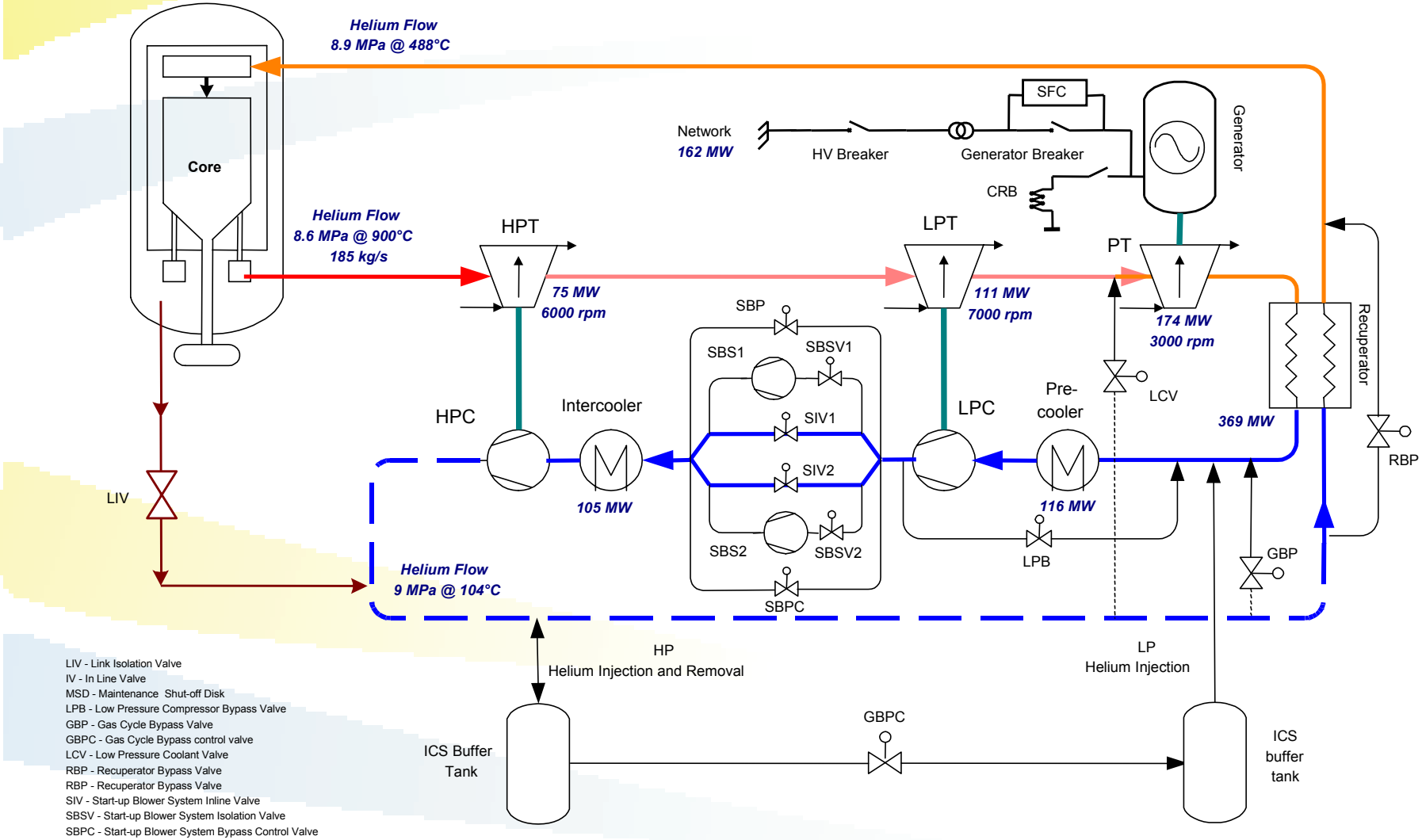
# PBMR Thermo Hydraulic Cycle and Thermal Design

