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THE ROLE OF HUMAN INTERVENTION IN THE PREVENTION AND MITIGATION OF SEVERE ACCIDENTS

Tabular Comparison of the Approaches Taken by Various Member Countries

Prepared by
CSNI PRINCIPAL WORKING GROUP No.5
TASK 3

JULY 1988

COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS
OECD NUCLEAR ENERGY AGENCY
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The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers who have responsibilities for nuclear safety research and nuclear licensing. The Committee was set up in 1973 to develop and co-ordinate the Nuclear Energy Agency's work in nuclear safety matters, replacing the former Committee on Reactor Safety Technology (CREST) with its more limited scope.

The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries. This is done in a number of ways. Full use is made of the traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences. Some of these arrangements are of immediate benefit to Member countries, for example by enriching the data base available to national regulatory authorities and to the scientific community at large. Other questions may be taken up by the Committee itself with the aim of achieving an international consensus wherever possible. The traditional approach to co-operation is increasingly being reinforced by the creation of co-operative (international) research projects, such as PISC and LOFT, and by a novel form of collaboration known as the international standard problem exercise, for testing the performance of computer codes, test methods, etc. used in safety assessments. These exercises are now being conducted in most sectors of the nuclear safety programme.

The greater part of the CSNI co-operative programme is concerned with safety technology for water reactors. The principal areas covered are operating experience and the human factor, reactor system response during abnormal transients, various aspects of primary circuit integrity, the phenomenology of radioactive releases in reactor accidents, and risk assessment. The Committee also studies the safety of the fuel cycle, conducts periodic surveys of reactor safety research programmes and operates an international mechanism for exchanging reports on power plant incidents.

The Committee has set up a Sub-Committee on Licensing which examines a variety of nuclear regulatory problems, provides a forum for the free discussion of licensing questions and reviews the regulatory impact of the conclusions reached by CSNI.

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CONTENTS

INTRODUCTION

CSNI's Principal Working Group No. 5 (PWG 5: Risk Assessment) established Task 3 to evaluate how results and insights gained by risk assessments can be used for accident management purposes. This report, as an initial step of PWG 5/Task 3, is confined to a description of the state-of-the-art in national approaches with regard to human intervention in the prevention and mitigation of severe accidents. A comparison table has been made up on the basis of the questionnaire replies given by ten Member countries; i.e. Canada, Finland, France, F.R. of Germany, Italy, Japan, Spain, Sweden, Switzerland and the United States.

A. TYPES OF EMERGENCY OPERATING PROCEDURES

	1/ RETENTION OF ORIGINAL PROCEDURES	NEW TYPES OF PROCEDURES	
		2/ DECIDED UPON IN PRINCIPLE, OR EVEN IN PLACE	3/ UNDER STUDY
CANADA	Yes, but with improvements. Procedures are primarily event-based.	Symptom-oriented procedures provided for accidents not appropriately covered in event-based procedures.	Revised standards for event-based and symptom-oriented procedures.
FEDERAL REPUBLIC OF GERMANY	Yes, but with some improvements including post TMI-measures and modifications of systems or operating procedures according to insights gained by German Risk Study.	Yes, for all plants decided in principle. Protection goal-oriented procedures already introduced in the operators manual of some plants but until now only for design basis accidents. The new procedures will also cover events beyond the design basis and accident management procedures.	Plant response under conditions not assumed for licensing purposes, to assess safety margins and evaluate interventions to influence accident sequences by existing operational safety-systems (classification of cooling states, diagnostic methods, modes of intervention).
FINLAND N.B. : The case of the LOVIISA PLANT (Soviet design) is presented here. The Swedish approach is followed for the other (Swedish type) plants.	Yes, but being gradually changed.	Yes, the procedures will not make any difference between DBA and beyond DBA events (self-sufficient for diagnosis and for emergency operation in multiple failure events). All available equipment and other resources of the plant are used : as back-up for the actual safety systems the operators may either use systems which are used in normal operation, or they may try an operating mode which has never been tested before.	
FRANCE	Yes, but with improvements.	Yes, for beyond design-basis situations (H and U procedures). In place in all reactors.	New procedures based essentially on the recognition of cooling states, applicable in all accident situations involving the primary circuit.
ITALY	Yes, but with some improvements. They are Event Oriented EOPs within design limits.	Yes. EOPs have been decided ; they are being implemented for Caorso. They are Symptom oriented EOPs of the U.S. BWROG type which are aimed at preventing severe accidents.	Yes. The study concerns both the extension of the EOP beyond core melt conditions and the development of new procedures for mitigating the consequences of severe accidents.

