Idaho National Engineering and Environmental Laboratory

Fluent/RELAP5-3D© Coupled Code

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The Fluent RELAP5-3D Coupling..

- *Background*
- *What we're doing*
- *Where we are at now*
- *Our future plans*

Overall Perspective…

- ***DOE's Generation IV Roadmap effort is reaching completion. It 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.***

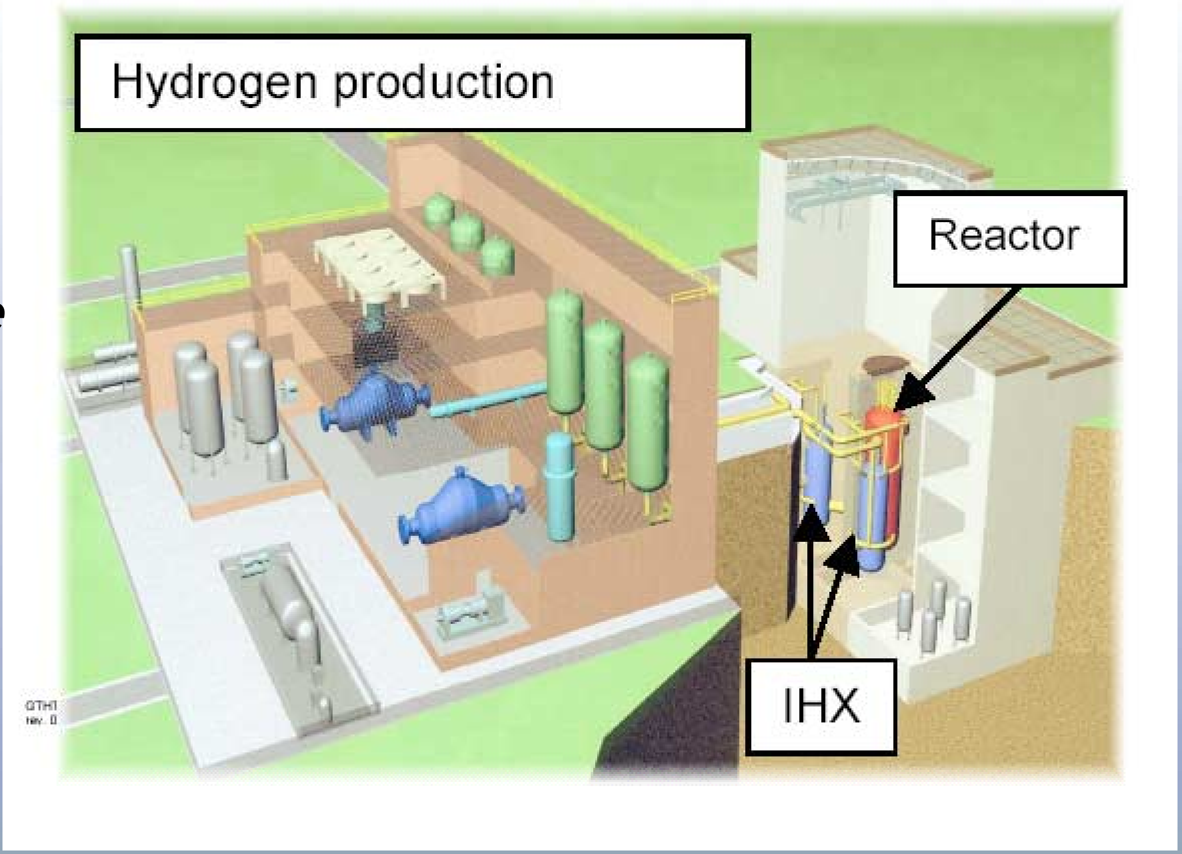
- ***Gen IV has identified 6 advanced concepts for further development; US will probably focus on half: Very High Temperature Reactor, Gas-Cooled Fast Reactor, & Supercritical Water Reactor. Others are the Pb-BI, Na-cooled, and molten salt.***

- ***In addition to Gen IV, there will also be Gen III advanced concepts to study, e.g., PBMR***

Very High-Temperature Reactor (VHTR)

Characteristics

- *He coolant*
- *>1000°C outlet temperature*
- *600 MWe*
- *Solid graphite block core based on GT-MHR*