Presented to the US DOE

7 August 2003

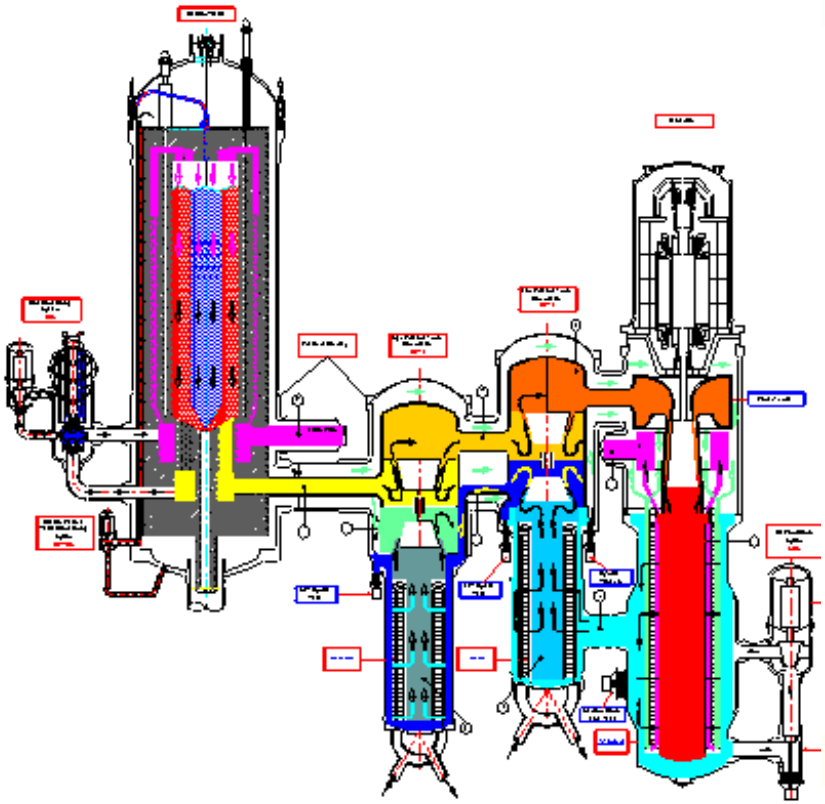
Johan Slabber

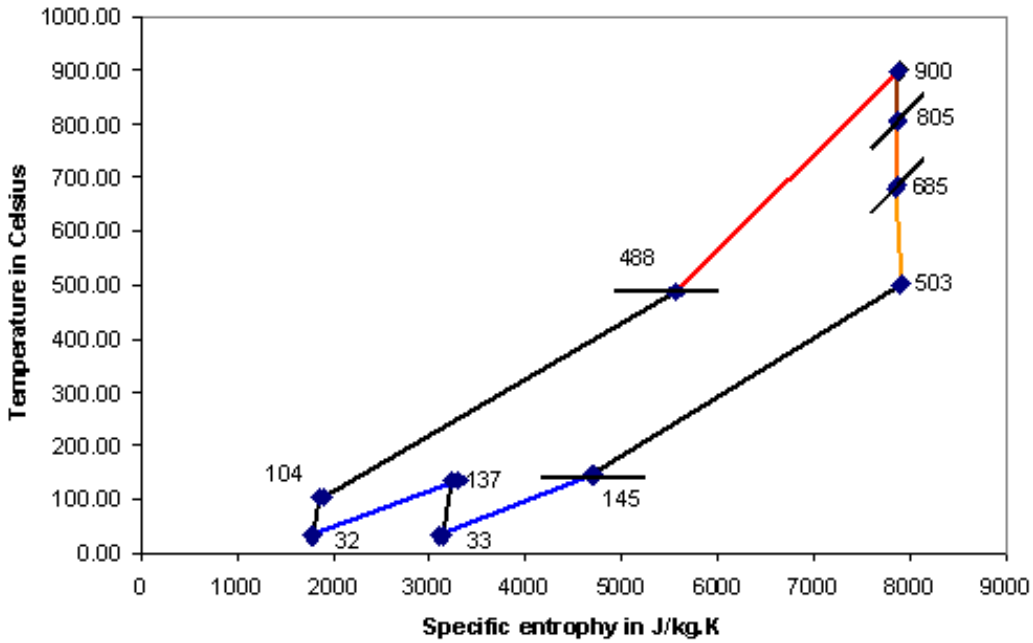
# MPS Circuit Schematic Diagram



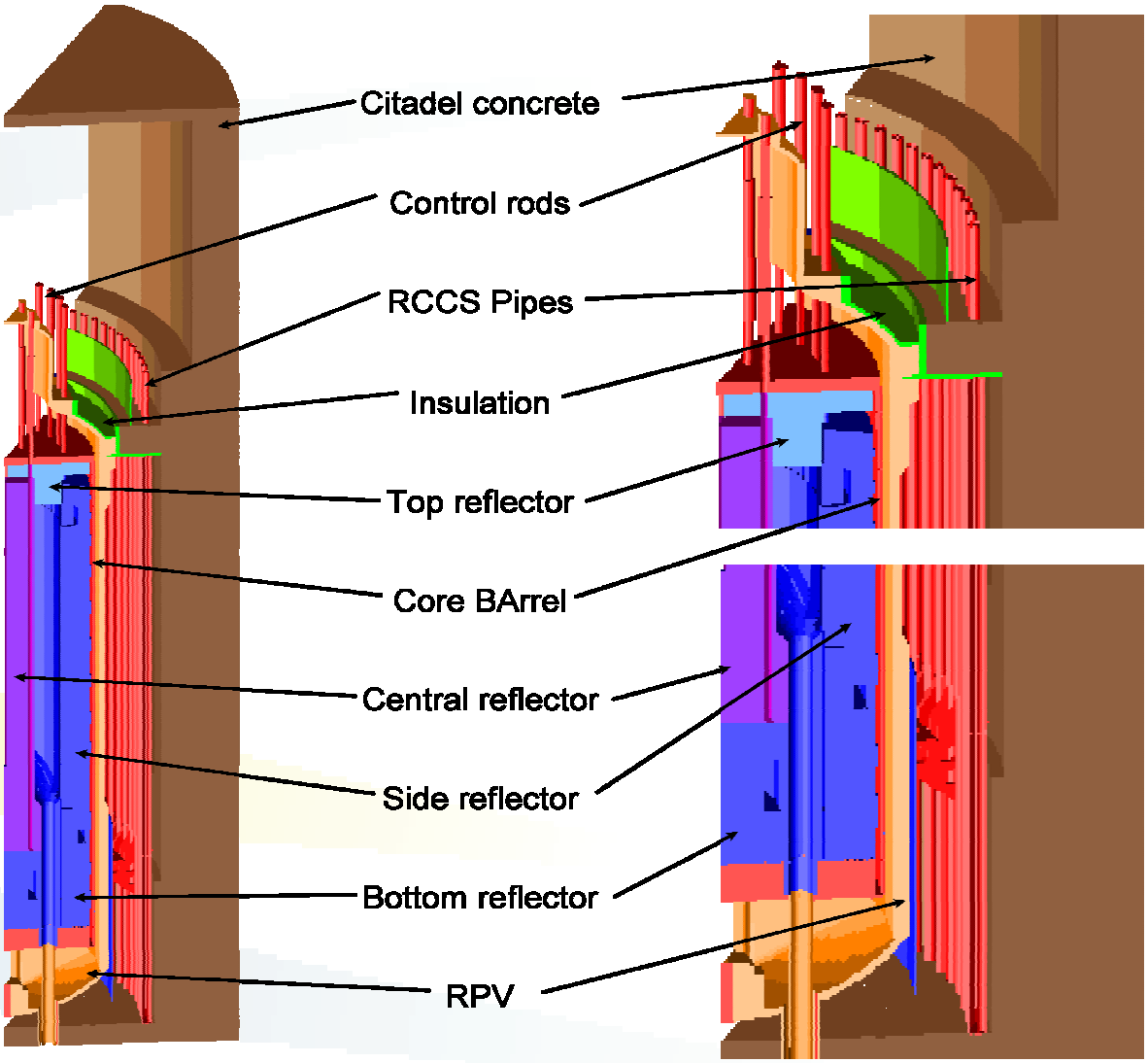

LIV - Link Isolation Valve
IV - In Line Valve
MSD - Maintenance Shut-off Disk
LPB - Low Pressure Compressor Bypass Valve
GBP - Gas Cycle Bypass Valve
GBPC - Gas Cycle Bypass control valve
LCV - Low Pressure Coolant Valve
RBP - Recuperator Bypass Valve
RBP - Recuperator Bypass Valve
SIV - Start-up Blower System Inline Valve
SBSV - Start-up Blower System Isolation Valve
SBPC - Start-up Blower System Bypass Control Valve
SBP - Start-up Blower System Bypass Valve

