Titre

SAFETY PRACTICE AND REGULATIONS IN DIFFERENT IGORR MEMBER COUNTRIES

C. HICKMAN,
JL. MINGUET,
F. ARNOULD
(TECHNICATOME)

1 INTRODUCTION

In the <u>*suggestions for future R&D work*</u> session of the 1996 IGORR 5 conference, Technicatome proposed « ***Comparing Regulations for Research Reactors in Participating Countries ».*** The aim was to enhance and facilitate the dissemination of pertinent information amongst potential utilities of operational research reactors. A questionnaire on the following topics was subsequently sent out to IGORR 5 participants : ***Procedures for Research Reactors and Associated Equipment, Safety Analysis, Safety Related Components, Radiation Protection and Management of Nuclear materials***. The French position on these topics was given in this questionnaire. Some fifteen exploitable replies were received, twenty seven questionnaires having been sent out. Technicatome is grateful to all participants who took the time and trouble to reply to the questionnaire. The object of the present paper is to identify major trends, similarities and differences in the approaches adopted by different countries. Its scope has been limited to the following topics :

- Licensing and Regulatory approach
- Operating and Safety documents
- Safety Analysis
- Radiological Safety
- Management of Nuclear Materials

The term ***research reactor*** is used in a generic manner for reactors devoted to research and testing purposes. Drawing attention to particular practices and regulatory aspects in specific countries does not imply that the same practices and regulatory aspects are not applied elsewhere.

2 LICENSING AND REGULATORY APPROACH

The nature of licensing authorities vary from one country to another; in some countries licenses are granted by the ministry (or ministries concerned), and in others by state designated Atomic Energy authorities. National legislation is established with the support of appropriate expert authorities. Because of the varied nature of research reactors there is often very little specific legislation and regulations available and it is necessary to treat them on a case by case basis. Regulations applicable to power reactors are adapted to research reactors when appropriate. Because of the federal nature of the German Republic, the ministries of the different states (Länder) are responsible for licensing. Requests to build and operate research reactors are addressed to appropriate national authorities. **Cf. Table 1**

3 SAFETY DOCUMENTS

The following safety documents have been identified from the responses of the majority of countries :

- Preliminary Safety Report necessary before excavation work can begin
- Final Safety Report (depending on the country)
  - ↗ authorizing the fuel loading of the reactor
  - ↘ authorizing the start up of the reactor

The Final Safety Report is divided in two parts in France :

- Provisional Safety Report before the first loading of the reactor with nuclear fuel

- Final Safety Report to be delivered to the authorities within 10 years of start up; this report describes the experience acquired and the measures taken to improve safety

Table 2 indicates the safety and operating documents to which the different countries refer.

4 SAFETY ANALYSIS

4.1 SAFETY APPROACH

There is a general tendency towards a deterministic approach based on the defense-in-depth strategy recommendations of the IAEA. Probabilistic studies are performed for some reactors in order to evaluate the probability of core damage occurring, and to consequently verify and validate design features. **D**esign **B**asis **A**ccidents (DBA) are defined on the basis of deterministic analysis based on conservative hypotheses and the Single Failure Criterion. Probabilistic studies enable accident scenarios to be classed as **B**eyond **D**esign **B**asis **A**ccidents (BDBA). It is frequent practice in different countries to assign three or more safety classes to components and systems in order to qualify the level of redundancy and reliability to be imposed. Countries such as Korea and France (Jules Horowitz reactor) also use couples of ***probability - radiological consequences*** considerations to define the safety objectives. **Table 3** indicates the safety approaches adopted by different countries.

4.2 CLASSIFICATION OF INITIATING EVENTS

Several countries (China, Korea, India, France...) have extended power reactor **I**nitiating **E**vent criteria to their research reactors. Four categories of Initiating Event are defined for Design Basis Events (DBE) and a 10^{-6}/year probability for Postulated Initiating Events (PIE) likely to lead to Beyond Design Basis Accidents. **Table 4** summarizes the situation in different countries. The table indicates that countries, such as Korea, set lower AFO values for the lower limits of 2nd and 3rd category PIE than those commonly encountered elsewhere. Other countries such as Yugoslavia, and for that matter, Australia, define an objective of < 10^{-4}/year for occurrences likely to lead to severe core damage. This value is 10 times higher than the one normally used for PWR reactors. As far as the currently projected French Joules Horowitz reactor is concerned, radiological limits for the personnel and environment are associated with the different PIE categories. The validity of these limits must be demonstrated to the Safety Authorities. The safety analysis performed in most countries enables PIE categories to be defined for DBE and BDBE. Some countries employ overestimated DBE for the melting of a fuel element while others postulate BORAX type reactivity accidents.

4.3 REACTIVITY ACCIDENTS

Past experience (SL1, Los ALAMOS, Chalk River....,....) has demonstrated that reactivity accidents represent the most severe type of accident for a research reactor or experimental facility. Some countries consider a reactivity accident as a DBA envelope for all systems associated with the risk of disseminating radioactive substances. The majority of countries take radioactivity accidents into consideration in there safety analysis without necessarily stipulating whether they are considered as DBE's or BDBE's. Some countries do not take into account accidents associated with AFO values less than 10^{-6}. Currently, the french approach for Reactor Insertion Accident is to consider as fourth level in the framework of defense in depth strategies. Mitigation systems are employed to prevent uncovering of the core and to ensure the confinement of radioactive substances. This approach has the advantage of adding an additional fourth defense-in-depth level to the three previous levels so as to reduce the consequences of such an accident.

4.4 EXTERNAL HAZARDS

4.4.1 Earthquakes

Table 5 indicates the approaches of different countries to earthquake and seismic phenomena. Earthquake strategies vary from one country to another and may be being either probabilistic (e.g. USA) or deterministically (e.g. France) based. A combined probabilistic-deterministic approach is most often employed. Three sorts of earthquake are generally considered : earthquakes during (and after which) the reactor will continue to function normally; safety shutdown-type earthquakes (during and after which) critical safety related components continue to fulfill their functions; beyond design basis earthquakes for which the annual probability of occurrence is $< 10^{-6}$. Complementary information would be useful on how design basis spectra are defined and determined together with the methods employed to calculate and verify the behavior of structures under earthquake conditions and afterwards.

