According to the World Energy Council, continued reliance on fossil fuels for the vast majority of our energy needs is simply not realistic. Viewing the situation in a worldwide context magnifies the

Enhancing Safety in the 21st Century

Solutions in Response to Insights from Fukushima Daiichi
Westinghouse has been committed to providing safe commercial nuclear power designs and solutions since the first commercial nuclear power plant was designed in the late 1940s. Today, that commitment is stronger than ever as we continue to develop safe, new plant designs and provide products and services to ensure successful operations within the existing plant fleet.

Westinghouse offers solutions on a global scale and can serve as your primary provider of services and products for both **pressurized water reactors (PWRs)** and **boiling water reactors (BWRs)**.

Westinghouse is ready to assist the nuclear industry in facing the challenges brought to light as a result of the events at Fukushima Daiichi. Since March 2011, our team of experts has been working, in conjunction with the global nuclear industry, to develop and bring to market solutions that increase safety and incorporate the lessons learned.

**Westinghouse can work with your team to assess your goals for enhancing reactor safety, develop a customized solution and efficiently implement that solution on a timely basis.**

This brochure highlights some of Westinghouse’s capabilities, but the list is growing rapidly. Please refer to [http://www.westinghousenuclear.com/enhancingsafety/](http://www.westinghousenuclear.com/enhancingsafety/) or scan the code at left to view from a list of Westinghouse’s products and services to enhance plant safety.

Westinghouse’s technologically innovative AP1000® PWR harnesses natural forces such as gravity, convection and condensation to achieve a passive safety system shutdown automatically, with no need for human intervention for up to 72 hours. Please refer to [http://ap1000.westinghousenuclear.com](http://ap1000.westinghousenuclear.com) or scan the code at left for more details on **AP1000** reactor technology.

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External Events

All safety-related systems, structures and components (SSCs) at nuclear power plants are designed specifically to withstand the effects of externally initiated events, such as seismic activity, high winds and floods, without loss of capability to safely shut down the plant and maintain it indefinitely in a safe condition. Although external events are typically low-probability occurrences, they can have far-reaching consequences. To protect the reactor core and the spent fuel pool (SFP), the possible vulnerabilities of a plant during an external event or a series of stacked external events must be understood, and defense-in-depth measures must be developed to compensate for related potential failures.

PRA Services

Both the industry and regulators use probabilistic risk assessment (PRA) as a decision-making tool to enhance plant safety. The PRA model identifies the risk significance of plant equipment, which can be used to identify vulnerabilities of the plant design to various postulated external events.

Westinghouse helps nuclear power plants establish a cost-effective, risk-informed, integrated decision-making framework to increase safety, improve plant operation, resolve emergent plant issues and address regulatory issues. Westinghouse’s full range of PRA services applies to both PWRs and BWRs and includes:

• Developing, upgrading and maintaining Levels 1, 2 and 3 PRA models
• Developing low-power and shutdown PRA models
• Developing PRA models for the SFP
• Performing thermal-hydraulic analyses to predict plant response to initiating events and to support equipment survivability assessments
• Providing a broad range of fire risk services, including fire PRAs, National Fire Protection Agency (NFPA) Standard 805 transition, safe shutdown analysis, fire modeling and classic fire protection engineering

Seismic Assessments

A systematic analysis of seismic risk is essential for plants to address changes to their hazard profiles. These changes may result from new earthquake observation data, the identification of new faults in the plant’s vicinity, or new information or refined modeling of seismic sources or of ground motion. Seismic PRAs (S-PRAs) and seismic margin assessments (SMAs) are two techniques available to analyze seismic risk.

Seismic risk assessments will identify which SSCs contribute to the majority of seismic risk. Understanding these SSCs enables the identification of cost-effective plant modifications to reduce seismic risk.

Seismic PRA

Westinghouse is currently completing S-PRA models of seven reactors for three licensees. Westinghouse is developing these models to meet American Society of Mechanical Engineers/American Nuclear Society (ASME/ANS) RA-Sa-2009 (the ASME/ANS PRA standard) and Capability Category II to support risk-informed applications. The S-PRA model will be complete in less than 17 months, including quantification of the model and the associated industry peer review. With proven experience and capabilities, our Westinghouse team can meet your plant’s needs for an S-PRA consistent with the U.S. Nuclear Regulatory Commission (NRC) timeline for responses to the 50.54(f) letter regarding Near Term Task Force Recommendation 2.1.

Westinghouse’s expert seismic team has partnered with Stevenson & Associates Inc. and Jack R. Benjamin and Associates Inc. to address all aspects of both S-PRAs and SMAs for PWRs and BWRs, including:

• Probabilistic seismic hazard assessment
• Fragility analysis
• Seismic response modeling
• Full seismic risk integration
• Walkdowns to address seismic capacity of structures and components
• Plant modifications

External Flooding Assessments

The Fukushima event and recent flooding along the Mississippi and Missouri rivers in the United States demonstrate that external flooding risks can pose very real and significant challenges to plant safety both during power operations and shutdown conditions. Westinghouse develops strategies based on its full understanding of the risk contributors and associated insights into such an event (e.g., probable maximum precipitation, dam failure, tsunami) to help plants cope.