# Schematic of the PBMR and Temperature – Entropy diagram for 100% MCR



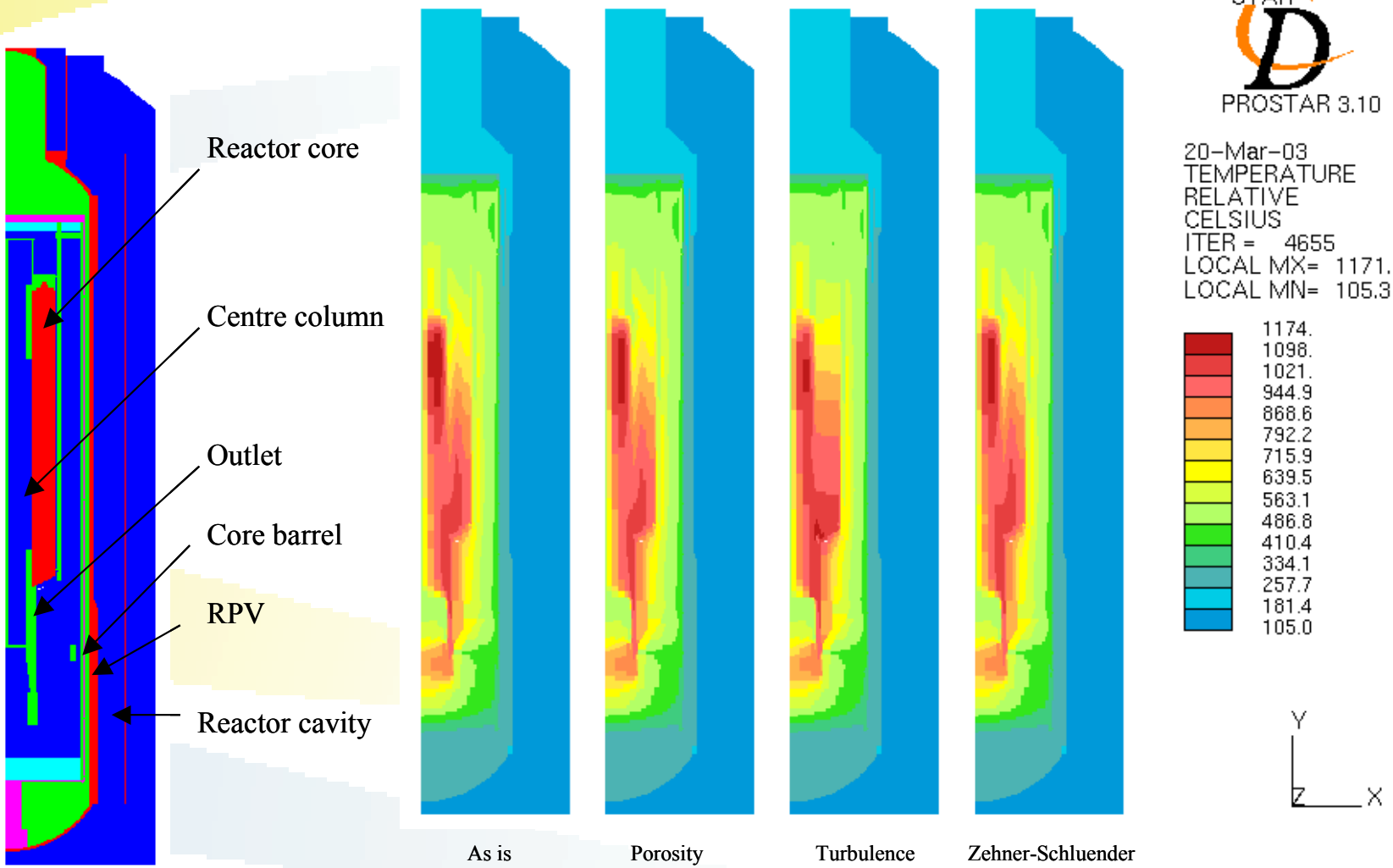


# An example of the CFD Reactor Unit model



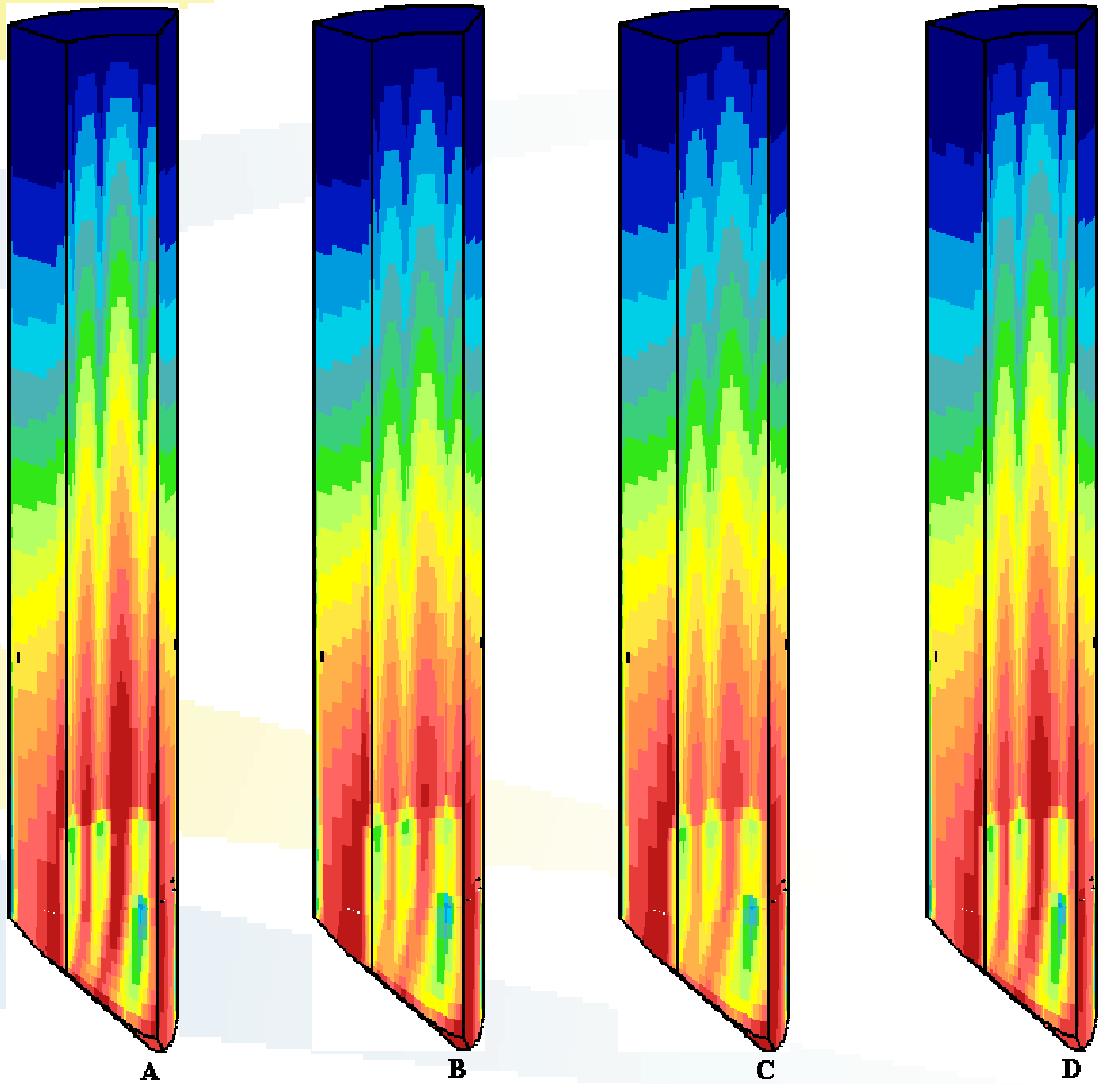
# Reactor Unit CFD Analyses

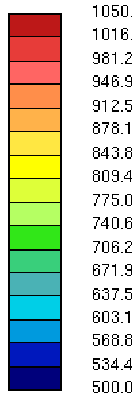
## Effect of Turbulent Mixing



# Reactor Unit CFD Analyses

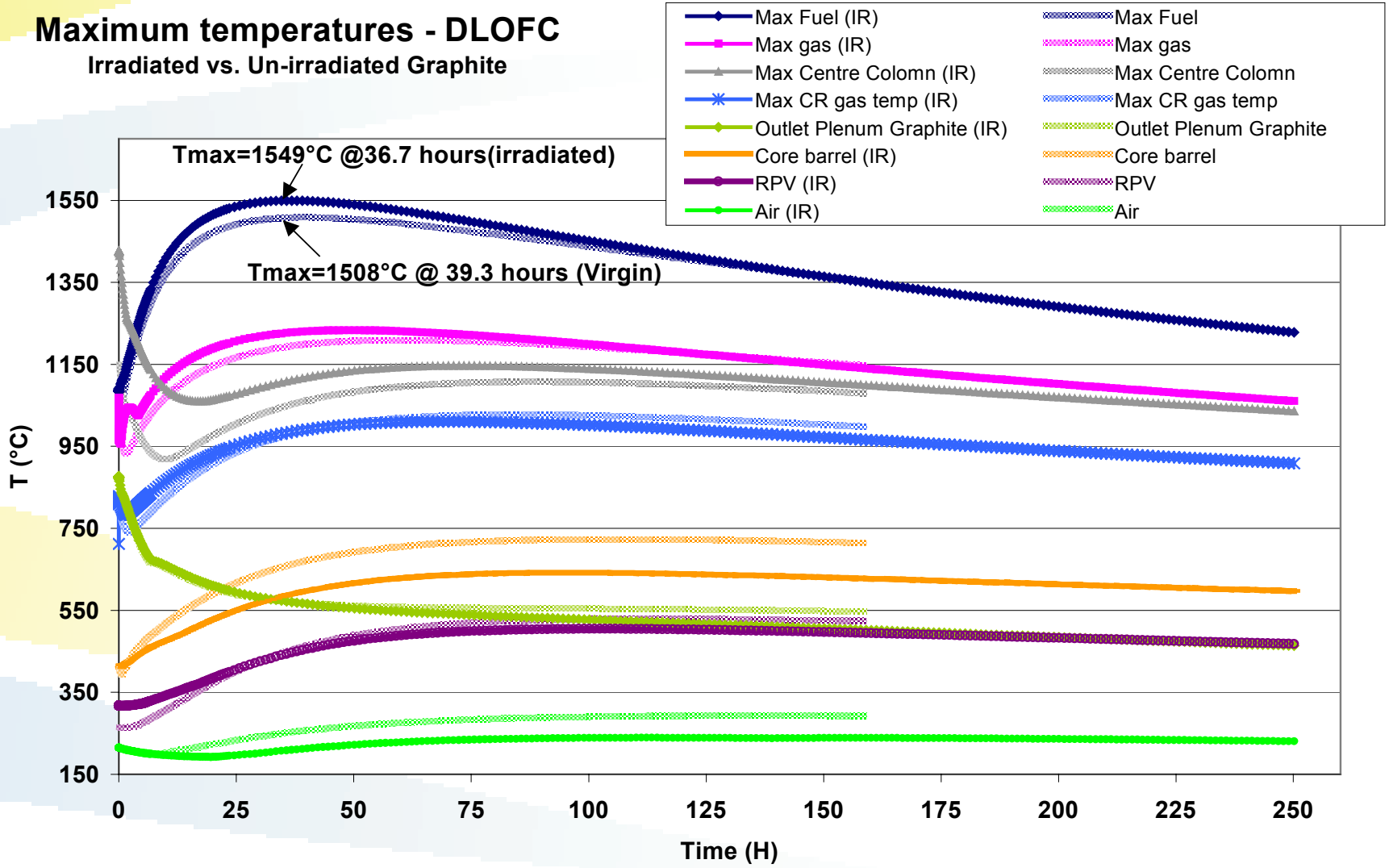
## Comparison of Helium Temperature in Core




