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The AP1000 Nuclear Reactor Design.

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Executive Summary

The AP1000 advanced passive nuclear reactor design has a weaker containment, and fewer back-up safety systems than current reactor designs. Conventional reactors rely on defence-in-depth made up of layers of redundancy and diversity – this is where, say, two valves are fitted instead of one (redundancy) or where the function may be achieved by one of two entirely different means (diversity). In contrast advanced passive designs rely much more on natural processes such as natural convection for cooling and gravity rather than motor-driven pumps to provide a backup water supply.

The AP1000 appears to be vulnerable to a very large release of radioactivity following an accident if there were just a small failure in the steel containment vessel, because the gasses would be sucked out the hole in the top of the AP1000 Shield Building due to the *chimney effect.*

Recent experience with existing reactors suggests that containment corrosion, cracking, and leakage is more common than previously thought, and AP1000s are more vulnerable to containment corrosion than conventional reactors.

In addition the AP1000 shield building lacks flexibility and so could crack in the event of an earthquake or aircraft impact.

A thorough review of the AP1000 design in the light of the Japanese accident at Fukushima has shown that:

- Ongoing nuclear fission after a reactor has supposedly been shutdown continues to be the source of significant pressure inside the containment. The AP1000 containment is extraordinarily close to exceeding its peak post accident design pressure which means post accident pressure increases could easily lead to a breach of the containment.

- At least seven ways in which an AP1000 reactor design might lose the ability to cool the reactors in an emergency have been identified. These include damage to the water tank which sits on top of the shield building and some sort of disruption to the air flow around the steel containment.

- The accidents at Fukushima, especially the overheating and the hydrogen explosions in the Unit 4 Spent Fuel Pool showed that the calculations and assumptions about the AP1000 Spent Fuel Pond design were wholly inadequate.

- Fukushima showed that when several reactors share a site an accident at one reactor could damage other reactors. In the AP1000 the water tank on top of the reactor, and the shield building could be vulnerable to damage.

- Westinghouse assumes that there is zero probability of an AP1000 containment breach. But the accidents at Fukushima have shown that there is a high, probability of Containment System failure resulting in significant releases of radioactivity directly into the environment.

The AP1000 reactor design is not fit for purpose and so should be refused a Design Acceptance Confirmation (DAC) and Statement of Design Acceptability (SDA).

Background

NuGen[1], a consortium of Toshiba and Engie (formerly GDF Suez)[2], is proposing to build three AP1000 reactors at Moorside in Cumbria – a site adjacent to Sellafield. These three reactors together would have a capacity of up to 3.8GW. [3]

The AP1000 reactor is a pressurised water reactor (PWR) designed and sold by Westinghouse Electric Company, now majority owned by Toshiba. But unlike other PWR designs it is what is called an advanced passive design. The idea behind advanced passive design is that it shouldn't require operator actions or electronic feedback in order to shut it down safely in the event of a loss of coolant accident (LOCA). Such reactors rely more on natural processes such as natural convection for cooling and gravity rather than motor-driven pumps to provide a backup water supply. Westinghouse claims that AP1000 plant safety systems are able to automatically establish and maintain cooling of the reactor core and maintain the integrity of the containment which holds in the radioactive contents indefinitely following design-basis accidents.[4]

A design objective of the AP1000 was also to be less expensive than other designs, by using less equipment than competing designs. The design decreases the number of components, including pipes, wires, and valves. The AP1000 has:

- fewer safety-related valves
- fewer pumps
- less safety-related piping
- less control cable
- less seismic building volume[5]

But Westinghouse claims that this enhances safety because there are fewer active components to go wrong. Because concrete and steel account for over 95 percent of the capital cost of modern reactors, Westinghouse has made it a priority to reduce the size of the safety-related structures and components such as the containment vessel.

In contrast to Westinghouse claims of "*greatly enhanced safety features*" the Union of Concerned Scientists (UCS) says that "*the Westinghouse AP1000 has a weaker containment, less redundancy in safety systems, and fewer safety features than current reactors*."[6]

There is a great deal of uncertainty about how these passive approaches would actually work in practice, so it is important for Cumbria to recognise that, as shown in the Annexe, and like the EPR reactor proposed for Hinkley Point C, there are no operating AP1000s anywhere in the world, so there is no operating experience to draw from.

