Atoms for the Future 2013

Loss of Off Site Power: An Operator's Perspective

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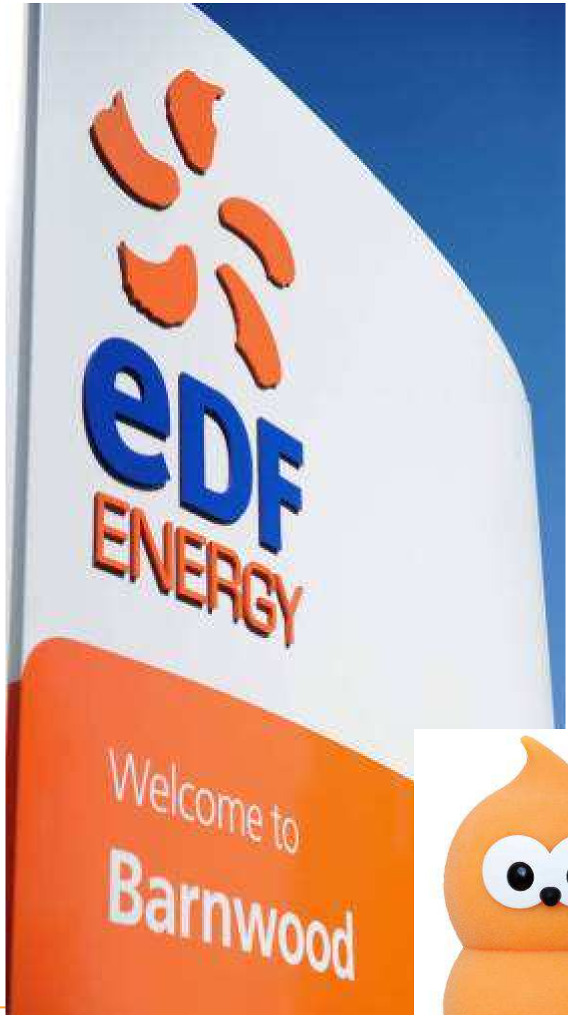
Overview

- EDF Energy
- Our UK Nuclear Operations
- Advanced Gas Cooled Reactors/PWR comparison
- Hunterston Power Station Loss of offsite power
  - The event
  - The consequences
  - Learning – WANO SOER
- Questions

EDF Energy is the largest electricity supplier by volume and the biggest generator of low carbon electricity in Britain



EDF Energy:

- generates around 20% of the UK's total electricity
- employs nearly 15,000 people
- operates eight nuclear power stations and wind farms as well as gas, coal and combined heat and power plants

5.5 million business and residential customers, making us the biggest supplier of electricity by volume in Britain

The Nuclear Generation business

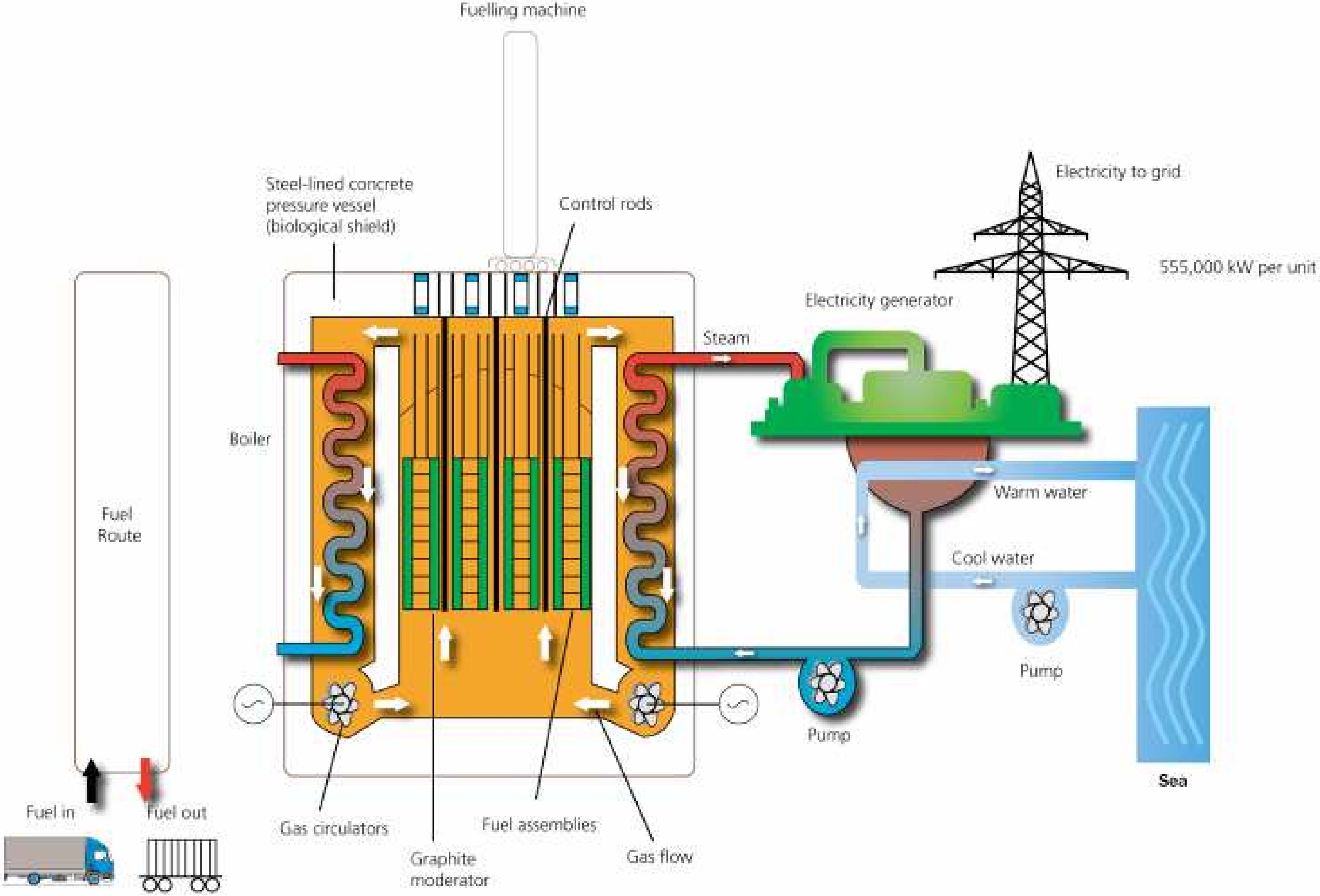
- We own and operate two types of nuclear reactor in the UK
  - advanced gas-cooled reactor (AGR)
  - pressurised water reactor (PWR)

