term core melt
- U4 = prevention of early releases during corium-concrete interaction
- U5 = prevention of containment failure due to slow pressurization, by the use of filtered venting.

The U3 and U5 procedures are further detailed below:

The U3 procedure mainly consists of implementing mobile connections and pumping devices to cope with long-term core cooling after a design basis accident. It implies the use of non-conventional circuit configuration - flexible connections between spray and low pressure injection circuits - to insure water injection into the core and removal of residual heat after a loss-of-coolant accident.

On the other hand, the U5 procedure is designed to limit the increase of the pressure in the containment below the design value in case of core melt; it mainly consists of a filtered venting device which can limit any slow increase of pressure in the containment below the design pressure while at the same time minimizing the fission products aerosol releases. The chosen device was a sand bed filter, which is now installed on all French PWRs; it was designed with regard to the following requirements:

- simplicity and passivity of the overall system, including manual initiation
- no interference with the normal function of the plant
- minimum time lapse of 24 hours before opening the filter
- minimal efficiency of 10 towards aerosols.

As this system is a complementary system designed to improve the safety of the plant in the hypothetical case of a severe accident, it has not the same qualification as the safety systems designed to cope with design basis accidents, i.e. it is not designed with the same redundancy and safety margins; on the other hand, it has to withstand on a realistic basis the conditions which would prevail under severe accident circumstances (temperature, pressure, dose rate, humidity...); the tests conducted at full scale have demonstrated the high efficiency of this device by realistic simulations of the thermohydraulics and physico-chemical loads to the filter in case of severe accident.

Concerning specific strategies like hydrogen mitigation, it is currently assumed in France that, due to the structural characteristics of the French containment buildings, there is for the time being no identified need to implement hydrogen counter-measures. Research actions are going on to evaluate more precisely some specific situations. There is no recommendation for the use of ignitors or recombiners, as early ignition is expected to occur at the time of vessel melt-through.

The emergency plans which are developed in France for the protection of the environment and the population are consistent in level and timing with source terms taking into account these ultimate procedures.

4.2.2 Germany

a) "Bleed and Feed" Measures

The results of German Risk Study, Phase B, for PWR's indicate that about 98% of the frequency of uncontrolled events (not coped with by safety systems) would lead to core melt under high pressure. Therefore special emphasis was laid on measures to depressurize the primary system. This can be achieved by secondary and primary side "bleed and feed" measures. The objectives of these measures are:

- restoring heat removal via steam generators by secondary depressurization and injection to maintain long-term core cooling
- re-establish sufficient core cooling by depressurization of the primary side and feeding with emergency core cooling systems
- if core melt is unavoidable, prevention of reactor vessel failure at high pressure by primary depressurization to maintain containment integrity.

The **secondary "bleed and feed"** measure consists of depressurization by opening the relief valves and use of the water content in the feedwater line and feedwater tank and maintaining long-term feed with mobile pumps. For better feed performance the pressure in the feedwater tank can be increased by loading the tank via an auxiliary steam line. The water volume available in the feedwater tank can maintain feedwater supply for approximately two hours. After that, or if the use of the feedwater tank has not been successful, feeding into the steam generators could be carried out with external pumps. For this, both on-site water supplies (demineralized water tanks, cooling tower ponds) and external water supplies (e.g. river, tank truck, drinking-water supplies) can be used.

Primary "bleed and feed" measures consist of opening the pressurizer valves (bleed) to release the residual heat into the containment and to enable feeding with safety injection pumps. In the long term the core can be cooled by operation of the low-pressure residual-heat-removal systems.

The "bleed and feed" measures will be initiated at very low water level at the secondary side. The secondary "bleed and feed" measure has to be performed with highest priority. Only if the necessary actions fail and certain plant states (e.g. low water level in the reactor pressure vessel or temperature at the core outlet greater than 400 °C) are reached then primary bleed has to be performed.

The secondary and primary "bleed and feed" measures require the following modifications:

- modifications in the reactor protection system to enable defeating interlocks or overriding protective trips
- modifications which permit a depressurization and feeding of the steam generators from the feedwater tank
- the installation of additional connections for mobile pumps to the emergency feedwater system
- the installation of a water level probe in the upper plenum of the reactor pressure vessel
- the design of the pressurizer valves and the associated control valves for water flow conditions.
- possibility for manual activation of pressurizer relief valves and the safety valves.

b) **Hydrogen Mitigation**

A great amount of hydrogen can be produced by the steam-metal reactions during the in-vessel core melt phase and by dry melt-concrete interaction later on. Late deflagration of large hydrogen masses may result in pressures exceeding the failure pressure of the containment. The objective of any H_2 counter-measure is to prevent H_2 concentration and to avoid loads due to hydrogen burning challenging the containment function. As one effective measure to keep the hydrogen concentration in the containment low, the approach of early ignition and combustion or recombination of H_2 has been persued in detail.