Westinghouse analyzes plant risk due to external flooding events from both PRA and design-basis perspectives for PWRs and BWRs. Westinghouse can perform plant walkdowns to identify and assess plant vulnerabilities. To mitigate risk, Westinghouse can develop a variety of plant procedures necessary to cope with external flooding events, and can also help develop plant modifications, evaluate the risk effectiveness of temporary measures and establish mitigation strategies for dealing with flooding events.

PRA of All Other External Events

Westinghouse offers external PRA (E-PRA) techniques for both PWRs and BWRs to address a plant’s response to external events, such as high winds (linear and cyclonic), transportation accidents, chemical releases and low-water events, from a perspective beyond design basis. Westinghouse’s E-PRA techniques provide an estimate of the residual risk associated with each particular external event, identify plant vulnerabilities and support a variety of operational and design changes.

Westinghouse’s team of risk analysts are skilled in the areas typically contained in an external events risk assessment, including hazard analysis, fragility analysis, and plant response model development and quantification.

AP1000 Plant PRA Development

Westinghouse is currently transitioning the licensing PRA for the AP1000 plant to an operational PRA. The operational PRA models include at-power and shutdown hazards (internal events and fire, flooding, seismic and other external events) and are developed to meet ASME/ANS RA-Sa-2009 (the ASME/ANS PRA standard) and Capability Category II to the extent possible for a new plant not yet in operation. This operational PRA is required by 10 CFR Part 52, to be complete at the time of fuel load. Westinghouse has completed the initial quantification of the internal events PRA model and has initiated work on the other hazards. The internal events and internal flooding models will be the pilot for the new plant addendum to the ASME/ANS PRA Standard, which is soon to be released for trial use. Westinghouse also has expertise in SFP PRAs used to support AP1000 plant licensing.

Backup Ultimate Heat Sink

In a nuclear power plant, waste heat is removed by various heat exchangers and then transferred to an ultimate heat sink (UHS). If the UHS is unavailable, provisions are made to transfer heat from the reactor core through the release of steam. Eventually, however, waste heat must be removed by alternate means to avoid damage to nuclear steam supply system (NSSS) equipment, the SFP or the reactor building. The failure of critical SSCs can result in the release of radioactivity, thereby endangering the health and safety of the public.

Westinghouse can work with customers to define the optimal solution for their plants, using permanent or mobile technology, to maintain
heat removal functions when the main UHS is lost. Westinghouse can design and install a permanent backup UHS that provides defense-in-depth through the use of air coolers or deep wells. Air fan cooling bays that have a seismically qualified structure can be installed in piping either parallel to the existing component cooling water heat exchangers or at a higher elevation to avoid tsunami or flood damage.

Westinghouse offers the Toshiba Mobile Cooling System to provide backup for cooling systems as a solution to remove decay heat and achieve cold shutdown within a specified time period. The Toshiba Mobile Cooling System has been successfully used in Japan. The compact and mobile design consists of a submersible pump, heat exchangers, valves, instruments and a control device, all of which are integrated into a cooling unit and mounted on a trailer. Power is supplied from a separate generator. For plants that have a non-water UHS, the system is available with cooling towers or air-cooled heat exchangers in place of the submersible pump. The system is connected to an existing system only when needed. Benefits of this design include:

- Is consistent with the FLEX approach since it is stored in an area protected from natural disaster and moved by truck only when needed.
- Requires only a small change to the existing system.
- Provides easy setup that consists of connecting the systems with flexible tubes.
- Provides existing system modification by Toshiba to optimize application of the Mobile Cooling System.

Modifications to SSCs

Upgrades and modifications to SSCs may require hardened structures to protect them from external events. These upgrades and modifications include seismic stiffening, enhanced flood protection and missile protection.

Westinghouse designs and installs hardened structures to protect pumps, motors, switchgear and other sensitive equipment from severe external events worldwide. Westinghouse has upgraded SSCs such as service water pumps and control room ceilings so they can withstand events not considered in the original design basis.

Bunkered Safety Systems

Safety bunkers are an additional defense to cope with external events such as earthquakes, floods, airplane crashes, fires, gas cloud explosions and sabotage. The total loss of all loss SSCs located in non-hardened UHS structures could result in extended loss of UHS, extended loss of all AC power and/or ability to access the main control room.

