LA-UR-14-20508

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Title: Early User Test: BISON for Fission Gas Release Modeling

Author(s): Johns, Russell C.

Intended for: Report

Issued: 2014-01-28

Early User Test: BISON for Fission Gas Release Modeling

Russell Johns
NEN-5

January 17, 2014

Introduction

As a test to develop an understanding of the capabilities and input of the nuclear fuel performance code BISON[1], we modeled the fission gas release of the Oconee rod 15309[2] as there is benchmark data available for comparison.

BISON has two fission gas models available, the Forsberg-Massih model[3] and the Simple Integrated Fission Gas Release and Swelling (sifgrs) model[4]. Due to time constraints and availability of model parameters (we did not have all of the parameters for the sifgrs model already in hand) we only tested the Forsberg-Massih model.

The Oconee rod test has been used in a number of benchmark studies including the integral assessment of FRAPCON 3.4[5]. The Oconee Rod test is a 5-cycle test bundle with an average burnup of 50GWd/MTU. The FRAPCON assessment predicted that the Oconee Rod15309 Test case would release 1.25% of all fission gas produced, while experimentally only 0.8 % was released at EOL. Other studies using BISON[6] with the sifgrs model have under predicted EOL fission gas release (FGR).

As a starting point, we looked at the effect of varying 3 parameters on FGR : the external pressure, the release fraction, and the grain size. The parameters used for the model along with the defaults in BISON are presented in the Table below.

Parameters used in Forsberg Massih fission gas release model:

Parameter	Default	Actual
Fuel Grain Radius	10E-6 m	5-25E-6 m
Resolution rate from Intergranular bubbles	1E-7/s	1.5E-5/s
Resolution depth	1E-8 m	1E-8 m
Bubble radius	5E-7 m	5E-7 m
Bubble shape factor	0.287	0.287
Surface Tension	0.626	0.626
Fractional coverage	0.5	0.5
External Pressure	10 MPa	5-30 MPa
Release Fraction	0	0 to 1
Fractional yield	0.3017	0.3017
Calibration Factor	1	1

General Calculation Observations:

All of the varying cases produced the same amount of fission gas to within a factor of 1E-5 and completed in 278 to 280 time steps. A prototypic evolution of fission gas production and release is shown in figure 1. Note that while we have not identified the responsible phenomenon, the irregularity of fission gas release at early times occurs over numerous time steps and is unlikely to be purely a lack of convergence.

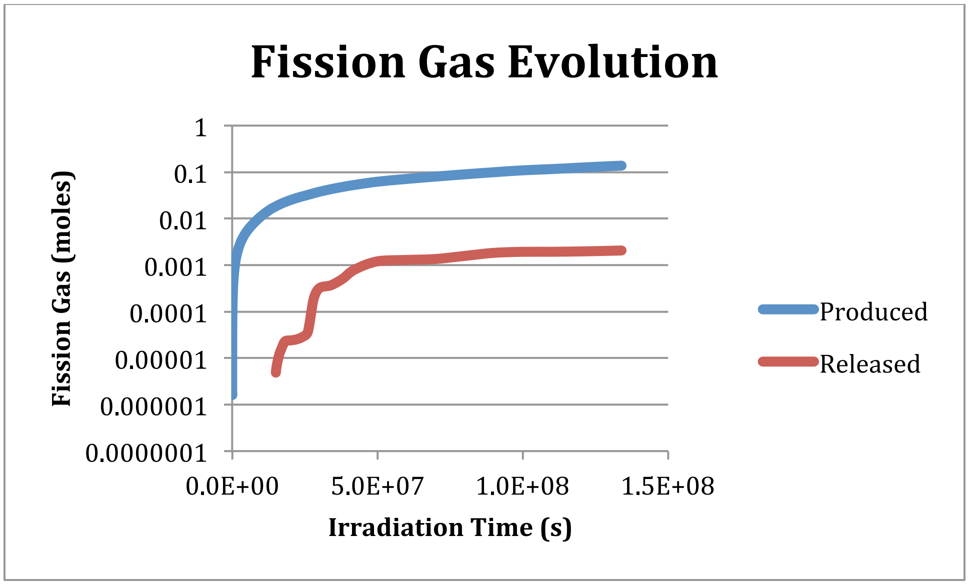

Figure1: Prototypic evolution of production and release of fission gas as a function of irradiation time. This run had parameters of 10MPa external pressure, 25μm grain size and release fraction of 1.0.

External Pressure

As can be expected from solubility on a gas in a solid or liquid, increasing the external pressure reduces the amount of gas release, and delays the initial release of fission gas. The sensitivity of FGR to External pressure is plotted in Figure 2. With sufficient external pressure FGR can be reduced to 0. Additionally the time to initial release is shown in figure 3.