- Seven of our nuclear power stations (14 of our reactors) are of the AGR design, Sizewell B is a PWR

- In 2012, our nuclear power stations generated nearly 60.02 TWh low carbon electricity - enough to supply over 50% of UK homes

- Turnover of around £3bn each year

The technology - Advanced Gas-cooled Reactor

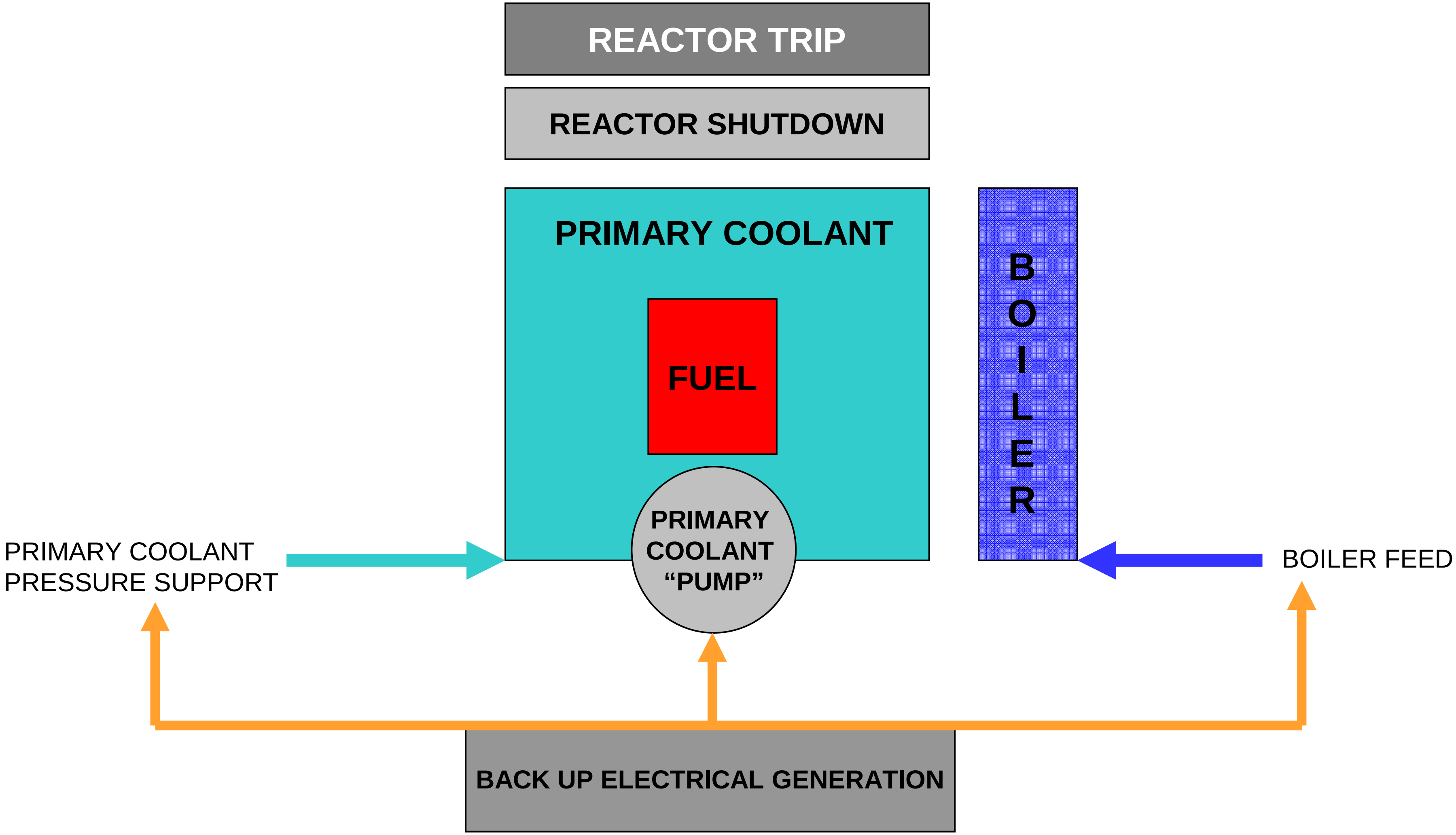


The AGR Design – Some Fundamentals (1)

