REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

Title	**Safety systems & accident mitigations**
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Table of Contents

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

Defence in Depth (DiD) concept

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Good first summary in INSAG-10 "Defence in Depth in Nuclear Safety 1996
- However, concept is older and was developed over time
- Recent update to incorporate lessons learned from Fukushima in IAEA TECDOC-1791 "Considerations on the Application of the IAEA Safety Requirements for the Design of Nuclear Power Plants" which became the Safety Guide "Assessment of the Safety Approach for Design Extension Conditions and Application of the Concept of Practical Elimination in the Design of Nuclear Power Plants" (DS 508, to be published this year)

Defence in Depth (DiD) concept

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

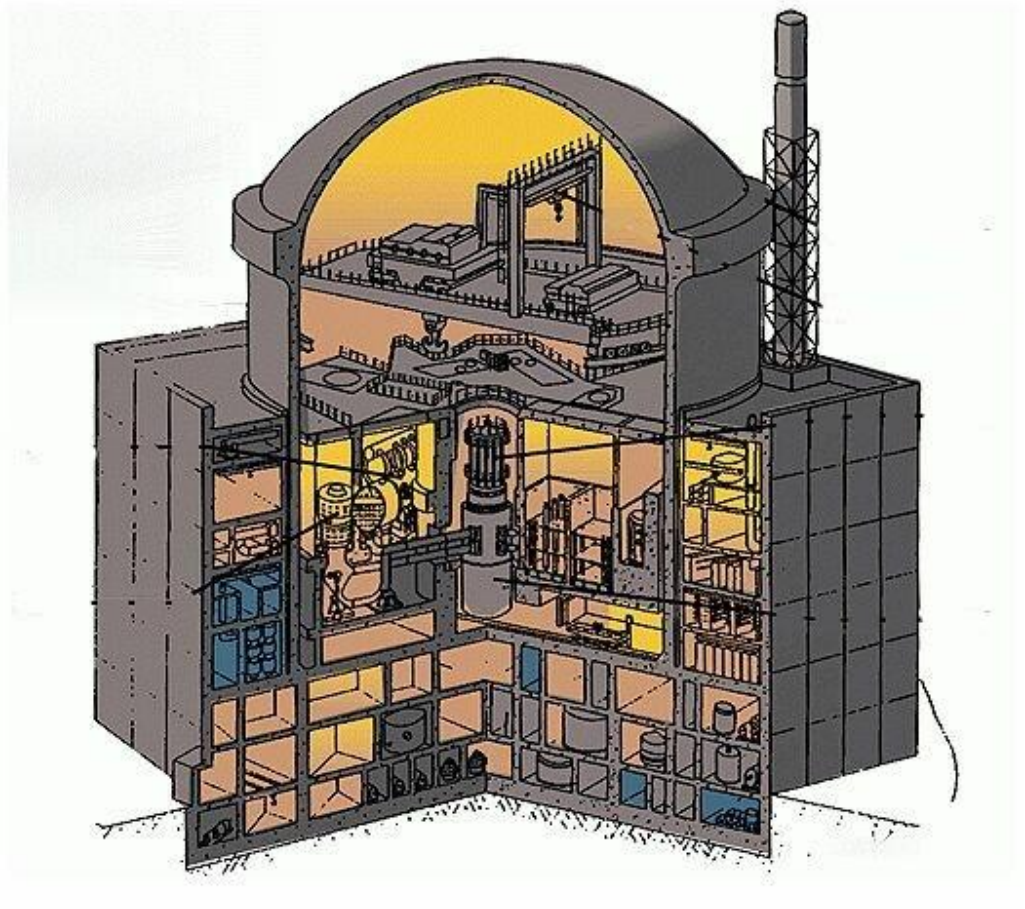
Level of defence Approach 1		Objective	Essential design means	Essential operational means	Level of defence Approach 2
Level 1		Prevention of abnormal operation and failures	Robust design and high quality in construction of normal operation systems, including monitoring and control systems	Operational limits and conditions and normal operating procedures	Level 1
Level 2		Control of abnormal operation and detection of failures	Limitation and protection systems and other surveillance features	Abnormal operating procedures and/or emergency operating procedures	Level 2
Level 3	3a	Control of design basis accidents	Safety systems	Emergency operating procedures	Level 3
	3b	Control of design extension conditions to prevent core melting	Safety features for design extension conditions without significant fuel degradation	Emergency operating procedures	4a
Level 4		Control of design extension conditions to mitigate the consequences of severe accidents	Safety features for design extension conditions with core melting[2] Technical support centre	Severe accident management guidelines	4b Level 4
Level 5		Mitigation of radiological consequences of significant releases of radioactive substance	On-site and off-site emergency response facilities	On-site and off-site emergency plans and procedures	Level 5

