



# ***CANDU Safety***

## ***#22 - Regulatory Requirements for Design***

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## *Differences from LWR Approach*

- λ there are very few regulatory documents on system design
- λ the documents focus on the special safety systems
  - shutdown systems, ECC, containment
  - overpressure protection
- λ the requirements are goal-oriented, not detailed
- λ the regulator audits the results
- λ benefits:
  - flexibility for new ideas
  - clear responsibility
- λ disadvantages
  - sometimes no clear rules, judgement required



## *Other Sources of Requirements*

- λ national standards cover many design aspects
  - Canadian Standards Association (CSA)
  - other recognized standards - ANSI, ISO, IEEE
- λ AECB participates in CSA Committees
- λ designer sets the detailed requirements
  - submitted to AECB and audited
- λ some must be formally accepted and need approval if changed
  - Safety Design Guides



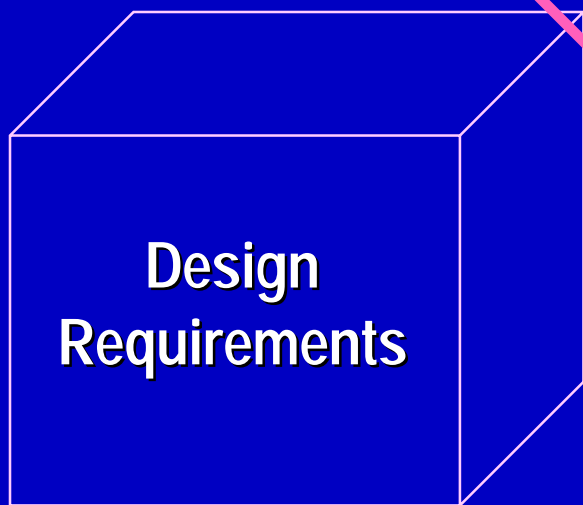
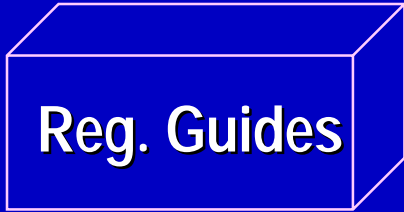
## *Safety Design Requirements Documents*

- λ Licensing Basis
- λ QA Programme
- λ Safety Design Guides
- λ Safety Critical Software Standards and Procedures
- λ Compliance with Regulatory Documents
- λ Human Factors Engineering Programme Plan
- λ Safety Analysis Initial Conditions and Standard Assumptions
- λ Probabilistic Safety Analysis Methodology
- λ Design Requirements for Safety-Related Systems
- λ Disposition of Generic Licensing Issues
- λ Severe Accident Programme, etc.



# Comparison of Requirements Documents

Goal-oriented



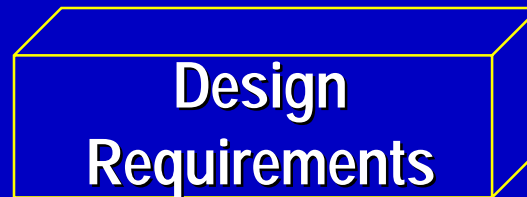
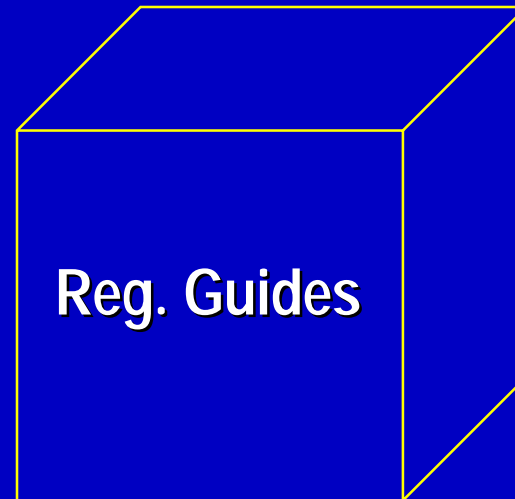
Regulatory



Design



Prescriptive





## ***AECEB Key Documents for Safety Systems***

- $\lambda$  R-7: Requirements for Containment Systems
- $\lambda$  R-8: Requirements for Shutdown Systems
- $\lambda$  R-9: Requirements for Emergency Core Cooling Systems
- $\lambda$  R-10: The Use of Two Shutdown Systems in Reactors