4.4.2 Meteorological and natural phenomena

An overview of the information provided by the different respondents reveals that the following phenomena are taken into consideration for different types of reactor and site locations : rain, floods, excessively high and low temperatures, winds, hurricanes, tornadoes, snow, tidal effects, lightening, thunderbolts, external fires, soil erosion, geological stability and seismically induced faults.

4.4.3 Hazards from industrial environments and crashing aircraft

Generally, research reactors are sited at a sufficient distance from risk generating (fire, explosions, projectiles,..) industrial installations. When this is not the case, specific risks must be taken into consideration and defense-in depth strategies implemented. External events likely to result in unacceptable releases of radioactivity must be taken into consideration in France when their corresponding probability of occurrence exceed 10^{-7}. Similar criteria are employed by other countries. The approaches adopted to hazards from crashing aircraft are largely probabilistic. In some countries specific laws exist concerning aircraft crashes onto nuclear reactor buildings e.g. Belgium, France, Korea, countries for which, precautions must be taken to reduce the occurrence of an aircraft crash leading to radiological consequences to below a pre-determined value (to typically $< 10^{-6}$ / year). In other countries, aircraft crashes are treated in the framework of general safety assessments.

5 RADIOLOGICAL SAFETY

5.1 ICRP 60 RECOMMENDATIONS (1990) AND THE EURATOM DIRECTIVE OF THE 13TH OF MAY 1966

Most countries are in the process of integrating 1990 ICRP 60 recommendations, 1996 IAEA Basic Safety Standards (and where appropriate, the 1996 L159 Euratom Directive) into national regulations and/or legislation. These new recommendations reduce the effective annual dose limits for workers and the public from 50 mSv and 5 mSv to 20mSv (averaged over a five year period with a maximum dose of 50 mSv in any one year) and 1 mSv (averaged over a five year period with, under special circumstances, a maximum dose of 5 mSv in any one year) respectively. In the intermediate period, the new dose limits are being implemented almost everywhere, and specially for new installations. The 1996 Basic Safety Standards and the 1996 L159 Euratom Directive also give new coefficients for converting inhaled and ingested Bq of different nuclides into Sv . **Table 6** shows the positions of different countries on this subject.

5.2 CLASSIFICATION OF AREAS

The concept of unrestricted, surveyed, controlled and forbidden areas is universal. **Table 7** presents the approaches of different countries. Attention is drawn to the case of Germany for which restricted areas are limited to less than 0.3 mSv/year. French practice is to subdivide and classify these areas as colored ***zones*** : blue (surveyed), green (ICPR limit for 2000 hours of presence), yellow (limited presence), orange (severely limited presence) and red (forbidden). Although the new dose limits of ▪ 5.1 are being implemented, most countries have not, as yet officially, defined these areas in terms of the new limits.

6 MANAGEMENT OF NUCLEAR MATERIALS

6.1 FUEL STORAGE

Table 8 indicates the regulations and practice for fuel storage in different countries. Sub-criticality, sufficient natural convection cooling and adequate biological shielding are the necessary requisites for the storage of spent fuel elements. Depending on the decay heat dissipated, fuel elements may be stored in either the wet or dry state. The length of time during which fuel elements are wet or dry stored depend on their activities, the facilities available and individual government policies. The absence of definitive solutions as to the disposal or transmutation of high-level radioactive waste has led to various specific dispositions being adopted for individual reactor storage facilities ranging from the use of neutron absorbing materials to prevent sub-criticality being reached (BATAN, Indonesia) to long-term pool storage scenarios (up to forty years for the TRII project in TAIWAN).

6.2 RADIOACTIVE WASTE MANAGEMENT

Producers of nuclear waste are, in general, legally responsible for their own waste up until the time that such waste has been disposed of, or transferred to the appropriate waste management authority. Different member countries impose specific criteria as to the surface activities below which wastes can be considered as non radioactive (see Table 9). Germany imposes, for example, the following surface activity limits below which ***suspect radioactive waste*** can be treated as ***normal waste*** : < 0.05 Bq/cm^2 for α contamination, < 5 Bq/cm^2 for β contamination and < 0.5 Bq/cm^2 for contamination by other radionuclides. In France obligations do not exist for the disposal of substances with activities of less than 100 Bq/g for artificial radionuclides and 500 Bq/g for naturally occurring radionuclides. Specific reference is made by Indonesia and Taiwan to their conformity with IAEA recommendations for A, B and C type wastes, namely :

Type A : Low and intermediate waste containing short or intermediate half-life ≤ 30 years) β and γ emitting radionuclides but no α emitters.

Type B : Low and intermediate activity waste containing significant quantities of long half-life (> 30 years) radionuclides (generally β and γ emitters)

Type C : High activity waste containing long half-life α (low activity), and high activity α, β and γ emitting radionuclides.

7 CONCLUSIONS

The investigations carried out indicate that to a large extent international recommendations (IAEA, ICPR,..) are being followed and that there is a general tendency to integrate them into national legislation and regulations. Although ***Safety Culture*** varies from one country to another an overall general consensus exists on the basic approach to safety inasmuch as :

- different countries have their own legally defined Safety Authorities,
- a Preliminary Safety Report is required before a research reactor can be built, and a final Safety Report before the core can be loaded with nuclear fuel and the reactor made critical; these documents must be accepted by the Safety Authorities concerned ,
- a combination of defense-in-depth strategy (deterministic approach) and probabilistic analysis is applied,
- three or more safety classes are used to categorize systems and components,
- the single failure criterion is taken into consideration for systems and components having safety functions,
- both Operating Basis and Safety Shutdown type earthquakes are considered,
- the crashing of an aircraft onto a research reactor is taken into consideration (either explicitly or implicitly),
- radiation areas are divided into unrestricted, surveyed, controlled and forbidden areas,
- radioactive waste is managed in accordance with IAEA recommendations (classification of wastes as A, B and C types).

