Multinational Design Evaluation Programme
Technical Report
TR-EPRWG-01

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MDEP Technical Report TR-EPRWG-01

Related to: EPR Working Group activities

REGULATORY APPROACHES AND CRITERIA USED IN THE ANALYSIS OF ACCIDENTS AND TRANSIENTS IN MDEP EPRWG MEMBER COUNTRIES

Participation

Countries involved in the MDEP working group discussions:	Canada, China, France, Finland, the United Kingdom and the United States
Countries which support the present common position	China, France, Finland, the United Kingdom, and the United States
Countries with no objection:	India, Sweden
Countries which disagree	
Compatible with existing IAEA related documents	

Objective and Scope of this document

This document aims to summarize key aspects of approaches used by the MDEP in evaluating the analyses submitted by the designer or a licence applicant. It is hoped that having such a summary allows us better appreciating similarities and understanding differences in national practices. The benefit of this effort is seen to be in facilitation of sharing experiences, in the short term, and harmonization of practices, in the long term.

The focus of the information presented in the document, as well as of the work of the EPR technical sub-group on Accidents and Transients is on the events traditionally included in the so called design basis. A separate sub-group deals with Severe Accidents and the relevant analysis methods.

Summary of similarities and key differences

1. Legislative basis

This section is for general information, primarily. All MDEP countries have mature legal basis for requirements for safety of NPP. The recent (~ last 10 years) changes represent fine-tuning of requirements based on the accumulated experience and expectations for new plants rather than fundamental shift in the regulatory views or practices.

2. Use of analysis

Analysis of Accidents and Transients serves multiple purposes, such as justification of design solutions, licensing at various phases, fuel reload or fuel management, development of emergency operating procedures, selection of operating limits and conditions, etc. The regulatory requirements for the analyses for all of the above purposes appear to be identical within each regulatory agency; however the degree of regulatory scrutiny would depend on the specific analysis objectives.

The licensees are expected to keep the analyses up to date and update them as necessary (when the existing analysis could no longer be considered adequate), for example in the following cases:

- During periodic safety reviews
- Renewal of operating licenses
- Due to significant modifications (such as power uprating, fuel burnup increase)
- In response to significant emerging technical issues which mandate an immediate revision of current practices
- To account for changes in operating practices (fuel reloads), etc.

3. Design Basis

Design Basis fault analysis examines the response of a system to the most severe reasonably foreseeable faults in each of the operating systems normally required. The analysis routinely makes pessimistic assumptions relating to safety system response and assumes that prior to the fault, the plant is operating at the most limiting conditions defined in the plant operating rules.

The concept of Design Basis is used in all countries and broadly they require a conservative deterministic analysis for initiating faults with a return frequency greater than typically 1 10^{-5} / a..

In the case of more frequent Anticipated Operational Occurrences (AOO), it is usual to expect a higher level of unrevealed or consequential failures in systems designed to mitigate the fault. However, the scope and definitions of events and conditions included in DB varies from country to country.

	Normal operation	AOO/Frequent	DBA	BDBA	BDBA*
Finland	DBC1	DBC2 f > 10-2 1/a	DBC3 10-2 > f >10-3 1/a DBC4 10-3 > f >10-5 1/a	Severe accidents f < 10-5 1/a	Design extension conditions DEC-A DEC-B
France	PCC1	PCC2 f > 10-2 1/a	PCC3 10-2 > f >10-4 1/a	Severe accidents	Risk Reduction Category RRC-A

			PCC4 10-4 > f >10-6 1/a		RRC-B
US	√	AOO	DBA	Severe accidents	
UK	√	f >10-3 1/a	f >10-5 1/a	Severe accidents f < 10-5 1/a	Classification up to designer
Canada	√	AOO f > 10-2 1/a	DBA 10-2 > f >10-5 1/a	BDBA f < 10-5 1/a	

In all countries, it is the applicant who is expected to identify the specific list of events/faults to be analyzed for a given facility. Classification of events or faults is done on the basis of their probabilities of occurrence with elements of engineering judgment and deterministic prescription.

Independent combinations of faults in a single accident are included in the scope of analysis as the design extension conditions (Finland), risk reduction category (France), or BDBA/Severe Accidents. A postulated worst single failure is not considered as an independent failure combined with the initiating event but is an analysis assumption. Special cases exist in some jurisdictions that postulate additional failures for certain events (US – station blackout and ATWS).

Expectations for demonstration of diversity of safety functions appear to be different in each country; however the exact nature of differences cannot be established from the brief information provided.

4. Analysis Methodology

Each regulator seems to employ a notion of the “analysis method” or “analysis methodology” but the exact definition appear to vary significantly. The common elements of the analysis method among all regulators are the computer codes and their input data sets. Other elements may include:

- assumptions
- uncertainties in input parameters and models
- acceptance criteria
- selection of key phenomena and parameters
- code validation information
- selection of bounding scenarios

- procedures for treating analysis inputs and outputs.

The overall objective is to demonstrate with a high level of confidence that plant operating limits are set at levels which ensure that the postulated fault will not lead to unacceptable levels of plant damage.

With the exception of US NRC, the analysis methods are not formally approved by the regulator. Nevertheless, all regulators are evaluating methods as part of, or prior to, acceptance of the analysis results.

Explicit requirements for conservatism of analysis of transients and accidents are spelled out only by the US NRC. Other regulators identified the general expectation that the analyses of design basis accidents are conservative but it is left to the applicant to select approaches such that there would be high confidence in demonstrating compliance with safety limits. Making sure that the analysis gives conservative results is a general way of providing safety margins; at the moment there are no specific requirements to establishing or demonstrating margins in safety analysis.

All regulators expect that the various uncertainties (in operating parameters, models or plant representation) be accounted for. The methods for achieving this are left to the applicant. Two principal approaches are identified – either by conducting sensitivity studies with conservative analysis, or by performing best estimate analysis supplemented by a systematic uncertainty assessment.

Non-safety grade (non-qualified) systems are not accepted to be credited in the analysis, unless their actions are detrimental to safety. The operator actions can be credited in certain circumstances (sufficient time, adequate indications) but in general it is expected that there should be no reliance on the operator intervention to terminate the accident.

5. Acceptance criteria

The approaches to setting the analysis acceptance criteria vary from country to country, as well as within countries. Some of the criteria are given in legally binding documents such as the laws or government decrees. Other criteria are set in regulatory guides, established through historical practices or selected by the reactor designer. There is also no hierarchy of the criteria, meaning that all established criteria should be met at the same time. In some countries, in particular the UK, the licensee can argue that the risk to the public has been reduced as low as reasonably practicable if some of the criteria have not been met (it should be noted that in the UK the licensee may also need to take further measures if it is practicable to do so despite all identified criteria being met). On the other hand, in Finland the designer has no other option but demonstrate that the existing criteria are met. In France, US and Canada the applicant may propose alternative, new criteria if justified by the R&D results.

In practice, there is more convergence in numerical limits than in the underlining regulatory framework. For example, in the area of fuel performance, the OECD Committee on the Safety of Nuclear Installations (CSNI) has a working group tasked with achieving convergence. The Working Group on Fuel Safety Margins (WGFSM) enables exchange of information on fuel criteria and the following reference compares the criteria used in member countries: http://www.oecd-nea.org/nsd/docs/2003/csni-r2003-10.pdf

6. Analytical tools

All regulators expect that the codes used analysis of A&T would be validated (the alternatively term used is “qualified”); moreover, there are specific guidelines on what should be covered in code validation. All countries accept best estimate codes with varying degree of preference (STUK requires code to be best estimate, others “encourage” use of best estimate codes).

With the exception of NRC, the regulatory agencies do not approve codes for use in safety analyses. Some regulators (or the TSO on their behalf) maintain a set of independent codes for confirmatory assessments, while others may engage independent contractors for undertaking verification on a case by case basis.

7. Plant representation

Aging effects are taken into account in performing analysis where important. Examples include heat exchangers’ fouling or steam generator tube plugging, changes in fuel cladding material properties with irradiation and oxidation, etc.

All regulators require that a single most penalizing failure be considered in safety systems (i.e., systems used to demonstrate meeting safety criteria). Loss of off-site power for many events is postulated in some countries if this is more limiting.

Plant nodalization is up to the applicant to develop and support; there are no regulatory expectations in this respect.

8. Documentation

All regulators identify to the prospective applicants the list of documents that must be submitted in support of licensing analysis – it is interesting to note that the indicated documents are quite different, at least at the first glance. However, the common theme is that the documentation needs to provide sufficient information to quality the analysis method for use under defined conditions and to provide sufficient information to minimize the likelihood of user error.

Recommendations and Conclusions

It is recommended by the EPR sub-group on Analysis of Accidents and Transients that this document be issued as an MDEP product. It presents, albeit in a condensed form, an overview of existing practices used by the regulatory agencies in evaluation of safety analyses in support of licensing (or certification) of the EPR. This information will assist in appreciation of national practices in MDEP countries used in the regulatory evaluations of EPF analyses of faults and accidents.

