P B M R

PBMR Thermo Hydraulic Cycle and Thermal Design

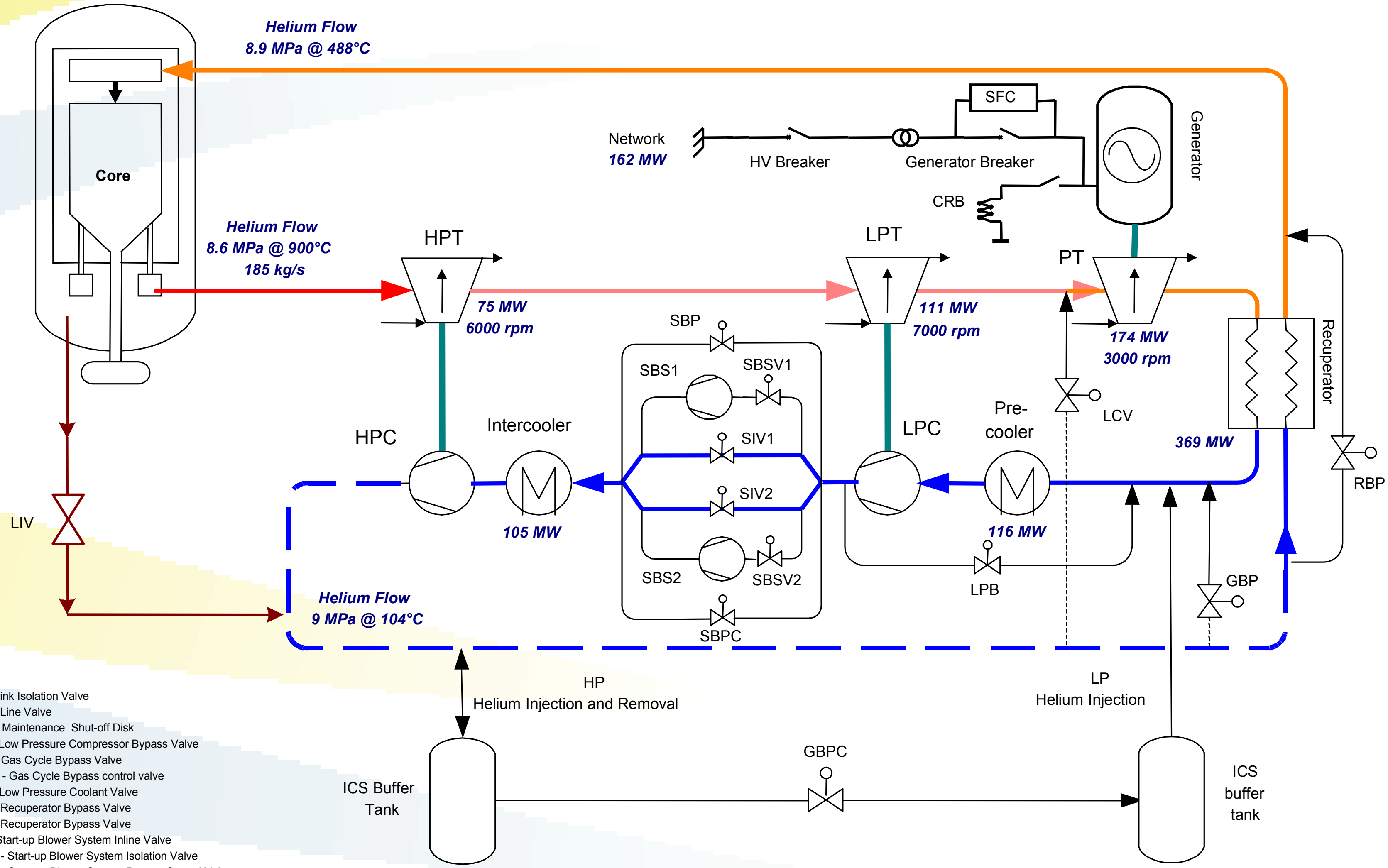
Presented to the US DOE

7 August 2003

Johan Slabber

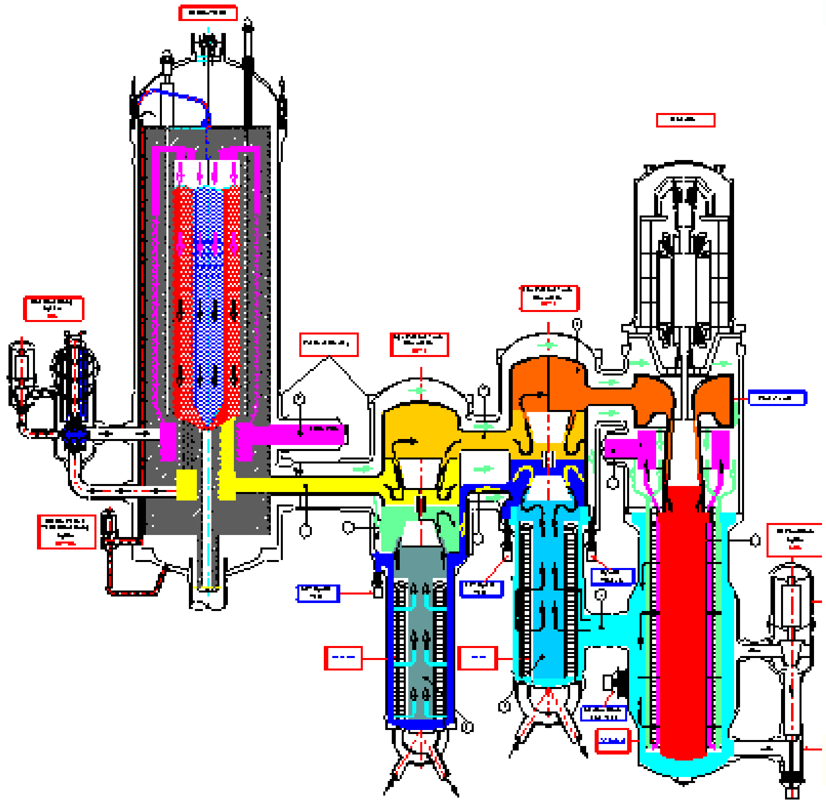
MPS Circuit Schematic Diagram

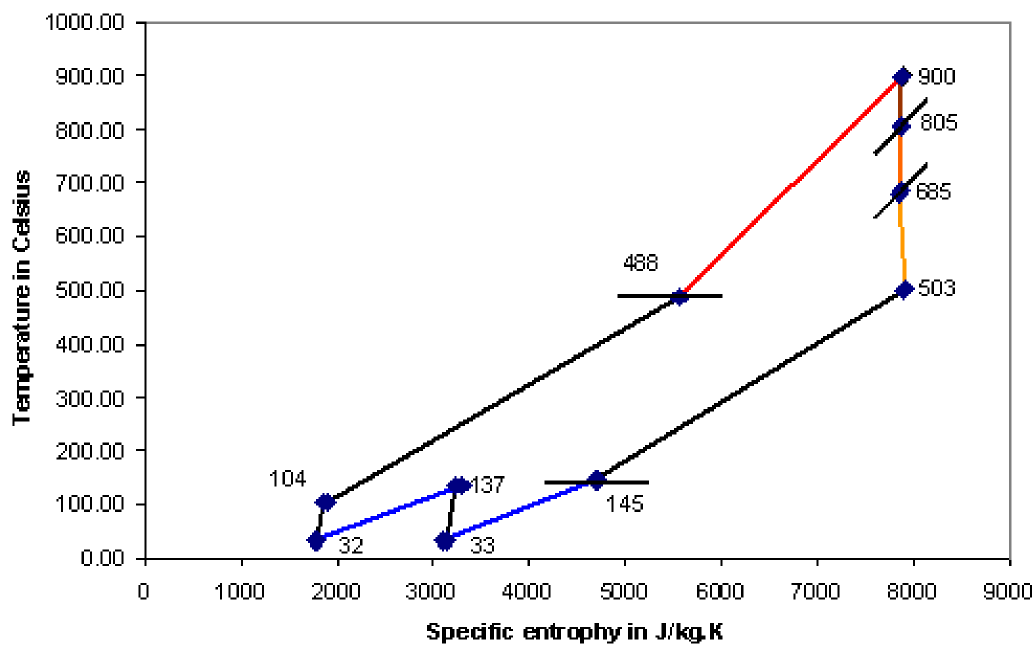
P B M R



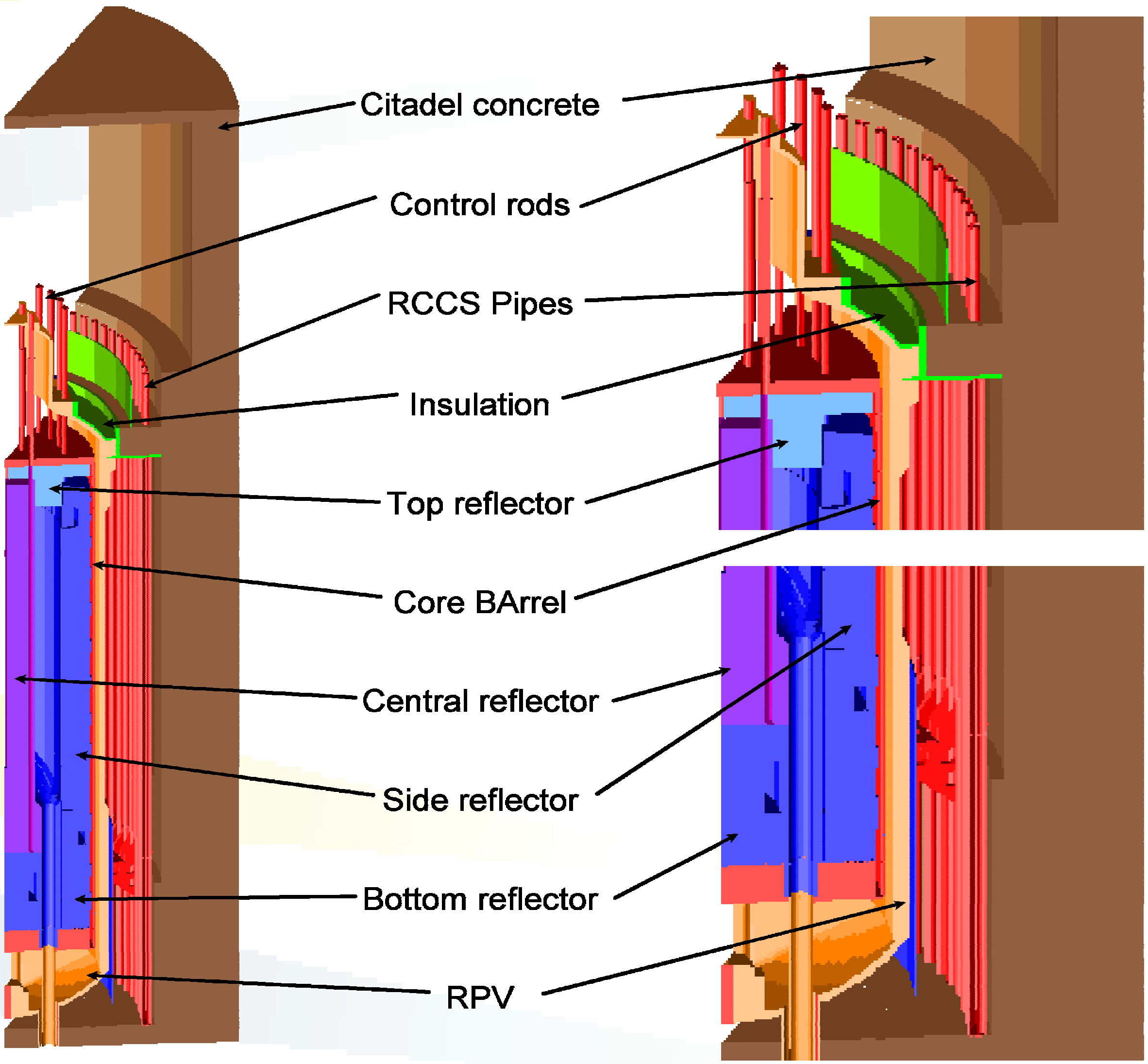
LIV - Link Isolation Valve
IV - In Line Valve
MSD - Maintenance Shut-off Disk
LPB - Low Pressure Compressor Bypass Valve
GBP - Gas Cycle Bypass Valve
GBPC - Gas Cycle Bypass control valve
LCV - Low Pressure Coolant Valve
RBP - Recuperator Bypass Valve
RBP - Recuperator Bypass Valve
SIV - Start-up Blower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



