Proof-of-concept Gas Reactor MELCOR Model

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Introduction

- Motivation: to show that a MELCOR model was possible and potentially useful for AGR

- Entirely an in-house effort by Jacobsen Analytics
  - No endorsement of modelling or results from EDF Energy or ONR etc
  - Model created using information available in publically accessible documents

- Nature of project leads to some limitations:
  - Limited possibility to benchmark model
  - Limited resource used – simple model

- References for data:
  1. "Description of the advanced gas cooled reactor (AGR)", Riso National Laboratory, Denmark, Nov 1996.
  2. "VEC – A transient whole circuit model for AGRs", paper presented at IAEA, Vienna, Dec 1985.
  3. "Decay heat generation in fission reactors", Chapter 8 of student material by M. Ragheb, Rensselaer Polytechnic, 2011.

Figure of AGR (from Ref. 1)

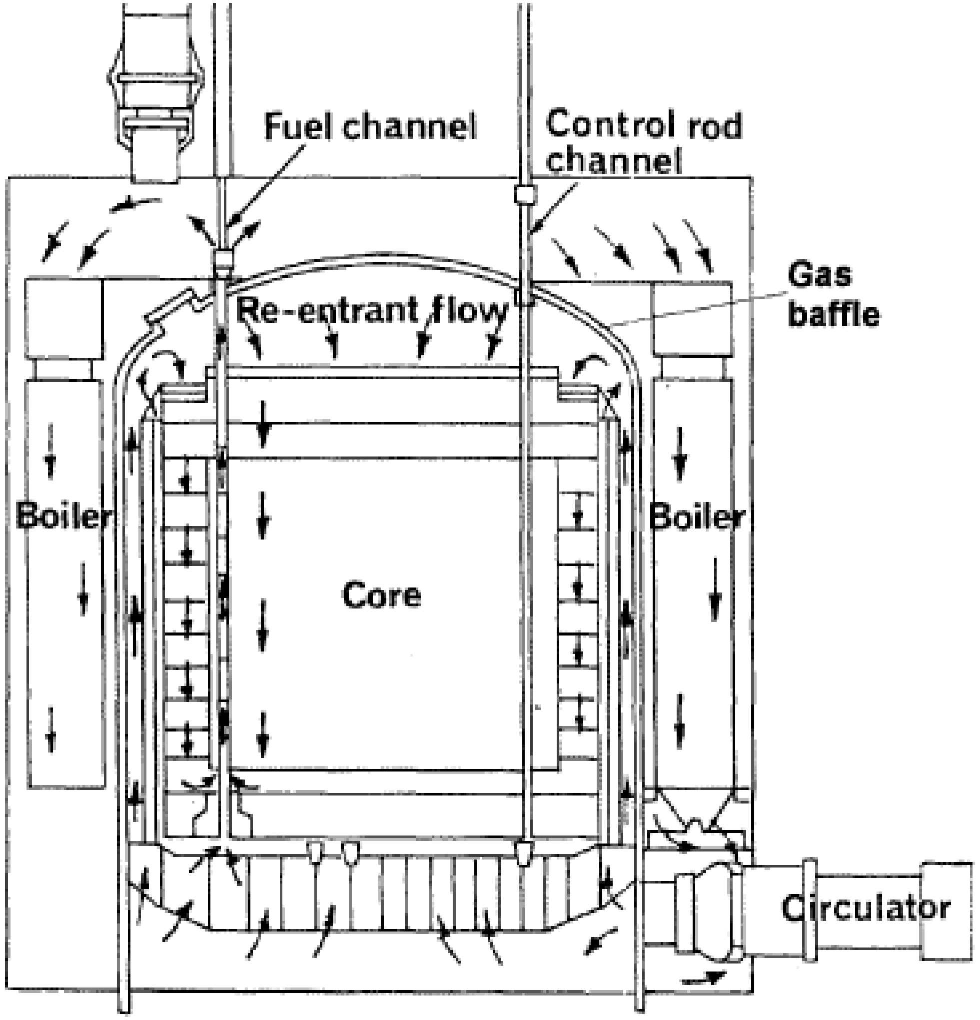
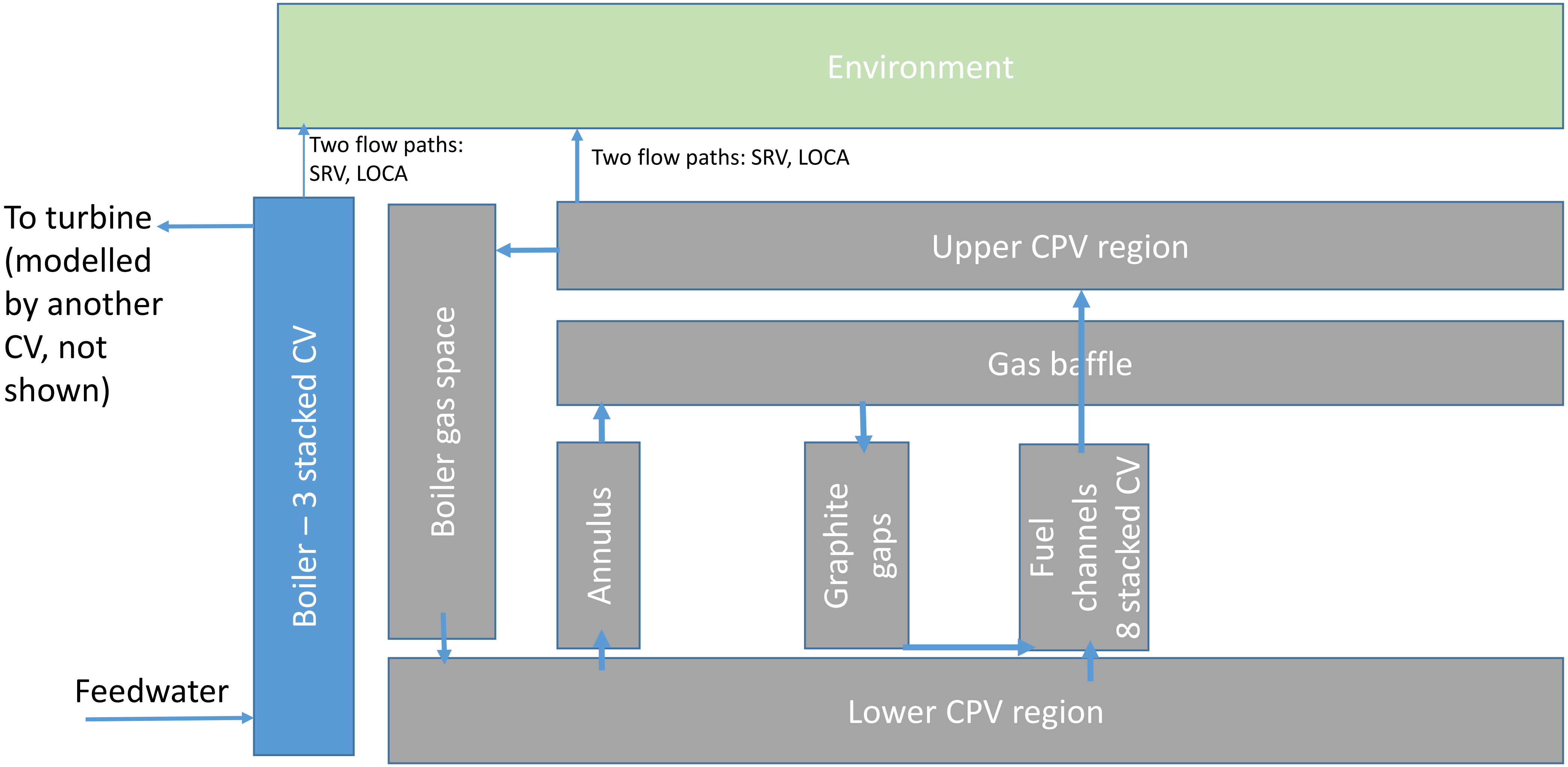


Figure 5.4. Gas baffle with gas flow paths.