## ***Common Elements - 1***

- λ minimum allowable performance standards (MAPS)**
- λ public dose limits for accidents**
- λ environmental qualification**
  - for those portions required for accident mitigation**
- λ system unavailability  $< 10^{-3}$  years / year**
- λ support system unavailability to meet system unavailability**
- λ long-term post accident availability**
- λ single component failure criterion**
  - not required for components which do not change state and which do not depend on safety support equipment**
- λ fail-safe where practicable**



## *Common Elements - 2*

- λ known failed component can be put in safe state
- λ all automatic actions can also be manually initiated from control room
- λ physical and operational independence from other safety systems, no shared equipment
- λ independence from process systems
- λ separation of redundant instrument channels
- λ justification of independent subsystems
- λ call-up of specific CSA Standards
- λ seismic qualification of portions that are credited in safety analysis after DBE





## *Common Elements - 3*

- λ no operator action credited until 15 minutes after clear signal
- λ in-service component testing to demonstrate availability
- λ testing does not impair system
- λ safety function cannot depend on Class IV power supply
- λ periodic but infrequent integrated system tests, for shutdown & containment
- λ safety systems cannot be intentionally made unavailable (except under specific conditions - e.g., guaranteed shutdown, backup heat sinks available)



## *Example of Goal-Oriented Requirement*

**“Design principles for separation of redundant instrument channels...shall be prepared and shall require approval by the AECB prior to the issuance of a construction approval”**

- no numbers or acceptance criteria given**
- designer prepares Safety Design Guide stating specific separation requirements**
- Safety Design Guide approved by AECB**
- major exceptions or changes to Safety Design Guide require approval of AECB**



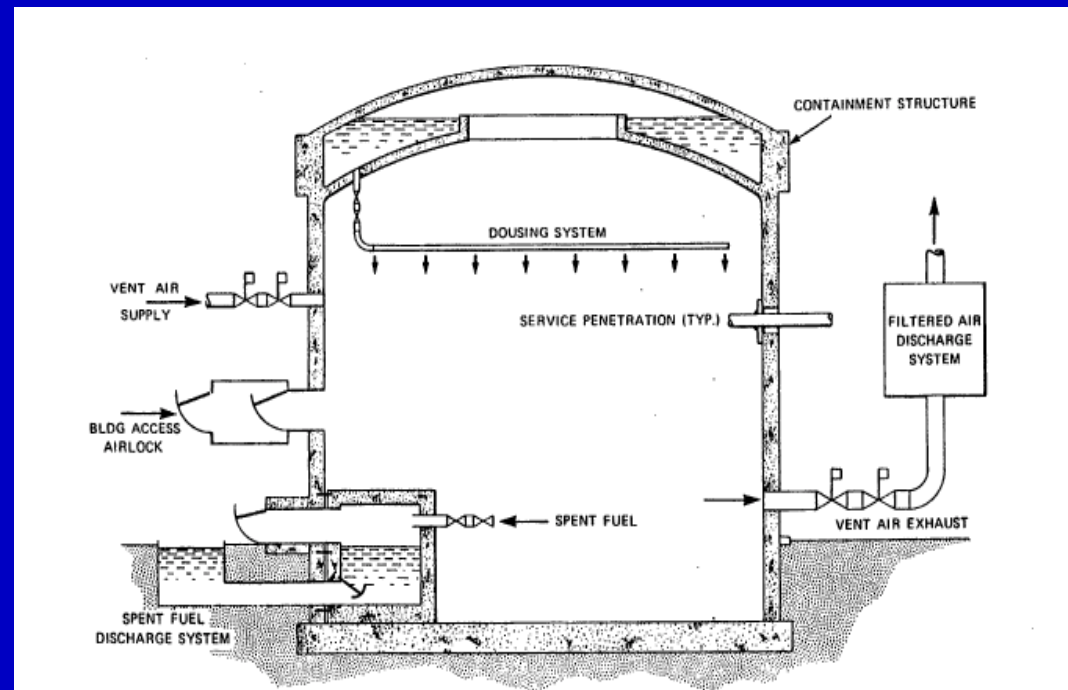
## *Specific Containment Requirements - 1*

- $\lambda$  design pressure set only by accidents which release radioactivity (LOCA)
- $\lambda$  must assume failure of dousing in setting design pressure
- $\lambda$  for primary and secondary side failures, with or without dousing, cannot impair structure so that damage to reactor systems occurs
- $\lambda$  for primary side failures with or without dousing, and secondary side failures with dousing, no damage to containment structure
- $\lambda$  maximum leakage rate set by value used in safety analysis



