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CUTTING CORNERS?

THE INTERNATIONAL BEST PRACTICE SAFETY UPGRADES NOT REQUIRED FOR KOEBERG'S LIFTETIME EXTENSION

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List of abbreviations.

ASN: Autorité de sûreté nucléaire (the French nuclear regulator)

CP 900 MWe: Generation II nuclear power station model

EDF: Électricité de France (the French state owned Electricity company).

EPR: European Pressurised Reactor

IAEA: International Atomic Energy Agency

INSAG: International Nuclear Safety Advisory Group

INSAG-10: INSAG's 10th report

LTO: Long-Term Operation

MWe: Megawatt electrical

NNR: National Nuclear Regulator (South Africa)

PWR: Pressurised Water Reactor

SAMGs: Severe Accident Management Guidelines

SAR: Safety Analysis Report

Introduction

As of May 2024, the Koeberg nuclear power station is applying to South Africa's National Nuclear Regulator (NNR) to extend the lifespan of its two reactors for another 20 years. The NNR will decide whether to grant a Long-Term Operation (LTO) licence for one of the reactors in July 2024. Application for the other reactor will be assessed in 2025.

However, the NNR's current safety requirements for the LTO are not in line with best practice. France is currently extending the lifespan of 18 reactors of the exact same design as Koeberg and built during the same time, 1970s to mid-1980s. Unlike in South Africa, the French regulatory requirements demand a significantly higher level of safety primarily based on learnings from the world's worst nuclear accidents: Three Mile Island, Chernobyl and Fukushima.

Section One of this briefing will begin with an overview of Koeberg's reactor design and Section Two will examine the philosophy behind the safety standards applied in France's reactor life extension projects, including those for nuclear plants of the same design as Koeberg's. The third section will compare the upgrades required by the NNR to those required in France and will show that Koeberg's upgrades fall short in at least three critical areas.

1. CP 900 MWe reactors: An outdated design

Koeberg's design and ongoing technical operation are closely linked to France's nuclear programme. The CP1 900 MWe class of reactors, to which Koeberg's reactors belong, were built by the French company Framatome, based upon a Westinghouse design in the 1970s-1980s. Électricité de France (EDF), a 100% state-owned enterprise, runs France's nuclear power plants via its subsidiaries Areva and Framatome.

EDF has and continues to provide a significant amount of technical support to Eskom, as well as material supplies for Koeberg: for example, EDF provided the six new steam generators necessary for Koeberg's LTO.

France has a total of 18 CP1 reactors spread across four nuclear power plants with an average age of 42 years. CP0, CP1 and CP2 reactors – which all share the same basic design and are collectively known at the CP 900 MWe series – account for 34 of France's 56 operational reactors. The youngest CP reactor is 36-years-old and oldest is 45-years-old: all of them are currently undergoing life extension programmes.

The CP series are pressurised water reactors (PWR) and the PWR design constitutes the majority of reactors not only in France but also globally. Approximately 70% of all operational commercial reactors worldwide are PWRs. Moreover, PWRs are used in nuclear powered warships and submarines. PWRs are the closest thing that the nuclear industry has to a mature technology and, as such, the design faults and safety challenges are relatively well-known.

The most significant of these revolves around the water cooling the reactor. Because the cooling water is so highly pressurised, a loss-of-coolant accident – a scenario when, through events such as pipes bursting, there is no more or insufficient water to cool the reactor – can have severe consequences including a partial or complete meltdown. Without sufficient water to cool the nuclear core, the fuel and reactor internals can melt through the bottom of the reactor vessel. The resulting molten mixture of uranium fuel, stainless steel, zirconium fuel cladding and waste products including plutonium continue to produce heat, and can reach a sufficient temperature to melt through the concrete base below the reactors.

