Validation & Verification: Fluent/RELAP5-3D© Coupled Code

Richard Schultz
William Wieselquist

2001 RELAP5 User's Seminar
Sun Valley, ID
September 2001

INEEL
Idaho National Engineering & Environmental Laboratory

The Fluent RELAP5-3D Coupling..

- *What we're doing*
- *Why we're doing it*
- *How we'll make sure it is OK*
- *Our future plans*

Overall Perspective…

- ***DOE's Generation IV Roadmap effort is a part of national strategy to gain public acceptance of nuclear power, and to encourage vendors and utilities to consider nuclear power as an option again.***

- ***The roadmap program has received nearly a hundred reactor plant designs to evaluate including water-cooled, gas-cooled, liquid-metal cooled and other concepts.***

- ***With the process underway to winnow the concept number down to 6 or so, a parallel effort is underway to evaluate our infrastructure:***
    - ***Analytical tools***
    - ***Regulatory & licensing practices…etc.***

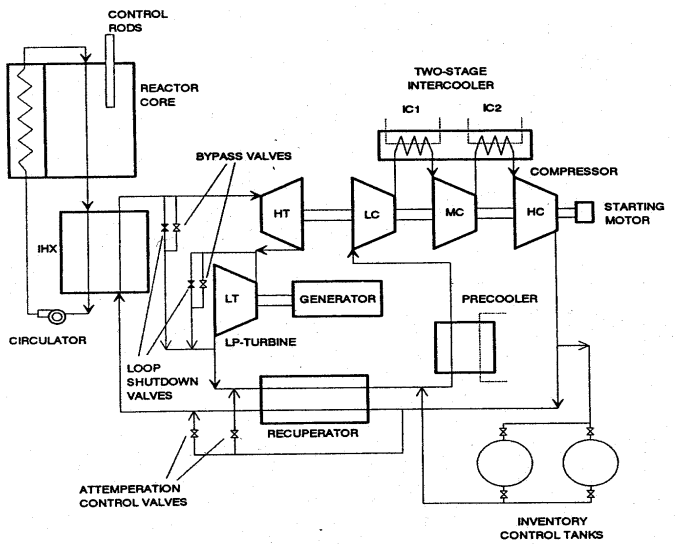
Analytical Tools for Advanced Systems

- ***Further development is needed—particularly for working fluids other than water.***

- ***Recent developments—particularly in the CFD world—need to be considered and used if advantageous.***

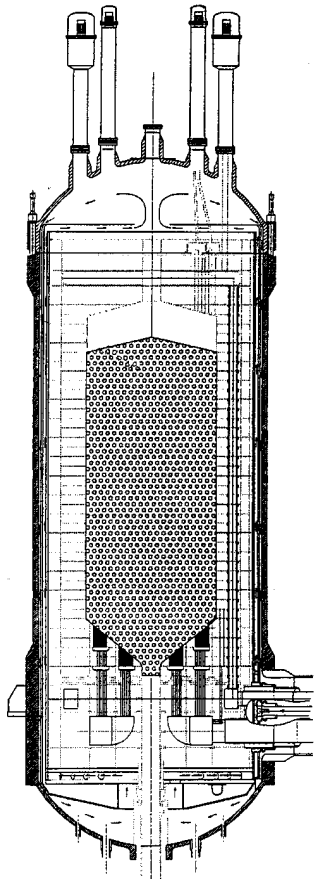
Fluent & RELAP5-3D Are Being Coupled to…

- *Enable an entire system to be modeled using 1-D features of RELAP5*
- *While modeling some sections of systems in great detail using Fluent*



Development Underway Using Gas-Cooled Reactors as Basis

- *PBMR is focus*
- *Working fluid: helium*
- *Work to couple codes is ongoing by Walt Weaver. He will use PVM & same techniques described in papers by himself & Aumiller, et al.*



Once Coupling Is Completed…

- ***Validation & Verfication* will be used to:***
  - ***Check that Fluent and RELAP5/ATHENA have been coupled properly***
  - ***Examine the strengths and weaknesses of the coupled code***
- ***Important features that will be examined:***
  - ***Behavior at interfaces between Fluent and RELAP5/ATHENA***
  - ***Using neutronics with Fluent***
  - ***Modeling flow through packed beds***