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1 http://www.nugeneration.com/about_nugen.html
2 See also Time for Engie to get the hell out of nuclear, CORE 30th August 2016 http://corecumbria.co.uk/news/time-for-nugens-engie-to-get-the-hell-out-of-nuclear/
3 Telegraph 5th Nov 2016 http://www.telegraph.co.uk/business/2016/11/05/government-could-part-fund-new-uk-nuclear-plants-nugen-suggests/
4 Defined by the US Nuclear Regulatory Commission as: "A postulated accident that a nuclear facility must be designed and built to withstand without loss to the systems, structures, and components necessary to ensure public health and safety." http://www.nrc.gov/reading-rm/basic-ref/glossary/design-basis-accident.html Fukushima is frequently described as a Beyond Design Basis Accident.
5 See http://www.westinghousenuclear.com/New-Plants/AP1000-PWR
6 Ellen Vankco, UCS, letter to the New York Times 26th February 2012 http://www.nytimes.com/2012/02/26/opinion/sunday/sunday-dialogue-nuclear-energy-pro-and-con.html

The Generic Design Assessment Process

The nuclear regulators – the Office for Nuclear Regulation (ONR) and Environment Agency – have been carrying out a new process called 'Generic Design Assessment' (GDA)[7], which looks at the safety, security and environmental implications of new reactor designs before an application is made to build that design at a particular site. Initially the GDA for the AP1000 was expected to be completed around spring 2011, when the regulators would have issued a statement about the acceptability of the design.

By the end of 2010 it was clear that the ONR would only be able to issue "interim" approvals for the Areva EPR and Westinghouse AP1000 reactor designs at the end of the generic design assessment (GDA) in June 2011. Construction could only occur after any outstanding "GDA issues" had been resolved.

On 14th December 2011 the Regulators granted interim Design Acceptance Confirmations (iDACs) and interim Statements of Design Acceptability (iSoDAs) for the UK EPR and the AP1000 reactor designs. The Regulators also confirmed that they are satisfied with how EDF and Westinghouse plan to resolve the GDA issues identified during the process.

ONR's interim approval for the AP1000 contained 51 GDA Issues. At this point Westinghouse decided to request a pause in the GDA process for the AP1000 pending customer input to finalizing it. Westinghouse has since become part of the NuGen consortium with its parent company Toshiba taking a 60% stake, the process for AP1000 has resumed, and is scheduled to be completed by March 2017 with issuance of DAC and SODA. By March 2016, the cost of the GDA for the AP1000 had reached £30 million.[8]

The GDA process is being carried out in, what is described as, an open and transparent manner, designed to facilitate the involvement of the public, who are able to view and comment on design information published on the web. Questions and comments can be submitted electronically via the Westinghouse website, or direct to the UK regulators. The deadline for making a comment on the AP1000 plant, as part of the GDA process is 30th November 2016.[9]

Concerns regarding the AP1000 Design

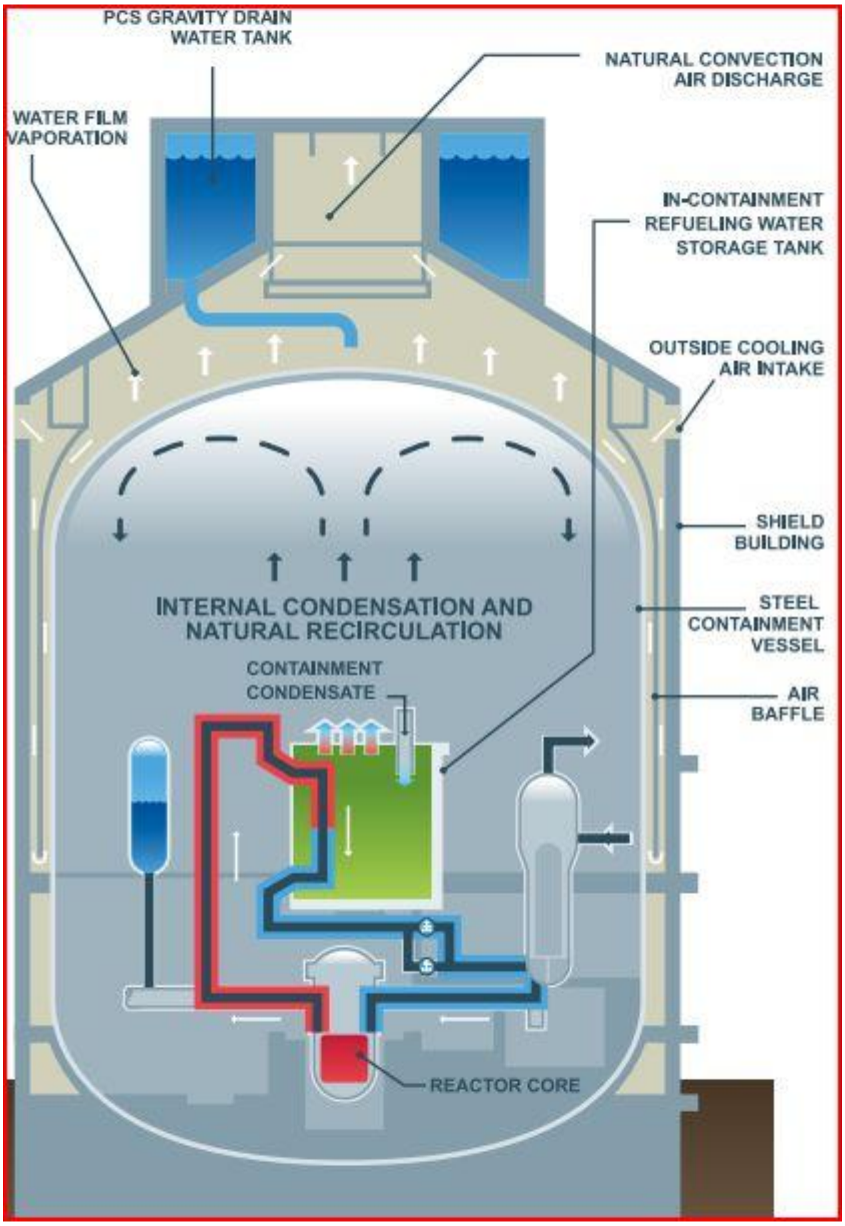
The major concern with the current generation of PWR reactors is with the reliability of systems used to shut down the reactor and remove decay heat. For a severe LOCA the decay heat removal system first has to quench the fuel core and prevent the zircaloy-cladding on the fuel rods catching fire. Then the decay heat of the core has to be removed and dissipated. These three heat management systems are referred to as Emergency Coolant Injection (ECI), Residual Heat Removal (RHR) and Containment Heat Removal (CHR) systems respectively.

