Report

Practical Elimination Applied to New NPP Designs - Key Elements and Expectations

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Summary

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The Nuclear Safety Directive of the European Union, as amended in 2014, demands that new nuclear installations be designed with the objective of preventing accidents and, should an accident occur, mitigating its consequences and avoiding early radioactive releases and large radioactive releases. Principle 1 in the Vienna Declaration on Nuclear Safety formulates the same objective for new nuclear power plants.

This report provides a common understanding of the approach to demonstrate the avoidance of early releases and large releases by using the notion of practical elimination. This notion is widely used in this context, inter alia by WENRA and IAEA. The report applies to new nuclear power plants. It deals exclusively with nuclear safety aspects. Existing plants and other nuclear installations, as well as security aspects, are outside its scope.

There are various kinds of scenarios to which the notion of practical elimination can be applied. In order to get an overview over all relevant cases, it is useful to classify the scenarios into three types:

Type I -- scenarios with an initiating event that leads directly to severe fuel damage and early failure of the confinement function.

Type II -- severe accident scenarios with phenomena that induce early failure of the confinement function.

Type III -- severe accident scenarios that result in late failure of the confinement function.

All WENRA countries apply the notion of practical elimination to types I and II; some countries also apply it to type III.

Considering that the safety of a nuclear power plant relies primarily on the application of the defence-in-depth (DiD) concept the report shows the relation between practical elimination and the DiD concept, establishing four basic elements. They concern the use of basic design features to screen out some initiating events and consequential phenomena; the implementation of provisions for prevention of occurrence and limitation of consequences for initiating events not screened out; the implementation of mitigation provisions for postulated severe accident scenarios; and the practical elimination of severe accident scenarios that lead to an unavoidable failure of containment, or its bypass.

The identification of all scenarios which could lead to early releases or large releases is a vital part of this approach and should rely on both phenomenological (top-down) and sequence-oriented (bottom-up) considerations.

For severe accident scenarios for which mitigation is practicable, it has to be verified that the occurrence of the scenario combined with the failure of the mitigative measures can be considered as extremely unlikely with a high degree of confidence. For scenarios that inevitably lead to a failure of the containment or containment bypass, the avoidance of early releases and large releases is adequately achieved by demonstrating practical elimination showing either that the scenario is physically impossible or that its occurrence can be considered as extremely unlikely with a high degree of confidence.

Physical impossibility is the preferred way to demonstrate practical elimination of a scenario because it rules out its occurrence. It is a robust way to demonstrate practical elimination.

Physical impossibility of a fault scenario can be achieved by two means: Complete absence of unacceptable loads by appropriate design features or measures, or demonstration that the maximum load is significantly lower than the minimum resistance of relevant SSCs. In both cases, the demonstration of physical impossibility will be based on physical laws, often translated into mathematical models. These models will have to be validated in the relevant range, the maximum range of their uncertainty has to be reliably determined, and they have to be shown to cover the worst case possible. Then, remaining uncertainties can be related to basic assumptions and the administrative measures they concern.

Demonstrating practical elimination via “extreme unlikeliness with a high degree of confidence” has to be based on the two pillars of deterministic and probabilistic considerations.

For the deterministic part of the demonstration, practical elimination should be primarily based on design provisions, supported by operations provisions. Attention has to be paid to the human factor. The needs for human actions should be limited to the extent practicable. The validity of underlying assumptions should be adequately controlled. Uncertainties have to be taken into account; sensitivity studies should cover the whole spectrum of possible conditions. Also, these provisions should withstand events caused by external hazards in a way that demonstration of practical elimination remains valid.

For the probabilistic part of the demonstration, practical elimination of a scenario can be considered successful by achievement of a target value.

This requires as basis a comprehensive level 1 and level 2 PSA. Inter alia, this PSA is expected to cover all operations modes. To provide a high degree of confidence for any demonstration based on it, this PSA is expected to include uncertainty analyses as well as sensitivity studies to demonstrate that cliff-edge effects are sufficiently remote. Truncation values for minimal cut sets have to be sufficiently low in order not to miss any relevant scenarios.

For both pillars, demonstration of practical elimination is based upon a set of assumptions. Their validity should be ensured with a high degree of confidence. In particular, this applies to physical conditions and administrative measures. Administrative measures play an important role to guarantee that the physical conditions are upheld. An assessment is to be performed to evaluate the effectiveness and the resilience of these measures.