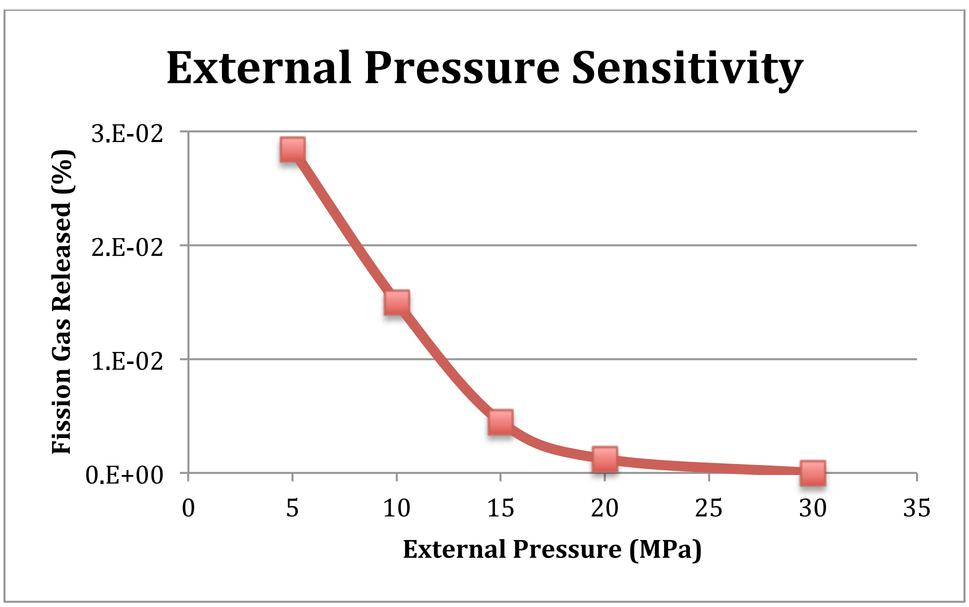

Figure 2: Percentage of fission gas released as a function of external pressure. The grain size was 25μm and release fraction of 1.0.

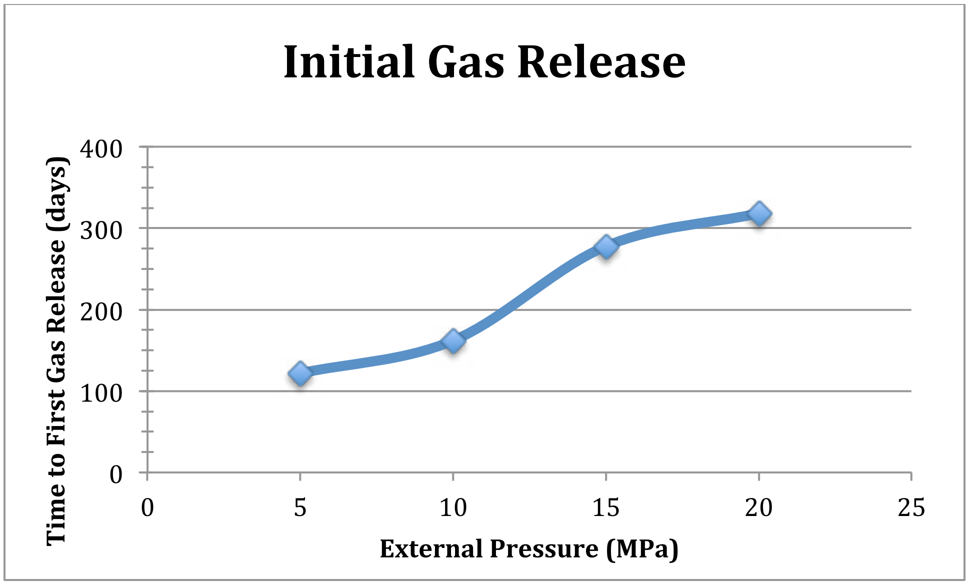

Figure 3: Variation of initial gas release as a function of external pressure. The grain size was 25μm and release fraction of 1.0. At 30 MPa the model predicts no gas release at EOL.

Grain Size

Intuitively, the grain size parameter should have a significant impact on FGR. Gas bubbles form preferentially on the grain boundaries and the further fission gases have to diffuse through UO_2 to get to a boundary the longer it should take. This effect is plotted in Figure 4.

