WSRC-RP-89-1438

PARALLEL CHANNEL FLOW EXCURSIONS (U)

by

Barry S. Johnston
Westinghouse Savannah River Company
Savannah River Laboratory
Aiken, SC 29808

An invited paper proposed for presentation at
VPI in Blacksburg, VA on
January 22, 1990
(WSRC 1989-1990 Traveling Lecturer Program)

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Among the many known types of vapor–liquid flow instability is the flow excursion which may occur in heated parallel channels. Under certain conditions, the pressure drop requirement in a heated channel may increase with decreases in flow rate. This leads to an excursive reduction in flow. For channels heated by electricity or nuclear fission, this can result in overheating and damage to the channel. In the design of any parallel channel device, flow excursion limits should be established.

After a review of parallel channel behavior and analysis, a conservative criterion will be proposed for avoiding excursions. In support of this criterion, recent experimental work on boiling in downward flow will be described.

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Parallel Channel Flow Excursions

Parallel Channel Flow Excursions

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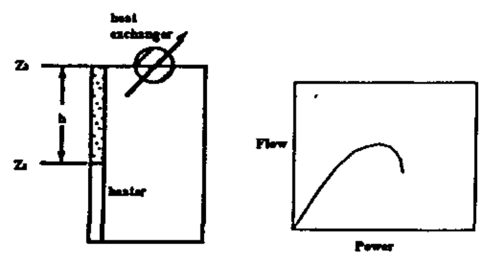
2-phase Natural Circulation



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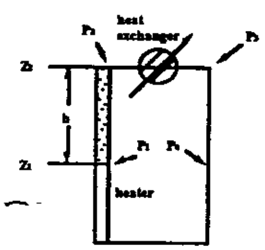
2-phase Natural Circulation



$$P_1 - P_2 = \int_0^h -\left(\frac{dP}{dz}\right)dz$$

$$P_2 - P_3 = k_2\frac{G^2}{\rho_m}$$

$$P_3 - P_4 = k_3\frac{G^2}{\rho_l} - \rho_l g h$$

$$P_4 - P_1 = k_4\frac{G^2}{\rho_l}$$

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Simple Analysis

$$\int_0^h -\left(\frac{dP}{dz}\right)dz = \rho_l g h - k_{2\phi}\frac{G^2}{\rho_m}$$

$$\rho_m = \left\{\frac{x}{\rho_g} + \frac{(1-x)}{\rho_l}\right\}^{-1}$$ mixture density

$$x = \frac{p(z - z_1)D}{GA\lambda}$$ quality

$$\frac{dP}{dz} = \left(\frac{dP}{dz}\right)_f + \left(\frac{dP}{dz}\right)_a + \left(\frac{dP}{dz}\right)_g$$ pressure gradient

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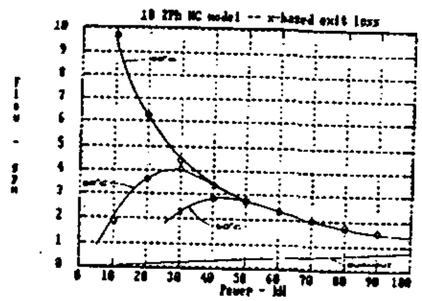
Model Predictions



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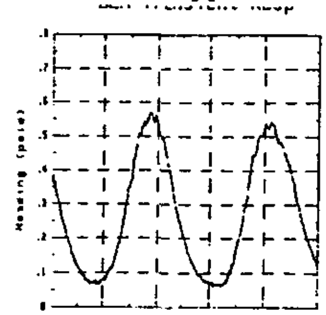
What Happened...



