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OVERVIEW ON SOME ASPECTS OF REQUIREMENTS AND CONSIDERATIONS FOR DESIGN OF A SCWR

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Presented by

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OBJECTIVES

Provide a short overview on the requirements and considerations which can be used for the design of a Super-Critical Water-Cooled Reactor (SCWR), as given below:

- Generation-IV Requirements
- European Utility Requirements (EUR)
- IAEA safety Requirements
- INPRO Requirements
- WENRA Requirements

OVERVIEW

- INTRODUCTION
- A SHORT OVERVIEW ON THE GENERATION IV INITIATIVE
- GENERATION IV TECHNOLOGY GOALS IN THE SAFETY AND RELIABILITY AREA
- USE OF GENERATION IV TECHNOLOGY GOALS FOR SAFETY ASPECTS OF FUTURE NUCLEAR REACTOR DESIGNS
- A SHORT OVERVIEW ON EUROPEAN UTILITY REQUIREMENTS
- SOME OF THE EUR FOR SAFETY ASPECTS
- USE OF EUR FOR SAFETY ASPECTS OF FUTURE NUCLEAR REACTOR DESIGNS
- IAEA SAFETY STANDARDS AND REQUIREMENTS
- THE INTERNATIONAL PROJECT ON INNOVATIVE NUCLEAR REACTORS AND FUEL CYCLES (INPRO) REQUIREMENTS
- WESTERN EUROPEAN NUCLEAR REGULATOR'S ASSOCIATION (WENRA) SAFETY OBJECTIVES FOR NEW NUCLEAR POWER PLANTS
- CONCLUDING REMARKS

INTRODUCTION (I)

- The major European utilities decide to take a lead role in defining the main features of future plants and they initiated the development of a common requirements document, the European Utility Requirements (EUR).
- The EUR scope was to allow development of competitive, standardized designs that would match the conditions in Europe and be licensable in the respective countries.
- The utilities provided their practical experience in the preparation of the EUR document.
- With the turn of the millennium, the importance of nuclear energy as vital and strategic resource in the U.S. and world's energy supply mix has also led to an initiative, termed Generation IV by the U.S. Department of Energy (DOE), to develop and demonstrate new and improved reactor technologies.
- As a result of this initiative, Generation IV technology goals are set and defined.

INTRODUCTION (II)

- For over 50 years the International Atomic Energy Agency (IAEA) has had a safety standards program. More than 200 safety standards have been published which reflect an international consensus on what constitutes a high level of safety for protecting people and the environment.
- IAEA International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) has established a set of requirements, organized in a hierarchy of basic principles, user requirements and criteria, comprising an indicator and an acceptance limit in all areas that must be fulfilled by an innovative nuclear energy system (INS) to meet the overall target of sustainable energy supply. INPRO was initiated in the year 2000, based on a resolution of the IAEA General Conference.
- Western European Nuclear Regulator's Association (WENRA) is a network of Chief Regulators of EU countries with nuclear power plants and Switzerland as well as of other interested European countries which have been granted observer status. WENRA co-operation was established in 1999 among 10 countries. Presently (from March 2003) 17 countries are represented in WENRA.

A SHORT OVERVIEW ON THE GENERATION IV INITIATIVE

- The Generation IV project was initiated by the United States Department of Energy's (USDOE's) Office of Nuclear Energy, Science and Technology
- Generation IV is a new generation of nuclear energy systems that can be made available to the market by 2030 or earlier, and that offers significant advances toward challenging goals.
- Formation of the Generation IV International Forum (GIF), a group whose member countries are interested in jointly defining the future of nuclear energy research and development.
- The Generation IV project is guided by a technology roadmap (2003) that will identify research and development pathways for the most promising technologies.
- Generation IV offers significant advances toward challenging goals.

TECHNOLOGY GOALS FOR GENERATION IV NUCLEAR ENERGY SYSTEMS (May, 2001)

The Generation IV goals (8) are defined in the broad areas (4) of:

- **Sustainability**

  Focus on fuel utilization, waste management, and proliferation resistance

- **Safety and reliability**

  Focus on safe and reliable operation, investment protection, and essentially eliminating the need for emergency response.

- **Economics**

  Focus on competitive life cycle and energy production costs and financial risk.