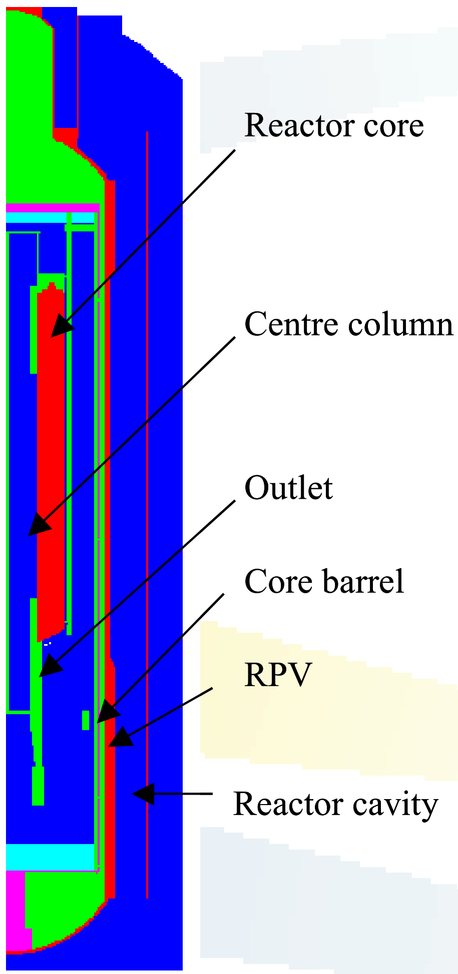


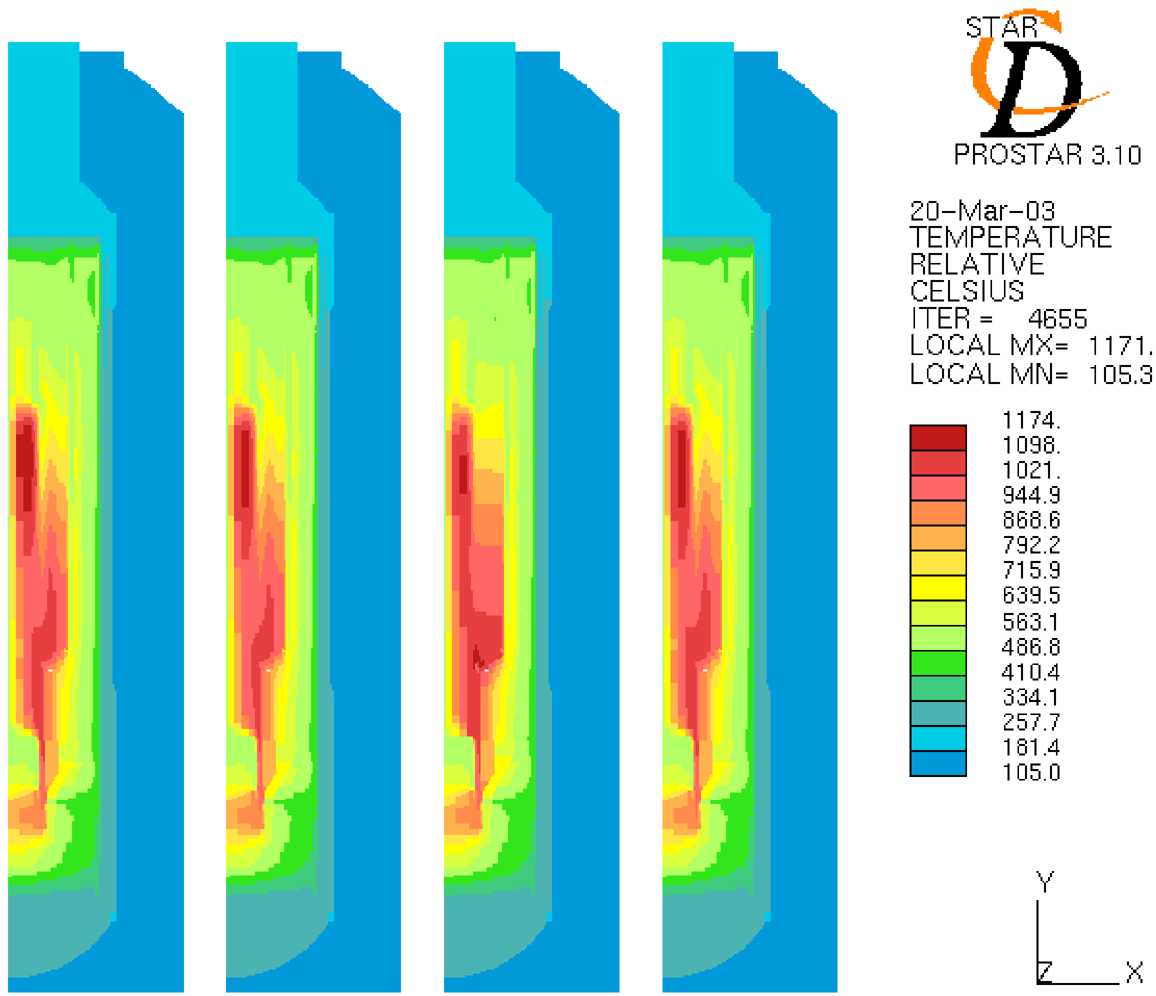
An example of the CFD Reactor Unit model



