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Stability Solution for Inherently Safe ESBWR Operation

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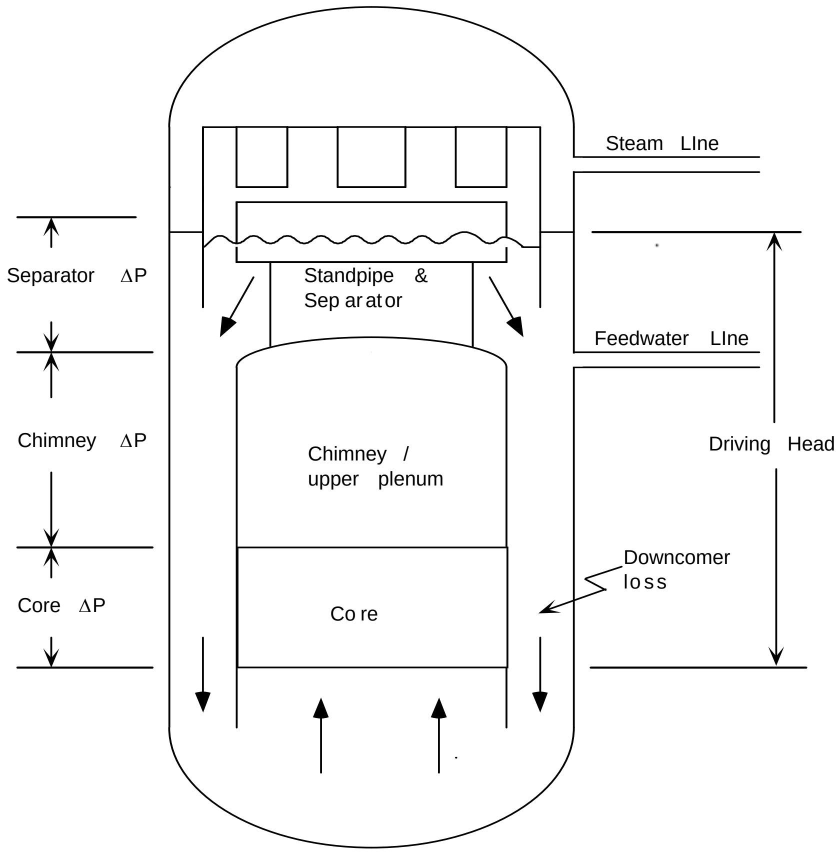
I. Major Differences among GE BWR cores

Parameter	BWR/4	BWR/6	ABWR	ESBWR
Power (MWt/MWe)	3293/1098	3900/1360	3926/1350	4500/1550
Vessel height/dia (m)	21.9/6.4	21.8/6.4	21.1/7.1	27.7/7.1
Fuel bundles, number	764	800	872	1132
Active fuel height (m)	3.7	3.7	3.7	3.0
Power density (kW/L)	50	54.2	51	54
Recirculation pumps	2 (external)	2 (external)	10 (internal)	0
Number/type of CRDs	185/LP	193/LP	205/FM	269/FM
Safety system pumps	9	9	18	0
Safety diesel generators	2	3	3	0
Alternate shutdown	2 SLC pumps	2 SLC pumps	2 SLC pumps	2 SLC accumulators
Control and instrumentation	Analog single channel	Analog single channel	Digital multiple channel	Digital multiple channel
Core damage (freq./yr)	10^{-5}	10^{-6}	2×10^{-7}	3×10^{-8}
Safety bldg vol (m^3/MWe)	120	170	180	130

II. ESBWR Introduction

- Natural circulation in ESBWR is designed with an unrestricted downcomer, enhanced through optimization on the chimney height, active core length, and separator configurations.
- Utilization of natural circulation and passive safety systems in ESBWR design simplifies reactor system designs, reduces cost, and provides a reliable stability solution for inherently safe operation.



