National Nuclear Laboratory

Water Chemistry Requirements for a New Generation of Nuclear Power Plants

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UK Nuclear Generation

Nuclear power has been used to generate electricity worldwide since the 1950s, with more than 440 operational nuclear reactor units providing around 16 percent of the world's electricity.

In the UK, the remaining 10 operational nuclear power plants produce approximately one-fifth of the UK's electricity

Two Magnox Stations (Oldbury and Wylfa)

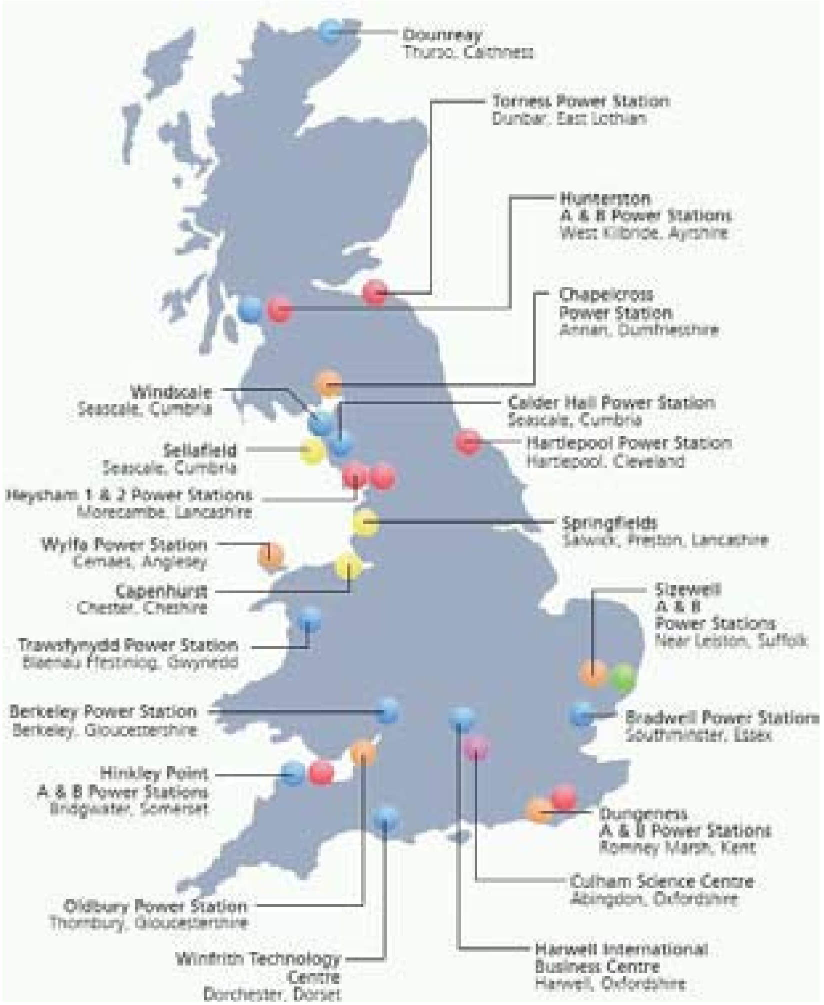
Seven Advanced Gas Reactors (AGRs)

One Pressurised Water Reactor (PWR)

However, the majority are due to be de-fuelled and decommissioned within the next few decades, hence, the requirement for a new nuclear build programme to replace the existing nuclear generation capacity.

Source: An evaluation of the capability and capacity of the UK and global supply chains to support a new nuclear build programme in the UK, IBM Business Consulting Services

Current UK Nuclear Energy Sites



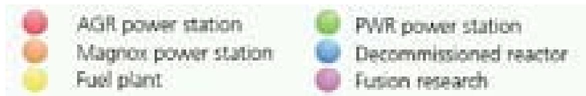


Image source: NIA report, "Nuclear Energy, Past, Present and Future", www.niauk.org

UK New Nuclear Build

In January 2008, following a period of consultation, the UK government gave formal backing to the construction of a new fleet of nuclear power plants

"Business Secretary John Hutton told MPs they would give a "safe and affordable" way of securing the UK's future energy supplies while fighting climate change." [1]

"Our ambition is to build four new European Pressurised Reactors (nuclear reactors) in the UK and we are responsible for developing the business case for each of them. If the right investment framework is in place, the first reactor will be operational by the end of 2017."[2]

It is now 20 years since the last UK licensing activities, which at that time was a very long and protracted process. Thus, the regulators have sought to try and streamline the licensing process to achieve the desired timescales for new build.