A - 2a - 100%MCR 100%MCRI
B - 2g - 40%MCR 40%MCRI
C - 2h - 16%MCR 40%MCRI
D - 2o - 43%MCR 100%MCRI

# CFD TRANSIENT SIMULATION OF DLOFC EVENT



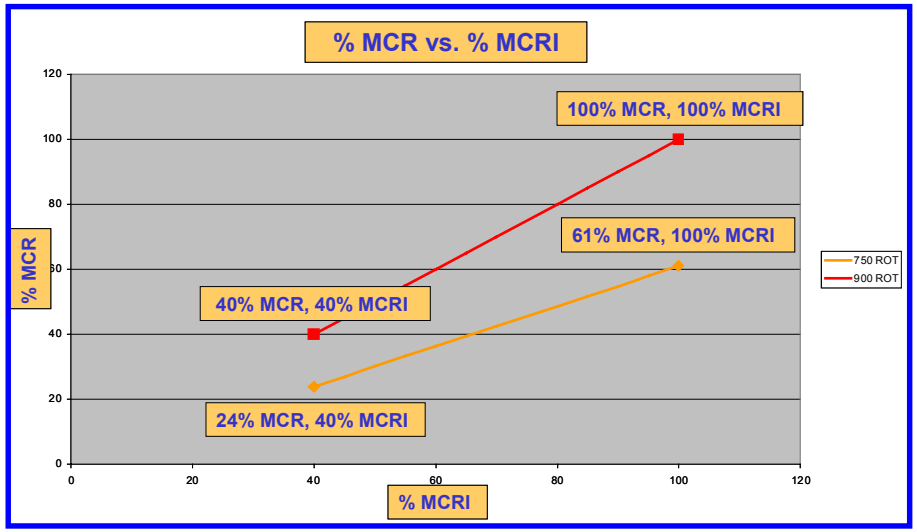
# MPS Sensitivity Analyses

**Definition:**

***Determine to which parameters the MPS are most sensitive by varying one input parameter at a time.***

**MPS output parameters examined are:**

- **HPTU & LPTU Rotational Speed,**
- **HPC & LPC Surge Margin,**
- **Cycle Efficiency**
- **Grid Power**



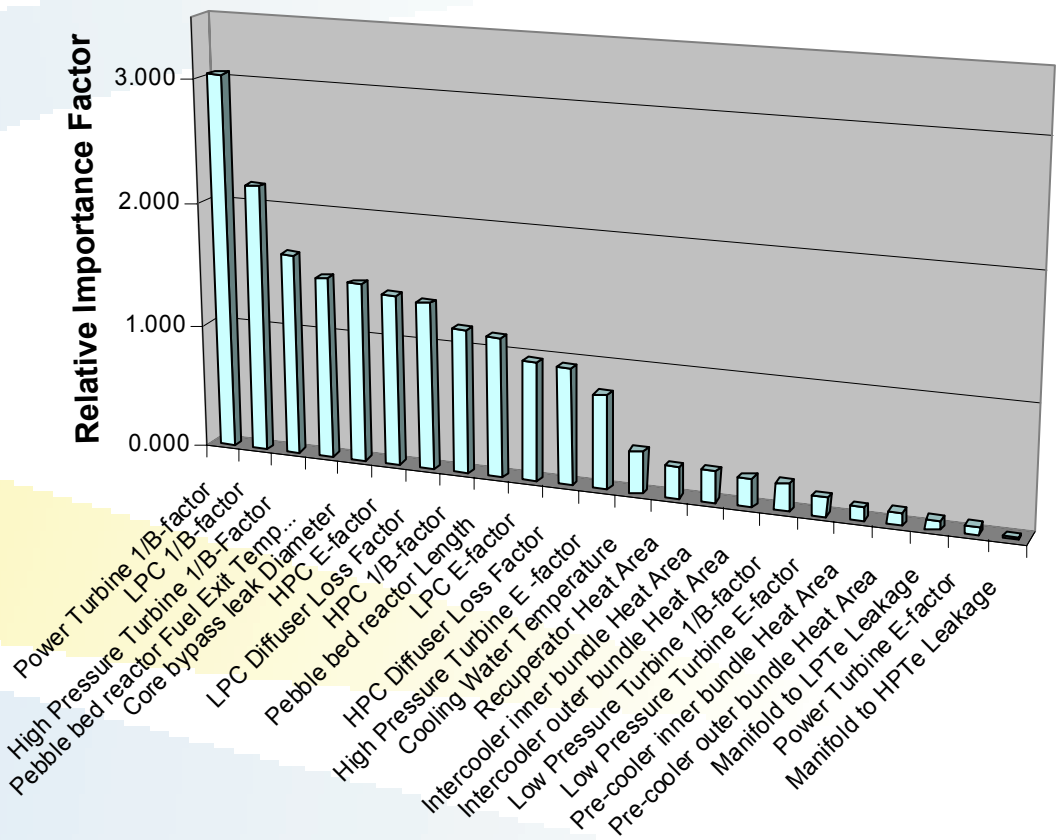

**49 parameters are varied, including:**

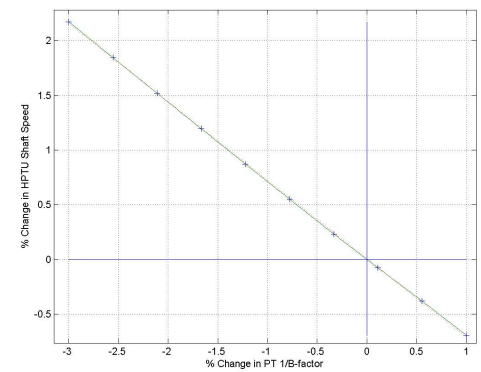
- **Turbo machine entrance and exit losses, efficiencies, throat areas & leakage**
- **Heat exchanger parameters (Heat Areas, etc.)**
- **Reactor parameters (Pebble bed length, bypass flow & outlet temperature)**
- **Cooling water temperature (Variation at Koeberg)**