In the AP1000 reactor heat is dissipated by atmospheric air passing into the space between the steel containment vessel and the concrete shield building (the annular space) and out of the top of the shield building. There are also tanks holding about 1,500m^3 of water located at the top of the concrete shield. In the aftermath of a LOCA, the water is gravity sprayed onto the outer surface of steel containment flashing to steam that is carried off by the air circulating through the annular space. The system is claimed to be entirely passive because the safety systems are triggered and operated by stored nitrogen pressure or gravity feed and there is no demand for powered pumps, chillers, or emergency diesel generators.

[7] See http://www.onr.org.uk/new-reactors/index.htm

[8] World Nuclear Association, Nuclear Power in the United Kingdom (accessed 3rd Nov 2016) http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-kingdom.aspx

[9] See http://www.westinghousenuclear.com/uknuclear/Make-A-Comment



The present generation of reactors rely on what is called defence-in-depth made up of layers of redundancy and diversity – this is where, say, two valves are fitted instead of one (redundancy) or where the function may be achieved by one of two entirely different means (diversity). Redundancy safeguards against single component failure and diversity bypasses common mode failure. Passively safe designs run counter to this redundancy and diversity philosophy. Instead the majority of the safety systems are passively activated and should not require human intervention in a post-accident situation. The downside of this arrangement is that if the reactor malfunctions in a way which is not expected then there little that the human operators can do to resolve the problem.[10]

The lack of redundancy and diversity means that, for instance, if the steel containment vessel fails or the gravity feed water sprays fail to function (say an aircraft crash that obliterates the high level water tanks) then the heat transfer/cooling function may not be sufficient to inhibit the containment

[10] Personal communication with John Large of Large Associates

pressure exceeding its maximum design pressure, thereby leading to a potential failure of the final containment and a radioactive release to atmosphere.

As we shall see even a small breach of the steel containment vessel could result in an enhanced release rate of radioactivity because of the naturally venting flue system arrangement via the annular space which exhausts directly to atmosphere through the top of the shield building.[11]

The Chimney Effect

Nuclear engineer, Arnie Gundersen, of Fairewinds Associates has repeatedly warned that the AP1000 design suffers the same design flaw as the old Windscale reactor. Gundersen argues that, like the Windscale disaster of 1957, huge amounts of radiation could be released from an AP1000 reactor during a meltdown.[12]

To summarize briefly, the problem identified by Gundersen is that during an accident if there were just a small failure in the steel containment vessel of the AP1000 reactor, the radioactive gasses inside the reactor would leak directly into the environment, because the gasses would be sucked out the hole in the top of the AP1000 Shield Building because of what is known as the *chimney effect*. Gundersen warns that this could produce an accident like "*Chernobyl on steroids*".

