Investigation to determine the feasibility of replacing hydrazine with carbohydrazide in the secondary feedwater circuit of the Advanced Gas Nuclear Reactors

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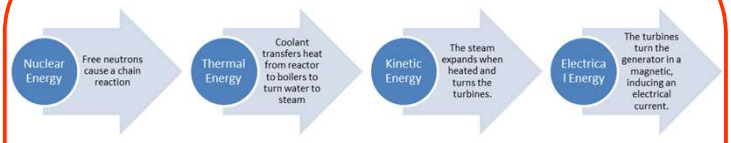
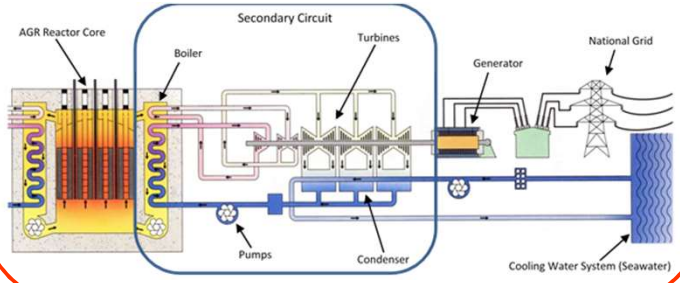
Principles of Nuclear Generation

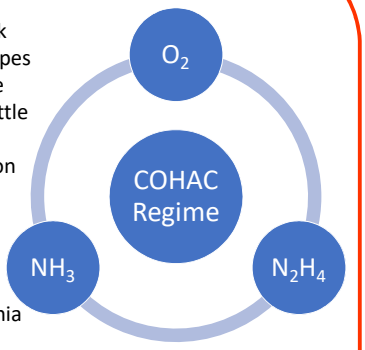


Advanced Gas Reactor (AGR) Design



Corrosion in the Secondary Water Circuit

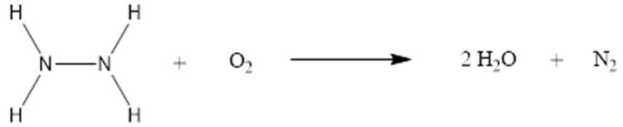
Corrosion control is an important task for chemists. The components and pipes in the circuit remain in service for the lifetime of the nuclear reactor with little chance for maintenance or replacement. As a result, the condition of the components is maintained through chemical corrosion control.



The method employed on the AGR sites to minimise corrosion is the Combined Oxygen-Hydrazine Ammonia Conditioning (COHAC) regime.

- Oxygen – reacts with steel surface to form protective haematite and magnetite layers to prevent flow accelerated corrosion.
- Hydrazine – reacts with and removes excess oxygen from the circuit in order to prevent stress corrosion cracking in boiler.
- Ammonia – creates basic conditions, which is proven to reduce general corrosion.

Hydrazine



Hydrazine is used to remove oxygen because:

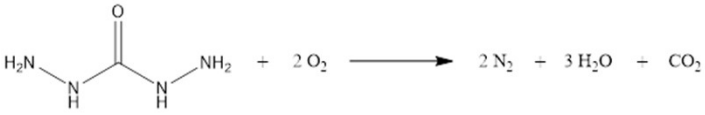
- ✓ Temperature dependent reaction – removes oxygen prior to boiler
- ✓ Acceptable decomposition products, H_2O, H_2, N_2 and NH_3
- ✓ Ability to use when both producing energy and not
- ✓ Able to accurately monitor the amount of hydrazine

Replacing Hydrazine because:

- × Carcinogenic
- × Controlled under COMAH regulations
- × May be banned under EU legislations (REACH)
- × EDF prioritise safety

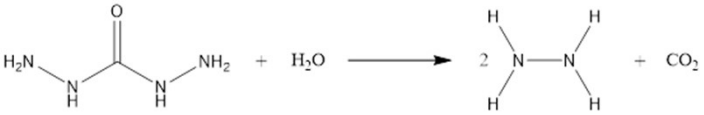
Carbohydrazide

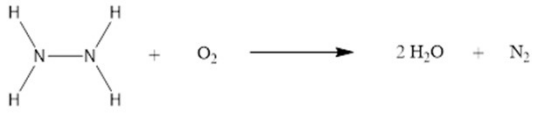
1. Direct reaction of carbohydrazide with oxygen



This reaction is pH dependent and believed to be the predominant reaction at temperatures below 135°C.

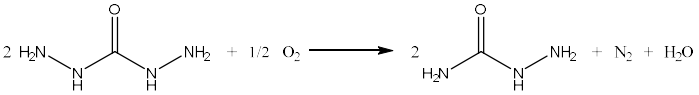
2. Reaction via hydrolysis to hydrazine

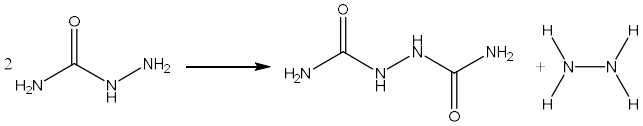


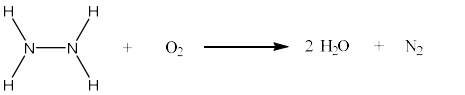


This is the most likely mechanism for oxygen removal within the boiler as carbohydrazide in the presence of water rapidly hydrolyses into hydrazine above 135°C. The hydrazine then goes on to react with oxygen.

3. Oxidation to semicarbazide prior to decomposition to hydrazine







Above is another proposed mechanism for the higher temperature reaction with oxygen. However, this mechanism is not fully understood.

Investigation into carbohydrazide

- ✓ Much safer than Hydrazine
- ✓ Removes oxygen effectively when producing energy, i.e. prior to boiler
- ✓ Evidence to suggest that it is more effective at lower temperatures
- ✓ Able to monitor amount of carbohydrazide

- × CO_2 decomposition product, may result in turbine corrosion and increased conductivity (measure of water impurity)
- × May be incompatible with carbon steel present in circuit
- × Considerably more expensive

Conclusion

Carbohydrazide is a feasible alternative to hydrazine as it effectively removes oxygen from the secondary feedwater circuit of an AGR. Further tests are needed to confirm the ratio of carbohydrazide to oxygen and the impact of the production of CO_2 on the circuit.