

CANDU Design: Accident Concerns

LM3-ACC

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Professor

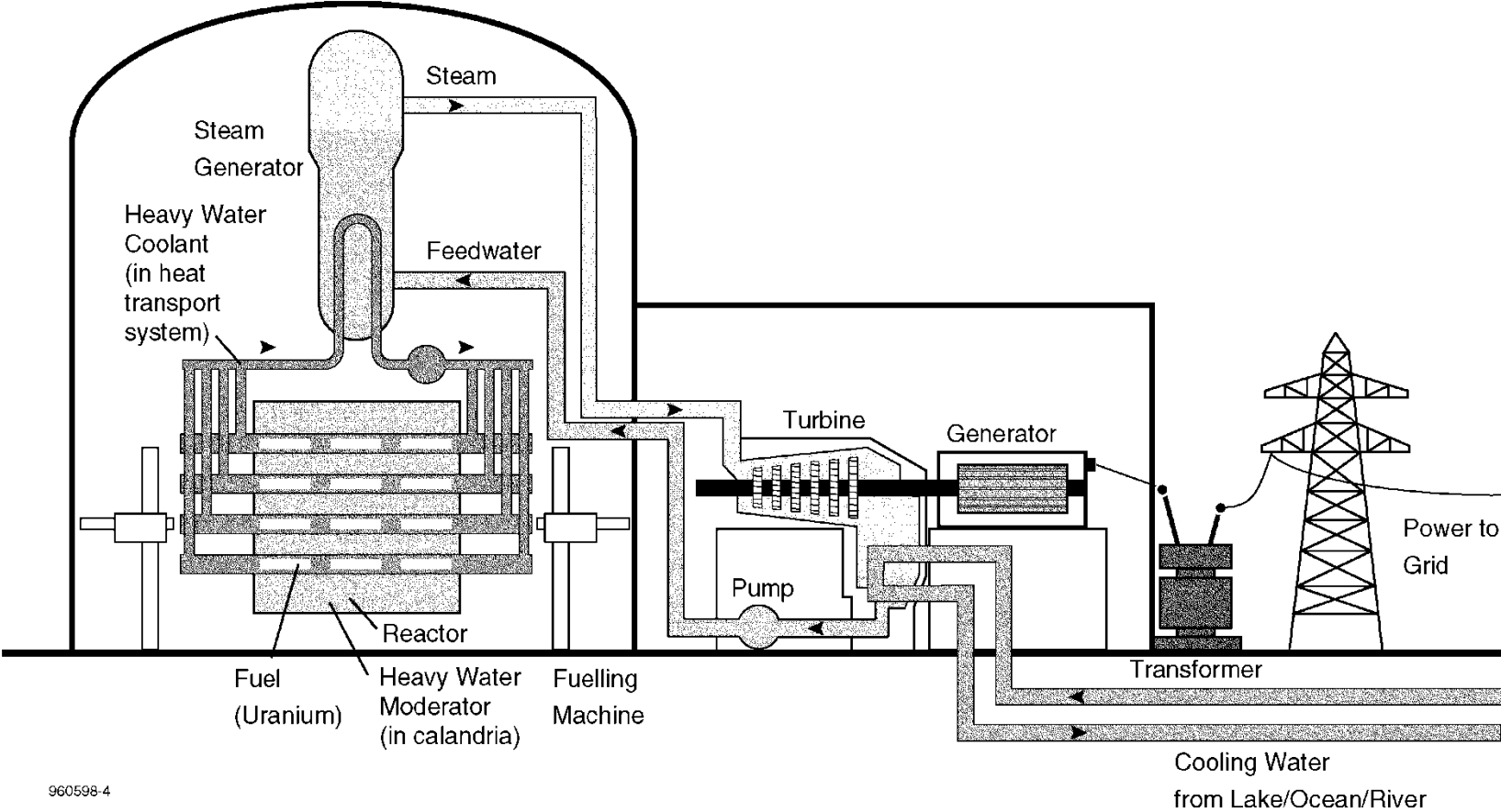
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Learning Objectives

- 1. Understand CANDU Behaviour for Accident Scenarios
- 2. Understand use of simulator for CANDU Type Accidents

