Modeling of the ^{3}He Density Evolution Inside the CABRI Transient Rods During Power Transients

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***Abstract*— CABRI is an experimental pulse reactor, funded by the French Nuclear Safety and Radioprotection Institute and operated by CEA at the Cadarache research center. It is designed to study fuel behavior under reactivity-initiated accident conditions. In order to produce the power transients, reactivity is injected by depressurization of a neutron absorber (^{3}He) situated in transient rods inside the reactor core. The shapes of power transients depend on the total amount of reactivity injected and on the injection speed. The injected reactivity can be calculated by conversion of the ^{3}He gas density into units of reactivity. So, it is of upmost importance to properly model gas density evolution in transient rods during a power transient. The ^{3}He depressurization was studied by computational fluid dynamics (CFD) calculations validated by measurements using pressure transducers. The CFD calculations show that the density evolution is slower than the pressure drop. Studies also show that it is harder to predict the depressurization during the power transients because of neutron/^{3}He capture reactions that induce a gas heating. Surrogate models were built based on CFD calculations and validated against preliminary tests in the CABRI transient system. Two methods were identified to evaluate the gas density evolution: CFD calculations and reverse point kinetics (PKs). The first one consists in adding a heat source in transient rods based on the experimental power conversion. The second one consists in using the measured power by boron ionization chambers to evaluate the net reactivity by a reverse PKs method and to subtract the reactivity feedbacks calculated with the DULCINEE multiphysics code.**

***Index Terms*— CABRI, computational fluid dynamics (CFD), DULCINEE, ^{3}He depressurization, TOP effect.**

NOMENCLATURE

n	Amount of substance of the gas (in moles).
P	Pressure.
V	Volume.
R	Gas constant ($8.314\ \mathrm{J \cdot K^{-1} \cdot mol^{-1}}$).
T	Absolute temperature.
$d_{^3\mathrm{He}}$	Mass density of the gas.
M	Molar mass of the gas.
P_{fis}	Power produced by fission reaction.
$\rho(t)$	Core reactivity (pcm).
β	Delayed neutron fraction.
Λ	Neutrons life time.
λ_i	Decay constants of delayed neutrons precursors.
C_i	Concentration of precursors of the group i.
β_i	Proportion of delayed neutrons of the group i.
ρ_{ext}	Exterior/injected reactivity.
ρ_{fb}	Feedbacks reactivity.

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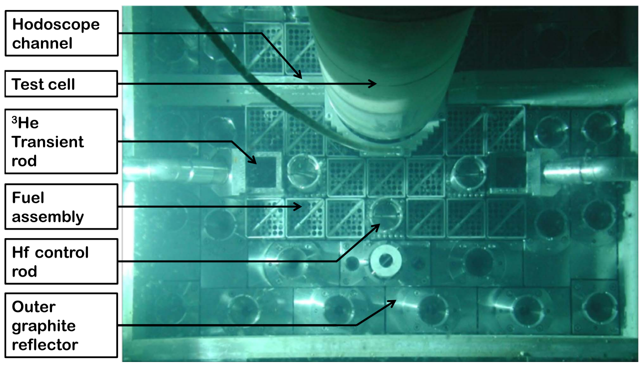
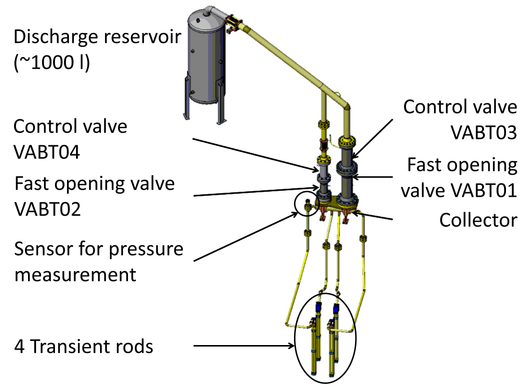
I. INTRODUCTION