Attachment: Full questionnaires

<table>
<tr><th colspan="2">Country</th><th>Response</th></tr>
<tr><td rowspan="3">Legislative Basis</td><td colspan="2">What are the most relevant legal and regulatory documents that govern the analysis of A&T? List those in hierarchical order</td></tr>
<tr><td>Finland</td><td>Top level requirements for methodology have been given in Nuclear energy act and Governmental degree 733/2008, which are mandatory.

Detailed requirements are given in
YVL guide 2.2 - Transient and accident analyses for justification of technical solutions at nuclear power plants,
YVL guide 2.4 - Primary and secondary circuit pressure control at a nuclear power plant,
YVL guide 6.2 - Design bases and general design criteria for nuclear fuel.</td></tr>
<tr><td>France</td><td>1) The 13 June 2006 law concerning nuclear transparency and safety (TSN Act)
2) The 2 November 2007 application decree (articles 10 and 20)
3) The creation authorization decree of the plant
4) ASN's prescriptions for the plant

This set of regulatory documents will be completed in the near future by:
• A ministerial order, presently submitted to consultation;
• A set of regulatory ASN decisions, presently under preparation or consultation.

Comments:
• According to the article 29 of the TSN Act: “the licensee proves that the technical or organizational measures taken or envisaged at the design [..] are likely to prevent or limit sufficiently the risks and drawbacks which the installation presents for the interests mentioned in I of article 28.” (i.e., safety, security, health , environment).
• The creation authorization decree is passed after consulting ASN, following a report from the ministers responsible for nuclear safety.
• The ministerial order: “arrêté régime INB” will specify the expectations for the demonstration of safety (public consultation on the draft order was ongoing as of October 2010, through the ASN website: www.asn.fr.)
• The new French regulations incorporate the safety "reference levels" developed by WENRA.
• Regulatory ASN decisions about “design basis” and “safety case” are undergoing public consultation too.</td></tr>
</table>

	Country	**Response**
Legislative Basis	**US**	The national law is the *Atomic Energy Act* of 1954 as amended. The regulations that implement the act are contained in *10 CFR Parts 50 and 52*. Specifically, 10 CFR 50.46 and Appendix K contain specific requirements associated with analysis of accidents and transients. *Regulatory Guide 1.157, Best-Estimate Calculations of Emergency Core Cooling System Performance,* and *Regulatory Guide 1.203 Transient and Accident Analysis Methods* provides specific guidance on our exceptions associated with analysis methodologies. Chapter 15 of *NUREG-0800 Standard Review Plan* describes the specific analysis needed.
	UK	Health and Safety at Work Act (1974) which requires all risk to be reduced so far as is reasonably practicable and includes the Nuclear Installation Act as one of its relevant provisions. The Nuclear Installation Act requires that all Nuclear Installations have a site licence. It also enables HSE to attach a series of Licence Conditions to the licence. It is through these licence conditions that HSE derives its primary powers to issue consents, Directions, Approvals, Specifications, Notifications and Agreements. The licensee also effectively grants secondary powers to HSE

Country		Response
		via its arrangements to meet the licence conditions. HSE specify that they must be informed of the licensee's arrangements. The licensee is then bound to follow them. HSE can chose to Agree to a licensee's arrangements in which case, they can not be changed without Agreement from HSE. In order to demonstrate that risk is as low as reasonably practical, the arrangements require that a safety case be written; documenting the evidence that any further enhancement to safety would incur a cost disproportionate to the safety benefit that would accrue. Significant modifications to the safety case would generally require HSE Approval.
	Canada	The national law is the *Nuclear Safety and Control Act*, which came into force on May 31, 2000. Under the *Act*, the Canadian Nuclear Safety Commission has put in place by-laws and regulations, including: *General Nuclear Safety and Control Regulations* *Class I Nuclear Facilities Regulations* The latter, in particular, requires that to obtain a licence, the applicant shall provide a "safety analysis report demonstrating the adequacy of the design of the nuclear facility". In 2008, Regulatory Document RD-310 was issued, providing high level regulatory expectations on safety analysis for a nuclear power plant. RD-310 or similar regulatory documents would constitute formal requirements once cited in a licence.
	China	The national law is Civil Nuclear Safety Control Regulations, which came into force on Oct 29, 1986. The regulations that implement the law are contained in "Nuclear Power Plant Design Safety Requirements". "Safety Assessment and Verification for Nuclear Power Plant" provides specific guidance.
Legislative Basis	**Has there been a change in the scope of requirements in the recent years (say during the transition from Gen II reactors to Gen III)? If yes, highlight the major changes**	
	Finland	Following changes have been introduced into our regulations during the last 10 years: • Postulated accidents have been divided into to classes i.e. Class 1 accidents and Class 2 accidents depending on their frequency. Class 1 (DBC 3), 10-2/a > f > 10-3/a , Class 2 (DBC 4), f < 10-3/a • A new category of conditions (i.e. design extension conditions) was introduced, which is mainly related to common cause failures in safety systems and multiple failures and rare external events.

Country		**Response**
	France	No real change in the scope of requirements but ASN admits some change in the design basis and its consequences on the safety demonstration: EPR Technical Guidelines: • "The complete guillotine rupture of a large pipe correctly designed, manufactured and inspected is very unlikely; so, when adequate design, manufacturing and inspection provisions are implemented, the complete guillotine break of a main coolant line can be "excluded" (with the meaning of section A.1.4)". • "The loads to be considered for the design of the internal structures of the reactor vessel and for the design of the structures in the containment building are then limited to those resulting from a break equivalent to the complete guillotine rupture of the largest pipe connected to a main coolant line (surge line)". Comments: These technical guidelines present the opinion of the French standing group for reactor safety (Groupe Permanent chargé des Réacteurs nucléaire - GPR) concerning the safety philosophy and approach as well as the general safety requirement to be applied for the design and construction of the next generation of nuclear power plants of the PWR (pressurized water reactor) type. On the 28th September of 2004, the ASN Chief Executive Officer in the name of the French minister in charge of industry and environment gave his opinion to the petitioner based on the GPR and TSO recommendations.
	US	There has been no change in scope of the requirements in the USA. The most recent requirement change occurred in the 1980s when conservative analysis has been allowed to be replaced by best estimate analyses with uncertainties. The NRC has put a greater emphasis on methodologies due to operating experience where the misuse of methodologies was identified. These issues were addressed with the issuance of *Regulatory Guide 1.157, Best-Estimate Calculations of Emergency Core Cooling System Performance,* and *Regulatory Guide 1.203 Transient and Accident Analysis Methods*. The *Standard Review Plan* was recently revised. The revision included minor changes in the event classifications.
Legislat ive	**UK**	There has been no change in the scope of the requirements in the UK. However, to reduce the regulatory risk for new build the UK has established the Generic Design Assessment process. This is allowing reactor vendors to submit their design to HSE in advance of the site licensing process. Although the GDA has no formal legal standing, HSE has committed that it will not reassess issues during site licensing that it has closed during the GDA process without good reason.

Country		Response
	Canada	Some relatively substantial changes in the area of safety analysis have occurred with the issue of a regulatory document RD-310 Safety Analysis for Nuclear Power Plants. This document is aligned with the recent IAEA publications on the deterministic safety analysis. For example, one of the significant changes, compared with the earlier Canadian practice, is the formal definition and requirement to consider Anticipated Operational Occurrences (AOO), Design Basis Accidents (DBA) and Beyond Design Basis Accidents (BDBA). However, for the currently operating plants, the previously issues regulatory requirements continue to apply, at least for the time being
	China	Nuclear safety guide HAD102/17 “Safety Assessment and Verification for Nuclear Power Plant” is issued on Jun 5, 2006

Country		Response
Use of analysis of Accidents and Transients	**What are the uses of the analysis of A&T? (For example, design support, licensing, support of OLC, fuel reloads, etc)**	
	Finland	Analysis are used for: • Design support (justification of technical solutions, safety classification etc) • Licensing (first at construction permit phase then operating licence phase, periodic safety assessment and licence renewal) • Emergency operational procedures • Fuel reloading analysis if necessary
	France	A&T analyses are used to support all of these activities especially: • Licensing to deliver the authorization decree • Change in fuel or fuel management • Fuel reload • OLC • Periodic testing of safety classed equipment
	US	All of these. Design changes, material changes, changes in operating practices all result in analysis of accidents and transients.
	UK	A&T analyses are used to support all of these activities.
	Canada	All of these. Most frequently, deterministic analyses for operating reactors are performed to support changes in design of systems or in plant operating conditions. For new reactors, the analysis supports the licensing application for construction and operating licenses.
	China	All of these.
	Are requirements for various analysis uses (identified above) identical? For example, are the same regulatory documents applicable? Would regulatory evaluations be equally detailed?	
	Finland	Requirements for various analyses are identical. STUK identify the most important cases (dimensioning) at each accident category and review them in detail.
	France	From a regulatory point of view, all these analyses shall show that the risks are prevented or strictly limited; so the requirements are fundamentally the same. The applicable documents are also the same (basically the 2007 decree, which states what the licensee has to do when he envisages modifying the plant or its general operating rules. Obviously, regulatory evaluation is more detailed for licensing than for fuel reload.