There are also design flaws within the CP series concerning the spent fuel pond. The French nuclear regulator, Autorité de sûreté nucléaire (ASN), stated in 2013:

> [D]espite the improvements defined during successive safety reassessments (periodic safety reviews and post-Fukushima stress tests), the design of the storage and handling of spent fuel in the deactivation pool is and will remain significantly out of step with the safety principles that would be applied to a new facility.[1]

In 2022, the International Atomic Energy Agency (IAEA) did an assessment of Koeberg. One of its key findings was that "Leakage through leakage collection system of spent fuel pool of unit 2 was observed irregularly during the plant life, it has even stopped for a few years. An investigation was performed, but the root cause of the leak and disappearance of [the] leak could not be found."[2]

CP series reactors are Generation II reactors[3] and were designed before four of the world's six worst nuclear accidents:

- 1978: Three Mile Island, Pennsylvania, USA. Partial meltdown.
- 1986: Chernobyl, Kiev Oblast, USSR. Complete meltdown.
- 1989: Saint-Laurent, Saint-Laurent-Nouan, France. Partial meltdown.
- 2011: Fukushima, Fukushima Prefecture, Japan. Complete meltdown

1. ASN, "Programme générique proposé par EDF pour la poursuite du fonctionnement des réacteurs en exploitation au-delà de leur quatrième réexamen de sûreté", letter CODEP-DCN-2013-013464 of 28 June 2013 to the President of EDF - translation by Institut négaWatt. See http://bit.ly/penf0096

2. International Atomic Energy Agency, Report of the Safety Aspects of the Long Term Operation Mission (SALTO) to the Koeberg Nuclear Power Plant Units 1 and 2, 2022, pg. 64, https://press-admin.voteda.org/wp-content/uploads/2022/10/50_Koeberg_SALTO-mission-report-final.pdf

3. Generation I were prototype reactors built in the 1950s and 1960s. Generation II were the first commercial reactors with the last constructions in the 1990s. Generation III and III+ are advanced commercial reactors. Generation IV are still in the design phase.

Modern reactors (Generation III and III+) have incorporated safety design improvements learned as result of these serious accidents. Generation III and III+ plants are safer than Generation II plants. Less serious accidents consequent to the CP design have also resulted in safety improvements in new plants.

Put another way, no nuclear regulator on the planet would approve the construction of a Generation II reactor today, simply because they are not as safe as Generation III and III+ reactors.

A view of Koeberg Power Station , Cape Town

2. The French life extension philosophy

In France, the Generation III+ successor to Generation II reactors like the CP series is the EPR; originally known as the European Pressurised Reactor but now simply the EPR. Three EPRs are operational worldwide: two in China (first operation in 2018 and 2019) and one in Finland (first operation in 2023). EDF is building two more; one in France and the other in the UK. The EPR's most notable safety improvements over Generation II reactors are:

1. Passive systems that shut down the reactor in case of an impending accident
2. A core catcher, which in the case of a meltdown prevents the molten core (corium) from leaving the containment building.

‚Defence-in-depth'

In nuclear installations, defence-in-depth means that in the case of a meltdown, there are a series of independent physical structures and management processes to prevent radioactive material from leaking into the environment. These include physical barriers as well as emergency plans and procedures. Each layer is intended to function if the previous layer fails . After the Three Mile Island disaster, the IAEA concluded that nuclear plants require five defensive layers.

France is currently seeking to extend the lifespans of 56 reactors. The nuclear regulator, Autorité de sûreté nucléaire (ASN), stated in 2013 that:

> In the years to come, existing reactors will coexist, worldwide, with reactors of the EPR type or equivalent, the design of which meets significantly enhanced safety requirements. **Existing reactors must therefore be upgraded in line with these new safety requirements, the state of the art in nuclear technologies and the operating lifetime projected by EDF.**[1]

1 ASN, "Programme générique proposé par EDF pour la poursuite du fonctionnement des réacteurs en exploitation au-delà de leur quatrième réexamen de sûreté", letter CODEP-DCN-2013-013464 of 28 June 2013 to the President of EDF - translation by Institut négaWatt. http://bit.ly/penf0096

In other words and as ASN put it in 2021, **the aim of the lifetime extensions is to "bring the level of safety of the 900 MWe reactors close to that of the most recent reactors (third generation)"**.[2] The vital safety improvements that have to be made beyond the original design of CP plants and which are necessary for an LTO are:

