CANDU Safety
#9 - Grouping & Separation

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Purpose of Grouping & Separation

- protection against events affecting a limited area of the plant
- common cause failures:
  - turbine disintegration and resultant missiles
  - fires
  - small aircraft strikes
  - failure of common support system
  - common adverse environment
- ensure that functional interconnections between systems do not change effectiveness for accidents

Two Group Design Philosophy

- ensure two independent ways to achieve same safety functions:
  - shutdown
  - remove decay heat and/or prevent release of radioactivity
  - monitor the plant
- group safety-related systems into two groups
  - Group 1 and Group 2
- reactor building is a natural barrier for some common cause events
  - both Group 1 & Group 2 systems are within reactor building

Three Types of Safety-Related Systems

- special safety systems
  - shutdown system 1, shutdown system 2, ECC, containment
- safety support systems
  - provide electrical power, instrument air & cooling water to special safety systems
- safety-related process systems
  - process systems which can mitigate an accident

Grouping

- each safety-related system assigned to one Group
- each Group can independently perform all the safety functions
- Group 1
  - power production systems
  - some of the special safety systems
  - safety support systems required by these special safety systems
- Group 2
  - the remaining special safety systems
  - safety support systems required by these special safety systems

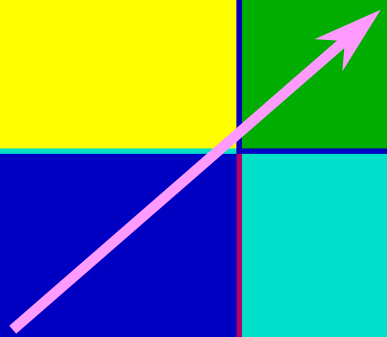
Systems Within Groups

Group 1

Normally Operating Process Systems
Shutdown System 1
Emergency Core Cooling System
Safety Support Systems

Group 2

Shutdown System 2
Containment
Safety Support Systems
(EPS, EWS)



Interconnection of support services
Group 1 to Group 2 in Normal Operation
Group 2 to Group 1 in accidents
Group 1 to Group 2 in accidents

System Grouping by Safety Function

Safety Function	*Group 1 Systems*	*Group 2 Systems*
Shutdown	Reactor Control System Shutdown System 1	Shutdown System 2
Heat Removal From Fuel	Heat Transport System Steam & Feedwater Systems Shutdown Cooling System ECC Moderator	Emergency Water System
Contain Radioactivity	Reactor building air coolers	Containment & containment subsystems
Monitoring & Control	Main Control Centre	Secondary Control Area

Rationale

- two shutdown systems are in separate groups so that a single event cannot prevent shutdown
- ECC and containment are in separate groups so that a single event cannot damage fuel and allow radioactivity to escape
- on CANDU 9, the grouping of containment and ECC has been switched for convenience in cable routing