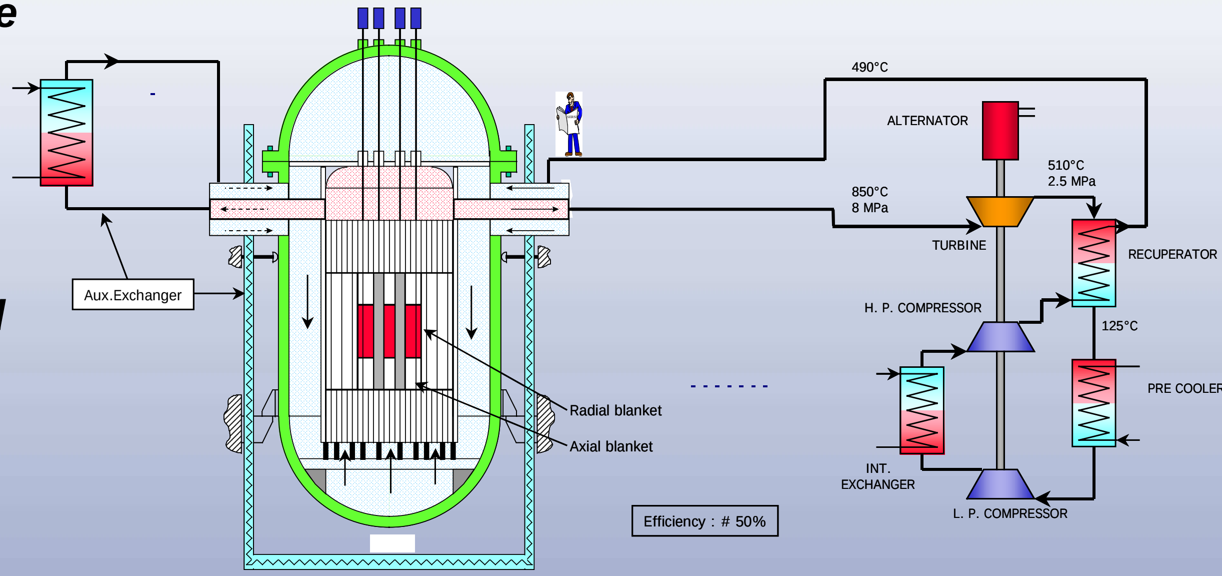
Benefits

- *High thermal efficiency*
- *Hydrogen production*
- *Process heat applications*
- *High degree of passive safety*

Gas-Cooled Fast Reactor (GFR)

Characteristics

- He coolant
- 850°C outlet temperature
- direct gas-turbine conversion cycle – 48% efficiency
- 600 MW_{th}/288 MW_{e}
- Several fuel options and core configurations



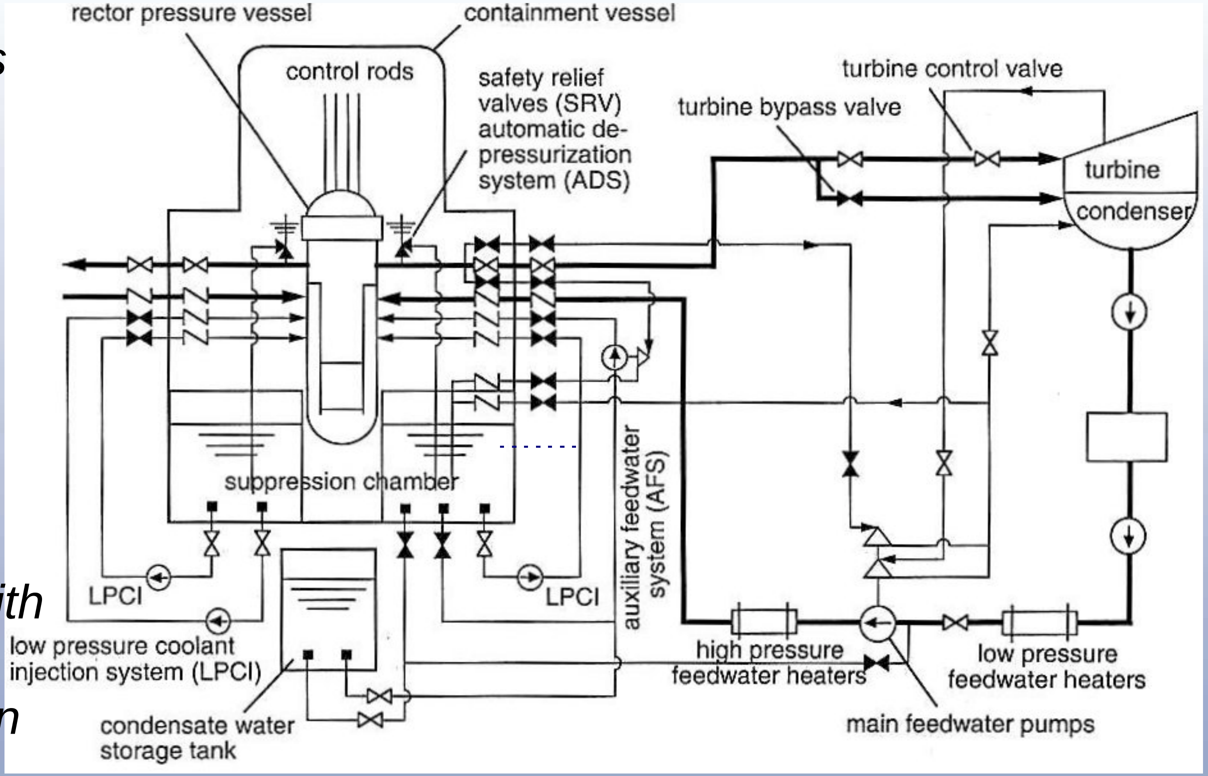
Benefits

- Waste minimization and efficient use of uranium resources

Supercritical Water Reactor (SCWR)

Characteristics

- *Water coolant at supercritical conditions*
- *500°C outlet temperature*
- *1700 MWe*
- *Simplified balance of plant*



Benefits

- *Efficiency near 45% with excellent economics*
- *Thermal or fast neutron spectrum*