Typical CANDU Production Systems

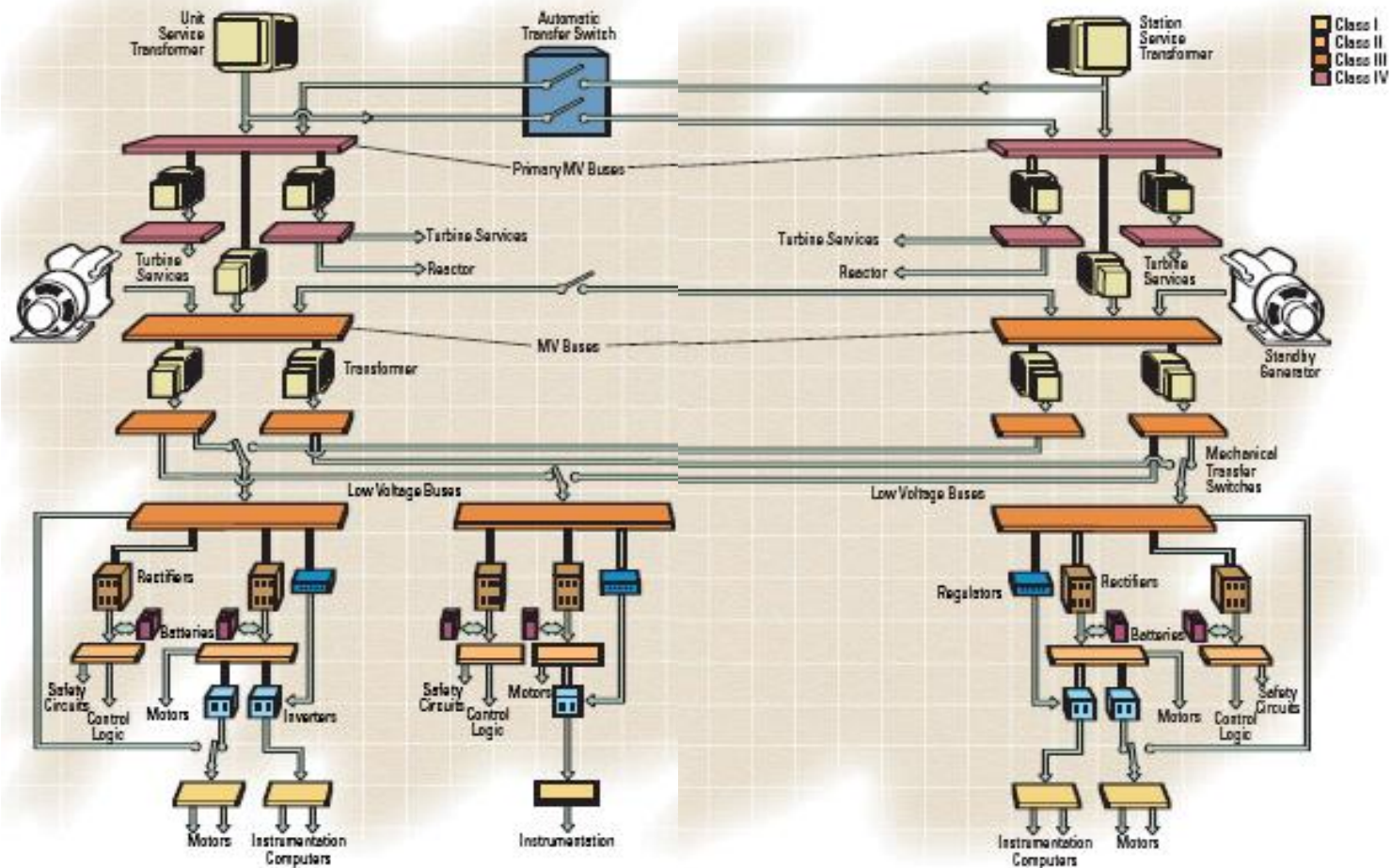


Class IV Power

- Class IV power is regular power. It is supplied from the grid or the main generator.
- All normal operating systems are on Class IV power. Most emergency systems are also on Class IV power and rely on Automatic Transfer Switches or other technologies to ensure the switchover occurs properly.
- Failure scenarios:
 - Transformer failure
 - Damage to transmission line (ice storm)
 - Blackouts (grid imbalances, etc.)

Consequences of Loss of Class IV

- All electrical supply is lost to all components that rely on electricity.
- Main heat transport pumps start to run down. Feedwater pumps run down.
- Inability to transfer heat from the reactor to the ultimate heat sink.
- Systems overheat. Overpressurize. Fuel failures. Loss of pressure boundary. Containment systems are challenged.



Potential Loss of Class IV

- Scenario 1
- Spurious Turbine Trip.
- All other buses still supplied by station power.

Reactor Trip	Turbine Trip	ROH Pres Lo Lo	Step Back Req'd	Setback Req'd	Turbine Runback	Gen Breaker Opn
Hi Neutron Pwr	ROH Press Hi Hi	Coolant Flow Lo	Stm Gen Level Lo	PRZR Lvl Hi	Low Fwd Pwr Trip	Main BFP(s) Trip
Hi Neut Pwr LogR	ROH Press Hi	Main Stm Pres Hi	Stm Gen Level Hi	PRZR Lvl Lo	Loss 1 PHT Pump	Malfunction Active

Labview
16
CASSIM
1290

THRML PWR
56.69 %FP
P 4736.0 T 260.78
F 639.6

S.G. LEVELS

BO1	L	13.97
BO2	L	14.00
BO3	L	13.99
BO4	L	14.00

MSR DRAINS
F 0.5

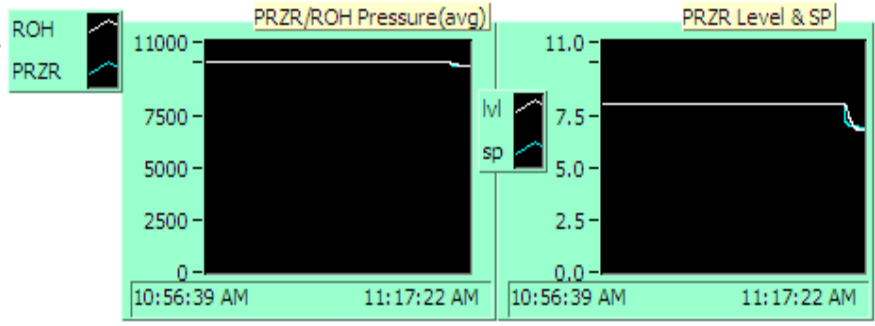
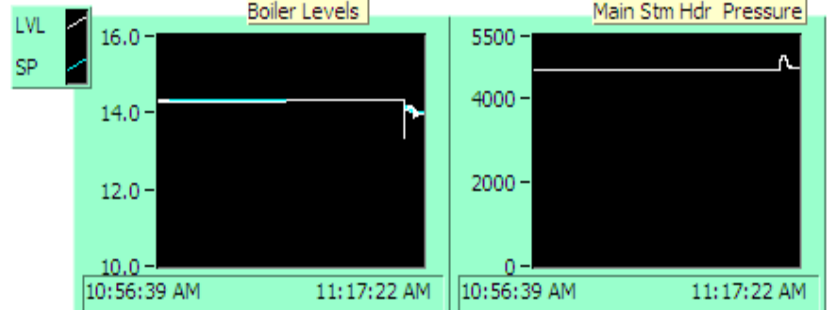
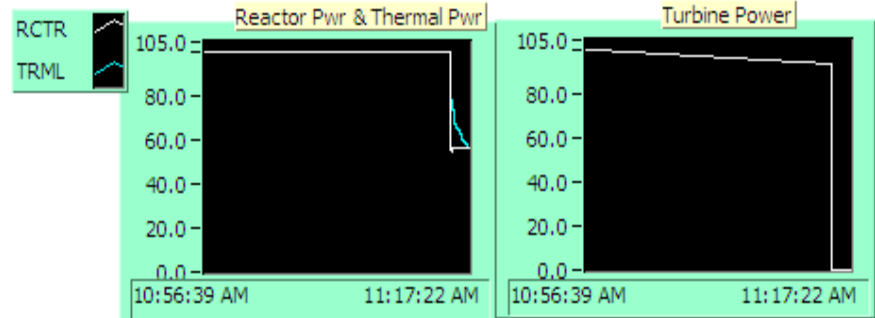
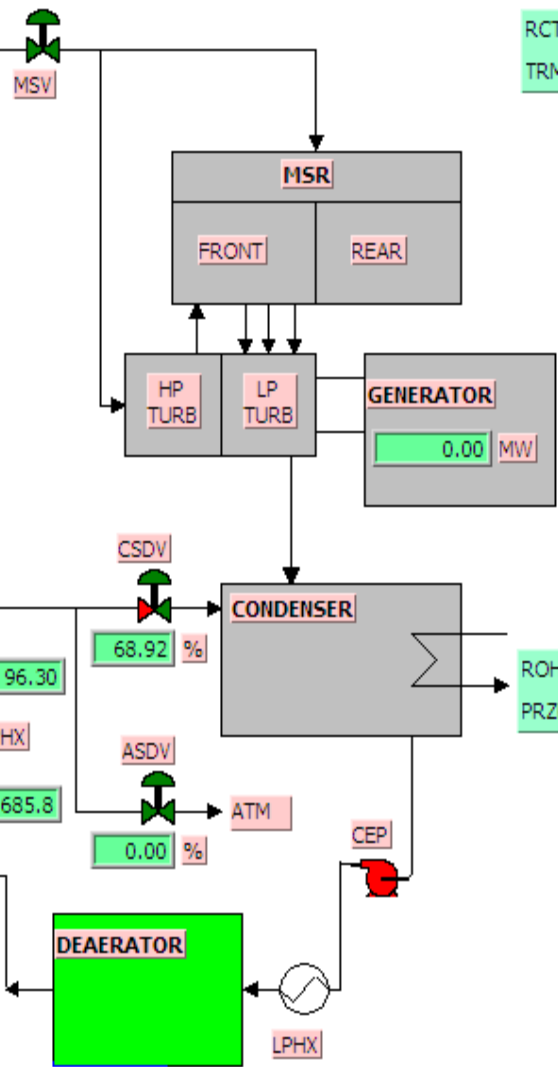
D20 STGE TANK
L 2.16