****"Verification" is solving the equations right while "validation" is solving the right equations.***

A Portion of V&V Matrix

Experiment or Case	Working Fluid	Phenomena of Interest or Objective	PBMR Region of Interest	Reference
Turbulent flow in pipe section	Helium	Mesh coupling between Fluent & RELAP5	PBMR inlet pipe	Streeter, V., 1961
Turbulent flow in backward facing step with heat transfer	Air	1. Mesh coupling between Fluent & RELAP5 2. Flow profiile calculated by Fluent	PBMR inlet pipe and inlet plenum	Baughn, J. W., et al, 1984
Neutronics-fluid Ineraction in core region(LWR)	Water	RELAP5/ATHENA neutronics coupling with Fluent mesh	Core; although this data set is for geometry unlike PBMR,	Bovalini, R., et al, 2001 (used by permission of Y. Hassan)
Countercurrent two-phase flow	Water & SF_6	1. Mesh coupling between Fluent & RELAP5 2. Flow behavior calculated by Fluent	Potential pipe break and countercurrent flow at break when not choked	Stewart, W. T., et al, 1992.
Flow through packed-bed	Air	Fluent's capability of calculating flow through portion of packed bed.	Core	Calis, H. P., et al, 2001.

Data (V&V Cases) Not Always Ideal

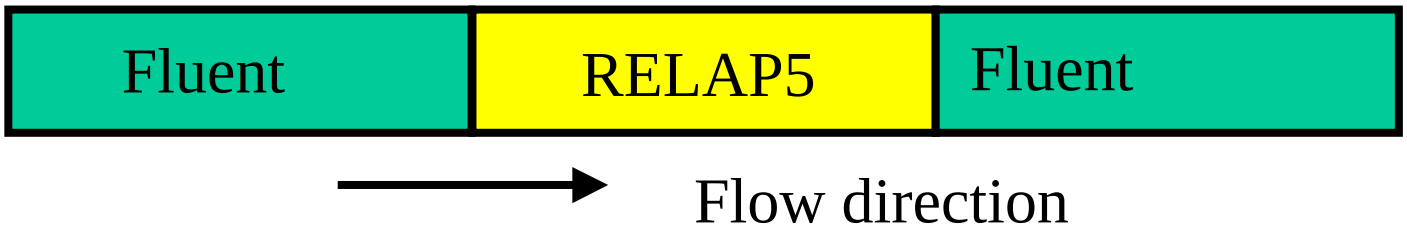
- German data (AVR & THTR at Uentrop-Schmehausen) not available to public
- Currently:
  - No neutronics-fluid interaction data for PBMR core—but Fluent can't model a packed-bed very well yet anyway.
  - Haven't found countercurrent flow data more applicable (for CFD code) than Stewart, et al, 1992
- Working fluid and scaling usually not desirable.

References

- **Streeter, V. L., *Fluids Handbook,* McGraw-Hill, 1961.**
- **Baughn, J., M. A. Hoffman, R. K. Takahashi, and B. E. Launder, 1984, "Local Heat Transfer Downstream of an Abrupt Expansion in a Circular Channel with Constant Wall Heat Flux," *Journal of Heat Transfer, Vol. 106:* 789-796, November 1984.**
- **Bovalini, R., F. D'Auria, G. M. Galassi, A. Spadoni, & Y. Hassan, 2001, "TMI-1 MSLB Coupled 3-D Neutronics/Thermalhydraulics Analysis: Application of RELAP5-3D and Comparison with Different Codes," *2001 RELAP5 User's Seminar,* Sun Valley, ID., September.**
- **Stewart, W. A., A. T. Pieczynski, & V. Srinivas, 1992, *Natural Circulation Experiments for PWR High Pressure Accidents,* EPRI Project No. RP2177-5.**
- **Calis, H. P. A., J. Nijenhuis, B. C. Paikert, F. M. Dautzenberg, & C. M. van den Bleek, "CFD Modeling and Experimental Validation of Pressure Drop and Flow Profile in a Novel Structured Catalytic Reactor Packing," *Chemical Engineering Science,* (56), 1713-1720,**