CABRI is an experimental pulse reactor, funded by the French Nuclear Safety and Radioprotection Institute (IRSN) and operated by Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA) at the Cadarache research center. Since 1978, the experimental programs have been aiming at studying the fuel behavior under reactivity-initiated accident (RIA) conditions. In order to study pressurized water reactor (PWR) high burn-up fuel and new cladding materials behavior under such transients, the facility was modified to accept a pressurized water loop in its central part able to reproduce thermal-hydraulics characteristics representative of PWR nominal operating conditions (155 bar, 300 °C). This project, which began in 2003 and supported first commissioning power tests from October 2015 to March 2017, was driven within a broader scope including both an overall facility refurbishment and a complete safety review. The global modifications have been conducted by the CEA project team and funded by IRSN, which is operating and managing the CABRI International Program (CIP) experimental program CIP, in the framework of an Organization for Economic Co-operation and Development/Nuclear Energy Agency agreement. The CIP program will investigate several fresh and burned Uranium Oxyde and Mixed Oxyde light water reactor (LWR) fuel samples with new cladding materials under RIA conditions, with a foreseen completion by the end of 2023.

Power transients are generated by a dedicated so-called transient rod system [1] allowing the very fast depressurization of ^{3}He tubes positioned inside the CABRI core. This paper [2] focuses on the study of the ^{3}He depressurization of CABRI transient rods. The main objective is to properly reproduce the ^{3}He density evolution in the transient rods situated in the CABRI core from experimental data provided by pressure transducers situated in the valve and piping system far from the core. This paper presents two methods of prediction based on measurements and on complementary calculations.



(a) Radial view of the CABRI core



(b) Main components of the CABRI transient rods system

Fig. 1. CABRI transient rod system. (a) Radial view of the CABRI core. (b) Main components of the CABRI transient rod system.

The first part of this paper consists of a brief description of the transient rod system, the experimental sequence, and the power transients measurements and prediction. In a second part, the computational fluid dynamics (CFD) approach is addressed. This approach allows the evaluation of state parameters in the entire system and not only at the pressure transducers locations. Afterwards, the elaboration of surrogate models based on CFD calculation is addressed. The last part of the paper deals with the explanation of the TOP effect that affects the depressurization during the transient over power.

II. CABRI Reactivity Injection System

CABRI is a pool-type reactor, with a core made of 1487 stainless steel cladded 6 *wo%* enriched UO_2 fuel rods. The reactor is able to reach a 25-MW power level in steady state conditions. The reactivity is controlled via a system of six bundles made of 23 hafnium control and safety rods.

A. CABRI Transient Rods

The key feature of the CABRI reactor is its unique reactivity injection system [1]. This device allows the very fast depressurization of the ^{3}He (strong neutron absorber) into a discharge tank. The ^{3}He is previously introduced inside 96 tubes (so-called "transient rods") located in four banks among the CABRI fuel rods [see Fig. 1(a)]. The CABRI transient rod system is made of the following main components [see Fig. 1(b)].

- Four fuel assemblies (7 × 7 pins) equipped on their periphery with 24 tubes instead of 24 fuel rods. These tubes are connected together in the upper part of each assembly in order to join a collecting line leading to a main collector. The four transient assemblies are pressurized to the target pressure (15 bar maximum) by the use of a compressor which pumps the ^{3}He from its storage tank via a devoted circuit.
- From the top of this collector, two flow channels (low and high flow rates) lead to a 1000-L discharge tank set under vacuum before operation. Both channels are equipped with a fast-opening valve (respectively, with small and large diameters) followed by a controlled valve. The volume of the circuit upstream the valves is around 50 L.
- A specific control device that triggers the different orders of the experimental sequence as for the opening time of the two fast-opening valves and the shutdown of the reactor control rods.
- Two different pressure transducers measuring the ^{3}He pressure at the inlet of the collector. For design reasons, the ^{3}He pressure cannot be measured directly in the transient rods.