PRZR
L 6.83
P 9878

ROH(avg) T 286.24 P 9879
RIH(avg) T 256.05 P 11261

REACTOR
AVE ZN LVL 45.07 %
PWR 56.84 %
PWR RATE -0.01 %/s

MODERATOR



Resolution Time Scroll

Max Out Max In

Plant Overview

Reactor Trip Turbine Trip

Reactor Neutron Pwr (%)	Reactor Thermal Pwr (%)	Turbine Pwr (%)	Main Stm Hdr Pressure (kPa)	SG1 Lvl (m)	SG2 Lvl (m)	SG3 Lvl (m)	SG4 Lvl (m)	UPR Mode
56.84	56.69	0.00	4736.04	13.97	14.00	13.99	14.00	Alternate

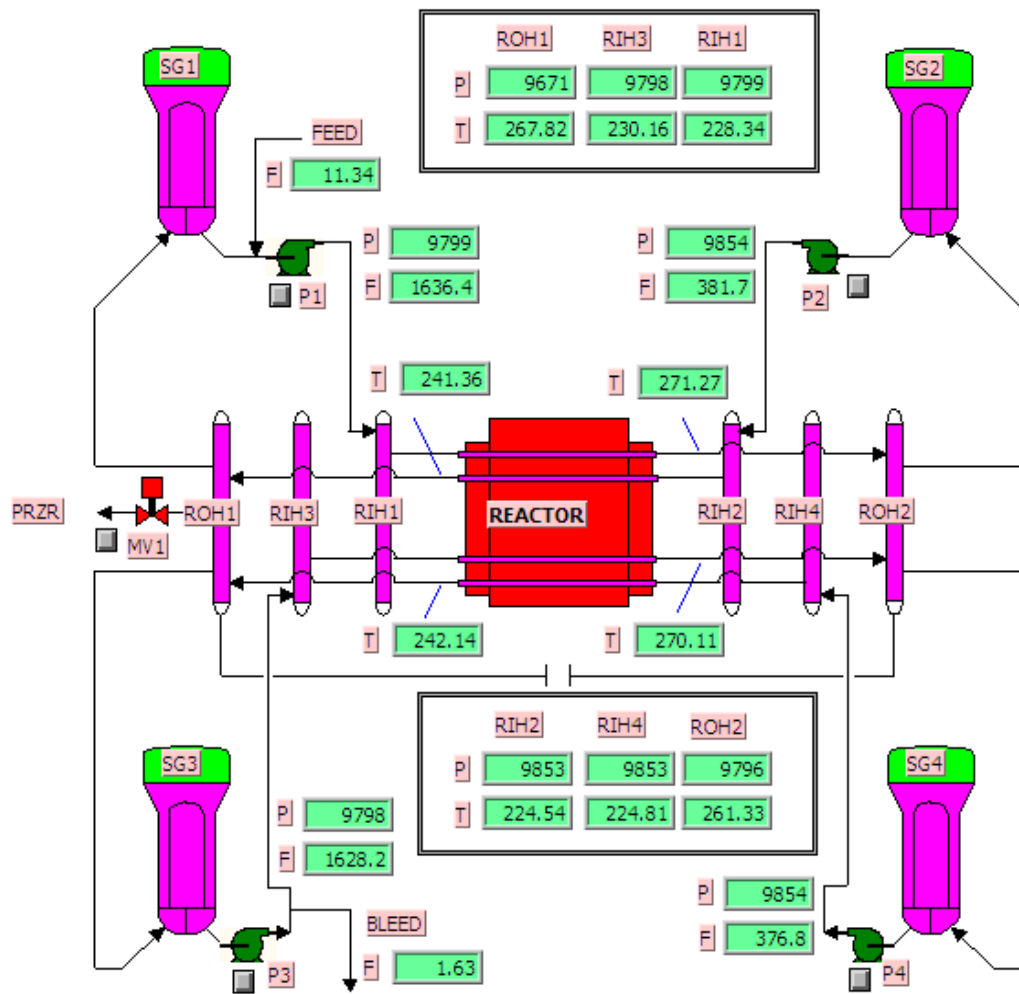
Freeze Run Iterate
IC Malf Help

Potential Loss of Class IV

- Scenario 2
- 4 PHTS Pumps Trip
- All else OK
- In reality, other trips occur but I cannot simulate all of them in the CANDU simulator easily.