Westinghouse can design and implement safety bunkers to include:

- Additional emergency safety systems (e.g., emergency feedwater, steam release, charging, reactor coolant pump (RCP) seal injection, shutdown cooling, water supply)
- Additional instrumentation and control (I&C) systems (e.g., emergency control room, reactor protection, safeguards actuation)
- Additional emergency support systems (e.g., emergency AC/DC power, air supply)
- Additional functions to existing systems (e.g., reactor coolant system (RCS) isolation steam generator isolation, isolation/stop to non-bunkered systems, cutoff controls from the main control room)

Westinghouse uses an exhaustive Reverse Failure Mode & Effect Analysis (RFMEA) to determine the design functions to be included in the safety bunker. This systematic approach demonstrates the extent of the emergency functions needed to protect the plant against all possible external events and all initial plant conditions. The mode to actuate and control the bunkered safety systems can range from fully manual to fully automatic.

Westinghouse has designed and implemented bunkered safety systems in Belgium, Switzerland and Germany either during plant construction or as a back-fit to existing plants with autarky times of three to 10 hours.
Extended Loss of AC Power Coping

Station blackout (SBO) is defined as the loss of all AC power at the generating station – that is, a loss of off-site power coupled with a run failure of the on-site emergency generators. Plants have defined coping strategies for postulated SBO conditions for a limited time period ranging from two to 16 hours, per 10 CFR 50.63. An extended loss of AC power (ELAP) event is defined as a loss of all off-site and on-site AC power sources for a potentially indefinite time period, which will challenge the long-term cooling of the reactor core and the SFP unless mitigating actions are taken. Westinghouse offers several solutions that address ELAP conditions.

Mobile Equipment and Connections – Technical Basis

Permanently installed plant equipment may be rendered inoperable from a beyond-design- basis external event, or may have a limited amount of time for operation. Plants cannot rely solely on permanent equipment to cope with an ELAP that is undefined in duration.

Westinghouse offers the capability to establish the technical basis for mobile equipment and connection points that can subsequently provide indefinite ELAP coping for the core, containment and SFP for all operating modes. A firm technical basis can optimize the amount of mobile equipment and connection modifications made to the plant, thereby reducing implementation costs and minimizing future rework on improper equipment sizing for coping with an ELAP.

Our technical basis process has proven to be successful at plants from implementation through regulatory approval. It includes:

- Selecting and confirming functional requirements for mobile equipment
- Establishing timing requirements for deploying mobile equipment
- Identifying and prioritizing site water sources to minimize fouling of steam generators
- Conducting electrical coping studies to prioritize equipment needs and load shedding
- Performing boration studies to establish basis for preventing recriticality
- Completing containment analyses to determine maximum pressures and temperatures, and to optimize long- term heat removal strategies in all modes

Westinghouse has conducted many of these analyses generically for the PWR design plants, and has performed plant-specific studies for more than 30 plants of both PWR and BWR designs.

ELAP Procedures

Current plant Emergency Operating Procedures (EOPs) require modifications to incorporate using mobile equipment and coping strategies (such as shedding battery loads, manual cooldown, etc.). Also, in high-stress situations during which mobile equipment must be connected to prevent a catastrophic accident, detailed ELAP procedures should be made available to minimize the potential for human error by operators or other plant personnel tasked with installing the equipment.

Westinghouse has developed both a generic set of ELAP procedures and generic modifications to existing EOPs to provide symptom-based entry conditions to the ELAP procedures. These generic procedures and modifications can be applied to any PWR design, including VVERs (Vodo-Vodyanoi Energetichesky Reactors). Procedure validation, training and setpoint calculations can also be provided. Our overall expertise in ELAP strategies and...
generic ELAP procedures allows Westinghouse to quickly generate high-quality, plant-specific ELAP procedures. Westinghouse also provides technical oversight to a plant’s own procedure writers for flexible implementation, which can assist plants in minimizing overall cost. Additionally, Westinghouse can appropriately relate ELAP procedures to existing EOPs, Severe Accident Management Guidelines (SAMGs) and Extensive Damage Mitigation Guidelines (EDMGs).

Westinghouse has been awarded several full-scope, plant-specific ELAP procedure development projects, as well as more encompassing technical consulting projects and setpoint calculation projects.

ELAP Connections – Hardware and Modifications

Typically, approximately a dozen ELAP connections into existing plants are made to allow for water and power from mobile sources. Many of these connections are installed in safety-related systems. The connections must not violate existing plants’ design bases, or codes and standards (for example, double isolation must be maintained for safety systems). The connections must also be capable of withstanding design-basis and sometimes beyond-design-basis external events.

Westinghouse offers design engineering support for these connection modifications to ensure these requirements are met. We can also provide the necessary safety-related hardware for isolating mobile equipment from safety-class systems.

Westinghouse is a global provider of safety-class valves and safety-related electrical switchgear and has performed modification design activities and supplied safety-related hardware at several plants.

Optimizing ELAP Connections to Reduce Outage Time and Risk

Since almost all plants must make physical modifications for ELAP events, with advanced planning based on current plant limitations during outages, certain connection modifications can be configured to help reduce outage times or provide defense-in-depth during outages that reduce overall risk, adding cost benefits while meeting regulatory requirements concerning potential ELAP events.