The replies to the questionnaire have been compiled into a single document which will automatically be sent to the different respondents and to other IGORR members on request.

All utilities and operators of research reactors and their associated experimental facilities are concerned by the overall safety of their installations. Technicatome has concluded from the results of the inquiry that overall safety of research reactors and their associated experimental facilities could be enhanced by:

- systematically introducing specific probabilistic safety criteria for damaged cores ; performing probabilistic safety analysis during the design stage (in order to optimize safety system concepts and to identify the main sequences leading to core failure),

- taking radiological criteria (for workers, the public and the environment) into consideration at a very early stage for the different categories of PIE, DBA, and BDBA; the validation of these criteria should be the ultimate objective of the deterministic safety analysis.

This above defined approach has been assimilated into Technicatome's ***Safety Culture*** and is being applied to the design of research reactors and military nuclear facilities. It is suggested that joint IGORR member /IAEA studies should be undertaken to develop guidelines for the safety of research reactors and associated experimental facilities.

8 TABLES

8.1 TABLE 1 : LICENSING AND REGULATORY APPROACH

Country	Authority responsible for licensing	Regulatory approach
Argentina :	Autoridad Regulatoria Nuclear (Nuclear Regulatory Body) reporting directly to the National Presidential Office	Legislation and regulations based on findings and support of organizations such as the National Atomic Energy Commission (CNFA), INVAP (reactor designer), Nuclear Power Pant Operator (NASA).
Belgium	National Agency for Nuclear Control	Regulatory texts based on a law for the protection of individuals and the environment from the dangers due to ionizing radiation, first promulgated in 1958. The General Regulations of the 28^{th} of February 1963 constitute the main royal decree for the enforcement of the above mentioned law. Regulations are regularly updated and published as General Regulations for the Protection of Work (RGPT). There are no specific regulations applicable to research reactors. The application of these regulations is ensured by the National Agency for Nuclear Control.
Canada	Atomic Energy Control Board (AECB)	Legislation and regulations concerning nuclear installations in Canada are published in the ***Canada Gazette*** as laws, decrees and circulars. The regulations for nuclear facilities are published by the AECB. The regulations are primarily applicable to CANDU power reactors. The licensee proposes and negotiates a consensus with the AECB on the application of the regulations to research reactors. The Canadian Environmental Assessment Act includes legislation for environmental assessments for nuclear facilities. The AECB administers regulations under the Canadian Environmental Assessment Act for nuclear facilities.
China	National Nuclear Safety Administration (NNSA)	The NNSA is responsible for the drafting and enactment of regulations related to the safety of nuclear installations There are some specific regulations applicable to research reactors.
France	Directorate for the Safety of Nuclear Installations (DSIN)	Legislation and regulations concerning nuclear installations in France are published in the *Journal Offficiel de la République Française (JO)* in the form of laws, decrees and circulars. Legislation and regulations based on findings and support of various national organizations such as the DSIN and the IPSN (Institute for Nuclear Safety and Protection). A section of the Basic Safety Rules RFS published in the JO is devoted to research reactors. However it is incomplete and regulations applicable to PWR's are most often extended to Research Reactors.
Germany	Ministries assigned responsibility for nuclear affairs (most often ministries dealing with environmental issues) in the different States	Federal laws and ordinances are published in the Bundesgesetzblatt (Federal Republic law papers). Rules guidelines and criteria of a technical nature are published in either Bundesanzeiger (Federal Republic notification) or Gemeinsames Ministerielblatt (Compilation of Ministerial papers) depending on the issuing ministry.
India	Atomic Energy Regulatory Board (AERB)	The provisions of the AERB Safety Manual deal with the authorization procedures for nuclear power plants/projects. The overall objective of AERB is to determine whether the proposed reactor can be sited, constructed, commissioned, operated and decommissioned without exposing, operating personnel, the public or the environment to undue radiological risks.
Indonesia	BAPETEN an independent organization responsible for nuclear affairs	Legislation and regulations are currently being updated by BAPETEN
Japan	Science and Technology Agency (STA)	Prime Minister in liaison with the STA.
Korea	Ministry of Science and Technology (MOST)	Legislation for nuclear installations is published in the form of decrees, rules, specific regulations atomic energy laws and MOST regulations
Morocco	Ministry of Energy and Mines (Safety Authority)	Legislation and regulations concerning nuclear installations in France are published in the *Bulletin Offficiel de la Royaume du Maroc*.
Russia	Federal Supervision Authority for Nuclear and Radiation Safety (Gosatomnadzor)	Standards and regulation on the safety of civil nuclear installations are published by the Gosatomnadzor with the participation of organizations such as the State Scientific Center (SSC) and the Kurchatovsky Institute.

Table 1 (continued)

Taiwan	Atomic Energy council of the Republic of China (ROCAEC)	A compilation of Atomic Energy law and regulations for its implementation is to be found in the ROCAEC handbook. Where insufficient regulations are available for research reactors, case by case studies are performed.
USA	Nuclear Regulatory Commission (NRC)	The code of federal regulations (CFR) Title 10, Part 50) exposes regulations applicable to research reactors. Research reactor regulations are less comprehensive than those available for PWR's
Yugoslavia	Federal Ministry of the Economy, Section Energy	Legislation and regulations related to nuclear installations are normally published in the Official Gazette FRY.