Gunderson says for the AP1000s proposed for Moorside we should either plan for an evacuation zone of up to 50 miles because "*[i]f this leaks it would be a leak worse than the one at Fukushima*" Or you could put a filter on the top of the AP1000 to trap the gases – that would cost about $100m.[13]

Four major concerns

(1) Recent experience with the current generation of nuclear reactors in the US shows that containment corrosion, cracking, and leakage are far more prevalent and serious than anticipated by the U.S. Nuclear Regulatory Commission (NRC).

(2) By design, the AP1000 containment has an even higher vulnerability to corrosion than containment systems of existing reactor designs because the outside of the AP1000 containment is exposed to a high-oxygen and high-moisture environment conducive to corrosion and is prone to collect moisture in numerous inaccessible locations that are not available for inspection.

(3) By design, the AP1000 containment has an even higher vulnerability to unfiltered, unmonitored leakage than the current generation containment system designs, and it lacks the defense in depth of existing structures. While the AP1000 is called an *advanced passive system*, in fact the containment design and structures immediately outside the containment are designed to create a chimney-like effect and draw out any radiation that leaks through the containment into the environment.

(4) Any leaks will be more severe than those previously identified by Westinghouse and would require a much larger evacuation zone than expected.

[11] ibid

[12] Independent 16th March 2015 http://www.independent.co.uk/news/business/news/nuclear-expert-arnie-gundersen-warns-of-chernobyl-on-steroids-risk-in-uk-from-proposed-cumbria-plant-10109930.html

[13] Fairewinds 19th March 2015 http://www.fairewinds.org/demystify/fairewinds-nuke-truth-at-house-of-commons?rq=Chernobyl%20on%20Steroids

US Nuclear Regulatory Commission Response

During the AP1000 review by the US Nuclear Regulatory Commission, concern was expressed about corrosion in the AP1000 containment. In response to these concerns Westinghouse agreed to make the containment 1/8th inch (0.125 inches) thicker and add a nuclear-grade protective coating. The AP1000 has access ports to allow for visual examination of some portions of the outside of the containment, so Westinghouse said operators would provide a schedule of coating inspections. On this basis the NRC found the Westinghouse response acceptable.[14]

But Fairewinds expressed concern that:

(a) Inspections have historically missed containment flaws;
(b) Application of protective coatings has historically allowed for coating degradation;
(c) Wall brackets on the outside of the AP1000 containment create crevices that allow for moisture build-up and creates a corrosive environment;
(d) The junction between the wall and the floor does the same;
(e) The shield building breathes in moist outside air;
(f) Corrosion rates could be up to 0.15 inches per year.

Containment Failure

Gundersen has shown that there have been at least 40 occasions when significant corrosion and other failures have developed in containment vessels of existing reactors, and that there are at least five different ways that this might happen – such as pitting – or localised corrosion; construction debris erroneously left in the containment; failure of the thick walls due to expansion and contraction; inadequate inspections; inadequate coating.