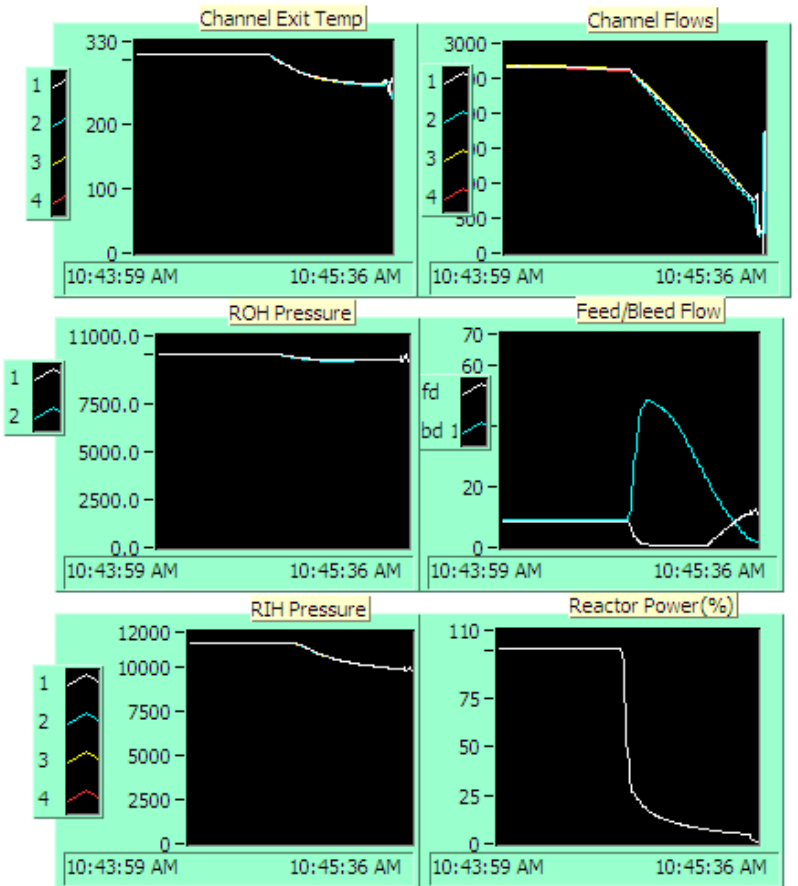
Reactor Trip	Turbine Trip	ROH Pres Lo Lo	Step Back Req'd	Setback Req'd	Turbine Runback	Gen Breaker Opn
Hi Neutron Pwr	ROH Press Hi Hi	Coolant Flow Lo	Stm Gen Level Lo	PRZR Lvl Hi	Low Fwd Pwr Trip	Main BFP(s) Trip
Hi Neut Pwr LogR	ROH Press Hi	Main Stm Pres Hi	Stm Gen Level Hi	PRZR Lvl Lo	Loss 1 PHT Pump	Malfunction Active

Labview
226
 CASSIM
605



	ROH1	RIH3	RIH1
P	9671	9798	9799
T	267.82	230.16	228.34

	RIH2	RIH4	ROH2
P	9853	9853	9796
T	224.54	224.81	261.33



Resolution Time Scroll

Max Out Max In

PHT Main Circuit

Reactor Trip Turbine Trip

Reactor Neutron Pwr (%)	Reactor Thermal Pwr (%)	Turbine Pwr (%)	Main Stm Hdr Pressure (kPa)
0.80	34.23	33.89	4137.89