Safety Systems – Example VVER 1000

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- VVER1000 –
- Water cooled
- Water moderated
- Electrical power 1000MW
- Thermal power 3000MW

Водо-водяной энергетический реактор



Safety Systems – Example VVER 1000

Power operated relief valve
(G = 50kg/s)

Emergency gas removal system
(G = 20-25 kg/s)

Steam Generator
(P=6.27 MPa, T=278 °C, G=408kg/s)

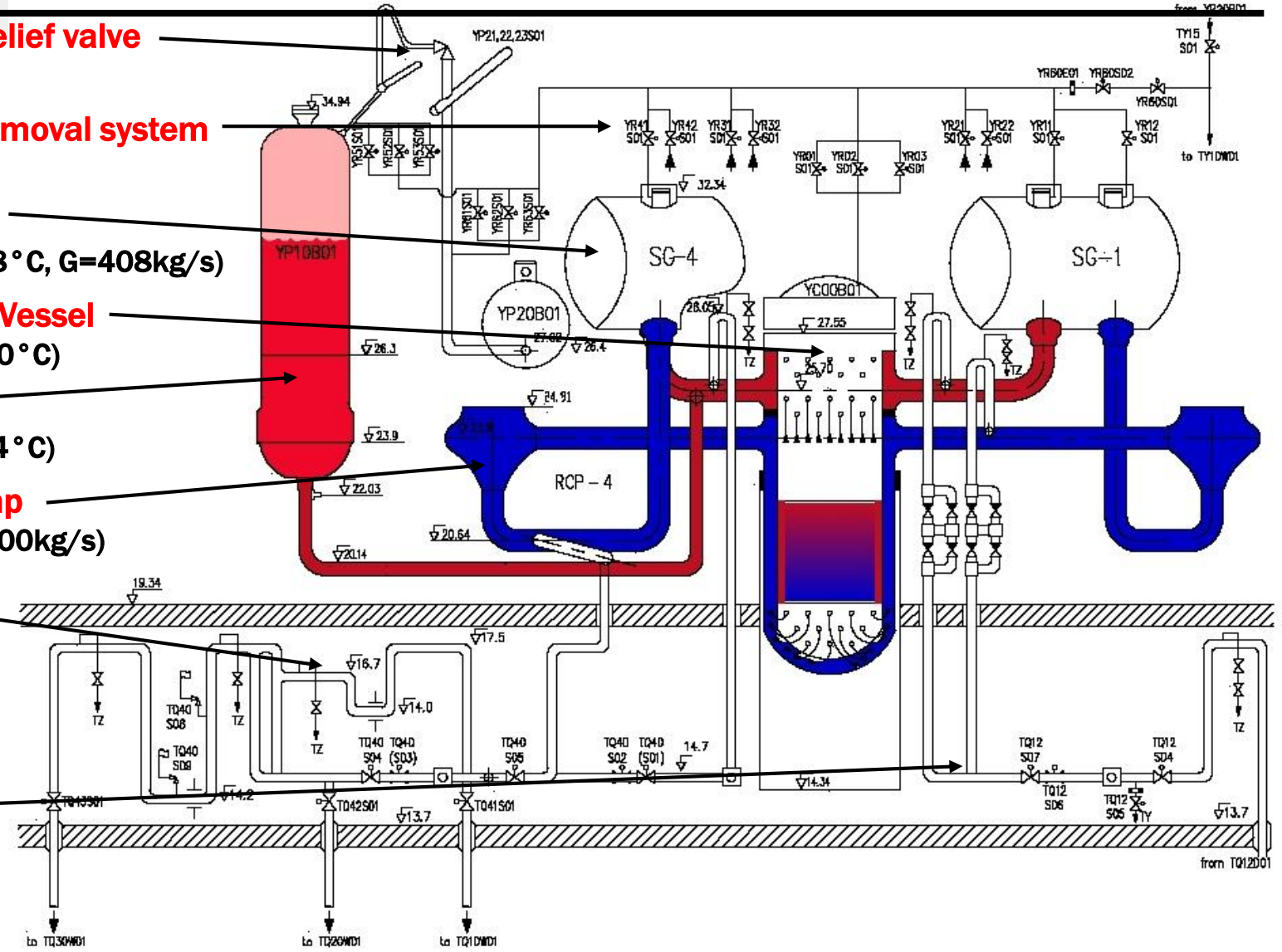
Reactor Pressure Vessel
(Ti=289.7 °C, To=320 °C)

