

PWR vs BWR

Pressure Water Reactor vs Boiling Water Reactor.

The two main types of reactor in use are the Pressure Water Reactor (PWR) and the Boiling Water Reactor (BWR)

The **PWR** raises steam for the turbo-generator(s) by circulating water at a high temperature and pressure through the primary tubing of a number of steam generators (2-4).

This allows the control rod drive mechanism (CRDM) housings to be mounted on the top of the reactor vessel (RV) head. They lower or lift the control rod assemblies located in the interstices between the fuel cans.

In the PWR the control rod drive mechanism (CRDM) housings are essentially pressure vessels attached to “penetrations” of the reactor vessel head as flanged branches. This means that they work at the same pressure as that in the reactor vessel. In a “scram”, triggered by a power failure, the control rods can drop by gravity in shutting down the reactor. The control rod assemblies, once unlatched, can fall by gravity reducing the reactor heat to that of the decay heat in a maximum of 3 seconds.

The **BWR** raise steam in its RV, which then is directed to the turbo-generator(s) from its top. In the BWR the CRDMs are forced up against the reactor vessel pressure from the underside by hydraulic control units, each consisting of a scram water accumulator and a scram accumulator nitrogen cylinder.

The contents of the accumulators are maintained by station services with condensate and nitrogen supplies to the accumulators, with instrument air and electricity for the control solenoid valves.

In principle the accumulators contain an excess of energy, the bulk of which will be expended when driving up the control rod assemblies when shutting down the reactor. In normal operation the contents will be replenished, from other operating reactors or from standby generators, but in a persistent station blackout (SBO) the services run down and the used energy will not be replaced.

The CRDMs are mounted in clusters under the reactor vessel in hot and radioactive circumstances in great congestion, affecting the maintenance of the control systems as maintenance workers are hot and time limited with film badges to control radioactivity doses.

In a “scram” the water accumulator pressure, would have been just enough to push up the control rod assemblies between the fuel cans. In a prolonged SBO, the nitrogen pressure in the accumulators will not be restored to that it was before the “scram”, because the services, including the nitrogen compressors, will not be powered.

In normal operation, condensate (condensed steam) from the turbine condensers is stored in a condensate storage tank and is returned to the reactor vessel to be raised to steam for the turbines.

Some of the condensate from the storage tank is raised in pressure by the service pumps to send to the control rod drives' scram water accumulators. The scram nitrogen accumulator holds stored, pressurised nitrogen, which is used to push condensate into the scram water accumulator.

The control rod drive mechanisms have a drive piston inside of which is a stop piston. In a scram the inserted water lifts the drive piston pushing up its control rod assembly up against the reactor internal pressure, eased by discharging the displaced water, but also compresses the collet springs levering the latches into grooves which are machined into the drive piston at regular intervals along it.

Without power the decay heat removal systems fail and the pressure in the reactor rises. The build up of pressure and push the control rod assemblies down incrementally at first, but part of the core will be uncovered and the decay heat will reverse its decline. The latches will be withdrawn as the collet springs will open without the restored water pressure by the failed power.

This will release more heat and in turn raise the RV pressure, initiating the positive feedback.

In normal operation this procedure would not occur, but would be stemmed by the renewal of the stored energy by the active station services, or the standby generators. But a persistent SBO will lead to a catastrophic increase in reactivity leading to the melting of a core.

SMR GEH BWRX-300

General Electric joined with Hitachi to design the GEH BWRX-300 as a 300 Mw SMR.

It has passed the scrutiny of the US Nuclear Regulatory Commission (NRC) and it has obtained a licence from the Canadian Nuclear Safety Commission (CNSC) to authorise Ontario Power Generation to construct a BWRX-300 reactor at the Darlington Nuclear Generating Station located in Clarington in the Durham Region 70 km East of Toronto.

It is regrettably a boiling water reactor (BWR), as were the four reactors at Fukushima Daiichi in Japan. Three of the reactors failed to survive the prolonged station blackout (SBO) caused by the tsunami, suffered core meltdowns and are now subjected to dowsing with huge quantities of cooling water for the unforeseeable future, contaminating the Pacific Ocean with low level radioactivity.