SG1 Lvl (m)	13.57
SG2 Lvl (m)	13.58
SG3 Lvl (m)	13.64
SG4 Lvl (m)	13.55

UPR Mode

Alternate

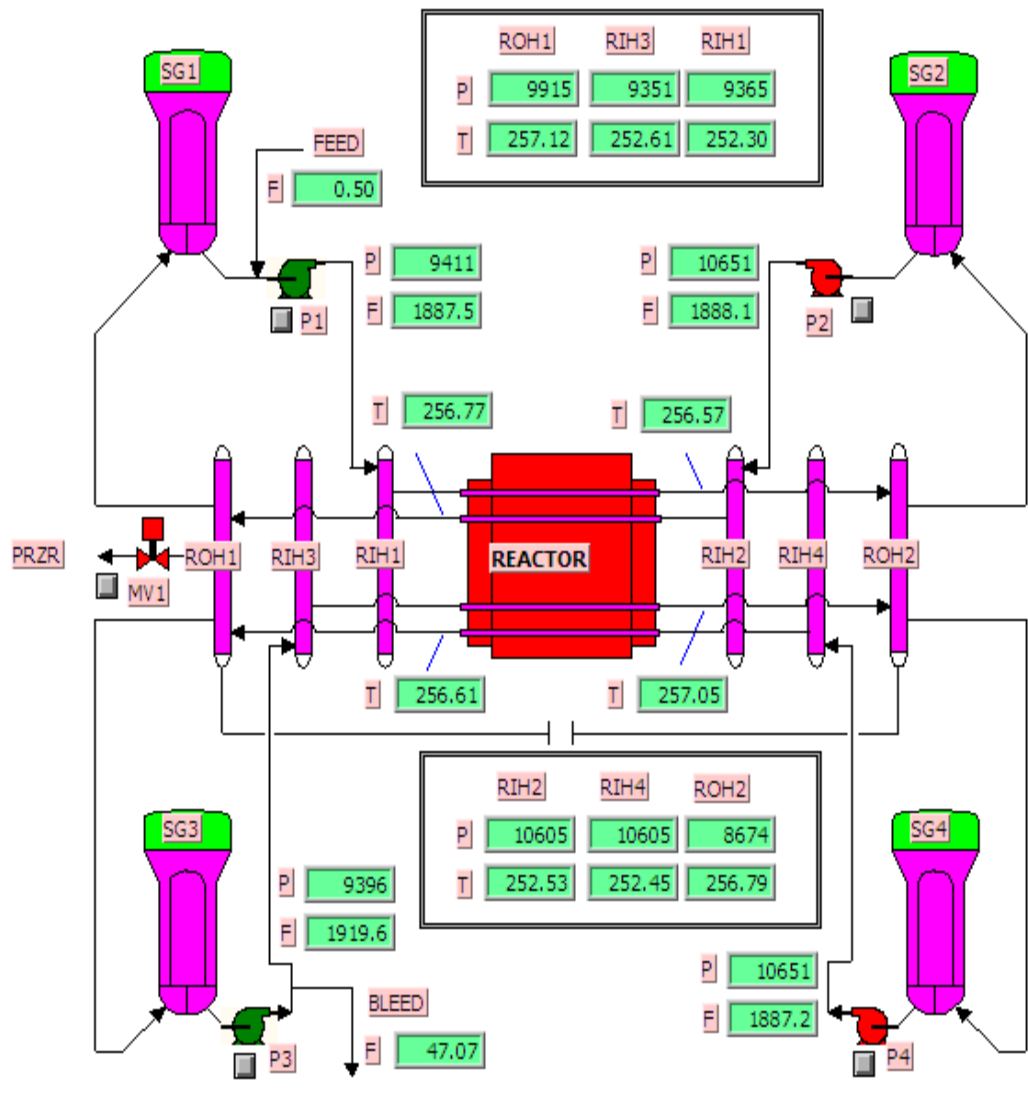
Freeze Run Iterate

IC Help

Potential Loss of Class IV

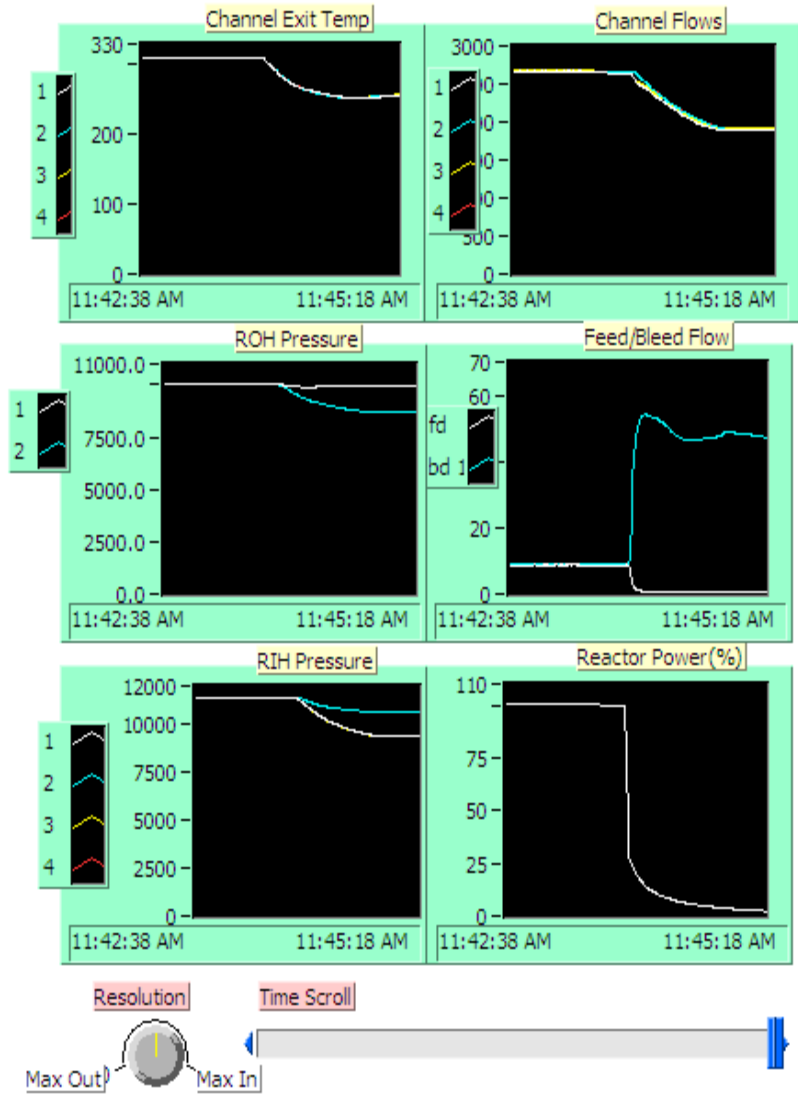
- Scenario 3
- Single PHTS Pump Trip per loop
- All other buses still supplied by station power.

Reactor Trip	Turbine Trip	ROH Pres Lo Lo	Step Back Req'd	Setback Req'd	Turbine Runback	Gen Breaker Opn
Hi Neutron Pwr	ROH Press Hi Hi	Coolant Flow Lo	Stm Gen Level Lo	PRZR Lvl Hi	Low Fwd Pwr Trip	Main BFP(s) Trip
Hi Neut Pwr LogR	ROH Press Hi	Main Stm Pres Hi	Stm Gen Level Hi	PRZR Lvl Lo	Loss 1 PHT Pump	Malfunction Active



	ROH1	RIH3	RIH1
P	9915	9351	9365
T	257.12	252.61	252.30

	RIH2	RIH4	ROH2
P	10605	10605	8674
T	252.53	252.45	256.79



PHT Main Circuit

Reactor Trip Turbine Trip

Reactor Neutron Pwr (%)	Reactor Thermal Pwr(%)	Turbine Pwr (%)	Main Stm Hdr Pressure (kPa)
2.28	5.57	0.00	4171.61