- The typical AGR has the following features;
  - 1500MWth rating
  - 100,000 fuel pins (each being about 1m in length)
  - An active reactor core of about 650m^3
  - A power density of 2.3MWth/m^3
  - A graphite moderator weighing 2000tonnes which acts as a large heat sink
  - Four Steam Generator Quadrants (ie about 400MWth rating each)

- By comparison, Sizewell B's Reactor has the following features;
  - 3411MWth rating
  - 50,952 fuel pins (each being about 3.5m in length)
  - An active reactor core of about 33m^3
  - A power density of 100MWth/m^3 (about 40 times that of the AGR)
  - A water moderator (which also acts as the coolant) equivalent to a mass of about 100tonnes
  - Four Steam Generator Quadrants (ie about 850MWth each)

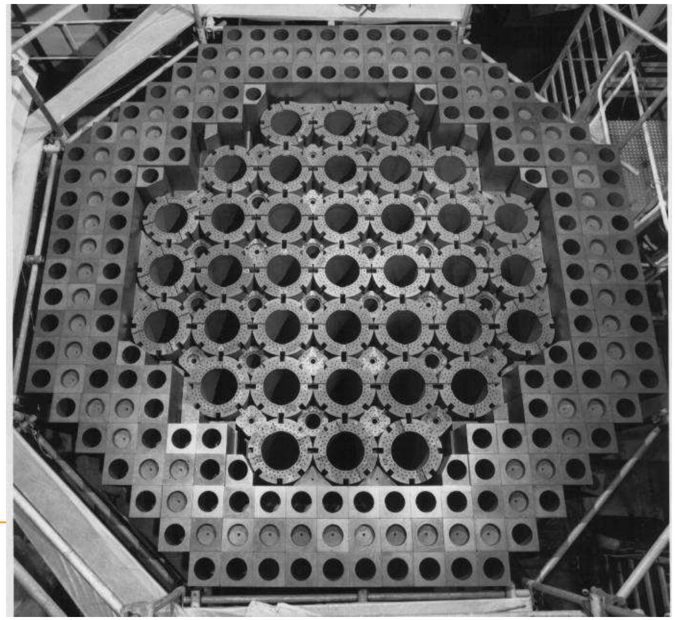
Key Plant Systems – PWR and AGR



The AGR Design – Some Fundamentals (2)

No cliff edge even in extreme scenarios…

- A lower power density and greater thermal inertia improves post trip thermal hydraulic dynamics
  - After a trip or a shutdown, and thanks to the thermal inertia of the graphite core and the water remaining in the boilers providing an effective heat sink, an AGR reactor could tolerate no gas circulators and no boiler feed for many hours as long as the reactor stays pressurised : The natural circulation of the CO_2 transports the heat from the fuel to the remaining water and the graphite



➢ ***This is very useful for scenarios involving loss of grid (off site electrical supplies)***

The AGR Design – Some Fundamentals (3)

No Reactor Containment Building…

- The main AGR fault is associated with reactor depressurisation. The most onerous fault is assumed to be a failure of a reactor penetration at a frequency of 10^{-4} per reactor year. The off site release is limited due to a combination of;
  - Low power density (40 times less than a PWR)
  - Limited fuel can failures (As the primary coolant does not change phase in the fault)
  - Modelling indicates less than 1% of fuel pin failures

➢ ***UK safety targets can be met for the AGR without containment***

Hunterston Power Station

Overview of Hunterston B

- Hunterston B
  - Two Advanced Gas cooled Reactors (AGRs) - R3 & R4
  - Each Reactor has one 660MWe turbine generator set

- Standby Diesel Generators
  - Four 11kV
    - Support forced cooling utilising Gas Circulators Post Trip
    - Two provide support to 3.3kV System should 3.3kV DG fail
  - Two 3.3kV
    - Support essential post trip plant (post trip cooling, control and instrumentation, alarms, emergency lighting, battery chargers)
  - Three 415V
    - Support essential plant (air compressors, H&V, battery chargers, computer supplies)

Hunterston Power Station (2)

- Four separate grid lines
- Vulnerable to salt spray
- Known phenomenon

- Trained on loss of grid
- Trained to operate RSSE manually
- Not trained to deal with both simultaneously

1998 Loss of Gird Event – Impact on our operators

On the 26th of December 1998, the "Great Boxing day storm", hit Scotland. Severe weather conditions over a 24 hour period during which time all grid supplies were progressively lost.

- When experiencing adverse weather:
  - Reactor Desk Operators experience additional stress due to environmental changes, e.g. frequent light dimming, wind noise, repeat alarms/actions required as plant trips out during voltage excursions
  - Effect of travelling to work with high wind, heavy rain influences mindset
  - Dealing with a unit trip when not all systems may be available due to a loss of grid.
  - Navigating round plant with no area lighting can challenge even experienced operators

1998 Loss of Gird Event – Timeline

- **27/12/1998 00:23 Both Reactors Manually tripped coincident with fourth (and final) grid connection loss**
  - Post trip cooling established automatically by Reactor Shutdown Sequencing Equipment (RSSE)

    -> No Issues during the transient
  - 02:30 Grid Supplies reinstated, Diesel Generators placed on standby

- **11:05 All grid supplies lost for a 2nd time**
  - Decay Heat Levels at 10MW thermal, post trip cooling operational for 10 hours (20 hours available to restore cooling before fundamental safety limits were threatened)
  - Many difficulties experienced (RSSE not fully reset, Manual reconfiguration required for essential electrical system, …)
  - 11:35 Natural circulation cooling established on R3