- **Proliferation resistance and physical protection**

Purpose of the Goals

- **Define and guide the development and design of Generation IV systems.**
- **They are challenging and will stimulate the search for innovative nuclear energy systems—both fuel cycles and reactor technologies.**
- **Serve as the basis for developing criteria to assess and compare the systems in a technology roadmap.**

Guiding Principles for the Generation IV Technology Goals

- **Technology goals for Generation IV systems must be challenging and stimulate innovation.**
- **Generation IV systems must be responsive to energy needs worldwide.**
- **Generation IV concepts must define complete nuclear energy systems, not simply reactor technologies.**
- **All candidates should be evaluated against the goals on the basis of their benefits, costs, risks, and uncertainties, with no technologies excluded at the outset.**

Caveats (explanations to prevent misinterpretations)

(The Generation IV technology goals are intended to stretch the envelope of current technologies. Hence, the following caveats are important to note)

- **The goals will guide the development of new nuclear energy systems. The objective of Generation IV systems is to meet as many goals as possible.**
- **The goals are not overly specific because the social, regulatory, economic, and technological conditions of 2030 and beyond are uncertain.**
- **The goals must not be construed as regulatory requirements.**

GENERATION IV TECHNOLOGY GOALS

- Eight goals for Generation IV nuclear energy systems are proposed in four areas: sustainability, safety and reliability, economics, and proliferation resistance and physical protection.
- The goals are arranged to facilitate the flow of information rather than to recommend an order of importance. Each goal is stated concisely.
- Supporting each goal is a discussion that clarifies the intent of the specific wording and the background from which it evolved.
- The discussion cites illustrative examples and suggests potential approaches.
- It is not meant to direct or constrain creativity and innovation.
- Also, much of the discussion is purposely drawn from worldwide experience that is useful in guiding the development of goals.

SUSTAINABILITY

Sustainability is the ability to meet the needs of present generations while enhancing and not jeopardizing the ability of future generations to meet society's needs indefinitely into the future.

- Existing and future nuclear power plants meet current and increasingly stringent requirements for clean air and avoid the emission of greenhouse gases.
- Sustainability requires:
    - The conservation of resources,
    - Protection of the environment,
    - Preservation of the ability of future generations to meet their own needs, and the avoidance of placing unjustified burdens upon them.
- The two sustainability goals encompass the interrelated needs of:
    - Effective fuel utilization,
    - Waste management.

Sustainability – 1.

Generation IV nuclear energy systems including fuel cycles will provide sustainable energy generation that meets clean air objectives and promotes long-term availability of systems and effective fuel utilization for worldwide energy production.

- Sustainability requires both the nuclear fuel to be available in the long term as well as the fuel cycle to be compatible with the environment.

- Conservation of resources encourages increasing fuel utilization beyond the level attained in current fuel cycles.

- Future nuclear energy systems have the unique opportunity to choose from a variety of fuels (e.g., uranium, thorium), reactor types (thermal, fast) and alternate fuel cycles (open, recycling). Evaluation of potential fuel cycles considered over their lifetime could provide Generation IV systems a basis to optimize their long-term nuclear fuel usage and economics, while reducing the environmental impact of high-level radioactive waste and preserving the resistance to proliferation. This strategy can increase the world energy supply significantly.

- These benefits need to be evaluated in terms of overall fuel cycle life cost, including disposition of high-level wastes and the need for infrastructure and technology.

- An additional factor to consider is the need to conserve other scarce materials or resources that ensure the long-term availability of Generation IV systems.

Sustainability – 2.

Generation IV nuclear energy systems will minimize and manage their nuclear waste and notably reduce the long term stewardship burden in the future, thereby improving protection for the public health and the environment.

- All energy systems have a number of waste streams generated in energy production or by the eventual cleanup of the energy producing facilities. Nuclear energy wastes range from those resulting from the mining of raw materials to the wastes generated in nuclear reactors or by decommissioning and decontamination (D&D).

- An important consideration of Generation IV systems is protection of public health and the environment by minimizing the amount and toxicity of discharged fuel and other high level radioactive products, and by evaluating the fate and transport of their radionuclides. This consideration should take the additional need for infrastructure and advanced technology into account, working within the regulatory framework.

- The United States and some other countries have adopted the once-through fuel cycle. Others use recycling to recover uranium and plutonium from the spent fuel to produce more power and reduce their needs for enrichment and new uranium. With recycling, the weapons-proliferation challenge increases but the high-level radioactive residues with recycling are less toxic, occupy a much-reduced volume, and can be processed into a vitrified form before disposal.