Finally, provisions important for achieving practical elimination have to remain in place and valid throughout the plant lifetime. This requires attention to ageing, maintenance, plant modifications, changes in operational conditions, procedures and external conditions as well as to new technical and scientific knowledge and new operational experience. The validity of the demonstration of practical elimination should be checked within every periodic safety review.

01

Introduction

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01.1 Avoiding early releases and large releases and the notion of "practical elimination"

The Nuclear Safety Directive of the European Union, as amended in 2014 [1], demands in Article 8a, paragraph 1: *"Member states shall ensure that the national nuclear safety framework requires that nuclear installations are designed, sited, constructed, commissioned, operated and decommissioned with the objective of preventing accidents and, should an accident occur, mitigating its consequences and avoiding:*

(a) early radioactive releases that would require off-site emergency measures but with insufficient time to implement them;
(b) large radioactive releases that would require protective measures that could not be limited in area or time."

Paragraph 2 states that this objective *"applies to nuclear installations for which a construction license is granted for the first time after 14 August 2014"*. Furthermore, it is also to be *"used as a reference for the timely implementation of reasonably practicable safety improvements to existing nuclear installations".* This refers to nuclear installations in general, including nuclear power plants.

Principle 1 in the Vienna Declaration on Nuclear Safety [2] formulates the same objective for new nuclear power plants.

The Nuclear Safety Directives also states, in recital 20, that *"the applicant for a license for the construction of a new power or research reactor […] should prove that a large or unauthorised release outside the containment is extremely unlikely, and that applicant should be able to demonstrate with a high degree of confidence that such a release will not occur."*

The latter quotation creates a link to the notion of "practical elimination" which has been highlighted in the international technical discussion after the Chernobyl accident and is frequently used in the context of avoiding both early releases and large releases.

In WENRA Safety Objective O3 for new nuclear power plants, the practical elimination of *"accidents with core melt which would lead to early or large releases"* is addressed [4][1]. It is

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[1] In accord with the understanding of RHWG [6] "core melt" is taken to include also *"severe degradation due to mechanisms other than melting, since radioactive releases can occur without melting (e.g. severe reactivity increase accidents)"*.

emphasized that this includes severe accidents in the spent fuel pool. The IAEA Specific Safety Requirements for design [3] stipulate: *“Event sequences that would lead to an early radioactive release or a large radioactive release are required to be ‘practically eliminated’.”*

There are two ways in which practical elimination can be achieved, as indicated in IAEA Specific Safety Requirements [3]:

“The possibility of certain conditions arising may be considered to have been ‘practically eliminated’ if it would be physically impossible for the conditions to arise or if these conditions could be considered with a high level of confidence to be extremely unlikely to arise.”

The IAEA TECDOC on the application of these Safety Requirements [5] devotes a section to the concept of practical elimination.

01.2 Objective, scope and structure of the report

The notion of practical elimination is widely used. However, there is little guidance available on how to demonstrate it and hence a potential for divergence between countries in its application. WENRA is committed to harmonisation of nuclear safety across its member states and hence needs to ensure that practical elimination is applied consistently.

The objective of this report is to provide a common understanding of the approach to demonstrate the avoidance of both early releases and large releases[2] by using the notion of practical elimination. The report explains the key elements that are necessary to this demonstration, as well as related expectations.

This report deals with avoiding early releases and large releases in the context of the Nuclear Safety Directive of the European Union and the Vienna Declaration on Nuclear Safety, by using the notion of practical elimination for accident scenarios. It applies to new nuclear power plants. Existing nuclear power plants are outside its scope, as are other nuclear installations. The report deals exclusively with safety aspects, security aspects are outside its scope.

The considerations in this report are not specific to any particular reactor type, although some examples provided may be reactor type specific, mostly related to water-cooled reactors.

The report is structured as follows: In section 2, the types of scenarios to be practically eliminated or sufficiently mitigated are considered, as well as their relation to DiD. Four basic elements characterizing this relation are formulated.

Section 3 deals with the identification of the relevant scenarios, using a phenomenological as well as a sequence-oriented approach.

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[2] The term “early releases and large releases” should not be misunderstood as equivalent to “large *and* early releases” (LER); both cases a and b of the Nuclear Safety Directive have to be avoided, not only their combination.

Section 4 provides a general introduction into the approaches to the demonstration of practical elimination for different types of scenarios.