1998 Loss of Gird Event – Timeline

- **11:42 On site emergency declared**
  - Emergency Control Centre Established & additional resource brought to site
  - 13:05 Natural circulation cooling established on R4
  - 14:05 Forced circulation cooling established to R3 and R4, Supplied via Diesel Generator supplies, Grid supplies restored shortly after
- **22:02 On-Site emergency stood down**
  - INES Level 2 Event

Post Event Operational Changes

- Improved simulator training scenarios
  - Manual configuration of Electrical System post trip
  - Loss of Reactor Shutdown Sequencing Equipment (RSSE)
  - Loss of Coolant Accident with a Loss of Grid
  - Loss of a Diesel Generator
  - Loss of Station Supplies
  - Brownout

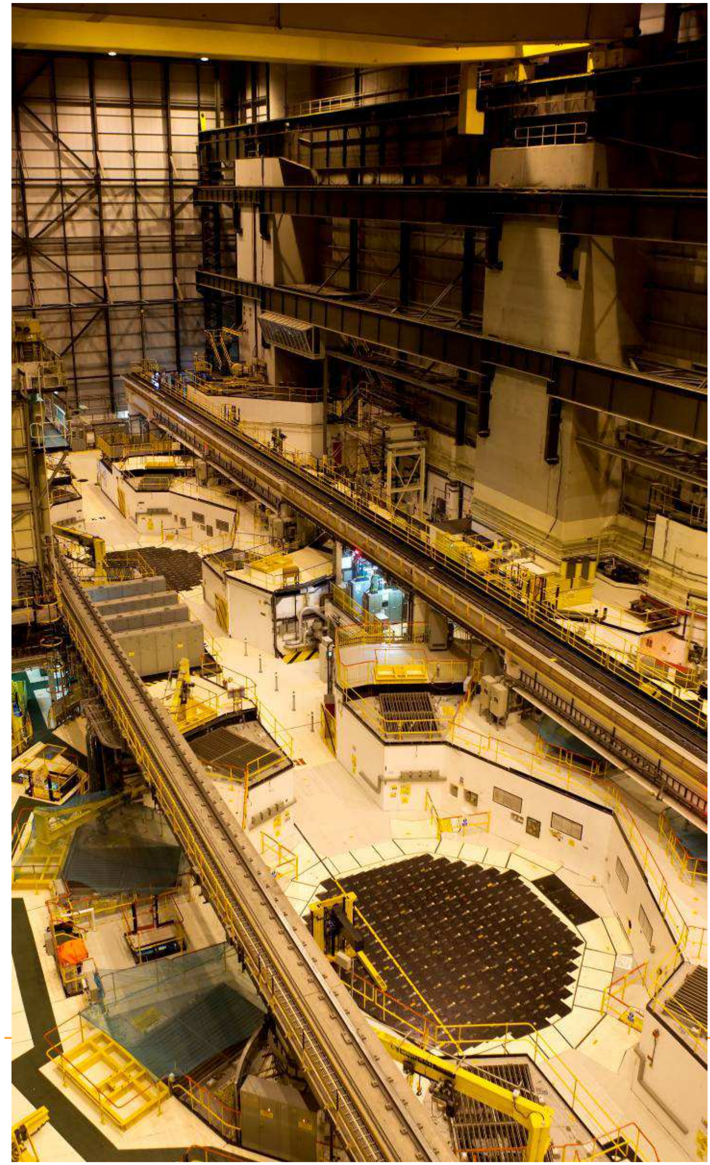
- Post Trip Focus
  - Reset RSSE as soon as practicable post trip
  - Maintain essential electrical supplies from diesel generators even if grid supplies are restored
  - Operations procedures introduced for combined loss of grid and loss of RSSE.

Post Event Equipment Changes

- Two additional 3.5MWe 3.3kV DG in diverse building
- Plant computers now supported by UPS
- ECC Essential equipment supplied via secure supplies
- ECC hard copy of drawings

- Diverse Insulator types fitted to 400kV Grid Lines
- Grid Cascade Protection
- New 132kV line

Fleet Learning



- Quantity of Stocks required for adequate onsite response
  - Equipment - Fuel, Emergency Equipment
  - Staff Welfare - Food, Sleeping Bags,
- Safety Case Review
  - Assumptions changed on duration of loss of grid
  - 16 hours to 10 days
- Grid Interface
  - Communications when lines are out of service and planning of work to take into account Statutory Outages