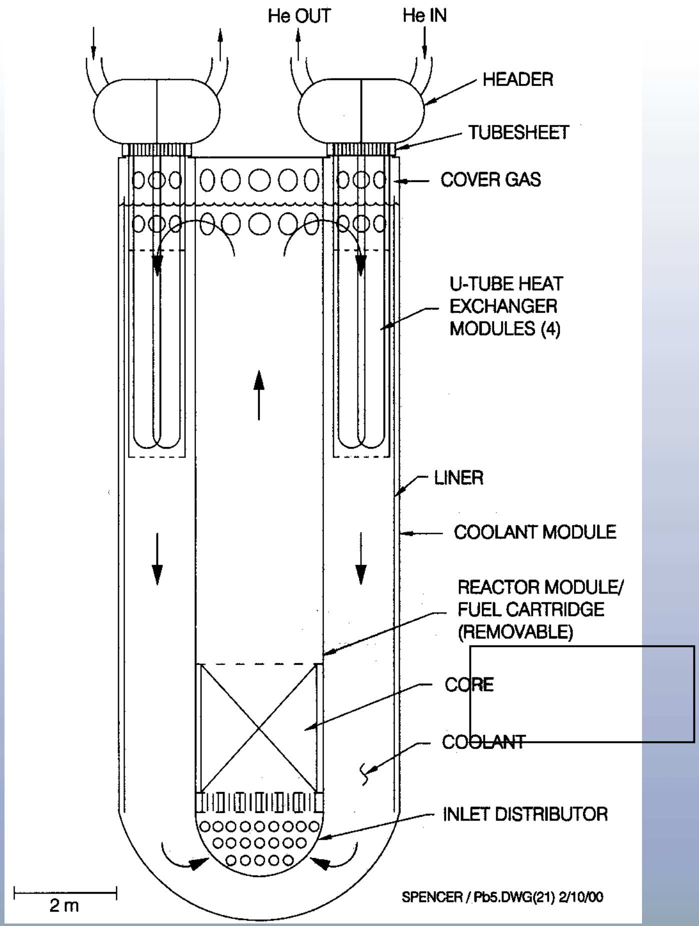
Pb/Bi Reactor – Cartridge Core (Pb/Bi Battery)

Characteristics

- *Pb or Pb/Bi coolant*
- *540°C to 750°C outlet temperature*
- *120-400 MWe*
- *15-30 year core life*

Benefits

- *Distributed electricity generation*
- *Hydrogen and potable water*
- *Cartridge core for regional fuel processing*
- *High degree of passive safety*
- *Proliferation resistance through long-life cartridge core*



Sodium Liquid Metal-Cooled Reactor (Na LMR)

Characteristics

- *Sodium coolant*
- *150 to 500 MWe*
- *Metal fuel with pyro processing / MOX fuel with advanced aqueous*

Benefits

- *Consumption of LWR actinides*
- *Efficient fissile material generation*

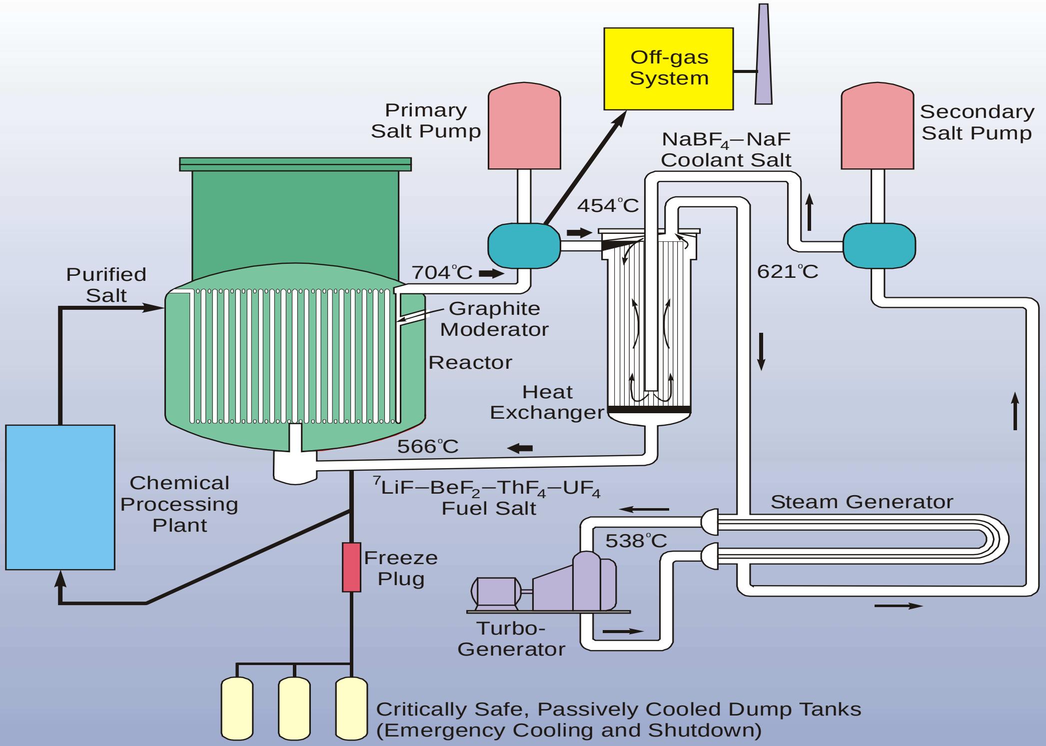
Molten Salt Reactor (MSR)