B. Transient Experimental Sequences

The transient rods depressurization causes the absorber ejection that induces a reactivity injection reaching up to 3.9 \$ in a few milliseconds. The characteristics of the transient (maximum power, full-width at half-maximum (FWHM), and energy deposit) depend on the experimental sequence applied to the fast valves and on the adjustment of the associated controlled valves. The transients are stopped by the Doppler effect and other delayed reactivity feedbacks, and then by the scram of the control rods. Short FWHM power transients, so-called "natural transients," will be generated by the fast opening of the unique high flow rate channel. In this case, the maximum power is then very high (until ∼20 GW) and the FWHM is short (∼10 ms). The energy deposit in the central experimental pressurized loop then depends on the initial pressure in the transient rods, the control valve aperture and the control rods drop time after transient

In order to be representative of other LWR accidental conditions, an increase of the transient pulse FWHM is necessary. This can be done by successively opening the fast-opening valves of the low flow and then the high flow rate channels. The adjustment of the time difference between the apertures of the fast-opening valves allows us to generate so-called "structured transients" characterized by FWHM varying from 20 to 80 ms. A good precision on this time difference is very important to fulfill the experimental goal. For those last transients, the final energy deposit in the tested fuel rod depends on the initial ^{3}He pressure but can also be adjusted by the control rods drop trigger time. The power transient shape (maximum, FWHM) is then adjusted by setting the control valves apertures and the openings sequence.

Two main parameters are influencing the depressurization speed and thus the speed of injection of reactivity: the control valves apertures and the initial pressure. However, the quality of ^{3}He and the initial temperature also lead to differences in the reactivity injection speed and magnitude. Indeed, the pollution of the gas (O_2, N_2) makes the gas heavier and hence slows the depressurization kinematics. In the previous life time of the facility, the air ratio in ^{3}He may have reached more than 10% in volume. Today, the ratio of air inside ^{3}He is around 1%.

C. Pressure Measurement

Two transducers (Kulite HKM-375 and HBM P3MB types) measure pressure transients. They are located near the collector (see Fig. 1). Two types of gauges can be used in those transducers depending of the pressure range.

- Those transducers can employ foil strain gauges to cover a large pressure range from 0 to 35 bar. Those lead to 0.2% sensitivity plus 0.1% sensitivity for 10-K temperature difference.
- For 0 to 5 bar, semiconductor strain gauges, so-called piezoresistors can be used. They have usually a larger gauge factor than a foil gauge; it results in better precision (0.1%), but also a bigger sensitivity to temperature changes (0.2%).

Those transducers work using piezoelectric properties of materials; in other words, their abilities to have their electrical conductivity changed with mechanical stress. In order to cover the entire range of the transient rods depressurization (0 to ~15 bar), the technology activated is the foil strain gauges.

D. Transient Measurement

Specific boron ionization chambers are used for measuring high power levels during steady states and during transients. In the case of power transients, several chambers, located at increasing distances from the core, are used to be able to measure the whole range power (i.e., from 100 kW to ~20 GW). More details can be found in [3]–[5].

E. Transient Prediction

In order to reach the experimental objectives, transients are predicted using the DULCINEE [6] code. DULCINEE is a multiphysics code including point kinetics (PKs) equations resolution, thermal transfers calculation, and two-phase thermal-hydraulics models. A dedicated algorithm included in DULCINEE allows us to calculate the power transients using the ^{3}He depressurization curve.

The measured pressure is converted into the injected reactivity by a spline function based on static experimental measurements of the ^{3}He reactivity worth versus pressure. However, the ^{3}He pressure is only measured at approximately 3 m from the rods, and might not be an adequate parameter to numerate the real number of atoms inside the transient core (i.e., inside the core). That is why studies were made using the STAR-CCM+ CFD code [7] in order first to validate measurements at the transducers, and second to extrapolate the results in terms of density as well as pressure drop in the transient rod (as far as satisfactory results are found at transducers location).