Country		Response
		In case of modifications of the plant, the decree requires to identify if there is any change in the safety case.
Use of analysis of Accidents and Transients	**US**	The regulatory requirements for loss of coolant accidents (LOCAs) are spelled out in detail. Regulatory requirements for other accidents and transients are not explicitly spelled out in the regulations. However, we hold applicants to a similar standard on all accidents and transients.
	UK	The regulatory documents used for assessment of licensee's submissions are identical for all licensing activities. These are the HSE Safety Assessment Principles (SAPs) and the supporting Technical Assessment Guides (TAGs). However, the depth of assessment carried out against the SAPs is determined by the professional judgment of the technical assessment inspector. Note that under the licence condition arrangements, the licensee is expected to categorize modifications to plant according to their safety significance. Less significant modifications would not be subject to formal regulatory assessment and approval.
	Canada	Regulatory requirements for all analyses are the same and are spelled out in the regulatory document RD-310. The scope of the regulatory evaluations may depend on the perceived risk significance as well as the novelty of the method and application.
	China	Requirements for various analyses are identical.
	Are there requirements to update earlier analyses from time to time, or due to specific reasons? For example, in the context of Periodic Safety reviews.	
	Finland	Analyses are required to be updated from time to time i.e. during periodic safety assessment, operating licence renewal or if major modifications at NPP are carried out, for instance during power uprating.
	France	The licensee must update the safety analysis report when he declares a modification of his plant that has an impact on it. This can involve updating the analysis of some A & Ts. Of course this is more likely to happen when big modifications (e.g. power increase or change in fuel burnup) are introduced rather than smaller ones. The licensee is expected to perform periodic safety reviews every ten years (TSN Act). On these occasions, he has to assess the situation of his plant according to the regulations and to update the assessment of the risks. Usually these reviews focus on plant modifications and some accidents but there is no obligation to update all the A&T studies on this occasion. In any case the licensees must maintain their safety demonstration up-to-date (TSN act).
	US	There are no specific requirements to update the analyses on a specific frequency; however, licensees are required to keep the analyses up to date. As the designs and operating practices (including reloads) are changed the analyses are changed as well. Regulatory documents (FSAR) are updated on a two year frequency and if any individual change requires NRC approval it is submitted to the NRC. 10 CFR 50.46 places reporting requirements on corrections and changes to LOCA analysis methods and plant reanalysis.
	UK	The licensees are expected to perform periodic safety reviews, typically every ten years. These reviews focus on updates to the safety case, operational experience, assessment against modern standards and an assessment of ageing issues. There are also

Country		Response
		periodic statutory outages, typically every three years on the AGRs, during which the licensee performs inspections according to a program that is agreed in advance with HSE. However, there is not a requirement to repeat analysis with the best available means. Reanalysis would only be performed if the existing analysis was no longer considered fit for purpose.
	Canada	In the Canadian practice, the plant Safety Reports are updated periodically, in accordance with the regulatory standard S-99, to reflect changes in the plant design, operating conditions and improved knowledge. Canada is moving towards implementation of the Periodic Safety Review process, as recommended by the IAEA. Once formalized, the PSR would necessitate a more formal and extensive re-evaluation of various safety areas, including safety analyses, on a periodic basis.
	China	There are no specific requirements, but reanalysis should be performed if there are important safety-related changes at NPP, and the licensee should update the safety analysis report.

<table>
<tr><th>Country</th><th></th><th>Response</th></tr>
<tr><td rowspan="3">Design basis / Analyzed events</td><td colspan="2">Is the concept of design basis used? If yes, how is it defined?</td></tr>
<tr><td>Finland</td><td>Yes. Postulated initiating events are divided into different design bases conditions (DBC). Division is based on the frequency of an event on the following way:

Normal operation (DBC 1)
Anticipated operational occurrences (DBC 2), f > 10-2/a
Postulated (design basis) accidents

Class 1 (DBC 3), 10-2/a > f > 10-3/a
Class 2 (DBC 4), f < 10-3/a

Design extension conditions (DEC)

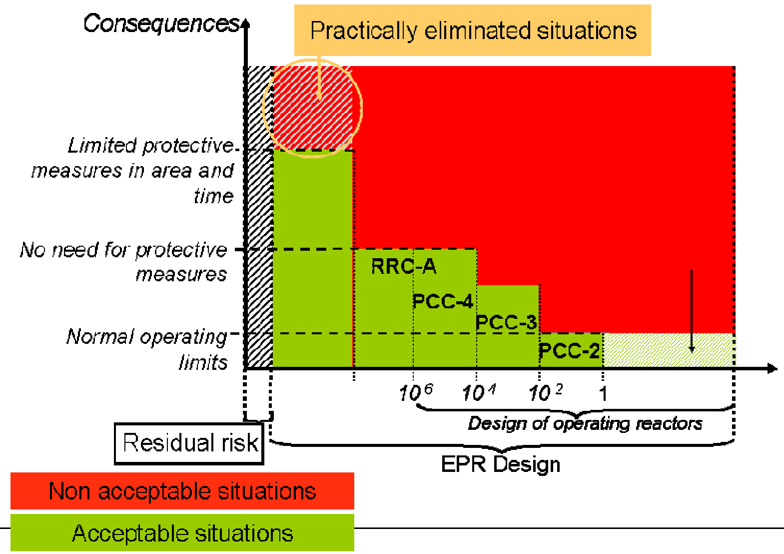
DEC A - includes conditions in which a common cause failure (CCF) in a safety system is assumed during anticipated operational occurrence (DBC 2) or class 1 accident (DBC 3)
DEC B - includes complex sequences and rare external events

Severe accidents f < 10-5/a
</td></tr>
<tr><td>France</td><td>Yes. For EPR the design basis is structured as follows :

3 categories of A&T studies:

1) The PCC (plant condition category) studies, with one initiating fault taken into account, are performed in a deterministic way to implement limit conditions in the I&C protection system and to prove the compliance with the safety thresholds.

Probability of occurrence associated:

<u>Category occurrence radiological consequences</u>
PCC1 1 =normal dose < 10µSV/year
PCC2 10-2 to 1 dose < 10µSV/ year
PCC3 10-4 to 10-2 body dose < 15 mSV
PCC4 10-6 to 10-4 body dose < 150 mSV

</td></tr>
</table>

	Country	Response
Design basis / Analyzed events		2) The RRC (Risk Reduction Category) studies, with multiple initiating events taking into account a probabilistic analysis. For some RRC B situations, technical devices must lead to the practical elimination of the accident. RRC-A: all combinations of initiating events taking into account the probabilistic studies and uses for the design basis RRC-B: serious accident (core melt) in order to reduce the consequences 3) Probabilistic studies: to identify sequences that lead to the core melt (PSA level 1) and radiological releases (PSA level 2).
	US	The concept of Design Basis is used in the USA. The regulations in 10 CFR Part 50.2 define Design Basis as "Design bases *means that information which identifies the specific functions to be performed by a structure, system, or component of a facility, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. These values may be (1) restraints derived from generally accepted "state of the art" practices for achieving functional goals, or (2) requirements derived from analysis (based on calculation and/or experiments) of the effects of a postulated accident for which a structure, system, or component must meet its functional goals*."
	UK	Yes. The fault analysis SAP, FA.5, requires that all initiating faults with the potential to result in significant releases and which have an initiating frequency greater than 1 x 10^{-5} per year are assessed using design basis methods. The exception is natural hazards for which a conservatively assessed initiating frequency of 1 x 10^{-4} per year is required. In addition, the design basis is considered to extend to cover all fault sequences with a frequency greater than 1 x 10^{-7} per year.
	Canada	The concept of Design Basis is currently widely used in Canada with the definition given by the IAEA "*The range of conditions and events taken explicitly into account in the design of a facility, according to established criteria, such that the facility can withstand them without exceeding authorized limits by the planned operation of safety systems*."
	China	Yes. Postulated initiating events are divided into different design bases conditions: Normal operation Anticipated operational occurrences Design basis accident Beyond design basis accident(including severe accident)
	How is the scope of events/faults for analysis (postulated initiating events) defined? Is the list of such events fully prescribed? Is it up to the designer/vendor/licensee to propose a list of events based on some principles?	
	Finland	Designer/vendor/licensee proposes the cases to be analyzed at each category during construction permit phase in PSAR.