Section 5 discusses one of the approaches to demonstrate practical elimination – via physical impossibility. Two means for this demonstration are explained; limitations are discussed.

Section 6 discusses the other approach – via extreme unlikeliness with a high degree of confidence. The demonstration is based on the two pillars of deterministic and probabilistic considerations. Expectations for both pillars are formulated

Section 7 deals with the importance of administrative measures in the demonstration of practical elimination. Section 8 treats the specific issues which arise in the context of provisions important for achieving practical elimination remaining effective during the lifetime of the plant.

02

Scenarios to be practically eliminated or sufficiently mitigated, and the relation to defence-in-depth

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It is possible to identify many fault sequences that could lead to severe fuel damage and potentially a large or an early release. For the purposes of analyses these may be grouped into scenarios which are understood as a set of sequences that lead to similar kinds of challenges of the confinement function.

There are various kinds of scenarios to which the notion of practical elimination can be applied. In order to get an overview over all relevant cases, it is useful to classify the scenarios into three types. The relation to the DiD concept may vary for different scenario types. Furthermore, distinction of the three types is of importance because not all countries apply the notion of PE to all of them.

The types of scenarios are as follows:

- Type I – scenarios with an initiating event that leads directly to severe fuel damage and to an early failure of the confinement function (e.g. spontaneous reactor pressure vessel rupture, large reactivity insertion). Once this initiating event occurs, effective provisions to limit the consequences are not practicable[3]. The notion of practical elimination applies to these scenarios.

- Type II – severe accident scenarios that induce an early failure of the confinement function (e.g. core melt with high energetic phenomena like direct containment heating or hydrogen detonation which threaten the containment integrity). There are means to prevent the phenomena from occurring, but once they occur, effective provisions to limit their consequences are not practicable. The notion of practical elimination also applies to these scenarios.

- Type III – severe accident scenarios that result in a late failure of the confinement function (e.g. core melt with loss of containment heat removal systems). They involve phenomena with relatively slow progression (e.g. slow containment over-pressurization, basemat melt-through). The consequences of these scenarios are

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[3] The term “practicable” should be understood as “practicable according to the current state of science and technology”.

expected to be less severe than those of type II scenarios. Large releases due to type III scenarios still have to be avoided, and some WENRA countries also apply the notion of practical elimination to the type III scenarios.

It is not always straightforward to associate one of the types described above to a particular scenario. In particular, this is the case for scenarios with severe fuel damage occurring whilst confinement is ineffective (i.e. open containment, or containment bypass). The type of these scenarios may depend, for example:

- on the feasibility of confinement closure in due time (before severe core damage occurs);
- or on the characteristics of the progress of the containment bypass that may be induced by severe accident conditions (e.g. induced steam generator tube rupture).

Scenarios with severe fuel damage in the spent fuel pool may also belong to these types, depending on the specific circumstances (e.g. design of the pool, location inside or outside the reactor building).

Furthermore, distinction of scenario types, and in particular the examples for scenario types, may also depend on reactor-type-specific and even plant-specific considerations. Thus, in this respect, the report at hand can only provide general indications which might require further differentiation in individual cases.

The typology described above therefore should not be considered as an exclusive approach by which each group of scenarios can stringently be assigned to one type.

The safety of a nuclear power plant relies primarily on the application of the defence-in-depth (DiD) concept. This is emphasized in the report on the safety of new NPPs by RHWG [6], in which a refined table of levels of DiD is presented (see Annex). Also, the WENRA Safety Objectives [4] have reinforced defence-in-depth implementation and stressed the importance of independence between the levels of DiD.

The following four basic elements can be established, which show the relation between avoidance of both large releases and early releases (using practical elimination of accident scenarios) and the DiD concept (not including level 5, which concerns off-site response):

1. Basic element 1 – rely on basic design features so that initiating events and potentially consequential, challenging phenomena can be screened out on the basis of their physical impossibility. Threats due to external hazards can be minimized by appropriate site selection and basic design features.

2. Basic element 2 – the initiating events which are not screened out according to the basic element 1 should be postulated[4]. Provisions for the prevention of their occurrence and limitation of their consequences should be implemented as far as practicable by adequate means at the different levels of DiD in order to prevent escalation to severe fuel damage.

3. Basic element 3 – severe accident scenarios should be postulated and considered in order to define and implement provisions for their mitigation as far as practicable and as far as this contributes to the objective of avoidance of early releases and large releases. The provisions of prevention and mitigation taken together over all levels of DiD have to result in the avoidance of early releases and large releases for these scenarios.