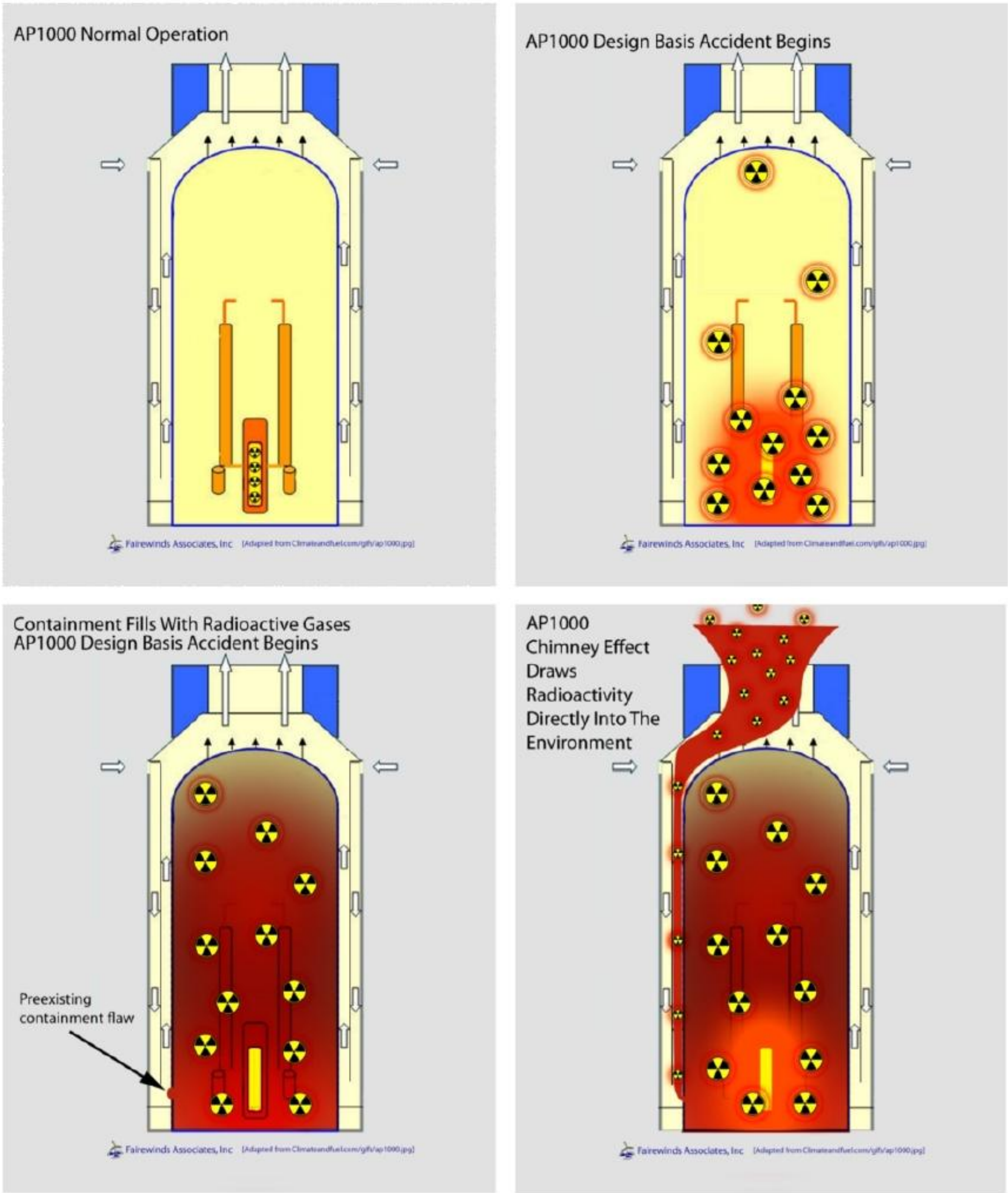
Gundersen concludes that as a result the Westinghouse Severe Accident Mitigation Design Alternatives (SAMDA) report must be re-evaluated. If a proper SAMDA analysis was carried out it would show that filters should be required on the Westinghouse AP1000 design in order to reduce potential accident exposures.

Gundersen gives examples of containment failures in American reactors that are relevant to the AP1000 design:

1. Corrosion in the Salem (NJ) reactor containment in the joint between the wall and the floor which started inside the vessel and progressed outwards, which meant it couldn't be detected early by visual inspection.
2. Cracks in the outside containment of the Fitzpatrick nuclear power plant in Oswego, NY due to differential expansion in a thick containment that is of similar thickness to the proposed AP1000 design.
3. The application of protective coatings throughout the nuclear industry has been proven to be prone to repeated failures, such as at the Oconee nuclear plant in South Carolina.
4. Corrosion associated with construction debris uncovered at Beaver Valley Nuclear plant in Pennsylvania.
5. A through-wall hole in the liner of a containment system discovered in October 2010 at Turkey Point 3, in Florida, which should have been spotted earlier by inspections.

[14] Post Accident AP1000 Containment Leakage, John Runkle AP1000 Oversight Group and Arnie Gundersen, Fairwwinds Associates. 21st April 2010 http://www.fairewinds.org/nuclear-energy-education/post-accident-ap1000-containment-leakage

Gundersen accuses the US Nuclear Regulatory Commission of pre-judging these AP1000 design concerns as insignificant in the rush to fast track the design in its accelerated certification process. It appears that the NRC staff once again ignored significant safety related issues.[15]



<u>The AP1000 Chimney Effect</u>

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[15] Nuclear Containment Failures: Ramifications for the AP1000 Containment Design, Fairwinds Associates, December 2010
https://static1.squarespace.com/static/54aac5e4e4b0b6dc3e1f6866/t/56211bfee4b0d7dad9a1be0c/1445010430544/142097389-NUCLEAR-CONTAINMENT-FAILURES.pdf

Loss of Coolant Accident

Given the history of containment failures it is reasonable to assume that a pinhole in the AP1000 containment could remain undetected. If such a pinhole were present at the start of a loss of coolant accident (LOCA) then we could see huge amounts of radiation being released due to the *chimney effect*.

