HITACHI

SAFETY MEASURES, SEVERE ACCIDENTS AND LESSONS LEARNED FROM FUKUSHIMA

NUCLEAR POWER PLANTS SAFELY DELIVER SIGNIFICANT QUANTITIES OF SECURE AND SUSTAINABLE ENERGY TO COMMUNITIES AROUND THE WORLD EVERY DAY.

Of course, nuclear power must be carefully managed, and safety naturally forms a key aspect of reactor design.

The following explanations outline the safety features of the UK ABWR. We look in particular at the 2011 incident at Fukushima, and explain some of the measures taken to guard against anything similar happening again.

GENERAL PRINCIPLES OF SAFETY

The principles of safety, if something unexpected happens in a nuclear power plant, are very straightforward. They focus on ensuring Control, Cooling and Confinement.

1 **Control** – Maintaining control of the nuclear reactor ensures that the reactor power can be increased, decreased or shut down as required. It can be achieved via chemical means or using control rods containing neutron absorbing material.

2 **Cooling** is about making sure that the reactor core – which reaches extremely high temperatures during operation – can be safely brought down to a manageable temperature. This is usually as simple as ensuring that water can be pumped through cooling pipes to remove excess heat.

3 **Confinement** ensures that radioactive materials inside the reactor do not come into contact in harmful quantities to people or the environment. This is achieved through multiple physical barriers, based mainly on concrete and steel structures.

All these functions are assured on a defence-in-depth approach. This means that each is achieved by multiple means which do not rely on any one system, component or process.

HOW THE UK ABWR MEETS THESE PRINCIPLES

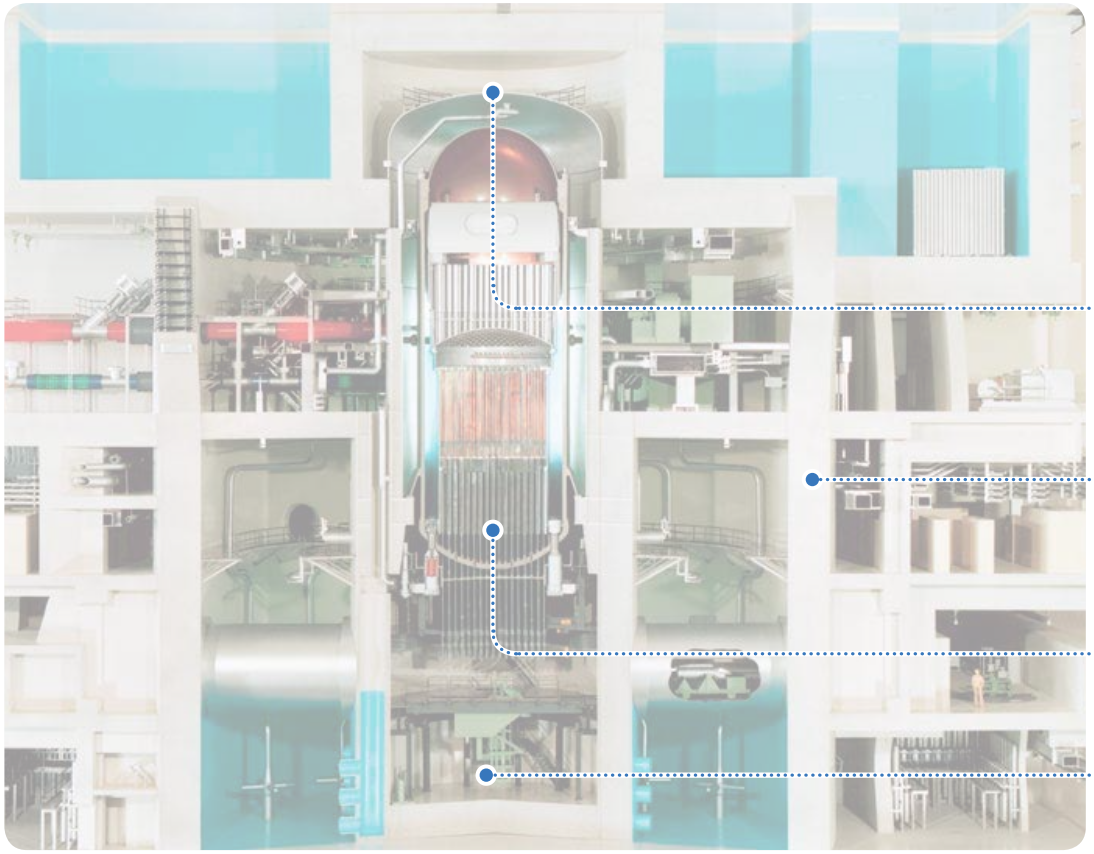
The UK ABWR is the latest generation of Boiling Water technology. Each new design has been improved, and has more advanced safety features.