Country		Response
	France	ASN expects the vendor/licensee to identify the list of faults and sequences for the different categories of accident studies but there is at the present time no regulatory requirements. For EPR, some events are defined in the technical guidelines.
Design basis / Analyzed events	**US**	With the exception of LOCA, which is specifically defined, the scope of events is not explicitly defined. The applicant specifies the design basis accidents. There is reasonably detailed guidance in Chapter 15 of *NUREG-0800 Standard Review Plan* for selecting the design basis accidents. Events are classified as AOOs and Postulated Accidents. Severe accidents are described in Chapter 19 of *NUREG-0800 Standard Review Plan*.
	UK	HSE expects the vendor/licensee to identify the list of faults using a process that is systematic, auditable and comprehensive as identified in SAP FA.2.
	Canada	In the past the list of events to be considered in safety analysis was essentially defined by the regulator. Since 2008, when RD-310 was published, it is the responsibility of the designer to implement a systematic process for identifying events to be included in the analysis and for characterizing them as AOO, DBA or BDBA.
	China	The list of events is prescribed for PWRs. Designer/vendor/licensee propose the list of events according to probabilities and engineering judgments for special reactors.
	Is the scope of analyzed events based on probabilities or engineering judgment?	
	Finland	The scope of analyses covers deterministic and probabilistic analyses and in some cases also engineering judgments.
	France	The scope of analyzed events depends on both probabilities and engineering judgment. The probability of occurrence of the event is taken into account and engineering judgment is used to make sure that all the postulated events which could lead to important consequences are considered in the analysis.
	US	The scope of analyzed events is described in the Standard Review Plan and are categorized by frequency. As such, the AOO are the events that are expected to occur one or more times in the life of a plant. Postulated accidents are unanticipated events.
	UK	As noted above, the frequency and unmitigated consequences of the postulated initiating event are taken into account. This would be supported by engineering judgment to ensure there is no potential cliff edge in the consequences just beyond the design basis frequency.
	Canada	The scope of analyzed events is defined mainly by their likelihood. As such, the AOO are the events with the probability of occurrence of greater than 10^{-2} 1/y; DBA in the range of 10^{-5} 1/y to 10^{-2} 1/y; and BDBA have frequency of less than 10^{-5} 1/y. On the other hand, the uncertainty in determining the frequency of occurrence also need to be taken into account as well as grouping of individual events into representative categories. A degree of engineering judgment inevitably remains.

Country		Response
	China	Yes. The scope of analyzed events is bases on probabilities and engineering judgments.
	Are combinations of independent failures/faults considered?	
	Finland	Yes. This is covered in design extension condition analyses.
	France	Yes, for sequence frequencies greater than 10^{-6} per year (RRC), it's the aim of RRC studies.
Design basis / Analyzed events	**US**	Combinations of independent failures of safety-related equipment are typically not considered in the design basis with the exception that the worst single failure must be considered. Multiple failures are evaluated under severe accidents and the PRA. There are certain exceptions – station blackout and ATWS are specifically evaluated as special cases. Although multiple failures are not considered, offsite power and non-safety systems (e.g., reactor coolant pumps and main feed water) are assumed to function if it is more limiting or not function if it is more limiting.
	UK	Yes, for sequence frequencies greater than 10^{-7} per year.
	Canada	Combinations of independent failures are not excluded from the consideration and are subject to the same frequency rules (see above) in defining whether an event combination is a DBA or BDBA. Nevertheless, it is expected that such combinations in the design basis accident range of frequencies would not be a significant group.
	China	Combinations of independent failures of safety-related equipment are typically not considered in the design basis with the exception that the worst single failure must be considered. Multiple failures are evaluated under severe accidents and the PRA. There are certain exceptions – station blackout and ATWS are specifically evaluated as special cases. Although multiple failures are not considered, offsite power and non-safety systems (e.g., reactor coolant pumps and main feed water) are assumed to function if it is more limiting or not function if it is more limiting.
	Are the analyzed events subdivided into classes or categories (for example, AOO, DBA1, DBA2, etc)? What is the basis for such sub-division?	
	Finland	Yes. See above.
	France	Yes. See answer above (design basis).
	US	Yes, in the USA there are AAOs, DBAs, and severe accidents.

Country		Response
Design basis / Analyzed events	**UK**	Given our non-prescriptive regime, vendors are allowed to categorization events within the design basis as they see fit. However, the concept of frequent events for faults with a frequency greater than 10^{-3} per year is generally taken as an indication of the need to demonstrate diversity using design basis techniques. This is based upon the sequence frequency cut-off at 10^{-7} per year coupled with an assumed common mode failure cut-off at 10^{-4} per demand for any safety system.
	Canada	Yes, in Canada we distinguish AOO, DBA and BDBA. The BDBA category also includes the severe accidents. The basis for categorization is primarily probabilistic.
	China	Yes. It is based on events frequency.
	Is there a need to demonstrate diversity for each safety function?	
	Finland	Yes. This is covered by the analyses of design extension conditions.
	France	Yes, EPR technical guidelines.§ A.2.2 "Redundancy and diversity in the safety systems" : "This reliability (of protection and safeguard systems) has to be achieved by an adequate combination of redundancy and diversity."
	US	With a few exceptions diversity of safety functions is not required. • Diversity for shutdown function is required (i.e., diverse shutdown means). There are specific requirements associated with ATWS. • Diversity of auxiliary feedwater is generally required. • The Station Blackout rule generally requires an alternate source of AC power.
	UK	Yes, subject to ALARP. See previous answer.
	Canada	Diversity for shutdown function is required (i.e., diverse shutdown means), but no similar requirement for emergency core cooling and containment functions. Diversity requirement for shutdown means does not depend on event frequency. Such a requirement is not specified directly. However, by including potential combinations of a frequent initiation event (which would be an AOO in the Canadian terminology) and a failure of a safety function into the design basis, we expect that the diversity of means of ensuring safety would be evaluated.
	China	Diversity should be adopted as possible, and it is required for the systems which need highly reliability.
	Can events/faults be screened out of the DBA based on low consequences? What are the screening criteria?	
	Finland	No.

Country		Response
	France	No, initiating events cannot be screened out based on low consequences, but exclusion is possible based on frequency: See "EPR technical guidelines. A.1.4 Redundancy and diversity in the safety systems: "In this demonstration (safety demonstration), single initiating events have to be "excluded" or "dealt with" that is to say that their consequences are examined in a deterministic way. Single initiating events can be "excluded" only if sufficient design and operation provisions are taken so that it can be clearly demonstrated that it is possible to "practically eliminate" this type of accident situations; for example, the reactor pressure vessel rupture and the other large components (as steam generator secondary side or pressurizer) rupture can be examined in that way."
	US	DBAs are still evaluated if they have low consequences. If there are low consequences they are not considered limiting events.
	UK	Yes. Faults for which the unmitigated consequences fall below the screening criteria of SAP target 4 need not be assessed using design basis techniques. As an example, frequent faults with an unmitigated off-site release less than 0.01 mSv need not be assessed. Some form of protection would be required for off-site releases greater than 1 mSv. This rises to 100 mSv for faults with an initiating frequency just within the design basis cut-off frequency of 10^{-5} per year.
	Canada	Since the DBA are defined on the probability basis, the low frequency events would be excluded. On the other hand, the low consequence events would formally be part of the Design Basis. It is permissible however, not to analyze certain events if it can be shown that their consequences are bound by the analyzed events.
	China	No. DBAs are still evaluated if they have low consequences.

Country		Response
Analysis methodology	**What is understood by the "analysis methodology"?**	
	Finland	The methodology in our regulations covers the description of accident analyses itself (procedure including main assumptions used in analyses, selection of input values including uncertainties in them, acceptance criteria etc) and description of codes and their validation (all codes shall be validated on the parametric area where they are intended to be used). The most important part of the methodology are confirmatory analyses, which are carried out by TSO for the worst case/cases at a different event category by using independent codes.
	France	A methodology is a procedure which defines a calculational route to prove the safety of the reactor, for each operational situation and with pre-established rules and hypotheses. From ASN's point of view, a methodology is based on: • the way to identify and select the main physical parameters to make the calculation; • the hypotheses concerning initial conditions, operating limit conditions, materials behaviour data; • the way uncertainties are taken into account; • one or several calculation procedures which can use modeling and codes; • one or several criteria with their numerical limits; • the way to identify and select the most penalizing transients.
	US	*Regulatory Guide 1.203 Transient and Accident Analysis Methods* provides the following definition. "An evaluation model (EM) is the calculational framework for evaluating the behavior of the reactor system during a postulated transient or design-basis accident. As such, the EM may include one or more computer programs, special models, and all other information needed to apply the calculational framework to a specific event, as illustrated by the following examples: (1) Procedures for treating the input and output information (particularly the code input arising from the plant geometry and the assumed plant state at transient initiation) (2) Specification of those portions of the analysis not included in the computer programs for which alternative approaches are used (3) All other information needed to specify the calculational procedure"
	UK	A calculational methodology such a transient analysis code used to assess the thermal hydraulic response of a reactor in fault conditions, together with reference data sets.
	Canada	RD-310 distinguishes the following steps in the analysis method 1. Defining the scope of events to which a method would be applicable

