

Lecture 6 - Chemistry in Auxiliary Core Systems

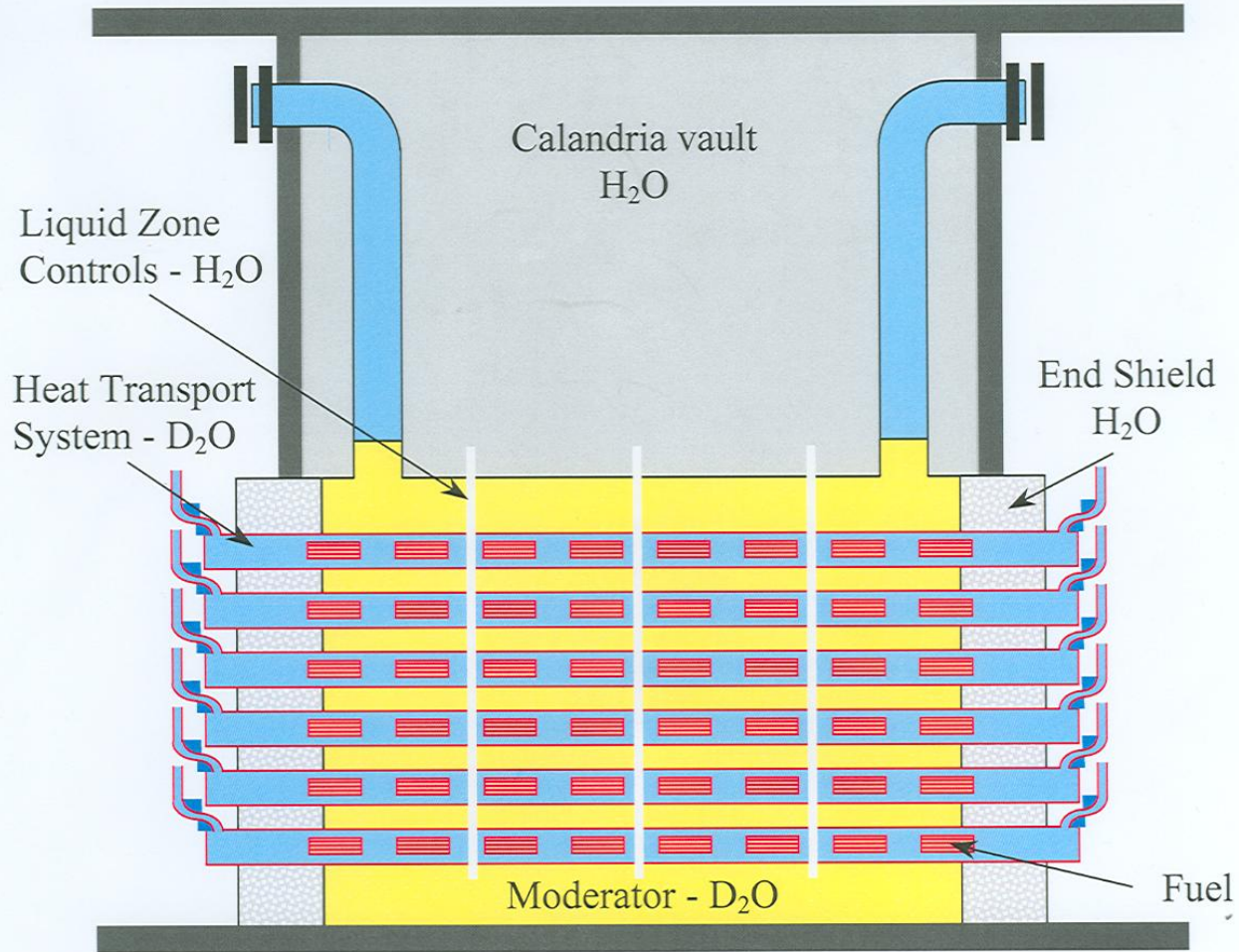
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Chemistry in Auxiliary Core Systems