1	Source:	bbc news website, January 2008
2	Source:	Nuclear New Build, EdF Energy Website

UK Regulatory Policy

Following the UK Government's Energy Review in 2006, the Health and Safety Executive, the parent body of the NII, agreed to revise and update its procedures for granting a licence for the start of nuclear power plant construction.

- Reactor design now assessed in advance of an application for a nuclear site licence
- Recognition that electricity generation market increasingly internationalised and new build proposals likely to be based on well developed designs

Aims:

- Reduce time period for regulatory assessment
- Reduce regulatory uncertainty for requesting parties
- Enhance openness and transparency in the regulatory process in line with Government policy

Revised procedures comprise two main phases:

Generic Design Acceptance (GDA) and Nuclear Site Licensing

Steps in Generic Design Assessment

Step 1: Involves initial discussions between the designers and the Regulators to agree requirements and how the process would be applied.

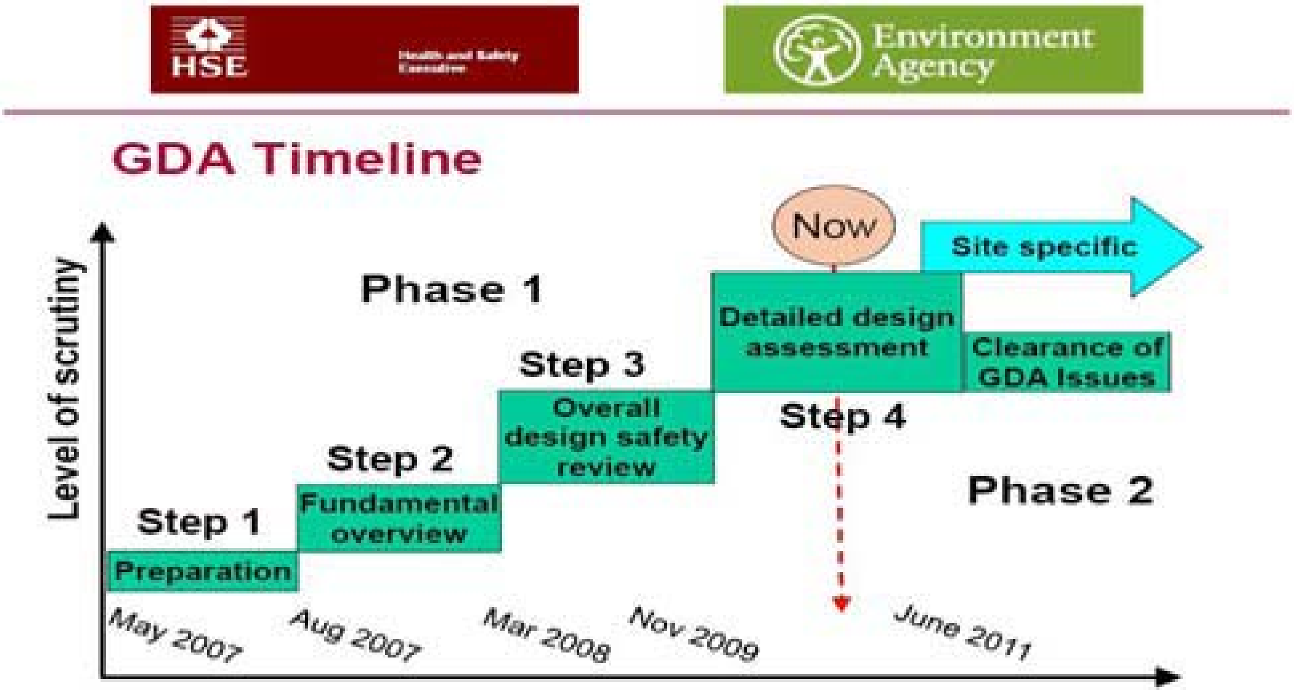
Step 2: Is an overview of the fundamental acceptability of the proposed reactor design concept to identify design aspects or safety shortfalls that could prevent construction in the UK *e.g. Safety, Security and Environmental report .*

Step 3: Is a system design safety and security review of the proposed reactor. This includes examination of the design at system level and analysing supporting arguments made by the design companies *e.g. Pre Construction Safety report.*

Step 4: Is a thorough and detailed examination of the evidence, on a sampling basis, given by the safety analysis and will include inspection of security plans.

