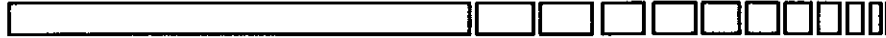


# *Principles of Nuclear Safety*



## **Module 4**

### **The 3C's: CONTROL, COOL & CONTAIN**

Slide 1

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## *Golden Rule of Reactor Safety*

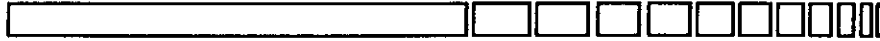


- There is no threat to public safety as long as
  - reactor power is controlled
  - the fuel is cooled
  - radioactivity is contained
- the 3C's are essential under all operating conditions:
  - at all power levels
  - during normal operation, shutdown or upset

Slide 2

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## Control: Defence Hierarchy



- 1) **RRS** -normal process control
- 2) **Setback** -automatic power ramp-down using normal RRS control devices
- 3) **Stepback** -sudden power reduction via CA full or partial drop
- 4) **SDS1** -sudden, deep shutdown via SA drop
- 5) **SDS2** -sudden, deep shutdown via LISS

Slide 5

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## Reactor Regulating System (RRS)



- First line of defence against fuel overheating
- Accepts set point from:
  - Operator in *Reactor Leading* mode
  - BPC in *Reactor Lagging* mode
- Compares actual power with demanded power
- Manipulates reactivity mechanisms to reduce power error = actual power - demanded power
- If RRS impaired, unit must be put in GSS to prevent Loss of Regulation Accident (LORA)

Slide 6

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## *What if Fuel Cooling is Inadequate?*

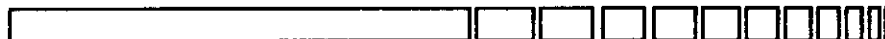


- Fuel overheats
- Fission product gases released from ceramic
- gas pressure increases inside sheath
- sheath softens as temperature nears melting point
- sheath balloons & ruptures
- fission products released into coolant

Slide 3

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## *Basic Requirements to Maintain Fuel Integrity*



- fuel heat production  $\leq$  heat removal
  - Heat production = fission heat + decay heat
  - Fission heat is proportional to neutron power  $P_n$
  - Decay heat production depends on core power history
  - Even if  $P_n$  is off-scale low, need heat sink for decay heat
- temperature well below melting point
  - Primary and back-up heat sinks must always be available

Slide 4

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## *Setback and Stepback*



- second line of defence against fuel overheating
- various parameters monitored by each system
- fuel heat production is reduced when
  - operating limit reached indicating actual or potential mismatch between heat production and removal
- Examples:
  - Boiler pressure high (setback some stations)
  - Boiler level low (setback backed up by trip)
  - High Rate Log N (stepback backed up by trip)

Slide 7

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## *SDS1 and SDS2*



- Final lines of defense to reduce fuel heat production via automatic protective action
- If either SDS is unavailable, then the GSS is mandatory
- Examples of trips protecting against excessive heat production:
  - neutron overpower, high rate log N, coolant high pressure
- Examples of trips protecting against impaired heat removal:
  - boiler low level
  - LOCA trips: RB pressure high, coolant pressure low, moderator level high, coolant flow low, core differential pressure low

Slide 8

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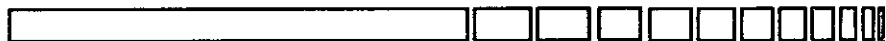
## *Control Room Neutron Power Indication*



Required at *all* times to confirm:

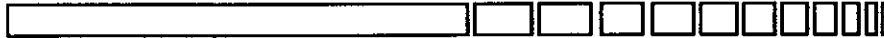
- during normal operation, that neutron power is within heat sink capability
- during accident conditions, that neutron power is responding predictably

## *Preferred Unit State for Fuelling*



- reactor critical and at high power
- local reactivity changes compensated by RRS via Liquid Zone Control System
- zone levels monitored for unusual reactivity effects by ANO
- No such capability with reactor power <15% FP
- Shutdown fuelling requires Manager's approval

## *Factors Affecting Fuel Cooling*



Under Operator control:

- Reactor thermal (fission + decay) power
- coolant inventory
- subcooling/saturation margin to dryout
- coolant flow
- heat sink availability and capability

Slide 11

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## *Primary & Backup Heat Sink Availability Requirements*



- Primary & backup are an OP&P requirement
  - total loss of heat sink results in fuel failures
- Exception: no backup full power heat sink available
- Backup *independent* of primary
  - including the power supply
  - single equipment failure cannot disable both
- O&M planned to keep backup heat sink available
- seismically qualified heat sink (except PNGS-A)

Slide 12

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## *Containment*



- last line of defence against releases
- If **CONTROL** and **COOL** fail, resulting in fuel failures, public safety depends absolutely on **CONTAINment** integrity
- barrier to chronic and acute tritium releases