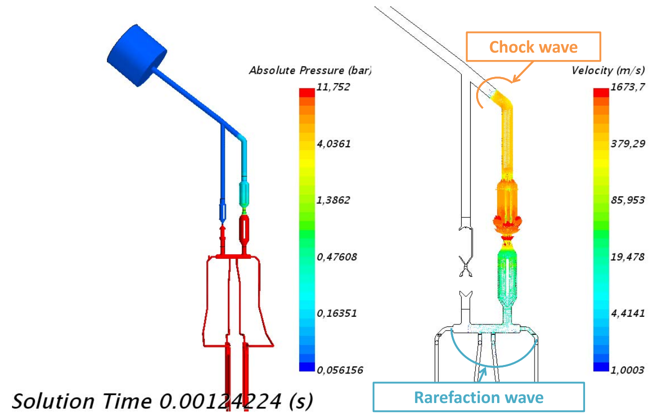


Fig. 2. Visualization of ^{3}He transient rods depressurization with STAR-CCM+ – pressure (left) – velocity (right).

III. CFD Simulation of ^{3}He Depressurization in Transient Rods

The CFD modeling, unlike an analytical approach, can precisely handle complex geometries. The ^{3}He pressure evolution during the depressurization will then be calculated in the entire transient rod system, and not only at the pressure transducers location.

A. Simulation Parameters

The main features and chosen physical models for the CFD simulation are as follows.

- 3-D modeling.
- Reynolds averaged Navier–Stokes approach to solve the Navier–Stokes equations.
- Use of a turbulence model. The usual k-ϵ model consists in representing the effects of turbulence and of eddy diffusivity by a turbulent viscosity. This eddy viscosity is calculated according to the turbulent energy "k" per mass unit, and energy dissipation "ϵ" per mass unit. Each of these two terms is the solution of a transport equation.
- Wall laws "All y + wall treatment" for approximating boundary layers.
- Unsteady calculation with the implicit solver.
- ^{3}He considered as an ideal gas.
- Laws of evolution of gas thermal conductivity and viscosity.

The complete validation of the CFD simulation is described in [8]. Fig. 2 reproduces ^{3}He pressure and velocity in the circuit shortly after the beginning of depressurization. Both pressure and velocity are calculated on a very refined meshing (~460 000). This is an interesting moment because the shock and the rarefaction waves are visible on the velocity profile.

B. Assessment of the Pressure and of the Temperature Evolutions Inside the Transient Rods

The ^{3}He gas depressurization induces a temperature drop in transient rods (see Fig. 3). The heat exchanges between the

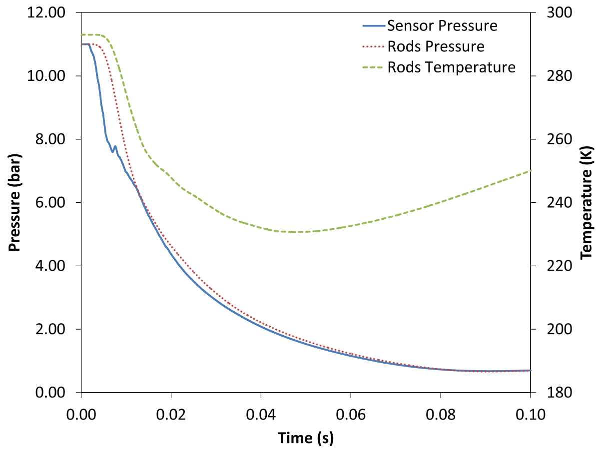


Fig. 3. Helium pressure and temperature evolution during a depressurization according to CFD calculation.