1 **Control** is primarily achieved through control rods containing Boron Carbide *(a neutron absorber), which are hydraulically forced into the core in an emergency situation, completely stopping the nuclear reaction.

2 **Cooling** is achieved via straightforward water circulation. There are diverse and redundant ways of providing cooling water, including on-site mobile pump trucks and a variety of access points.

3 **Confinement** is achieved through a multi-barrier approach: The design of fuel itself, The Reactor Pressure Vessel (RPV), The Reinforced Concrete Confinement Vessel (RCCV), and lastly the reactor building, which has recently been re-designed to provide additional protection.

THE UK ABWR – KEY SAFETY FEATURES



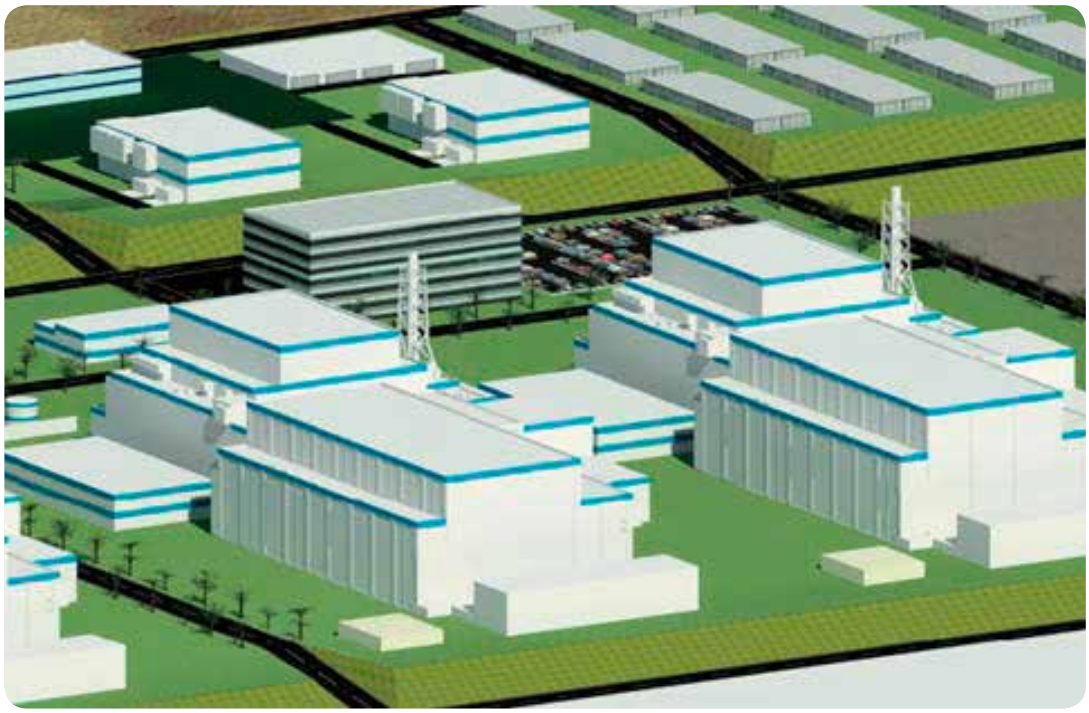
REACTOR BUILDING
A newly strengthened roof, to guard further against any external impact. This is designed to withstand the worst possible aircraft impact.