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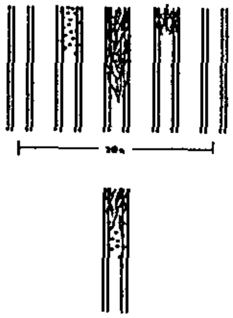
Flow Patterns



Instabilities in Vapor-Liquid Flow

Dynamic - Transient Analysis Required

- Density wave
- Pressure wave
- Thermal nonequilibrium

Static - Steady Description Sufficient

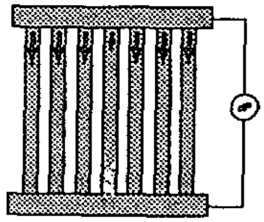
- Flow regime transitions
- *Burnout and quenching*
- Flow excursions

Outline

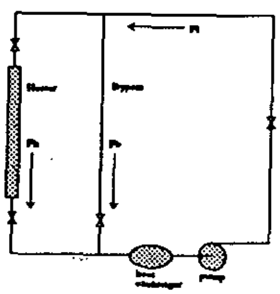
- Review background information on flow *excursions in parallel channels*
- Propose a conservative criterion for avoiding their occurrence
- *Describe results* of an experimental study on boiling in downward flow

Background -- 1

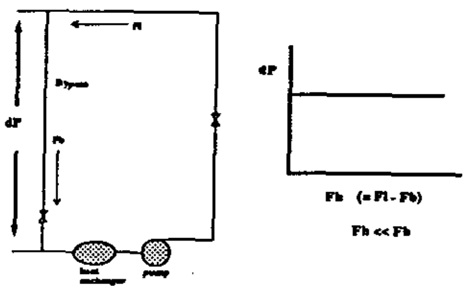
Flow excursions in parallel channels when driving pressure is reduced.



Parallel Channel Flow Loop



Supply Curve



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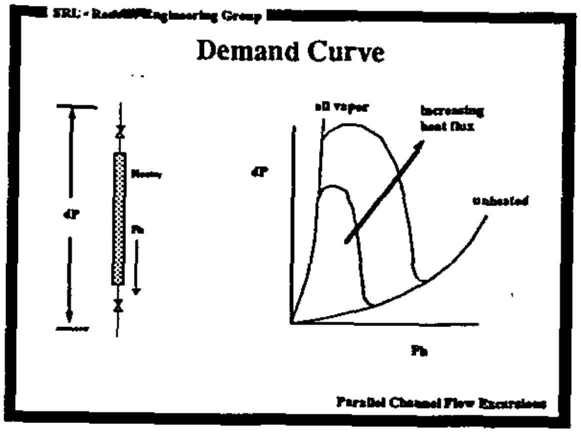