Sustainability – 2 (continued)

- Reactors that operate with a high neutron energy can be used to regenerate the fissile material they consume, and at the same time transmute long-lived heavy elements to further improve the management of high-level waste and fuel utilization.
- Disposition of discharged fuel or other high-level radioactive residues in a geological repository is the preferred choice of many countries involved in nuclear power generation, and good technical progress is being made. A number of countries are developing proposals in this area, and will need to continue to implement policies which are both scientifically and technically sound and provide a basis for building public confidence, which remains crucial to the success of the geological repository strategy.
- It is important that radioactive materials generated by Generation IV nuclear energy systems be produced in a form that best achieves safe and cost-effective waste management.
- Also, Generation IV systems should generate fewer low- and intermediate-level radioactive wastes and reduce their volume in order to decrease their impact at waste disposal sites.

SAFETY AND RELIABILITY

Safety and reliability are essential priorities in the development and operation of nuclear energy systems.

- During normal operation or anticipated transients, nuclear energy systems must preserve their safety margins, prevent accidents, and keep accidents from deteriorating into more severe accidents.
- At the same time, competitiveness requires a very high level of reliability and performance.
- A definite trend over the years to improve the safety and reliability of nuclear power plants, reduce the frequency and degree of off-site radioactive releases, and reduce the possibility of significant damage.
- Generation IV systems have goals to achieve the highest levels of safety and reliability and to better protect workers, public health, and the environment through further improvements.
- The three safety and reliability goals continue the past trend and are in accord with the regulatory policy to have designs that are safe and minimize the potential for severe accidents and their consequences.

Safety and Reliability – 1.

Generation IV nuclear energy systems operations will excel in safety and reliability.

- This goal aims at increasing operational safety by reducing

  - The number of events,
  - Equipment problems,
  - Human performance issues that can initiate accidents or cause them to deteriorate into more severe accidents.

- It also aims at achieving increased nuclear energy systems reliability that will benefit their economics. Appropriate requirements and robust designs are needed to advance such operational objectives and to support the demonstration of safety that enhances public confidence.

- During the last two decades, operating nuclear power plants have improved their safety levels significantly. At the same time, design requirements have been developed to simplify their design, enhance their defense-in-depth in nuclear safety, and improve their constructability, operability, maintainability, and economics.

Safety and Reliability – 1 (continued)

- Increased emphasis is being put on preventing abnormal events and on improving human performance by using advanced instrumentation and digital systems.
- Also, the demonstration of safety is being strengthened through prototype demonstration that is supported by validated analysis tools and testing, or by showing that the design relies on proven technology supported by ample analysis, testing, and research results.
- Radiation protection is being maintained over the total system lifetime by operating within the applicable standards and regulations. The concept of keeping radiation exposure as low as reasonably achievable (ALARA) is being successfully employed to lower radiation exposure.
- Generation IV nuclear energy systems must continue to promote the highest levels of safety and reliability by adopting established principles and best practices developed by the industry and regulators to enhance public confidence, and by employing future technological advances.
- The continued and judicious pursuit of excellence in safety and reliability is important to improving economics.

Safety and Reliability – 2.

Generation IV nuclear energy systems will have a very low likelihood and degree of reactor core damage.

- This goal is vital to achieve investment protection for the owner/operators and to preserve the plant's ability to return to power.
- There has been a strong trend over the years to reduce the possibility of reactor core damage. Probabilistic risk assessment (PRA) identifies and helps prevent accident sequences that could result in core damage and off-site radiation releases and reduces the uncertainties associated with them. For example, the U.S. Advanced Light Water Reactor (ALWR) Utility Requirements Document requires the plant designer to demonstrate a core damage frequency of less than 10-5 per reactor year by PRA. This is a factor of about 10 lower in frequency by comparison to the previous generation of light water reactor energy systems.
- Additional means, such as passive features to provide cooling of the fuel and reducing the need for uninterrupted electrical power, have been valuable factors in establishing this trend.
- The evaluation of passive safety should be continued and passive safety features incorporated into Generation IV nuclear energy systems whenever appropriate.

Safety and Reliability–3.

Generation IV nuclear energy systems will eliminate the need for off-site emergency response.