Early ignition by ignitors requiring no external power supply and the recombination of H_2 by catalytic devices are currently under investigation. A combination of deliberate ignition and catalytic recombination is under discussion in Germany. This concept could have the following advantages:

- in case of limited H_2-release burning could be prevented
- continuous H_2-recombination could occur even at high steam content
- early H_2-burn would take place in case of fast increase of H_2-concentration
- long-term H_2-recombination could account for radiolysis of sump water.

The final concept will be expected in early 1992.

c) **Containment Venting**

The objective of this mitigation measure is, as it is the case in France, to prevent overpressurization of the containment and subsequent uncontrolled release of fission products.

The energy and mass releases into the containment after core melt result in a continuous pressure increase. In case of melt contact with sumpwater the design pressure of the containment can be reached after about four days in the German reference case. To maintain containment integrity a filtered venting system was installed to reduce the pressure and to limit off-site releases. The pressure relief system is designed to keep the pressure below the test pressure of the containment and to depressurize the containment to half of the design pressure within two days. This can only be achieved by water injection into the containment sump to reduce flashing of sump water.

As filter units deep bed fiber filters with additional filter device for elemental iodine (molecular screen) or venturi scrubbers have been chosen. Both systems show a very high retention capability of >99,99% for aerosols. The venturi scrubber has in addition significant retention capability for elemental iodine (>99%) and for organic iodine as well.

5. GENERAL APPROACH FOR DEVELOPMENT AND IMPLEMENTATION OF ACCIDENT MANAGEMENT

Basic Principles

The following principles are applied for development and implementation of accident management procedures:

- The accident management measures should not impair plant operation under normal or upset conditions nor may they unacceptably interfere with existing procedures.
- Accident management measures take credit of all existing systems and equipment.
- The usual design criteria for safety systems, such as the single failure criterion, are not systematically applied.
- Accident management actions are in general considered as manual actions.
- Accident management measures may be initiated after a sufficient period of time essential for diagnosis and decision-making and preparation.
- It must be possible to interrupt the accident management measures at any time.
- Any necessary equipment for initiating accident management measures must be arranged in such a way that operator errors or inadvertant initiation during normal operating are avoided.
- Normally prohibited actions on safety-related systems (e.g. defeating interlocks, overriding protective trips) should be permissible under proper control.

The following topics address elements important for the development and implementation of accident management measures.

5.1 Technical Basis

A technical basis is under development to understand the plant behavior under severe accident conditions, to identify strategies, to investigate instrumentation and to assess the feasibility and effectiveness of accident management strategies before implementing procedures.

5.1.1 Methodological Considerations

The development of accident management in both countries must be based on some fundamental safety objectives. One way chosen by GRS to cover all possible plant states (including severe accident phenomena) is the development of safety objectives trees as a basis for the systematic evaluation of strategies and information needs. Safety objectives trees are considered as a broad approach and a systematic way to relate safety objectives to strategies using a hierarchical structure.

5.1.2 Plant Behavior under Severe Accident Conditions

It is necessary to understand the phenomena and "key"-responses of beyond-design-basis events, in particular during severe accidents, and to identify the vulnerabilities of the plant, challenges to safety functions and the mechanisms that cause the challenges. The assessment should be based on an analysis using best-estimate methods and should include all possible plant situations and operation modes. The analysis should be supplemented by input of PSAs, safety research, and investigation of operational experiences.

5.1.3 Identification of Accident Management Strategies

Based on known plant vulnerabilities and challenged safety functions, potential accident management strategies can be developed.

- The following safety objectives are considered:
  - prevention of core damage
  - retention of core in vessel

- prevention of containment failure
- limitation of fission product release.

To meet the predetermined safety objectives certain safety functions have to be maintained. During an accident the safety functions can be challenged due to different physical mechanisms. Then the appropriate strategy can be developed and selected and translated into safety function or state-oriented procedures.

5.1.4 Information Needs and Instrumentation

Effective accident management requires information needed by operating staff to

- diagnose the challenges to safety functions
- identify trends in accident progression
- select and initiate strategies and
- verify the effectiveness of strategies.

The capability of existing or potential measurements to supply the identified information in severe accident situations has to be assessed. Particularly the range and accuracy of instruments as well as the environmental qualification conditions and failure conditions have to be determined. Then it can be identified whether existing measurements supply the necessary information and which additional information or modifications are needed.

5.1.5 Feasibility and Effectiveness of Accident Management Strategies

Analyses with best-estimate codes are performed to assess the effectiveness of the accident management strategies and to answer questions with respect to minimum equipment requirements, timing of actions, influence of uncertainties and different plant conditions as well as adverse effects.

The feasibility assessment considers equipment and human performance under severe accident conditions and information availability. A further important aspect is the evaluation of the accessibility of equipment which has to be operated or repaired.