HSE are currently working on Step 4 of the assessment. A concluding set of reports will be published in June 2011.

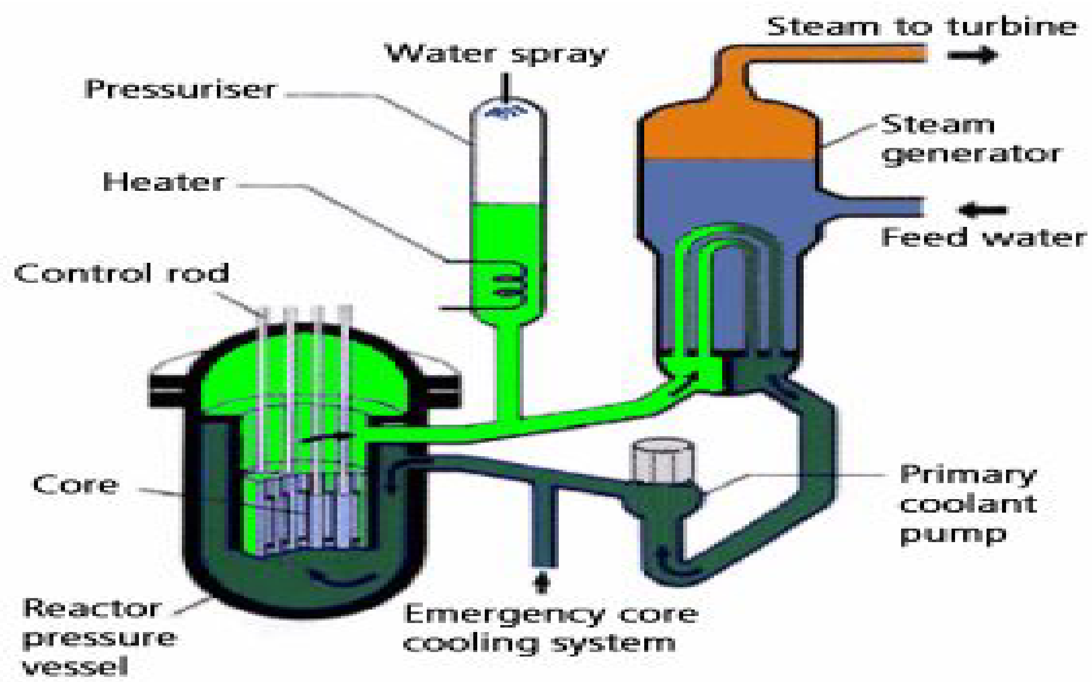
Timescales for the GDA



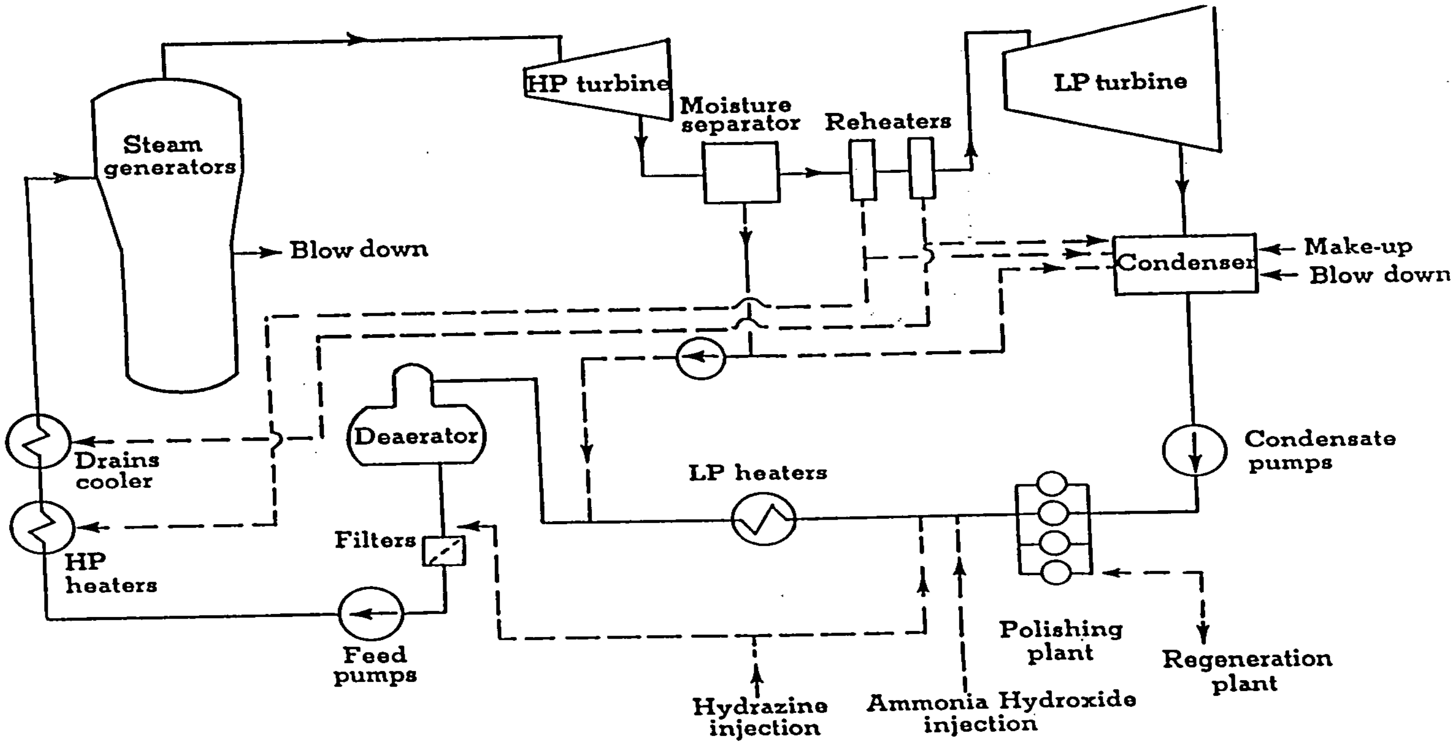
GDA Potential Outcomes

1) Regulators are fully content with safety, security and environmental aspects. The HSE issue Design Acceptance Confirmation (DAC) and the Environment Agency a Statement of Acceptability (SofA). GDA process Ends
2) Regulators are largely content, HSE/EA issues Interim DAC/SofA and a resolution plan would be needed. Regulators assessment ends
3) Regulators are not content, no DAC/SofA issued and Requesting Party must decide if it wishes to proceed.

Primary Circuit of a Pressurised Water Reactor



Secondary Circuit of a Pressurised Water Reactor



Reactor Designs Currently in Generic Design Assessment

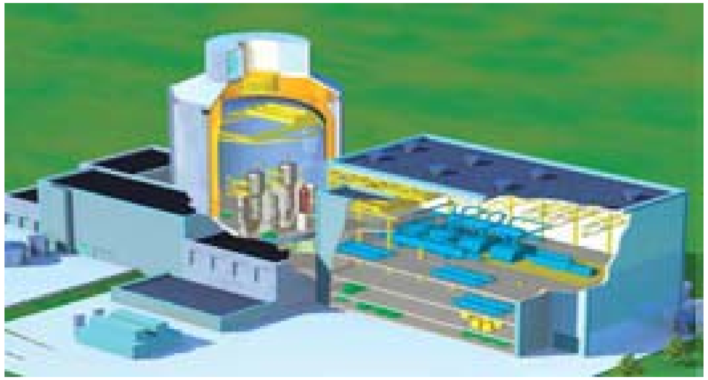
Four companies submitted Safety, Security and Environment reports to UK regulators detailing significant aspects of potential new build reactor designs and these each subsequently cleared the first stage of a Generic Design Assessment. Two of these designs have since been withdrawn from the process by the vendors leaving the following:

- AP-1000 is a Westinghouse two-loop reactor design with an output of 1117 MWe and additional plant features designed to achieve passive safety in an accident scenario. It is the successor design to the AP-600, which received licensing from the US Nuclear Regulatory Commission in late 1999 .

- UK-EPR is an EDF/Areva design based around the Framatome N4 and KWU Konvoi reactor designs. It is a four-loop design with an output of 1630 MWe and four fully independent safety trains each capable of cooling the reactor after shutdown.