Reactor Unit CFD Analyses

Effect of Turbulent Mixing

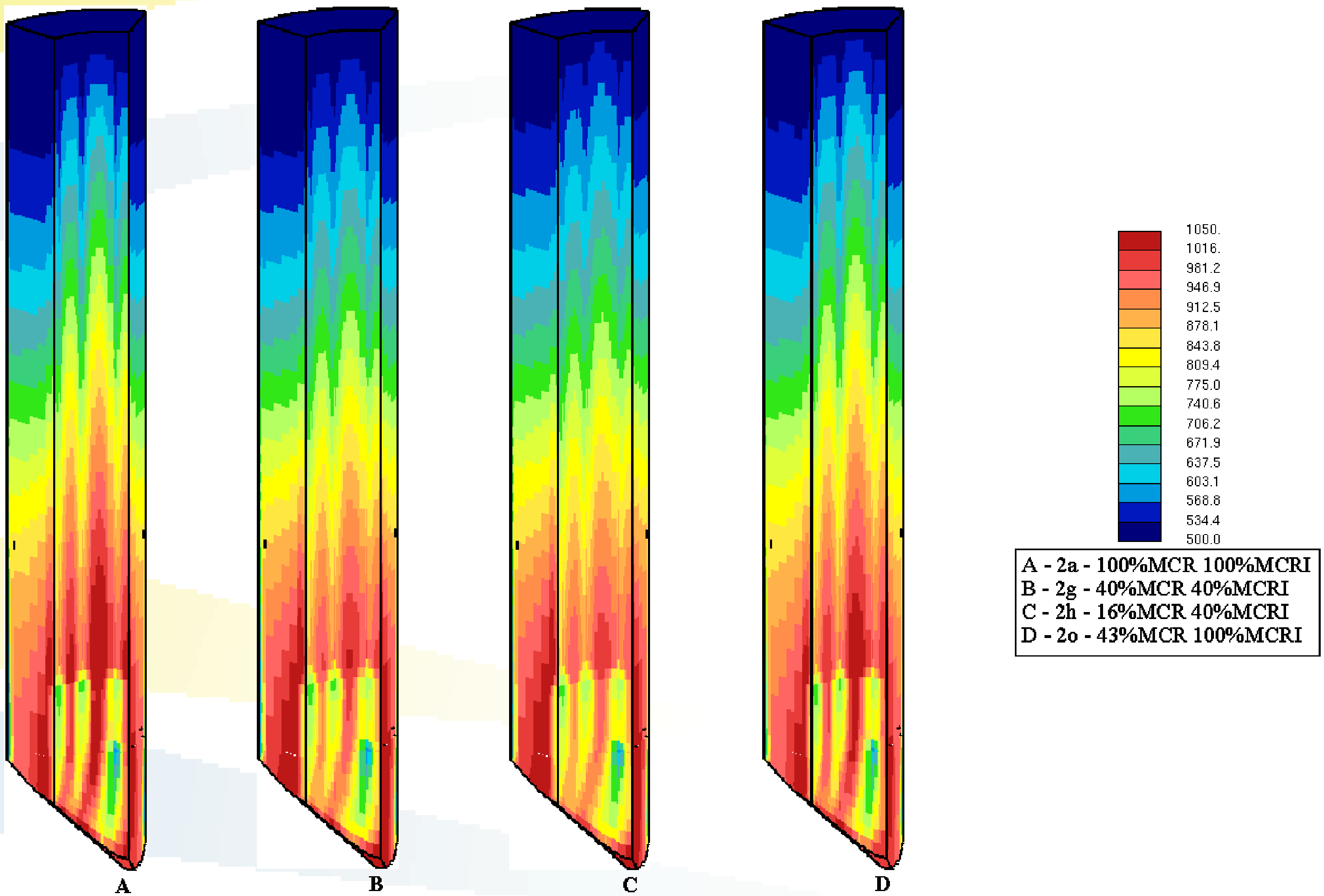




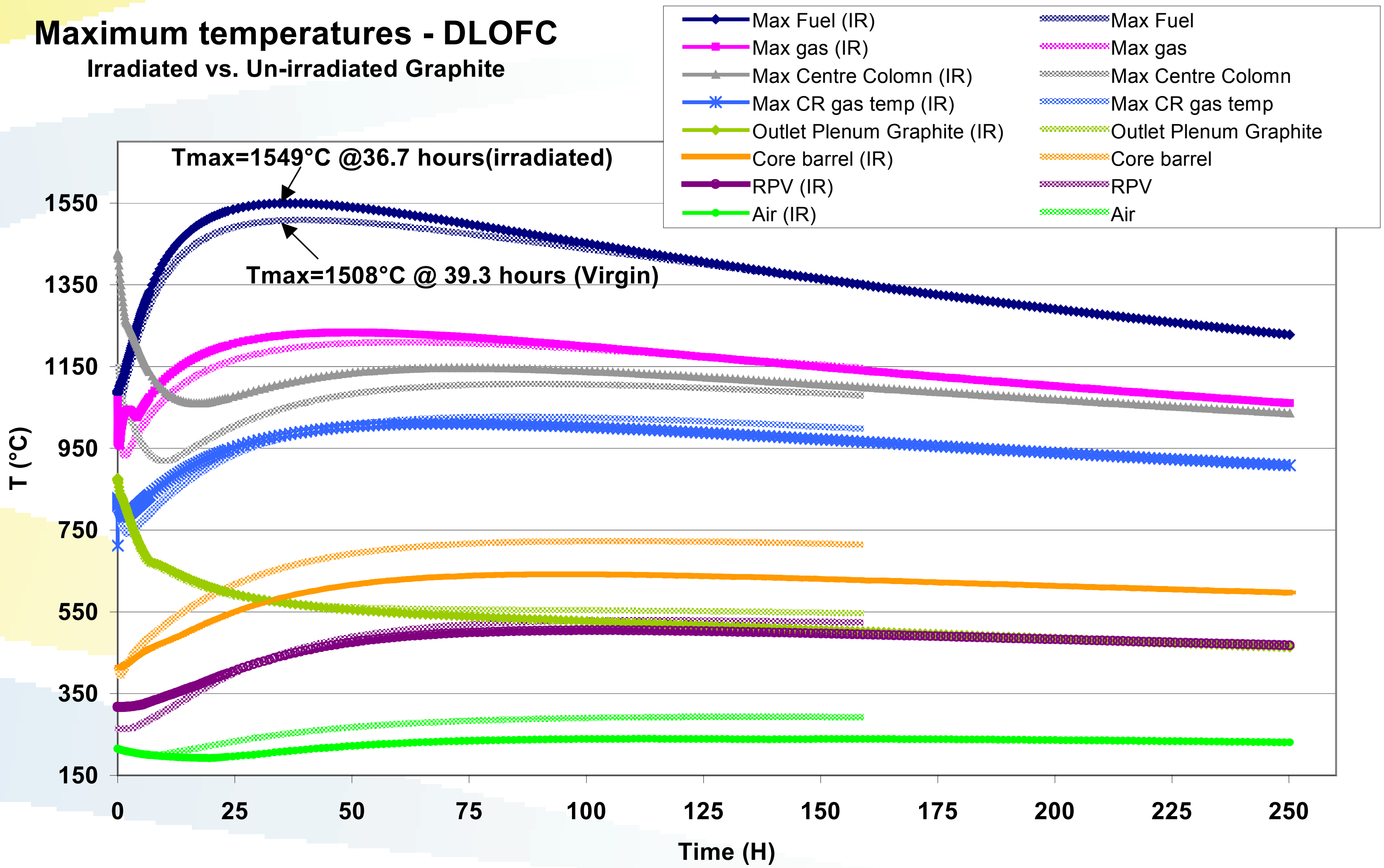
As is Porosity Turbulence Zehner-Schluender

Reactor Unit CFD Analyses

Comparison of Helium Temperature in Core



CFD TRANSIENT SIMULATION OF DLOFC EVENT



MPS Sensitivity Analyses