Country		Response
		2. Identifying applicable acceptance criteria
Analysis methodology	**Canada**	3. Identifying important phenomena 4. Selecting appropriate computer codes, including demonstration of the code validation 5. Defining boundary and initial conditions and selecting appropriate representation of the facility (nodalization) 6. Accounting for uncertainties in models and plant data 7. Defining scenarios to be simulated 8. Performing analysis, including sensitivity studies 9. Assuring verification, processing and documentation of analysis results
Analysis methodology	**China**	The safety analysis should demonstrate by test, assessment, calculation or engineering analysis that the equipment incorporated to prevent escalation of anticipated operational occurrences or design basis accidents to severe accidents and to mitigate their effects, as well as emergency operating procedures and the accident management measures, is effective in reducing risk to acceptable levels.
Analysis methodology	**Does the regulator approve the methodology? Is there a methodology "change control" (can the methodology be improved / modified by the utility without seeking a regulatory approval?)**	
Analysis methodology	**Finland**	If modifications are done for methodology, it needs regulatory approval.
Analysis methodology	**France**	Formally, no. In practice, ASN would not accept the conclusions of a study performed according to a methodology which would not have been previously accepted. A common practice is that the licensee submits a file which justifies that the evolution of the methodology or the new methodology is appropriate to demonstrate the safety. ASN gives its whether the method is appropriate or whether the licensee has to improve the demonstration of safety. For example, for Flamanville 3 EPR's case, the licensee submitted files for 4 new methods (steam line break, one control rod ejection, loss of flow rate, control rods withdrawal at 0% nominal power) + 1 procedure of statistical treatment of uncertainties.
Analysis methodology	**US**	Yes. LOCA methodologies require specific NRC approval. Other accident analyses are included in the FSAR and are approved by the NRC. Safety analysis supporting safety-related systems are covered under the *10 CFR Part 50, Appendix B* document control. Additionally, licensees are given limited change authority. The change authority is described in *10 CFR 50.59*.

Country		Response
	UK	Not as such. The methodology might be assessed as part of any regulatory approval of a safety case depending on the judgment of the technical assessment inspector. HSE would expect the licensee/vendor to have a change control procedure for any analysis code that is used in support of safety analysis. HSE would not be part of the approval route for any change in the methodology unless a significant change was presented as a free-standing modification to a station safety case, but HSE might choose to assess such a change if it was used to justify any change to plant operation or design.
Analysis methodology	**Canada**	The CNSC does not approve analysis methods. The issue of making changes in the existing licensing analysis method (i.e., the method that has been used initially to obtain the licence) is being currently debated between the CNSC and utilities. When a new analysis methodology is proposed it becomes a subject of careful and detailed assessment before the results could be used in licensing applications.
	China	The methodology needs regulatory approval. The improvement/modification also needs regulatory approval.
	Are there explicit requirements for ensuring conservatism of analysis, for example by incorporating certain penalties into the methodology?	
	Finland	Yes. Two optional methods: 1) Conservative method complemented by sensitivity analysis: Input values (power, temperature and pressure etc), performance of safety systems (failure criteria) are selected conservatively 2) Best-estimate method complemented by uncertainty analysis: Approval of statistical methods and acceptance criteria used in uncertainty analysis are required
	France	There are no regulatory requirements. But ASN expressed its expectations in a letter sent in 2006 : "some of the phenomena may be not well known and then taken into account by applying penalties". The licensee/vendor needs to demonstrate conservatisms (for PCC transients) within the design basis assessment but can select how this is achieved in practice. The regulator and its TSO assess the methodology in regard to the relevance of its conservatisms, so that the compliance with safety limits is demonstrated with a high level of confidence, commensurate with the probability and consequence of the event.

Country		Response
	US	Yes. For example, if using a *CFR Part 50, Appendix K* methodology the conservatisms are explicitly defined. Correlations and models are specified and a 20% penalty is applied to the decay heat. Other methodologies typically include specific conservative approaches. The design basis source term in the NRC guidance is another area of considerable conservatism. The NRC also accepts best estimate approaches if uncertainties are quantified statistically.
	UK	HSE is non-prescriptive. The licensee/vendor needs to demonstrate conservatism within design basis assessment but has the option to select how this is achieved in practice. They need to demonstrate the adequacy of the safety margin to HSE assessment inspectors based upon technical arguments. The test is that compliance with safety limits be demonstrated with a high level of confidence, commensurate with the risk and hazard of the event.
Analysis methodology	**Canada**	RD-310 states that: The safety analysis shall build in a degree of conservatism to off-set any uncertainties associated with both NPP initial and boundary conditions and modeling of nuclear power plant performance in the analyzed event. This conservatism shall depend on event class, and shall be commensurate with the analysis objectives.
	China	Yes. There are explicit conservative assumption for DBAs.
	Are there any specific requirements for “safety margins”? Elaborate if so.	
	Finland	Safety margin to acceptance criteria have to be demonstrated.
	France	No specific requirements till now. A recently prepared ministerial order (not yet finalized) includes a general requirement of providing safety margins.
	US	“Safety margin” can be defined a number of ways. Use of conservative acceptance criteria and use of conservative methodologies are ways the NRC ensures adequate margins. Each of these are addressed in the requirements.
	UK	There are no specific requirements although existing relevant good practice would be taken into account. There is the concept of confidence level in the calculation, which needs to be consistent with the design basis sequence frequency of 10^{-7} per year.
	Canada	RD-310 requires to establish a margin in the demonstration of meeting acceptance criteria, as quoted below: *The results of safety analysis shall meet appropriate derived acceptance criteria with margins sufficient to accommodate uncertainties associated with the analysis.*
	China	There should be margins sufficient to accommodate unknown uncertainties. “safety margin” can be defined by use of conservative acceptance criteria, conservative methodologies, etc.

Country		Response
	How are various sources of uncertainties (e.g., modeling, system representation, plant parameter measurements) considered in the analysis?	
	Finland	Confirmatory analyses are performed to consider uncertainties in modeling. Selection of input values with accounting for uncertainties (conservatism) in them and sensitivity analysis are taking care of other uncertainties in the conservative method. In the best estimate method uncertainties are included and treated statistically.
	France	It is for the licensee/vendor to justify how these are treated. This is requested in the aforementioned ASN letter.
	US	There are two approaches: 1. Conservative analysis which considers each uncertainty deterministically. 2. Best estimate with consideration of uncertainties statistically.
	UK	It is for the licensee/vendor to justify how these are treated.
Analysis methodology	**Canada**	Two generic alternative safety analysis approaches are acknowledged: 1. Conservative (called Limit of Operating Envelope, LOE) which assumes all important operating parameters to be simultaneously at their extreme allowable values including instrumentation uncertainty allowances. In this case, the random modeling uncertainties are not usually added but could be considered through sensitivity or confirmatory studies. Biases in modeling parameters should be considered. 2. Best estimate with consideration of uncertainties (called BEAU) allows explicit treatment of various uncertainties by employing statistical techniques to propagate uncertainty in input parameters and models to the output parameters.
	China	Conservative approach which considers uncertainties deterministically, and best estimate approach with consideration of uncertainties statistically.
	What are the requirements for the treatment of non-safety systems within the DBA?	
	Finland	The use of non-safety systems within the DBA is not acceptable for mitigation of accident consequences.

Country		Response
	France	Non safety systems cannot be claimed within the design basis analysis unless they would affect the transient in an adverse manner. For EPR "safety demonstration should take into account only F1 and F2 equipment“. F1A = every safety function, even support functions, needed to reach state A for PCC 2 to 4 (no critically state, short term heat dissipation). F1B= every safety function, even support functions, needed to reach state B for PCC 2 to 4 (no critically state, long term heat dissipation). F2: safety functions needed to reach the final state for multiple failures conditions are classified F2.
	US	Non-safety systems (e.g., reactor coolant pumps and main feed water) are assumed to function if it is more limiting or not function if it is more limiting. Non-safety grade equipment is not credited in mitigation of the DBA.
	UK	Such systems should not be claimed within the design basis analysis unless they would affect the transient in an adverse manner. This requirement might be subject to reasonable practicability considerations depending on the consequences and the frequency of the sequence being considered.
	Canada	Any system can be credited in analysis if it has been shown to be environmentally qualified for the conditions predicted in this analysis. An action of an unqualified system need to be considered if such an action has a negative impact on safety.
	China	Any control systems should be assumed to operate only if their functioning would aggravate the effects of the initiating event. No credit should be taken for the operation of the control systems in mitigating the effects of the initiating event. All plant systems and equipment not designated and maintained as safety grade (full QA, seismic and equipment qualification) should be assumed to fail in the manner that causes the most severe effects for the PIE being analysed.
Analysis methodology	**How are claims on operator action treated within the DBA?**	
	Finland	If adequate emergency operational procedures are available, it is acceptable for the operator to follow these guidelines but only after certain time period, which normally is 30 minutes.
	France	The preliminary safety case states: • First operator action, in the control room, is taken into account after 30 min.