## Specific Containment Requirements - 2

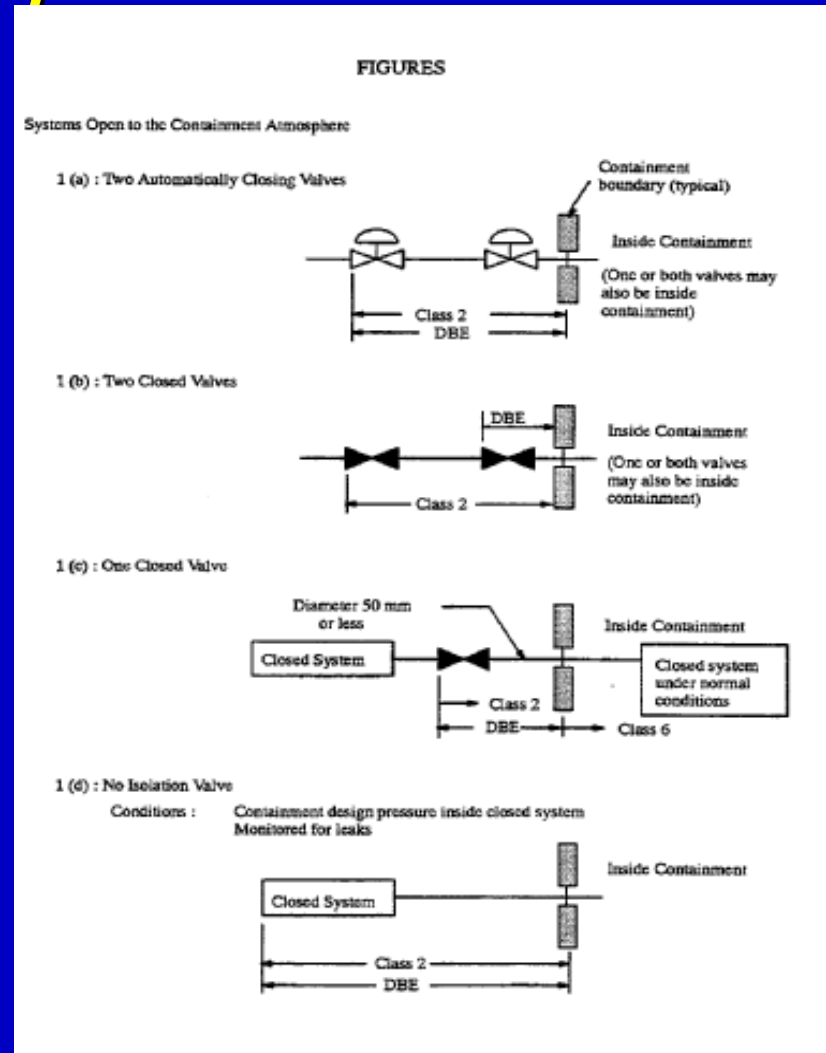
- λ pressure control following an accident
- λ control of hydrogen / oxygen after an accident unless no possibility of explosion or deflagration
- λ isolation of compressed air
- λ proof testing at  $>1.15$  design pressure prior to operation





# Specific Containment Requirements - 3

- λ tests of penetration and isolating devices (no method specified)
- λ appendix giving detailed requirements for metal extensions of the containment envelope