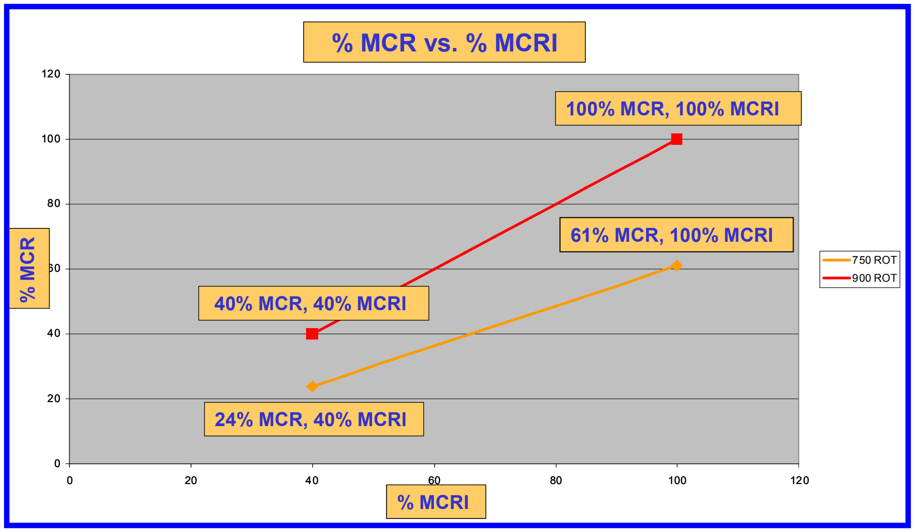
P B M R

Definition:

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

MPS output parameters examined are:

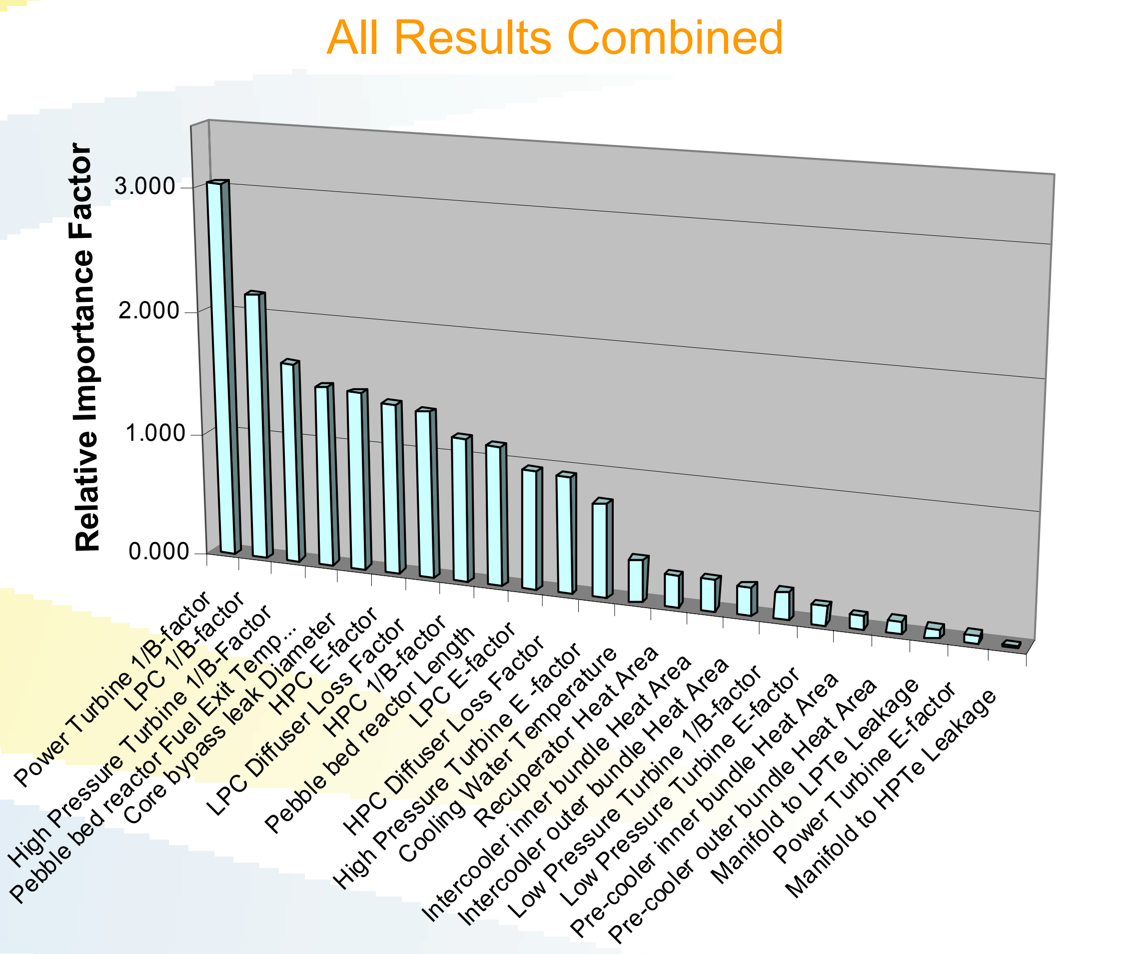
- **HPTU & LPTU Rotational Speed,**
- **HPC & LPC Surge Margin,**
- **Cycle Efficiency**
- **Grid Power**