Pressurizer
(P=15.7 MPa, T=344 °C)

Main coolant pump
(G=21200m3/h, 4400kg/s)

Chemical and volume control system

Low pressure injection system (one train)



Safety Systems – Reactor Protection System

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Power > 107%
- Low level in any of the steam generators
- Pressure above the core > 17.65
- Pressurizer level < 4.6 m
- Pressure in any of the steam lines > 7.848 MPa
- Temperature in any of hot legs 10 degree from saturation margin
- Temperature in any of the hot legs higher than 324 deg C
- Pressure above the core lower than 13.73 MPa and temp
- In any of the HLs > 260 deg C
- Pressure above the core lower than 14.51 MPa and Power above than 75% of nominal power
- Two out of four pumps tripped, power above than 75% with a delay of 6s
- All four pumps tripped, without delay

Safety Systems – Emergency core cooling system

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- High pressure boron injection system HHPIS (TQ4)
  - Three independent trains 3x100%, each consisting of
  - Tank (15m^3 40g/kg of boric acid in water)
  - Pump (injection up to 20MPa, flow rate at nominal pressure 6.3 m^3/h, 2 kg/s)
  - Pipes and valves – injection into loop 1,3 and 4 after MCP

- High pressure injection system HPIS (TQ3)
  - Three independent trains 3x100%, consisting of
  - Tank (15m^3 40g/kg of boric acid in water)
  - Pump (injection up to 10.9 MPa, flow rate at 8.8 MPa 130 m^3/h, 36 kg/s)
  - Pipes and valves
  - Once tanks are empty, pumps can take suction from the containment sump (500 m^3 water boric acid
  - Common injection lines with TQ4

Safety Systems – Emergency core cooling system

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Hydro accumulators (YT)
  - Four hydro accumulators (4x33%)
  - Boric acid concentration 16g/kg water
  - Activation pressure 5.9 MPa +/- 0.3 MPa
  - Pipes and Valves (four independent lines)
  - Injection point into upper plenum (2) and downcomer (2)
  - Water volume 50 m^3, Nitrogen volume 10 m^3
- Low pressure injection system LPIS (TQ2)
  - Three independent trains 3x100%, consistent of
  - Pump (injection up to 2.6 MPa, flow rate at 1 MPa 750 m^3/s, 210 kg/s)
  - Emergency cool-down heat exchanger
  - Pipes and valves
  - Suction from containment sump (500 m^3, 16g/kg of boric acid)
  - Two trains injection into UP and DC respectively, one into HL/CL of loop No 1