An examination is conducted to determine whether the equipment concerned can be assessed without exposing the plant staff to excessive radiation, temperature, etc.

For some accident management strategies, plant personnel must be allowed to deactivate functions of safety-related Instrumentation and Control (I&C). It will be assessed whether the actions can be performed in time and whether the administrative controls to prevent inadvertant execution are effective.

5.2 Development of Procedures and Guidance

On the basis of the technical assessment of strategies final procedures and guidelines are developed. The procedures in the prevention area are plant-specific while in the mitigation regime procedures or guidance could be more generic. The accident management procedures should be safety function- or state-based with few exceptions (e.g. ATWS, Station Blackout) because these events could be easily diagnosed. The interfaces of the new procedures with existing emergency operating procedures are carefully analyzed.

Integrating the large variety of information requires different skills and is done by a team with involvement of operating personnel to increase the acceptance of the procedures.

5.3 Validation

The procedures and guidance are validated from the point of view of technical accuracy, scope and function. Functional validation includes demonstration of the compatibility of the procedures with the control room lay-out and of the accessibility to rooms where actions have to be performed during severe accidents. Use of an interactive simulator with severe accident capability is useful. In view of the limitations of their capability to represent severe accident behavior, desk top validations on the basis of code results can be made, completed by plant walk-throughs. Training workshops with plant personnel including management deliver valuable feedback to the validation process. The validation considers the large uncertainties in understanding severe accidents and ensures that there is sufficient flexibility in the procedures to accommodate potential uncertainties.

5.4 Training

Since the success of accident management relies heavily on manual actions, training is of special importance to overcome the degradation of human performance during stressful situations and to reduce the potential for human errors. Therefore appropriate training requirements are determined to develop an integrated training program. Comprehensive training must be provided to plant personnel and management to ensure a common understanding of the concept and contents of procedures and guidance as well as of the roles and responsibilities of various personnel.

5.5 Accident-Management-related Investigations

France

The probabilistic safety studies which have been performed in France have examined a number of situations, including normal operation, hot and cold shut-down; the results of qualification programs and operational feedback have been taken into account.

This study has given highly valuable results on the probability of severe accidents in French type reactors; at the same time, considerable effort has been drawn to study both theoretically and experimentally a number of phenomena which were identified as the leading phenomena to determine the potential of radioactive releases into the environment:

- primary circuit depressurization in the case of secondary heat sink loss has been recognized as an effective prevention measure;

- the containment being the ultimate barrier against the escape of radioactive products, models have been developed to simulate the ultimate strength of the containment;
- correspondingly, various challenges to the containment, including slow or rapid pressure and temperature transients, have been studied;
- fission product aerosol behavior in the containment has been systematically parameterized as a function of initial release (quantity and duration), time ellapsed after that release, resuspension and condensation phenomena; this allows to estimate the potential releases as a function of containment leaktightness and, if needed, as a function of time and characteristics of filtered venting procedure;
- the efficiency of the filtering device implemented on plants has been experimentally quantified.

Finally, the source term S3, which has to be taken into account by the emergency plans, is derived from these studies.

Germany

The following investigations are related to accident management:

- German Risk Study
  (Bleed and feed, influence of accident management in terms of probabilities)
- Accident management investigations on behalf of BMU
  SR 461, SR 465
- Experimental work on H_2-ignitors, catalytic foils
- Filter experiments by SIEMENS and KfK

6. COMPARISON OF APPROACHES

From the above examination of accident management measures in both countries it is clear that the philosophy for AM, the approch, and even the implementation are very similar in both countries; only few differences may be found.

In both countries, the main goal is to minimize off-site counter-measures; in addition, France has a reference source term for AM and emergency planning definition.

In Germany, a separate Accident Management Manual has been implemented for complementary situations, describing possible unusual uses of existing systems and giving practical indications to the operating team; in France, the first response is provided by the H and U procedures which are in continuity with emergency operating procedures; in case of further degradation, local operating teams are assisted by national crisis teams, which rely themselves on the GIAG and diagnosis/prognosis tools.

Other types of technical differences arise from the different containment designs in both countries, for example hydrogen risk assessment.

Compared with the German "feed and bleed" procedure, the French H2 procedure gives priority to the primary feed and bleed in order to remove the residual heat via the pressurizer; the containment is then cooled by the internal spray system. Some delay is then available to restore secondary cooling systems.

The specifications of the French and German venting systems are different due to the choice of different design basis sequences and to different structural characteristics.

7. FURTHER WORK

More work has to be done in various fields:

- investigation of effectiveness and feasibility of strategies, especially of the use of existing systems and instrumentation outside the qualification range,

- finalization of specific manuals for complementary or ultimate situations in both countries,
- validation and training of procedures using simulators and test facilities,
- development of efficient crisis tools to predict the evolution of a crisis situation and give sufficient information to ensure the best possible protection of the population and the environment.

All these topics are or will be the subject of active work in both countries.