8.2 TABLE 2 : SAFETY AND OPERATING DOCUMENTS

Country	Safety and operating documents
Argentina	– Preliminary Safety Analysis Report (4 months before site excavation) – Code of Radiological Practices – Emergency Plan – Final Safety Analysis Report (It contains the Operational Limiting Conditions and Safety Systems Settings). – QA manual for design, construction, commissioning and operation – Project progress reports and engineering updates – Staff organization chart – Commissioning program – Operation Manual – Maintenance Manual
Canada	– Preliminary Safety Analysis Report (description of installation together with preliminary safety analyses) to obtain Construction Approval from the AECB (submitted about 6 months prior to start of construction) – Final Safety Analysis Report (final detailed description of the installation and detailed safety analyses) to obtain an Operating Licence from the AECB (submitted about 9 months prior to initial fuel load) – Safety Analysis Report giving information on the results of commissioning tests and re-evaluation of safety analyses based on updating the assumptions to match the real reactor systems performance; and – Additional supporting documentation as requested by the AECB. – Environmental Screening Report (brief description of installation, intended use, assessment of impact on the environment from normal operations and limiting accidents) for Siting Approval – Operational Limits and Conditions which provides the detailed operating regulations (document that must accompany Final Safety Report)
China	– Before construction, the organization operating nuclear installations shall submit a “Nuclear Installation Construction Application”, a “Preliminary Safety Analysis Report” and other relevant information to the NNSA. – Nuclear fuel loading and commissioning can only be started after documents granting, nuclear fuel loading and commissioning are approved – Operations can only be pursued after the “Operating Permit for the Nuclear installation” has been granted
France	The future operator of a nuclear research reactor is required to submit the following documents to the DSIN: – Preliminary safety report (description of installation together with a preliminary analysis which must be communicated to the safety authorities at least a few months before the beginning of building work on the reactor); – Provisional safety report (which must be communicated to the safety authorities at least a few months before the first loading of the reactor with nuclear fuel; this report must be accompanied by propositions for general operating regulations), – Definitive safety report giving information on tests and controls carried out after the submission of the previous report, real conditions observed in early operations, the results of tests during power ascension and the results of commissioning tests. – Operational requirements document (a dozen or so pages) which defines all operational parameters.
Germany	– Safety report and a plant description. The next part of the licensing procedure involves the submitting of additional documentation such as descriptions of systems, design justifications for all the systems to be licensed, safety analyses. Updating of the safety report is not required. – Commissioning program – Operating manual

Table 2 (continued)

Country	Safety and operating documents
Indonesia	All documents related to safety should be assessed and approved by the reactor safety review committee before being submitted to the regulatory body, including : – Preliminary safety analysis report and safety analysis report – Experimental practices likely to have significant implications on Reactor Safety Modifications that change the Tech. Spec & OLC.
Korea	– Environmental impact evaluation report which describes the impact of the nuclear reactor installation on the surrounding population and the environment. – Safety analysis report (This is revised after the more detailed design phase) – Quality assurance plan – Technical specifications which ensures the safe operation of the research reactor – Commissioning test reports which confirm that design objectives have been achieved.
Morocco	– Preliminary Safety Report (Description of the Installation together with a preliminary analysis; physical security plan, emergency plan, QA program..), information about the installation accompanied with standard operating procedures). – Final Safety Report giving information on tests and controls carried out after the submission of the previous report, the results of commissioning tests, Safety Systems settings and operating limits and conditions...etc.
Russia	– Report on safety substantiation (to get a license for siting and erection. given in Appendix 2 of RD-04-26-97. The Report has 15 sections and includes a description of the area and the RR site, RR constructions and specifications, as well as details about the different systems and equipment employed, safety analysis, operational dispositions, commissioning, etc. (The initial report on safety substantiation is corrected for changes introduced in the course of construction, installation and “pre-start” stage modifications) – Final report on safety substantiation being corrected with the account of results of the reactor's physical and energy start-up (in order to get license for further reactor operation) Report on safety substantiation of the reactor for decommissioning
Taiwan	– Preliminary safety report together with an application form shall be submitted and a construction license shall be obtained before the beginning of construction work – Description and analysis of siting, characteristics of the reactor structures, systems and components, safety considerations, organization planning, training program, preliminary in-service inspection plan, quality assurance plan and emergency plan shall be provided as a minimum requirement in the preliminary safety report. The final safety analysis report together with an application form and technical specifications shall be submitted and a utilization license shall be obtained before fuel loading begins.
USA	– Preliminary Safety Analysis Report : PSAR – Final Safety Analysis Report : FSAR
Yugoslavia	– Preliminary safety report – Final safety report The content of these documents comply with IAEA recommendations.