III. Stability Introduction

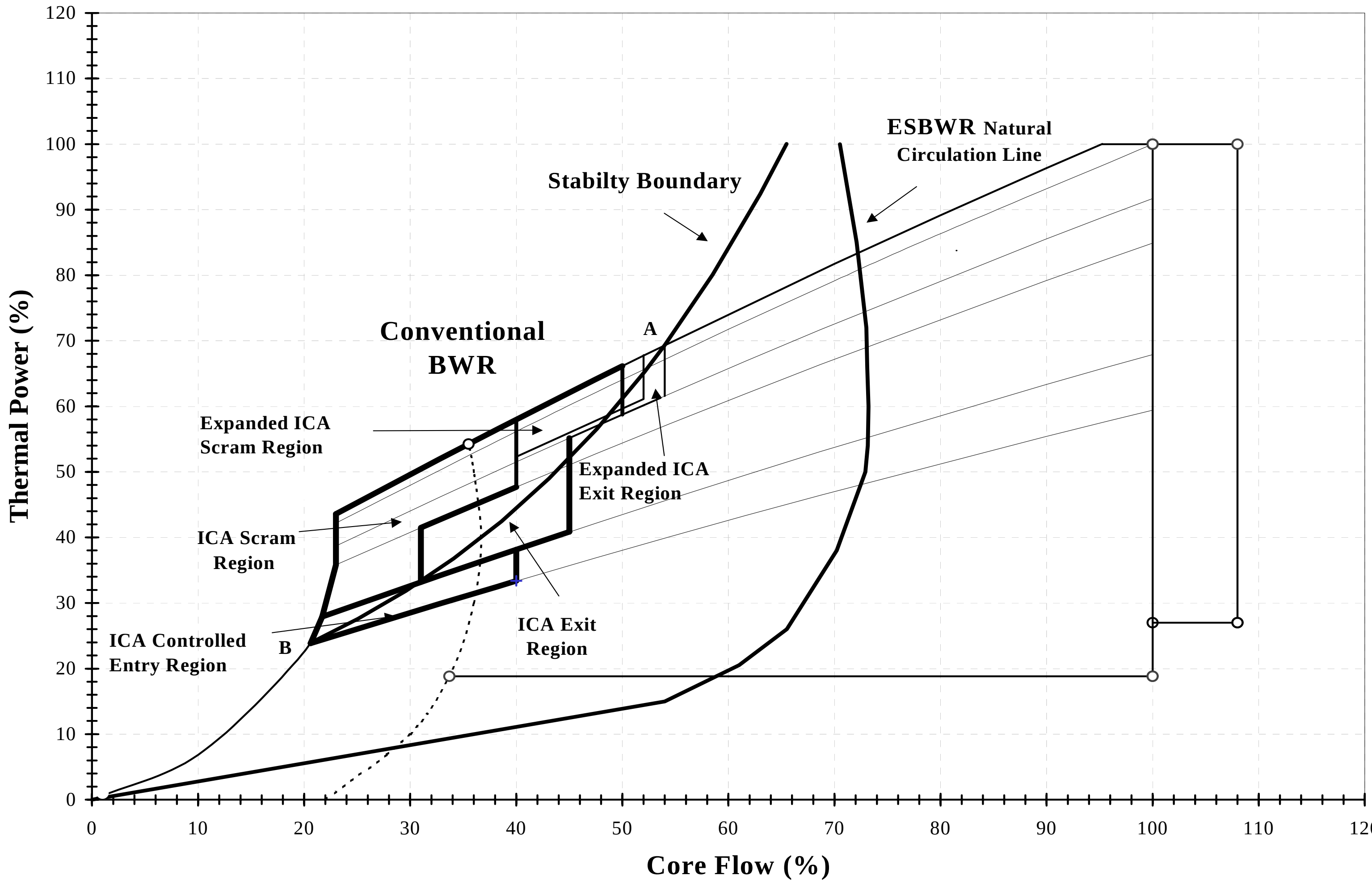
- Stability protection goal – Fuel integrity
- Conventional BWR instability -- during startup and after all recirculation pumps trip during normal operation.
- BWR power oscillations -- inside an area with core flow close to natural circulation line and core power above 70% rod-line power.
- Core-wide oscillation -- dominant mode of power oscillation and associated with excited fundamental mode of neutron flux in a BWR core; core-wide mode bundle power oscillations in entire core are in phase.

- Regional oscillation -- important in a large BWR core and associated with the excited 1st harmonic mode of neutron flux; regional mode bundle power oscillations in a half core are out of phase to corresponding regional mode bundle power oscillations in opposite half core.
- BWR instabilities can be analyzed in terms of core and bundle (or channel) power decay ratios (DR).
- Stability DR acceptance criterion must be much less than one (e.g., 0.80) in order to incorporate method uncertainty and adequate safety margin.