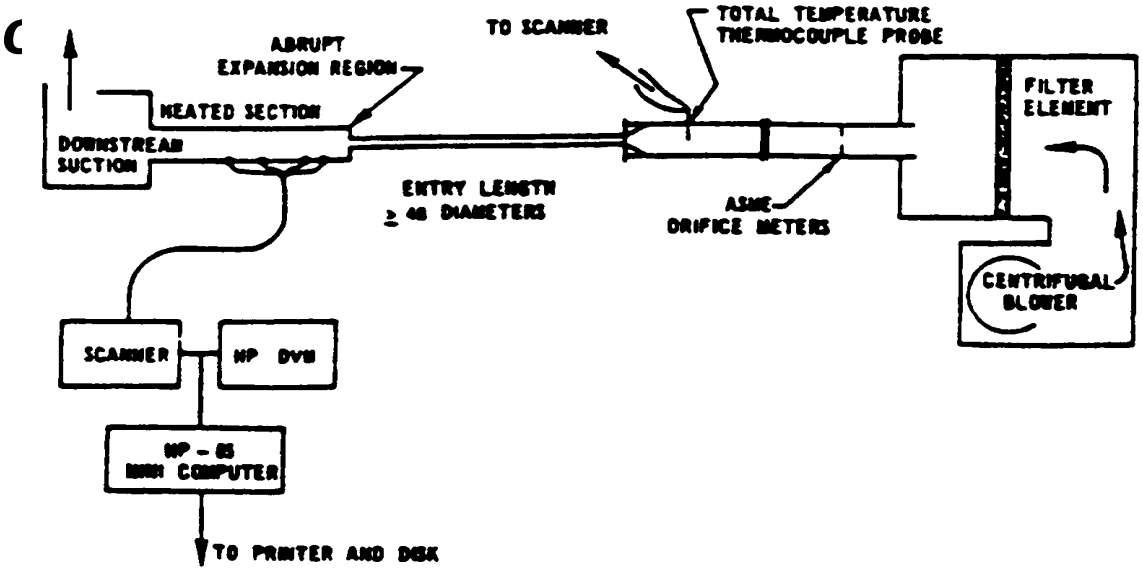
Turbulent Flow in Straight Pipe

- ***Purpose: Study mesh coupling between Fluent and RELAP5/ATHENA. Determine factors which may detrimentally influence flow***
- ***Assume well-developed flow (left to right); study mesh couplings and influence on velocity profile at Fluent/RELAP5 interface.***

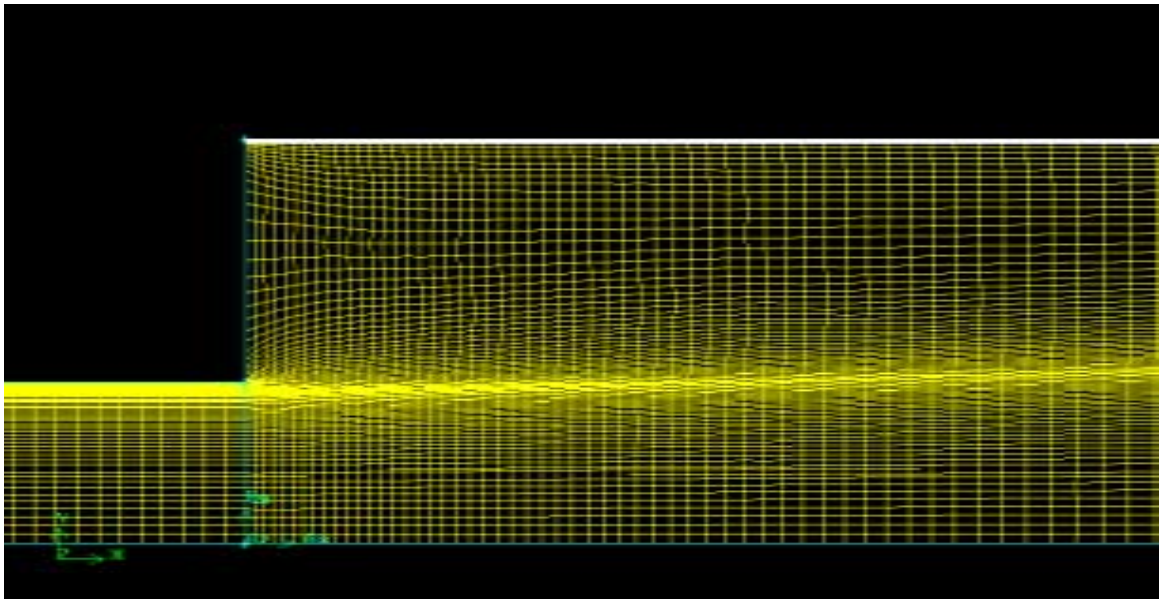


Backward-Facing Step: Expanding Flow with Heat Transfer

- *Purpose: Study coupling between Fluent—RELAP5/ATHENA and validate Fluent's capability to model flow distribution downstream of step.*
- *Region c* *MR core.*