A. TYPES OF EMERGENCY OPERATING PROCEDURES

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JAPAN	Yes.	No, at this moment.	Under the sponsorship of the Japanese utilities, vendors have been preparing the domestic version of a function-oriented or symptom-oriented procedure which can be utilized beyond the DBA.
SPAIN N.B. : Case of the SANTA MARIA DE GARONA PLANT (General Electric-type NSSS) presented here.	Yes, two sets of event-oriented EOPs : - General IOEGs - Particular IOEPs based on design basis accidents.	Symptom-Oriented and Function-Oriented Procedures (ref. NUREG 0899).	A level-1 PRA now under way will be used to establish the method for reviewing procedures.
SWEDEN	Yes, but being replaced. The revised ones are completed.	Yes, revised EOPs covering, in principle, all types of disturbances including severe accidents, are available in draft. The new generation of EOPs is symptom- and function-oriented, rather than event-oriented. Already now, plants have "skeleton" procedures for extreme situations.	
SWITZERLAND N.B. : Beznau plant	Yes.	New emergency operating procedures so called "Emergency Response Guidelines (ERGs)" (WESTINGHOUSE type). The new procedures will assure operator preparedness for events within and beyond the design basis.	
UNITED STATES OF AMERICA	Yes (in the FSAR).	Yes. New Emergency Operating Procedures (EOPs), including symptom- and function-oriented EOPs. Existing plant systems usable to prevent severe accidents.	

B. WAY IN WHICH SEVERE ACCIDENTS ARE HANDLED

	FAILURE OF SAFETY SYSTEMS OR FUNCTIONS	3/ WAY IN WHICH COMPLEX SITUATIONS ARE HANDLED (diagnostic errors, multiple failures, etc.)	4/ SPECIFIC CASES INVOLVING DEGRADED OR MOLTEN CORE	5/ RELATED SPECIFIC TECHNICAL PROVISIONS
CANADA	1/ TAKEN INTO CONSIDERATION Loss of heat sink ; Loss of auxialiary feedwater ; Loss of electrical power ; Failure of auto-initiation and control of shutdown system, containment isolation, and emergency injection ; Loss of instrument air ; Loss of service water. 2/ NOT TAKEN INTO CONSIDERATION Structural failures of containment.	Control panel layout, alarms, indications arranged to give specific information on performance of safety functions and safety support functions. EOPs provide separate pages of diagnostics. Critical safety, process and support systems have individual control panels. Safety functions addressed in all procedures include sub-criticality, core-cooling, heat sinks, containment response.		Specific technical provisions include : - two independent shutdown systems - independent emergency injection and recovery - separate seismically qualified control areas - emergency power and service water systems.
FEDERAL REPUBLIC OF GERMANY	1/ TAKEN INTO CONSIDERATION Loss of normal and auxiliary feedwater ; Total loss of electrical AC-power ; Loss of heat sink ; ATWS 2/ NOT TAKEN INTO CONSIDERATION Structural failure of the containment (late failure prevented by venting, uncertainties concerning early failure modes reduced by AM-procedures if necessary).	Specific operating assistance systems, special diagnostic aids in some older and newer plants.	Containment venting interventions are elaborated. Other mitigation measures are possible and foreseen. Accident management measures cover the severe accident regime in order to prevent further core degradation or to mitigate the situation. Flexible use of existing operational and safety systems to ensure cooling even for severely damaged cores. Additional measures to mitigate consequences of severe core damage within the plant and to maintain the containment system function.	Special main cooling water pump seals to avoid LOCA situation during station black-out. Venting devices for PWR and BWR containments. Containment inertisation for BWR. Possibility of using in a flexible manner all existing operational and safety equipment in AM procedures, e.g. Primary Feed and Bleed, containment filtered venting.
FINLAND N.B. : The case of the LOVIISA PLANT (Soviet design) is presented here. The Swedish approach is followed for the other (Swedish type) plants.	1/ TAKEN INTO CONSIDERATION Loss of normal heat sink Loss of normal and auxiliary feedwater Total loss of external electric power and simultaneous loss of all four diesel generators Total loss of high pressure safety injection 2/ NOT TAKEN INTO CONSIDERATION For example (because it is hard to replace or back-up) : loss of containment spray, of low pressure safety injection, of sump recirculation line.	No dedicated diagnostic tools. But, separate protection system panel (on safety equipment response), and specific means in control room.	"All encompassing" procedure : "general instructions for an emergency" (on a single sheet of paper in the control room), which reminds the operators about the most important things which have to be taken care of.	No supplementary technical measure. Possibility of using all existing equipment, even if not foreseen in the safety design basis, explained in detail in the EOPs in the case of total loss of a safety system.