Characteristics

- *Fuel: liquid Li, Be, Th and U fluorides*
- *700°C outlet temperature*
- *1000 MWe*
- *Low pressure (<0.5 MPa) & high temperature (>700°C)*

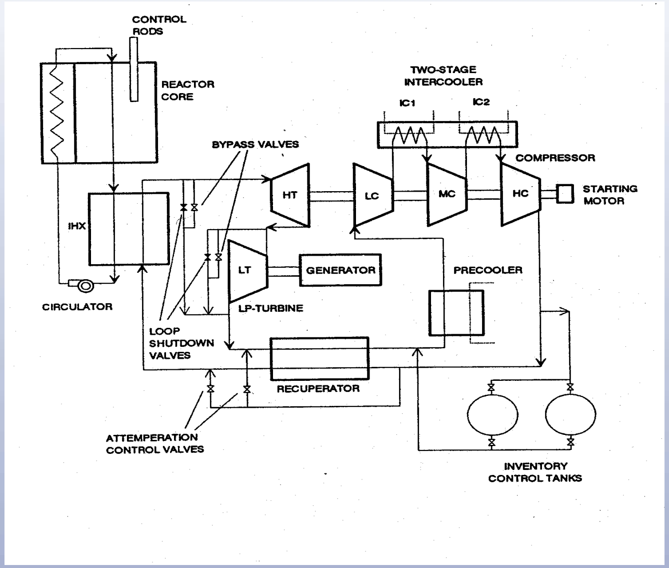
Benefits

- *Low source term due to online processing*
- *Waste minimization and efficient use of uranium resources*
- *Proliferation resistance through low fissile material inventory*



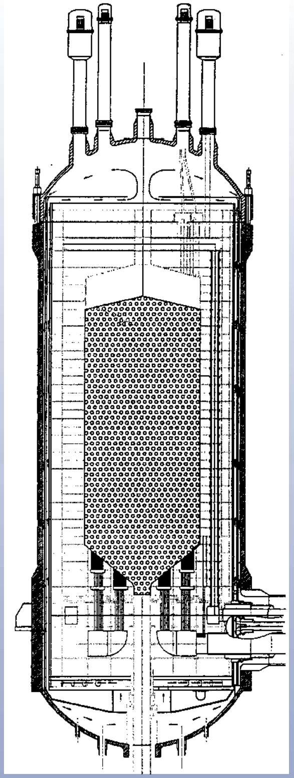
Fluent & RELAP5-3D Are Being Coupled to…

- *Develop tools to analyze advanced systems in the detail required—so:*
- *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*
- *We'll model input plenum, perhaps a portion of the core, and the outlet plenum.*



International Community has also Recognized this need…

IAEA recently announced a meeting to discuss: "…interest in the application of 3-dimensional CFD software as a supplement to or in combination with system codes, which provide the boundary conditions for CFD codes." Problems under discussion include:

- *Evaluation of performance of passive safety features;*
- *Local phenomena leading to cladding ruptures;*
- *Multidimensional TH in various components;*
- *Liquid/gas stratification and interface tracking; and*
- *Bubble dynamics in suppression pools."*