4. Basic element 4 – severe accident scenarios that lead to an unavoidable failure of the containment or its bypass should be practically eliminated as, once they occur, effective provisions to limit their consequences are not practicable.

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[4] If an initiating event can be demonstrated to be extremely unlikely with a high degree of confidence, it may not need to be postulated.

03

Identification of relevant scenarios

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The identification of all scenarios which could lead to early releases or large releases is a vital part of the approach to demonstrate avoidance by the use of practical elimination.

In order to achieve this, the following approaches should be included:

- Phenomenological (top-down) approach:

  Consideration of the entirety of the modes of failure or bypass of the containment in case of severe accidents, and identification of scenarios which can lead to these modes. This approach allows the identification of the phenomena likely to lead to failure of the containment.

- Sequence-oriented (bottom-up) approach:

  Consideration of the accident sequences leading to severe accidents (using bounding sequences whenever practicable and appropriate), with the goal to identify the potential to damage or bypass the containment. Subsequently, the relevant sequences are grouped into scenarios (see section 2). This approach allows the evaluation of loads to the containment, and of possible release routes.

All modes of normal operation of the plant (full power, low power and shutdown states, with special attention for states with open containment) as well as all relevant initiating events have to be considered.

04

The notion of practical elimination within the context of avoidance of early releases and large releases

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For severe accident scenarios for which mitigation is practicable (in accordance with basic element 3), the avoidance of large releases resulting from the scenarios is achieved by:

- demonstrating the adequate design and performance of the safety features implemented to cope with the envisaged scenarios (for instance, performance of the containment heat removal system, qualification to severe accident conditions, electrical back-up, efficiency of the core catcher for all possible scenarios that could lead to a vessel melt-through, etc.); and
- demonstrating that the radiological consequences of these scenarios are limited as far as practicable and meet the safety goals of the plant (limitation of the consequences in area and time); and
- verifying that measures implemented for mitigation of severe accident scenarios are sufficiently reliable and therefore the occurrence of these scenarios combined with failures of the mitigative measures can be considered as extremely unlikely with a high degree of confidence.

For scenarios that inevitably lead to a failure of the containment or containment bypass (in accordance with basic element 4), the avoidance of early releases and large releases is adequately achieved by demonstrating practical elimination on a case-by-case basis, by showing either:

- that the scenario is physically impossible, or
- that the occurrence of the scenario can be considered as extremely unlikely with a high degree of confidence[5].

In the next two sections, physical impossibility and extreme unlikeliness with a high degree of confidence will be further discussed.

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[5] For some scenarios, this refers to the occurrence of a single initiating event (if it directly leads to a large release or an early release); for others, to the occurrence of more complex scenarios which include additional failures.

05

Demonstration of practical elimination via “physical impossibility”

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Physical impossibility is the preferred way to demonstrate practical elimination of a scenario because it rules out its occurrence [6].

Physical impossibility is a robust way to demonstrate practical elimination, since it is based on physical laws which are generally applicable, verifiable and well validated in a given range of interest. Remaining uncertainties can be related to the administrative measures which have to guarantee that appropriate physical conditions are upheld (see section 7).

Physical impossibility shall be based on inherent physical characteristics or static features. Physical impossibility cannot rely on active technical provisions which need to change state to perform a necessary function in the course of the scenario.

Physical impossibility of a fault scenario can be achieved by two means:

A) <u>Complete absence of unacceptable loads by appropriate design features or measures</u>

This approach is the more straightforward one. Examples are:

- Making a severe power excursion impossible by appropriate inherent feedback characteristics of the reactor core.
- Making hydrogen detonation impossible by choosing materials so that no hydrogen can be produced.

Practical elimination may also rely on specific features not directly related to the phenomena threatening the containment, for example:

- Ensuring absence of a water source in a particular building, making local internal flooding impossible.
- Ensuring separation, making failure propagation from one component to another impossible.

B) Demonstration that the maximum load is significantly lower than the minimum resistance of relevant SSCs

Cases in which a maximum load is compared to a minimum resistance will be often encountered when checking whether physical impossibility can be demonstrated.

This comparison is relevant for many accident analyses, for example involving thermo-hydraulic loads, stress calculations, and fracture mechanics.