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FRANCE	1/ TAKEN INTO CONSIDERATION Loss of external heat sink → H1 Loss of normal and auxiliary feedwater → H2 Total loss of electrical power → H3 Loss of low pressure safety injection and containment spray systems → H4 and U3 Loss of high pressure safety injection system → U1 Loss of containment integrity → U2, U4 and U5 2/ NOT TAKEN INTO CONSIDERATION Rapid rupture of containment.	No dedicated diagnostic tools. But, separate safety panel : - indication of initial failure - surveillance of actuators - diagnostic and safety injection operating aid - aid for cooling and depressurising the primary circuit - continuous post-accident surveillance - aid for executing the U emergency procedures - surveillance of safety functions	Approach of using (U) procedures in order to get control over the consequences of all cases of simple and multiple failure. Even so, intermediate measures based essentially on the recognition of physical states. All necessary measures should be covered inside one of the five ultimate U procedures.	The most important specific provisions : - LLS turbo-pump system in H3 - switchover from ISBP to EAS and vice versa in H4 - mobile pump containment heat sink in U3 - supplementary instrumentation in U1, U2 and U5 - special filtration system in U5
ITALY	1/ TAKEN INTO CONSIDERATION For severe accidents (not included for regulatory or licensing considerations) the actual trend is to make reference to the failed systems identified in existing PRAs. 2/ NOT TAKEN INTO CONSIDERATION Consideration of rapid containment failures is excluded from the severe accident management.	Probabilistic target of 0.05 conditional upon core melt, to mitigate radiological consequences compatible with external emergency countermeasures. The analysis takes into account probabilities of both the failure of specific operator actions and preexisting openings on containment structure. In correspondence to these conditions iodine fraction releases should be lower than 10^{-3} times core inventory.	No intervention has been elaborated. Specific actions will depend on the current investigations.	No supplementary technical measure is foreseen at the moment.
JAPAN	1/ TAKEN INTO CONSIDERATION Actions in order to complement the single failure criteria.	Operator training programmes with a training simulator including typical multiple failure scenarios.		The emergency instrumentation for radioactivity measurement in the severe accident conditions including postulated site evaluation accident are to be designed and fixed. No special instrumentation for the purpose of manoeuvring the severe accidents.
SPAIN N.B. : Case of the SANTA MARIA DE GARONA PLANT (General Electric-type NSSS) presented here.	1/ TAKEN INTO CONSIDERATION Failure of automatic initiation of the containment spray. Failure of automatic initiation of high pressure safety injection. "Diesel Generator" failure. Loss of the vital bus. Service water failure.	Safety Parameters Display System (SPDS). (a dependable tool, but not strictly meeting design basis requirements).		