8.3 TABLE 3 : SAFETY APPROACH

Country	Safety approach	Application of Single Failure Criterion	DBA
Argentina	Deterministic analyses used to show that safety systems are effective in protecting against DBA. A PSA is required for every Research Reactor. Radiological consequences of BDBA are analyzed.	Yes	
Belgium	Deterministic methods are employed ; they are complemented by probabilistic analyses for research reactors as BR2.-	Yes for front line systems	BORAX
Canada	The defense-in-depth strategy is used to compensate for potential human and mechanical failure and unexpected occurrences. Abnormal events are prevented, then mitigated, then accommodated in order of importance, and a series of barriers is included in the design to prevent, reduce or slow down releases of radioactivity to the environment.	Yes	
China	Deterministic approach are favored. Much attention is given to "Defense in depth approach	Yes	BORAX
France	Deterministic approach is favored. Much attention is given to the "Defense in depth approach one aspect of this approach is to ensure the interring of the successive confinement barriers. Probabilistic analysis is used for external events . France use safety objectives. For each category of PIE correspond radiological limits for workers and public. The main objectives are to avoid counter measures for DBA and to have limited counter measures for BDBA.	Yes	BORAX for old research reactors.
Germany	Deterministic approach is applied. Concerning research reactors, probabilistic arguments for not considering beyond design basis events, and notably those due to external events may be accepted. Reliability assessments of safety relevant systems are applied additionally to ensure a high degree of safety.	Yes	Melt down of one fuel element
India	Defense in depth approach is applied.	Yes	
Indonesia	Deterministic methods are favored. Much attention is given to the defense in depth and foul safe approaches.	No but common failure criteria considered	
Korea	Safety analysis methods for a research reactor are generally similar to those applied to commercial power reactors. The safety objectives, principles and other major ideas elucidated in the IAEA safety series are usually adopted. The principle of 'Defense in depth' (i.e. defense in depth in design, accident prevention and mitigation) is fundamental and essential for nuclear reactor safety. The deterministic safety analysis method is required to obtain an operating license. Probabilistic safety assessment is also used to supplement the deterministic safety analysis and recommended for the safety assessment of internal and external events by the regulatory body. The quantitative safety goal is to reduce the possibility of events likely to lead unacceptable releases of radioactivity to less than 10^{-6}/yr.	Yes	
Russia	Deterministic methods prevail. The main principles and criteria of safety provision are given in Section1.2 of the "General provisions securing research reactor safety (OPB IR-94,PN AE G-16-34-94. M. 1994)". The main RR safety criteria are health protection of personnel, population and environment. These criteria are satisfied through the implementation of the "Defense in Depth" principle, which is based on the application of the multiple barrier system in order to protect against ionizing radiation and to prevent the dissemination of radioactive substances in the environment, and by the system of technical and organizational measures on barrier integrity and efficiency (Item 1.2.5 OPB IR-94). The "Defense in Depth" principle is implemented throughout the different safety stages involved in the construction and operation of RR's.	Yes	Fall of a transport cask on the core leading to the meltdown of the core.
Taïwan	The Defense-in-depth approach is adopted. Safety systems are designed to ensure the safe shutdown of the reactor, heat removal from the core and to limit the consequences of anticipated operational occurrences and accident conditions. Safety analysis shall be performed to ensure that the functions of the safety systems have been properly designed. Some considerations of safety analysis are: – to ensure that enough events have been considered to include any accident of significant radiological consequences. Rejection of a potential event should be justified in the discussion. – to categorize the initiating events and scenarios by type and likelihood of occurrence so that only the limiting cases in each group must be quantitatively analyzed. to develop and apply consistent, specific acceptance criteria for the consequences of each postulated event.	Not although it is now planned to employ them for TRR II	
USA		Yes, but existing USDOE reactors are not certified	
Yugoslavia	Methodology applied should be based on IAEA recommendations and standards.	No explicitly stated requests on this matter exist	

6.4 TABLE 4 : INITIATING EVENTS

Country	Initiating events
Argentine	Potential accident scenario are examined. Events with an extremely low annual frequency of occurrence are not considered. The following initiating events are considered : 1. Loss of electric power supply 2. Insertion of reactivity 3. Loss of cooling system flow 4. Loss of coolant 5. Erroneous handling or failures in equipment or components 6. Internal events (fire, flood, miscellaneous failures) 7. External events (earthquakes, floods, fires, fall of aircraft, etc.) 8. Failures in the instrumentation of the protection system 9. Human errors
Canada	Initiating events are classified in 4 categories: • Category 1 Events: serious process failures – 1A Events: AFO > 10^{-1} – 1B Events: 10^{-6} < AFO < 10^{-1} • For Category 1 events, a "serious process failure" is any failure of equipment that, in the absence of safety system action, could result in a significant fuel failure, thereby leading to a significant release of radioactive material. The reactor is protected by safety system actions as well as process protective and mitigative systems. • Category 2 Events: other internal events not included in Category 1 (10^{-6} < AFO < 10^{-1}) Category 2 events meet the following criteria: internal events that could lead to significant radionuclide release and automatic safety system action cannot prevent the release. • Category 3 Events: external events Category 3 events are natural catastrophic events, meteorological extremes or other disruptive events originating external to the nuclear facility. • Category 4 Events: rare events (AFO < 10^{-6}) Category 4 events are beyond design basis. **AFO = Annual Frequency of Occurrence**
China	Normal Operation AFO > 1 Anticipated Operational Occurrences 10^{-2} < AFO < 1 Infrequent Accidents 10^{-4} < AFO < 10^{-2} Limiting Accidents 10^{-6} < AFO < 10^{-4} Beyond Design Basis Events AFO < 10^{-6}
France	Initiating events are defined in terms of their probability of occurrence. Classifications of 1, 2, 3, and 4 are assigned to events having the following AFO : 1. Operating events AFO > 1 2.Incident events 10^{-2} < AFO < 1 3.Accident events 10^{-1} < AFO < 10^{-2} 4.Hypothetical events 10^{-4} < AFO < 10^{-6} Beyond design base events AFO < 10^{-6}
Germany	In the BMI-Sicherheitskriterien (safety criteria), only operational events and incidents (failure of a system which does not require plant shutdown) on the one hand and accidents on the other hand are distinguished, without determining a frequency of occurrence. Practically, all events occurring at least 1/plant lifetime are operational events. Accidents are not expected to occur during plant lifetime.
India	Initiating events are defined in terms of their probability of occurrence. Design Basis Events are classified as follows according to their annual frequency of occurrence (AFO): 1. Normal AFO ≥ 1 2. Upset 10^{-2} < AFO < 1 3. Emergency 10^{-4} < AFO < 10^{-2} 4. Faulted AFO < 10^{-6} Beyond design basis events AFO < 10^{-6}
Indonesia	AFO have not been, as yet, determined

Table 4 (continued)

Country	Initiating events
Korea	In accordance with the estimated occurrence frequencies and the potential radiological consequences, the postulated initiating events are classified into one of the following reactor conditions. If a high probability event in RC-2 has a high potential consequence, it is grouped in RC-3 or RC-4. RC1 Normal Operation AFO > 1 RC2 Anticipated Operational Occurrences $1 > AFO > 10^{-1}$ RC3 Accident Condition $0.1 > AFO > 10^{-3}$ RC4 Limiting Accident Condition $10^{-3} > AFO > 10^{-6}$ Beyond Design Basis Accident $AFO < 10^{-6}$
Russia	For various RR groups (see Item 4.3.10), accidents are classified as AO1 or AO2 depending on their severity; events are classified within a range extending from PO1 to PO8 according to there severity
Taiwan	The following draft proposition to define AFO’s is currently being examined : Transient $10^{-2} < AFO$ Accident $10^{-4} < AFO < 10^{-2}$ Hypothetical accident $AFO < 10^{-4}$
Yugoslavia	There are no regulations defining design probability criteria for new installations. However the probability of the occurrence of serious core damage for existing nuclear installations should be less than 10^{-4}.