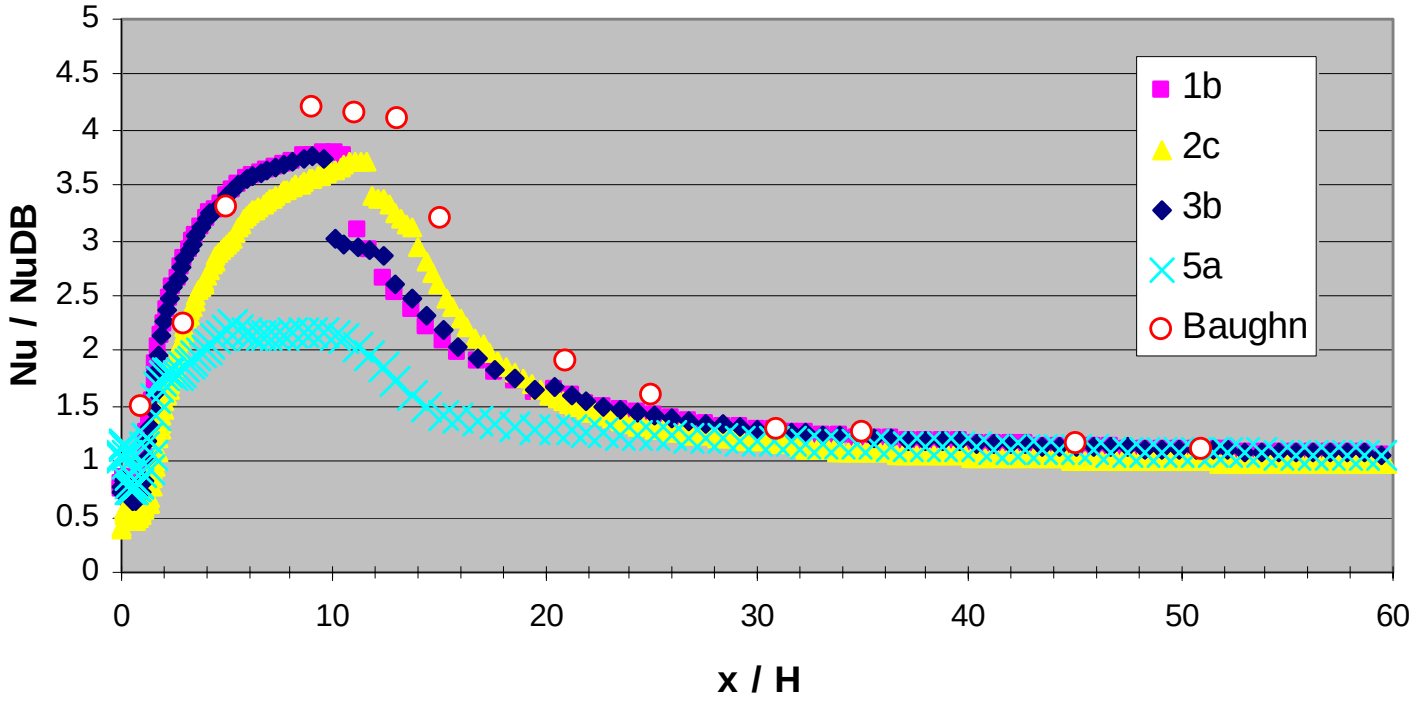


Backward-Facing Step (Cont-2)



Backward-Facing Step (Cont-3)