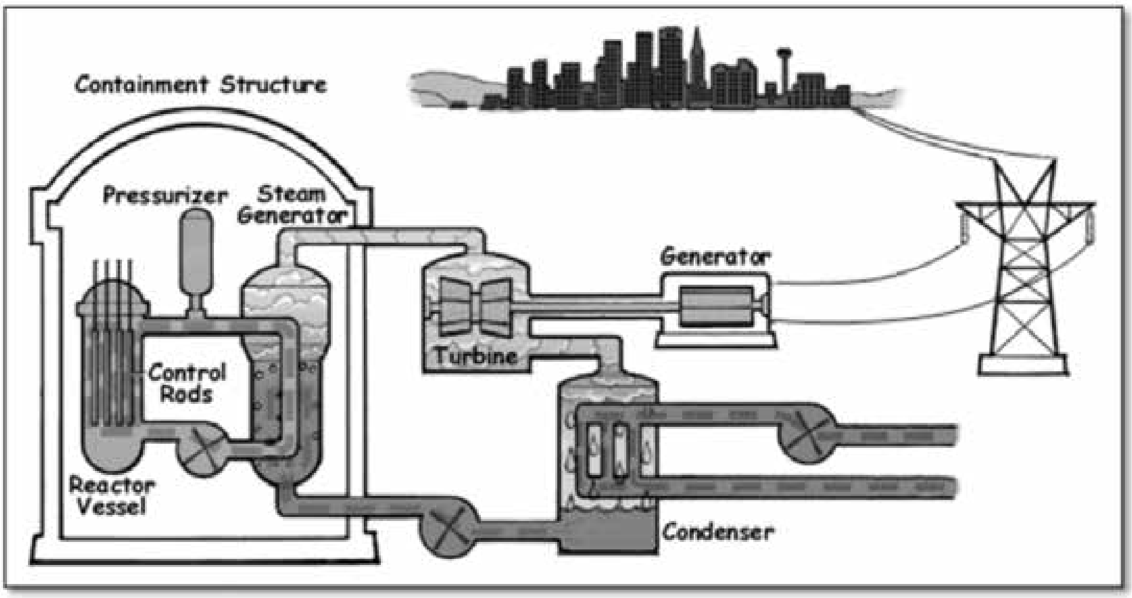
1. Controlling the risks of extreme hazards such as fire, explosion, earthquake and flooding and similar.
2. Increasing the safety of the spent fuel storage pool
3. Mitigating the consequences of core meltdowns. **Practically speaking, this means that CP reactors undergoing life extensions must be retrofitted with a kind of core catcher.**

Another two marked safety advancements are the length of life extensions given and the frequency of critical safety tests. The French regulator will only grant nuclear plants a ten-year LTO extension, after which the plants need to go through a complete safety review in order to keep their licence. If the plants pass the safety review, their LTO will be extended for another ten years. After which, EDF can apply for another ten-year licence, and so on.

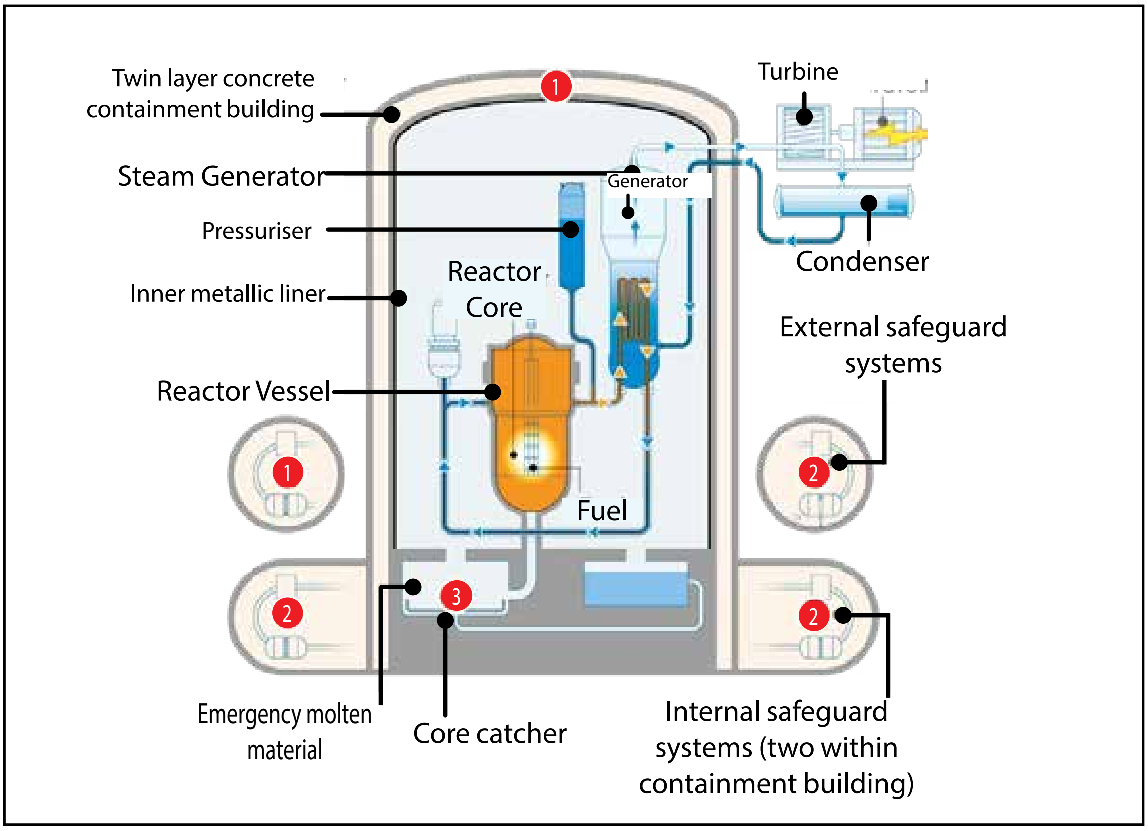
Additionally and as part of their LTO licensing conditions, nuclear plants must undergo integrated leak tests every five years, instead of the previously mandated ten. These tests are critical: if the reactor vessel is breached in the case of a major accident will the containment building be able to contain the pressure or will it leak radioactive material and gases into the environment? The containment building is the last physical defence in the case of a partial or complete meltdown.