Fairewinds concludes that post accident radiation doses to the public could be several orders of magnitude higher (one hundred to one thousand times higher) than those assumed by Westinghouse in its AP1000 design. This seriously impacts emergency planning over a much broader area than that presently assumed in the Westinghouse SAMDA analysis and NRC staff review.

Cracking Shield Building

The AP1000 Chimney Effect identified by Fairewinds is not the only significant technical issue that the NRC appears to have downplayed. In a closed session of the NRCs Advisory Committee on Reactor Safeguards (ACRS) in December 2010, NRC engineer John Ma discussed his concern that the AP1000 shield building lacks flexibility and could crack in the event of an earthquake or aircraft impact. [16] A cracked shield building would cause the AP1000 passive "chimney effect" airflow to fail, creating an accident scenario even worse than that postulated by Fairewinds. The engineer also stressed his concern that the AP1000 shield building design does not even meet American Concrete Institute (ACI) standards and the design also failed required shear test certifications.[17]

Post-Fukushima

In the aftermath of the Fukushima accidents, the AP1000 Oversight Group - an alliance of US non-profit organizations concerned about safety issues and costs of AP1000 reactors - issued a report to alert US Nuclear Regulatory Commission to six additional areas of concern regarding both the safety and reliability of the AP1000, after a thorough review of the design in the light of the Japanese accident.

These six areas are:

• Additional Heat Load on the Containment;

• The Loss of the Ultimate Heat Sink (LoUHS) and the Containment/Shield Building Interface;

• Loss of the Ultimate Heat Sink and cooling the Spent Fuel Pool (SFP);

• Multiunit Site Accident Interactions; and

• Containment Integrity;

• Design Basis Events.[18]

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16 Mathew Wald, Reactor Design Edges Toward Approval, but Not Without Complaints
New York Times 8th March 2011 http://green.blogs.nytimes.com/2011/03/08/reactor-design-edges-toward-approval-but-not-without-complaints/

17 Nuclear Containment Failures: Ramifications for the AP1000 Containment Design, Fairwinds Associates, December 2010
https://static1.squarespace.com/static/54aac5e4e4b0b6dc3e1f6866/t/56211bfee4b0d7dad9a1be0c/1445010430544/142097389-NUCLEAR-CONTAINMENT-FAILURES.pdf

18 Fukushima and the Westinghouse-Toshiba AP1000, A report for the AP1000 Oversight Group by Fairewinds, 10th November 2011. http://www.ncwarn.org/wp-content/uploads/2011/09/Rept-Fukushima-AP1000-

Additional Heat Load on the Containment

The AP1000 Containment is extraordinarily close to exceeding its peak post accident design pressure. Given that three out of three Containment Systems failed at Fukushima, allowing for only a very small margin of error in the pressure burden to the Containment System is too great a risk to public health and safety.

Fukushima has shown that ongoing nuclear fission after a reactor has supposedly been shutdown continues to be the source of significant pressure inside the containment. Such post accident pressure increases could easily be to levels above what the containment is designed to withstand.

Loss of the Ultimate Heat Sink (LoUHS) and the Containment/Shield Building Interface

Dr. Susan Sterrett, a former Westinghouse-Toshiba engineer believes the AP1000 Ultimate Heat Sink (UHS) is inadequate. Dr. Sterrett's concerns centre on the inability of the Shield Building and Containment to adequately transfer heat that has built up inside the steel containment, into the annular gap.

The inability to cool the reactors by emergency means is called a Loss of the Ultimate Heat Sink (LoUHS). Fukushima showed that this can cause a meltdown and/or a hydrogen explosion.

The Westinghouse-Toshiba Severe Accident Mitigation Design Alternative (SAMDA) analysis assumes that there is zero probability of a LoUHS. But the AP1000 Oversight Group has identified at least seven ways a LoUHS could occur. Several of these involve damage to the water tank which sits on top of the shield building. Others involve some sort of disruption to the air flow through the annular gap or clogging of the air-intake vents. Dirt and dust could be drawn into the annular gap if there is some sort of explosion on an adjacent site. This could hinder the ability of the steel Containment to transfer heat into the air of the annular gap.

The AP1000 Oversight Group also identified the possibility of the failure of the squib valves to operate due to explosive debris from some sort of attack or accident. These squib valves have been specially designed for the AP1000 to release water from the water tank in the event of an accident.