RPV
Steel pressure vessel provides a physical barrier.

RCCV
A steel and concrete shell strong enough to withstand aircraft impact, deliberate detrimental actions, or an internal build up of pressure.

CONTROL RODS
To quickly stop the nuclear reaction.

FLOODED DRYWELL
To contain and stabilise a molten core.



EMERGENCY DIESEL GENERATORS
To manage a loss of offsite power.

BACKUP BUILDING
To provide vital control and recovery facilities in the event of a "beyond design basis" event.

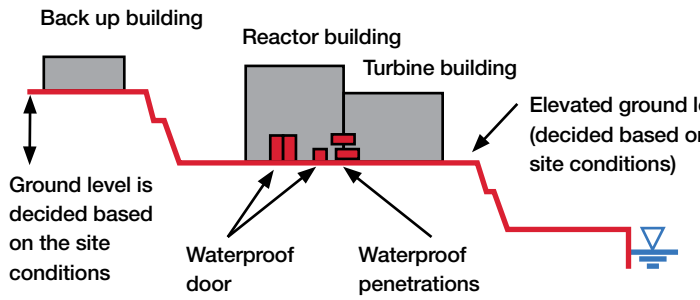
PHYSICAL DEFENCES
To protect the site from hazards such as flooding, and other external or internal risks.

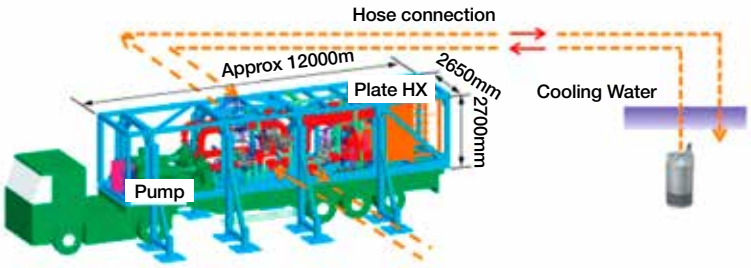
FUKUSHIMA ACCIDENT – AN OVERVIEW

AND THE COUNTERMEASURES PROPOSED FOR THE UK ABWR

ON MARCH 11 2011, THE FOURTH LARGEST EARTHQUAKE ON RECORD HIT THE NORTH-EAST COAST OF JAPAN. THIS MAGNITUDE 9.4 EVENT CAUSED SIGNIFICANT DAMAGE TO AREAS OF COASTLINE, INCLUDING AROUND THE FUKUSHIMA DAI'ICHI AND FUKUSHIMA DAI'INI POWER STATIONS, OWNED AND OPERATED BY TEPCO.

Both stations seismic defences worked as expected, and they automatically shut-down. The damage to local infrastructure included the destruction of the power lines to both power stations, causing a loss of off-site power. However on-site backup generators began operating, ensuring that vital functions such as cooling pumps could operate. Control, cooling and confinement all remained in place.





Around 40 minutes later, a Tsunami approximately 14m high hit the affected coastline, causing widespread damage to remaining infrastructure. In one of the stations, Fukushima Dai'ichi, this damaged the backup generators. The station, now without any power from outside or within the site, was no longer able to operate its cooling pumps, and the ability to cool the reactor was lost.

Over the coming hours, the resulting build-up of heat led to the partial melting of three reactor cores, as well as a range of problems including those associated with spent fuel pools. Excess steam – caused by high temperatures – was vented from within the reactor pressure vessel to reduce pressure. Hydrogen particles within the steam were also released, causing the dramatic explosions seen on televisions around the world.

The loss of local infrastructure, and the debris caused by the tsunami, further hampered efforts to recover the situation, but over the coming days the reactors were brought to a safe state, and the site was ultimately returned to a 'cold shutdown'. The site is now being decommissioned.