For example, connection points could be used to borate faster at outage initiation, mobile equipment can refill the plant at outage end, and mobile equipment can be connected to provide defense-in-depth to allow systems to be removed from service and maintained earlier in outage schedules.

Depending on the current limitations, plants may be able to save 24 hours or more compared to their current outage durations without added risk. Westinghouse has worked with at least one utility to provide such value.

Gen III SHIELD™ Passive Thermal Shutdown Seal

In the event of a loss of all seal cooling in the RCP, primary coolant will leak through the RCP seals. In an SBO or ELAP event, the seal leakage cannot be made up using normal plant systems. In such events, operators must initiate rapid RCS cooldown through steam generator depressurization to allow accumulator injection for RCS makeup. Without power restoration or an alternate means of injection into the RCS, the core will eventually be uncovered.

Westinghouse developed the Gen III SHIELD passive thermal shutdown seal (patent pending) as a passive means of protecting the reactor core by
permitting). pool boiling events (static net positive suction head of steam, without supporting services (AC/DC power for extended periods. It also can be used to support subsystems and can be operated without AC or turbine/pump assembly that has fewer parts and no coolers and barometric condensers. Westinghouse requires support subsystems such as lube oil pump/
and ease of maintenance in nuclear service. The pumps require support systems also, such as lube oil pumps/coolers and barometric condensers for BWRs.

Steam-driven Pump Upgrades

The most safety-significant system in the case of an ELAP in a BWR is the reactor core isolation cooling (RCIC) system and in a PWR is the auxiliary feedwater (AFW) system. The steam-driven water pump in each of the PWR and BWR systems is typically the frontline component maintaining core heat removal during an ELAP. However, existing steam-driven pumps can require DC power for operation and control, which can be a limiting factor during an ELAP. In addition, both the turbine and the control system have historically experienced shortcomings in reliability, performance and ease of maintenance in nuclear service. The pumps require support systems also, such as lube oil pumps/coolers and barometric condensers for BWRs.

Westinghouse is pursuing U.S. NRC approval on PRA model enhancements that are gained by installing the SHIELD. Once approved, the PRA model will allow plants to credit the RCP SHIELD in PRA and Fire Protection applications.

The Gen III SHIELD provides plants tangible financial benefit in risk reduction due to the much lower seal leakage that can be credited following a loss of seal cooling. The SHIELD does not require any other plant modifications and can be installed simply during a normal seal package maintenance window.

Westinghouse, together with ClydeUnion Pumps, an SPX® brand, offers a turbine water-lubricated (TWL) turbine/pump set that addresses the limitations of the current pumps of both the BWR RCIC system and the PWR AFW system. The TWL turbine/pump set can either replace an existing pump set or be installed as an additional function for added defense in depth. It has an impressive 40-year operating history, including use in both nuclear and non-nuclear installations worldwide. The TWL turbine/pump set has fewer parts, no support subsystems and can be operated without AC or DC power for extended time periods. It provides the following significant normal and emergency operation benefits:

- Part of an extended SBO coping strategy in which the system can operate using steam, without supporting services (AC/DC not required)
• Reduced room fire loading (no lubricating oil used)

• Fewer system components that require maintenance and surveillance

• Smaller system footprint

• Excellent transient response

• For BWRs, hot suppression pool recirculation (to 250°F) capability

• For PWRs, self-governing for duty control

Westinghouse can provide full implementation, from event transient analysis simulations to design change packages, field labor, and startup testing and procedures. Westinghouse can also deliver all services related to procurement, design, analysis, licensing and installation to extend plant coping.

PWR Alternate Reactor Coolant Makeup System

In the event of an ELAP situation that results in a loss of coolant, whether from seal leakage, leakage from another source, or shrinkage due to an RCS cooldown, plants can benefit from the ability to add inventory to the RCS in terms of margin and physical safety. In addition to inventory control, borated water injection can help mitigate criticality concerns that would arise as a plant cools and reactivity is added.

Westinghouse supplies a permanently installed alternate reactor coolant makeup system. It is a dedicated pump with an independent power supply and associated valves and piping. The system can be supplied with an independent pressurizer level control feature to avoid overfilling the pressurizer. It can also be seismically qualified.

Emergency Backup Power Supply and Connection Points

Nuclear plants are modifying safety-class power distribution systems to allow for input from outside power sources (such as portable generators). These modifications can be complicated as the design basis of the safety-class power distribution system must be maintained. Also, seismically qualified, safety-related isolation devices are typically required.

Westinghouse supplies electrical switchgear and seismically qualified isolation devices to nuclear plants around the world. For plants with existing Westinghouse safety-related switchgear, duplicate technology can be provided. Westinghouse can also qualify and seismically test other original equipment manufacturers’ (OEMs’) devices through its commercial dedication process and in-house equipment qualification testing capabilities.