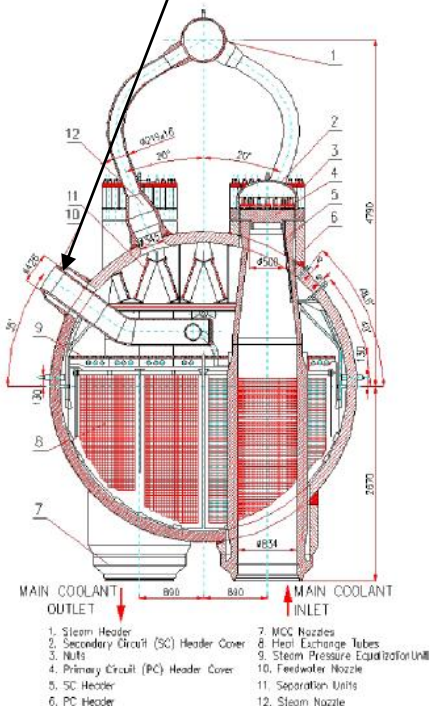
Safety Systems – Example VVER 1000

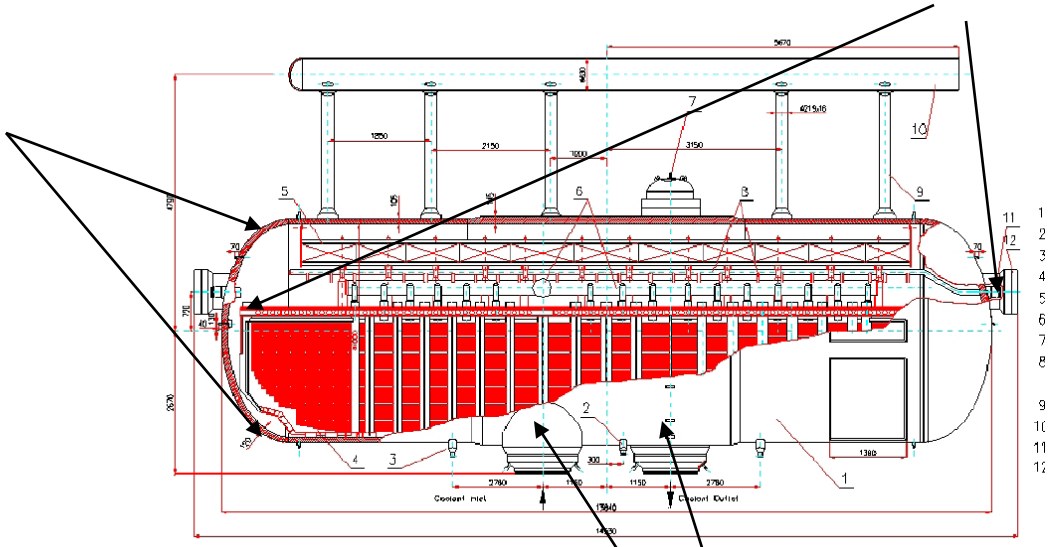
REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