# MPS Sensitivity Analyses Results

P B M R

## All Results Combined

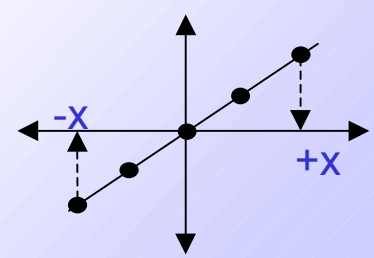



**Sensitivity:**

**Gradient of straight line**
**x input variation.**

$$y = mx + c \qquad m = \frac{\Delta y}{\Delta x}$$



# MPS Monte Carlo Analyses

P B M R

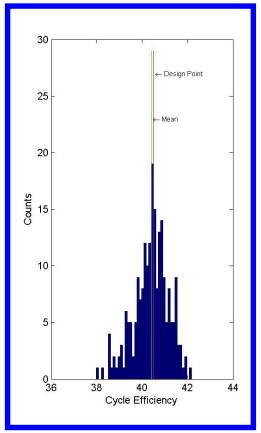
**Definition:**

***Determine the likely variation in the MPS output parameters by simultaneously varying all the input parameters randomly, according to an uncertainty distribution.***

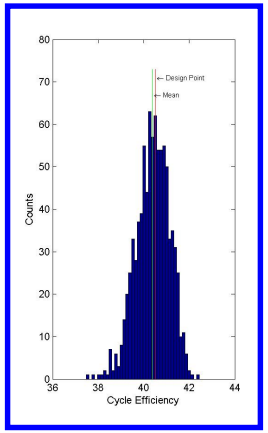
**MPS output parameters examined are:**

- **HPTU & LPTU Rotational Speed,**
- **HPC & LPC Surge Margin,**
- **Cycle Efficiency**
- **Grid Power**

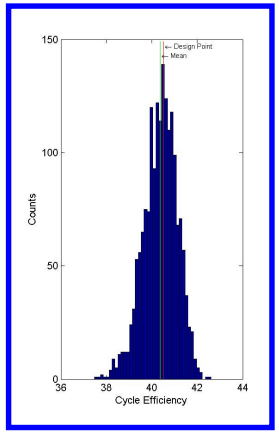
**Comparing number of runs (Cycle Efficiency)**