8.5 TABLE 5 : EARTHQUAKES

COUNTRY	Earthquakes
Argentina :	Definition of a: - probable earthquake (most relevant earthquake expected to occur at least once in the reactor's lifetime) and a - severe earthquake (most relevant earthquake which can be reasonably postulated for the site); the probability of occurrence of a more devastating earthquake shall not exceed 10^{-3}
Belgium	Following reference parameters used for BR2 reactor - most significant historical earthquake : maximum intensity at epicenter I = VII (MKS) - safety shutdown earthquake (in vicinity of site) - horizontal Peak Ground Acceleration (PGA) = 0.1g - vertical PGA = 2/3 0.1g Belgian approach based on American Code of Federal Regulations reference 10CFR 100
Canada	Seismic spectra generated from site specific data: - spectra characterizing ground motion and response - design basis spectra and spectra for the determination of structural characteristics Richter scale used for evaluations
China	Design basis earthquakes determined form seismo-tectonic evaluation of region based on: - the maximum historical earthquake - design basis vibratory motion for specific local conditions
France	Concept of safety overestimated earthquake (SMS) determined from the maximum historical earthquake (SMHV) $I_{sms} = I_{smhv} + 1$ (I = intensity) MKS scale used for evaluations
Germany	Concept of dimensioning earthquake (the highest intensity earthquake judged to be scientifically possible within a radius of 200 kilometers around the site). This earthquake is characterized in terms of : - maximum acceleration - duration of the strong motion phase - ground motion and response spectra based on local geological conditions
India	Two design basis earthquakes are considered for nuclear components: - Operating Basis Earthquake - Safety Shutdown Earthquake
Indonesia	Indonesian and German regulations are employed. Response spectra based on the superimposition of modal loads, dynamic models and load combinations have been established for rector building design.
Korea	Geological and seismic characteristics are investigated and analyzed. Both regional earthquake history and current earthquake activity status are taken into consideration. Reactor facilities are installed at sites where geological and seismic investigations have shown the probability of earthquake occurrence of to be low.
Morocco	Recent nuclear site studies involved: - setting up a dynamic geologically based tectonic plate model with seismo-tectonic zones - definition of seismo-tectonic characteristics of the site and surrounding terrain - studies of geographical and stratigraphic characteristics of the site zones - definition of reference earthquakes and local terrain conditions - definition of seismic movements, attenuation of ground acceleration peaks and acceleration spectra - calculation of elastic response spectra
Russia	Design Basis Earthquakes (DBE) and Maximum Calculated Earthquakes are considered . A DBE is an earthquake generating the maximum observed tremor observed over a period of 100 years. An MCE is an earthquake generating the maximum observed tremor likely to occur over a period of 100,000 years
Taiwan	Combination of deterministic and probabilistic methods used for the design of TRR II reactor. PGA's determined from the magnitudes of maximum credible earthquakes that could occur in different regions of the country and there distances from the site. The probability of an earthquake resulting in an acceleration more severe than the design PGA shall not exceed 10^{-3}

Table 5 (continued)

COUNTRY	Earthquakes
USA	The 10 CFR part 100 defines two pertinent earthquakes : – Safe Shutdown Earthquake (SSE) based upon an evaluation of the maximum earthquake considering the regional and local geology and seismology and corresponds to the maximum vibratory ground motion compatible with the continued functioning of critical components – Operating Basis Earthquake (OBE) corresponds to the earthquake that could reasonably be expected to occur during the lifetime of the reactor

8.6 TABLE 6 : ICRP RECOMMENDATIONS

Country	ICRP 60 recommendations, 1996 IAEA Basic Safety Standards and the L159 Euratom Directive
Argentina	Integration of 20mSv (professional exposure) and 1 mSv (public exposure) into national legislation.
Canada	New radiation protection regulations with dose limitations of 1 mSv/y for the public and 20 mSv/y over a 5 year period (limitation of 50 mSv in any one year) for nuclear energy workers have been drafted by the AECB and are awaiting final implementation.
France	France is committed to integrating the legislation of the L159 Euratom Directive on Radiation Protection into its national legislation by the 13th of May 2000. The regulations defined by this Directive are nevertheless already implemented wherever possible (e.g. the new dose limitation of 20 mSv per year for workers and 1 mSv per year for the public). France is however awaiting a decree of application (or similar) which is expected to give more precise information on how the Directive is to be interpreted on a national level
Germany	The L159 Directive is not yet included in the Strahlenschutzverordnung (Radiation Protection Ordinance), but work is under way. For the public, a more restrictive dose limit of 0.3 mSv/year has been employed in Germany for many years.
India	ICRP 60 recommendations are implemented.
Indonesia	The annual dose limitation has up to now been based on a 50 mSv dose limit.
Korea	ICRP 60 recommendations have not been implemented yet.
Morocco	ICRP 60 limits have been integrated into national legislation.
Russia	ICRP limits are not at present imposed for existing installations; however from the 1st of January 2000, the 20mSv limit for workers and 1 mSv limit for the public will be implemented.
Taiwan	ROCAEC regulations will be respected.
USA	The 50 mSv/y limit continues to be applicable in the USA, but is controlled below this limit by ALARA considerations
Yugoslavia	IAEA, BSS (**B**asic **S**afety **S**tandards): 1996, ICRP recommendations and the L159 Directive have been integrated into Yugoslavian regulations.