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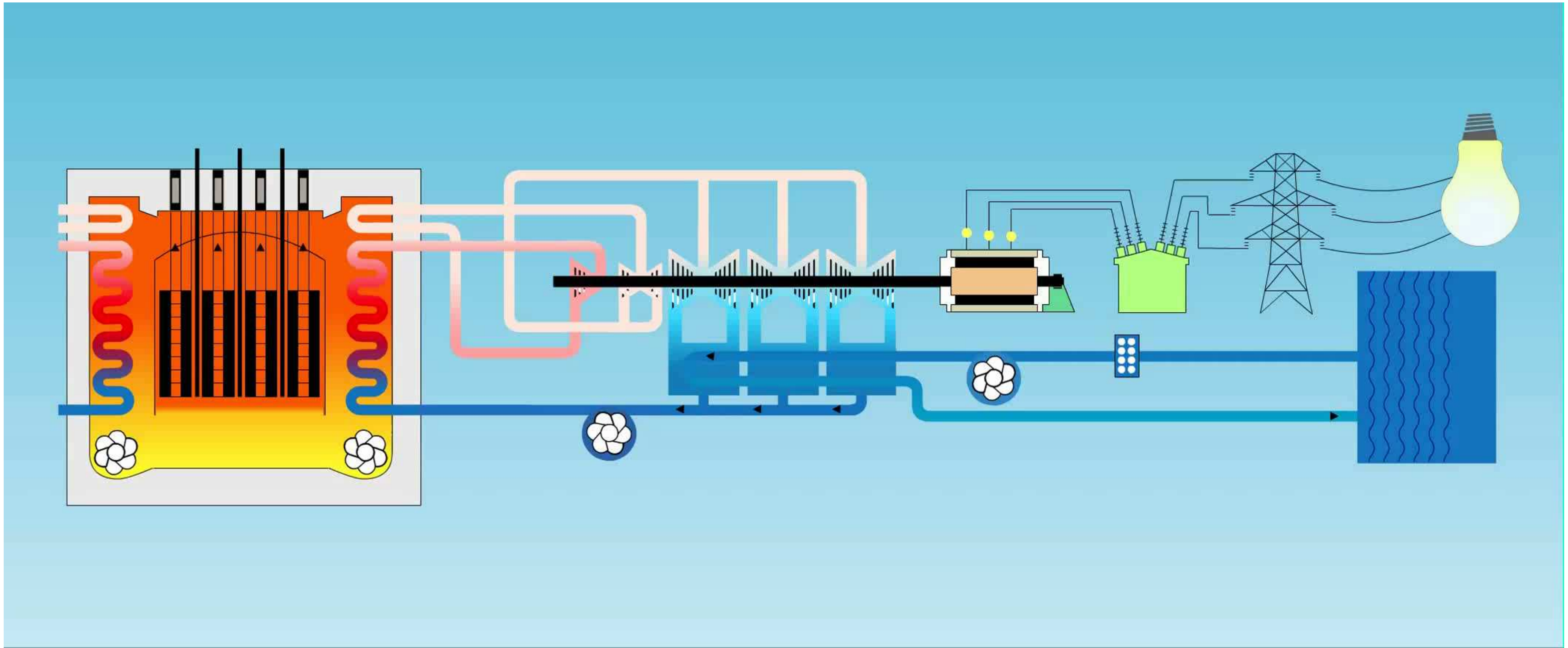
- Recommendations
  - Establish appropriate interfaces between nuclear power plants and grid operators
  - Review adequacy of procedures for loss of grid
  - Review preventive maintenance programmes
  - Incorporate degraded grid voltage conditions into operator training
  - Better understand the problems occurring with switchyard equipment
  - Review arrangements when supplies are lost for an extended period of time.