Nodalisation – Control Volumes



Nodalisation – summary of heatsinks

- Heatsinks modelled:
  - Boiler wall (tubes)
  - Channel modelling very simplified – 8 heatsinks represent graphite sleeves in channels stacked vertically (multiplicity: 308 for each one)
  - Single graphite “lump” to represent graphite bricks in core (heat conduction to sleeves modelled)
  - Core support structures
  - Concrete walls, ceiling and floor
  - Core: no use of core package, no attempt to simulate core degradation
    - Fuel and clad represented using heatsinks (HS with multiplicity)
    - Control function for power input to UO2 pellets
    - 8 vertical sections, ~11000 fuel pins (UO2 + Steel cladding)

- Uncertainties
  - Estimated graphite heatsink dimensions based on overall core and fuel channel dimensions (fuel channel dimensions and numbers known precisely from Refs)
  - Core support (diagrid) dimensions/mass not known – estimated based on overall physical dimensions of lower CPV region
  - These items likely important for overall accident response

Boiler model

- Boiler modelled as three sections:
  - Subcooled water
  - Steam/water zone
  - Superheated steam
- Used typical PWR SG tube dimensions due to lack of better information
- Important area of modelling uncertainty: lack of information on boiler design – number of tubes, orientation (coiled), heat transfer area, etc
- Tuned heat transfer area to get reasonable agreement with operating parameters
- Steady state results suggest that boiler model would need improvement
  - More vertical nodes probably needed – e.g., VEC model (Ref 2) uses 10 stacked nodes

Steady state

- Tuning of boiler heat transfer allowed reasonable agreement with published parameters in normal operation

Parameter	**Value from Ref 1**	**Value - MELCOR Model (% error)**
Gas flow through core	3680 kg/s	3732 kg/s (+1.4%)
Gas inlet temperature	565 K	592 K (+4.8%)
Gas outlet temperature	918 K	969 K (+5.5%)
Boiler temperature range (subcooled – superheated)	431 K to 813 K	486K to 636K (+12.8% to -21.8%)

Steady state

- Predicted temperatures in steady state (no comparison data available)

Parameter		**Value - MELCOR Model**
Fuel centreline temperature (mid core)		2022K
Clad temperature (mid core)		936K
Graphite temperatures (range)*		649 K to 932 K
		* Ref 1 suggests graphite temperatures in operation are above 670 K

Transients

- TR1 – reactor, turbine, gas circulator trip. Loss of feedwater
- TR2 – 3” break in boiler steamline with loss of feedwater. Reactor, turbine and gas circulator trip.
- TR3 – primary circuit breach (1.5” diameter). Reactor, turbine, feedwater and gas circulator trip.

Example results will be presented at meeting

Note sensitivity to accuracy of heat sink masses and heat transfer between structures expected – i.e., heatup timescales may be significantly different to those shown here.

Conclusions (1)

- MELCOR model considered a success, given resource and information limitations
- MELCOR can produce credible accident response and initial steady state –especially bearing in mind simplicity of modelling
- Built-in materials properties for needed fluids and structures – CO2, water, graphite, UO2, steel (clad)
- Good models for two phase water behaviour – advantage over traditional gas reactor transient analysis codes

Conclusions (2) - areas of modelling to improve for real application

- Areas related to information needs:
    - Graphite and steel heatsink dimensions
    - Boiler model
        - arrangement, heat transfer area
    - Roughness of fuel pins (ribbed steel cans)
- Areas related to simplified modelling:
    - Arrangement of core, representation of channels
    - Structure to structure heat transfer modelling (e.g., between graphite heatsink):
        - Conduction modelling, review radiation HT modelling
    - Severe accident simulation:
        - Use of core model
        - Model reduction of CO_2 to CO
- Benchmarking
    - Benchmark against traditional AGR code analyses