8.7 TABLE 7 : CLASSIFICATION OF AREAS

Country	Classification of areas
Argentina	Definition of controlled areas (in which workers must respect pre-established procedures to limit exposure and prevent the dispersion of radioactive contamination) and supervised areas (in which it is not necessary to follow specific procedures on a routine basis.
Belgium	Forbidden areas are not defined Controlled areas > 7. 5 µ Sv/h Surveyed areas > 2.5 µ Sv/h Unrestricted areas < 2.5 µ Sv/h
Canada	Radiation zones are usually divided into four categories: 1. ≤ 0.5 µ Sv/h 2. > 0.5 µ Sv/h but < 10 µ Sv/h 3. > 10 µ Sv/h but 4. > 1 mSv/h

	4. > 1 mSv/h but ≤ 100 mSv/h 5. > 100 mSv/h
France	Forbidden areas >100 mSv/h Controlled areas > 7. 5 µ Sv/h Surveyed areas > 2.5 µ Sv/h Unrestricted areas < 2.5 µ Sv/h
Germany	Four areas, based on effective dose limits, are defined in the Strahlenschutzverordnung : – a restricted area, > 0.3 mSv/year – a surveyed area, > 5 mSv/ a (1year = 2000 h) – a controlled area, > 7.5 µSv/h – a forbidden area, > 3 mSv/h
India	Zone 1. White area ≤ 1 µSv/h, absence of contamination Zone 2. Green area ≤ 2.5 µSv/h, area in which contamination is normally ≤ 0.1 DWL and air contamination ≤ 1 DAC Zone 3. Amber area : contamination probability high, area contamination ≤ 10 DWL and air contamination ≤ 1 DAC, Zone 4. Red area : high levels contamination, high levels of radiation, unsealed sources
Indonesia	Radiation areas in Indonesia divided into two categories : Surveyed areas : Low activity (L) : 2.5 µSv/h < 7.5 µSv/h Controlled areas : - Medium activity (M) : 7.5 µSv/h < 2.5 x 10^{-2} mSv/h - High activity (H) : D > 2.5 x 10^{-2} mSv/h

Table 7 (continued)

Country	Classification of areas
Korea	Forbidden area(Contaminated area) > 500 mSv/hr Controlled area(Temporary operations area) <500 mSv/hr Surveyed area(Normal operations area) < 25 µSv/hr Unrestricted area (Clean area) < 6.25 µSv/hr .
Morocco	Controlled areas > 3µ Sv/h Surveyed areas > 1 µ Sv/h Unrestricted areas < 1 µ Sv/h
Russia	The following zones have been defined – Unoccupied rooms and areas in which there are high-levels of external radiation and radioactive contamination – Rooms and areas, temporarily occupied when the equipment inside is under repair; rooms used for the temporary storage of radioactive waste, etc are also classified in this zone – Rooms and areas, permanently occupied by workers.

Taiwan	• Radiation Area
	  – Controlled area > 7.5 µSv/h
	  – Surveyed area > 2.5 µSv/h
	  – Unrestricted area < 2.5 µSv/h
	
	• Contaminated Area
	  – α > 0.4 Bq/100 cm^2
	  – β and/or ϒ >4 Bq/100 cm^2

Yugoslavia	Controlled and surveyed areas are distinguished by the fact that the dose rate in controlled areas may exceed 3/10th of the dose limit.

8.8 TABLE 8 : FUEL STORAGE

Country	Fuel Storage
Argentina	The design shall guarantee that the irradiated fuel elements are stored in a geometrical layout that guarantees sub-criticality with an anti-reactivity margin of at least 11% and allowing for sufficient natural-convection cooling, so that the integrity of the cladding is not threatened. Adequate biological shielding should be provided. Fuel may be stored in a pool or in a dry storage (inside sealed drums) depending on the of decay heat.
Canada	Spent fuel elements are stored in a pool for cooling over several years. They are then moved to an intermediate-term dry storage at an approved waste management area.
France	Spent nuclear fuel elements are suitably emplaced in the reactor pool for cooling over a one to two year period during which the activity due to short half-life fission products diminishes. After this period the elements are removed from the reactor pool and stored elsewhere (under wet or dry conditions depending on their activities).
Germany	Spent nuclear fuel elements are stored in the plant under water. Depending on the decay heat, they may be moved into transport casks as early as handling under gas atmosphere becomes feasible. Transport casks are stored in intermediate storage facilities, or transferred to the country that delivered the fresh fuel.
India	Spent fuel elements are stored in the reactor or outside under water to allow for decay heat from fission products to reduce to acceptable levels. They can be stored under air cooling after decay heat has been reduced to acceptable levels after their storage in the reactor for an adequate time. Special containment is provided for storage of spent fuel if deemed necessary.
Indonesia	Spent fuel elements are stored in two racks located in the reactor pool; sub-criticality is prevented by neutron absorber material. Due to the limited capacity of the rack (sufficient space for 200 assemblies), BATAN has constructed the new spent fuel storage presently being commissioned.
Korea	Spent fuel assemblies are suitably emplaced in the spent fuel storage pool which is designed to store spent fuels for 20 years operation at design power and has a cooling system for decay heat removal as well as its own purification system to keep the water as required.
Russia	Fuel storage of fuel is carried out in compliance with Safety Regulations. Nuclear fuel from research reactors is emplaced in a cooling pool, which assures cooling over a period of more than 3 years during which the activity of the fission products present decreases. The fuel can then be transported to a processing facility.
Taiwan	Spent nuclear fuel elements are stored in the spent fuel pool before being removed and stored elsewhere. A lifetime (forty years) of spent fuel pool storage capacity has been proposed for the TRR II project.
USA	Disposal not currently available in the US for spent fuel. Spent reactor fuel (low enrichment) from power reactors is kept on site. High enriched fuel is sent to government centers for eventual disposal.
Yugoslavia	According to the original project, spent nuclear fuel from the 6.5MW research reactor, RA, has to be temporarily stored at the spent fuel pool in the reactor building. After 4 to 5 years of cooling this fuel will be removed for reprocessing or permanent storage. However, all spent fuel resulting from 25 years of RA reactor operation is still stored in the temporary storage pool, which has recently been identified as a serious safety problem. Measures have thus been initiated in order to identify the actual state of the fuel, to improve storage conditions in the existing pool, as well as to propose a long term or permanent solution for the problem. There are no specific legal regulations or practice concerning this matter.