- The intent of this goal is, through design and application of advanced technology, to eliminate the need for offsite emergency response. Although its demonstration may eventually prove to be unachievable, this goal is intended to stimulate innovation, leading to the development of designs that could meet it.
- The strategy is:
  - To identify severe accidents that lead to offsite radioactive releases,
  - To evaluate the effectiveness and impact on economics of design features that eliminate the need for offsite emergency response.
- The need for off-site emergency response has been interpreted as a safety weakness by the public and especially by people living near nuclear facilities.
- Hence, for Generation IV systems a design effort focused on elimination of the need for offsite emergency response is warranted.
- This effort is in addition to actions, which will be taken to reduce the likelihood and degree of core damage required by the previous goal.

ECONOMICS

Economic competitiveness is a requirement of the marketplace and is essential for Generation IV nuclear energy systems.

- Presently, base-load units that were purchased and operated by regulated public and/or private utilities.
- A transition from regulated to deregulated energy markets, which will increase the number of independent power producers and merchant power plant owner/operators.
- Future, accommodate a range of plant ownership options and anticipate the increased use of distributed power, including load following and smaller units.
- Generation IV nuclear energy systems will primarily produce electricity, they may also find it profitable to produce a broader range of energy products beyond electricity. For example, potable water, process heat, or hydrogen will likely be needed to keep up with increasing worldwide demands and long-term changes in energy use.

Economics – 1.

Generation IV nuclear energy systems will have a clear life-cycle cost advantage over other energy sources.

- Life-cycle costs consist of four principal elements:
  - Capital costs,
  - Operation and maintenance costs,
  - Fuel cycle costs, and
  - Decommissioning and decontamination costs.
- Other important factors are:
  - Overall project duration,
  - Construction schedule,
  - Plant capacity factor,
  - Plant lifetime, and
  - Various financial assumptions for the project.
- At present, capital cost and length of construction are the principal financial barriers to increased use of nuclear power, while operation and maintenance costs at existing plants have improved dramatically in recent years.
- For Generation IV projects, all elements of life-cycle costs should be addressed to produce an advantage over other energy sources, including current nuclear systems, and to assure competitive energy production at the time of deployment

Economics – 2.

Generation IV nuclear energy systems will have a level of financial risk comparable to other energy projects..

- In competitive capital markets, Generation IV nuclear energy projects must attract the capital required for their deployment.
- Generation IV plants must independently demonstrate an acceptable level of financial risk to attract the necessary capital, although the allowable level of financial risk is limited by the need to achieve the life cycle cost advantage.
- A number of factors are important:
  - The cost and schedule risks associated with the construction, start-up, operation, and decommissioning must be well defined and managed for Generation IV projects.
  - Choices must be made balancing the benefits of volume production and economy of scale.
  - Achieving a comparable financial risk will also require that the systems adequately address external factors such as licensing and public concerns.

Proliferation Resistance and Physical Protection

Generation IV nuclear energy systems will increase the assurance that:

- They are a very unattractive and the least desirable route for diversion or theft of weapons-usable materials (Details in next 2 slides),

- And provide increased physical protection against acts of terrorism.

Existing nuclear plants are highly secure and designed to withstand external events such as earthquakes, floods, tornadoes, plane crashes, and fires. Their many protective features considerably reduce the impact of external or internal threats through the redundancy, diversity, and independence of the safety systems. This goal points out the need to increase public confidence in the security of nuclear energy facilities against terrorist attacks. Advanced systems need to be designed from the start with improved physical protection against acts of terrorism, to a level commensurate with the protection of other critical systems and infrastructure.

Proliferation Resistance and Physical Protection (continued)

Generation IV nuclear energy systems including fuel cycles will increase the assurance that they are a very unattractive and least desirable route for diversion or theft of weapons-usable materials.

- When nations acquired nuclear weapons in the past, they generally developed dedicated facilities to provide fissile materials for nuclear weapons rather than diverting such materials from civilian nuclear power systems. This does not mean that nuclear fuel cycles are, or can be, proliferation proof. Rather, the civilian nuclear fuel cycle has a history of being a less desirable route for production of weapons-usable materials. Generation IV nuclear energy systems should continue being highly resistant to proliferation and minimize the risk of proliferation by their operation.