We view Fluent RELAP5-3D coupling as applicable to…

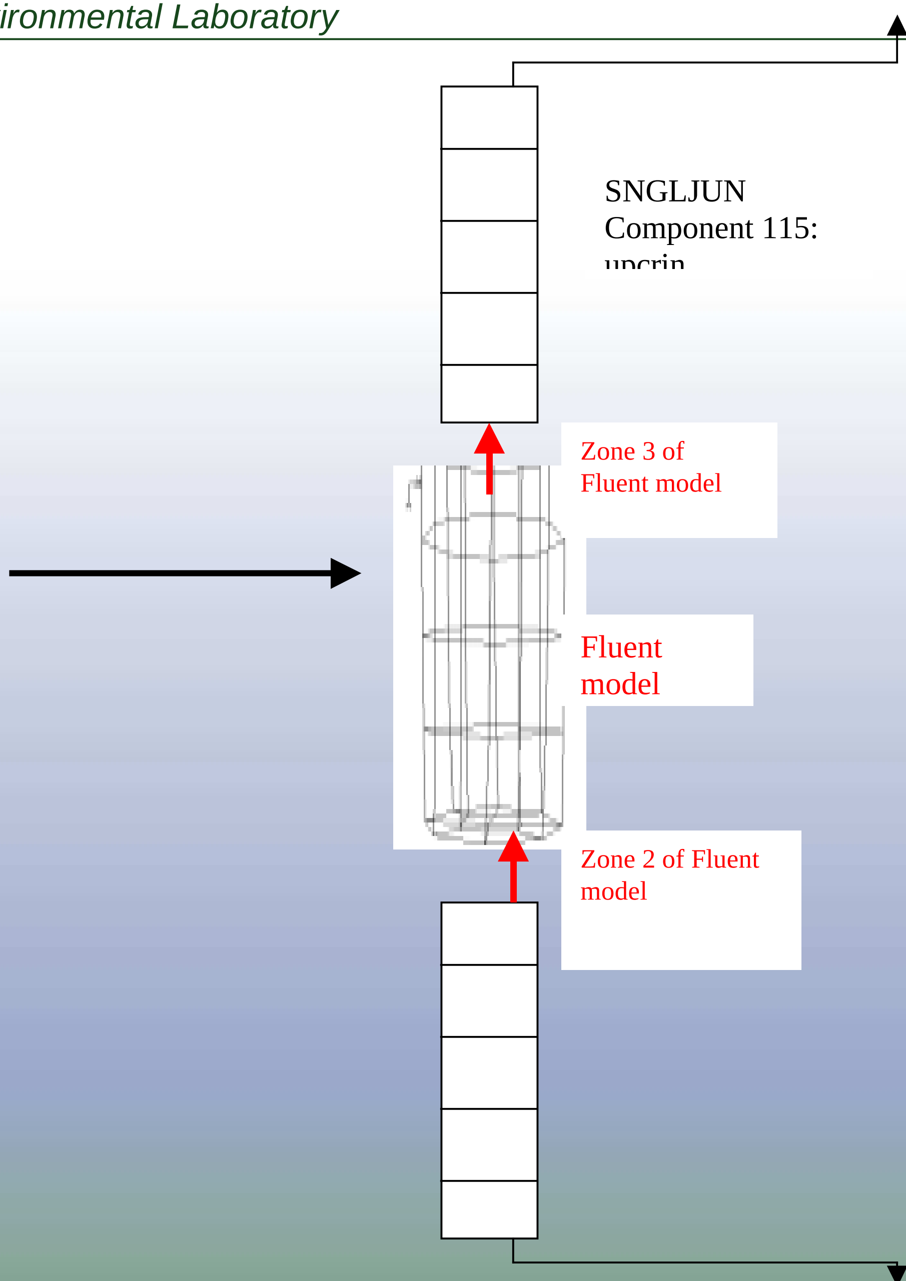
- *Most scenarios in VHTRs, gas-cooled fast reactors, Pb-Bi reactors, and liquid sodium reactors.*

- *Some specific phenomena in water-cooled systems such as supercritical water reactors.*

Status

- *Fluent and RELAP5-3D are coupled.*
- *Writing User Guidelines*
- *Will focus on latter part of V&V matrix over next year.*

Blowup of Fluent model linked to RELAP5-3D model



RELAP5-3D provides 1-D boundary conditions to Fluent

- *Fluent performs 3-D calculation*
- *Inlet velocity profile, for example, is flat if not modified.*
- *Inlet profile can be modified to known condition if desired using Fluent user defined functions.*
- *Fluent 3-D output converted to 1-D for RELAP5-3D.*

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.