PWR Mobile Boration

In the event of a beyond-design-basis accident, a continual source of borated water is required to maintain RCS inventory and subcriticality within the core. The volume of borated water on-site is finite; the ability to create more borated water is limited using conventional batching equipment, and off-site resources are limited. Therefore, a compact, mobile solution that creates sufficiently concentrated borated water and that can be
easily protected from applicable hazards could provide an additional diverse strategy and would enhance beyond-design-basis safety at sites.

Westinghouse has worked with a customer to complete the functional and design specifications for a state-of-the-art mobile boration system (MBS) capable of providing 2,600 ppm of borated water continuously for 30 days, with operator action required only for setup, startup, stopping and refilling boric acid. The system is transportable and can be stored either on-site or off-site at a regional center that supports several nuclear facilities.

This system can be scaled to meet specific requirements and can be designed for use during outages to help provide high-concentration boric acid to the RCS, potentially reducing outage time.

**Advanced Battery Technology**

For an ELAP event, battery capacity can limit coping time for maintaining core cooling and monitoring plant conditions. To extend battery life, plants are implementing load-shedding procedures and providing portable charging through AC generators or other means. These operator-intensive coping strategies could detract from other recovery actions. Advancements in battery technology offer the industry solutions to bridge gaps in coping time, supplying staged-battery assets to provide critical DC power to vital systems.

Westinghouse offers ELAP coping solutions using proven Toshiba super-charge ion battery™ (SCiB™) lithium-ion battery technology. This technology uses a new negative electrode material that is inherently safer than traditional lithium-ion batteries and is proven to be seismically rugged, withstanding accelerations of 3g horizontal and 1g vertical. When compared to traditional lead-acid batteries, SCiB offers a superior life cycle and requires little maintenance. In addition, the design and sealed construction eliminate hydrogen gas generation during charging and the need for ventilated battery rooms. Its compact size and increased power capacity provide the flexibility to generate customized power solutions for a wide range of applications, including:

- Emergency lighting systems
- RCIC system
- Safety relief valve systems
- Filtered vent systems
- DC drive motor-operated valve actuation
- Instrumentation panel for reactor protection system
- Accident management panel
- Portable and/or fixed-mount supplemental banks

**PWR and BWR Engineering, Procurement and Construction Services**

Many factors impact the successful implementation of a plant modification, including available resources, experience, risk mitigation, and a single point of contact with whom to communicate and resolve issues.

Utilities choose Westinghouse to be their single point of contact, acting as the owner’s agent to engineer, procure and construct (EPC) plant modifications of any size.
Rooted in its OEM heritage and decades of EPC project involvement, Westinghouse offers EPC services for both BWR and PWR plants. Westinghouse reduces customers’ project risk through Customer 1st tools and innovative approaches. Customers rely on experienced Westinghouse professionals to reduce their workloads, provide a single point of contact, and control the risks associated with both large and small projects.

**BWR Alternate Feedwater Injection**

After the reactor pressure vessel (RPV) depressurizes such that the steam-driven pumps are not available during an extended SBO, plants need alternative systems to inject water into the RPV.

Westinghouse designed a nonsafety-related, single-train, low-pressure alternate feedwater injection system capable of injecting water into a BWR pressure vessel and SFP when all installed systems are not available. The system is located outside the reactor building, has dedicated power and water sources, and can be operated even if the control room becomes inaccessible. The design for advanced BWR use has been approved by the U.S. NRC for aircraft impact.

**BWR alternate feedwater injection**

- AFI - alternate feedwater injection
- CST – condensate storage tank
- DG – diesel generator
- MO – motor operator
- RPV – reactor pressure vessel
- SRV – safety relief valve
- UHS – ultimate heat sink
Spent Fuel Pool Protection

Since the events at Fukushima, the industry has seen an increased focus on protecting the Spent Fuel Pool (SFP) and providing defense-in-depth cooling and makeup during an extended loss of AC power and/or a beyond-design-basis external event. Westinghouse provides an integrated solution for SFP protection, including enhanced monitoring, analytical software, defense-in-depth cooling and makeup systems and services related to relocating the spent fuel into dry cask storage.

Spent Fuel Pool Instrumentation

The ability to quickly and remotely monitor key SFP parameters, such as water level, is an essential function in responding to events like those that occurred at the Fukushima Daiichi Nuclear Power Plant. Plants currently do not have a wide-range level that measures to the top of the fuel in the SFP. This monitoring capability is essential to understanding the water level in the SFP and the corresponding prioritization of actions that plant staff can take to mitigate water inventory loss.