- The International Atomic Energy Agency (IAEA) has an essential and continuing role of preventing nuclear weapons proliferation through surveillance, monitoring, inspection, and accountancy of nuclear materials. The nuclear supplier states support the IAEA role by defining and enforcing export controls on proliferation-prone nuclear materials, technology, and equipment. All member states that are parties to the Non-Proliferation Treaty have pledged adherence to full-scope safeguards, i.e., compliance with these extrinsic (institutional) barriers to avoid proliferation.

Proliferation Resistance and Physical Protection (continued)

- Nuclear facilities have used technology to create intrinsic (design) barriers that enhance the extrinsic barriers and help prevent diversion of weapons-usable nuclear materials and misuse of nuclear facilities or technology for weapons purposes. An example of a key intrinsic barrier found in many civilian nuclear energy systems is that their nuclear materials become considerably less subject to diversion after irradiation because they are highly radioactive and their weapons-usable materials are unseparated.

- Although very beneficial, intrinsic barriers are not sufficient by themselves. Rather, a combination of intrinsic barriers and extrinsic barriers is needed to achieve the required level of proliferation resistance. To date, the combination of intrinsic and extrinsic features has made the diversion or theft of materials from the nuclear power fuel cycle very difficult and comparatively the least attractive to potential proliferators.

- Generation IV systems will extend this current regime into the innovative fuel cycles or reactor technologies that emerge as the most promising candidates. Means for easy detection and intrinsic barriers will be evaluated to avoid the misuse of novel features of Generation IV systems.

USE OF GENERATION IV TECHNOLOGY GOALS FOR SAFETY ASPECTS OF FUTURE NUCLEAR REACTOR DESIGNS

- Generation IV International Forum (GIF) established a technology roadmap to guide the Generation IV effort in December 2002.
- This effort was completed in two years with the participation of over 100 experts from the GIF countries.
- The roadmap evaluated over 100 future nuclear reactor systems proposed.
- The roadmap ultimately identified six most promising systems.

  - Two employ a thermal neutron spectrum with coolants and temperatures that enable electricity production with high efficiency: Supercritical Water Reactor (SCWR), and the Very High Temperature Reactor (VHTR)

  - Three employ a fast neutron spectrum to enable more effective management of nuclear materials through recycling of most components in the discharged fuel: Gas Cooled Fast Reactor (GFR), the Lead-cooled Fast Reactor (LFR), and the Sodium-cooled Fast Reactor (SFR)

  - The last one, Molten Salt Reactor (MSR) employs a circulating liquid fuel mixture that offers considerable flexibility for recycling nuclear fuel.

- During the R&D phases of future reactor system designs, it is necessary to review the application of Generation IV Technology Goals at different stages of the development such that for the final design of the future reactor systems these goals are fulfilled and satisfied.
- This type of application has already been done for preliminary design of HPLWR

A SHORT OVERVIEW ON EUROPEAN UTILITY REQUIREMENTS

- The major European electricity producers have worked on a common requirement document for future LWR plants since 1992 to get specifications acceptable together by the owners, the public and the safety authorities.

The major objectives of the EUR document have been to develop requirements addressed to the LWR plant designers and vendors.

- All the main vendors are developing a number of standard designs that could be built in many countries with minimum adaptation, that show acceptable economic prospects and that actually meet the needs of the customer, including safety and licensing aspects.
- EUR document is structured in 4 volumes
  - Volume 1 Main policies and top tier requirements
  - Volume 2 Generic nuclear island detailed requirements
  - Volume 3 Design specific nuclear island requirements
  - Volume 4 Power generation plant requirements
- Altogether the EUR has some 5650 requirements
- The EUR promoters keep the final content of the document under close control and provide the contents of the different volumes in confidence and for limited use through the utilities, which are involved in the development of the EUR.

SOME OF THE EUR FOR SAFETY ASPECTS

- **Application of "As Low As Reasonably Achievable (ALARA)" Principle**
- **Design to be forgiving and characterized by simplicity and transparency with the use, where appropriate, of passive safety features**
- **Safety classification based on: design basis conditions (DBC) (See next table); design extension conditions (DEC).**
- **Safety systems performing DBC functions and certain DEC functions are required to have a degree of redundancy, diversity (e.g. passive versus active), independence, functional isolation and segregation to ensure prevention from common cause failure**
- **Design shall ensure autonomy that for DBC's and Complex Sequences, a Safe Shutdown State can be reached, as a goal within 24 hours from accident start and anyway within 72 hours. For DEC a safe Shutdown State should be reached within 1 week as a goal and before 30 days anyway.**