**250**




**1000**



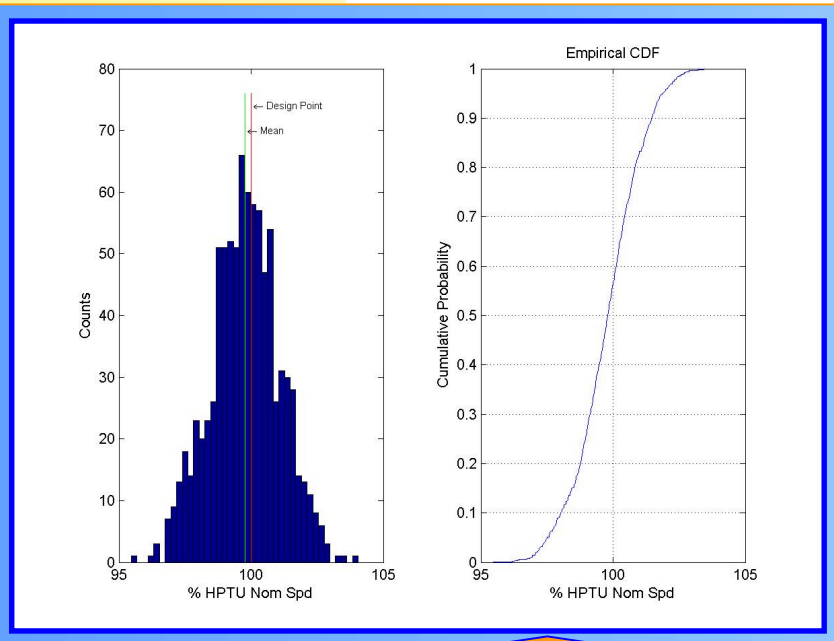

**2000**

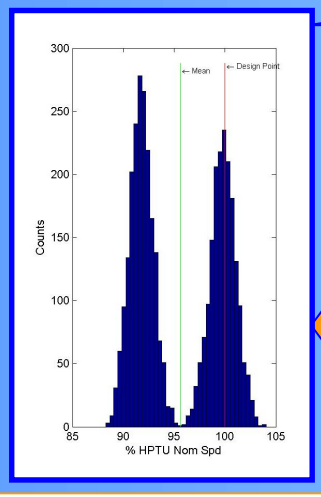
**Assumed sufficient for convergence**

**The same 49 parameters that were used in the Sensitivity Analyses, were used to perform the Monte Carlo Analyses.**

# MPS Monte Carlo Analyses

## Turbo Machine Speed

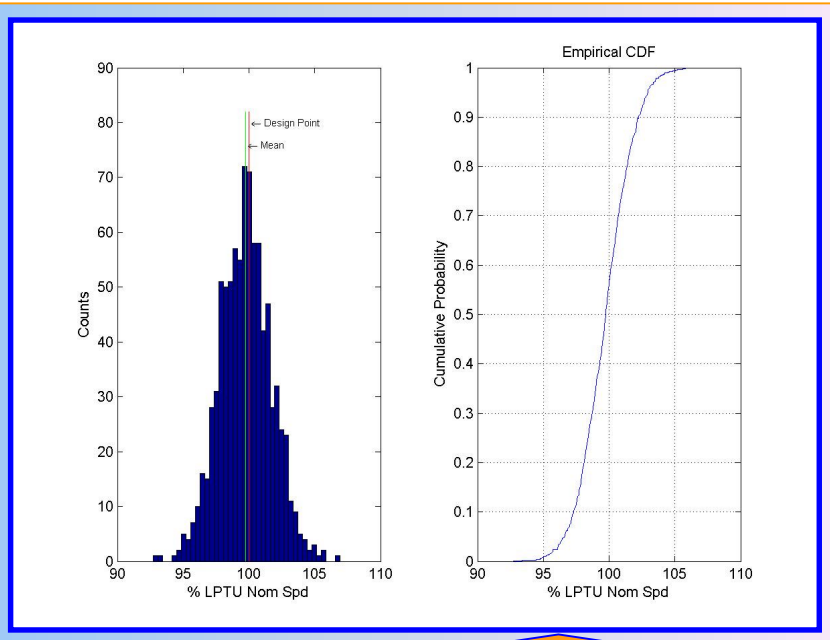


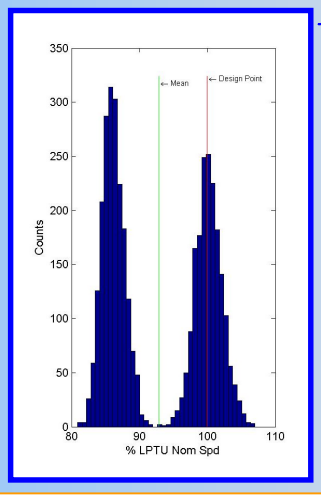




900°C ROT

750°C & 900°C ROT Combined

HPTU




900°C ROT

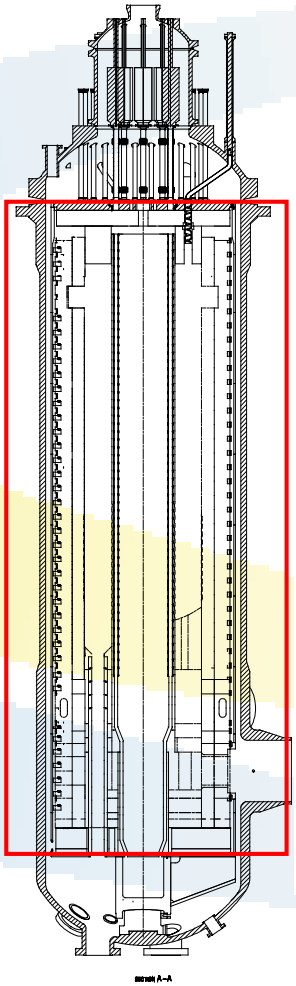
750°C & 900°C ROT Combined

LPTU