- Liquid Zone Controls (H_2O)
- End-Shield Cooling System (H_2O)
- Annulus Gas System (CO_2)
 - Focus will be on chemistry of systems around reactor core that see a radiation field

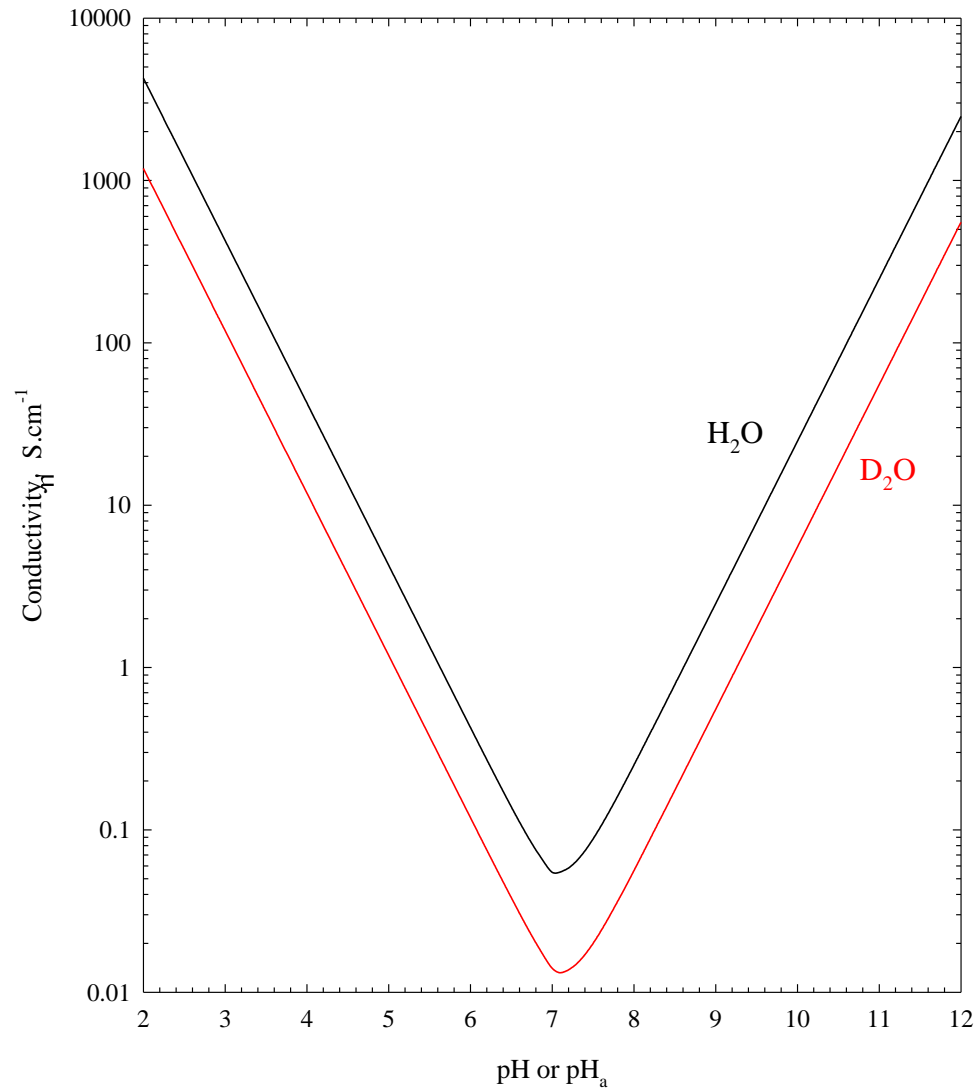
CANDU Aqueous Core Systems



Liquid Zone Control Chemistry

- Demineralized light water system with He cover gas
- Low conductivity to minimise radiolytic production of hydrogen
- Stainless steel heat exchangers, pumps, compressors, tanks, recombiner units; Zircaloy tubes
- Side-stream IX purification to maintain water quality
- Catalytic (Pd) recombination prevents build-up of flammable mixture of H₂ and O₂ in cover gas