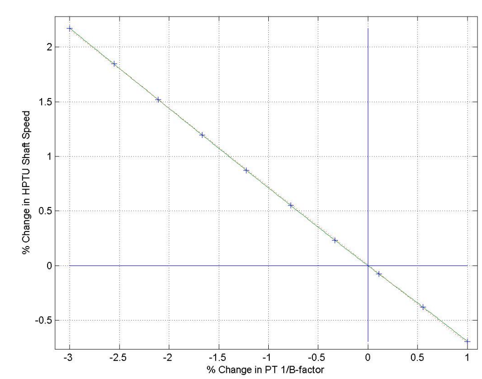


49 parameters are varied, including:

- **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

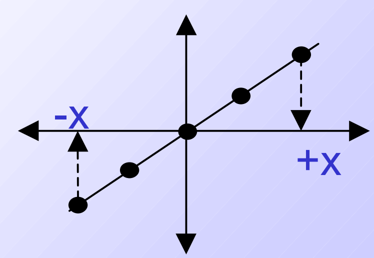




Sensitivity:

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

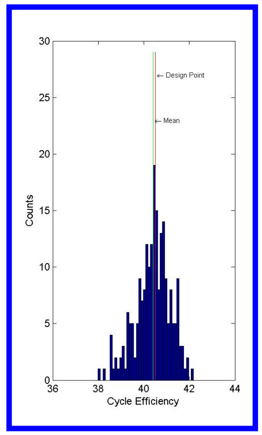
Definition:

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

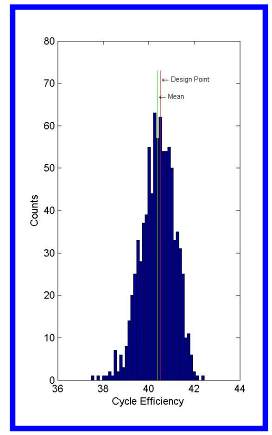
MPS output parameters examined are:

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

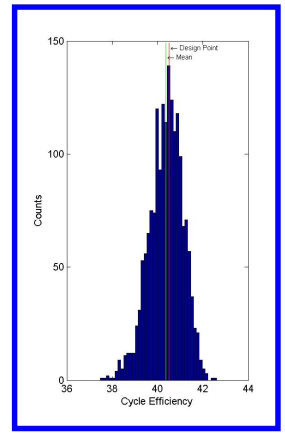
Comparing number of runs (Cycle Efficiency)