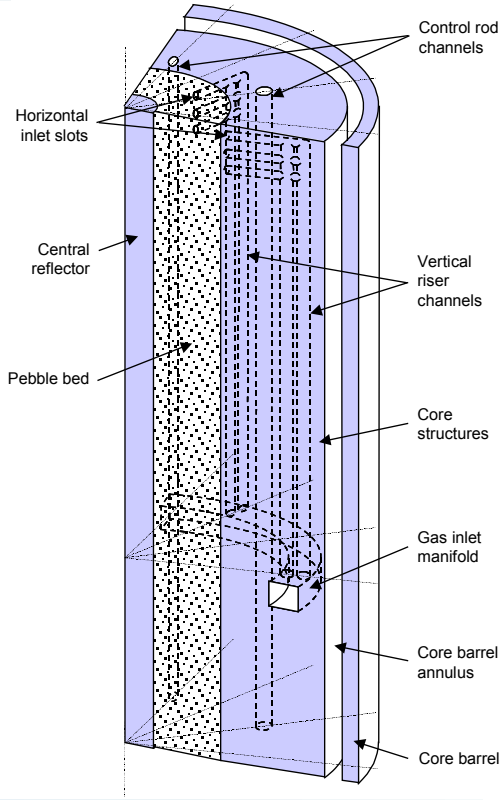
# DLOFC Monte Carlo Analyses on Reactor

## Maximum Fuel Temperature Distribution

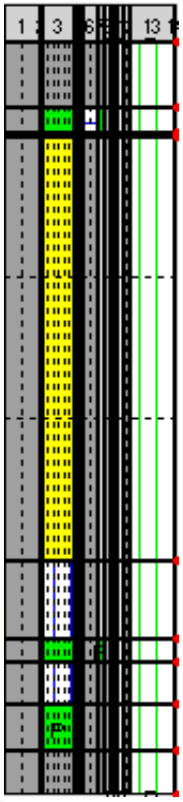
**Reactor Layout**

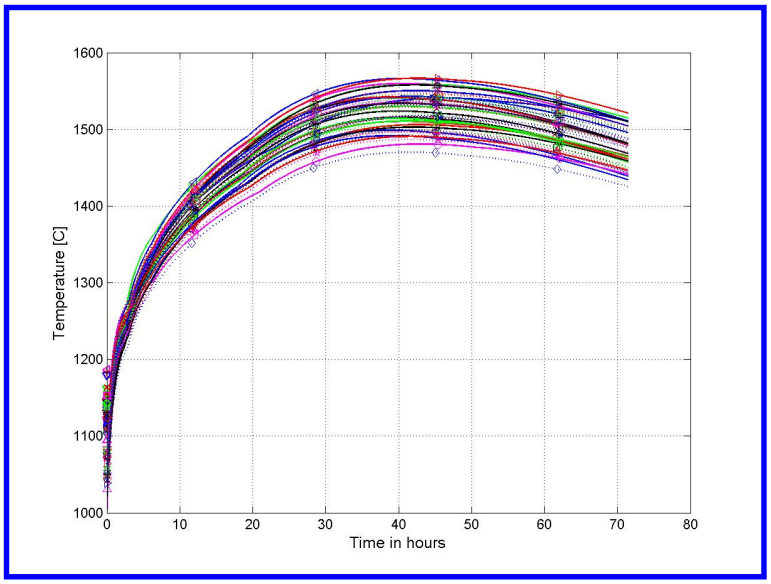


**Simplified Model**




**Flownex Model Layout**

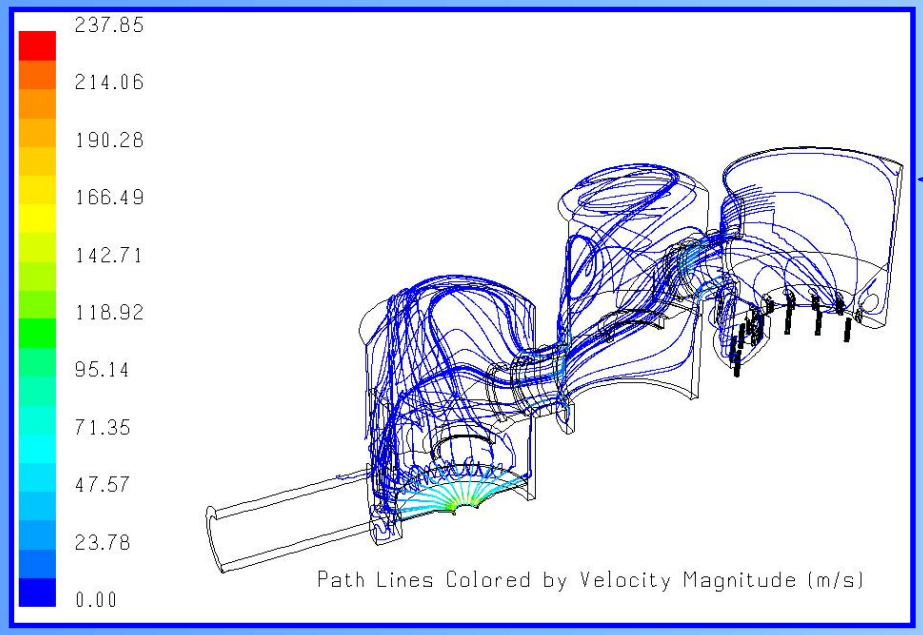





**Transient Results**

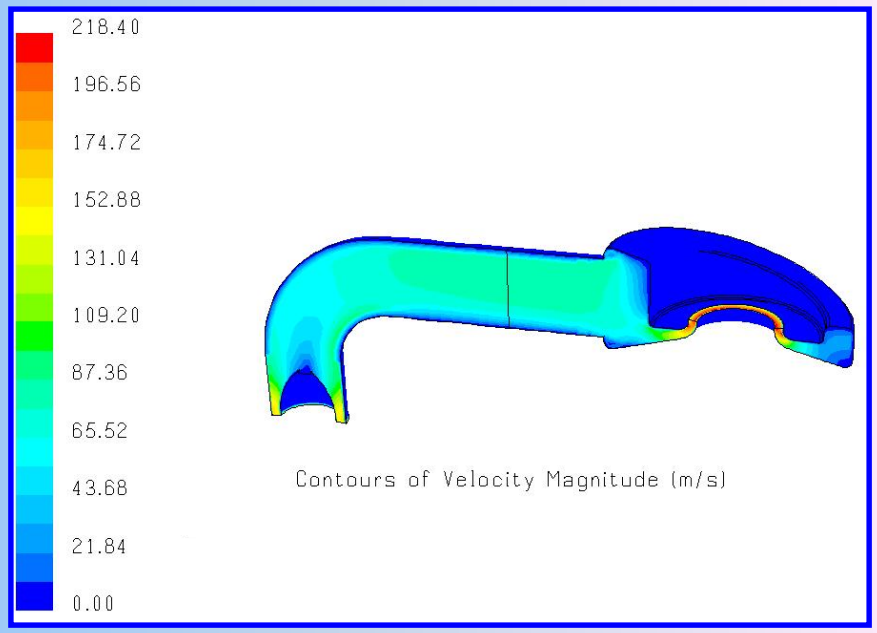
# PCU CFD Analyses

## Manifold & HPT-LPT Connection



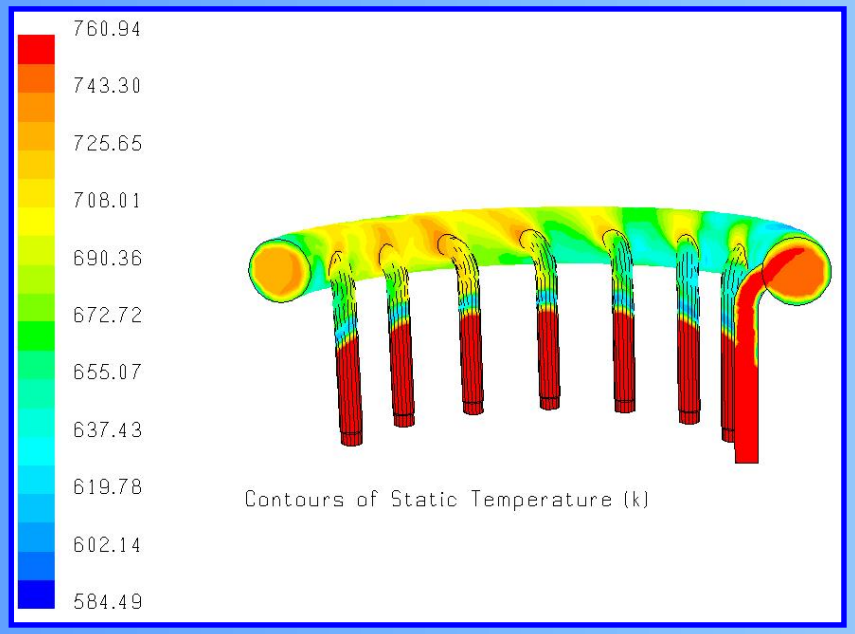

Velocity Path Lines

Velocity Magnitude

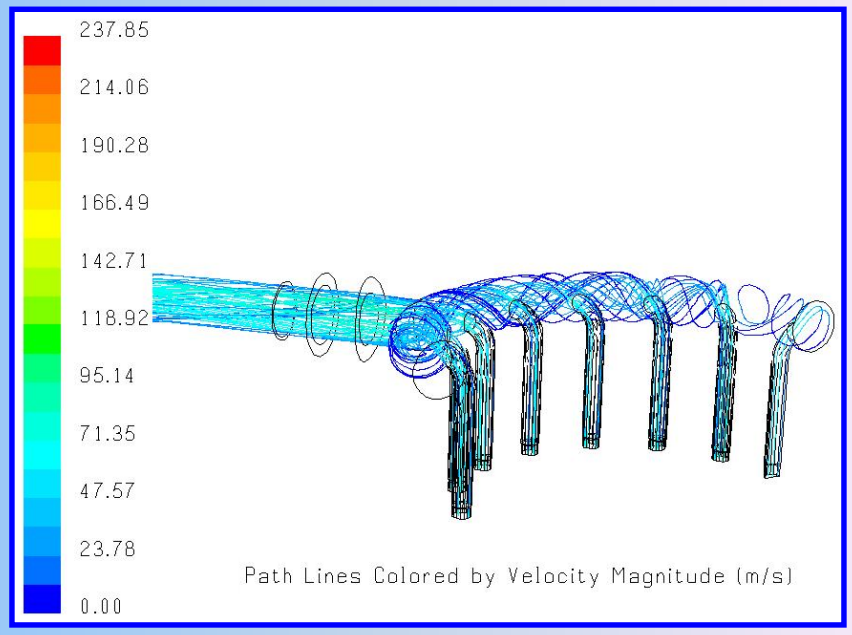