Some examples are:

- In case of load drop on SSCs important to safety, maximum dropping height and maximum mass can be limited by design and capacity of lifting gear, and the resistance of the SSCs is determined accordingly.
- The amount of hydrogen which can be produced is limited by design, and the containment can withstand detonation of this amount.
- The amount of water available for internal flooding is limited (by the capacity of tanks), and relevant SSCs are protected by a barrier of sufficient height.
- The design of the pipes' connections in the spent fuel pool is such that the uncovering of the fuel assemblies due to draining via these pipes is physically impossible.

It has to be noted that in most cases, load and resistance will not be given as point values, but by some probability distribution. If no definite upper and lower bound value, respectively, can be determined, the distributions of the variables will overlap, there is a non-zero probability of failure and physical impossibility cannot be demonstrated.

For both ways to achieve physical impossibility (A and B described above), its demonstration will have one or more physical laws as foundation. In many cases, these laws will have to be translated into mathematical models. Finally, the models will have to be validated in the relevant range.

Generally recognized physical laws can be regarded as given, and universally valid in a given range. They have to constitute the basis of the demonstration of physical impossibility.

Mathematical models of physical processes (e.g. thermo-hydraulic, fracture mechanic, detonation dynamic) used in the demonstration have to be well-established. In almost any case, they will be beset with uncertainties. They can only be used in the demonstration of physical impossibility if both: (a) the maximum range of their uncertainty can be reliably determined, taking into account all relevant factors, and (b) they can be shown to cover the worst case possible. If these conditions are not fulfilled, practical elimination could only be demonstrated via “extreme unlikeliness with a high degree of confidence”.

As noted in section 2, physical impossibility can also be a means for screening out events and phenomena by basic design features.

06

Demonstration of practical elimination via extreme unlikeliness with a high degree of confidence

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Demonstrating practical elimination via "extreme unlikeliness with a high degree of confidence" has to be based on the two pillars of deterministic and probabilistic considerations[6] [6].

For each scenario, expectations for the deterministic and probabilistic parts of the demonstration have to be considered and adequately fulfilled as formulated below.

For the deterministic part of the demonstration, these expectations should include the following[7]:

1. As a general principle, practical elimination should be primarily based on design provisions, supported by operational provisions. In order to ensure that the design provisions are and remain effective, due consideration should be given to high quality of construction and manufacturing as well as inspection, testing, and maintenance.
2. Attention has to be paid to the human factor as far as applicable:
    a. The needs for human action should be limited to the extent practicable, in particular when accident sequences can develop rapidly.
    b. For provisions that need human actions, their failure probabilities due to human error should be minimized.
    c. If human actions are needed, the operators have to receive all necessary information to unambiguously define their required actions. This implies receiving the information in a timely manner. Alert systems have to be reliable and clear and operator actions should only be credited if it is demonstrated that there is sufficient time to perform them, taking into account environmental conditions and the organizational structure. Operators also

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[6] There may be cases for which probabilistic considerations are not considered as meaningful by some member countries.

[7] The term deterministic is used in a broad sense here and includes all considerations and expectations not explicitly relying on probabilistic analyses.

have to be adequately trained, and supported by appropriate procedures and/or guidelines.

3. Assumptions underlying the specification of provisions have to be well-established and validated. There should be adequate control of their validity (see also section 7).
4. The uncertainties associated with the scenario should be taken into account:
    a. Sensitivity studies should be performed. The spectrum of possible conditions (with variations of parameters as well as modelling) should be covered.
    b. The analyses of some phenomena include very large uncertainties. If the reliability and robustness of the provisions for the mitigation of the consequences of a particular phenomenon cannot be demonstrated because of these uncertainties, the occurrence of the phenomenon has to be prevented with a high reliability.
5. The quality of the provisions against a scenario developing at the plant state corresponding to DiD level 1 and skirting higher levels of DiD or challenging them simultaneously (e.g. spontaneous RPV rupture during normal operation) has to be particularly high.
6. Provisions to achieve practical elimination should remain effective during and after events caused by internal and external hazards in such a way that demonstration of practical elimination remains valid.

For a complete demonstration of practical elimination, the provisions which have been implemented to fulfil these deterministic expectations have to be taken into account in the probabilistic part of the demonstration.

The probabilistic part of the demonstration of practical elimination of a scenario which could lead to early releases or large releases can be considered successful either if the frequency of the release resulting from this scenario is below a specific target value or if the frequency of the scenario in question is below this target value. Furthermore, for the overall demonstration of avoidance of both early releases and large releases, the overall frequency target for these releases has to be achieved.