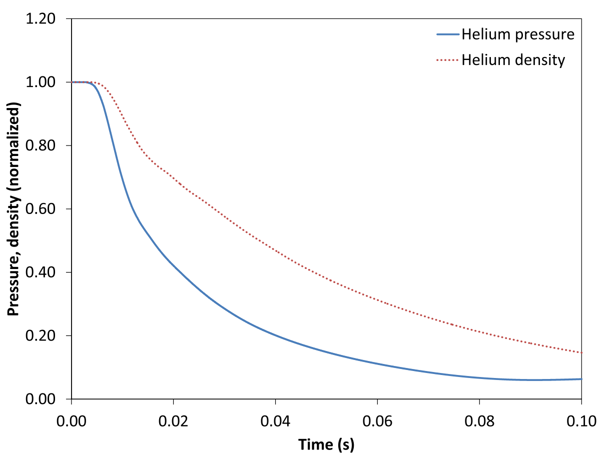


Fig. 4. Helium pressure and density evolution during a depressurization according to CFD calculation.

^{3}He transients rods and the pool water through the Zircaloy-4 cladding then induces a temperature increase. Assuming an ideal gas, the gas quantity "n" is defined as in the following equation:

$$n = \frac{PV}{RT}. \quad (1)$$

A good state parameter that can be linked to the injection of reactivity is the ^{3}He density, that is proportional to the number of atoms (2)

$$d_{^3\mathrm{He}} = \frac{nM}{V} = \frac{PM}{RT}. \quad (2)$$

The density evolution inside the transient rods is slower than the pressure "P" evolution (see Fig. 4), as temperature "T" varies in about the same proportions. That induces a slower calculated evolution of the reactivity injection.

IV. Surrogate Models Based on CFD Calculations

Several types of surrogate models were built based on validated CFD simulations. Some of them are used to evaluate pressure at the transducer in order to validate the CFD calculation results. The others are built to evaluate the ^{3}He density variation in the transient rods during CABRI transients.

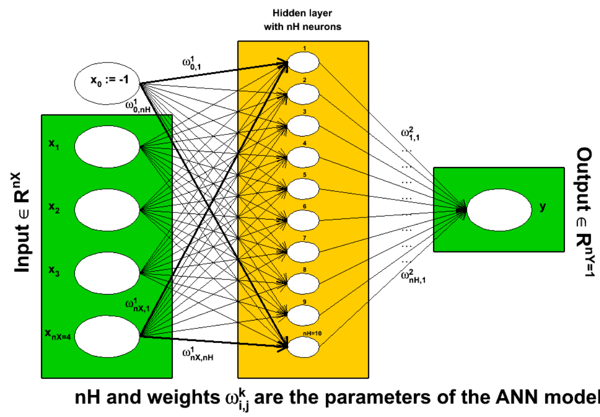


Fig. 5. Multilayer perceptron representation (URANIE manual).

A. Making Surrogate Models

The CEA's URANIE uncertainty platform [9] was used for the surrogate models construction. The creation of surrogate models consists of four main steps as follows.

- Make of a design of experiments using deterministic or stochastic methods for simulating the target parameter. In our case, we mostly used Sobol sequences which better cover the parameter space than a pseudorandom distribution.
- Launching of the code with the different entry parameters.
- Treatment of the results.
- Configuration of the surrogate models. We chose to use multilayer perceptron (artificial neural network, see Fig. 5), with an hyperbolic tangent as an activation function. This method gave better approximations of the simulation results than other models such as polynomial multiparameter regression. Good precision was reached with six hidden layers.

B. Surrogate Model Validation

The surrogate models are validated by experimental comparison to measured depressurization. One example of validation is reproduced Fig. 6. For the density evaluation, the only results come from the best-estimate calculations from CFD, by extrapolating the transducer response to transient rods location. We can logically assume that if the method works for the pressure, it also works for the density.

C. Limits of Those Surrogate Models

In fact, transient rod depressurization is a little different when core power evolves. This little difference can have big effects on power transients. This effect appears when the gas pressure and the core power are both relatively high. The effect is referred to as the "transient over power"or TOP effect. We can observe it on the pressure curves measured during power transients (Fig. 7).

