The Advanced CANDU Reactor

Adrian Connolly

Shared Features Between CANDU 6 And ACR

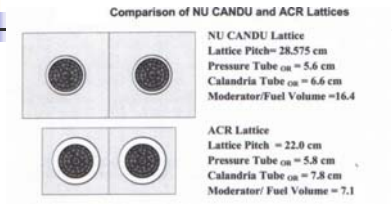
- Use Of Pressure Tubes
- Separate, Low Pressure, Low Temperature Heavy Water Moderator
- On-Power Refuelling

Design Developments For ACR

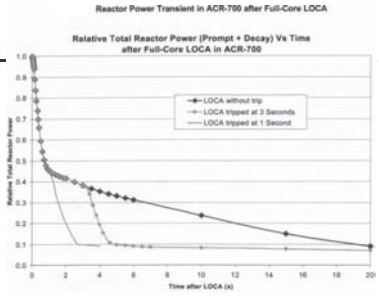
- Use Of Light Water Coolant
  - Passive Shutdown Feature Following In-Core Loss Of Coolant
  - Reduction Of Tritium Hazard

Negative Reactivity Coefficients

- Use Of Slightly Enriched Uranium
- Reduced Lattice Pitch
- Burnable Poison In Central Pin
- Leads To Slightly Negative Coolant Void Reactivity And Power Coefficient



Comparison ACR and CANDU 6 Lattices



ACR Full Core LOCA

Consequences Of Negative Reactivity Coefficients

- ACR Design Now Employs Just One "Figure Of Eight" Coolant Loop
- Smaller Fuel Channel Lattice Pitch, Smaller Light Water Scattering Length Leads To Smaller Reactor Core
  - Cost Savings In Terms Of Size
  - Feeder Pipes At Reactor Face Now Smaller (Need To Carefully Size To Maintain Safety Margins To Dryout)
  - Need To Optimize Coolant Velocities, Heat Transport Pumping Power

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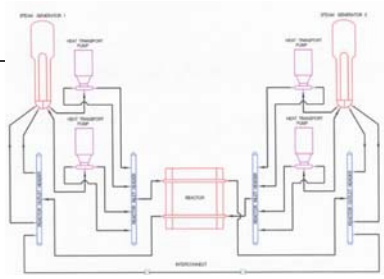

ACR Heat Transport System

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Development OF CANFLEX Fuel Bundle

- New Bundle Now Has 43 Elements Compared To 37 For CANDU 6
  - Element Rating Has Been Reduced From 57 kW/m Down To 51 kW/m, Thereby Improving The CHF Safety Margins, Despite An Overall Increase In Reactor Power
  - Use Of SEU (With Other Changes) Leads To Great Fuel Burnup Rates (From 7.5 MWd/kgU Up To 20.4 MWd/kgU)

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ACR CANFLEX Bundle

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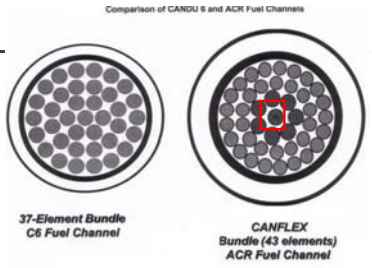

ACR and CANDU 6 Fuel Channels

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ACR Displays Naturally Flat Thermal Flux Distribution

- Improvements To Neutron Reflector, And Increase In Size OF Inner 8 Fuel Elements Compared To Outer 35
- Channel Power Now Much Flatter Axially, Core Power Flatter Radially (Form Factor From 0.83 To 0.95)
  - Each Fuel Channel Produces 15% More Power (Fewer "Dead Zones"
  - Flatter Power Distribution Increases Limits On Maximum Power Per Channel (Yields Extra 10% Higher Power)
  - Combined Effects Lead To 28% More Power Over CANDU 6
  - New Coolant Flow Set At 26 kg/sec

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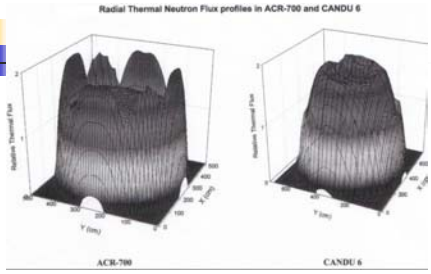