It is important to differentiate between targets for the practical elimination of individual scenarios, and overall targets for the avoidance of large and/or early releases. There should be consistency between these two types of targets.

Targets can be specified in regulations, as is the practice in some WENRA countries. Some member countries prefer the applicant to propose a target which can then be assessed for its adequacy.

The probabilistic part of the demonstration requires as basis a comprehensive level 1 and level 2 PSA, including relevant internal and external hazards and also covering the spent fuel pool and supplemented with in-depth analyses of specific scenarios as needed.

To achieve the maximum possible confidence in the demonstration of practical elimination, the following expectations for the PSA are particularly important:

1. The PSA should cover all operational modes of the NPP (full power, low power and shutdown states, with special attention for states with open containment), as well as consider all relevant initiating events.
2. Uncertainty analyses should be performed in a manner sufficient to permit the demonstration of a high degree of confidence in the practical elimination of a scenario and in the avoidance of both large releases and early releases. Whenever practicable, this should cover both aleatory and epistemic uncertainties; uncertainties of input data and parameters as well as of models should be included. For input data and parameters, probability distributions, statistical coupling and correlations should be addressed as practicable.
3. When a truncation threshold for minimal cut sets is used to facilitate quantitative evaluation of the PSA model, this truncation value should be sufficiently low in order not to miss any relevant scenarios and thus not to affect the overall results.
4. The quantitative results should assess the contributions of the accident sequences to the frequencies of early releases and large releases.
5. Sensitivity studies should be performed, taking into account the effects of variations of parameters and modelling on the results to demonstrate that cliff-edge effects are sufficiently remote.
6. The documented results should show the uncertainties by including high fractiles of the frequencies involved, not only median and mean, whenever practicable.
7. In addition, the quality of the PSA should be examined (methodology, input data, results), taking into account internationally recognized standards, to check whether it is fully adequate to achieve a high degree of confidence, sufficient for the demonstration of PE.

In addition to showing compliance with the target values, PSA also can provide insights related to the deterministic considerations, in particular regarding the quality (independence, diversity etc.) of provisions (deterministic expectations 1 and 5) and the influence of the human factor (deterministic expectation 2). Furthermore, the results of the PSA may show that it is necessary to strengthen existing provisions, or to add new suitable provisions, in order to improve the confidence in the results.

Comprehensive PSAs should also be used to support the identification of scenarios for practical elimination according to section 3 to ensure the completeness of the identification.

07

The role of administrative measures

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Demonstration of practical elimination, both via extreme unlikeliness with a high degree of confidence and via physical impossibility, presupposes that certain assumptions always apply or that it is extremely unlikely, with a high degree of confidence that they are invalid.

These assumptions concern features and circumstances at the nuclear power plant which are generally regarded as given. In particular, this applies to physical conditions and administrative measures.

The administrative measures are crucial to guarantee that the physical conditions are upheld. For example, a specific chemical environment needs to be maintained in order to be able to guarantee the good condition of the reactor pressure vessel; or if fire is to be physically impossible, there are physical conditions concerning the flammability of the materials in the room, the maximum temperature, the possibility of sparks, the composition of the room atmosphere etc. In either case, there are administrative measures which have to ensure that all parameters and factors relevant for the physical situation are adequately controlled.

To recognize the importance of the administrative measures is a precondition for adequate control of the physical situation. As a part of the demonstration, an assessment is to be performed to evaluate the effectiveness and the resilience of the administrative measures during the whole lifetime of the plant. This implies, in particular:

- All relevant administrative measures should be identified and documented.
- Administrative measures should, when needed, be emphasized in the relevant OLCs, procedures and guidelines and should be verified as far as practicable.
- Personnel that may influence the effectiveness of administrative measures should have adequate background knowledge regarding the importance of these assumptions.
- Analyses and assessments of organization and human reliability should be performed to demonstrate the effectiveness of the administrative measures.

These points are relevant for all aspects of the safety demonstration. They are of particular importance in the context of practical elimination.

Administrative measures can fail. If the measures refer to simple conditions, e.g. concerning the position of locked valves it could be feasible to estimate the probability of their failure.

For more complicated forms of failures – e.g. the installation of a wrong type of valve in a particular position, or the transfer of burnable material into a room which should not contain any, with both failures due to implausible but not impossible chains of human errors – the estimation of probabilities could be beset with very large uncertainties.

