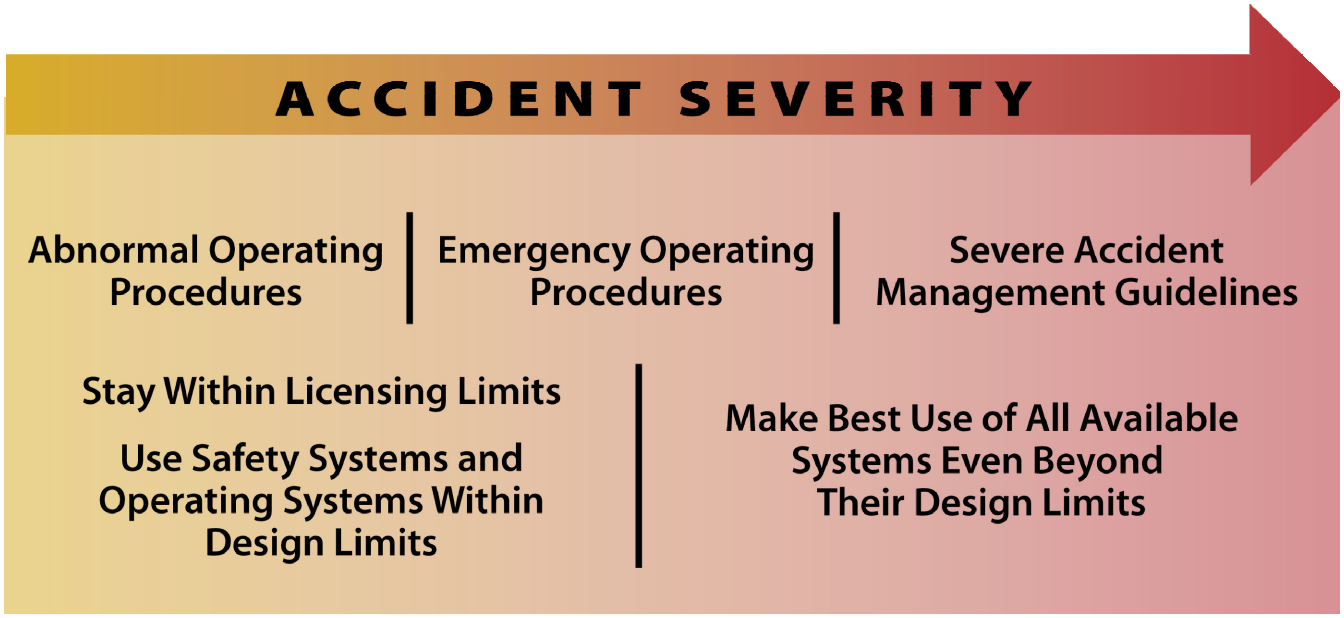
Argonne NATIONAL LABORATORY | Energy Engineering and Systems Analysis

Design Basis and Severe Accidents

Nuclear power plants are designed to maintain their integrity and performance of safety functions for a bounding set of normal operational events as well as abnormal events that are expected to occur or might occur at least once during the lifetime of the plant.



Nuclear power plants are designed to maintain their integrity and performance of safety functions for a bounding set of normal operational events as well as abnormal events that are expected to occur or might occur at least once during the lifetime of the plant. In addition, they are designed to maintain performance of safety functions for a set of design basis accidents that involve failures that are possible but unlikely to occur during the plant lifetime. The plant design incorporates redundant safety systems which meet requirements for inspection and testing to assure their performance when required. An example of a design basis accident for a Light Water Reactor (LWR) is the loss of electrical power from the electrical grid. The plant design includes redundant safety systems to shut down the nuclear chain reaction in the core as well as redundant multiple diesel generators that will start automatically to provide the electricity needs with an electrical power backup from batteries to assure core cooling to remove the decay heat generated in the core.

EOPs Developed

Following the accident at Three Mile Island Unit 2 in 1979, Emergency Operating Procedures (EOPs) were developed as a result of U.S. nuclear industry initiatives and were implemented at all LWRs in the U.S. The EOPs are procedures that the reactor operators inside of the control room follow for a spectrum of accidents including mainly design basis accidents but wider than the design basis accidents to

diagnose and recover critical safety functions including adequate cooling of the core.

SAM Developed

Following the accident at Chornobyl in the Soviet Union in 1986, Severe Accident Management (SAM) was developed for all nuclear power plants in the U.S. in an industry-led initiative coordinated by the Nuclear Energy Institute (NEI) and agreed to by the U.S. Nuclear Regulatory Commission (NRC). Severe accidents are very unlikely events involving an initiating event such as occurs in a design basis accident together with other equipment failures. A severe accident is one that involves damage to the fuel rods inside of the reactor core, fuel rod failure, core degradation, and fission product release into the reactor vessel, containment, or the environment. A criterion for transition from EOPs to SAM is when the water level inside of the reactor vessel decreases uncovering the upper part of the fuel rods and the temperature of the fuel rises above 660 degrees Celsius (1200 degrees Farenheit) at which the zirconium in the zircaloy cladding reacts chemically with steam at a greater rate resulting in the generation of gaseous hydrogen and zirconium oxide. Severe Accident Management involves the use by the plant staff of plant-specific guidance known as Severe Accident Management Guidelines (SAMGs) to terminate core damage if it begins, maintain containment integrity for as long as possible, and minimize offsite radionuclide releases. The SAMGs in the U.S. have been developed by the owners' groups of the different existing LWR designs in the U.S. to assist plant operating and technical staff in implementing strategies for the best use of existing plant capabilities to diagnose, respond to, and recover from a severe accident.

Severe Accident Management has been implemented at LWRs in all "Western" nations; it was implemented at all Japanese LWRs by 2002. We have seen examples of SAM in the actions taken at the Fukushima Dai-ichi power plant such as the deliberate venting of hydrogen and steam to prevent containment failure (i.e., protect the containment), and spraying of water to cool used fuel inside of used fuel storage pools.

Mitigation Strategies Adopted

Following the events of September 11, 2001, the U.S. NRC ordered that all U.S. LWRs adopt mitigation strategies using readily available resources to maintain or restore core cooling, containment, and used fuel pool cooling capabilities to cope with the loss of large areas of a facility due to large fires and explosions from any cause including aircraft impacts that are beyond the design basis. In December 2006, the Nuclear Energy Institute issued guidance for implementing a set of strategies including adding makeup water to the used fuel pool, enhanced initial command and control activities for challenges to core cooling and containment, and enhanced response strategies for challenges to core cooling and containment. In March 2009, the U.S. NRC amended the rules for licensing of nuclear power plants to include mitigating the loss of large areas of a plant from large fires and explosions to any number of beyond design basis initiating events not limited or directly linked to an aircraft impact including natural phenomena such as earthquakes, tornadoes, floods, tsunami, and seiches.

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