We'll focus on PBMR…

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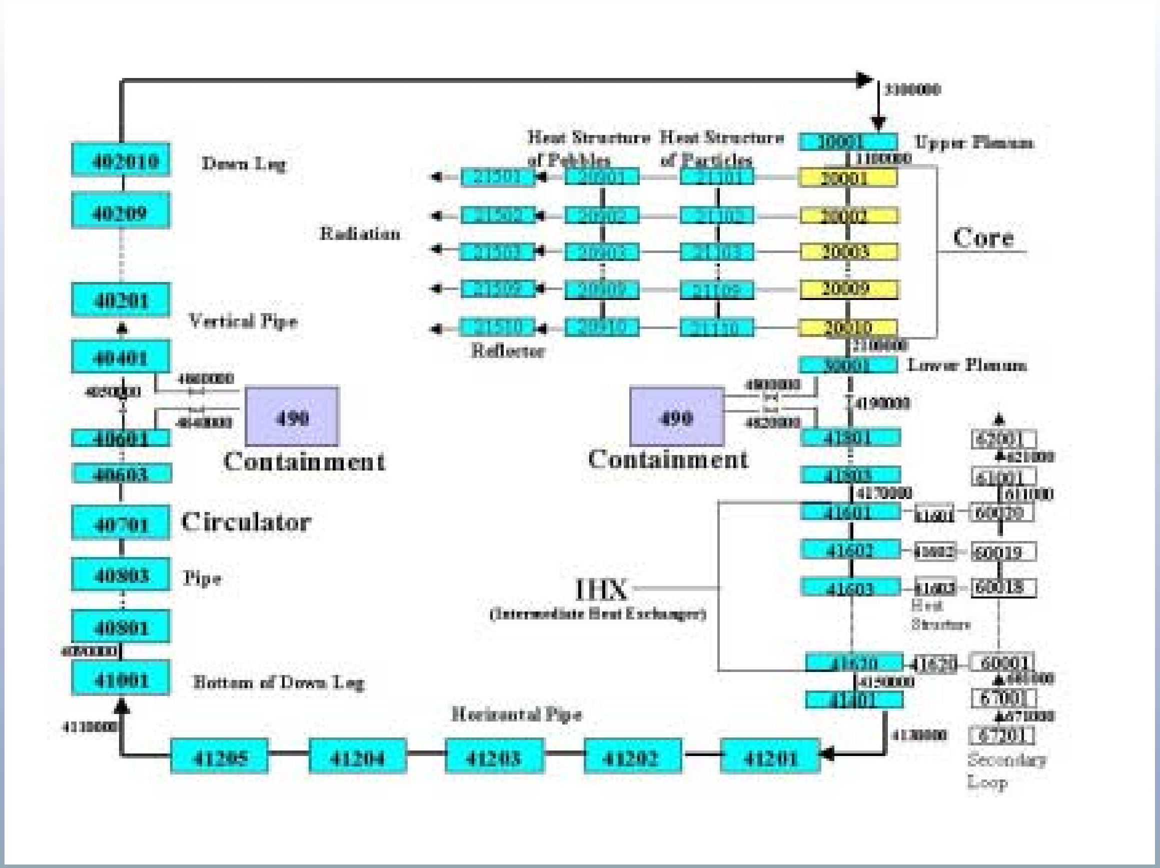
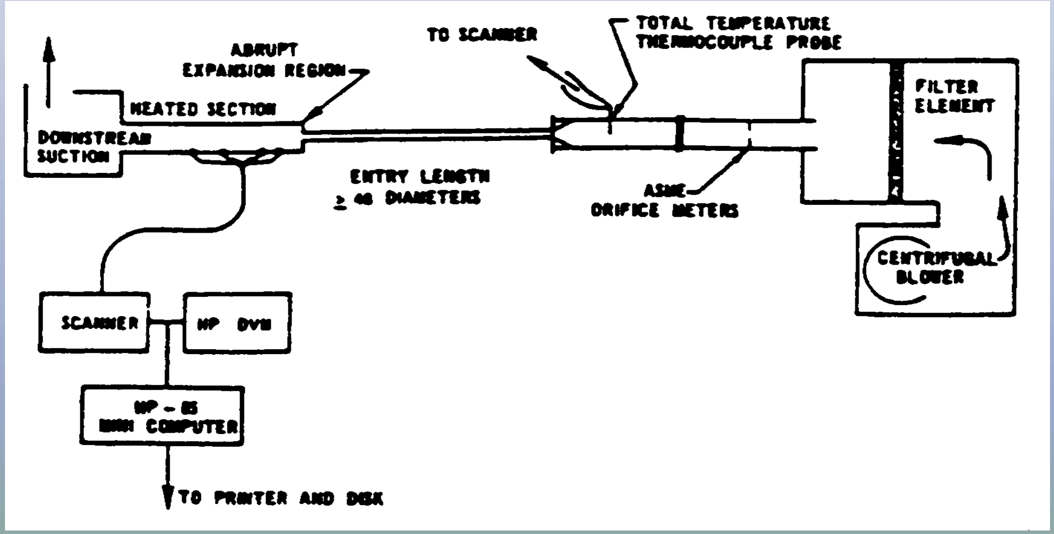


Relevant V&V Cases…

- *Turbulent pipe flow.*
- *Backward facing step*
- *Packed beds*

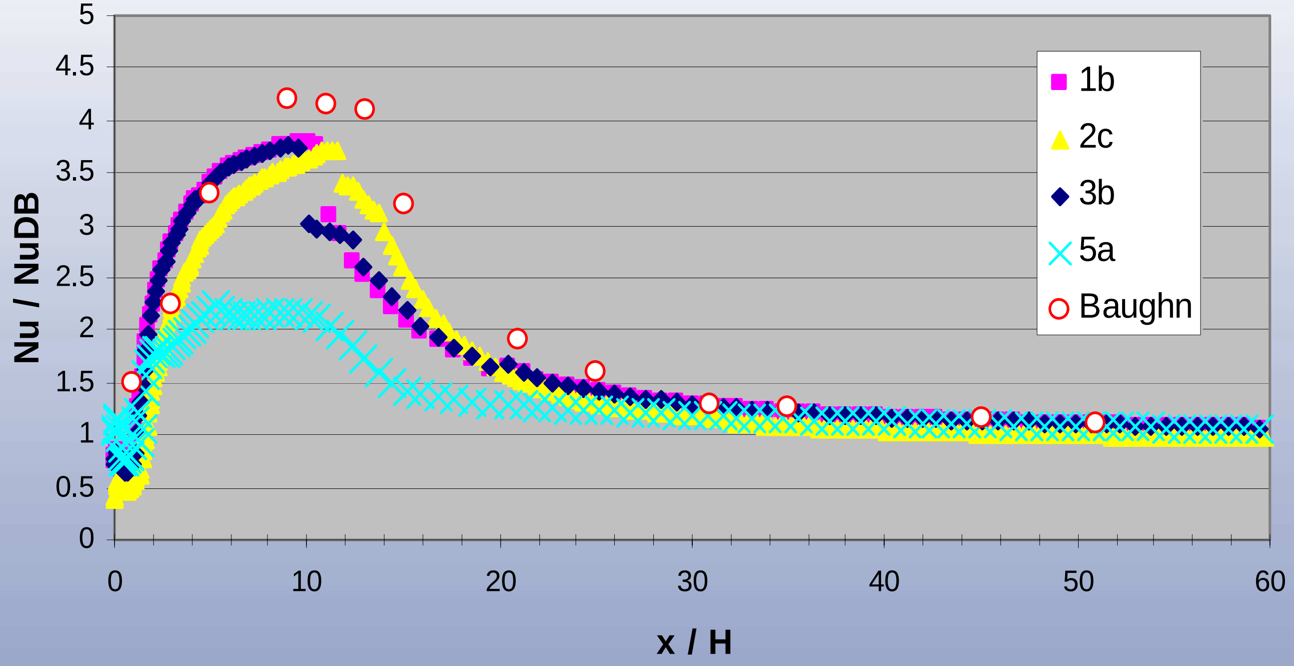
Backward-Facing Step: Expanding Flow with Heat Transfer