The possibility of the failure of administrative measures, even in cases in which the frequency of the failure can be assumed to be small, is of considerable importance in the context of practical elimination.

There is no straightforward answer to the question which types of administrative measures are acceptable for the demonstration of practical elimination. Some measures are easier to maintain than others, conditions may change over time, additional administrative measures may be needed as new features are implemented, etc. In general, the administrative effort required to control and ensure the fulfilment of assumptions is an important aspect in this context.

The role of administrative measures will generally be smaller in case of screening out of events and phenomena by basic design features due to physical impossibility according to basic element 1 in section 2, since basic design features generally will not submit to change easily. This contributes to the preference of physical impossibility as a way to demonstrate practical elimination.

08

Practical elimination during the lifetime of the plant

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Provisions important for achieving practical elimination have to remain in place and valid throughout the plant lifetime [6] even if the conditions in and around a nuclear power plant change. This should include attention to:

- Ageing of SSCs contributing to practical elimination.
- Maintenance (inspection, repair and replacement).
- Plant modifications.
- Changes of the operational conditions (e.g. power uprate and introduction of a load following operational mode).
- Changes of procedures (which may, for example, affect administrative measures).
- Changes in external conditions (e.g. due to climate change or human activities in the vicinity).
- New technical and scientific knowledge relevant for the conditions in and around the NPP.
- New operational experience gathered at the site or in other NPPs.

The impact both on the provisions and on the administrative measures has to be assessed in each case.

In addition, it has to be noted that changes over time may introduce potential new accident sequences leading to early or large releases.

Therefore, the identification of scenarios for practical elimination and the demonstration of practical elimination should be kept up to date and periodically reassessed.

The validity of the demonstration that practical elimination has been achieved should be checked within every periodic safety review.

Furthermore, all factors that could affect the basis of practical elimination should be considered continually, notably in OLCs, the ageing management programme, in-service inspections and other periodic checks, the evaluation of operational experience feedback of the plant in question and also of other plants, and other reviews of the plant, as required; as well as generally by evaluating all relevant new information which becomes available, in a timely manner.

Some factors (e.g. ageing and external influences) have to be considered already in the design phase of the plant.

During the lifetime of a plant, it is also possible that technical abilities improve and knowledge about phenomena increases. Thus, following the principle of continuous improvement of safety, the possibility of introducing mitigation provisions for scenarios for which mitigation has previously been regarded as impracticable should be discussed, taking into account the practicability of their introduction and the resulting safety benefits. This can be the case, for example, during periodic safety reviews.

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Acronyms

DiD	defence-in-depth
IAEA	International Atomic Energy Agency
NPP	nuclear power plant
OLC	operational limits and conditions
PE	practical elimination
PSA	probabilistic safety analysis
RHWG	Reactor Harmonization Working Group
RPV	reactor pressure vessel
SSC	systems, structures and components
TECDOC	Technical Document
WENRA	Western European Nuclear Regulators Association

Annex: Refined structure of the levels of defence-in-depth

RHWG [6] developed positions on selected issues, concerning the safety of new NPPs. In position 1, a refined structure of the levels of defence-in depth has been developed:

Levels of defence in depth		Objective	Essential means	Radiological consequences	Associated plant condition categories
Level 1		Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation, control of main plant parameters inside defined limits	No off-site radiological impact (bounded by regulatory operating limits for discharge)	Normal operation
Level 2		Control of abnormal operation and failures	Control and limiting systems and other surveillance features		Anticipated operational occurrences
Level 3 (1)	3.a	Control of accident to limit radiological releases and prevent escalation to core melt conditions (2)	Reactor protection system, safety systems, accident procedures	No off-site radiological impact or only minor radiological impact (4)	Postulated single initiating events
	3.b		Additional safety features(3), accident procedures		Postulated multiple failure events

Levels of defence in depth	Objective	Essential means	Radiological consequences	Associated plant condition categories
Level 4	Control of accidents with core melt to limit off-site releases	Complementary safety features(3) to mitigate core melt, Management of accidents with core melt (severe accidents)	Off-site radiological impact may imply limited protective measures in area and time	Postulated core melt accidents (short and long term)
Level 5	Mitigation of radiological consequences of significant releases of radioactive material	Off-site emergency response Intervention levels	Off-site radiological impact necessitating protective measures(5)	-

For explanation of footnotes see reference [6].