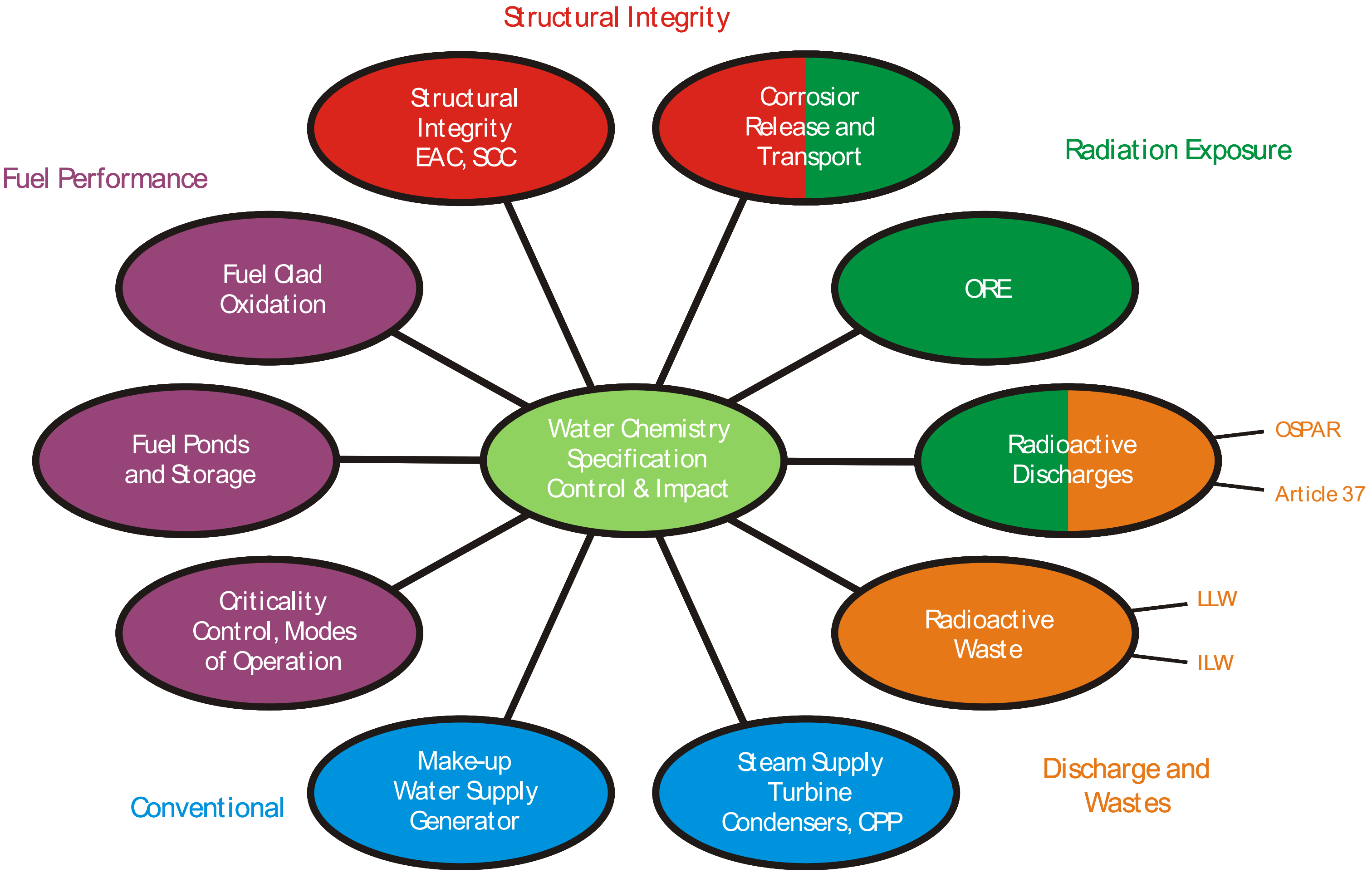
Reactor Designs Currently in Generic Design Assessment

AREVA- UK EPR



Westinghouse - AP1000

Water Chemistry Related Issues



Water Chemistry Requirements – primary circuit

The water chemistry of the primary circuit is controlled for four main reasons:

- Control of nuclear reactivity by boric acid (H_3B0_3) addition.
- Control of pH via the control of lithium hydroxide (LiOH) to ensure low corrosion.
- Control of pH to minimise activity generation and transport.
- The control of radiolysis by the addition of hydrogen e.g. $H_20 \leftrightarrow H^+ + OH^-$

Water Chemistry Requirements – secondary circuit

To maintain steam generators and turbines at a high level of availability and efficiency, the chemical control of water and steam purity is aimed at the prevention of:

- Corrosion in feed, steam generator and steam systems e.g.
- Scale and deposit formation on heat transfer surfaces
- Deposition and corrosion in turbines

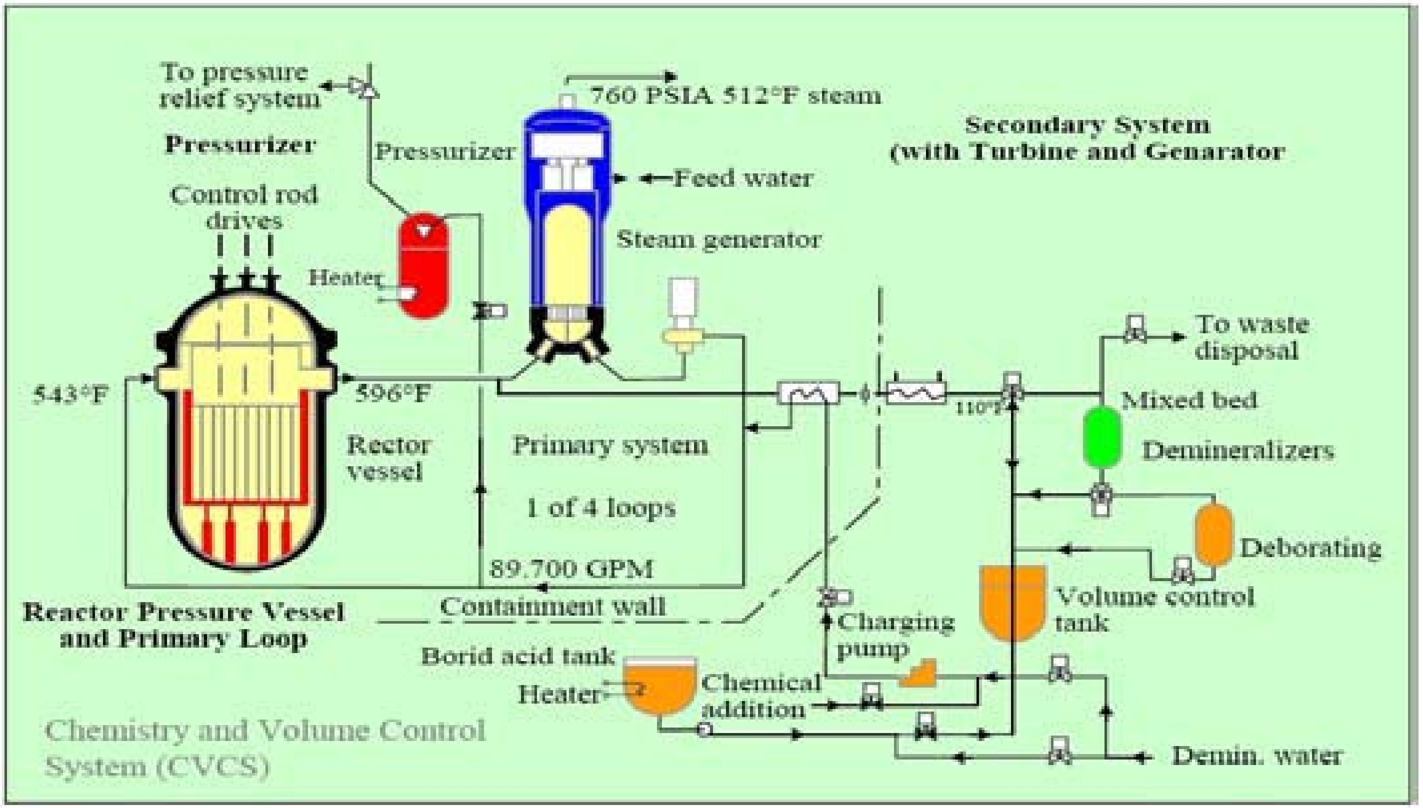
$\Rightarrow$ elevated pH, reducing conditions and very low concentrations of potentially corrosive impurities