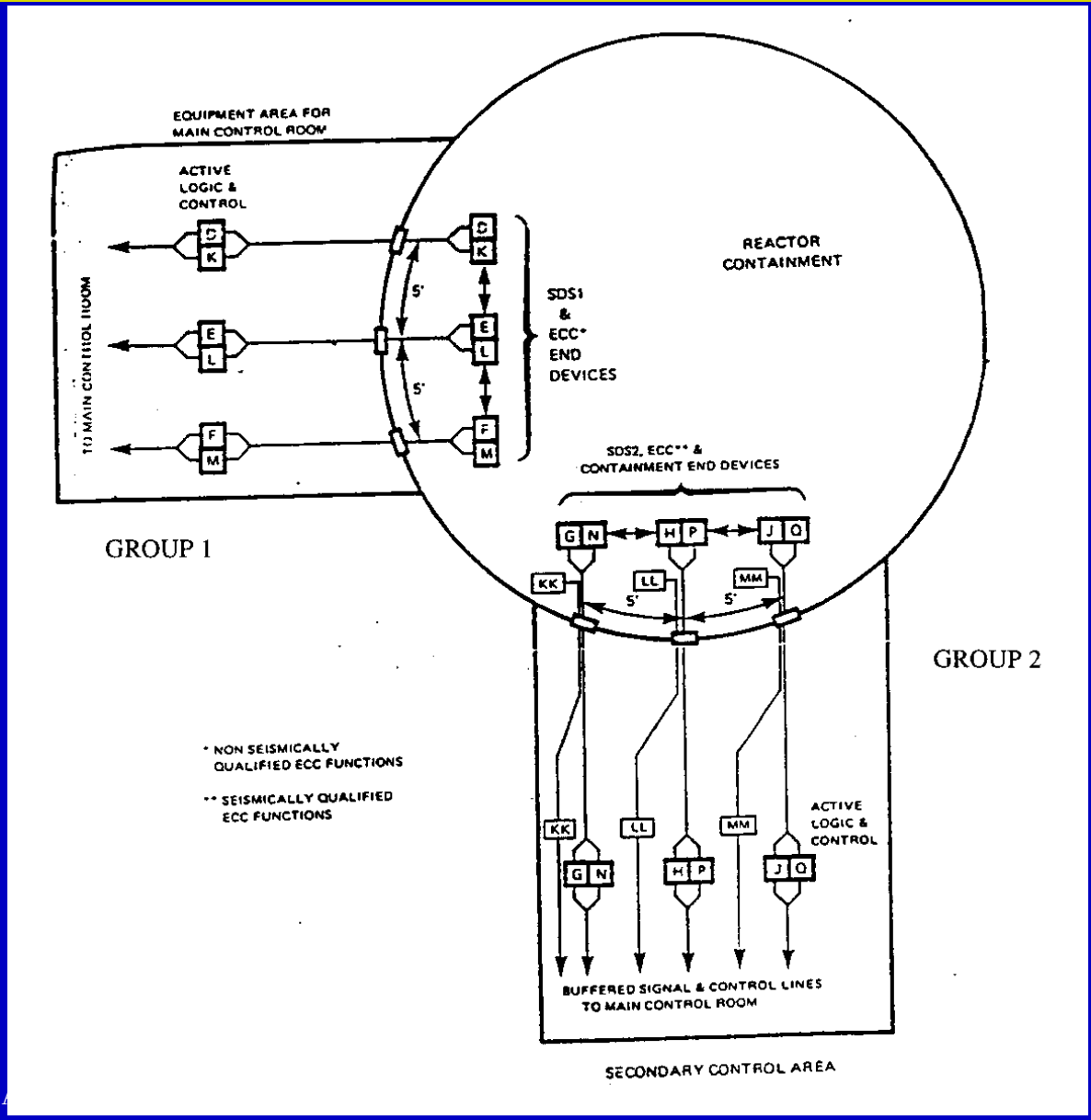
Safety Support Systems

Safety Support Function	*Group 1 Safety Support*	*Group 2 Safety Support*
Electrical power	Class IV Class III diesels Class II Class I	EPS Diesels Class II Class I
Service Water	Raw Service Water Recirculating Service Water	Emergency Water System
Instrument Air	Instrument Air System	Local Air Tanks

Separation Between Groups

- outside reactor building, Groups in different areas of the plant
- typically 90 degree separation
- separate buildings for Emergency Power System diesels, Emergency Water System
- inside reactor building: barriers and physical separation to extent practical
- separation barrier or distance assessed to show adequacy
  - fire, missiles, harsh environment
- main control room protected from steam line breaks and external events so operators can proceed to SCA; access route protected

Plant Layout



Avoidance of Common Cause Failures

- where specified separation cannot be achieved:
  - show no credible hazard in area
  - another Group 2 system outside the area will mitigate
  - system or component protected by barrier
  - system or component is fail safe
  - component designed to withstand hazard
- Group 2 systems generally seismically qualified
- location above flood levels

Instrumentation Cable Designations

System Group	System Name	Channel Designation		
1	Reactor Regulating System	A	B	C
1	Shutdown System No. 1	D	E	F
1	Emergency Core Cooling System	K	L	M
2	Shutdown System No. 2	G	H	J
2	Containment System	N	P	Q
1	Emergency Core Cooling System (seismically qualified)	KK	LL	MM