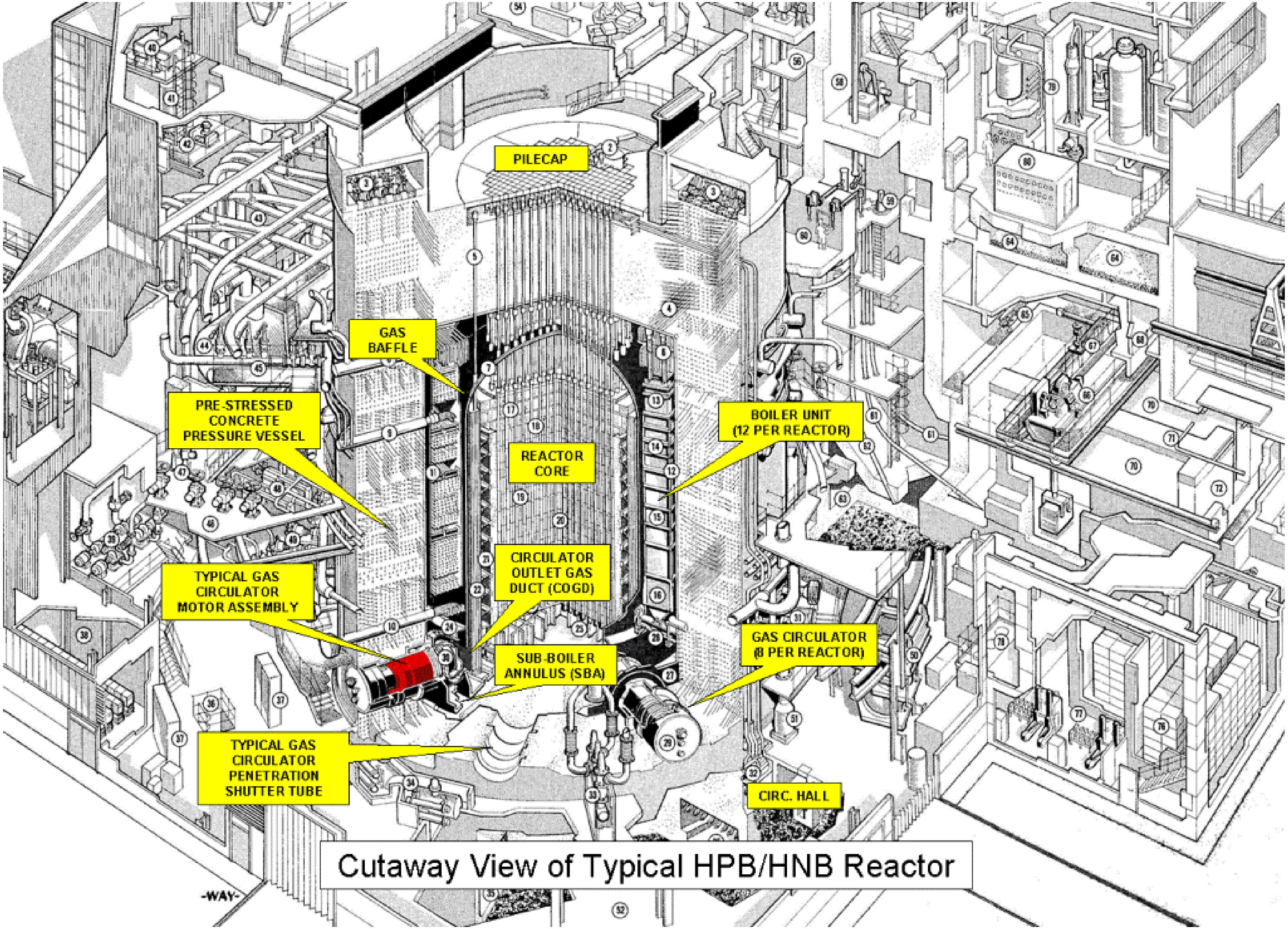
Thanks for your attention

Very happy to answer any questions

Appendix

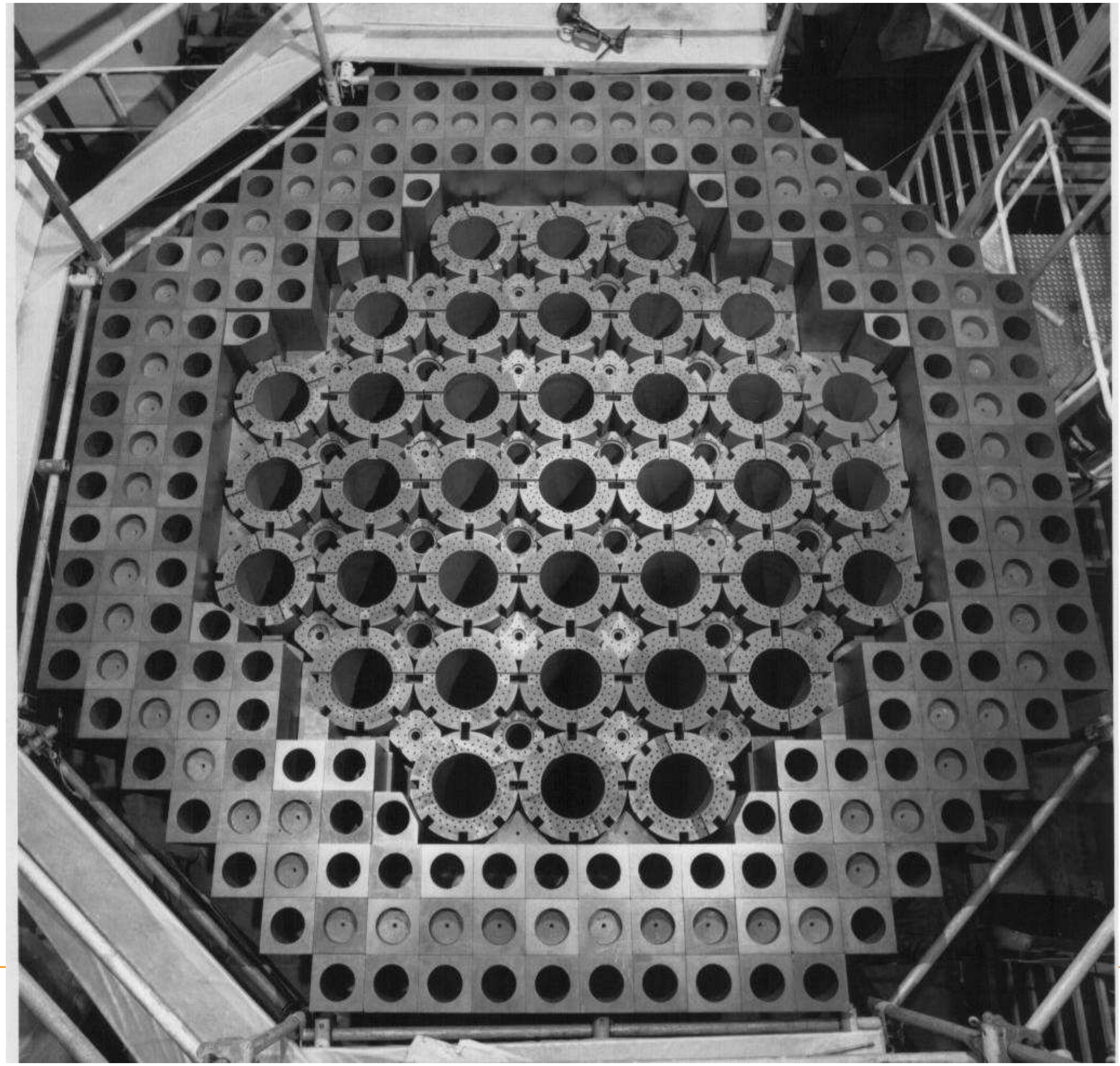