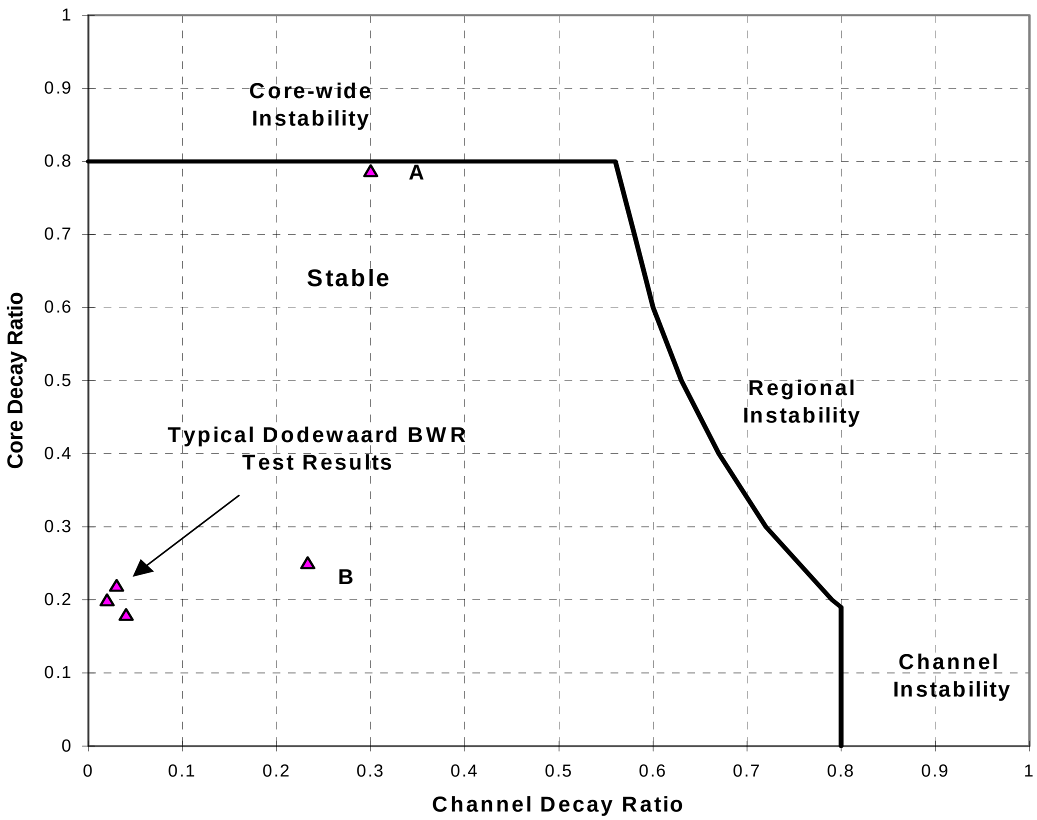
IV. ESBWR Stability Solution

- BWR Owners Group recommended guidelines on Interim Corrective Actions (ICA) Regions -- emphasize instability prevention but are based on industry experience.
- Three ICA operating regions: Scram, Exit, and Controlled Entry Regions, to be validated using Core and channel DRs.
- Core and channel DRs are computed using ODYSY, a frequency-domain stability analysis computer program with physical parameters generated from results of PANACEA 3D BWR simulator calculations.
- Bounding ICA Regions: expanded ICA Regions of a conventional BWR for minimum feedwater operation.

Comparison between ESBWR and Conventional BWR Power/Flow Maps



Stability Decay Ratio Acceptance Criterion



- A stability boundary is established by connecting the two bounding state points A and B of expanded ICA Exit/Controlled Entry Region boundary with a fitting function and by extending boundary to 100% rated power.
- Stability boundary plus a conservative (at least 5%) core flow margin at 100% rated power can be used to design an inherently safe ESBWR with a sufficiently high natural circulation flow line.
- Design of a high flow natural circulation system in an ESBWR can be achieved by:

    1) Replacing a restricted downcomer with an unrestricted downcomer (natural circulation core flow can be increased as much as 100%; from roughly 23% rated to roughly 46% rated),

    2) Optimizing chimney height, active core length, and separator configurations (natural circulation is further increased from 46% rated to over 70% rated with a flow margin at least 5% higher than stability boundary flow at 100% rated power).

V. Conclusion

- Conceptually reliable stability solution for inherently safe ESBWR operation has been developed by establishing a sufficiently high natural circulation flow line, which has a core flow margin at least 5% higher than the stability boundary flow at 100% rated power of a conventional BWR
- Design of a high flow natural circulation system in an ESBWR can be achieved by replacing a restricted downcomer with an unrestricted downcomer and by optimizing the chimney height, active core length, and separator configurations.
- ESBWR stability solution eliminates instability risk in reactor operation and may be considered as an ideal case in risk management