We can also observe on Fig. 7 a recovery of pressure near the beggining of the depressurization measured at the sensor is called "Saddle" effect. It happens when the upstream flow

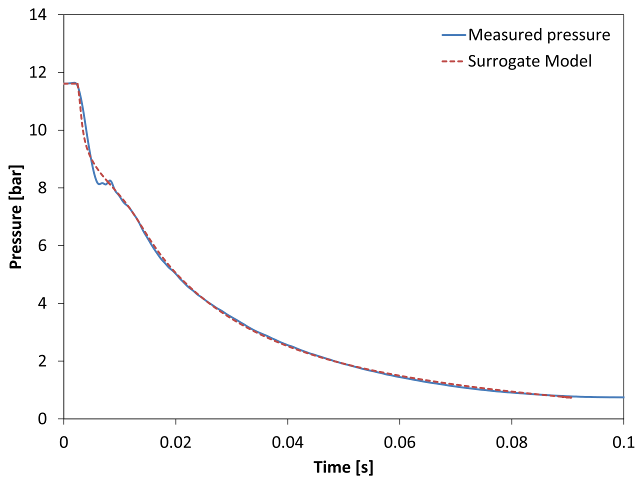


Fig. 6. Comparison between surrogate model pressure (red dotted line) and experimental depressurization (blue solid line) results.

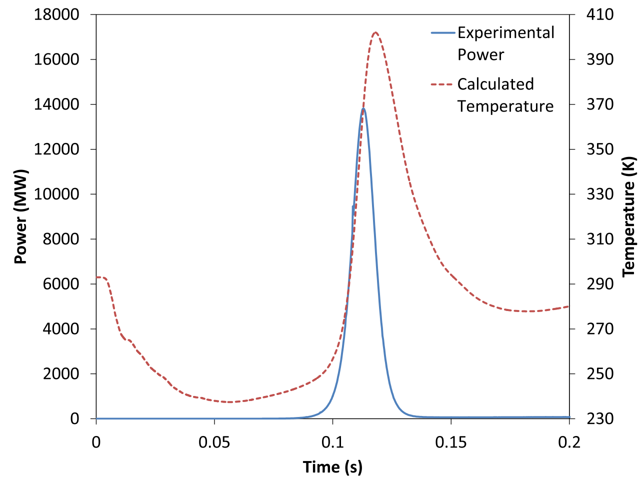


Fig. 8. Evolution of ^{3}He temperature in transient rods according to CFD calculation.

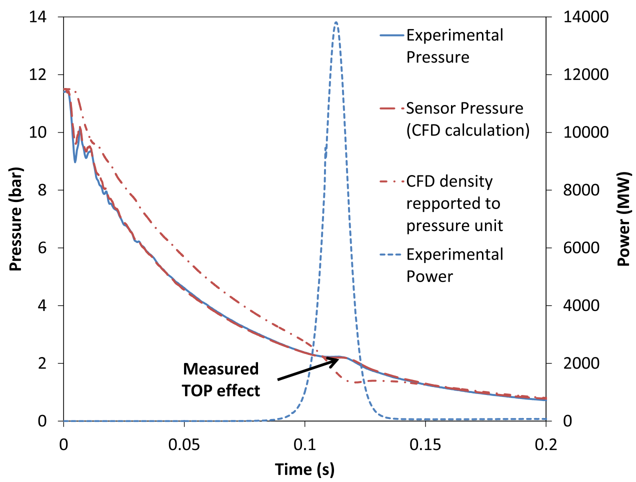


Fig. 7. CFD calculation of simple depressurization by high flow rate channel (VABT03 aperture ∼40%) including TOP effect.

is higher than the downstream flow at the sensor location. It occurs before the flow stabilization in all the circuit. When the aperture of the control valve is small compared to the aperture of the fast valve, this phenomenon is amplified. The transient rods are away from the valves (≃4–5 m), so the “Saddle” effect does not impact the depressurization inside the rods and the reactivity insertion.