Animation of an AGR plant



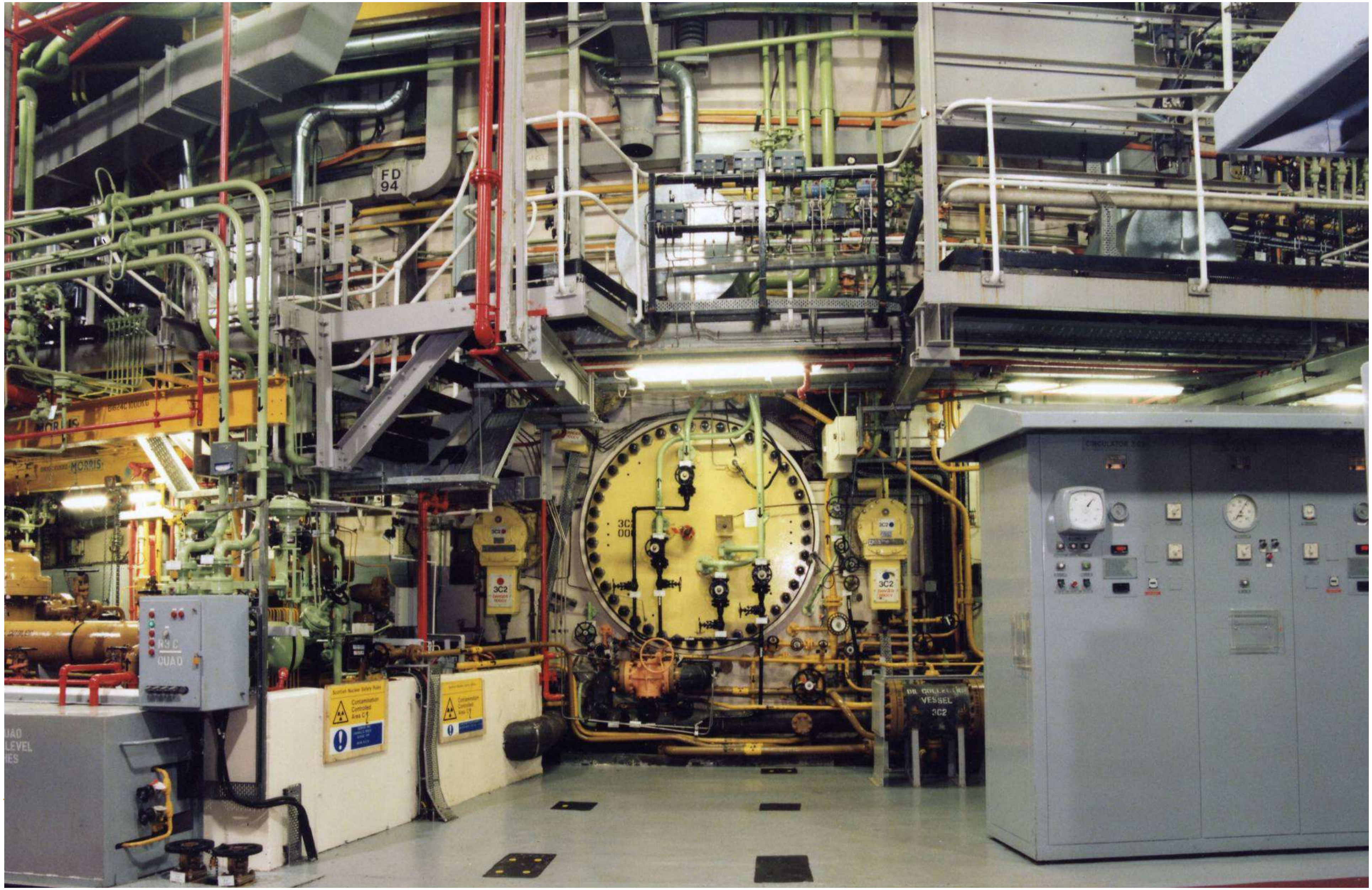


Cutaway View of Typical HPB/HNB Reactor

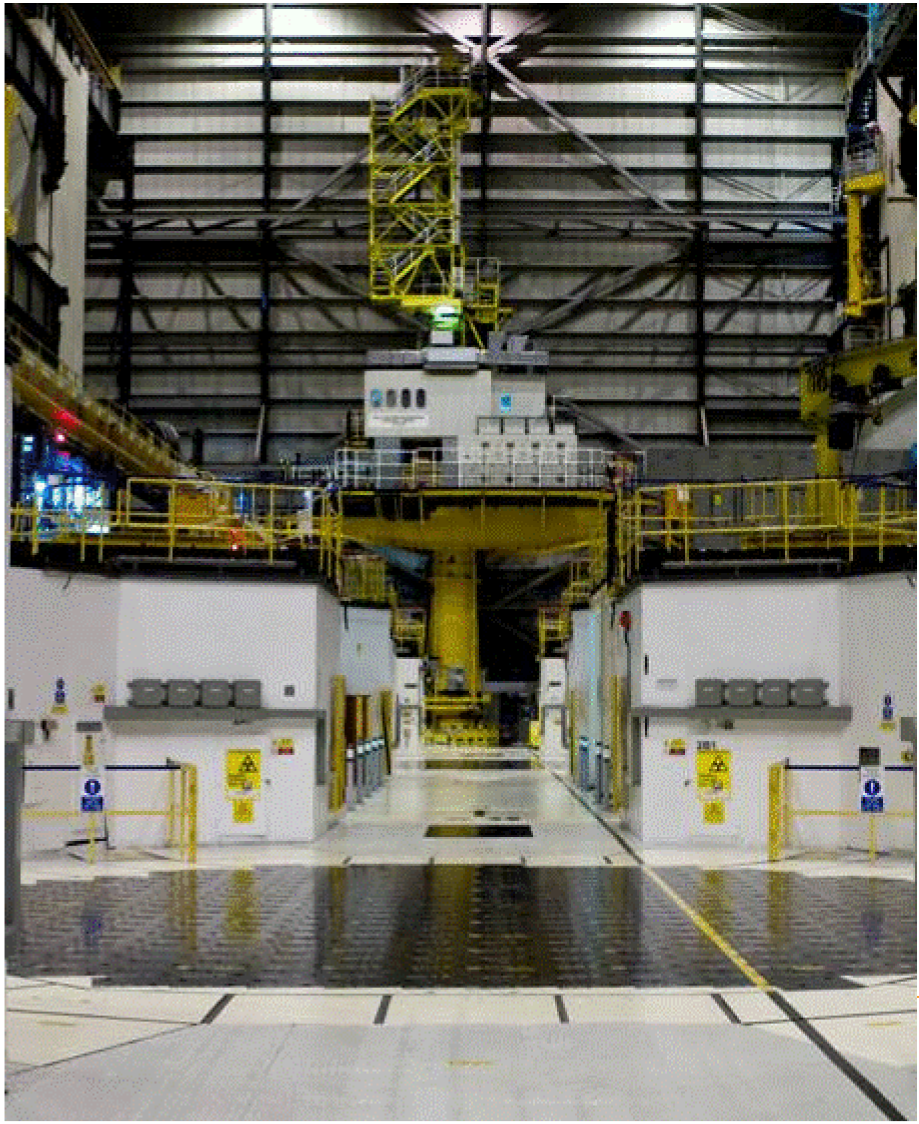