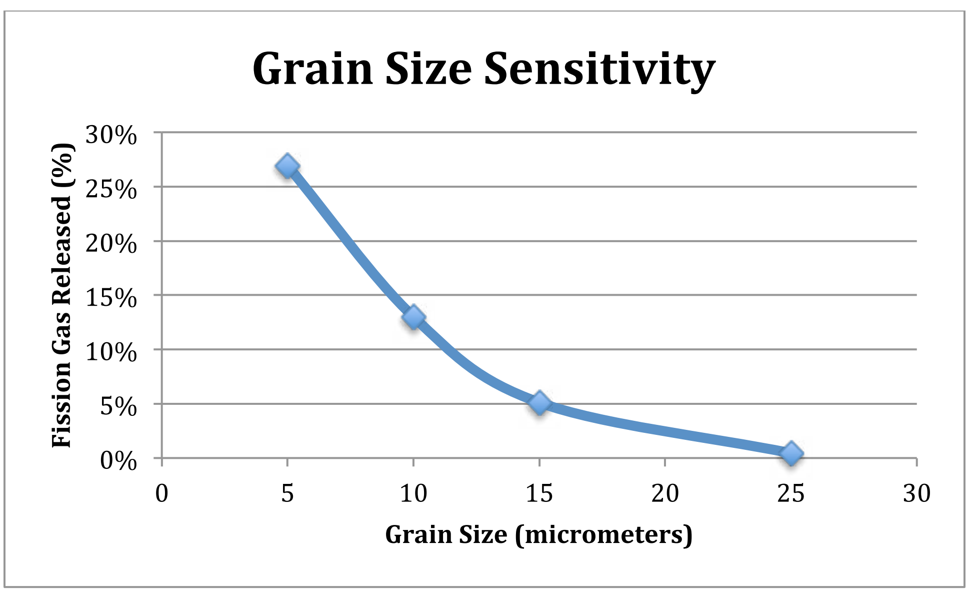

Figure 4: Percentage of fission gas released as a function of fuel grain size. The external pressure was 15 MPa and the release fraction was 1.0.

Release Fraction

The release fraction parameter per Forsberg and Massih is the fraction of fission gas at the boundary that is released upon saturation. The default value in BISON is zero[1], and surprisingly enough this still results in gas release (0.11%). Overall the fission release parameter affects FGR by up to a factor of 80 over the entire range at nominal grain size of 11.8 μm. At larger a grain size, 25 μm, the fission release parameter has a reduced impact of only 1 order of magnitude (0.04 to 0.45%).

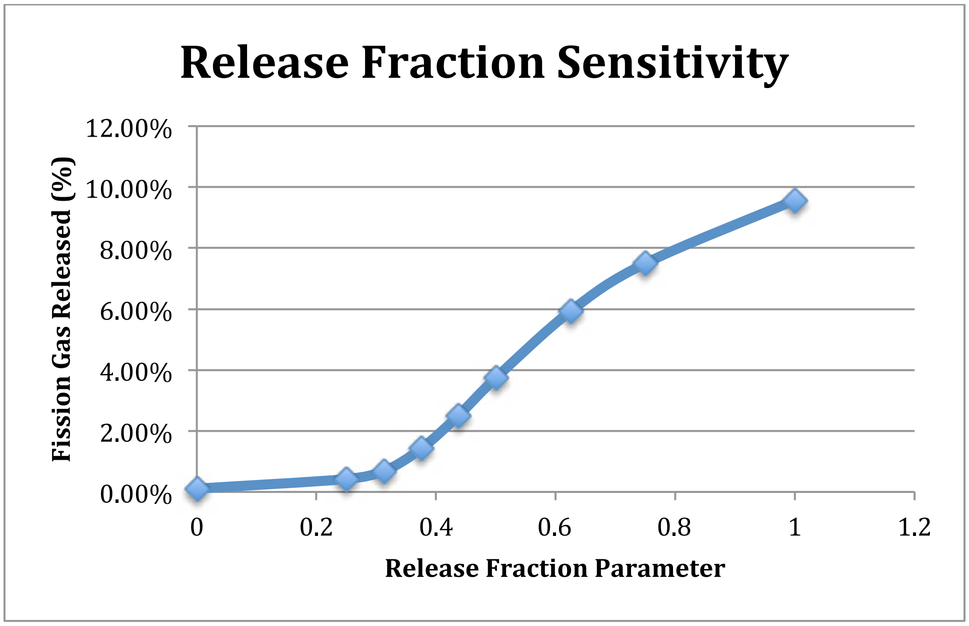

Figure 5: Change in FGR due to release fraction parameter. The grain size was 11.8μm and external pressure was 15MPa.

Best Estimate

The most defensible settings for these parameters is to use measured values where available and recommended values in any remaining locations. The Oconee -1 PWR operates at 2200 PSI (15.168 MPa). Post- irradiation micrography of the fuel rods showed an average grain size of 11.8 μm. The predicted fission gas release using these parameters and the default release fraction at EOL is 1.50E-4 / 1.37E-1 moles = 0.11%. If we choose the release fraction to be the maximum value(1.0), the model predicts total FGR of 9.6% at EOL. From Figure 5, a release fraction of 0.3 should agree closely with the benchmark result.

Conclusions

We were able to study the effect of several of the primary parameters in the Forsberg-Massih fission gas release model. Grain size appears to be the most sensitive parameter, altering the release fraction by up to a factor of 60 and limiting the impact of the release fraction parameter. There is a choice of release fraction that matches the benchmark result. Further analysis with other benchmarks are needed to establish whether a release fraction parameter near 0.3 reliably predicts Fission Gas release for similar configurations.

References:

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