EUR Categorization of Design Basis Conditions (DBC)

Normal operation, incident and accident conditions of internal origin for which plant is designed according to established design criteria and conservative methodology

Design Basis Category	Definition	Frequency of initiating event (per year)	Plant parameters
DBC 1	Normal operation		Process parameters within normal operation range of Technical Specifications
DBC 2	Incidents	f> 1E-02	Process parameters within applicable acceptance criteria
DBC 3	Accidents (low frequency)	1E-02>f>1E-04	Acceptance criteria for Category 3 Limited fuel damage Shutdown for inspection may be necessary
DBC 4	Accidents (very low frequency)	1E-04>f>1E-06	Acceptance criteria for Category 4 Core coolable geometry retained Plant restart may be impossible

SOME OF THE EUR FOR SAFETY ASPECTS (Continued)

- EUR requires in addition the consideration of other engineering criteria, such as prevention of Common Cause failures, diversity, independence and segregation
- External hazards like earthquake, extreme weather, floods, aircraft crash, adjacent installations, electromagnetic interference, sabotage and internal hazards like fire, noxious substances, failure of pressure parts, disruption of rotary equipment, dropped loads and electromagnetic interference must be addressed
- Requirements on the systems are set in terms of operational performance to ensure the reactivity control, heat removal and radioactivity confinement. Reactivity coefficients acceptable values, stable operation and reliability of the shutdown systems are all EUR requirements
- For the core heat removal, temperature, pressure, flow and inventory control are required besides depressurization capability and pressure boundary integrity. For the latter, the use of the Leak Before Break (LBB) methodology is foreseen

SOME OF THE EUR FOR SAFETY ASPECTS (Continued)

- In the very long term after an accident, provisions for the connection of mobile equipment are required
- Important provisions required by EUR to demonstrate the in vessel corium cooling and avoidance of base mat perforation by the use of automatic depressurization system and the core spreading area that allows for solidification of the crust
- Under DEC's, not a classical environmental qualification is required, rather the equipment survival has to be demonstrated

EUR REQUIREMENTS ON THE CONTAINMENT SYSTEM

- Aim mainly at strengthening the confinement of the fission products and protection against external events. The containment shall perform these functions in normal operation (including shutdown), DBC and DEC's
- Under DEC's conditions early failure of the Containment system has to be ruled out by design (e.g. for PWR's adoption of a full primary circuit depressurization system). In vessel core debris interaction with water (steam explosion), high pressure ejection of molten core leading to direct containment heating; ex-vessel debris interaction with water (subcooled water, steam explosion) and reactivity accidents (including heterogeneous) boron dilution) have all to be prevented by design
- The design of the Containment system has to exclude hydrogen concentrations that can lead to detonation. As a consequence the effectiveness of a hydrogen recombination system must be demonstrated. As an alternative inertization is required. The effect of other flammable gases e.g., CO must be accounted for
- If in-vessel coolability cannot be demonstrated ex-vessel coolability and non-criticality features must be provided. A core catcher or corium spreading room must be provided to drive the corium into a stable situation

EUR REQUIREMENTS ON THE CONTAINMENT SYSTEM (Continued)

- For the design of the Containment shell, particular attention has to be given in requiring that also severe accidents be taken into account, even if not necessarily directly determining the Containment design pressure. The Designer must demonstrate that, in case the pressure and temperature exceed the design values, the assumed leakrate is adequately supported. Also the local effects of hydrogen deflaration and sustained flames have to be considered
- Credible Primary Containment leak rate values are provided by EUR: for a pre-stressed concrete shell without liner 0.5 to 1.0 V%/d; for a pre-stressed concrete with liner 0.1 to 0.5 V%/d; for a metal shell 0.1 to 0.5V%/d
- Means should be provided to ensure on-line monitoring of Containment leak-tightness during operation
- Containment should not remain at elevated pressure for a long time after the accident. In 24 h the pressure has to be reduced at least to 50% of its peak value in the worst DBC

EUR REQUIREMENTS ON THE CONTAINMENT SYSTEM (Continued)

