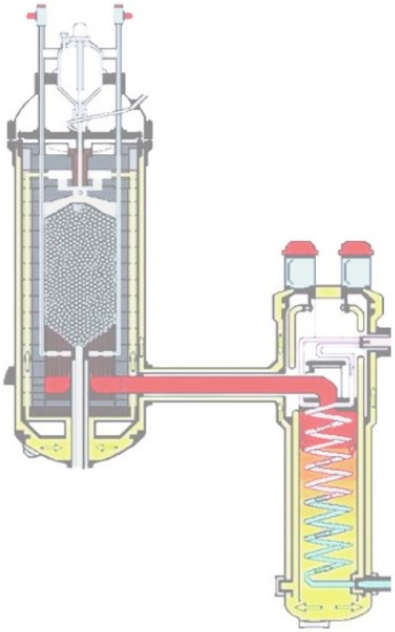
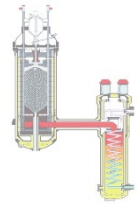
“CLEAN ENERGY”



VERIFICATION AND VALIDATION (V&V) COMPUTER BENCHMARKING FOR HTGRs

Jan J M Jansen van Vuuren

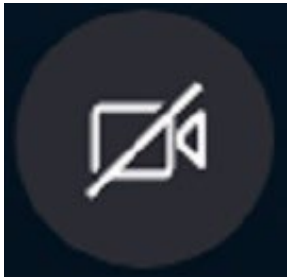


VERIFICATION AND VALIDATION (V&V) COMPUTER BENCHMARKING FOR HTGRs

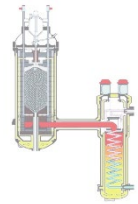
18 March 2024

DOCUMENT 003304

Be Here Now

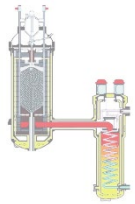


AGENDA



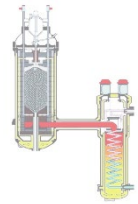
- Mozweli status
- Verification & Validation
- Reactor computational Aspects
- Other Computational Aspects
- Simulation Model
- Non-ideal world of simulation
- Approaches
- Benchmarking as a Process
- Collaboration for Reactor Analysis
- Conclusion

MOZWELI STATUS



- Mozweli programme is in a Preliminary Phase
- Only scoping analysis has been performed
- Preliminary Reactor Model created
- This presentation:
  - Challenges
  - Approach
  - Process

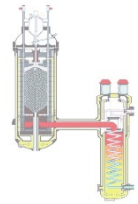
VERIFICATION AND VALIDATION



The distinction between the ***Verification and Validation (V&V)*** is due to the role of specifications:

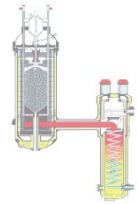
- **Validation** is the process of ensuring compliance with requirements or that specifications are correctly implemented by the system. Ensure the design intend has been achieved.
- **Verification** is the process of ensuring that the software meets specifications. Software integrity and correctness to ensure analysis intend has been achieved.

VERIFICATION AND VALIDATION CONTINUED



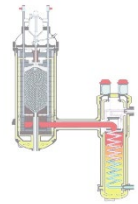
- **Validation** against Specification:
  - User Requirements:
    - Operating envelope
    - Site and location specific
    - Laws and Regulations
    - IAEA and Nuclear Regulator requirements with reference to Safety classification
  - Design and Safety Analysis
- **Verification** to ensure integrity of analysis:
  - by means of using best practice
  - Accepted codes by IAEA & Nuclear Regulator
  - Proven and Accepted codes

REACTOR COMPUTATIONAL SOFTWARE ASPECTS



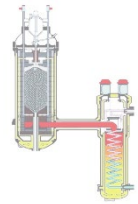
- Nuclear reaction kinetics
  - Neutron flux distribution and flow
  - Fission product behavior
  - Moderator and reflector effect
  - Effect of Control Rods
  - Fuel depletion
  - Preliminary static conditions
  - Dynamic conditions and transients
  - Core temperature distribution
- Heat transfer to coolant
- Heat transfer to Reactor Pressure Vessel (RPV) and external environment
- Effect of event conditions
- Integration of software packages
- Thermo-hydraulic flow
- Integrated Simulator

OTHER COMPUTATIONAL SOFTWARE ASPECTS



- Heat Exchanger design
- Fluid dynamics (Computational Fluid Dynamics (CFD))
- Pressurized equipment design
- Finite Element Analysis (FEA)
- Structural Analysis & Design
- Seismic Analysis
- Computer Aided Design and 3D modelling
- Civil Design

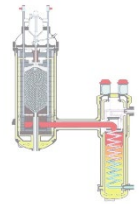
SIMULATION MODEL



The Computer software model includes:

- A Representation of the physical model:
  - Input model
  - Material Specification
  - Physical characteristics
- Mathematical models and equations
- An integration of the mathematical models
- Numerical techniques used to solve equations

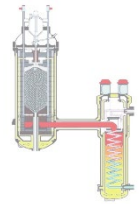
NON-IDEAL WORLD OF SIMULATION



- Physical characteristics:
  - Verified Gen-III Codes applicability
  - Limitation on Generation IV Reactor Verified codes
  - Fuel elements: Pebble geometry and characteristics [1]
  - Pebble Local effect implementation in global model
  - Pebble distribution and flow
- Analysis characteristics:
  - Mathematical equation simplification
  - Application of mathematical equations in a discrete mesh
  - Boundary conditions
  - Software speed of calculation in a dynamic environment
  - Software model interfacing and integration

[1] IAEA CRP on HTGR Uncertainty Analysis: Benchmark Definition and Test Cases, Gerhard Strydom, Frederik Reitsma, Hans Gougar, Bismark Tyobeka, Kostadin Ivanov. Nuclear Science and Engineering, Idaho National Laboratory,

APPROACHES

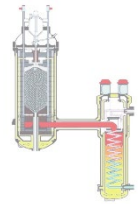


The objective of the computer software product, when coupled with a specific model, is to describe the actual physical system with acceptable accuracy

- Deterministic analysis
- Probabilistic approach
- Level of accuracy [2]
  - Uncertainty Analysis
  - Sensitivity Analysis

[2] Uncertainty and Sensitivity Analyses of a Pebble Bed HTGR Loss of Cooling Event. Gerhard Strydom. Nuclear Science and Engineering Division, Idaho National Laboratory (INL),

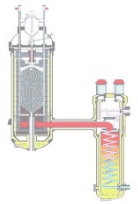
BENCHMARKING AS A PROCESS



- Against similar Codes
- Pragmatic research and experimental tests of identified aspects
- Verification against similar technologies
- International Collaboration
- Life cycle verification backed up by history
- Reference facilities:
  - Previously measured data is limited
  - China HTR10 [3]
  - Japan HTTR [3]
  - Russia
  - United States of America [INL]

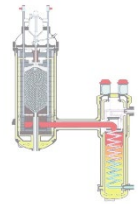
[3] IAEA-TECDOC-1382 Evaluation of high temperature gas cooled reactor performance: Benchmark analysis related to initial testing of the HTTR and HTR-10

COLLABORATION FOR REACTOR ANALYSIS



IAEA-facilitated international collaboration framework: Open-source Nuclear Codes for Reactor Analysis (ONCORE)

CONCLUSION



MORE WORK TO BE DONE

COLLABORATION OPPORTUNITIES

MDEP – GOOD FORUM TO ENGAGE

THANK YOU