Safety aspects of Nuclear Power plants
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Ensuring safety is the first and foremost factor that is taken into account while constructing and operating a nuclear power plant. Dedicated agencies make sure that nuclear power reaches every household and at the same time poses an absolute minimum risk possible.

The safety systems in a Nuclear power plant are designed with an aim to reduce the probability of the release of any radioactivity and in case it releases, to reduce the consequences. This aim is achieved by designing the reactor system to be as safe as reasonably achievable and including multiple barriers. The safety aspects are two-fold. One is to form and enforce strict rules and regulations regarding the operation of the plant to maintain a steady and controlled state at all times. The other is to bring in safety via engineering, construction and operational methods. A detailed plan of a power plant almost always includes a bunch of safety and engineering features to prevent the release of any radiation or other harmful gases from the reactor.

Reactor Protection Systems

Safety needs to be taken into account at all times during the operation of a reactor. The features that ensure a steady operation of the reactor come under the category of Reactor Protection Systems. These are basically the different mechanisms that are used to shut down the reactor in the event of an emergency.

1) Primary Shutdown – It is achieved by shut-off rods. These rods are generally made of boron that absorb all extra neutrons so that the nuclear reactions inside the reactor can be stopped thereby shutting down the reactor.

2) Secondary Shutdown – This system backs the primary system by poison injection in tubes. Poison here implies substances like Xenon that can make the probability of occurring of nuclear reactions very small thereby slowly forcing the reactor to eventually shut down.

3) Tertiary Shutdown – It is achieved by poison addition in the moderator system. This increases the Xenon availability and forces reactor shutdown at a faster rate.

4) Manual trip by operator – This allows the operator to manually force the reactor to shut down immediately in case any undesirable situation arises.

Certain events may arise within the reactor that require immediate shutdown of the system. All the above emergency shutdown mechanisms become available when either of the following *Reactor Trip Signals* are encountered:

1) High rate of rise of neutron flux – Conditions might develop within the reactor leading to the increase in the rate of nuclear reactions producing a large number of neutrons. These neutrons in turn increase the reaction rate even more and ends up creating an avalanche of neutrons making the reactor environment super-critical (unsteady and hence too dangerous to operate).

2) High system temperature or pressure – This can also lead to a high neutron flux rate by increasing the nuclear reaction rate thereby forcing the reactor to go into a super-critical stage.

3) Loss of coolant flow – If the coolant flow rate drops, heat produced by the nuclear reactions occurring within a reactor cannot be efficiently removed. This leads to accumulation of heat and increase in the system temperature.

4) High steam flow rate due to steam line break – A steam line break can also cause inefficient heat removal forcing the reactor to become super-critical.

5) High/low level in pressurizer – Changing pressurizer levels can lead to change in the coolant flow rates leading to inefficient heat removal and hence a situation that needs immediate attention.

6) Loss of water to steam generator – Leads to an inefficient heat exchange between the coolant and water flowing in steam generators.

7) Loss of power to key instruments (like pumps) – This might lead to system failures that disable the decay heat removal required after the reactor has been shutdown.

8) High radioactivity in coolant or containment – This can lead to an occupational hazard for the workers of the power plant and therefore needs an emergency shutdown of the system to prevent any radioactive releases from entering the environment.

Nuclear reactions occurring within a reactor die out slowly after the reactor has been shutdown. Therefore even after complete shutdown, the reactor produces enough heat, called *decay heat* that needs to be removed to keep the reactor in a steady and controlled state. Systems that ensure the cooling of the system post shutdown are referred to as *Shutdown cooling systems*. These systems are a requirement for all nuclear power plants. A proper maintenance of these systems can avoid a Fukushima-like situation where the failure of Shutdown cooling systems led the reactor to accumulate excess heat and explode.

Engineered safety features

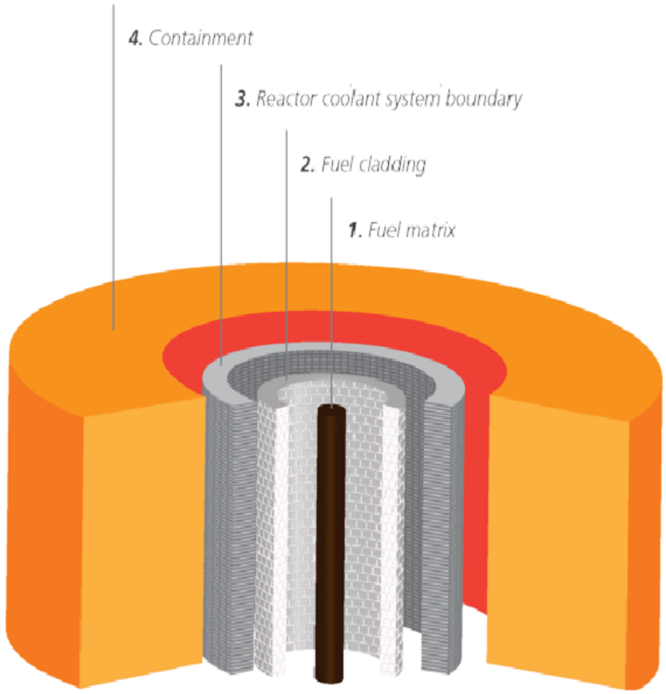
Other features include the Engineered Safety Features (ESF). The main purpose of these is to prevent and limit the spread of radioactivity. The ESF systems are:

1) Containment with special features – It is the final barrier to prevent the release of fission products. Materials like concrete are generally used for the construction of such barriers. A double containment concept is also used these days.