Westinghouse designed an SFP instrumentation system (SFPIS) that meets the requirements of NRC Order EA-12-051 in providing the capability to reliably monitor the SFP water level under adverse environmental conditions. The SFPIS solution uses permanently installed guided wave radar (GWR) sensors to continuously monitor the SFP water level. GWR is a proven level-measurement technology for a wide variety of process media and conditions, including water at saturation (boiling) conditions. Key advantages of GWR include:

- Ease of installation
- No reliance on “open space” (that is, no interferences between sensor and medium) to maintain operability and accuracy
- Readily accessible for maintenance/repair without safety risks
- If desired, functionality to measure temperature can be added to the system.
The SFPIS draws upon Westinghouse’s many years of experience of innovatively applying sensor technology to solve difficult measurement challenges and conducting water-level measurements in nuclear applications, such as in vessels and sumps. Westinghouse has captured more than 50 percent of the U.S. market for spent fuel pool monitoring. Also, Westinghouse has implemented SFP level measurement in European plants and in the AP1000 plant design.

Emergency Fuel Pool Cooling System

New requirements are causing plants to assess whether they have adequate fuel pool cooling, especially at the beginning of an outage, when a full core off-load occurs. Existing fuel pool cooling systems would not typically be available during an extended SBO.

Westinghouse provides a solution based on our patented temporary fuel pool cooling technology and experience. The emergency fuel pool cooling system (EFPCS) provides defense in depth and is a stand-alone backup system for removing decay heat. It is its own power source to allow operation during extended SBO conditions; other system features address industry requirements for SFP makeup. The system can be adapted to meet other needs, as well.

Time-to-boil Simulation Software

Plants have a higher sensitivity to SFP conditions and therefore must maintain a higher state of readiness to respond to events that challenge SFP integrity. This is accomplished by knowing the time it would take the SFP to boil or, in some cases, reach 200 F (93 C) if normal cooling capability were to be lost.

Westinghouse developed the PoolWorks™ software program to help utilities effectively run time-to-boil (TTB) calculations and generate pool capacity information years into the future. The PoolWorks software uses a link to the Westinghouse ShuffleWorks® software program, and together, the two products provide all the tools needed to easily and quickly calculate TTB at discrete points in an off-load, a reload or an in-core shuffle.

Installation of the Westinghouse temporary cooling system provides up to 12 million BTUs per hour additional cooling capacity, and the system is sized to enable the plant to begin off-loading fuel just two-and-a-half to three days after shutdown at a U.S.-based plant. Since 2006, this system has maintained SFP temperatures during refueling outages.

The system can help plants schedule routine maintenance of fuel pool cooling systems and operation during refueling outages can reduce fuel movement delays. In addition, the secondary cooling loop is mobile and can be moved within or between sites for emergency or preplanned use.
Spent Fuel Dry Cask Storage Solutions

Many plants have decided to supplement wet pool storage with dry spent fuel storage as a way to maintain full core off-load or reduce heat load in the SFP. Utilities have subsequently begun to design, license and construct independent spent fuel storage installations (ISFSIs). ISFSI operations and canister loading campaigns require special technology, such as canister closure welding, and trained and qualified personnel.

Westinghouse’s team of dry cask storage experts and experienced technicians provide specialized services to assist utilities with specific activities, up to and including complete project implementation and pool-to-pad cask loading services. Our automatic canister welding system is a modular design, used with either a cold- or a hot-wire approach, and can be adapted to any commercially available spent fuel canister on the market.

Spent Nuclear Fuel Cask Management Software

More plants are moving spent fuel out of the pool and into dry cask storage as a way to maintain full core off-load or reduce heat load in the SFP. Plants need a data management package that minimizes the cost and risk associated with dry cask loading activities and helps plan future fuel loading projects.

By integrating cask loading tasks with site-specific special nuclear material data, fuel movement planning tools and industry standard analysis modules, the Westinghouse CaskWorks® software program provides an excellent tool for fuel and reactor engineers responsible for qualifying fuel for dry cask loading. It reduces dry fuel storage operational costs by efficiently selecting and arranging fuel assemblies and components for dry cask loading, while ensuring compliance with cask certification and site business rules.

Spent Fuel Pool Probabilistic Risk Assessment

Probabilistic risk analysis identifies the risk importance of the SFP equipment and, consequently, vulnerabilities. Opportunities to improve the overall risk profile of the SFP can be identified and implemented.

Westinghouse can evaluate the frequency of SFP boiling, SFP uncovering and associated releases by analyzing all of the internal and external events that can occur at the plant.

Spent Fuel Dry Cask Storage Services

Westinghouse continues to invest in dry cask storage training and technology, and in 2013 made a significant investment in an industry-unique dry cask storage training program. The program boasts actual-size mockups and the use of the Chattanooga, Tennessee (USA), BWR fuel pool mockup. Additionally, PCI Energy Services, the company’s Lake Bluff, Illinois (USA)-based subsidiary, is working on unveiling the Terminator-2™ canister welding system via a robotic arm-based platform. The Terminator-2 system will build upon the current system with enhancements – it is lighter, more flexible and faster.