- In addition to the Primary Containment, the EUR requires also a Secondary Containment. Secondary Containment function can be demonstrated to meet also in the case that the Secondary Containment is not kept under a negative pressure, provided that the leak tightness is ensured. For the secondary containment a "partial" solution enclosing all the penetrations is acceptable.
- The Secondary bypass leakage is required not to exceed 10% of the Primary Containment leakage
- Through the combination of the different lines of defense the EUR Requirements aim at achieving a degree of protection of the population and the environment higher than the one achieved by previous generation of NPP and by the majority of other industrial hazards. This high degree of protection is aimed to be reached with very limited or no external mitigative action. In the next generation of NPPs an improvement in safety will be reached through increasing the role of design robustness, better operation and maintenance (preventive means) rather than through protective actions.
- Public evacuation planning should not be necessary. Eventually nuclear emergency situations should be managed with those protective measures normally planned in the industrialized countries for generic public protection

ACCIDENT PREVENTION

- Simplification of safety systems
- Elimination of common mode failures by physical separation and diverse back-up functions for safety functions
- Less sensitivity to human errors by designing components with larger water inventories to smoothen transients
- Optimized man-machine interface by digital instrumentation and control systems and status-oriented information supplied by modern operator information systems. Nevertheless, it is intended to consider, beyond the deterministic design basis, events with multiple failures and coincident occurrences up to the total loss of safety grade systems on a probabilistic basis in order to limit the residual risk

USE OF EUR FOR SAFETY ASPECTS OF FUTURE NUCLEAR REACTOR DESIGNS (I)

- The EUR promoters are producing evaluations of selected LWR designs and they include the results of these applications in Vol. 3 of the EUR document.
- Six subsets dedicated to the ABWR, BWR90, EPR, EPP, SWR1000 and AES92 (VVER 1000) projects have been published
- The requirements are also being employed for the design of the ESBWR, and AP1000 application and are published
- In addition, use of EUR has been also seen in the framework of calling bids, e.g., Olkiluoto-3 (Finland), Belene (Bulgarian), etc.
- All the EUR safety requirements have also been considered and taken into account during the evaluation of the merit and feasibility of the High Performance Light Water Reactor (HPLWR) concept

USE OF EUR FOR SAFETY ASPECTS OF FUTURE NUCLEAR REACTOR DESIGNS (II)

- The analyses of compliance, which is detailed process and application, have been carried to the elementary level. This process have requested and needed much resources and time both by the EUR utilities and by the interested vendors.
- The EUR document is a reference user’s document for LWR plants to be built in Europe beyond the turn of the century, but it is not a document for licensing the plants.
- The plant designs will always need to duly comply with the national licensing regulations and laws.

IAEA SAFETY STANDARDS AND REQUIREMENTS

- While regulating safety is a national responsibility, international standards and harmonized approaches to safety promote consistency and help to provide assurance that nuclear and radiation related technologies are used safely. The International Atomic Energy Agency (IAEA) is required by Statute to promote international cooperation.
- For over 50 years the International Atomic Energy Agency (IAEA) has had a safety standards programme. More than 200 safety standards have been published which reflect an international consensus on what constitutes a high level of safety for protecting people and the environment.
- The standards provide a robust framework of fundamental principles, requirements and guidance to ensure safety. They are applicable, as relevant, throughout the entire lifetime of facilities and activities.
- The principle users of the safety standards are regulatory bodies and organisations that design, manufacture and operate nuclear facilities.
- The Safety Standards are not binding on states and are used in different ways in different countries. As examples:
    - The Safety Standards were used to benchmark the recent review of Safety Assessment Principles (SAPs) for Nuclear Facilities and in the continuing review of the Technical Assessment Guides (TAGs)
    - Also the Safety Standards were used in deriving the WENRA reference levels

IAEA SAFETY STANDARDS AND REQUIREMENTS

The hierarchy of the IAEA Safety Standards are as follows:

- **Safety Fundamentals**

As the primary publication in the Safety Standards Series, Fundamental Safety Principles (unified in 2006) establishes the fundamental safety objective and principles of protection and safety. Principles cover thematic areas and facilities and activities.

- **Safety Requirements**

An integrated and consistent set of Safety Requirements publications establish the requirements that must be met to ensure the protection of people and the environment. The requirements are governed by the objectives and principles of the Safety Fundamentals. If they are not met, measures must be taken to reach or restore the required level of safety.

They use the word ' shall'.