B. WAY IN WHICH SEVERE ACCIDENTS ARE HANDLED

	FAILURE OF SAFETY SYSTEMS OR FUNCTIONS	3/ WAY IN WHICH COMPLEX SITUATIONS ARE HANDLED (diagnostic errors, multiple failures,etc.)	4/ SPECIFIC CASES INVOLVING DEGRADED OR MOLTEN CORE	5/ RELATED SPECIFIC TECHNICAL PROVISIONS
SWEDEN	1/ TAKEN INTO CONSIDERATION Considered are LOCAs and failure of essentially all safety functions, including normal and auxiliary feedwater systems, heat sinks and electrical power supplies. Loss of all AC power has been chosen as a design sequence. In BWRs, degradation of the normal pressure suppression function together with LOCA is also a design sequence. 2/ NOT TAKEN INTO CONSIDERATION Incidents of extremely low probability are not considered.	Mimicry displays are used extensively in Swedish control rooms providing good overview of essential plant functions. Also, the start-up of safety functions is highly automated ("30-minute principle"), to give operators more time for diagnosis and checking. Control room instrumentation is successively improved to provide better overview, also in complex situations.	Based on plant-specific studies of severe accidents sequences, revised EOPs taking into account cases involving degraded or molten cores will be implemented before 1989 for all Swedish plants. For Barsebäck, a first level was implemented in 1985 along with the installation of FILTRA.	Possibilities to use all available technical equipment at the plant to maintain essential safety functions. For the Barsebäck site, filtered venting of the containments (the FILTRA system). For the other Swedish plants requirements set up in 1986 will lead to installation of mitigation measures before 1989 including : - strengthening of containment weak points - containment venting via scrubber system, MVSS - for BWR, large area unfiltered venting with isolation valves for the sequence LOCA and insufficient pressure suppression - for PWR, continued studies of hydrogen issues.
SWITZERLAND N.B. : Beznau plant	1/ TAKEN INTO CONSIDERATION Loss of heat sink Loss of normal and auxiliary feedwater Total loss of electrical power Consequences from extreme events like sabotage, airplane crashes, fires, explosions and extreme earthquakes	Use of the Optimum Recovery Guidelines, the Status-Trees and the Functional Restoration Guidelines The following Critical Safety Functions are monitored (high priority functions) : subcriticality core cooling, reactor coolant system integrity, heat sink, containment integrity, reactor coolant system inventory		Project (under study) including : - special emergency system, acting as an independent ultimate heat sink - additional on-site emergency power - provisions for monitoring and controlling the plants from outside the control rooms. No mobile safety feature for installation only when an accident has occured All features mentioned above are designed in compliance with the safety criteria and regulations in force at the time of their approval by the Regulatory Authority
UNITED STATES OF AMERICA	1/ TAKEN INTO CONSIDERATION Loss of reactivity control Loss of core cooling Loss of vital electric power EOPs relating to these events with regard to multiple failure and other contingencies. Through PRA studies and SASA program, the NRC is exploring opportunities of improved safety by means of augmented human intervention. 2/ NOT TAKEN INTO CONSIDERATION Loss of containment integrity (for large dry PWR containments).	Concerning symptom or function-based emergency response procedures : - SPDS - Information about : reactivity control, reactor core cooling and heat removal from the primary system, reactor coolant system integrity, radioactivity control, containment conditions - selected measurements in the control room concerning requirements in R.G. 1.97.	Accident management of a core melt event is analyzed to evaluate feasibility and value/impact of extending emergency procedures guidelines into the severe accident regime. However, no procedure at present required by NRC for the mitigation of severe accident ; but that remains an open item.	Specific design rules in R.G. 1.97, NUREG 0737, Generic letter 82-33. With respect to design rules for additional supplementary measures, research programs are underway that should generally clarify the NRC requirements in these matters.

C. PREPARATION AND VALIDATION OF INTERVENTION MODES AND/OR OPERATING PROCEDURES			
	1/ ROLE OF SAFETY AUTHORITIES AND PARTNERS INVOLVED	2/ TECHNICAL ANALYSES : role of simulators, of R & D results,etc.	3/ EMERGENCY ORGANISATION - EMERGENCY EXERCISES
CANADA	EOPs are written by plant technical and production sections. The Safety Authorities review the procedures but do not give formal approval.	All procedures verified to be in accordance with plant design specifications and safety analyses. Validation done on simulators or in walk-throughs. Validation normally done in conjunction with training programs.	Control room is the primary area for directing and controlling plant process/safety system response. Off-site emergency management centres and procedures are provided. Regular emergency exercises are practised by the utilities and are monitored by the regulators.
FEDERAL REPUBLIC OF GERMANY	Safety authorities and their consultants (GRS, TUEV) are performing studies. Proposals for procedures and measures developed by utilities or vendors are reviewed and -if acceptable- recommended, so that the appropriate procedures may be followed.	The EOPs for design basis accidents are a part of the simulator training. In future it is planned to validate EOPs by more advanced simulators for further optimization of prevention of core damage. Study of : Diagnostic methods and diagnostic and decision aids ; improved instrumentation to recognize "status". Supplementary training of personnel, value of simulators, possibilities for "back-up" measures, planning of supplementary or substitution measures (use of existing systems, mobile equipment, etc).	Emergency crew supports plant manager in case of an accident. He can be assisted by external experts. Regular emergency exercises are performed.
FINLAND N.B. : The case of the LOVIISA PLANT (Soviet design) is presented here. The Swedish approach is followed for the other (Swedish type) plants.	The EOPs, based on guidelines received from the plant designer, are written and reviewed by the operating organizations. The Safety Authorities analyse the procedures, but do not give formal approval.	Procedures validated on full-scope training simulator, specific to the LOVIISA PLANT, able to simulate most accidents and transients up to the onset of core damage (including multiple failure situations). The simulator includes two-phase modelling for all breaks less than Ø 10 cm. It thus makes it possible for personnel to practise on complex situations involving multiple failures.	Emergency command centre for exceptional (not preplanned) operating measures, which directs the control room staff. The command center is assisted by a technical support centre. Annual emergency exercise involving the different organisations concerned.
FRANCE	The general approach underlying the H and U procedures was defined collaboratively by the utility (EDF) and the Safety Authorities. The Safety Authorities analyse the procedures and give formal approval.	Existing simulators adapted for personnel training on current (design basis) procedures. Simulators with two-phase models being prepared to handle all imaginary accident sequences on the primary circuit. Continuous post-accident surveillance ensured by a safety and radioprotection engineer, who intervenes to direct control room operations in complex or deteriorated situations (use of U1 procedure in particular).	The Plant Manager is assisted by an emergency centre set up in or near the control room. The shift leader is in charge of execution of the procedures. However, the "Ingénieur de Sûreté et de Protection" (ISP) has the responsibility of deciding about implementing the U1 procedure. Regular emergency exercises are performed.
ITALY	Training, validation and verifications of any kind of procedures are subject to ENEA/DISP approval and audit.	Validation of emergency procedures and operator training will depend on results of current investigations.	No special in-plant organization is foreseen at the moment to react to severe accident sequences. At present outside the plant, emergency exercises are requested and organized. However, having adopted new in-plant protective measures in defence against severe accidents, new technical basis for developing external emergency plans are being assessed.