2 ASN, ASN Report on the state of nuclear safety and radiation protection in France in 2020, 2021, pg. 24-25. http://bit.ly/penf0107

The PWR and EPR nuclear plant designs compared. Note the core catcher in the EPR, which French regulators insist must be added to older nuclear models such as PWRs.



A diagram of a Pressurised Water Reactor (PWR) nuclear plant. Source: Eskom. Public information document for Koeberg LTO



A diagram of a European Pressurised Reactor (EPR) nuclear plant. Source: EDF/Areva via Financial Times.

What are the risks?

The nuclear industry is fond of stating that the probability of a serious nuclear accident is extremely low: for example, Eskom calculates the likelihood of an early containment failure occurring at about 0.000000237 times a year per reactor. You could also think of this as a probability of 2 in 10 million every year, or 2 in 5 million since there are two reactors at Koeberg. In comparison, the odds of winning the Powerball lottery is somewhere around 1 in 20 million. In terms of a major event – such as internal fires, flooding or an aircraft crash – Eskom estimates that the probability of the containment system holding is only 86.6%.[1]

There is, however, another way of looking at the likelihood of a major nuclear accident. From 1952 to 2011, there has been one partial or complete meltdown every decade. Obviously then, a serious accident is a possibility and that is why a plant's defence-in-depth is so important.

IAEA experts at TEPCO's Fukushima Daiichi Nuclear Power Station as part of a mission to review plans to decommission the facility.
Source: IAEA

1 The Koeberg Risk Assessment Report PSA-R-T19-01 Revision 10. Table 8-2 pg 37

3. Koeberg's safety upgrades

The previous sections described the improved safety measures adopted by French authorities in extending the lifetimes of nuclear plants belonging to the CP series. Once again, it is worth noting that these additional safety measures have been introduced because the French regulator believes that **the original design of the CP series, to which Koeberg belongs, isn't safe enough for continued operation.**

Therefore, how do Koeberg's LTO requirements compare to those for France's identical plants? The main difference is precisely that while France is investing significantly to ensure its plants are as close to Generation III safety standards as possible, Eskom maintains that Koeberg's Generation II design is safe, and the NNR does not question this claim.

After the Three Mile Island disaster, the IAEA concluded that nuclear plants require five defensive layers. Koeberg was originally designed to have three layers and Eskom has basically stuck to three, only adding a quasi-layer: namely, an emergency plan to be implemented after radioactive material has left the plant. In the latest test of the emergency plan, a drill held in November 2022, 14 non-compliances with the plan were identified. The NNR and Eskom have refused to release details of how these failures have been addressed, if at all.