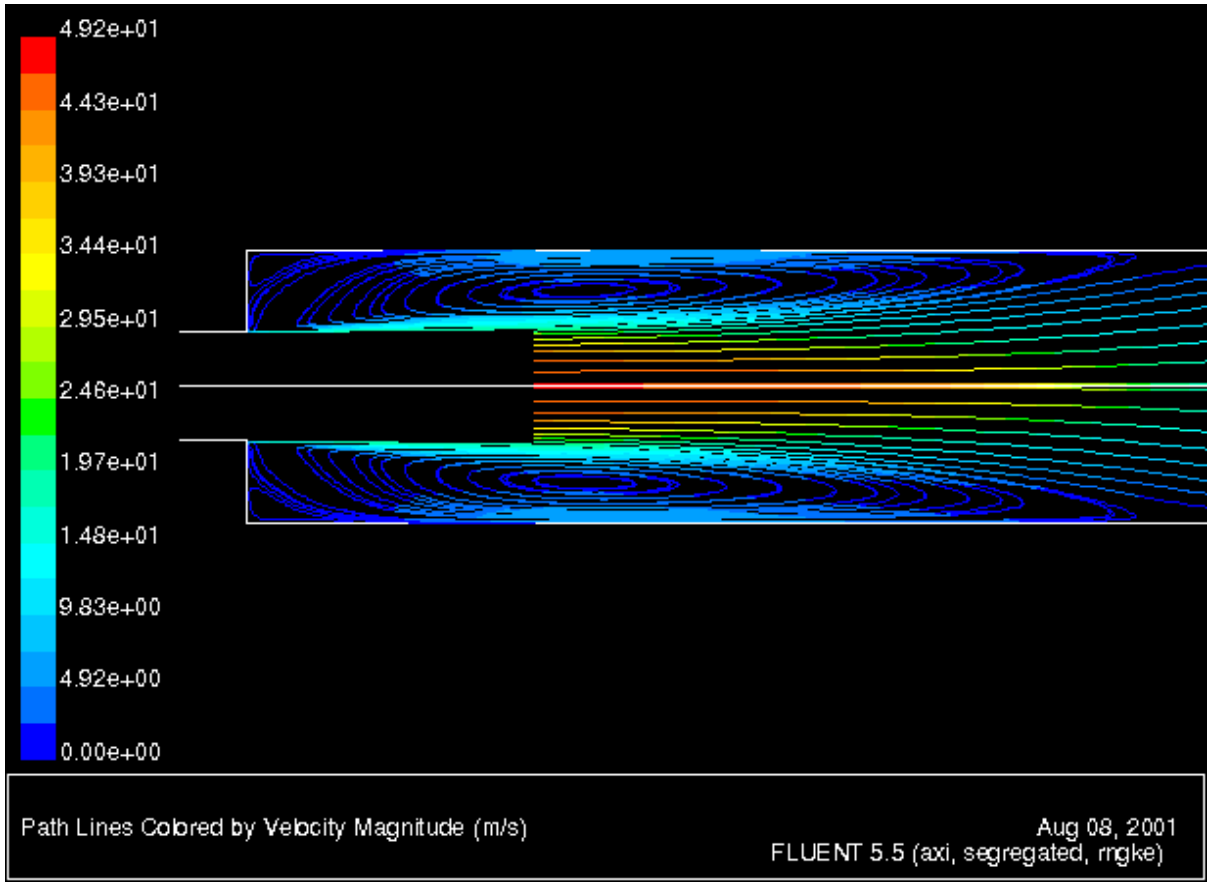
Ratio of local Nu to Nu for fully-developed flow as function of length for various turbulence models in Fluent—compared to Baughn data



Backward-Facing Step (Cont-4)

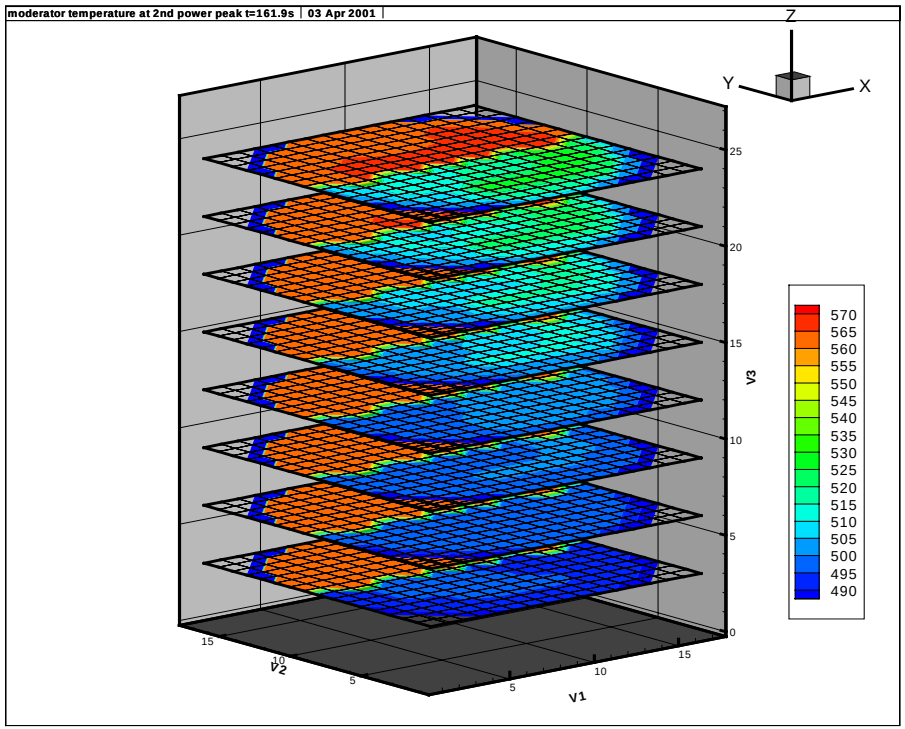
Typical velocity profiles calculated by Fluent.