pH vs. conductivity



Chemistry Specifications

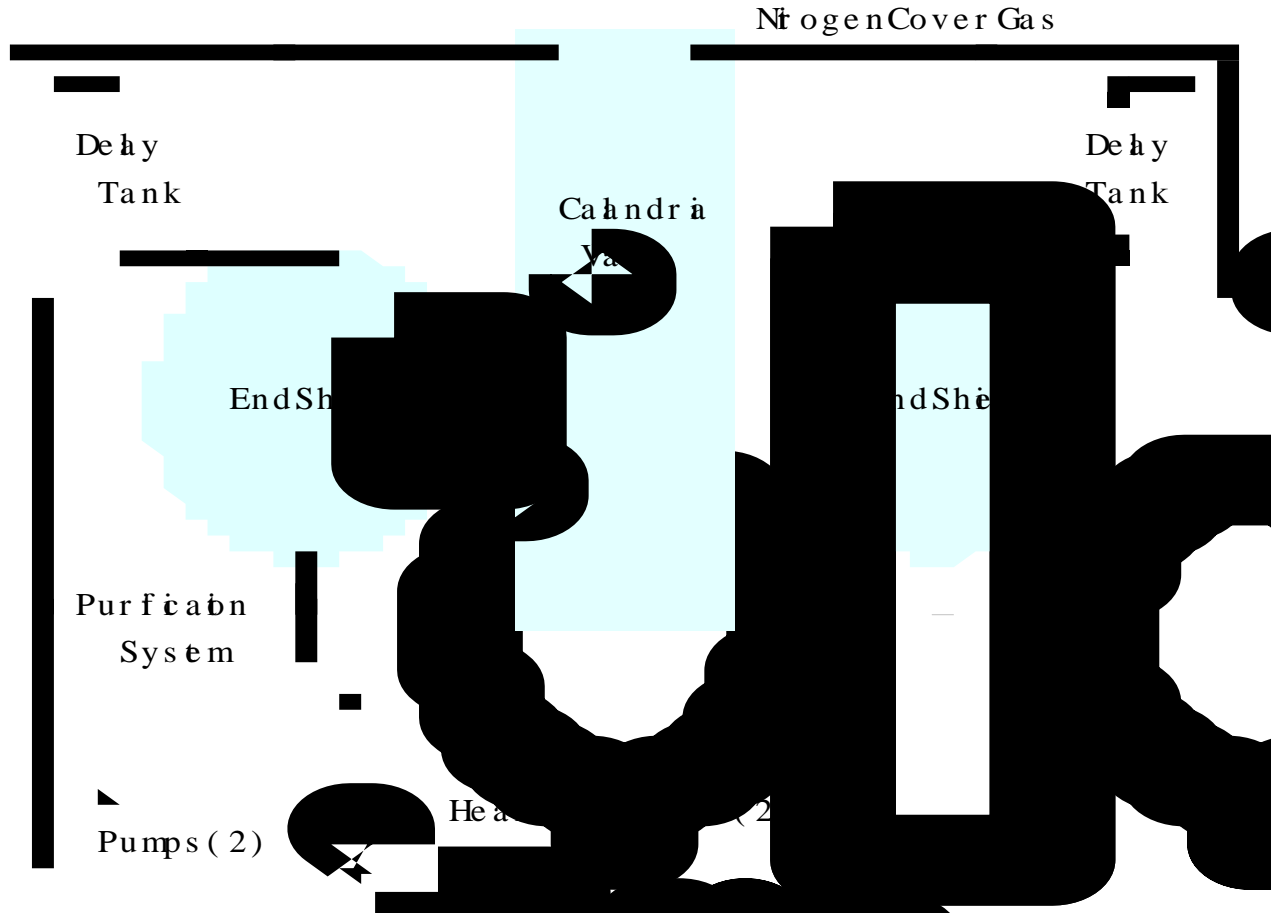
Parameter	Type	Specification	Rationale
Conductivity	Control	< 0.1 mS/m	Minimize radiolysis
Hydrogen	Control	< 4 vol% at recombiner inlet	Minimize flammability hazard
Oxygen	Control	< 2 vol% at recombiner inlet	Minimize flammability hazard
Hydrogen	Diagnostic	< RU inlet	Verify RU operation
Oxygen	Diagnostic	< RU inlet	Verify RU operation
Nitrogen	Diagnostic	< 2 vol%	Minimize air ingress
Radionuclides: ⁵⁸ Co, ⁵⁹ Fe, ⁶⁰ Co	Diagnostic	ALARA	Verify resin performance