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



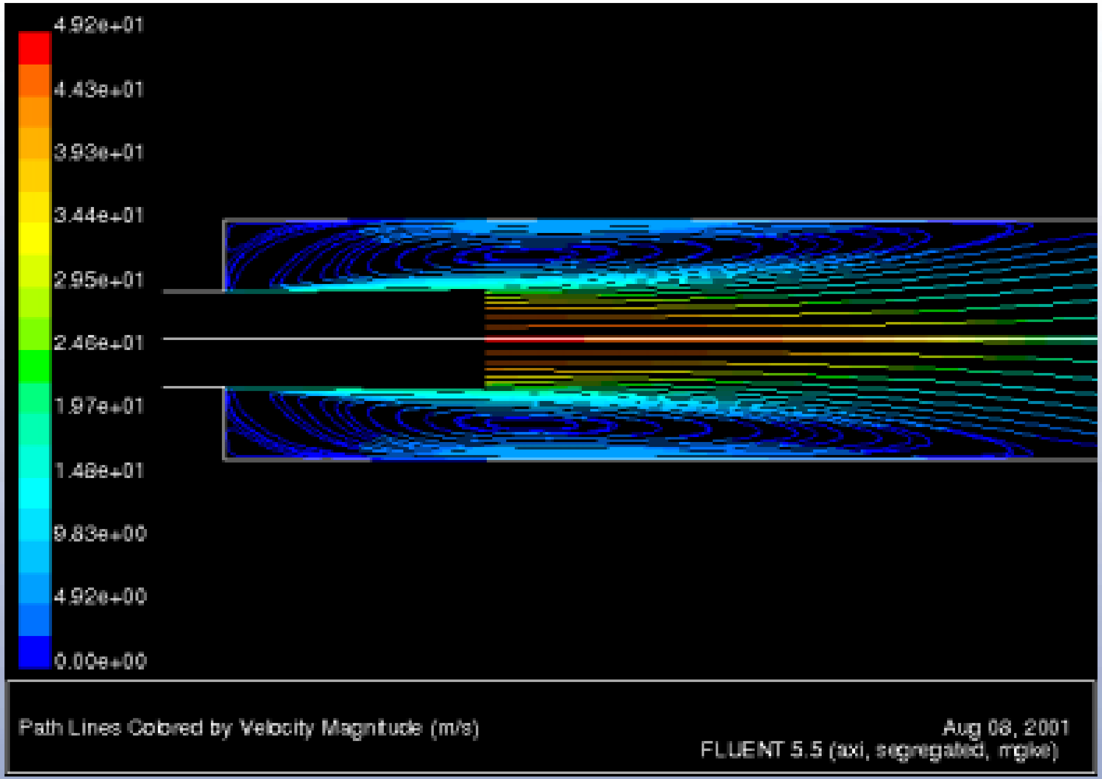
Backward-Facing Step (Cont-3)

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



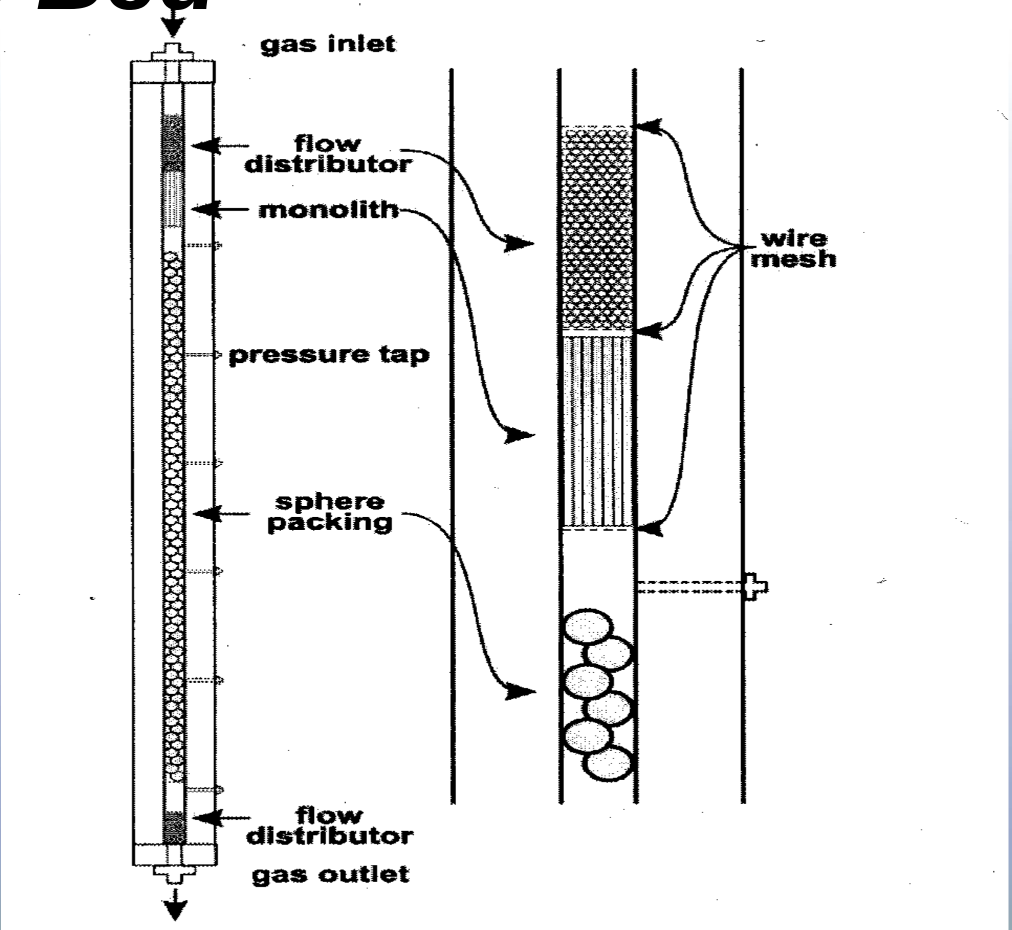
Backward-Facing Step (Cont-4)