Arnie Gundersen says the water in the tanks on top of the shield should last two to three days. But Nuclear Engineer Clive Semmens points out that, because emergency core cooling systems don't work nearly as well as you might expect, you can't ensure that the coolant reaches all parts of the reactor in proportion to the amount of heat being generated in each particular part of the reactor. Some parts will be cooled more than is necessary, while others are insufficiently cooled – unless you use a lot more water. One of the big problems is the Leidenfrost effect: once the pressure is off the system, the water doesn't get to touch the hottest places because there is an insulating layer of steam between the water and the hot surface.[19]

Loss of the Ultimate Heat Sink and cooling the Spent Fuel Pool (SFP)

The accidents at Fukushima, especially the overheating and the hydrogen explosions in the Unit 4 Spent Fuel Pool showed that the calculations and assumptions about the AP1000 Spent Fuel Pond design were wholly inadequate. The emergency service water pumps were destroyed at Fukushima,

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Fairewinds_11_10_11.pdf also see video here http://www.fairewinds.org/nuclear-energy-education/fukushima-and-its-impact-upon-the-westinghouse-toshiba-designed-ap1000-atomic-power-plant

[19] see http://clive.semmens.org.uk/Recounts.html?MyNuclearExp.

and since the AP1000 relies upon a similar cooling system for its spent fuel pools, a new analysis of these Fukushima issues must be conducted in order to answer these "unreviewed safety questions".

The Westinghouse-Toshiba SAMDA analysis assumes that there is *zero probability of a Loss of the Ultimate Heat Sink accident in the Spent Fuel Pool*, which means there are "unreviewed" and unanalyzed "safety questions". Furthermore, Fukushima Unit 4 showed that local boiling within each spent fuel bundle could occur even if the bulk pool temperature is only 75^{o}C. Thus, the local spent fuel bundle boiling will cause excessive hydrogen generation and excessive humidity even if bulk pool temperature is below 100^{o}C. None of these dangerous possibilities have been addressed in current nuclear power plant spent fuel storage design or in the design of the AP1000, which has its fuel storage both inside and outside of the Containment System.

Multiunit Site Accident Interactions of Design Basis Events at Shared Nuclear Power Plant Sites

When the AP1000 shares a site with older nuclear power plants or another AP1000, an explosion at one reactor could damage the water tank on top of another reactor, or it could damage the shield building. Flying rubble could damage the squib valves or plug the air intake vents in the shield building. All of this could limit the ability of the containment system to transfer heat away from the reactor.

Containment Integrity

The Westinghouse-Toshiba SAMDA analysis assumes that there is zero probability of Containment breach. This assumption was inappropriate before Fukushima but certainly can no longer be supported in light of the three Fukushima Containment failures. Events at Fukushima have shown that three Containment Systems have failed completely, thereby leaking radioactivity into the environment. Unfortunately, the accidents at Fukushima have shown that there is a high probability of Containment System failure resulting in significant releases of radioactivity directly into the environment. And as we have seen, the AP1000 design could see leakage of significant amounts of radioactivity due to the "chimney effect".

Because there is little or no remaining design margin for the AP1000 Containment design pressure in Westinghouse-Toshiba accident calculations, a detonation (a shock wave that travels faster than the speed of sound) due to hydrogen generation as occurred at reactor three at Fukushima could shatter the containment.[20]

Design Basis Events

According to industry definition, a design basis event should occur infrequently, in general less than once in one thousand years. Yet four such natural catastrophe design basis events (the Japan earthquake and tsunami, the Ft. Calhoun flood, and the North Anna earthquake) occurred over a six month period in 2011 indicating that the nuclear industry has grossly underestimated the magnitude of any design basis event.

Conclusions

The AP1000 advanced passive nuclear reactor design has a weaker containment, and fewer back-up safety systems than current reactor designs.

[20] See Fairewinds video here for further explanation: http://www.fairewinds.org/nuclear-energy-education/more-lessons-from-the-fukushima-daiichi-accident-containment-failures-and-the-loss-of-the-ultimate-heat-sink-2

Its so-called advanced passive design make the reactor particularly vulnerable to a very large release of radioactivity following an accident if there were just a small failure in the steel containment vessel, due to the *chimney effect.*

A thorough review of the AP1000 design in the light of the Japanese accident at Fukushima has shown that the containment is dangerously close to exceeding the maximum post accident pressure that it could withstand. Several ways in which the AP1000 design could lose the ability to cool the reactors in an emergency have been identified, and Fukushima has shown that a containment breach is possible, and that arrangements for keeping the spent fuel ponds cool are inadequate.

The AP1000 reactor design is not fit for purpose and so should be refused a Design Acceptance Confirmation (DAC) and Statement of Design Acceptability (SDA) by the Office for Nuclear Regulation and the Environment Agency.