	Country	Response
		• First operator action, out of the control room, is taken into account after 1 hour (action out of the control room).
	US	Operator action can be credited if it can be demonstrated that there is time and there is adequate instrumentation. Operators are then trained and tested on any required manual actions. For new reactors, most accidents do not require early operator action.
	UK	Ideally, for fast acting fault transients, HSE would expect automatic protection to be provided subject to ALARP. The 30-minute rule is expected to be applied to claims on operator action.
	Canada	Most of the accidents are expected to be designed not to require operator's intervention. An operator action may be credited in the analysis if certain conditions are observed, such as: • Unambiguous indications of the need for such actions, • adequate procedures and sufficient time to perform the required actions, and • environmental conditions that do not prohibit such actions.
	China	Operator action can be credited if it can be demonstrated that there is time and there is adequate instrumentation. Operators are then trained and tested on any required manual actions.
	What are the requirements governing the process for the grouping/bounding of event sequences within the DBA?	
	Finland	Grouping of events is based on their frequency, which is descried above. In each even category there are the most limiting case, which is the bounding event sequence in that event category.
	France	Extract from EPR technical guidelines: D1. List of reference transients, incidents and accidents "The definition of the reference transients, incidents and accidents to be assessed comprises several steps: • identification of possible initiating events which could result in a release of radioactive materials inside or outside the plant; • exclusion of single initiating events sufficiently prevented by design and operation provisions; • **grouping of all other identified events so as to define a limited number of reference transients, incidents and accidents in such a way that the consequences of each reference event cover those of the corresponding group of events**."
Analysis methodology	**US**	There are no specific requirements on the subject. The SRP Chapter 15 has a grouping of events. Applications have been submitted consistent with the SRP.
	UK	For the design basis assessment, it is expected that all initiating events that result in similar claims on protection systems would be grouped together to provide a bounding assessment for the initiating frequency for challenging the safety system.

Country		Response
	Canada	There are no requirements on the subject. The general expectations are as follows: The identified events could be grouped into categories based on similarity of the initiating failures, key phenomena, and of system and operator responses. Examples of event categories include: loss of coolant, reactivity initiated events, secondary side breaks, etc. Within each category of events, bounding events should be identified for each applicable safety requirement (the bounding event is the event with the smallest predicted margin to a specific safety limit). In some cases, one accident scenario in the same category of events may be more severe in terms of one acceptance parameter (for example, peak containment pressure) and another may be more severe in terms of a different safety parameter (for example, public doses). All these scenarios should be carried through the analysis process as bounding events for different safety parameters.
	China	The normal practice is to group the PIEs, and for each group, to choose bounding cases for analysis.

Country		Response
Acceptance / Success Criteria	**What is the hierarchy of criteria? (For example, is the public dose a higher level criterion than the prevention of fuel dryout?)**	
	Finland	Acceptance criteria for fuel (CPR, DNB, embrittlement of cladding, number of failed fuel rods, PCMI, PCT, max enthalpy) , overpressure of primary circuit and doses for public are given in our regulations for different event category.
	France	There is no hierarchy of criteria ; thus it would not be acceptable to exceed the fuel safety criteria on the ground that dose limits to the public are not reached (although one of the first general safety objectives is the reduction of individual, collective doses and reduction of potential radioactive release due to all conceivable accidents, including core melt accident).
	US	Practically, all criteria have to be met at all times so there is no real hierarchy. The NRC change process contained in *10 CFR 50.59* focuses on offsite dose consequence sand then the limits for the three fission product barriers. As a result, these would be higher level criteria.
	UK	The licensee is expected to identify conservative safety limits such as a DNB or clad melt criteria for assessment within the design basis. However, the licensee/vendor has the option to present an ALARP justification based upon assessment of the consequences to members of the public if there is a shortcoming within the design basis assessment. HSE would form a judgment of the adequacy based on the arguments presented. Generally, frequent faults would be expected to be mitigated prior to exceeding plant damage limits, while infrequent faults would be expected to respect limits designed to prevent uncontrolled release of radiation. The exact acceptability of the consequences would be assessed on an ALARP basis according to SAP FA.7. This requires, so far as is reasonably practicable, that none of the physical barriers to prevent the escape or relocation of a significant quantity of radioactivity is breached or, if any are, then at least one barrier remains intact such there is no release of radioactivity. Where releases cannot be avoided, the doses to persons should limited to meet the numerical targets for doses set out in Target 4.
	Canada	Legally, all analysis acceptance criteria, such as public doses or maintaining integrity of physical barriers, have the same status, i.e., specified in the documents of the same level. In practice, however, the public doses are perceived as the ultimate defence that cannot be compromised under any circumstances, whereas the other limits may, at least in principle, be varied depending on the extent of the available margin, quantified or perceived.
	China	Acceptance criteria include global criteria and detailed criteria, but all criteria should be met at all times.
	How are criteria established? Are they prescribed by legally binding documents / defined by the regulator / selected by designer/ vendor?	

	Country	Response
	Finland	At top level i.e. in Nuclear energy act and Governmental decree 733/2008, which are mandatory, acceptance criteria are given for doses to the public, acceptance criteria for fuel and primary circuit overpressure have been given only at general level. Detailed acceptance criteria are given in YVL-guides.
Acceptance / Success Criteria	**France**	From a general point of view, criteria are not prescribed in legally binding documents. For EPR, some criteria are mentioned in technical guidelines. Other criteria are specified in the RCC-C code (French code for nuclear fuel). Generally, the licensee uses criteria which have been informally accepted (historical context). If the licensee wants to propose a new criterion, an analysis by TSO (IRSN and GPR) is necessary.
	US	How the acceptance criteria are determined varies. Some, like the LOCA, ATWS and does limits are codified in the regulations. Others are established in the SRP or Regulatory Guide process, which includes public comments. Others are established statistically/experimentally by the applicant through testing like the DNB limits.
	UK	The licensee/vendor is expected to identify appropriate criteria.
	Canada	Analysis acceptance criteria are defined, on a general level, in RD-310 and are not legally binding unless incorporated in the licence. RD-310 states that: "*Qualitative acceptance criteria shall be established for each AOO and DBA to confirm the effectiveness of plant systems in maintaining the integrity of physical barriers against releases of radioactive material. These qualitative acceptance criteria shall satisfy the following general principles:* • *Avoid the potential for consequential failures resulting from an initiating event;* • *Maintain the structures, systems and components in a configuration that permits the effective removal of residual heat;* • *Prevent development of complex configurations or physical phenomena that cannot be modeled with high confidence; and* • *Be consistent with the design requirements for plant systems, structures and components.* *To demonstrate that these qualitative acceptance criteria applicable to the analyzed AOO or DBA are met, quantitative derived acceptance criteria shall be identified prior to performing the analysis.* " It is the designer or the licensee who is expected, in most cases, to establish quantitative acceptance criteria, with the exception of the public dose criteria.

Country		Response
	China	Global criteria are defined by the regulatory body. Detailed criteria are defined by the designer or analyst. There are detailed requirements in guidance for these criteria.
	List the most important criteria used in analysis of A&T	
	Finland	Acceptance criterion for fuel at different design basis conditions are following: • *DBC 1, Normal operation* • *DBC 2, Anticipated events* ▪ 95/95 confidence with respect DNB or dry-out, no (internal) fuel melting, nor damage due to pellet-cladding mechanical interaction.

<table>
<tr><th></th><th>Country</th><th>Response</th></tr>
<tr><td>Acceptance / Success Criteria</td><td>Finland</td><td>

DBC 3 “Class 1” postulated accidents
Number of rods in heat transfer crisis < 1%, PCT < 650 °C, and extremely low probability of fuel damage by the mechanical interaction between fuel and cladding
DBC 4 ”Class 2" postulated accidents
The higher the frequency of a postulated accident, the smaller the number of damaged fuel rods. Number of damaged fuel rods < 10%. Max PCT < 1200 C. Limited embrittlement. The enthalpy limit of 140 cal/g for failure (230 cal/g) should not be exceeded. Enthalpy limits are valid for fuel burnups up to 40 MWd/kgU. Limits for higher burnups shall be justified by experiments. No danger to long-term coolability
DEC, Design extension conditions
DEC A
Max PCT < 1200 C. Limited embrittlement. Enthalpy limit 140 cal/g for failure (230 cal/g not to be exceeded). No danger to long-term coolability
DEC B,
Max PCT < 1200 C. Limited embrittlement. Enthalpy limit 140 cal/g for failure (230 cal/g not to be exceeded). No danger to long-term coolability

Acceptance criterion for primary circuit pressure at different design basis conditions are following:

DBC 1, Normal operation
Nominal pressure
DBC 2, Anticipated events
Design pressure of primary circuit
DBC 3 “Class 1” postulated accidents
1,1 x design pressure of primary circuit
DBC 4 ”Class 2" postulated accidents
1,1 x design pressure of primary circuit
DEC, Design extension conditions
DEC A
1,2 x design pressure of primary circuit
DEC B,
1,2 x design pressure of primary circuit.