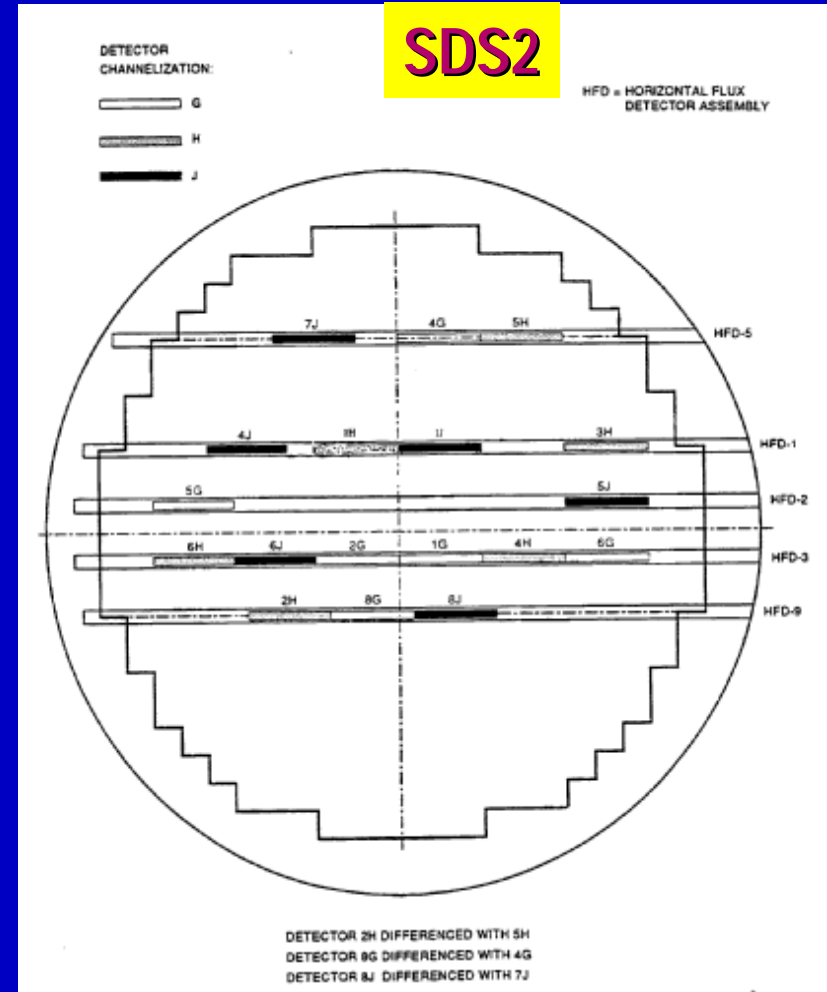
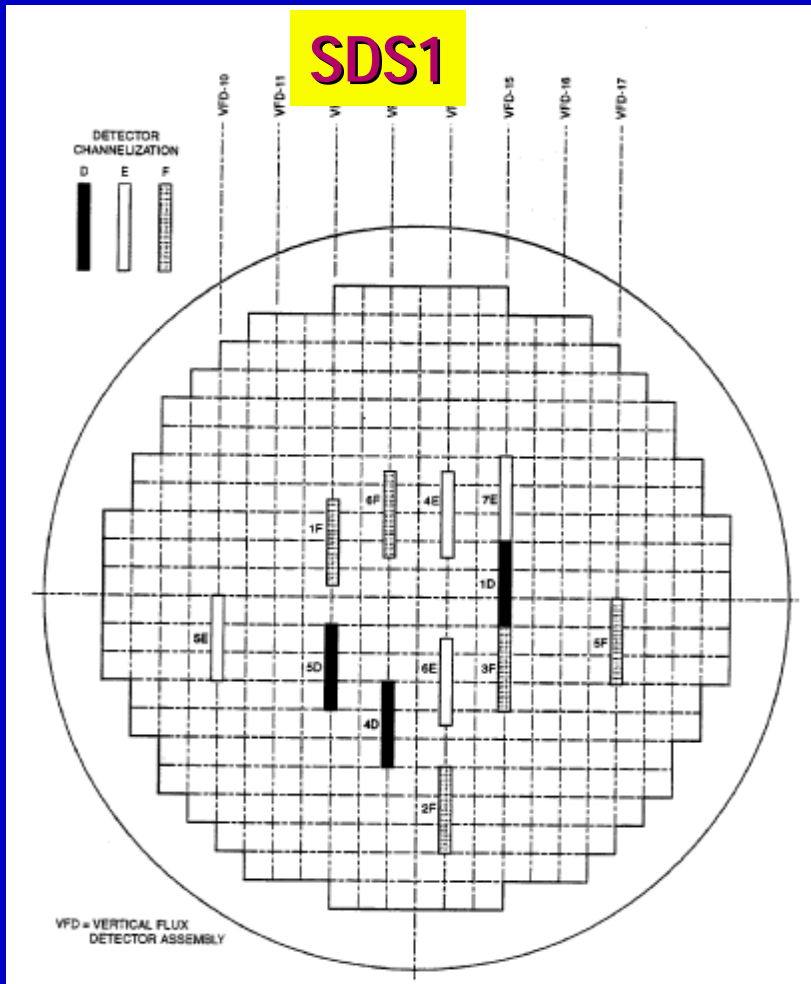


## *Specific Shutdown System Requirements*

- λ provision of 2 independent shutdown systems
- λ prevent loss of heat transport system integrity
- λ manual operation from main control room and remote location
- λ diverse designs
- λ normal process system action, or inaction, cannot reduce effectiveness
- λ two diverse trip parameters on each shutdown system for each accident (unless impracticable or detrimental to safety)
- λ re-poising of shutdown systems after trip
- λ procedures for guaranteed shutdown but at least one shutdown system must be available even then