The UK is not subject to the kind of extreme natural events that are seen in Eastern Japan. However we as designers are still committed to – and the regulators still demand – the most rigorous and robust defences against a range of external hazards, such as flooding, extreme weather events, aircraft impacts, and much more.

A number of countermeasures will be in place for the UK ABWR – these include a robust regulatory enforcement of site defences, to reduce the vulnerability to off-site impacts; revised consideration of site layout, such as positioning back-up buildings on higher ground; and increased safety-critical protection of emergency generation and back-up power systems, such as water-tight and impact-proof buildings.

The UK ABWR will be equipped with increased on-site options to ensure cooling in an emergency, including on-site cooling vehicles, which can independently ensure the circulation of cooling water, and maintained cooling. These systems – which will be housed in protective buildings – can be attached to the station to ensure cooling is retained, even if primary cooling systems are lost and the site has no power.

In addition to heat removal and back up power systems, the UK ABWR will also have construction machinery, housed in protective buildings, so that debris from natural events can be swiftly removed in an emergency situation.

UK REGULATION – SOME KEY PRINCIPLES

EMERGENCY PREPAREDNESS IN THE UK

The UK has had operating nuclear power stations since 1956, and emergency preparedness measures and arrangements have been under continuous development and review throughout this time.

Communities living adjacent to an operational nuclear site receive regular communications not just from the site operators, but from the local authorities who are responsible for designing, managing and reviewing off-site emergency planning arrangements and – if ever necessary – implementing response plans in cooperation with the local emergency services. This will also apply to sites where UK ABWRs are constructed, with future operators and local authorities putting appropriate measures in place.

Full scale emergency exercises – involving the local authorities, emergency services, site operators and all levels of Government – are undertaken regularly, and are subject to strict assessment by the nuclear regulators.

These exercises test the local planning arrangements surrounding an operating nuclear power station and are the responsibility of the Local Authority. The extent and distances for these planning areas are determined by the nuclear regulators following a technical assessment of the areas likely to be affected by a radiation emergency. The assessments involve consultation with the local authorities and include local demographic and geographical considerations.

Communities within these areas will be given regular and clear information on what to do if notified of a nuclear emergency. On the whole, UK off-site emergency plans focus on initial sheltering – staying inside with doors and windows closed – for the immediate local population as opposed to immediate evacuation of large areas. However each site will have its own plans in place and these will vary according to what is most appropriate at a specific site.

Despite the strong levels of emergency planning in place, it is important to remember that the UK nuclear industry has an excellent safety record, and these plans are in place to ensure that local communities are well prepared, only in the extremely unlikely event that they are needed.

1 IN 10,000 YEARS

In order to satisfy the regulators, UK nuclear power stations have to show that they are able to resist events, even if they are so rare as to statistically happen once in every 10,000 years. This means that when considering natural events such as flooding, seismic activity and changing landscapes, we aren't just looking at what has happen in recent years and decades, but at what has happened over many millennia.

DEFENCE-IN-DEPTH AND REDUNDANCY

These principles focus on having multiple different safety features that do not rely upon any one system, component or process – so that if one, or multiple, fail – others remain. This is shown in the diverse methods available to ensure cooling, control and confinement, or the diverse options for sustaining on-site power.

NON-PRESCRIPTIVE AND ALARP

Non –prescriptive regulation means that rather than setting a bar that the regulators consider 'safe', designers and developers are expected to continually drive risk out of nuclear energy and increase safety.

The ALARP principle is focused on reducing risk "As Low As Reasonable Practicable". In other words, it is not enough for a reactor-designer just to show that features of a design are as safe as competitor designs, or safe to a pre-defined level, but they must show that the design reduces risk 'as low as reasonably practicable'.

REGULATORS ALWAYS HAVE THE FINAL SAY

Fundamentally, the regulators' decision is final. If they are not happy with a design, it will not be built. If they are not saitisfied with the situation at a nuclear site, work will be halted until the situation is resolved to the regulators satisfaction. No ifs, no buts and no-one is exempt. Even Government cannot overrule the regulator: unless a practice is safe, it will not be allowed to take place in the UK.