ACR Thermal Flux Profiles

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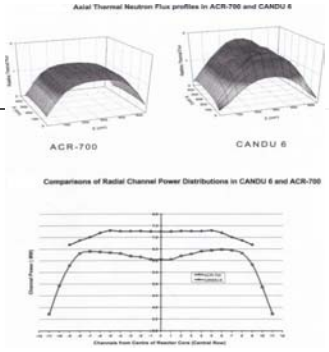

ACR Thermal Flux Profiles

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Use Of SEU, Manufacturing Advances, Leads To Thicker Pressure Tubes

- Coolant Conditions Raised From 310 C / 10 MPa To 325 C / 12 MPa
- Secondary Side Steam Conditions Change From 260 C / 4.7 MPa To 6.5 MPa / 281 C
- Thermal Efficiency Increases From 0.353 (gross MWe/MWth) To 0.368

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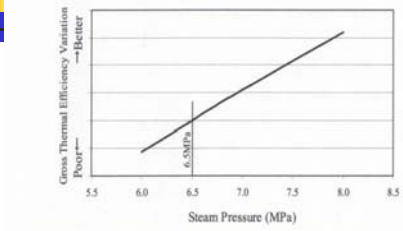

ACR Thermal Efficiency vs Steam Pressure

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Setting Other Secondary Side Parameters

- Choice Of Condenser Pressure Strikes Balance Between Small HT Area (High P) Versus Low Exhaust Losses (Low P)
  - ACR Condenser Pressure Set At 4.9 kPa(abs) For Assumed CCW Temperature Of 18.8 C
- For Chosen Steam Pressure, Extraction Steam Condition, Turbine Design, Need To Set Optimal Final Feed Water Temperature (Balance Turbine Power Output, Exhaust Losses)
  - For ACR Final Feed Water Temperature Set At Approximately 220 C

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Steam Generators, Pumps, Retained Above Reactor Core

- CANDU ACR Retains Passive Safety Feature Of Thermosyphoning In Event Of Loss Of Power To Coolant Pumps

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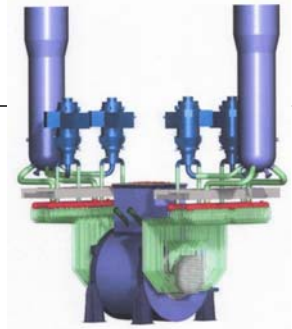

ACR Heat Transport System Layout

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Emergency Core Cooling (ECC)

- CANDU ACR Incorporates Two ECC Systems
  - On Detection Of LOCA Signal EC1 System Injects High Pressure Light Water Into RIH From Pressurized EC1 Accumulators
  - Long Term Cooling System (LTC), Consisting Of Two Independent Sub-Systems, Pumps Water From Containment Sumps To RIH
- ECC Emphasizes Goals Of Separation And Independence

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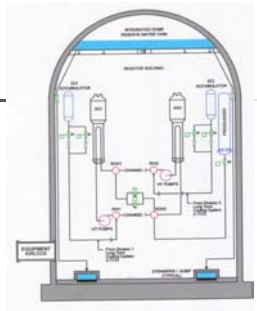

ACR Emergency Coolant Injection System

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ACR Choice Of Fuels

- ACR Has Been Developed To Be Very Flexible As To Choice Of Fuels
  - Nominal SEU Fuel
  - Up To 100% MOX Fuel (Recycled Pu In Form Of Mixed Oxides Of Pu / U)
  - Thorium Fuel Cycle
- On-Line Re-Fuelling Important Part Of This Flexibility

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Locating, Removing Defective Fuel Bundles

- New Radioactivity Tracing Diagnostics Allow Location Of Defective Fuel Bundles Within Core
- On-Line Refuelling Feature Allows Defective Fuel Bundle To Be Removed Promptly

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ACR Design Conclusions

- Trend Towards Passive, Inherent Features
- ACR Retains Low Temperature Moderator (Passive Safety Feature)
- Light Water Coolant Introduces New Passive Shut-Down Method, And Reduces Tritium Risk
- ACR Displays Naturally Negative Reactivity Coefficients (Passive Feature)

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Conclusions - Continued

- CANFLEX Fuel Bundle Has More Pins, Yielding Lower Power Rating And Greater Safety Margins
- ACR Displays Naturally Flat, Stable Core Power Distribution
  - Eliminates Need For Reactivity Controls (Passive Feature)
  - Naturally Flat Power Distribution Makes For An Inherently Safer Reactor
- Thermosyphoning Passive Feature Retained

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