In Eskom's submission to NNR on the LTO, it states:

> "The Koeberg (Safety Analysis Report), which focuses on Levels 1, 2, and 3, is not fully aligned with the approach documented in IAEA INSAG-10[1]; however, evidence of elements of Levels 4 and 5 does exist at Koeberg such as the severe accident guidelines and associated design provisions to support the severe accident management guidelines (SAMGs) and a comprehensive emergency plan."[2]

1 The IAEA's International Nuclear Safety Advisory Group (INSAG) Report: Defence in Depth in Nuclear Safety https://www-pub.iaea.org/mtcd/publications/pdf/pub1013e_web.pdf

2 Eskom's Safety Case for Long-Term Operation of Koeberg Nuclear Power Station Document Identifier:331-618 pg 89 https://nnr.co.za/wp-content/uploads/2024/03/1.-Safety-Case-for-Long-Term-Operation-of-Koeberg-Nuclear-Power-Station-Revision-3.pdf

Unlike what the French are doing on their CP plants, the NNR doesn't require Eskom to install a core catcher, which is a significant part of modern defence-in-depth. According to ASN, having a core catcher to prevent molten fuel from melting through the containment building in the case of a meltdown is a non-negotiable element of a modern nuclear plant's safety criteria.[3]

Another concern is that Eskom will be granted a 20-year operating licence for Koeberg. Yet, the builder of Koeberg and continued supplier of materials and technical support to Koeberg will have to prove the safety of their CP plants every ten years. One can only ask why the NNR is not requiring this conservation approach.

The final area in which there is major divergence between France and South Africa is that the intervals between integrated leak tests4 in France have been shortened to five years, yet, South Africa will keep to ten-year intervals. Absurdly, as Koeberg's last integrated leak test was undertaken nine years ago, the next test will only take place after the NNR has made its decision on the LTO.

In regards to the spent fuel pond, Eskom's documentation is not clear whether repairs and upgrades implemented at Koeberg's spent fuel pond are in line with IAEA recommendations and ASN requirements. The NNR should provide clarity to the public on this matter.

3 Hasti Nasiri, "Assessment of PSA Level 2 for core catcher design using a combined probabilistic and deterministic method for a case study: IR-360 NPP", Annals of Nuclear Energy (Volume 163, 1 December 2021), https://doi.org/10.1016/j.anucene.2021.108534

4 Hasti Nasiri, "Assessment of PSA Level 2 for core catcher design using a combined probabilistic and deterministic method for a case study: IR-360 NPP", Annals of Nuclear Energy (Volume 163, 1 December 2021), https://doi.org/10.1016/j.anucene.2021.108534

French mandatory safety enhancement	Rationale	Eskom and NNR's position
Retrofit a core catcher on Generation II plants, including those of the same design as Koeberg.	To prevent molten fuel from burning through the bottom of the containment building and into the external environment in case of a meltdown.	Not required at Koeberg.
Shortening the licence period of an LTO from 20 years to 10.	Having to go through a complete safety, ageing and materials assessment every 10 years decreases the risk of a major accident.	Eskom is requesting a 20-year licence extension for Koeberg.
Integrated leak tests on the containment buildings have to happen every 5 years.	The containment building's integrity has to hold in the case of a major nuclear accident where the reactor vessel is breached. Increased testing helps to determine the building's integrity and make any necessary repairs. More frequent testing reduces the risk of a major accident becoming catastrophic.	Koeberg will undergo integrated leak tests every 10 years.

4. Conclusion

Bringing a Generation II plant closer to the safety standards of Generation III plants is possible. The total cost of upgrading 56 nuclear reactors in France is currently estimated at €66 billion [ZAR 13 trillion][1]. In August 2023, the Tricastin nuclear plant in France received approval for a ten-year LTO extension for one of its four reactors: the other reactors will follow, depending upon regulatory approval. The Tricastin plant is of the exact same design as Koeberg.

Yet, as this analysis shows, the upgrades required by the NNR for Koeberg fall short to those required in France in at least three critical areas. Consequently, EDF and Framamtome, the builders of Koeberg and continued suppliers of materials and technical support to Koeberg, will have to follow far higher standards on their own plants than those they are building for others. One can only ask why aren't the same standards required for Koeberg? Are the NNR and Eskom cutting corners on safety to save costs? When it comes to nuclear power, this is a particularly bad idea: An accident at Koeberg would come at a far higher cost to both lives and South Africa's economy.

1 IWR Online, "France is Increasing Prices For Nuclear Power by More Than 60 Percent And is Relying on Offshore Wind Energy", Dec. 2023, https://www.renewable-energy-industry.com/countries/article-6490-france-is-increasing-prices-for-nuclear-power-by-more-than-60-percent-and-is-relying-on-offshore-wind-energy