In a nuclear power plant, ESF includes a four barrier system to prevent the release of fission products and radioactivity from the reactor containment.

i) The first barrier is provided by the ceramic fuel pellets which are capable of binding the fission products within itself.
ii) The second barrier, known as clad, is provided by a sealed metal tubing that creates an envelope for the fuel.
iii) The third barrier is created by a closed coolant system which includes the reactor pressure vessel. This prevents the release of fission products to the environment at all design pressures and temperatures.

iv) The fourth barrier is created by a hermetic steel-reinforced concrete containment which contains the radioactive materials that might have been released from the second and third barriers.



2) Emergency Core Cooling System (ECCS) – This system is utilized during a Loss of Coolant Accident (LOCA). The fuel temperature rises, clad may undergo metal water reaction and fuel may melt releasing fission products. The purpose of the ECCS is to limit the clad surface temperature to a predetermined and safe value. Different reactors generally have different ECCS arrangements. When pressure drops, long term cooling system can be adopted.

3) Clean up system – Special equipments like filters slowly remove any suspended aerosols and volatile fission products from the environment surrounding the reactor to prevent them from spreading to other populated areas.

4) Hydrogen control system – This system controls the level of hydrogen concentration with the help of systems called re-combiners so that an explosion does not occur in case of failure of decay heat removal systems.

Crises Management

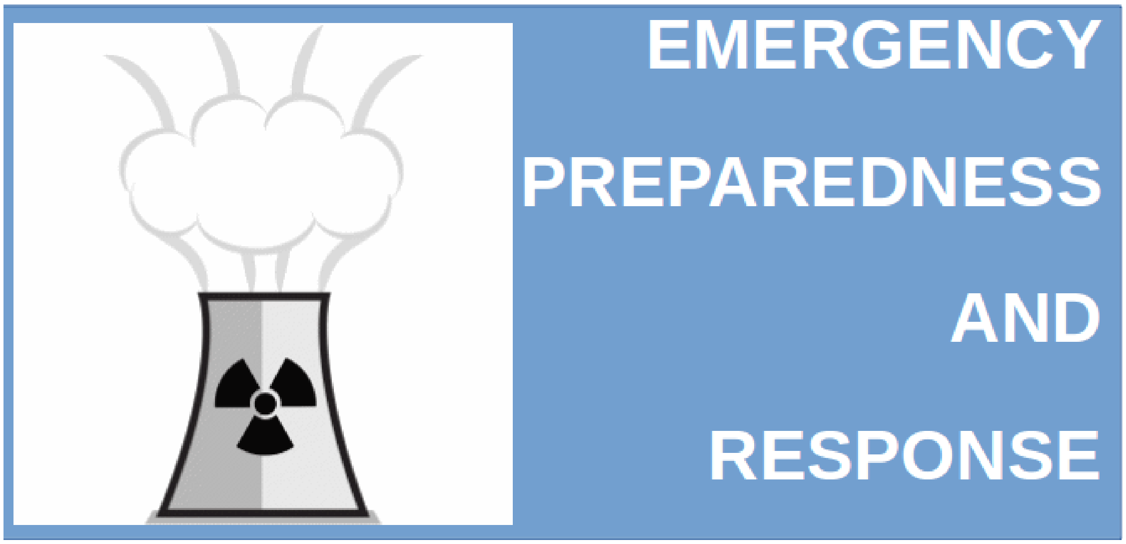
Every nuclear power plant has a dedicated department to handle situations involving a crises. Crises Management in Nuclear power plants is done in two ways:

1) Multi level safety features are incorporated in the nuclear power plants to prevent an accident from occurring in the first place and limit its magnitude if it occurs. Limiting the consequences of the

accident itself is also a major agenda. The philosophy followed is to limit the spread of the affected area and to reduce any harmful effects.

2) An off-site crises management group is established prior to the commencement of the construction of any nuclear power plant. The objective of this group is to prevent the public from any possible adverse radiological impact.

Emergency preparedness plans



These plans are prepared during the design phase of the power plant. Area around the plant is divided into three zones:

1) Exclusion zone – Area around the reactor up to 1.6 km radius is the exclusion zone. Entry is restricted only to the employees of the power plant. High boundary wall is erected around the zone. Multi-level security system is adopted.

2) Sterilization zone – Area outside the exclusion zone and up to a radius of 8 km around the reactor is the Sterilization zone. Developmental activities in this zone are controlled. Check is kept to control any increase in the population.

3) Emergency planning zone – The area around the sterilization zone up to the radius of 16 km around the reactor is the Emergency planning zone. After studying the demography of the population and their activities, an Emergency plan is prepared. Regular emergency drills are arranged. Time to time emergency evacuation drill is undertaken. This keeps the 'Emergency Preparedness' in ready state.

Nuclear power plants, in the present day, are equipped with all these safety systems making them as safe and as dependable as possible. Every country has its own independent *licensing authority* that ensures the implementation of the safety of the nuclear power plants starting from site selection, during operation and up to decommissioning.

This authority performs detailed analysis of various events that is done from time to time to evaluate the safety and the design is upgraded as and when required. Safety systems, at all times, ensure the protection of the public and the plant from dangers caused by human errors, equipment failures and malfunctions and from effects of natural calamities like floods and earthquakes. All these together make sure that the nuclear electricity that reaches your house is safe for all personnels working in the plant and for the general public alike.