REACTOR MECHANICAL DESIGN

by

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OUTLINE

(Note: Items marked ** may require more time for presentation)

SECTION 1 - Introduction; Overview of the design process; Regulatory requirements, Nuclear design codes and standards [5.0 hrs**]

1.1 Introduction [1 hr]

a) Outline of the Lecture Program: objectives, scope & format

b) General Arrangement of the CANDU NSSS: *(Refer to Figures)*

i) Main Assemblies and Systems of Reactor Assembly

ii) Major systems *inter-facing* with the reactor assembly: overview

1.2 The Design Process [1.5 hr]

- Define it as a rational, organized process to achieve a design to meet specified requirements
- We identify eight steps in the process
- Design of Reactor Assembly dominated by inter-related *geometric and functional requirements, despite significant pressure vessel design challenges*

1.3 Regulatory Requirements and Design Codes and Standards** [2.5 hr**]

- The Federal government agency, the AECB, licenses, and sets fundamental guidelines for design and operation of all nuclear facilities. *(List and define key Guidelines)*
- Provincial governments define standards for design, fabrication and operation of all pressure retaining items, and register and inspect such items
    - They require use of CSA N285.0 **standard, and associated standards it designates: N285 series, N286 **series, Z299 series (now ISO 9000 series), parts of ASME BPVC

NOTE: The steps in the process to be followed, to design a pressure vessel or section of piping will be revealed in describing the CSA N285.0 standard.

SECTION 2 - CANDU Reactor Design Philosophy and Practices; Rationale for Lay-out and Configuration of the Reactor Assembly; Key Operating Parameters [5.5 **hrs]

2.1 CANDU Design Philosophy; Rationale for Basic Concepts & Configuration [0.5 hr]

2.2 Configuring the Core, Calandria, End Shields, Supports, RCU layout, RMD and Reactor Vault [1 **hr]

2.3 Normal Operating Fluid Conditions - Temperatures, Pressures and Flows [0.75 hr]

2.4 Normal Operating Weight and Pressure Loads [1 hr]

2.5 Normal Operating Thermally Induced Loads [1 hr]

2.6 Other Key Operating Conditions: [1 hr]
Startup, Shutdown, Setback, Trips, LOCAs: (PHT pipe burst, PT + CT burst)

SECTION 3 Stress Analysis of Reactor Structure Assembly (RSA) [5.5 hrs]

3.1 Combinations of Loads and Loading Cases [0.5 hr]

3.2 Finite Element Modeling (FEM) & Static Load Analysis [1.5 hr]

3.3 Considerations for Fatigue, Buckling Stability, Crack Propagation [1.5 hr]

3.4 Workshop: Analyses for typical CANDU reactor designs [2.0 hr]

SECTION 4 Seismic Design of Structures and Components [5.5 hrs]

4.1 Review of Fundamentals of Vibration, Response and Damping [1.5 hr]

4.2 FEM Seismic Analysis of CANDU RSA [1 hr]

4.3 Simplified Representation of CANDU Reactor Seismic Behavior [1.5 hr]

4.4 Testing for Seismic Behavior & Qualification [0.5 hr]

4.5 Workshop: Design for Improved Seismic Capability [1.0 hr]

SECTION 5 Design of Fuel Channels [5.5 hrs**]

5.1 Pressure Tube [1.5 hr**]

5.2 End Fittings [1 hr]

5.3 Positioner Assembly [0.5 hr]

5.4 Spacers, Closures, Shield Plugs, Bearings, Liner Sleeves [1 hr]

5.5 Workshop: Improved Fuel Channel Designs [1.5 hr]

SECTION 6 Reactivity Control Units (RCUs) [8.5 hrs]

6.1 Descriptions, Functions and Performance of RCUs for RRS, SDS1 & SDS2 [2 hrs]

6.2 Design of Fission Sensing RCUs:
Flux Detectors, Fission Counters and Ion Chambers [0.75 hr]

6.3 Design of Neutron Absorbing RCUs: SORs, ADJs, MCAs, LZCs, MZCs and LISs [1 hrs]

6.5 Design of Drive Mechanisms for SORs and ADJs [1.0 hrs]

6.6 Thimbles, Guide Tubes, Penetrations in RMD and Vault Wall [0.75 hrs]

6.7 Seismic Qualification of SORs, FDs and Other RCUs [1.5 hrs]

6.8 Environmental Qualification of SORs, FDs and Other RCUs [0.5 hrs]

6.9 Workshop:

SECTION 7 The Fuel Handling System [8.5** hrs]

7.1 The Fuel Changing Process [0.5 hr]

7.2 Fueling Machine Design [1.5 hrs**]

7.3 FM Support System: Cradle, Carriage, Bridge and Columns [1 hr]

7.4 FM Ancillary Systems and FM Control [1.5 hr]

7.5 Irradiated Fuel (IF): Handling, Transfer and Storage [1 hr]

- Discharge through port; transfer routing; containment porting; storage bay systems; detection & disposition of damaged fuel

7.6 IF Concepts and Reactor Building Lay-out: [1 hr]

- IF storage bay location & size: strategies for short and long term storage

7.7 New Fuel Handling & Routing [0.5 hrs]

7.8 The Option for Reprocessed 'New' Fuel [0.5 hr]

7.9 Workshop: Improved FH Systems [2 hrs]

SECTION 8 Additional Considerations for CANDU Reactor Assemblies [5.0 hrs]

8.1 Non-Technical Influences on Configuration and Construction [1 hr]

- Shop-built modules vs site-built structures: vendor's shop-controlled productivity vs client-controlled local labour (eg, steel shield tank vs concrete vault)
- Cost Benefit vs Proven-ness: replicate field-proven systems and components; or upgrade and evolve design from field-proven items; or new concept based on technology and knowledge gained from field-proven items

8.2 Changing CANDU Design Targets: [1 hr]

a) Longer Plant Life:
   - Status of items which might effect operating life: calandria shell; calandria tubes; pressure tubes; RCU absorbers, elements, mechanisms; system wiring & piping
   - Economics of refinements for long life vs increased construction cost; prolonging component life vs design for easy replacement

b) Design for Passive Operation and Passive Safety

c) Extreme Safety Design Cases:
   - Positioner Strength vs Floating PT
   - EF Ejection and LOCA and LO Fuel

8.3 Computer Simulation of SOR: SORDROP [1hrs]

8.3 Design of Faster SORs; Optimization [1 hrs]

8.4 Design of Faster LISUs; Optimization [1 hrs]