V. Top Effect

A. Phenomenon Description

The TOP effect comes from ^{3}He heating during power transients. As power increases, the thermal neutron flux also increases. So, the neutron absorption by ^{3}He intensifies. This reaction produces two charged particles: proton and tritium. One part of their energies is deposited in the ^{3}He gas by ionization before reaching the metallic wall of the transient rods. As the initial gas density increases, the probability of ionization increases, and the impact on the deposited energy grows. The direct effect of this energy deposit is that the gas temperature increases. A temperature increase is equivalent to a pressure increase. The differential pressure between rods and flow channels implies a faster depressurization of helium from the transient rods. That is why we observe a rise of pressure at the transducers location during the pulse, that corresponds to a decrease of the gas density in the transient rods. This finally implies a rise of the reactivity injection speed. TOP effect increases the maximum power and the energy deposit. For relatively slow transients (at least 20-ms FWHM), it can represent more than the half of the maximum power and at least 30% of the energy deposit. Thus, the TOP effect has to be taken into account in order to have an accurate predictive tool for transient of power. In this paper, two methods are presented. The first one consists in calculating the density evolution using the best-estimate CFD calculations.

B. ^{3}He Density Evaluation Using CFD

To take into account the TOP effect, a factor linking core power and energy deposit in ^{3}He has to be calculated. The research of this factor was the object of a study realized in 2010–2011. This study consisted of two steps as follows.

- The first step was made of neutronics calculations of the CABRI core using the French stochastic TRIPOLI4 [10] code. One function was designed giving the ratio between the energy created by (n, p) absorption reaction rates inside ^{3}He and the energy deposited in the CABRI core, depending on the ^{3}He density.
- The second step was devoted to the study of the ionization after neutron/^{3}He interaction. The code SRIM [11] was used to establish a function giving the average energy deposited in the Helium volume by proton and tritium particles, depending on the gas density.

Then, a heat source was added to the CFD simulation using those last functions and experimental powers. The ^{3}He heating was tested on the cases of a simple depressurization by low flow rate channel and a simple depressurization by high flow rate channel. Fig. 7 shows the results of CFD calculation for the case of the simple depressurization by high flow rate channel using the experimental recordings during a power

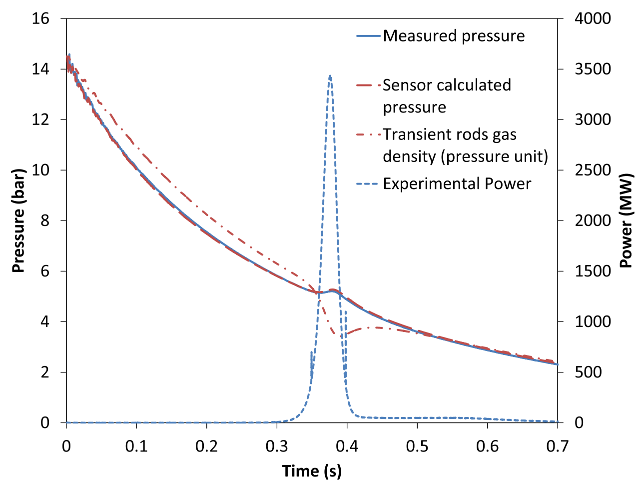


Fig. 9. CFD calculation of simple depressurization by low flow rate channel (VABT04 aperture ~30%) including TOP effect.

transient. We can observe the density and pressure evolution during the transient. On the one hand, it shows the good consistency between calculated pressure at the transducers location with TOP effect and measured pressure. On the other hand, we observe that density evolves slower than pressure until the power rise. During the pulse, the ^{3}He density is dropping very fast. At the same time, the gas temperature is increasing rapidly (see Fig. 8).

In the case of a depressurization by the low flow rate channel, the TOP effect has a bigger influence on transient shape. That can be explained by the fact that the ^{3}He pressure is still high at the pulse moment (see Fig. 9). This type of transient requires a higher initial pressure to reach the same energy deposit in the reactor core as the reactivity insertion is much slower. This higher pressure at the moment of the peak implies a higher heating ratio of ^{3}He and thus a larger ^{3}He quantity depressurized though the TOP effect.