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<tr><th colspan="2">Country</th><th>Response</th></tr>
<tr><td rowspan="2">Acceptance / Success Criteria</td><td>Finland</td><td>Acceptance criterion for doses to the public at different design basis conditions are following:

DBC 1, Normal operation
Radiation dose limit 0,1 mSv / year for the entire site
DBC 2, Anticipated events
Radiation dose limit 0,1 mSv
DBC 3, Class 1 postulated accidents
Radiation dose limit 1 mSv
DBC 4, Class 2 postulated accidents
Radiation dose limit 5 mSv
DEC, Design extension conditions
Radiation dose limit 20 mSv
Severe accidents
Release < 100 TBq Cs-137 equivalent
No acute health effects
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<tr><td>France</td><td>Here are examples of criteria used for 3 major transients in the EPR preliminary safety analysis report

For LOCA:

The safety criteria to be respected are the radiological limits for PCC3-4 events,

For LOCA analysis, the following decoupling criteria must be respected:

The maximum temperature of the fuel cladding must stay below 1200°C;
the maximum oxidation of the cladding must stay less than 17% of the total clad thickness;
the maximum production of hydrogen must stay below 1% of the quantity of hydrogen which would result form the oxidation of all the zirconium in the fuel cladding;
the changes of core geometry must not prevent core cooling;
the long term cooling must be assured: the core temperature must be maintained at an acceptable value and the residual heat must be removed.
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Country		Response
Acceptance / Success Criteria	**France**	**For steam line break**: The safety criteria are the radiological limits for PCC-4 events. The consequences of a steam line break are analysed with decoupling criteria for the following aspects: • absence of fuel degradation • integrity of the primary circuit • integrity of the reactor containment • quantity of radioactive discharges The decoupling criteria related to fuel degradation are based on the percentage of fuel rods reaching critical heat flux and on the percentage of fuel oxide reaching melting temperature. **For control rod ejection (RIA):** Safety criteria: • Radiological limits for PCC3-4 events Decoupling criteria: • Percentage of fuel pins exceeding the Critical Heat Flux (DNB) less than 10 per cent; • peak clad temperature less than 1482°C; • percentage of fuel melted at the hot spot less than 10 per cent by volume, that is the fraction of the fuel melted in the hottest pin must not exceed 10 percent of the cross section at the level corresponding to FQ (heat point factor); • fuel enthalpy limited to 220 cal/g for unirradiated fuel and to 200 cal/g for irradiated fuel; • maximum coolant pressure less than 130 percent than the design pressure (175 bar) for transients of category 4 (PCC4), hence less than 228.5 bar.
	US	Offsite dose criteria and criteria for the fission product barriers are the most important. The Important acceptance criteria include - • Offsite and control room dose limits • Fuel critical heat flux, specific enthalpy, peak clad temperature and clad oxidation • RSC peak pressure and cool down limits • Containment pressure and leak-rate

	Country	Response
Acceptance / Success Criteria	**UK**	For PWR, DNB, fuel rod failures, clad oxidation, clad melt, fuel melt For AGR, fuel pin failures, clad melt, fuel melt Regardless of technology, Target 4 of the HSE SAPs sets out effective dose targets received by any person from a design basis fault: **Off-site** Basic Safety Objective of 0,01 mSv to be met by most faults Basic Safety Limit: 1 mSv for initiating event fault frequencies exceeding 1 x 10^{-3} pa 10 mSv for initiating event fault frequencies between 1 x 10^{-3} and 1 x 10^{-4} pa 100 mSv for initiating event fault frequencies less than 1 x 10^{-4} pa Note that the dose targets are for comparison with the assessed consequences of mitigated design basis fault sequence, while the frequencies are the summed initiating event frequencies of all sequences assumed to be bounded by the design basis fault sequence.
	Canada	Existing regulatory documents do not provide a complete set of acceptance criteria for all accidents and transients considered in Safety Reports. However, on a conceptual level, it is expected that for the majority of AOO the analysis would demonstrate “fitness for service” of the affected components, meaning that any impacts would be within design tolerances. For DBA, the analysis is meant to demonstrate integrity of physical barriers such as fuel, fuel cladding, primary circuit and containment. They are often the most limiting criteria and therefore considered to have an immediate importance in safety analysis.
	China	Offsite dose criteria and criteria for the fission product barriers are the most important. The Important acceptance criteria include - • Offsite and control room dose limits • Fuel critical heat flux, specific enthalpy, peak clad temperature and clad oxidation • RSC peak pressure and cool down limits Containment pressure and leak-rate
	What are the options for the designer/vendor if a criterion cannot be met? Could there be alternative ways to demonstrate safety?	
	Finland	There are no options. The designer/vendor shall show that above mentioned criteria are met.
	France	The licensee/vendor has the option to propose: • A new methodology (more realistic) in order to reduce provisions and penalties

Country		Response
		• New safety demonstration rules to analyze the transient (aggravating failure, loss of site power, etc...) • A new criterion based on R&D results
	US	Alternative approaches are always entertained. These approaches need to be documented so that the new acceptance criteria are well established.
	UK	As noted above, the licensee/vendor has the option to make an ALARP argument that the risk has been reduced to as low as reasonably practicable.
	Canada	Alternative ways to demonstrate safety are recognized, but the acceptance criteria are expected to be observed.
	China	The designer/vendor should show that the most important criteria are met
	How are margins incorporated into acceptance criteria? (for example, are the acceptance criteria set below or at the failure limits?)	
	Finland	Acceptance criteria have been set at the limits mention above.
	France	Generally the acceptance criteria are decoupling criteria; as such they entail margins with respect to failure.
	US	Safety margins are built into the acceptance criteria. However, different criteria are developed with a different basis. It is difficult to generalize how safety margins are incorporated into the criteria.
	UK	Uncertainties in the safety limits need to be included within the overall assessment methodology. These can be included within the explicit value of the safety limit or added as a penalty in the transient calculation.
	Canada	There are no unambiguous guidance or accepted practice. However, the modern thinking anticipates that an acceptance criterion would be set at a comfortable margin below the failure threshold.
	China	Not all safety margins are built into the acceptance criteria.

Country		Response
Analytical Tools	**Are there requirements to demonstrate code "applicability" for the analyzed accident?**	
	Finland	Yes. All codes shall be validated on the parametric area where they are intended to be used.
	France	At the present time, there are no formal requirements but, when the licensee uses a new code or a new code version in the framework of a methodology accepted for safety demonstration, ASN asks him to give an application calculation with parameters from the plant. ASN requires that the code (or the new version) be qualified even though the qualification is not formally endorsed by ASN. The TSO (IRSN) assesses the applicability of codes used by the licensee.

Country		Response
	US	There are specific requirements associated with a *CFR Part 50, Appendix K* evaluation models. For other models the NRC expectations are described in *Regulatory Guide 1.157, Best-Estimate Calculations of Emergency Core Cooling System Performance,* and *Regulatory Guide 1.203 Transient and Accident Analysis Methods.*
	UK	It is expected that the demonstration of applicability and validity of any analysis code would be provided as part of the technical support documents for any safety case that places claims on the analysis methodology.
	Canada	The code applicability is taken to mean that all phenomena of importance occurring during the analyzed accident are modeled in the code, and all the ranges of applicability for each model are defined. Alternatively it would be acceptable to demonstrate that absence of a model, or any interpolations or extrapolations outside of the range of applicability, would lead to conservative results.
	China	Yes. Each code should be validated for each application made in the safety analysis.
	Are there specific requirements for code validation?	
	Finland	Yes. All codes shall be validated on the parametric area where they are intended to be used.
	France	EPR technical guidelines § D.2.3 - Use of computer codes "For each of the computer codes used to justify the design, the designer has to demonstrate its experimental validation and qualification and how the remaining uncertainties are taken into account (e.g. sensitivity studies). This applies to computer codes used for neutronic, thermalhydraulic and thermo-mechanical calculations related to reference transients, incidents and accidents, and especially to computer codes of the new generation (3 D neutronic and thermalhydraulic coupled computer codes), in order to demonstrate that the envelope values determined by the results are actually conservative for the whole set of PCC studies."
	US	The NRC expectations are described in *Regulatory Guide 1.157, Best-Estimate Calculations of Emergency Core Cooling System Performance,* and *Regulatory Guide 1.203 Transient and Accident Analysis Methods.*
Analytical Tools	**UK**	HSE has a technical assessment guide (TAG 042) on its expectations for the validation of computer codes.
	Canada	Yes. RD-310 specifies that the computational methods or computer codes, models, and correlations should be validated for the intended applications. The Canadian Standard CSA N286.7-99 "*Quality Assurance of Analytical, Scientific and Design Computer Programs for Nuclear Power Plants*" provides more detailed requirements for code validation.
	China	Yes. All the computer codes used in the safety analysis should be validated and verified.
	Does the regulator expect use of "conservative" or "best estimate" codes in analysis of A&T?	