Annexe: AP1000s – The Stalled Nuclear Renaissance

Eight AP1000 units are currently under construction worldwide: two each at Vogtle (Georgia) and V.C. Summer (South Carolina) in the U.S. and two each at Sanmen and Haiyang in China. Discussions are still ongoing about building an AP1000 at Kozloduy in Bulgaria, and, of course, there are plans to build three at Moorside.[21]

Four other AP1000 reactors in the US are awaiting a construction and operating licence (COL). These are expected late in 2016 or early 2017. Four other American AP1000s have been suspended indefinitely and another two have applied for an Early Site Permit.[22]

Of the AP1000 reactors under construction, two in Georgia are both at least 3 years late and estimated costs for the two have, so far, gone up from $14.3bn to around $16.5bn. More delays are expected.[23]

Two in South Carolina are three or four years late. The total cost has gone up by from $11.4 billion to $13.8 billion, or about a 21 percent increase.[24]

In China four AP1000s are under construction none of which are expected to be completed before 2017 and all will be at least three years late, an unprecedented delay in China's nuclear history. It would be surprising if China was not disillusioned with its foreign suppliers and their technologies. Along with the EPR, the AP1000 reactors have been problematic to build. The four AP1000s are being built by China's State Nuclear Power Technology Company (SNPTC), which has not built reactors before. There is some publicly available information about the problems suffered in China with the AP1000s, including continual design changes by Westinghouse. For example, the reactor coolant pumps and the squib valves, which are essential to prevent accidents, have been particularly problematic.

China didn't want to be the first country to complete construction of the AP1000 (and EPR) designs. The government is required to develop and demonstrate test procedures for bringing the plants into service, which could take up to a year. These test procedures are developed by vendors and generally standardised although national safety regulators must approve them and can add specific requirements.

In 2014, a senior official at China's nuclear safety regulator, the National Nuclear Safety Administration (NNSA) complained that only a small number of test procedures had been developed for the AP1000, and no acceptance criteria had been submitted for review. He said the same issues affect the EPR. China will likely be reluctant to commit to further AP1000s (and the CAP1400, a Chinese design modified from the AP1000) until the first of the Westinghouse designs is in service, passes its acceptance tests, and demonstrates safe, reliable operation. There are no plans to build additional EPR reactors.[25]

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[21] Westinghouse 20th August 2014 http://www.westinghousenuclear.com/About/News/View/ArticleId/447/Westinghouse-Blue-Castle-Working-to-Bring-Benefits-of-AP1000-Plant-Technology-to-Western-US

[22] World Nuclear Association 27th October 2016 http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power.aspx

[23] The Energy Collective 11th July 2016 http://www.theenergycollective.com/djwamsted/2382457/time-for-a-reality-check-more-delays-are-coming-for-georgia-powers-new-vogtle-reactors

[24] The State 21st September 2016 http://www.thestate.com/news/business/article103353107.html

[25] China Dialogue 26th Oct 2016 https://www.chinadialogue.net/article/show/single/en/9341-China-s-nuclear-roll-out-facing-delays

		Construction Started	**Target for Start of Operation**	**Delay**
Vogtle 3, GA	South Nuclear Operating Co.	March 2013	Q2 2019	3 years late
Vogtle 4, GA	Southern Nuclear Operating Co.	Nov 2013	Q2 2020	3 years late
V.C. Summer2, SC	Southern Carolina Electric & Gas	March 2013	2019	3 years late
V.C. Summer3, SC	Southern Carolina Electric & Gas	Nov 2013	2020	3 years late
William States Lee, SC x2	Duke Energy	COL target date 2016	2024 2026	
Turkey Point, FL x2	Florida Power & Light	COL target date 2017	2027 2028	
Levy County, FL x2	Duke Energy			Suspended indefinitely
Shearon Harris, NC x2	Duke Energy			Suspended
Green River, UT x2	Blue Castle/Transition Power Development		2030	Early Site Permit application expected 2016
China				
Sanmen 1	State Nuclear Power Technology Corporation (SNTPC).	April 2009	Originally August 2013 Now 2017	4 years late
Sanmen 2	State Nuclear Power Technology Corporation (SNTPC).	Dec 2009	Originally June 2014 Now 2017	3 years late
Haiyang 1	State Nuclear Power Technology Corporation (SNTPC).	Sept 2009	May 2014 Now 2017	3 years late
Haiyang 2	State Nuclear Power Technology Corporation (SNTPC).	June 2010	March 2015 Now 2017	2 - 3years late