Study not yet completed



Neutronics (RELAP5)-Fluent Coupling

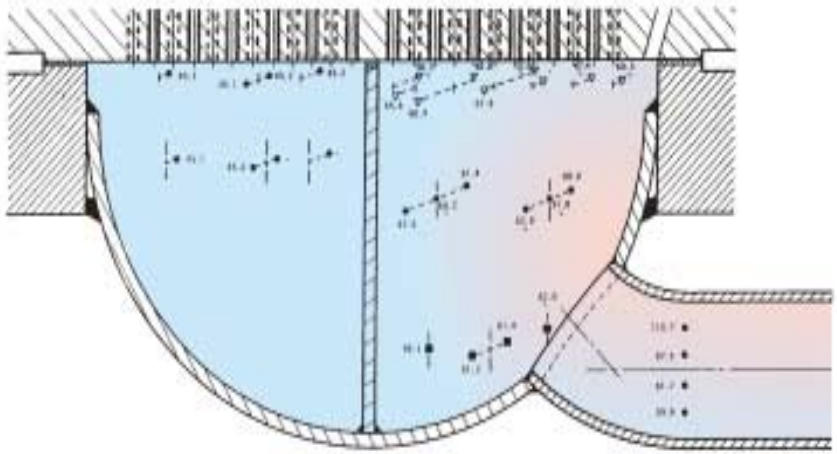
- ***Perhaps best approach is to use OECD, CSNI-NSC PWR MSLB benchmark.***
- ***Approach not defined. Perhaps model only portion of core using Fluent.***