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JAPAN			Technical support centre in site. "The Disaster Countermeasure Basic Law" requires the local governement (prefecture) to fix an off-site emergency plan.
SPAIN N.B. : Case of the SANTA MARIA DE GARONA PLANT (General Electric-type NSSS) presented here.	Acceptance by the Spanish Regulatory Body.		Technical support to the shift supervisor and operators : - Technical Support Centre (TSC) - Operational Support Centre (OSC) - Emergency Operations Facility (EOF) Emergency exercices once every year.
SWEDEN	The utilities have the full responsibility for the preparation and validation of the EOPs. The Inspectorate will audit the whole process. This includes checking of the end result by monitoring full scale simulator runs of chosen EOPs or occasionally ordering a "walk-through" during a plant inspection.	Efficient use of R & D results is promoted by carrying out relevant Swedish R & D programs, e.g. on severe accidents, and other studies. Full-scale simulators are used for training operating personnel in the handling of complex disturbances (multiple failures), although complex states such as two-phase flow or core damage cannot be simulated on present simulators.	There are procedures for establishing emergency command centres (ECC) at each site. The ECC and the control room crew will be assisted by a technical support center (TSC). The ECC will also serve as a communication center, providing information to local and central authorities. At present, there is typically one major emergency exercise per site per year, involving staff both at the plant and at local and central authorities. Plant staff have more frequent in-plant emergency exercises.
SWITZERLAND N.B. : Beznau plant	The basic ERGs (WESTINGHOUSE program originally from the USNRC TMI Action Plan) were evaluated by the NRC and found acceptable for implementation into plant specific emergency procedures. A verification and validation of the ERGs was conducted at the SEABROOK station.	Generic guidelines validated during a simulator validation program (training courses, WESTINGHOUSE simulator, compact simulator on site in the near future). Utility experience with ERGs is also available. Possible improvements suggested by the PSA study.	Within approximatly 10 minutes the "Engineer-on-call" or the manager of "Plant Operations" will be in the control room and take the lead. Within 1 hour the Beznau Emergency Staff is expected to be at the site. As soon as three of its members are present, the Emergency Staff is considered to be operational and takes the lead. The Emergency Staff is supported by an NOK-International Emergency Support Centre.
UNITED STATES OF AMERICA	Training, validation and verification of procedures are subject to NRC audit.	Research programs are underway to develop nuclear plant analysers and nuclear plant data banks which permit engineering explorations. Application of this research to operator training or validation of emergency procedures is dependent on many research findings and the final commission policy on severe accidents.	No special organization within the control room to react to accident sequences. Outside the control room specific organizations are set. Licensee emergency exercise once every year. State and local authorities participate in these exercises every two years.