- **Safety Guides**

Safety Guides provide recommendations and guidance on how to comply with the Safety Requirements, and reflect a consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices and increasingly they reflect best practices to help users striving to achieve high levels of safety.

THE INTERNATIONAL PROJECT ON INNOVATIVE NUCLEAR REACTORS AND FUEL CYCLES (INPRO) REQUIREMENTS

- The sustainability of nuclear systems that are operating today is questioned by the public and by some decision makers, because of concerns related to safety, nuclear waste disposal, and the proliferation of nuclear weapons.
- To address these concerns and ensure a sustainable development of nuclear energy, the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) was initiated in the year 2000, based on a resolution of the IAEA General Conference. Since its establishment, membership in INPRO has grown to 31 members. Several other countries have observer status as they consider membership or are participating on a working level.
- INPRO has established a set of requirements, organized in a hierarchy of basic principles, user requirements and criteria, comprising an indicator and an acceptance limit in all areas that must be fulfilled by an innovative nuclear energy system (INS) to meet the overall target of sustainable energy supply.
- the INPRO methodology will be employed by two broad classes of users
  - *technology users*
  - and *technology developers/holders*.
- INPRO takes a holistic approach to assess innovative nuclear systems in seven areas

Structure of the INPRO methodology using Basic Principles, User Requirements and Criteria

List of Volumes of the INPRO Manual (TECDOC-1575 Vol. 1, Rev.1, 2008)

Number of volume	Content of volume
1	INPRO Manual Overview of the INPRO methodology
2	INPRO Manual for the area of economics
3	INPRO Manual for the area of infrastructure
4	INPRO Manual for the area of waste management
5	INPRO Manual for the area of proliferation resistance
6	INPRO Manual for the area of physical protection
7	INPRO Manual for the area of environment
8	INPRO Manual for the area of safety of nuclear reactors
9	INPRO Manual for the area of safety of nuclear fuel cycle facilities

WESTERN EUROPEAN NUCLEAR REGULATOR'S ASSOCIATION (WENRA) SAFETY OBJECTIVES FOR NEW NUCLEAR POWER PLANTS

- WENRA is a network of Chief Regulators of EU countries with nuclear power plants and Switzerland as well as of other interested European countries which have been granted observer status. WENRA co-operation was established in 1999 among 10 countries. Presently (from March 2003) 17 countries are represented in WENRA.
- The main objectives of WENRA are to develop a common approach to nuclear safety, to provide an independent capability to examine nuclear safety in applicant countries and to be a network of chief nuclear safety regulators in Europe exchanging experience and discussing significant safety issues.
- There were two main reasons why WENRA was established
- One of the objectives of WENRA, as stated in its terms of reference, is to develop a harmonized approach to nuclear safety and radiation protection issues and their regulation.
- A significant contribution to this objective was the publication, in 2006, of a report on harmonization of reactor safety in WENRA countries. This report addresses the nuclear power plants that were in operation at that time in those countries.

CONCLUDING REMARKS (I)

- The European Utility Requirements (EUR), as general guide.
- The EUR is considered to be most advanced and complete in Europe and already applied in the design of advanced LWRs.
- Additionally, Technology Goals for Generation IV can be considered in order to include further advance ideas.
- Using the EUR as a guide for the detailed design of the future reactor systems will most probably insure the conformity of that design with Generation IV goals
- IAEA-INPRO provides a forum for discussion and cooperation for experts and policy makers from industrialized and developing countries on sustainable nuclear energy planning, development and deployment.

CONCLUDING REMARKS (II)

- Much more details are included in the EUR, such as
  - Quantitative specification of deterministic and probabilistic targets (never done in IAEA Standards)
  - Specification of certain computational methods (hydrogen, containment loading, radiation doses, etc.)
  - Prescription of some engineering solutions to address the challenges.
- No contradictions found between EUR and IAEA/WENRA, but differences in terminology and level of details

CONCLUDING REMARKS (III)

- WENRA Reference Levels represent reasonably balanced requirements applicable for both existing and new designs
- WENRA Levels have been derived from IAEA Safety Requirements, and also from Safety Guides. Consequently resulting in good consistency in between these two.
- In several cases wording of WENRA more stringent using statements such as "…shall exist", "…shall be possible", etc. rather than "adequate consideration shall be given…" used by IAEA
- In principle, WENRA is for existing reactors, EUR is for new reactors

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