Methods of controlling water chemistry

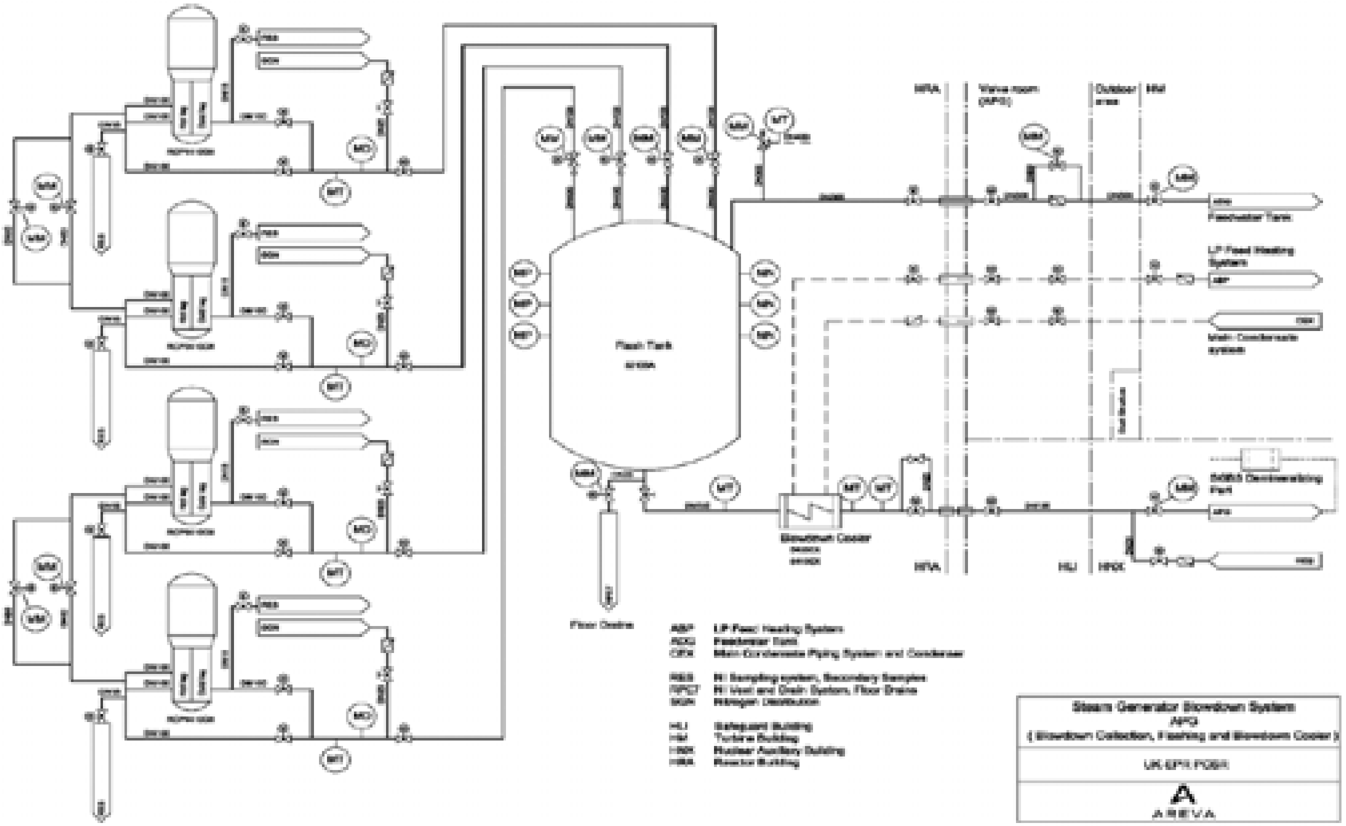
The new class of reactors to be built in the UK have extensive water treatment requirement to produce primary and secondary side water of sufficient quality to allow safe operation of the plant:

- Filtration
- Ion exchange
- Addition of chemicals to control pH and oxygen levels
- Physical removal of dissolved gases
- etc.