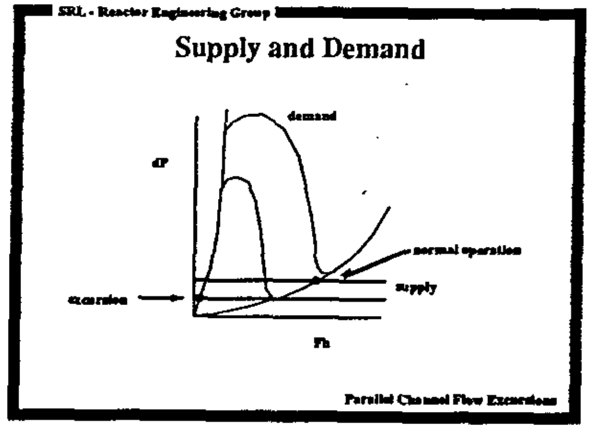

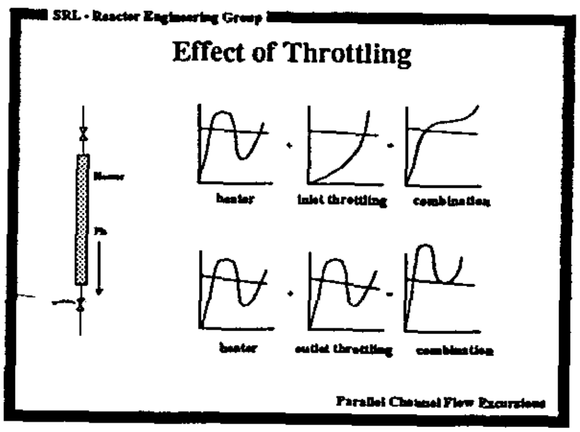

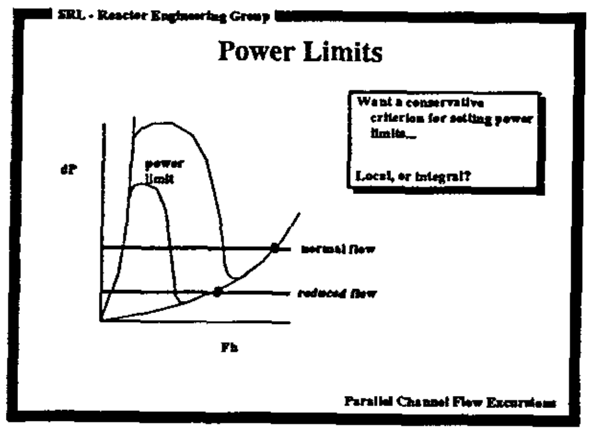

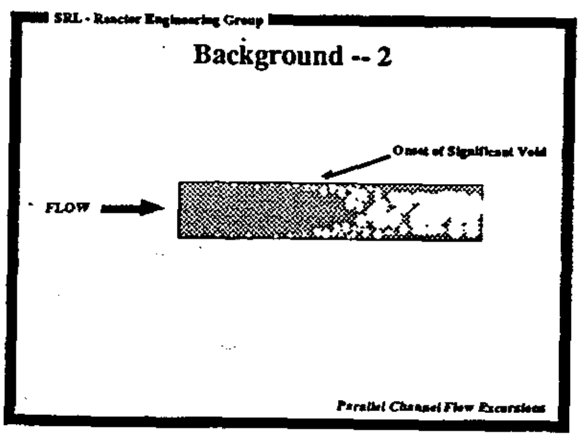

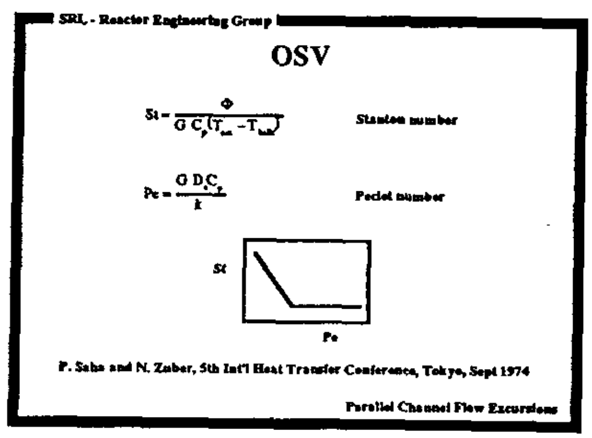

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Proposal

- Set power limits to avoid flow excursions
- Use OSV as an indicator of flow excursions
- Get conditions for OSV from accepted correlations
- Calculate these conditions with thermo-hydraulic code

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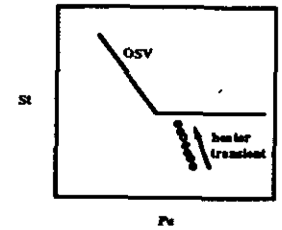
OSV in Limits Calculation



But does OSV precede the minimum?

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Experimental Study

- Generate demand curves for steady flow in a heated annulus
- Cover a range of heat flux and inlet *temperature*
- Compare the demand curve minima to criteria for OSV

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Findings

- *For conditions studied*, OSV is a good predictor of flow excursion

but...

- OSV correlation needs to be modified for downward flow at low velocity

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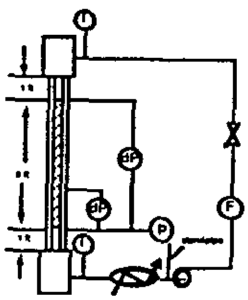
Equipment

DI = 1.0 in, heated
Do = 1.5 in
L/De = 144
no ribs

TI = 25 - 90 C
F = 1 - 15 gpm
P = 20 psia
q = 0 - 87 kBTU/hft2



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Data

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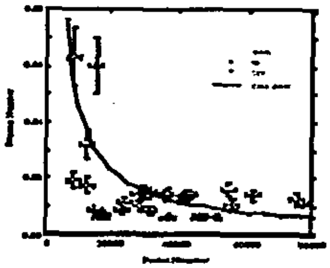
Results



In Conclusion

- **Expect FE at minimum of demand curve.**
- **Use OSV as conservative predictor.**

however...

- **Need a special OSV correlation for restricted geometry?**
- **Is the steady analysis appropriate for rapid change in pressure?**