# Diversity & Separation of Flux Detectors





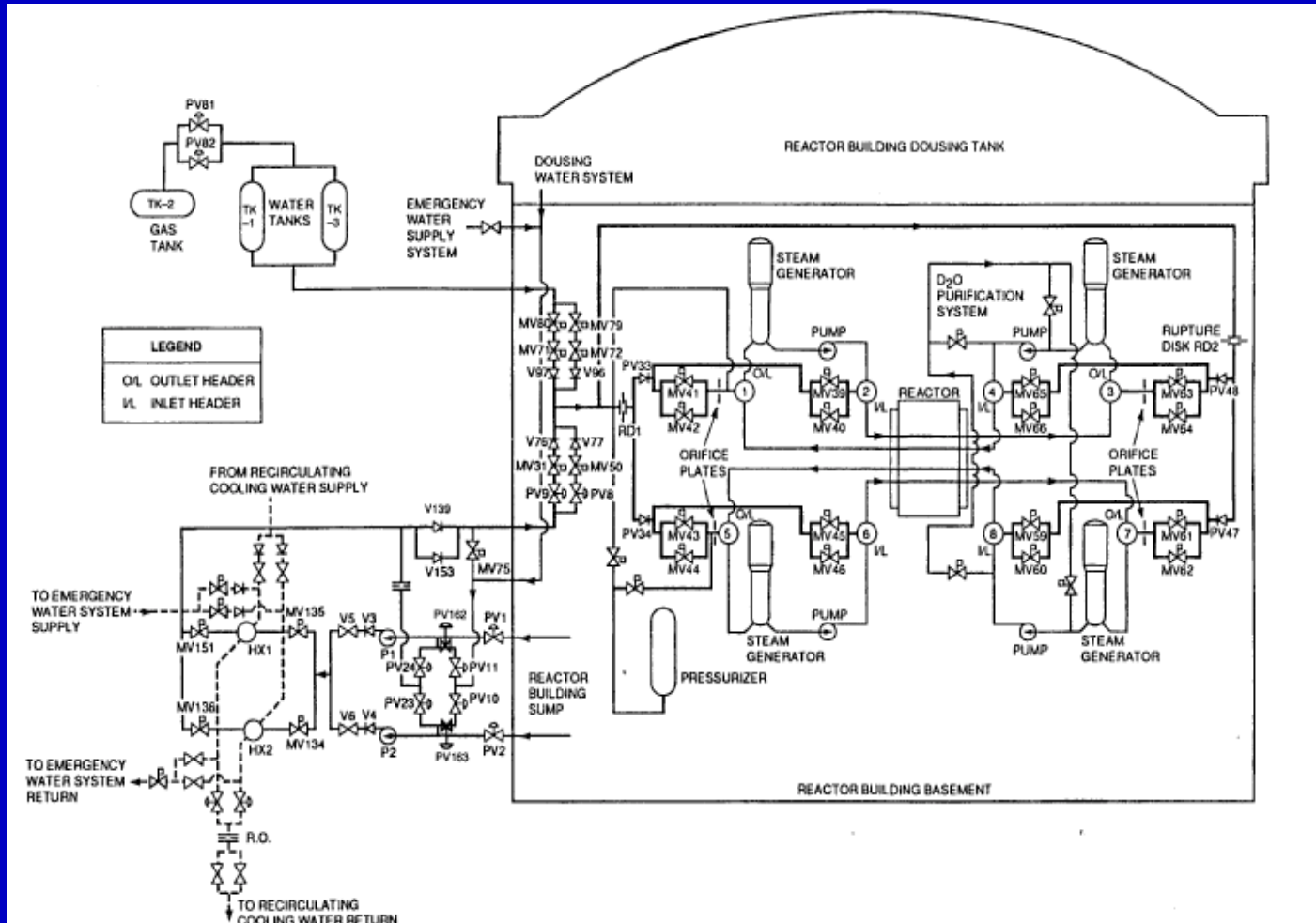
## *Specific Emergency Core Cooling System Requirements*

- λ fuel failures prevented for small LOCA and secondary side breaks
- λ coolable geometry in fuel channels for all LOCAs
- λ no further fuel damage after ECC has re-established cooling
- λ long-term reliability targets required, defined by designer (typically unavailability in long term  $< 10^{-2}$  years/year)
- λ leakage collection and control for ECC components outside containment
- λ no detrimental safety affect due to inadvertent operation





# ECC Schematic





## ***Conclusions***

- $\lambda$  regulatory requirements on design are goal-oriented**
- $\lambda$  detailed requirements set by designer & approved by regulator**
- $\lambda$  emphasis on reliability, separation, testability**
- $\lambda$  strong tie to accident analysis through MAPS**
- $\lambda$  qualification where required**