In the United States, there are more than 1,500 welded canister systems in service. Given the uncertainty about long-term disposal, these systems will likely remain at reactor sites for an extended period before they are eventually shipped to a repository, such as Yucca Mountain, for example. It is crucial that these canister systems are properly fabricated, given the possibility of longer-than-planned at-site storage and the eventual shipping off-site.
Severe Accident Mitigation

The Fukushima Daiichi event prompted plants to evaluate currently available strategies to mitigate severe accident scenarios. Westinghouse has proven experience providing integrated mitigation solutions, including hydrogen control, filtered containment venting systems and updates to Severe Accident Management Guidelines (SAMGs).

Filtered Containment Venting Systems

During a severe accident, the containment may pressurize due to either steaming of core debris in the reactor cavity, or from non-condensable gas formation from core debris interacting with concrete. Venting the containment may be required to preserve containment integrity during a severe accident. Yet venting could release radioactive material to the environment, causing adverse short- and long-term environmental effects. Filtering the steam prior to its release significantly reduces both the surrounding population’s risk of exposure to radiation and the potential for land contamination near the site.

Westinghouse offers multiple filtered containment venting systems that provide highly efficient removal of aerosols and iodine from the steam before it is released into the atmosphere.

Dry Filter Method (DFM)

The DFM uses a deep bed metal fiber filter to remove aerosols and a zeolite filter to remove iodine gases. The modular design of the DFM makes it ideal for installing in existing plant structures, eliminating the need to construct a new building on-site. The DFM’s aerosol filter has been installed inside the containment, ensuring that long-life radioactive aerosol material is safely contained during the venting process while still effectively reducing containment pressure. The DFM requires no operator action to actuate, needs no water or chemical make-up and support systems, can be passively operated for months during an accident, has an efficient passive air-cooling system, and needs essentially no maintenance during normal operation.

The biggest advantage of the DFM is modular installation, which allows existing buildings to be used and facilitates the potential to reduce the overall filtered vent installation project cost by up to 50 percent.
Safety Vent (SVEN) System

The SVEN Systems uses filter cartridges in a water pool to remove aerosols and various forms of iodine. The increased efficiency of the filter cartridges results in a system that is very compact; it easily fits into existing buildings, while still being able to operate with higher heat loads due to the water pool. A zeolite filter can be added to remove organic iodine.

The biggest advantage of the SVEN System is that it is robust: able to handle a high flow rate, high heat loads, and high aerosol loading, all in a small construction volume. This allows the SVEN System to be installed in an existing building, eliminating the need to construct a new building. The SVEN System has undergone a rigorous test program that demonstrates similar capabilities and functionality as other scrubber systems that are currently installed or being offered. The use of standard filter cartridges significantly reduces the lead time for this system.

Filia-Multi-venturi Scrubber System (MVSS) Venting System

The Filtra-MVSS Venting System uses an MVSS in a water pool to remove aerosols and various forms of iodine. It requires no operator action to actuate and can passively operate without adding water for at least 24 hours. The Filtra-MVSS Venting System’s water pool makes the system ideal for meeting higher aerosol loading requirements. A zeolite filter can be added to remove organic iodine.

The biggest advantage of the Filtra-MVSS Venting System is the high and consistent decontamination factor for aerosols and elemental iodine at a wide range of flow rates. This system has been applied to all operating plants in Sweden and one BWR in Switzerland.
Filtered Vent Scoping Studies

There are many factors that go into designing a filtered vent application, including decontamination factors for aerosols, elemental and organic iodine, heat loads, aerosol loading, and time when the vent is opened, among others. Prior to starting a filtered vent project, it is very important to develop the technical basis for the requirements of a filtered vent that takes into account all of these factors.

Westinghouse has performed filtered vent scoping studies for a variety of customers around the world. These studies combine containment fragilities, probabilistic risk assessment results and country regulatory requirements to define reasonable filtered vent functional requirements.

Summary

All three of Westinghouse’s filtered vent products provide outstanding efficiencies across a wide range of aerosol particle sizes, permanently retaining aerosols, as well as elemental and organic iodine. The systems are seismically rugged and are also designed to effectively address concerns of potential hydrogen build-up in the systems during venting.

Our filtered vent scoping studies along with our multiple filtered vent products allow Westinghouse to customize a solution that considers both requirements and available space, so that we can offer the lowest overall project when cost factoring in installation activities.

Hydrogen Management

Following fuel damage, hydrogen released into the containment or other buildings can cause a combustible or even detonable mixture of gases to develop, and high-pressure loads of these gases could pose a threat to the integrity of those buildings. The hydrogen explosions at three of the Fukushima Daiichi Nuclear Power Plant units significantly complicated the site recovery efforts and led to significant radionuclide releases to the environment. Mitigating the effects of hydrogen is a critical severe accident management strategy.