# PCU CFD Analyses

## HP Recuperator outlet header

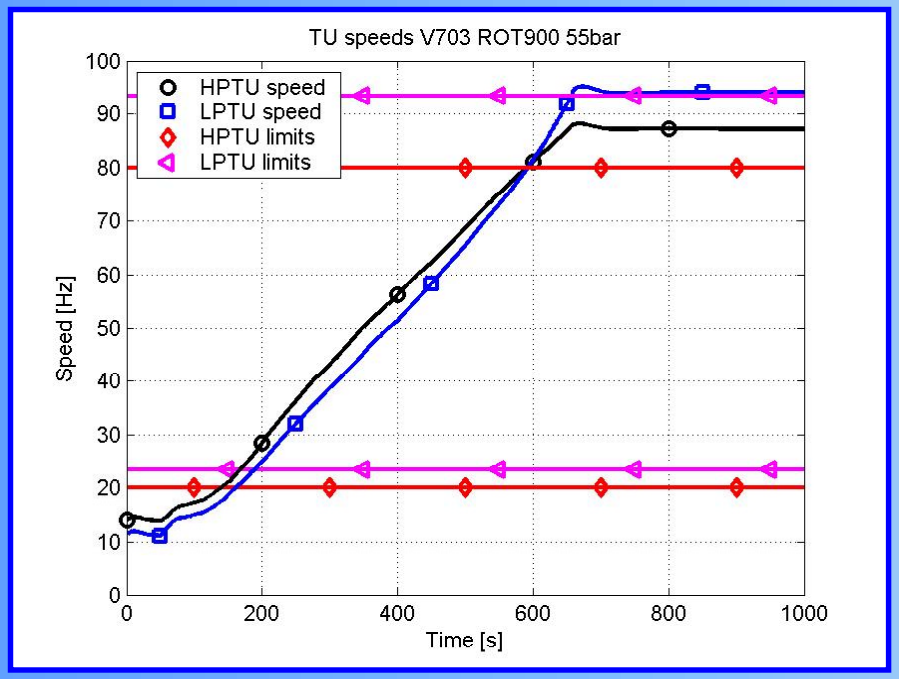



Static Temperature



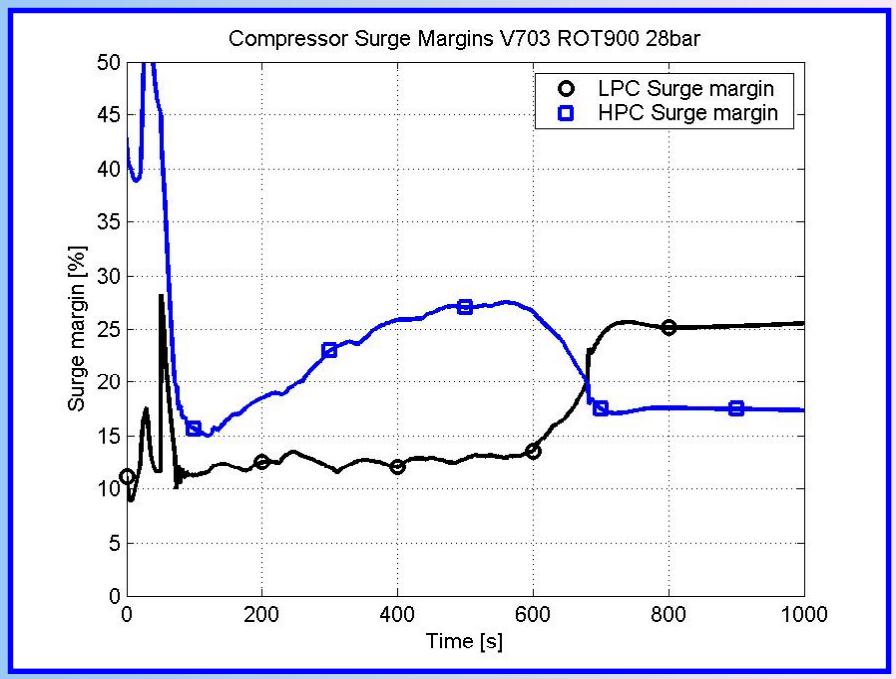

Velocity Path Lines

# Start-Up – Turbo Unit Parameters

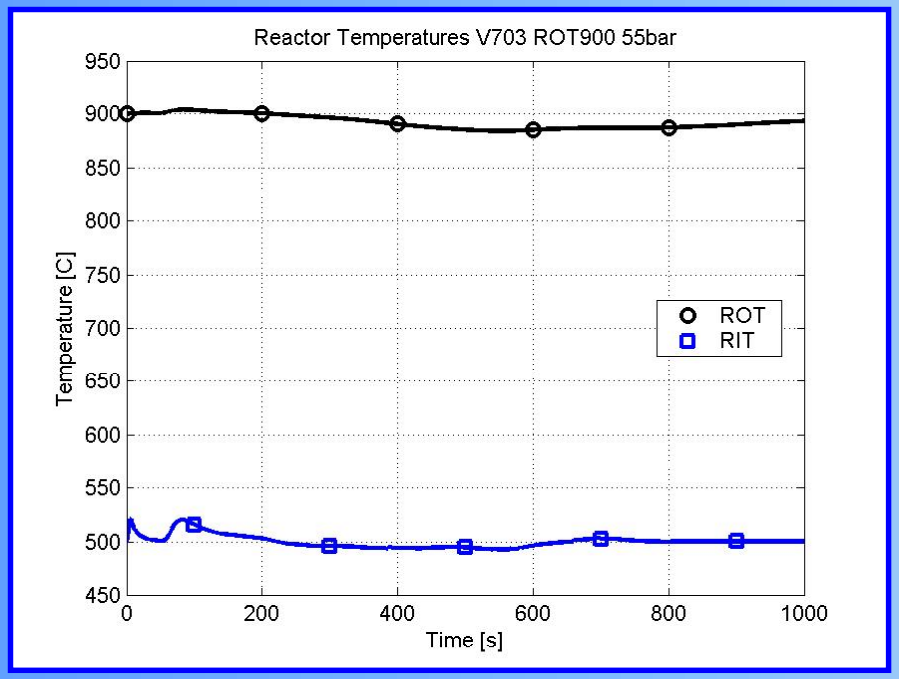



Turbo Unit Speeds

Compressor Surge Margins

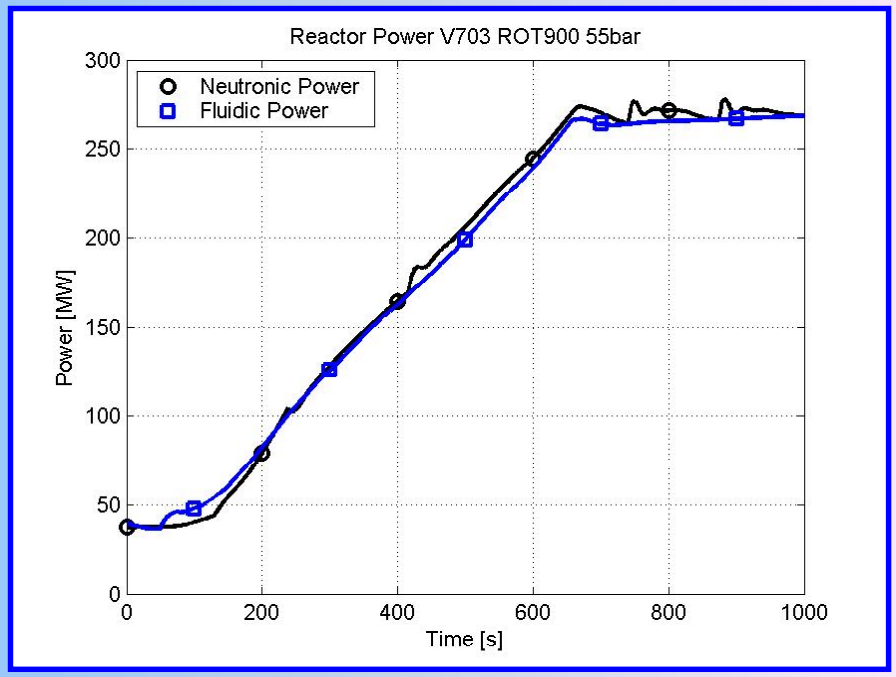


# Start-Up – Reactor Parameters

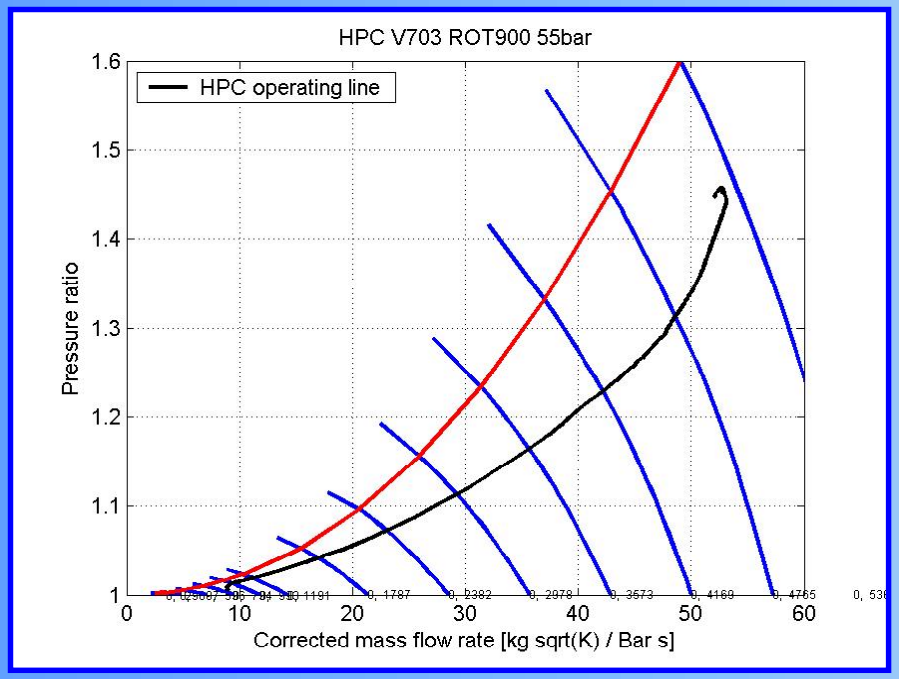



Reactor Temperatures

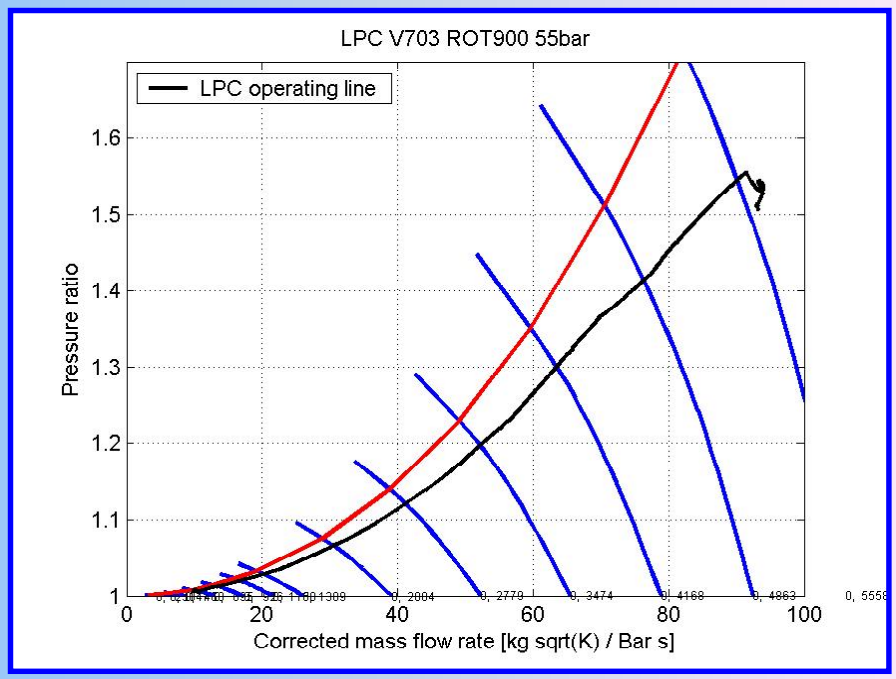
Reactor Power



# Start-Up – Compressor Map Movement




HPC movement




LPC movement