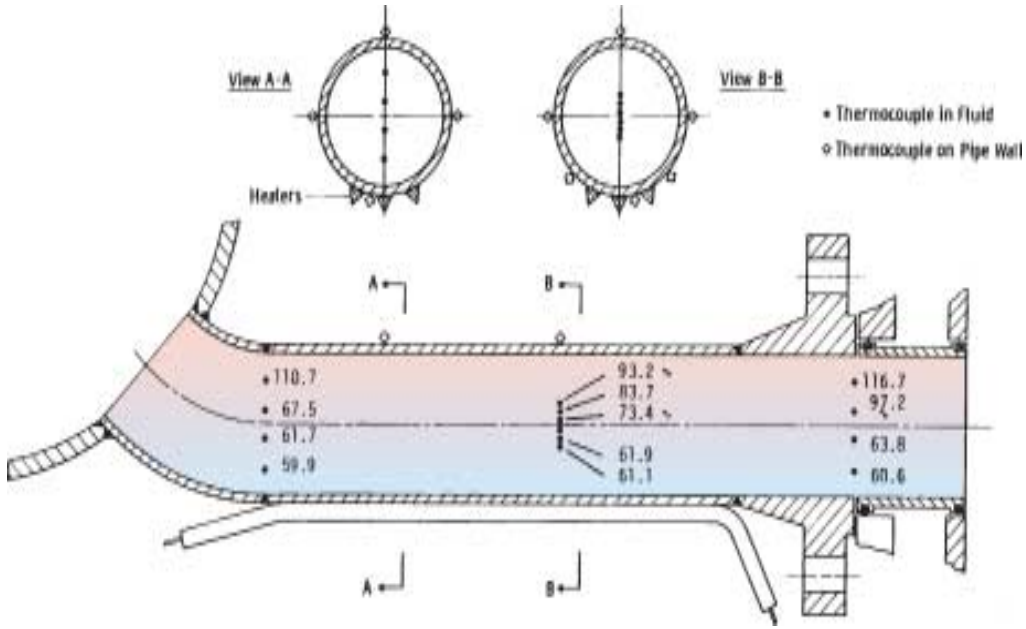


Countercurrent Steam-Water Flow Modeled Using Subcooled Water & SF_6

- **Purpose: Examine capability of Fluent to model countercurrent flow of two different fluids**
- **Test performed by Westinghouse to study movement of superheated steam into SG and return of saturated water to core**
- **SF_6 (sulfur-hexafluoride) used to model superheated steam at high pressure.**
- **Virtue of these data are the nice temperature distribution measurements in leg, SG plenum, and core**

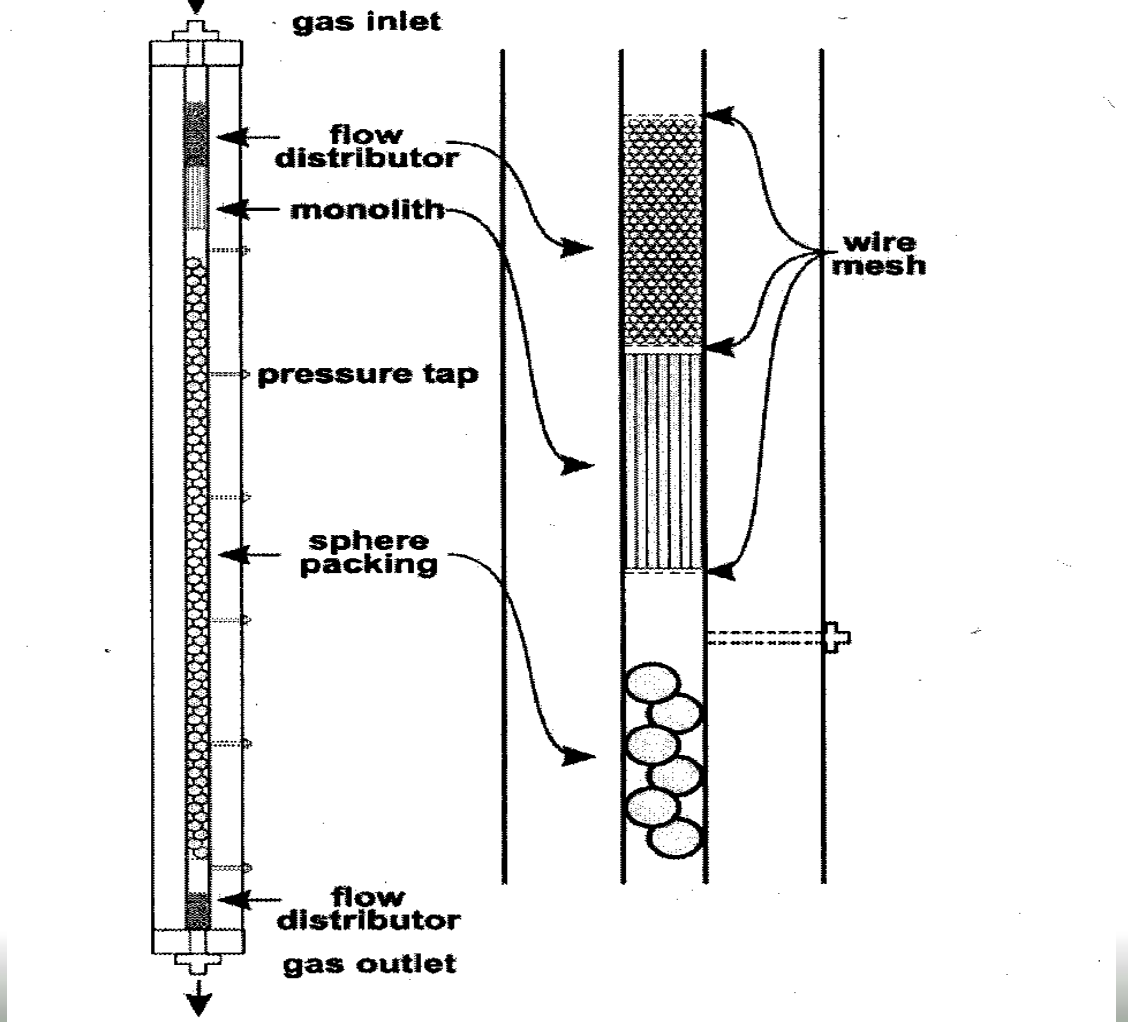
Interim Plans: Use These Data Unless Better (More Applicable) Data Can Be Found