Westinghouse has proven experience in hydrogen control and mitigation, and offers an integrated solution for utilities that desire to simplify procurement of the hardware, design, analysis, installation, and implementation into their procedures and Severe Accident Mitigation Guidelines. Using proven computer codes, Westinghouse identifies the scenarios with the highest hydrogen risk and tailors strategies to mitigate that risk in the containment building, reactor building and spent fuel pool building.

Westinghouse has teamed with Siempelkamp Nuclear Services Inc. and NIS Ingenieurgesellschaft mbH to offer passive autocatalytic recombiners (PARs). The PARs are a proven and qualified technology that can remove hydrogen from the atmosphere without power sources or containment penetrations. Simple to install with little maintenance, the PARs are robust with respect to atmospheric conditions and mechanical (seismic) loads since they do not have moving parts. Westinghouse offers PARs with the lowest start-up concentration available (1.5 percent).

Westinghouse has also teamed with Meggitt Safety Systems to provide hydrogen monitoring systems. There are two systems available. The sample extraction system is located in the auxiliary building and relies on sampling lines that are used to pull atmosphere from the containment into the system. The other system is in-situ and measures the containment atmosphere directly.
Severe Accident Management Guidelines

Following the Three Mile Island and Chernobyl events, SAMGs were developed to document plant-specific accident management strategies. Generic SAMGs are now being enhanced to incorporate lessons learned from the Fukushima event, and plants will be required to undertake plant-specific implementation.

Westinghouse offers global, plant-specific SAMG development, upgrades and training. The SAMG upgrades leverage the strengths of current and new severe accident mitigation equipment (e.g., filtered containment vents and hydrogen management hardware) and extend the accident scenarios to low-power and shutdown conditions. Westinghouse has experience developing shutdown SAMGs for reactor and spent fuel pool accidents. Under contract to the Electric Power Research Institute, Westinghouse developed the initial technical basis document for severe accident phenomenology upon which the original SAMGs were based, and developed the original SAMGs through the respective PWR owners groups.

Westinghouse has experience developing shutdown SAMGs for reactor and spent fuel pool accidents. Westinghouse is developing generic guideline updates for Westinghouse- and Combustion Engineering-designed plants to reflect Fukushima lessons learned under a contract for the PWR Owners Group®.

Severe Accident Management Training

Since the Fukushima event, the nuclear power industry has increased its focus on ensuring that nuclear power plants update their training programs for severe accident management scenarios.

Westinghouse provides a focused severe accident management course structured around the SAMGs. Through individual and group exercises and engineering simulator demonstrations, the course provides detailed instruction on the use of the SAMGs.

Modular Accident Analysis Program (MAAP) Analysis

Developing a basis for severe accident management strategies requires insight into the progression of the accident scenario. Using a computer code, a plant can quickly analyze and predict the progression of a postulated accident scenario.

Fauske & Associates, LLC, an affiliate of Westinghouse, developed the MAAP computer code to simulate the progression of accident scenarios. MAAP is an Electric Power Research Institute-owned and licensed computer software. MAAP Version 5 provides engineers with a tool to rapidly evaluate the progression of an accident in terms of the reactor core, the containment and the radiological consequences. It also can model the progression of an accident in a nuclear power plant's spent fuel pool. Experts at Westinghouse and Fauske & Associates can use all versions of the MAAP computer code to analyze specific accident scenarios.

In addition to the MAAP code, Westinghouse also has experience in other global analysis tools including MELCOR, GASFLOW and GOTHIC, and can perform analysis in any of these codes, as well to support local licensing requirements.

Severe Accident Management Pre-planned Drills and Exercises

Nuclear power plants will need to develop drills and exercises for responding to additional types of severe accidents, including multi-unit events and extended station blackouts during which power is not available in the technical support center.

Westinghouse has used MAAP to develop SAMG validation and training drills that provide the time history of important plant parameters and simulate loss and subsequent recovery of critical equipment. Pre-planned exercises prepare emergency responders for a variety of actual emergency situations.

Westinghouse developed the Modular Accident Response System (MARS) to model nuclear plant response during severe accident conditions. MARS models and predicts a plant's post-fuel damage state based on actions taken during a severe accident. MARS also provides realistic practice scenarios that can model and predict the future state of the plant, based upon current actions taken.
According to the World Energy Council, continued reliance on fossil fuels for the vast majority of our energy needs is simply not realistic. Viewing the situation in a worldwide context magnifies the

This brochure highlights some of Westinghouse’s current capabilities, but the list is growing rapidly. For additional information on the services and products listed here, we encourage you to contact your Westinghouse representative, visit www.westinghousenuclear.com/enhancingsafety or scan the code at left.

The nuclear industry has a long history of continuous learning and improvement with safety as the number one goal. As the nuclear industry addresses the lessons learned from Fukushima Daiichi, Westinghouse will continue to develop innovative solutions and partner with our operating plant customers to ensure safe, clean, reliable electricity to fuel the world’s ever-growing demand for energy.