Country		Response
	Finland	The use of best estimate codes is required in the way described above.
	France	EPR TG D2.3 "Realistic assumptions and models can be used for the safety demonstration related to the surge line break (PCC 4) in reactor state A; but the compliance of the results with acceptance criteria must be proven at a high confidence level -this implies the use of a frozen version of the computer code which has to be qualified and verified and an explicit evaluation of the associated uncertainties, combining the elementary uncertainties (code models, scaling effects, initial and boundary conditions, user effects, ...). An alternative approach could be the use of models and criteria already applied to existing plants in a conservative way."
	US	The NRC accepts both.
	UK	It is for the licensee/vendor to justify its approach but HSE generally encourages more realistic modeling providing it is adequately validated and justified as this gives greater insight into the analysis. Uncertainty is then addressed by sensitivity studies varying modeling parameters and boundary conditions.
	Canada	Both conservative and best estimate codes would be acceptable. Preference would be given to "best estimate" codes with appropriate validation, and uncertainty estimates.
	China	Both conservative and best estimate codes would be acceptable.
	Are codes formally approved by the regulator? Does the regulator maintain and use an independent set of codes? Are there any other ways of assessing computer codes (for example, by involving services of independent technical organizations)?	
	Finland	STUK does not formally approve the codes. The confirmatory analyses, which are carried out by TSO for the worst case/cases at different event category, are giving justification that results are adequate.
	France	Codes are not formally approved by ASN. Their qualification is examined by our TSO and can give rise to requests from ASN. The TSO (IRSN) maintains a set of independent codes,
Analytical Tools	**US**	Yes. Codes used to analyze the LOCA are required to be submitted for formal approval. Non-LOCA codes can be submitted for formal approval and can be approved and applied generically. In this case, there is a stand-alone description of the code and a stand-alone Safety Evaluation describing the application and limitations and restrictions. Codes can also be accepted as part of a licensing proceeding. In this case, the code is accepted for a particular licensing proceeding. The NRC also maintains codes for independent confirmatory assessments.

Country		Response
	UK	Codes are not formally approved by HSE although we do approve safety cases for which the thermal hydraulic codes make a significant contribution to the safety case. HSE does not maintain its own set of codes but does have access to USNRC codes such as FETCH, RELAP and MELCOR. It is also utilizing technical support contractors to perform independent analysis for the GDA for new reactors. For example, GRS are currently developing ATHLET models of the EPR and AP1000.
	Canada	Computer codes used in deterministic safety analysis are not approved by the CNSC; however their development, maintenance, validation and use would be assessed against the CSA N286.7-99. CNSC does not maintain a complete set of independent codes but may, and does, use codes for specific checks. Often this is done with the help of independent organizations.
	China	Regulator does not formally approve the codes but the validation and verification of the codes should be assessed. The capability of independent verification is in the process of establishment.

Country		Response
Plant Representation	**In the analysis, is there an expectation that plant ageing effects be identified and considered?**	
	Finland	Yes. Fuel burnup is taken into account and ageing effects of other components are taken into account in the uncertainty of their performance.
	France	In general, ageing effects on equipment is taken into account through specific files. Fuel ageing effect are identified and taken into account: hypotheses used to perform the accident study include ageing effects. Steam generator plugging is taken into account by making use of a bounding value in the studies.
	US	There is an expectation that the analysis be consistent with the actual plant. For example, analysis typically assumes some sort of heat exchanger fouling or steam generator plugging and fuel has some operational oxidation. Additionally, thermal properties of materials are chosen to bound plant operation for some time. If aging causes effects that were not considered, re-evaluation may be necessary. The NRC is in the process of revising 10 CFR 50.46 to include the effect of fuel cladding material changes during operating exposure. This will make the oxidation limit a function of hydrogen absorbed during operation.
	UK	Yes, where applicable. For example, the effects of ageing on the graphite moderator have been taken into account for the AGR safety analysis. The effect of ageing on the likelihood of boiler tube failures on the AGRs has also been considered. A review of the affects of ageing is one of the key issues in any periodic safety review, which the licensee is typically expected to perform every ten years.
	Canada	Based on the experience with the operating plants, it is expected that the analysis would take into account ageing effects and explicitly specify up to what plant age it is to remain adequate.
	China	Yes. The analysis is consistent with the actual plant
	What are the requirements for availability of systems to be credited in analysis (N+1, N+2)?	
	Finland	Failure criterion in our regulation means N+2 or N+1 depending on the safety class of the safety system. N+2 criterion is applied for safety class 2 safety systems and N+1 for safety class 3 systems.
	France	In principle, only F1 (see above) systems can be used for the safety demonstration in order to reach and to maintain the safe shutdown state. There is no particular requirement related to the degree of system redundancy, except the single failure criterion. Manual action from the main control room can be assumed to take place, at the earliest, 30 minutes after the first significant information is given to the operator. For a local manual action, outside the main control room, the earliest time to be taken into account is 1 hour.

Country		Response
Plant Representation	**France**	In addition, reference transients, incidents and accidents (except those initiated by human action), have to be studied with a loss of off site power at the most penalizing time ; only seismically classified equipment can be used for the safety demonstration. The technical decoupling criteria to be complied with are similar to those of the reference accidents.
	US	The single most limiting credible active failure must be considered. After 24 hours, a passive failure is considered, if it is more limiting. All consequential failures are considered as well.
	UK	Generally, the most bounding plant maintenance state and the most bounding single failure should be considered within the design basis analysis (N+2). For frequent faults, the most bounding common mode failure should be considered.
	Canada	There are no such generic availability requirements on a system level. When crediting a system in safety analysis the single failure criterion is applied to each system. Additionally, effects of maintenance or testing of system components on their availability also need to be considered.
	China	The single failure criteria is required in our regulation act.
	How is the single failure criterion applied in the analysis: **To what systems is it applied?** **How is the failed component identified?**	
	Finland	The failure criterion (N+2 and N+1 depending on safety class) has to be applied to a safety system in the safety analysis. The worst failure or combination of failures (for instance in ECCS) is required to assume in safety analysis.
	France	The most penalizing aggravating failure must be taken into account : it is a single failure applied to an equipment used to achieve the safety demonstration; preventive maintenance must be combined with the implementation of the most penalizing aggravating failure.
	US	See previous question.
	UK	The single failure criterion can be applied to any of the safety systems claimed to mitigate a design basis fault. Both active and passive failures should be considered. Any shortfall will be subjected to an ALARP assessment to see if it can be eliminated by a design modification. The licensee/vendor is expected to perform a systematic assessment of all single failures to identify the most bounding single failure.
	Canada	The SFC is applied to each system credited in the analysis except the passive systems (if designed according to certain rules). The designer is expected to identify the most crucial system components for each function.
	China	The worst single failure should be assumed to occur in the operation of the safety groups required for the initiating event. Generally, single failure of active safety system should be considered.

	Country	Response
	Are there requirements for additional postulated failures (e.g., loss of offsite power, etc)	
	Finland	Yes.
	France	Loss of offsite power is assumed for most events if it is more limiting.
Plant Representation	**US**	Loss of offsite power is assumed for most events if it is more limiting. Additionally, non-safety systems are treated in the most limiting way.
	UK	Depending upon the conditional probability, consequential failures may need to be considered within in the design basis up until the design basis sequence cut-off frequency of 10^{-7} per year.
	Canada	There no such pre-determined additional failures; however, any likely consequential failures (caused by the initial fault) are expected to be considered in the analysis of the initial fault.
	China	Loss of offsite power is assumed for most events if it is more limiting.
	Is there any regulatory guidance for plant nodalization?	
	Finland	No.
	France	No. The plant model nodalization is a matter for the licensee/vendor. And the TSO (IRSN) judges its adequacy, for example while performing methodologies assessments.
	US	Plant nodalization is specifically addressed in the development and review of the methodology and included in *Regulatory Guide 1.203 Transient and Accident Analysis Methods.* There are no specific requirements on nodalization but the applicant must demonstrate the nodalization is adequate.
	UK	No. The adequacy of the plant model nodalization is a matter for the licensee/vendor to justify although TAG 042 on validation does identify that this needs to be covered in the validation/verification report for the computer code.
	Canada	No. But sensitivity and convergence analyses are expected, for example, to be included in establishing the basis for appropriate nodalization.
	China	No.

Country		Response
Documentation	**Is there any regulatory guidance for the analysis documentation? For example, what information in support of analysis needs to be presented to the regulator?**	
	Finland	Yes.
	France	There is an ASN letter, which is not a regulatory document, which enumerates all the justification and documents the licensee needs to submit in a methodology case.
	US	Regulatory Position 3 of *Regulatory Guide 1.203 Transient and Accident Analysis Methods* provides specific guidance on documentation. Documentation should include the - (1) EM requirements, (2) EM methodology, (3) code description manuals, (4) user manuals and user guidelines, (5) scaling reports, (6) assessment reports, and (7) uncertainty analysis reports.
	UK	The TAG 042 on validation does identify the documentation of the codes that HSE would expect to see. These would include procedures addressing code and dataset verification, version control, testing, documentation, user training, peer review and endorsement. The documentation should identify the limits of applicability of the code, uncertainties in the modeling, and guidance on the input description.
	Canada	RD-310 provides the following expectation: The safety analysis documentation shall be comprehensive and sufficiently detailed to allow for a conclusive review. The documents shall include: 1. The technical basis for the analyzed event and key phenomena and processes; 2. A description of the analyzed facility, including important systems and their performance, as well as operator actions; 3. Information describing the analysis method and assumptions; 4. A description of the assessments of code applicability for the analyzed event and computer code uncertainty; and 5. A description of the analysis results in a manner that facilitates their understanding and the drawing of conclusions related to conformance with acceptance criteria.
	China	Designer/vendor should provide all safety analysis documentation that the regulator considers it needs.