250



1000



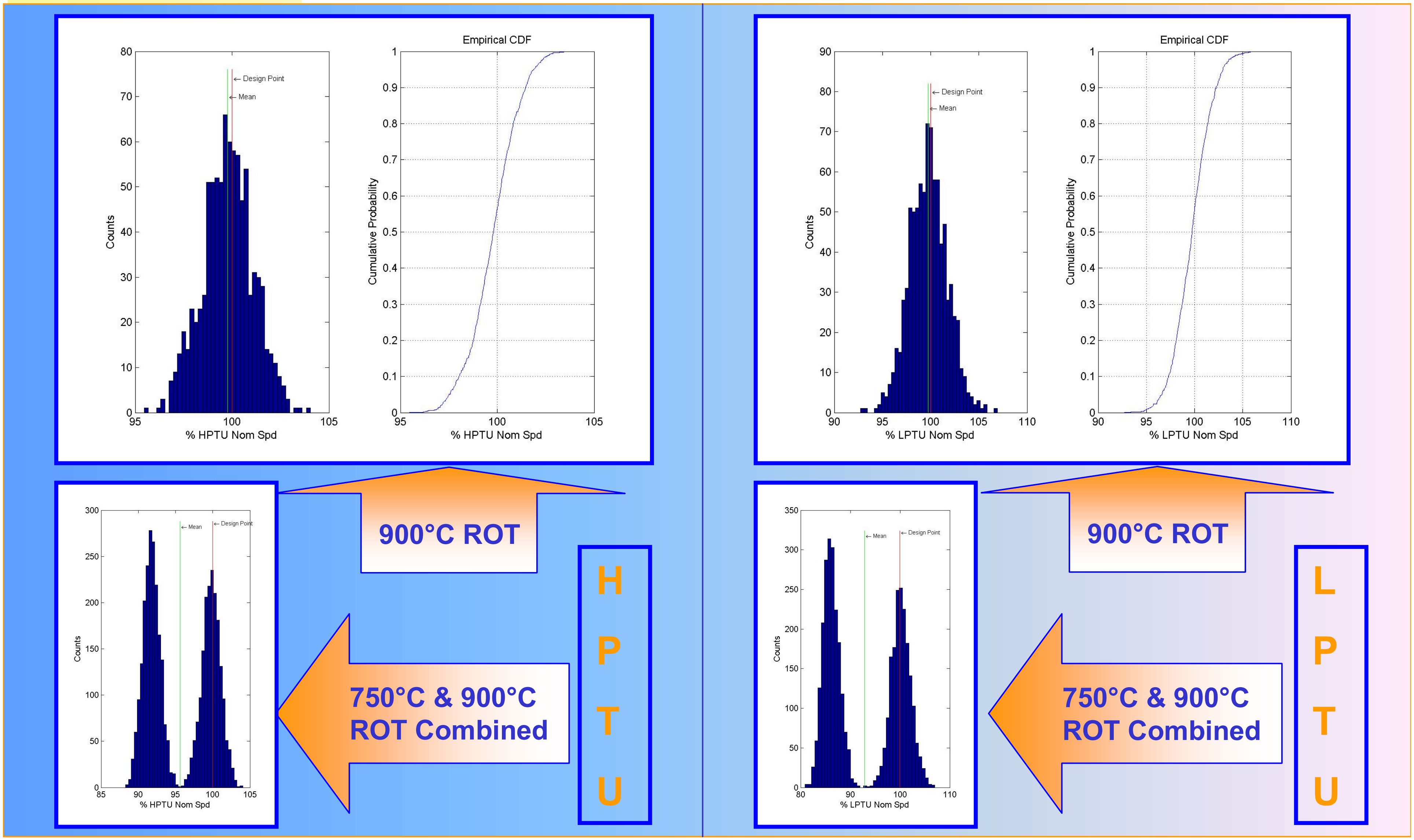
2000

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

Assumed sufficient for convergence

MPS Monte Carlo Analyses

Turbo Machine Speed

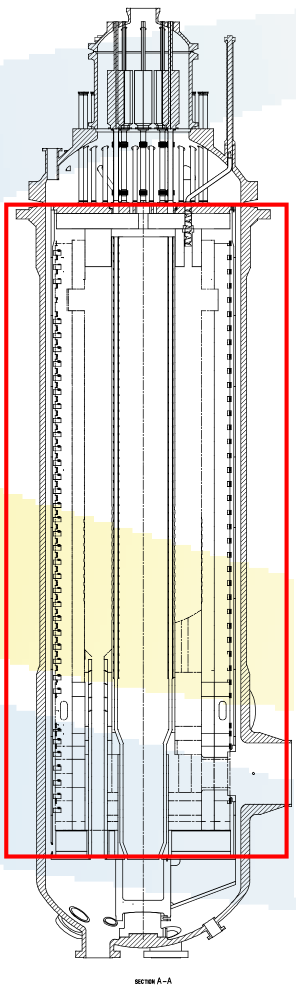


DLOFC Monte Carlo Analyses on Reactor

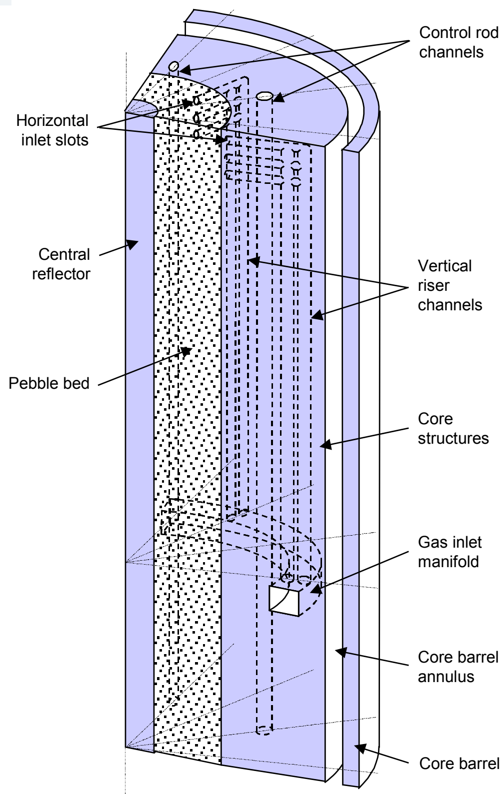
Maximum Fuel Temperature Distribution

P B M R

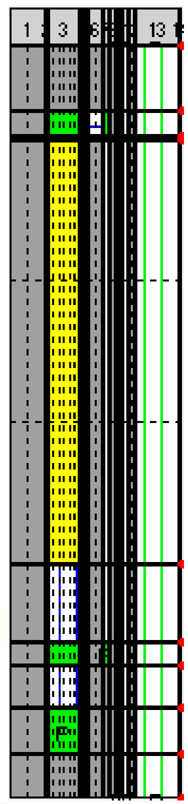
Reactor Layout