8.9 TABLE 9 : RADIOACTIVE WASTE MANAGEMENT

Country	Radioactive waste management
Argentina	Research Reactors are obliged to have suitable practices to handle, monitor and store radioactive wastes on a temporary basis. The National Atomic Energy Commission (CNEA) is responsible for medium and long term storage of radioactive wastes.
Belgium	The official guidelines for the management of radioactive waste have been established and are enforced by the National Organization for Radioactive Waste and Fissile Material: (*NIRAS/ONDRAF) *similar to ONDRA.
Canada	AECB have established regulatory guidelines for radioactive waste management. It has also set a de minimis dose of 0.05 mSv per year for deciding exemptions from AECB licensing on a case-by-case basis, provided that the radiological impact will be localized and the potential for exposure of large populations is small.
France	A law edicted the 15th of July 1971 (not specific for radioactive waste) states that the ***producers*** of waste are responsible for their wastes up until the time that these wastes have been disposed of, treated or eliminated in compliance with the law. Radioactive waste can only be eliminated in compliance with the directives of the appropriate decrees. The decree of the 20th of June 1966, modified in 1988 does not impose obligations for the disposal of substances with activity levels less than 100 Bq/g for artificial radionuclides or 500 Bq/g for naturally occurring radionuclides. Regulations do not, as yet, exist for activities below these limits.
Germany	Producers of waste are responsible for waste up until its treatment, disposal or elimination in compliance with legal dispositions. The overall target for waste treatment is that humans should not be exposed to a dose exceeding 10 μSv/y due to waste disposal, treatment or elimination. Wastes with surface contamination less than the following values may be treated as non-radioactive: 0.05 Bq/cm^2 for α contamination, 5 Bq/cm^2 for β contamination, 0.5 Bq/cm^2 for contamination by other radionuclides.
India	Solid wastes are classified in 4 categories depending on surface dose rates: Category I (≤ 2 mGy/h), Category II (2 to 20 mGy/h), Category III (> 20 mGy/h). These apply to wastes with beta, gamma emitters. Category IV is for alpha bearing wastes, with dominant alpha activities. There is also a stipulation that the specific activity levels (in Bq/m^3 or Bq/g) should be indicated for all four categories of waste in order to be able to estimate total activities. Different categories also exist for liquid and gaseous wastes.
Indonesia	Substances with activities less than 37 Bq/l, can be disposed of, provided due consideration is given to the half-lives of the radionuclides in these wastes. Conformity with IAEA recommendations for A, B and C type wastes.
Korea	Regarding the radioactive waste management, the law divides the treatment into three steps: prevention of contamination, disposal and storage. The following criteria apply to waste storage: - Equipment shall have sufficient capacity to store radioactive wastes produced during the normal operation of the facility - Equipment shall be capable of withstanding decay heat and heat generated by irradiation, and there shall not be any significant chemical corrosion risks - Contamination by radioactive waste shall not be dispersed. In facilities where liquid radioactive waste storage equipment is installed, catchment areas shall be installed in order to prevent the leakage of liquid radioactive wastes outside facilities as a result of equipment failing or malfunctioning.

Table 9 (continued)

Country	Radioactive waste management
Russia	The responsibility for collecting and conditioning radioactive waste is attributed to the company/organization generating the waste. Sites intended as repositories or for the temporary storage of waste shall be selected in coordination with the health authorities. Liquid radioactive waste shall be considered radioactive, if its specific activity exceeds between (1 and 4.2) x 10^4 Bq/kg depending upon the contaminating isotopes present. Liquid radioactive waste is divided into three categories: low-activity – up to 370 Bq/kg medium-activity – from 370 to 37 GBq/kg high-activity greater than 37 GBq/kg Solid radioactive waste shall be considered as radioactive, if its specific activity is greater than: 74 kBq/kg – for alpha and beta emitting substances 10^{-7} g. eqv. Ra/kg – for gamma emitting substances or if there is more than: 0.37 kBq present – for transuranic elements or if there are more than: 5 alpha particles per 100 cm^2 or 50 beta particles per 100 cm^2 for items exhibiting surface contamination Solid radioactive waste is divided into three groups depending on the dose rate at a distance of 10 cm: Group I – up to 0.3 mSv/h Group II – between 0.3 mSv/h and 10 mSv/h Group III – greater than 10 mSv/h.
Taiwan	The producers of radioactive waste are responsible for waste minimization, volume reduction as well as waste treatment, storage and final disposal. The radwaste code declares clearance levels. Radwaste with activities below these levels can be exempted after safety assessment. Fuel Cycle and Materials Administration (FCMA), a subsidiary of ROCAEC, is charged with regulating the safe management of radioactive waste, nuclear fuels and nuclear source materials. The supplementary regulations for radwaste categories, issued by FCMA, define four types of waste, namely, A, B, C and C^+ classes. The classification is based on the specific activities of nuclides. Waste has to be stabilized for displacement except type A. In TRR decommissioning, type A, B, and C waste were generated. – type A waste from dismantled equipment – type B waste from core internal components – type C waste from the spent fuel pool
Yugoslavia	Producers of waste are responsible for their wastes. Their responsibility is to keep the waste temporarily on the site and to contact the authorized institution for its collection and temporary storage. There is no final radioactive waste disposal facility in Yugoslavia. All radioactive waste (medium and low level) is kept in temporary storage at the site of the VINCA Institute of Nuclear Energy. According to the law a new facility for the final disposal of medium and low level radioactive waste has to be built before the year 2002. At the moment the implementation of IAEA standards for RADWASS in Yugoslavia is in progress.