SG1 Lvl (m)	12.79
SG2 Lvl (m)	12.85
SG3 Lvl (m)	12.81
SG4 Lvl (m)	12.83

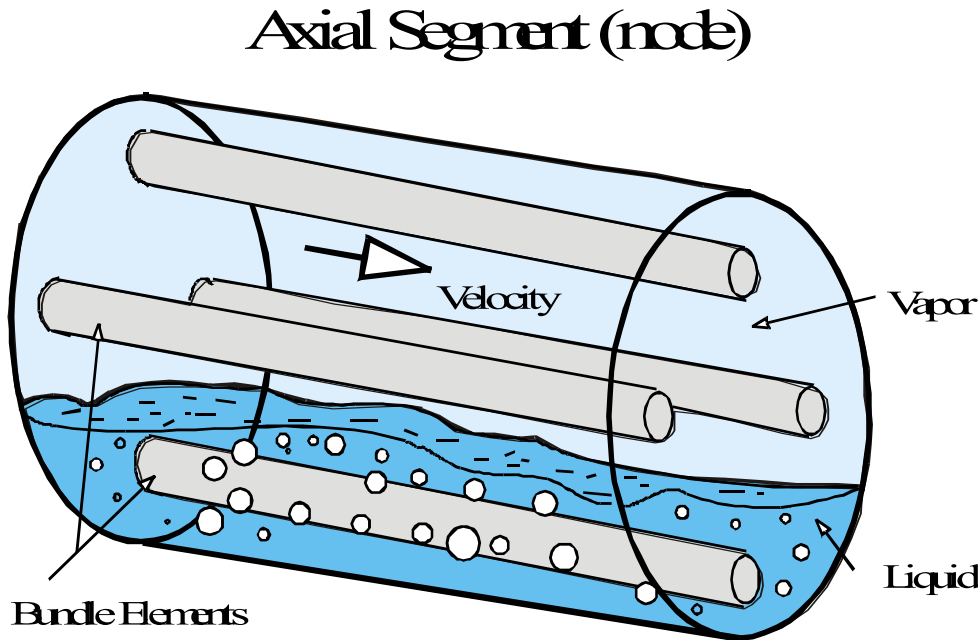
UPR Mode
 Alternate

Freeze	Run	Iterate
IC	Malf	Help

LOCA: Pipe Breaks PHTS

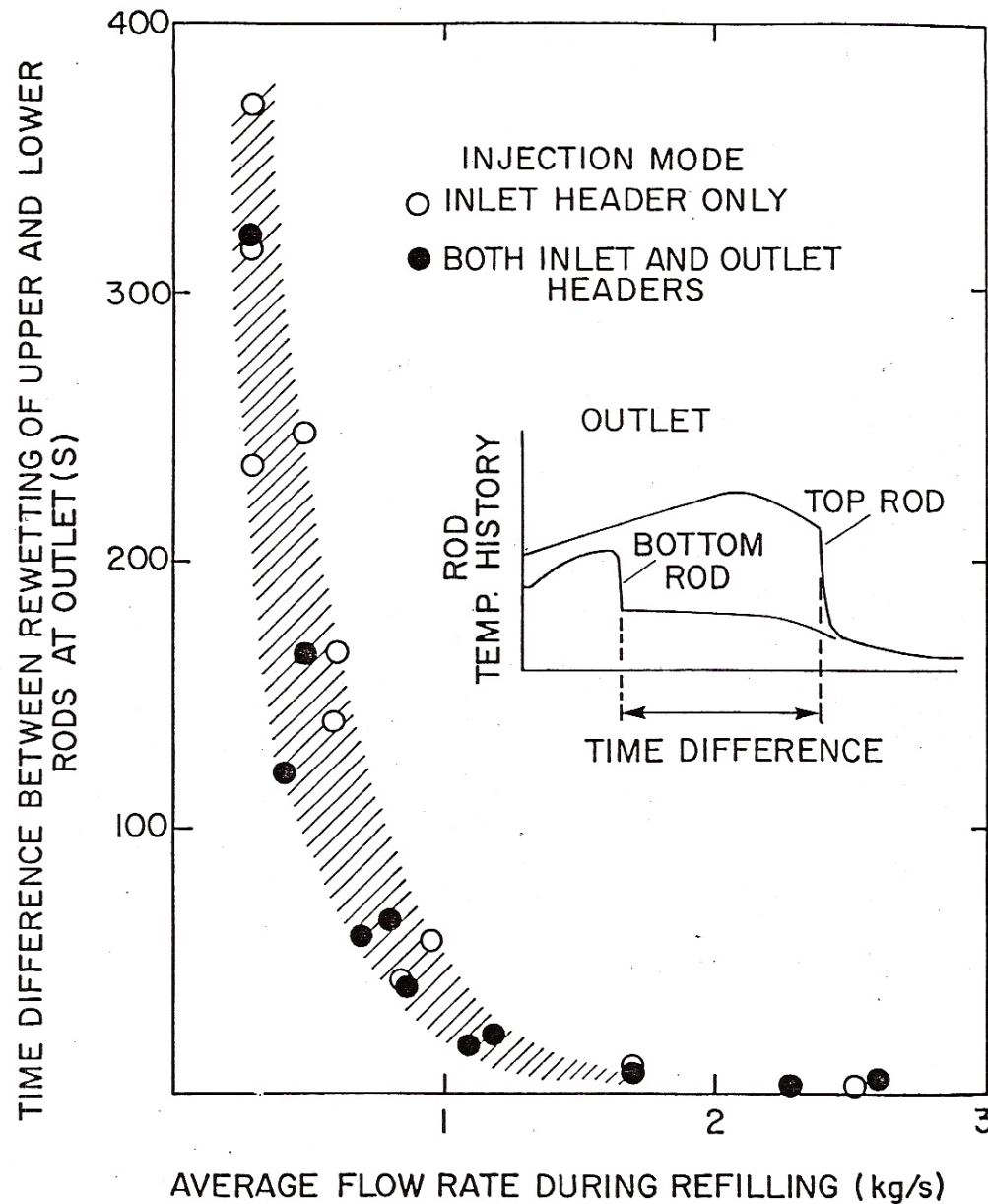
- Phase I: Blowdown
 - Heat transport system pressure drops from normal operating level to emergency core cooling injection pressure.
- Phase II: Transition ECC
 - Aka rewetting and refilling. The initial phase of emergency injection when the heat transport system is refilled and the fuel elements rewet (if dryout occurred)
- Phase III: Long Term ECC
 - Post accident recovery phase which removes decay heat