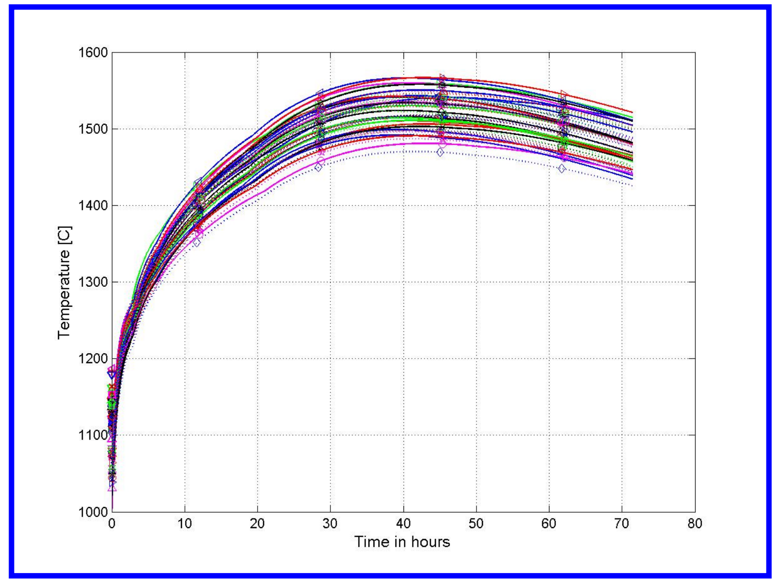


Simplified Model



Flownex Model Layout

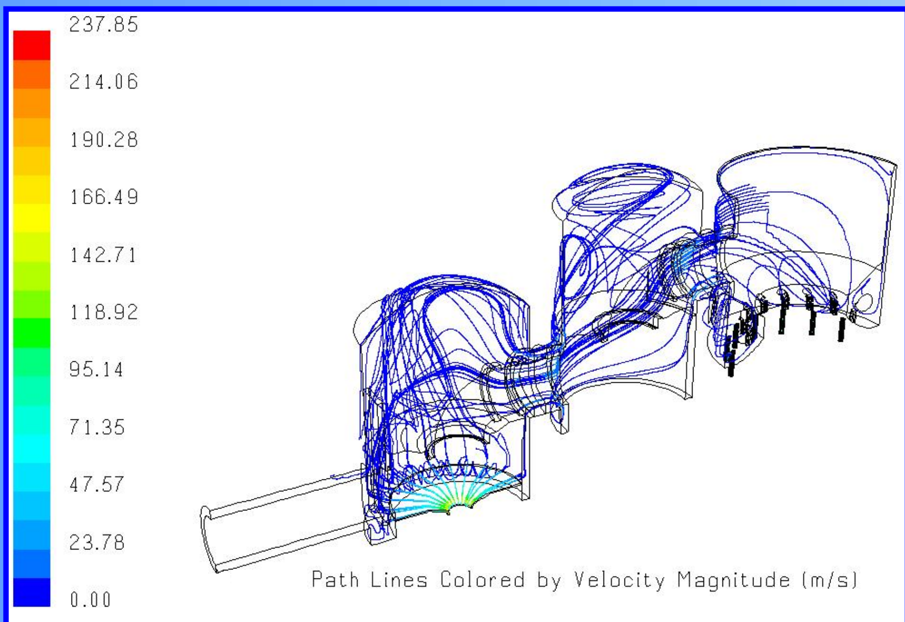




Transient Results

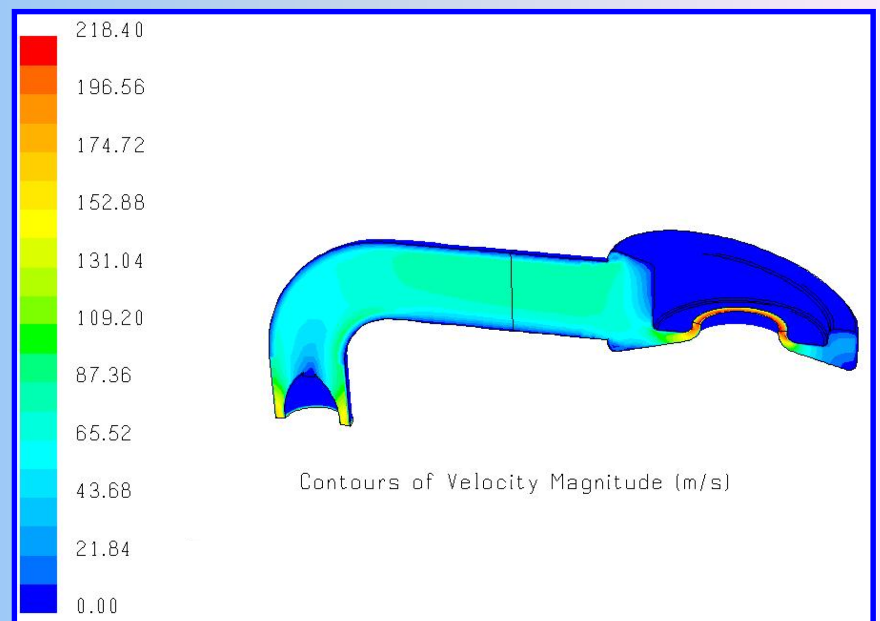
PCU CFD Analyses

Manifold & HPT-LPT Connection



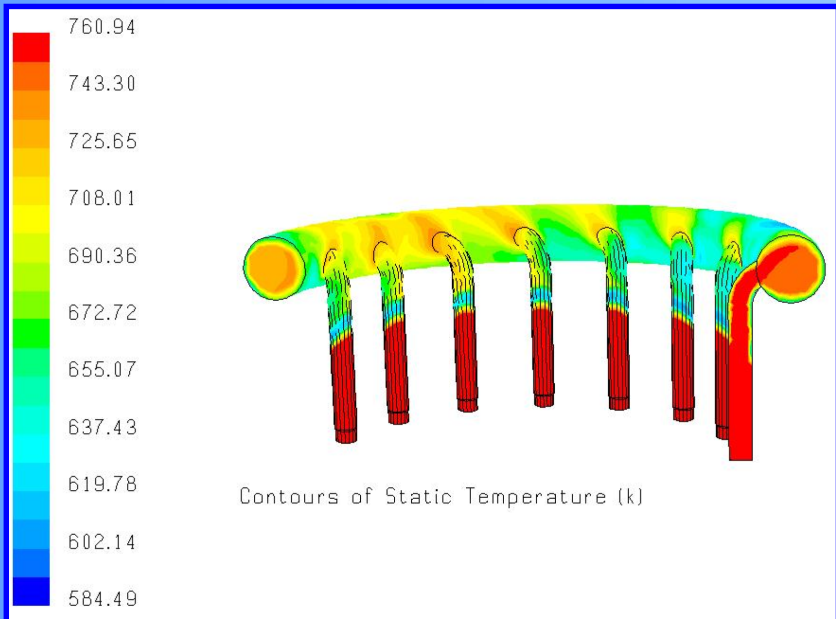
Velocity Path Lines

Velocity Magnitude

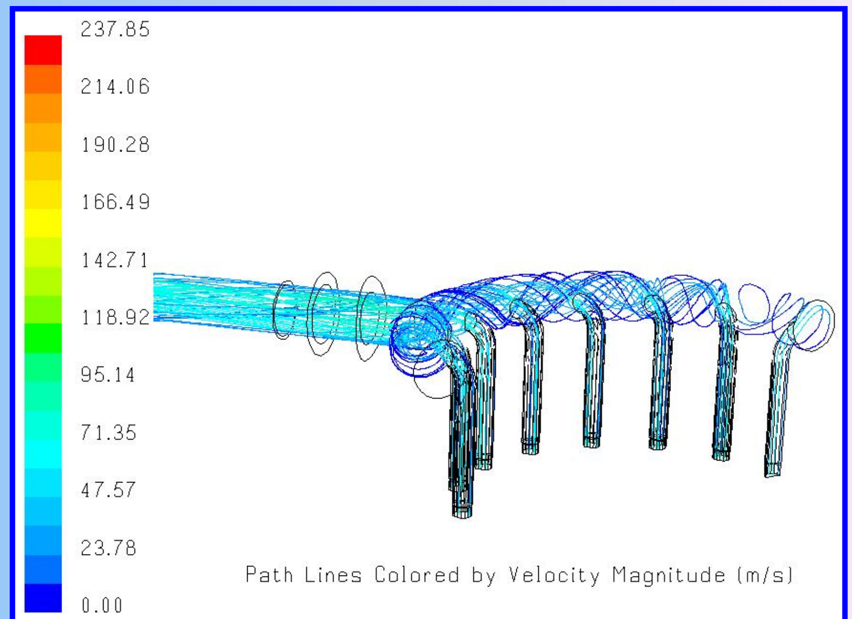


PCU CFD Analyses

HP Recuperator outlet header



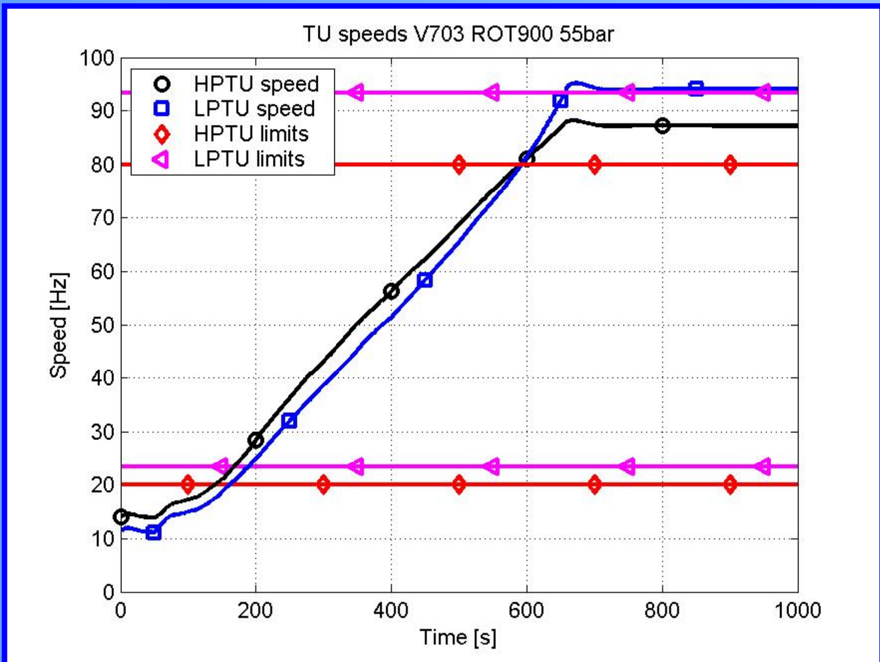