RU = Recombiner Unit

End-Shield Cooling Chemistry

- Alkaline (LiOH) light water system under nitrogen (vault) cover gas
- Materials:
 - Carbon steel balls (end shield), piping, pumps, tanks;
 - Stainless steel heat exchanger tubes, tube sheet, IX column, strainer
- Side-stream IX purification; vault cover gas purged, as required

End Shield Cooling System



Pickering and CANDU 6 – Darlington and Bruce slightly different

End Shield Cooling Chemistry

- Relies on large carbon steel surface (principally shielding balls) to remove trace O₂
- Residual H₂ (from radiolysis of water) controls further radiolytic H₂, O₂ and H₂O₂ production



- Significant O₂ addition will not be removed by corrosion, will enhance radiolytic H₂ and O₂ production
 - Cover gas H₂ concentration too large
 - No recombiners
 - Purging not simple

End Shield Cooling Chemistry

- A few CANDU plants have chronic water leaks from the ESC
 - Frequent additions of oxygenated water
 - O₂ 'titrates' the residual H₂ away
 - Net radiolytic production of H₂, O₂ and H₂O₂
- Consequences
 - H₂ builds up in cover gas
 - Need to purge cover gas frequently (difficult)
 - H₂O₂ degrades IX resin leading to poorer water quality and frequent resin changes (\$\$\$)
- Solutions
 - Degas feedwater (best – fixes source rather than symptom)
 - Redesign cover gas system (doesn't stop IX resin breakdown)
 - Degas water in purification (doesn't stop IX resin breakdown)

Chemistry Specifications

Parameter	Type	Specification	Rationale
pH	Control	9 - 10	Minimize corrosion of carbon steel
Hydrogen	Control	< 4 vol%	Avoid flammable mixture
Conductivity	Diagnostic	0.24 – 2.4 mS/m	Correlate with pH and lithium
Lithium ion	Diagnostic	0.07 – 0.7 mg/kg	Correlate with pH and lithium
Total anions	Diagnostic	< 1 mg/kg	Minimize radiolysis
Radionuclides: ⁵⁸ Co, ⁵⁹ Fe, ⁶⁰ Co	Diagnostic	ALARA	Minimize activity transport Verify resin performance

Annulus Gas System Chemistry Specifications

- Dry CO₂ gas (thermal barrier) mixed with < 5 vol% O₂ flowing in annulus between calandria and pressure tubes

Materials:

- Stainless steel heat exchanger tubes, compressors, tanks, strainers
 - Zirconium alloy calandria tube, pressure tube;
 - Cu/Ni alloy, Alloy 600, carbon steel also used
- No purification system

Annulus gas system chemistry

- Helps provide protective oxide on pressure tubes
- Minimizes D build-up in pressure tubes
- Requires purging on either high D_2 concentration or high moisture
- Radiolysis can result in synthesis of higher weight molecular compounds
 - Flow blockages
 - O_2 addition helps break these compounds down

Annulus Gas System Chemistry

- Provides detection of in-leakage of water from calandria, pressure and/or lattice tubes (extend from PT through end shield)

Chemistry Specifications

Parameter	Type	Specification	Rationale
Oxygen	Control	0.5 – 5 vol %	Maintain protective oxide on pressure tube Oxidize organic to carbon dioxide Minimize hydrogen in annulus gas
Dew point	Control	< -10°C	Monitor for water in-leakage; leak-before-break
Nitrogen	Control	< 0.1 vol %	Minimize formation of nitric acid in radiation field
⁴¹ Ar	Diagnostic	-	Indicator for air in-leakage