The reactor power is controlled by the insertion and withdrawal of control rod assemblies from the underside of the reactor vessel in the same manner as the Fukushima 4 BWRs, except for the positioning of the control rods.

In the case of the BWRX-300 each set of accumulators lifts two control rods assemblies to make the best use of the limited space. Each set of pressurised nitrogen and water accumulators moves two control rods assemblies but the positioning is changed by a motorised worm screw able to be overcome in a scram by pressurised water from the sets of accumulators.

In an SBO the screw positioners may for a short time be powered from batteries, but the reduced stored nitrogen pressure will not be restored by the lost power to the station services. And, as at Fukushima, the prolonged lack of power will lead to a core meltdown as the decay heat increases the reactor internal pressure triggering the positive feedback mechanism described above.

Fukushima

The logic of the analysis above came from a study of the Fukushima catastrophe, enter

https://www.after-oil.co.uk/Fukushima_Reviewed_2021.pdf
in Google

to see my 10 years after “Fukushima Review 2021”, which describes a positive feedback amplification effect on the CRDM process.

Open AI chatGPT fact check of Fukushima Reviewed 2021 made on 30 August 2023

The claim in your review is that the loss of electrical power (both AC and DC) caused the withdrawal of control rods in the reactors. This is hypothesized to have resulted in a positive feedback loop, raising fission heat and pressure, leading to the control rods being progressively withdrawn.

Let's analyze this claim based on the information available up to September 2021:

1. **Loss of Power and Control Rods:** It's true that the loss of electrical power can impact the control systems of a nuclear reactor, including control rod positioning. Control rods are used to regulate the reactor's power output by absorbing neutrons and slowing down the fission process. If power is lost, control systems might not function as expected.
2. **Positive Feedback:** The idea of a positive feedback loop causing an escalating chain of events is plausible in certain scenarios. If control rods were withdrawn due to power loss, it could lead to an increase in reactor power and pressure. However, the specifics of this scenario can depend on reactor design, control mechanisms, and safety systems.
3. **Withdrawal of Control Rods:** The withdrawal of control rods, particularly during a power loss, can indeed lead to increased reactor power. Control rods are used to absorb neutrons and regulate the fission process. Withdrawing them allows for more neutron interactions and a potential power increase.
4. **Pressure Increase:** If the fission process is not properly controlled, it can lead to increased heat generation and pressure within the reactor vessel.
5. **Hydrogen Formation and Explosions:** The formation of hydrogen gas due to the interaction of zirconium alloy with steam is a well-known phenomenon in nuclear accidents. Hydrogen explosions can occur if hydrogen accumulates in confined spaces and mixes with air.

It's important to note that the Fukushima disaster was a complex event influenced by a combination of factors, including the earthquake, tsunami, and subsequent failures in cooling systems and power supply. While the claim you've mentioned is plausible, the exact sequence of events and the extent of control rod withdrawal contributing to the disaster might still be a subject of ongoing analysis and debate among experts.

For the most accurate and up-to-date information, it's recommended to refer to authoritative sources, such as reports from regulatory bodies, investigations, and nuclear engineering experts who have studied the Fukushima disaster in detail.

UK Based European data centre hub

As part of the US President's State Visit, the UK and US have agreed the Tech Prosperity Deal, focused on developing the fastest growing technologies like AI, quantum and nuclear.

Unfortunately, the US Vice President JD Vance has met with US nuclear companies, including GE Hitachi Nuclear Energy (GEH), to discuss opportunities for deploying small modular reactors (SMRs) and advanced reactors in the UK. The BWRX-300 is GEH's specific SMR design that is being actively promoted for international development including in Britain.

JD Vance has held private talks with senior executives from several American nuclear firms, including GEH, Westinghouse, X-Energy, Terra;power and Holtec. The purpose of these discussions was to lay the ground work for a “nuclear building blitz” in the UK.

The GEH BWRX-300 is in Step Three of its General Design Assessment (GDA) with the UK Office of Nuclear Regulation (ONR) - a necessary formality before licensing.

This PWR vs BWR comparison is written to highlight the potential denouement of the Tech Prosperity Deal in a Fukushima-like catastrophe after a prolonged loss of power leading to a nuclear power station core meltdown if the further building of boiling water reactors is contemplated.

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