Thermohydraulic Model

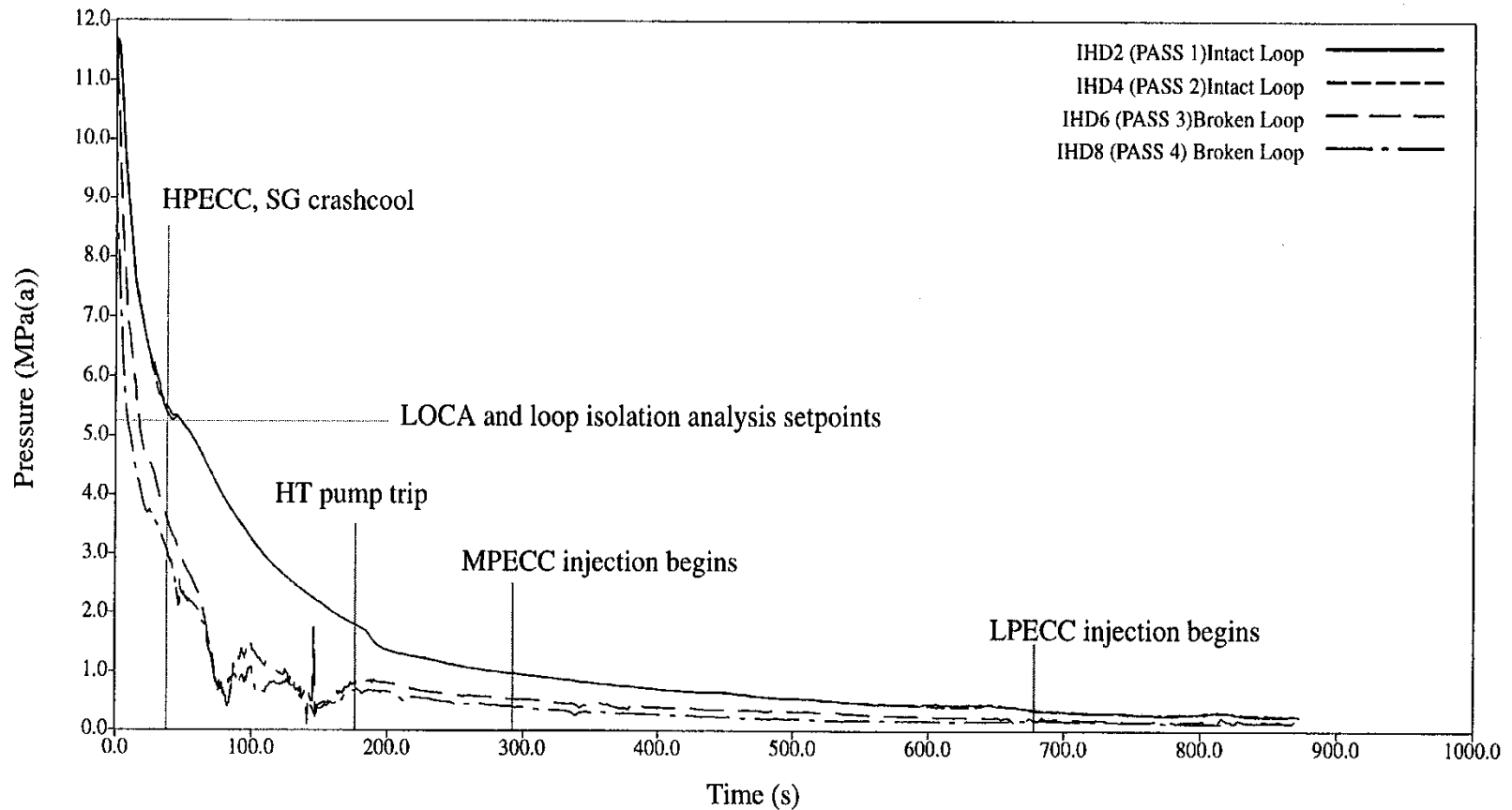


- **Non-equilibrium model**
 - 2-velocities,
 - 2-temperatures
 - 2-pressures
 - plus noncondensables
- **Flow regime dependent constitutive relations couple two-phase model**
- **Interfaces to other codes:**
 - Fuel Behaviour
 - Plant Control
 - Physics