AGR Core and fuel



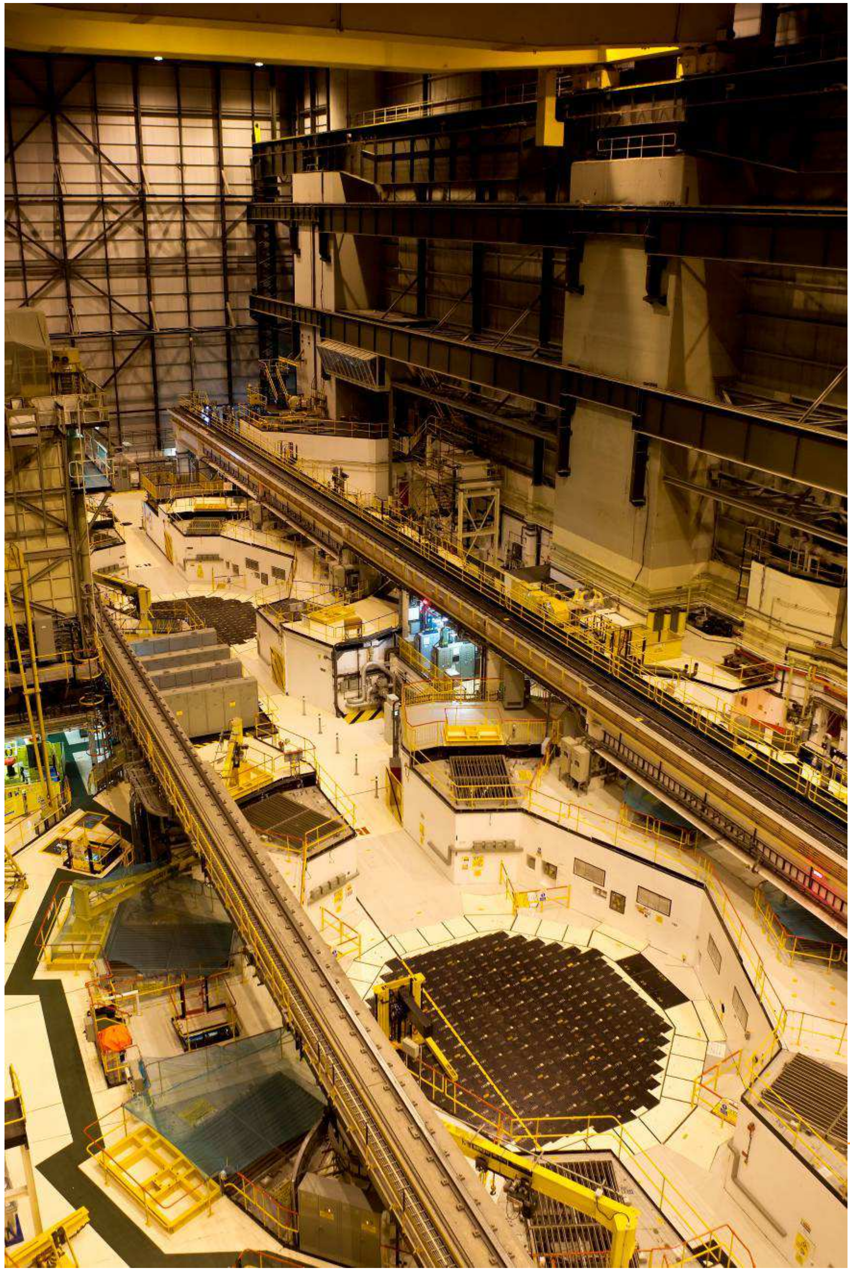
AGR gas circulator



AGR fuelling machine



AGR power cap



AGR Control room