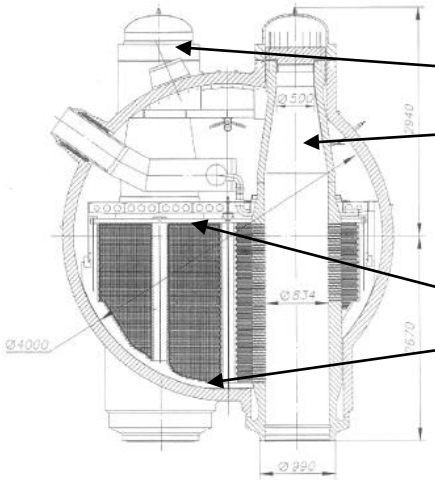
12m length

SG 4m diameter

Feed water inlet







Hot- and cold collector

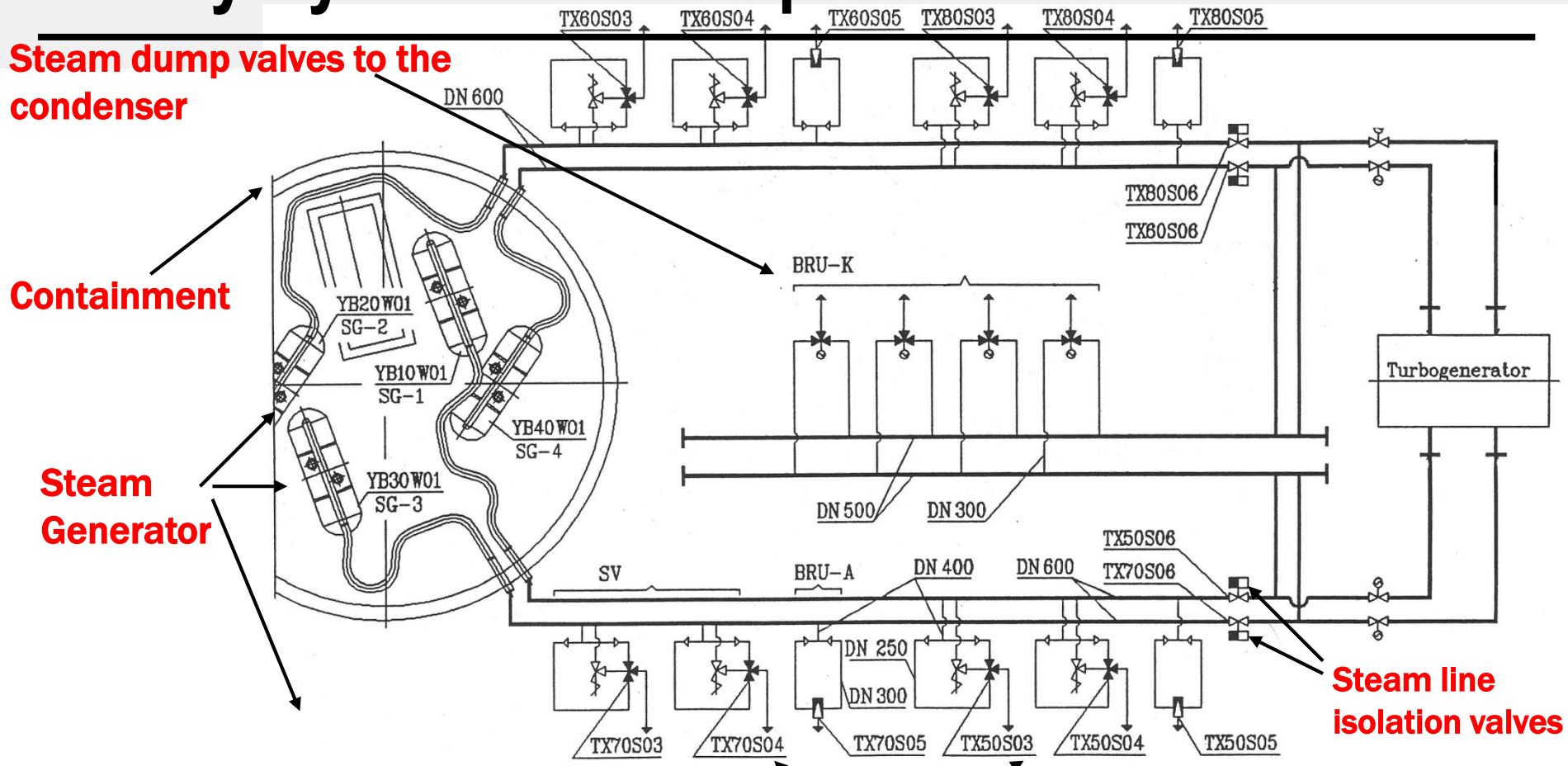
Horizontal SG “U” tubes

Safety Systems – Example VVER 1000

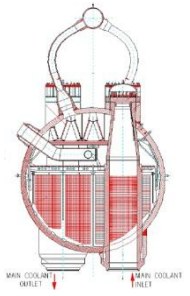
Steam dump valves to the condenser

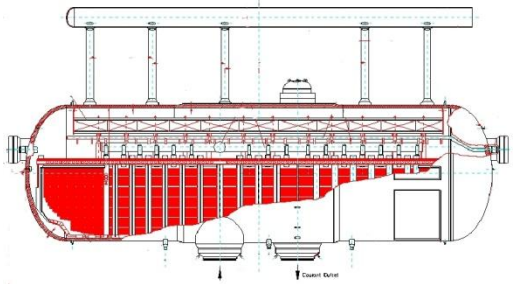
Containment

Steam Generator



Steam line isolation valves





Steam dump valves to the atmosphere

Safety Systems – Emergency Feed Water System

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Feed water system (from deaerator to SG)
  - Two feed water (deaerator) tanks (5.8 bar, saturated steam/water, roughly 160 °C, Volume 185 m^3 each)
  - Two booster pumps and main feed water pumps, capacity 950 kg/s (3750 m^3 /h) each
  - Two auxiliary feed water pumps (for startup- and shutdown), capacity 40 kg/s (150 m^3 /h) each
  - Pipes, heat exchanger and valves (volume of pipes roughly 170 m^3)
- Emergency feed water system
  - Three independent trains (3x100%) consisting of:
  - Feed water tank (atmospheric pressure, temperature 50°C)
  - Pump capacity 40 kg/s (150 m^3 /h)
  - Pipes and valves
  - Supply from diesel generator in case of loss of offsite power

Safety Systems – Summary

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Safety Systems: automated response of the plant in case of
  - Anticipated operational occurrences (AOO)
  - Design basis accidents (DBA)

- Main elements of Safety Systems:
  - Reactor Protection System (Instrumentation and Control)
  - Emergency core cooling system
  - Other emergency systems – Emergency Feedwater System, Primary System Safety Valves, Secondary System Safety Valves, Containment Spray System, …

Thank you!

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