Separation Within Groups (Examples)

- safety system triplicated instrumentation channels within a group separated by 1.5 metres
- power supplies split into “ODD” & “EVEN” to serve redundant components within a Group
- “ODD” & “EVEN” cables separated by 1.5 metres
- single channels within same Group can share common routing (e.g., A, D, K)
- buffering of connections between Main Control Room & SCA
- power cables >600 volts must be 0.45m. above instrumentation cables

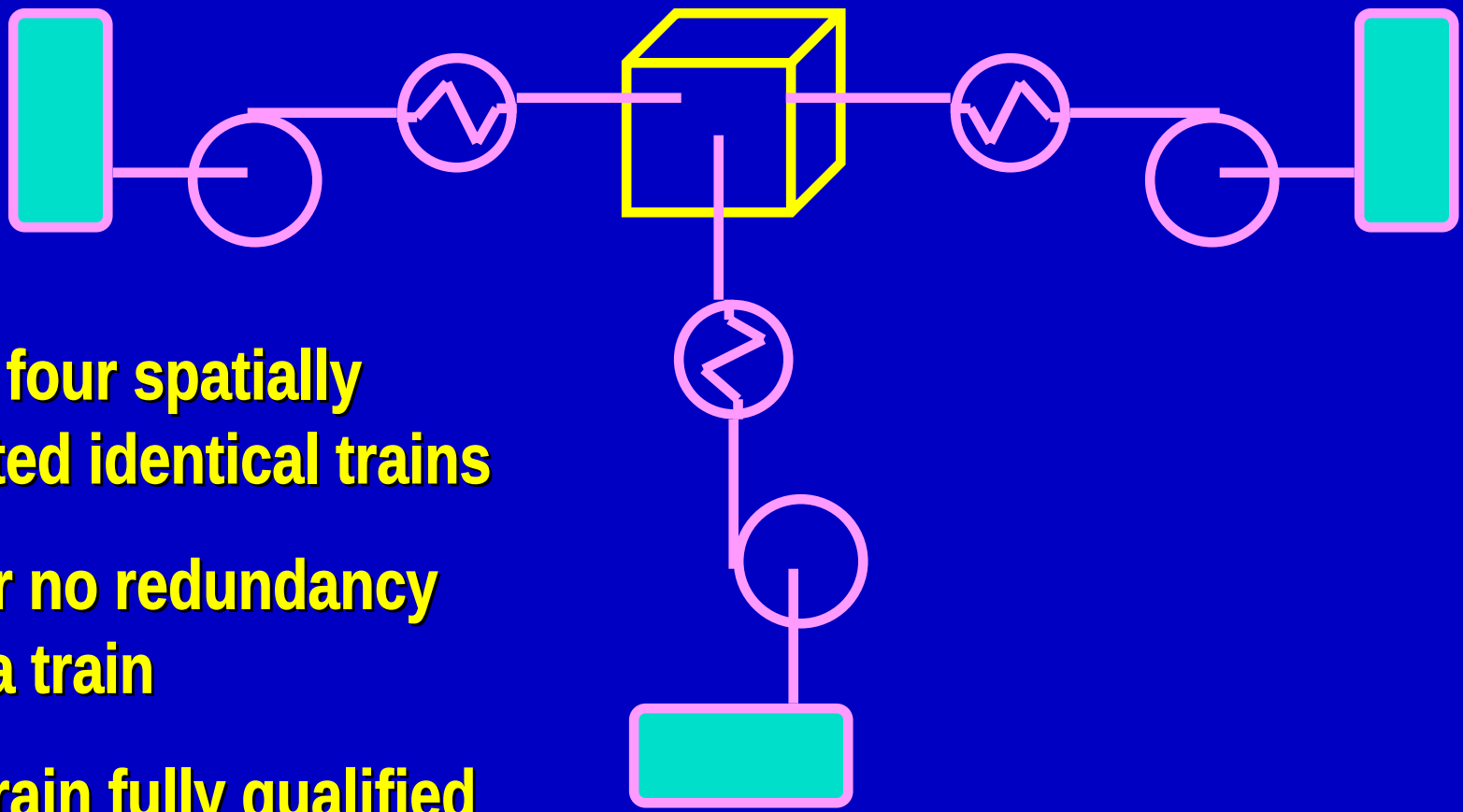
Isolatable or Buffered Interconnections - 1