Duration of flow stratification



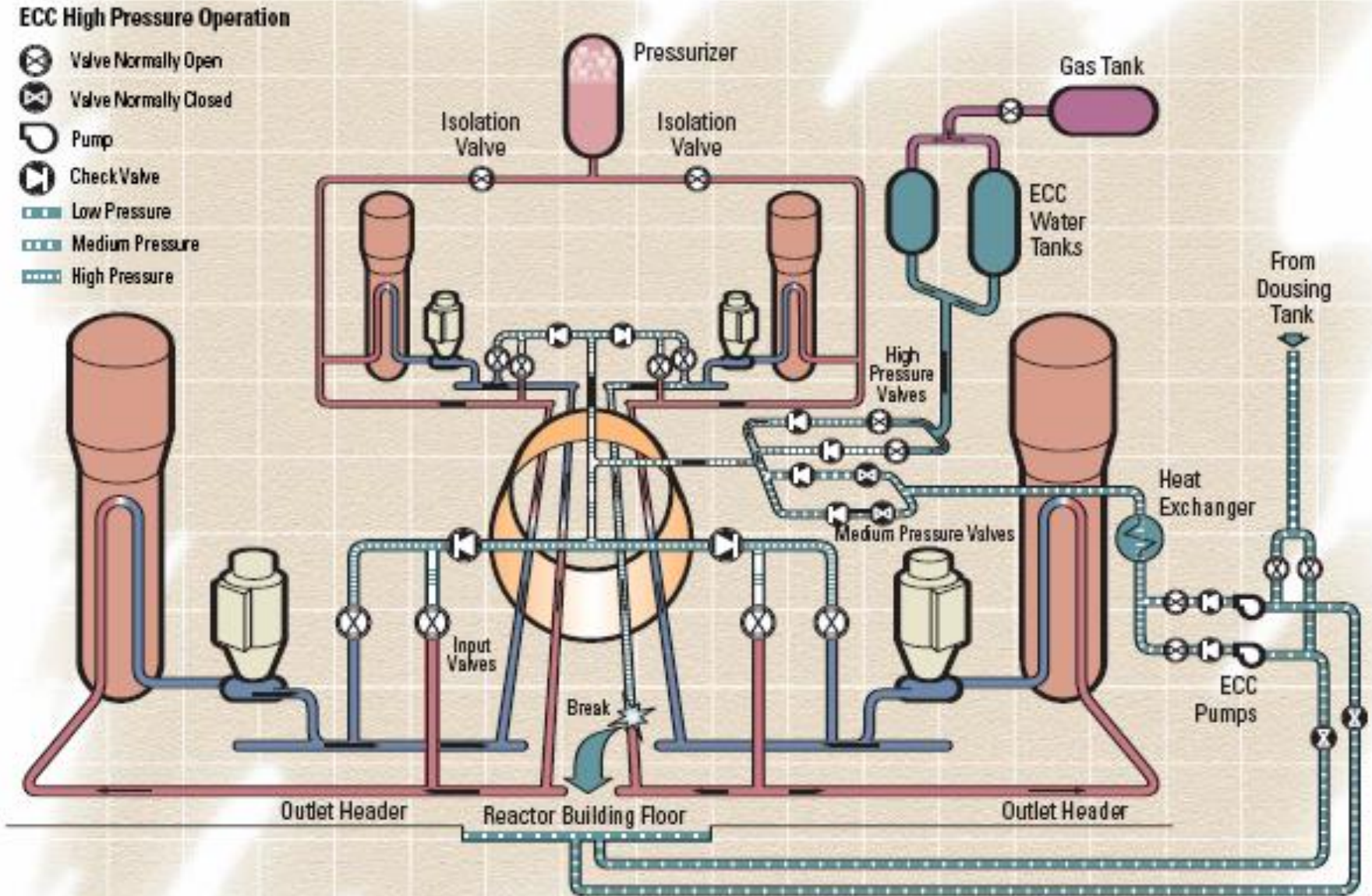
Time Scale of Large LOCA

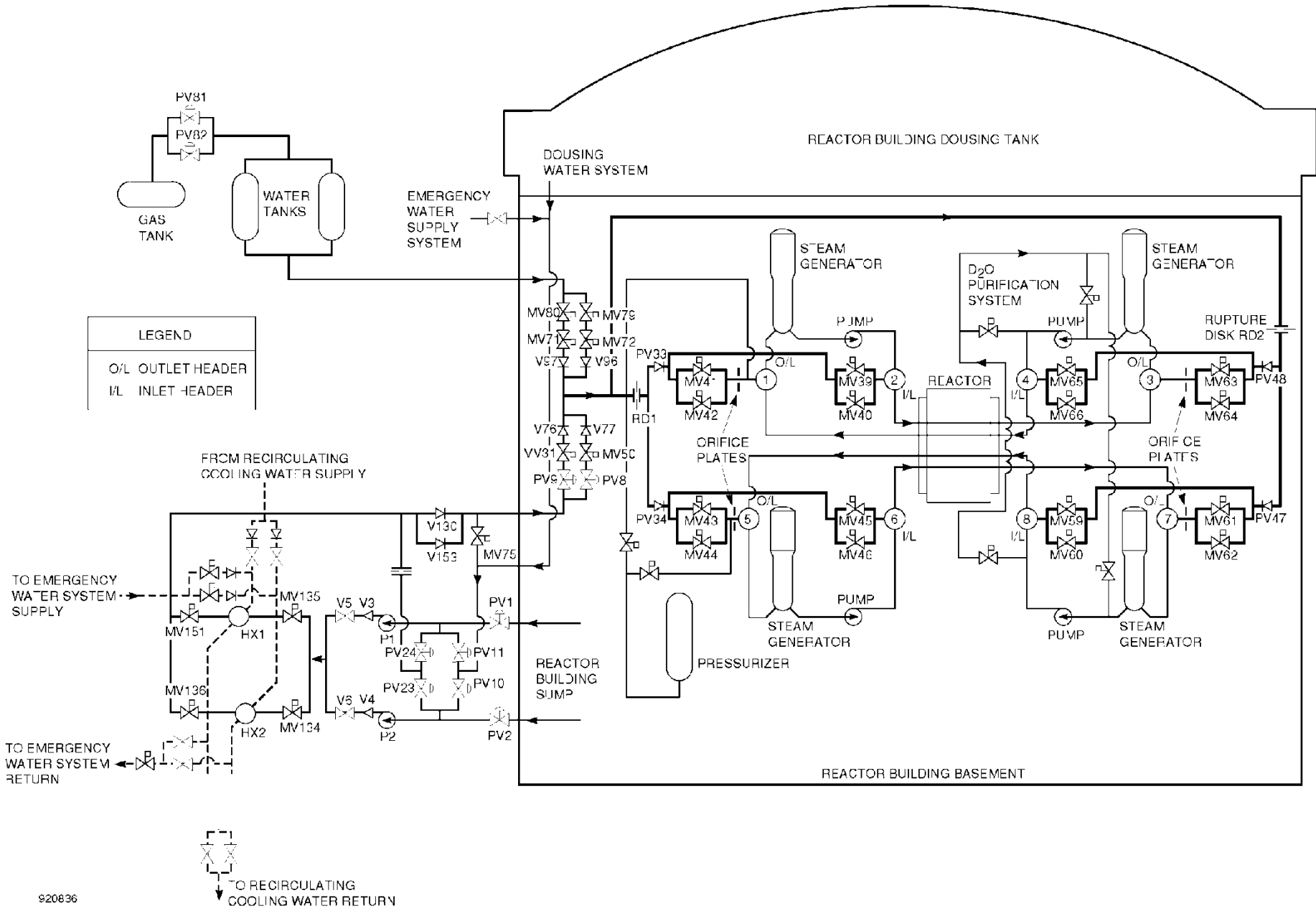


ECCS Design Functions

- Backup Coolant source for Heat Transport System following a LOCA
- Provide HT make up inventory
- Provide cooling to the reactor core
- Remove decay heat from reactor core
- Support Heat Transport Loops Isolation (C6)
- Support Steam generator Crash Cooldown
- Dousing spray to cool R/B and keep pressure below R/B design and add to sump mixture for long term recovery (C6)

Emergency Core Cooling





LEGEND	
O/L	OUTLET HEADER
I/L	INLET HEADER



Other Scenarios

- Valve Failures
- Loss of Boiler Feed Pumps
- Main Steam Line Break
- Loss of Regulation

- CANDU 9 Simulator
 - Simulates current CANDU/PHWR technology.
 - Good for overall understanding of plant operations.
- ACR-700 Simulator
 - Simulates future CANDU concepts. Includes more accident scenarios.