Static Temperature



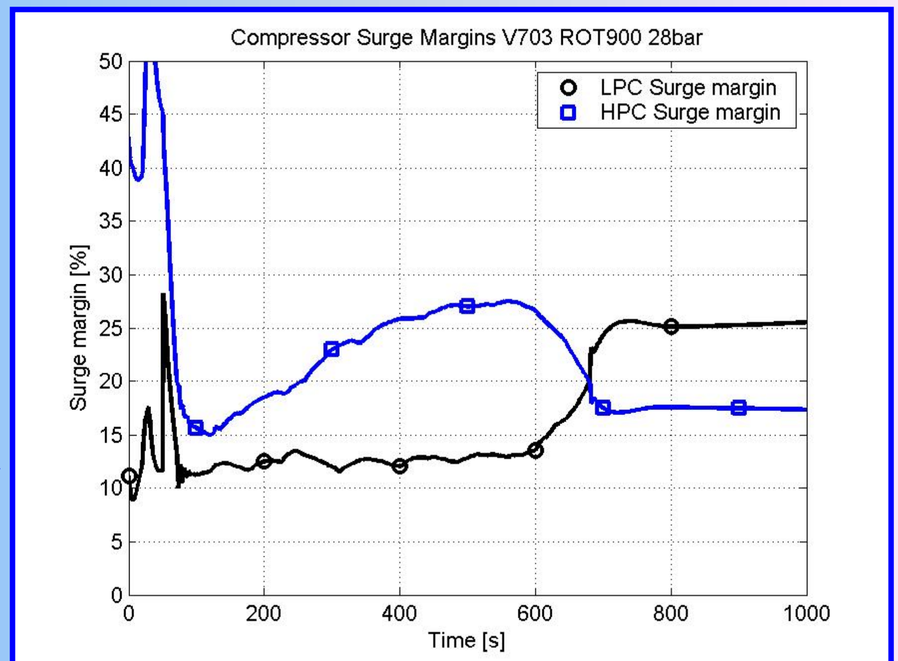
Velocity Path Lines

Start-Up – Turbo Unit Parameters

P B M R

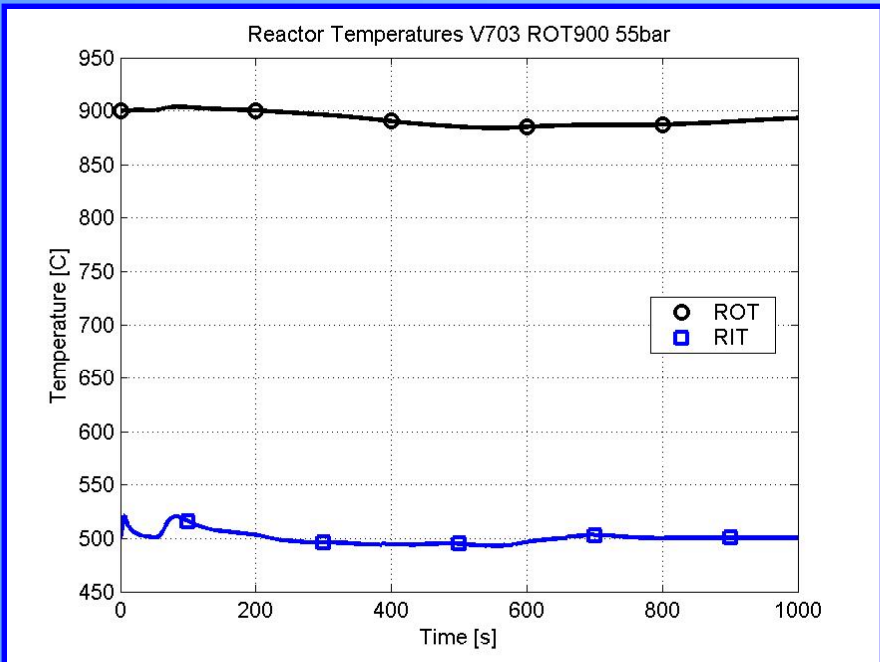


Turbo Unit Speeds



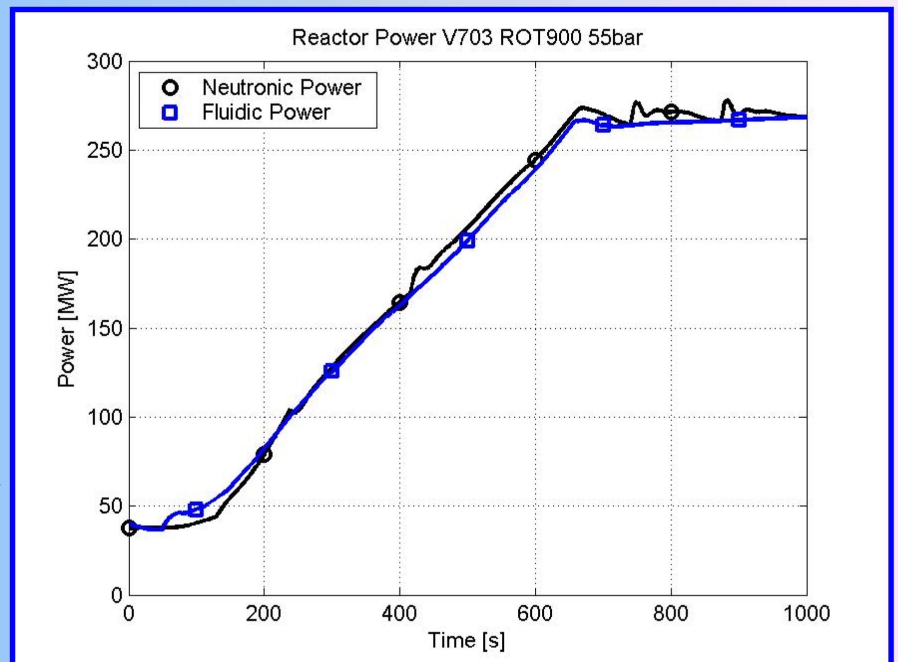
Compressor Surge Margins

Start-Up – Reactor Parameters



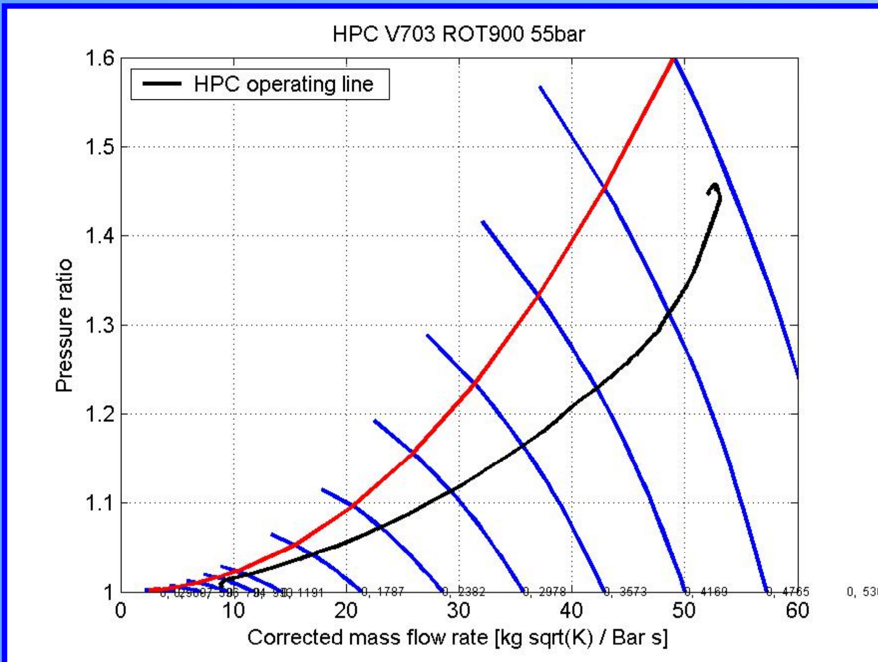
Reactor Temperatures

Reactor Power



Start-Up – Compressor Map Movement

P B M R



HPC movement

LPC movement