- Buffered control and instrumentation cables between the Main Control Room and the Secondary Control Area
  - to enable Group 2 equipment to be controlled from the Main Control Room
- Buffered post-accident monitoring and control cables
- Electrical power supply from the grid or from the turbine generator to Group 2 components, where required for reliability
- Cooling water supply from Group 1 to Group 2 components, where Group 1 supplies remain available or can be re-established for long-term reliability

Isolatable or Buffered Interconnections - 2

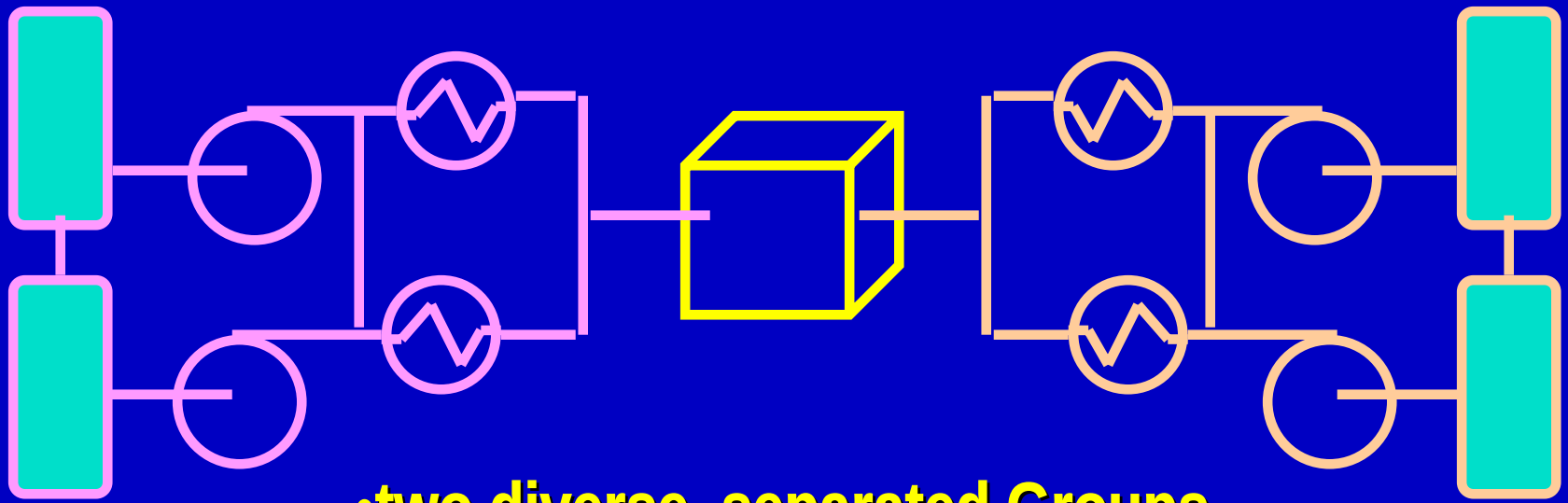
- Compressed air supply from Group 1 for the supply of air storage tanks during normal operation of the plant
- Support services from Group 2 (i.e., EWS, EPS) to Group 1 Special Safety Systems and other safety related components (e.g., supplies to ECC)
- interconnections must ensure that failures cannot propagate from one Group to the other

LWR Approach (simplified)



- two to four spatially separated identical trains
- little or no redundancy within a train
- each train fully qualified

CANDU Approach (simplified)



- two diverse, separated Groups
- redundancy within each Group
- qualification determined by safety function

Summary

- common cause failures handled by grouping & separating mitigating systems
- each group can perform key safety functions
- separation protects against common cause failures of both groups
- groups have limited cross-connections to increase reliability of mitigation for more frequent events
- diversity is more important than redundancy
- qualification depends on each specific accident to be mitigated