Typical velocity profiles calculated by Fluent.

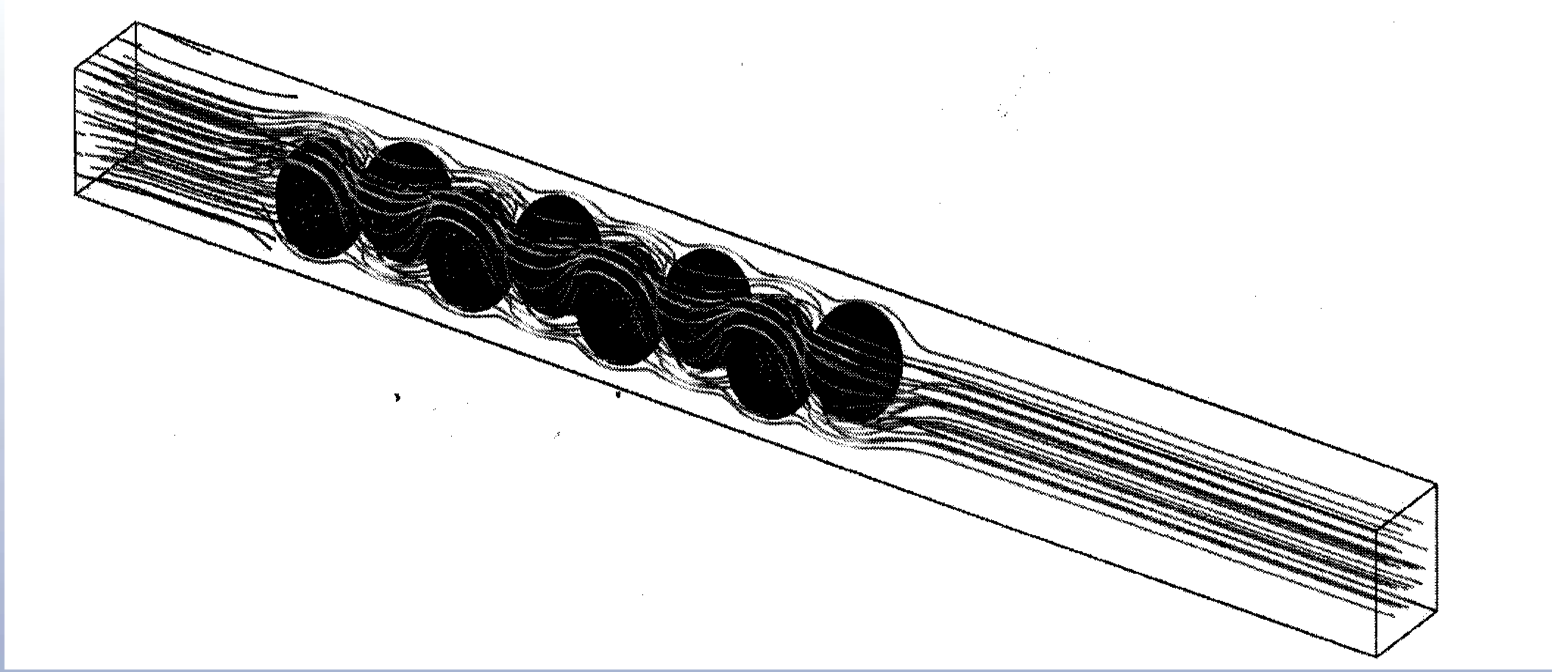


Fluent Calculation of Flow Through Pebble Bed

- *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 functional.*
- *First system case to be studied: PBMR.*
- *The V&V matrix problems are being used.*
- *User Guideline document is being written—expect first draft at year end.*