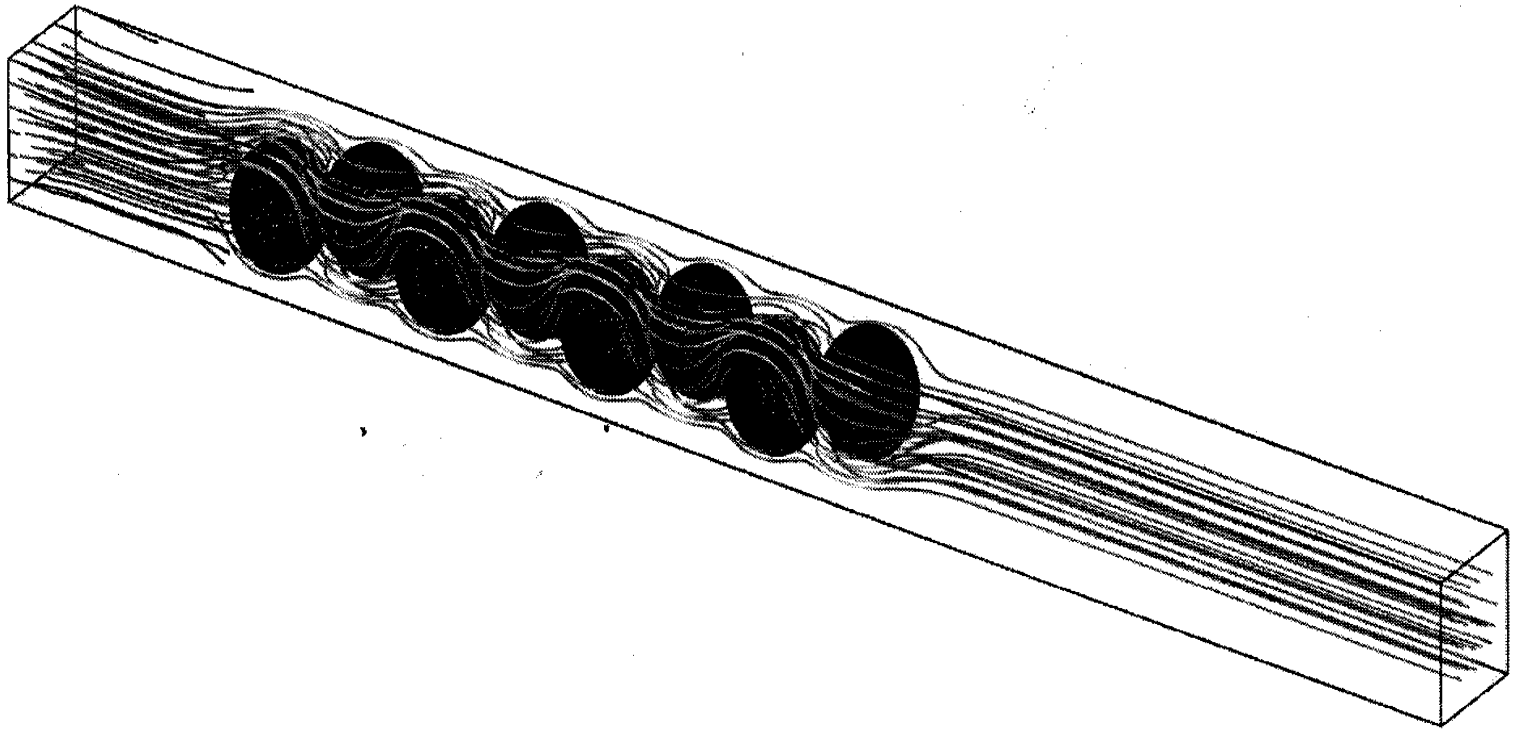


Fluent Calculation of Flow Through Pebble Bed

- *Calculation was performed using CFX5*
- *Ageement with data within 10%.*
- *Both laminar flow and turbulent flow were modeled.*



V&V Packed Bed Data-CFX5 Comparison: Within 10%



Summary

- ***The Fluent-RELAP5 coupling is underway.***
- ***A preliminary V&V matrix has been constructed.***
- ***A search is underway for better data—but data are not readily available***