

111 - 4/7/77

NATURAL CIRCULATION

Objective

Keep reactor core cool by natural circulation mode.

Assumptions

1. Heat removal on secondary side with or without power.
2. Pump seal can be kept at temperature to avoid damage without seal flow.
3. Makeup is available to compensate any leakage or loss from primary system.
4. Prior to natural circulation, plant is degassed enough to avoid gas bubble formation which can block circulation at selected operating pressure.

Alternates

A. All liquid system

1. Natural circulation at 1500 psig
2. Natural circulation at current pressure
3. Natural circulation at less than current pressure

B. Boiling System

1. Closed system
2. Open system (feed and bleed at reduced flow rate, being investigated by others)

Control and Instrumentation

A. Pressure maintenance

1. High pressure maintained by pressurizer heater
2. High pressure maintained by high pressure pump
3. Pressure below current pressure maintained by accumulation
4. Pressure below current pressure maintained by low pressure pump

B. Makeup and Boron Control

1. At high pressure, high pressure pump
2. At reduced pressure, low pressure pump

C. Degassing

1. Pressurizer vents
2. Letdown system
3. Add or open vent to top of steam generator

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D. Instrumentation

1. Essential

Assurance of adequate water ^{inventory} reverting in primary loop.

a) Solid system - need one in order of preference

pressure measurement
pump discharge head (charging rate useful)
pressurizer level

b) Boiling system

core temperature
pump flow and pressure (?)

2. Desirable

a) Removal of heat on secondary side

core outlet temperature
steam generator temperature

b) Degree of gas in primary system

employ present method of measurement
gas balance with time

Advantages

Natural circulation

Minimum operating equipment
Operation without offsite power
Minimum instrumentation
Inherent self regulation (temperature up, more flow)

All liquid

Absolute minimum instrumentation
Verified in PWR operation
Greater assurance of adequate inventory
Better predictability
No boron boiloff
Less possibility of flow instability

Boilings

Low pressure
Greater flow
Reduced makeup

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High Pressure - current and above up to 1500 psi

minimum gas problem
margin above local boiling in core

Low Pressure - below current

lower leakage
easier and more makeup options

Disadvantages

Natural Circulation

Uncertainty of gross reactor core cooling and local core coolings
Uncertainty in gas effect
Greater susceptibility to loss of pressure and assurance of closing vent valves

All liquid

Greater susceptibility to gas

Boiling.

See advantages of all liquid

High Pressure

Greater makeup and control
Greater impact on fuel cladding in event of sudden depressurization
leakage to steam generator

Low Pressure

~~More~~ gas problem
Less margin to boiling

Recommendations

1. Natural circulation use is recommended only when recirculation pumps not available
2. All liquid natural circulation preferred over boiling and is recommended. Boiling mode should be used only as a last resort.
3. Recommend current pressure to minimize impact on potential brittle cladding of fuel
4. Recommend steam generator fuel and as cold as possible
5. Recommend refill accumulator and put them on. Accumulator pressure high (recognize disadvantage in event of big leak)
6. Hold pressure with pressurizer heater, no vent in pressurizer and degas through letdown. (try to accelerate degas)
7. Keep all seals running as long as seal water temperature is below cold leg temperature except when pumps are permanently non operable.
8. Backup to pressurizer is high pressure pumps.
9. Recommend following calculations to verify feasibility

(a) do calculation with B loop not available due to potential leak

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- (b) evaluate range of pressure to verify feasibility at different pressures
 - (c) study sensitivity to core pressure drop
 - (d) evaluate sensitivity to all recirculation and injection to pump seal temperature
 - (e) calculate tolerable gas level at various pressures to avoid gas blockage.
 - (f) calculate to see if this system can be depressurized and cooled down over long period of time to cold shutdown mode through letdown line g/evaluate parallel loop opposing natural circulation
 - (g) *evaluate flow through letdown that could oppose natural circulation*
10. Develop contingency procedure for loss of pressure
11. Assure adequate maintenance of high pressure pumps and low pressure pumps.

Prerequisites

1. Provide secondary cooling both with and without offsite power
2. Continue to reduce gas level and maintain below level which will give ~~to~~ difficulty at set accumulator pressure.

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