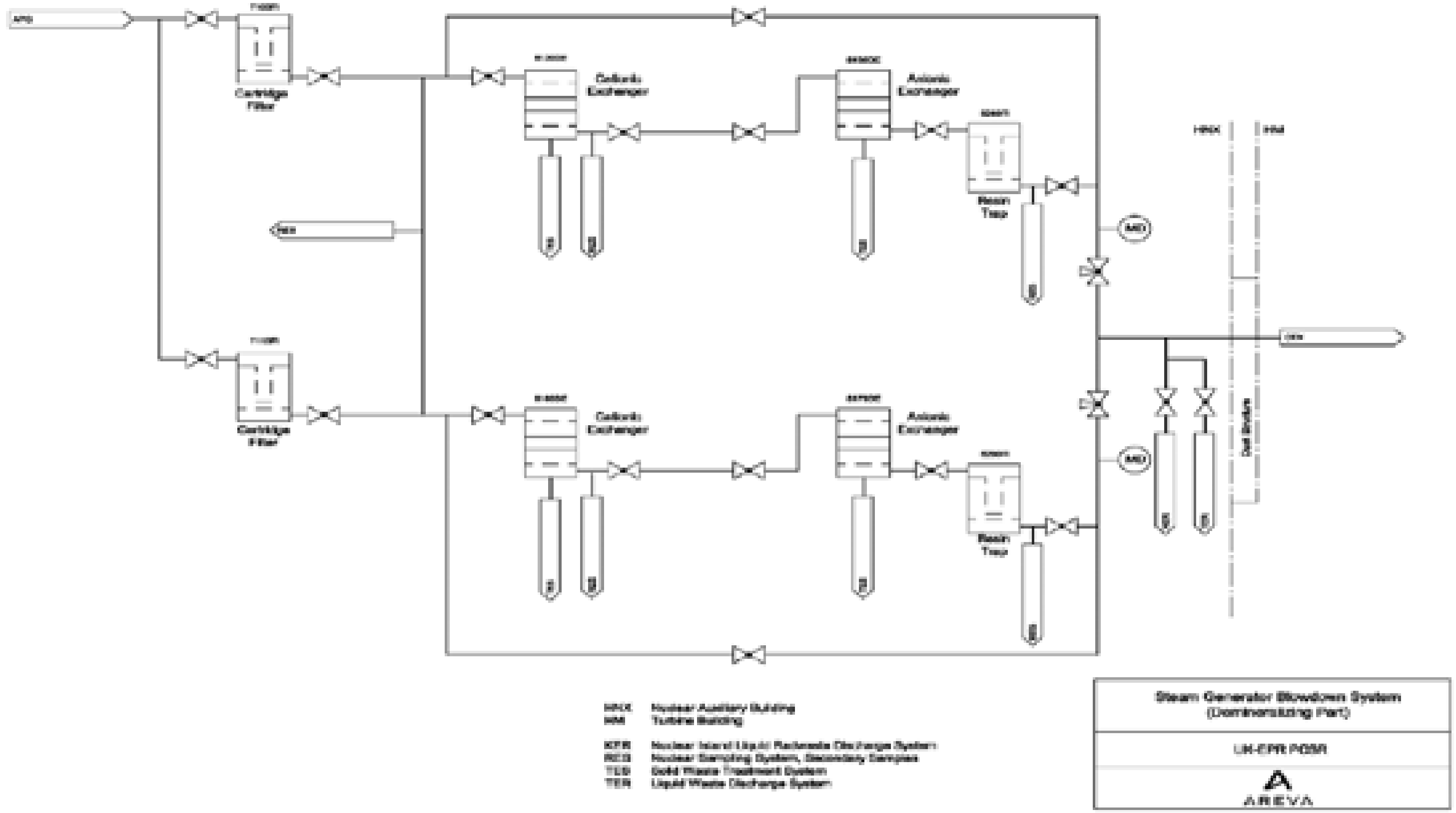
PWR primary circuit water treatment



PWR Secondary circuit water treatment



PWR Secondary circuit water treatment



Conclusions and Questions…

The highest standards of water chemistry are required for the new generation of nuclear reactors in the UK to help control a number of processes in both the primary and secondary circuits *e.g. corrosion rates, fuel performance, and radiation management.*

To achieve this aim, either of the two potential designs within the GDA will require very extensive water treatment requirements using the most up-to-date technology.

Any questions?