The final project is to elaborate a surrogate model including TOP effect, based on approximately 60 experimental transients and complementary calculations. Those transients have a large range of maximum power (120 kW–20 GW) and energy deposit (0.1–250 MJ in ~1 s). In the future, this density surrogate model could replace the pressure model as an input data of DULCINEE, in order to improve the code predictability. Today results of this evaluation of the ^{3}He density by CFD calculation work well. Nevertheless, one calculation needs around one to two weeks. So, a complete surrogate model of TOP effect would require more than a year to be built. Another method, much faster (few minutes to analyze the 60 transients), is presented here after. It consists in using a reverse PKs method from the power transients to recreate the density curve inside the transient rods. Based on those calculations a surrogate model can be made.

C. ^{3}He Density Evaluation Using a PKs Method

The algorithm for density calculation is described as follows.

- Using power transient shapes to evaluate net reactivity evolution using PK equations (3)

$$\frac{dP_{\text{fis}}}{dt} = \frac{\rho(t)-\beta}{\Lambda}\cdot P_{\text{fis}} + \sum(\lambda_i \cdot C_i)$$
$$\frac{dc_i}{dt} = \frac{\beta_i}{\Lambda}\cdot P_{\text{fis}} - \lambda_i \cdot C_i. \qquad (3)$$

- Evaluating the reactivity feedbacks using the DULCINEE code in an imposed power mode.
- Injected reactivity is then computed (4) by subtracting feedbacks reactivities to the net reactivity as follows:

$$\rho_{\text{ext}} = \rho - \rho_{\text{fb}}. \qquad (4)$$

- Injected reactivity comes from two phenomena: ^{3}He depressurization and control rods drop. Control rods drop reactivity is subtracted to isolate ^{3}He reactivity.
- Correlation between ^{3}He density and reactivity is finally used to evaluate the density at each moment. Here, a surrogate model coming from TRIPOLI4 calculations of the CABRI core in different configurations of control rods insertion and ^{3}He density is used.

However, unlike the first method, this procedure sums a large number of uncertain parameters. Uncertainties reduction is, in that case, the biggest issue. Those uncertainties come from feedback calculations, kinetics parameters of the core (effective delayed neutron fraction and prompt neutrons generation lifetime), control rods drop reactivity, and correlation between density and reactivity. However, it is also possible that a gap exists between real density and CFD calculation. A comparison was done between the two methods and is illustrated in Fig. 10.

The power transients calculations were done with Simulation Prediction Analysis of RIA Transients and Excursions (SPARTE). SPARTE is based on DULCINEE code and includes several new functions based on the best-estimate simulations (see [12] for more informations). Dotted lines represent ^{3}He density evolutions, whereas solid lines represent transient power shapes. In red is presented transient prediction without TOP effect. We can observe that the reactivity injection is a little too fast by comparison of calculated power to the measured power. Because of the lack of TOP effect, the power transient is only reaching 1 GW, compared to 3.4 GW in reality. Simulation of TOP effect by CFD simulation (green) shows a really better consistency with experimental transient. The calculated power pulse is reaching approximately 2 GW. So, calculated TOP effect doubles maximum power in that case. Moreover, we can observe a better consistency in power rise, power stabilization, and power drop after control rods drop. We can see on blue dotted line the ^{3}He density evolution that would have been needed to recreate the transient by PK algorithm. It is not far from green dotted line, but we can see that the ^{3}He density drop is faster on the reverse kinetic curve. We can assume that it is a 3-D effect: 96 tubes are composing the transient rods, and every tube is heated more or less according to his location in the core. So, the TOP effect should be more intense in most heated tubes where neutron streams are the highest. The effect on reactivity injection is then more important as we can observe on Fig. 10.

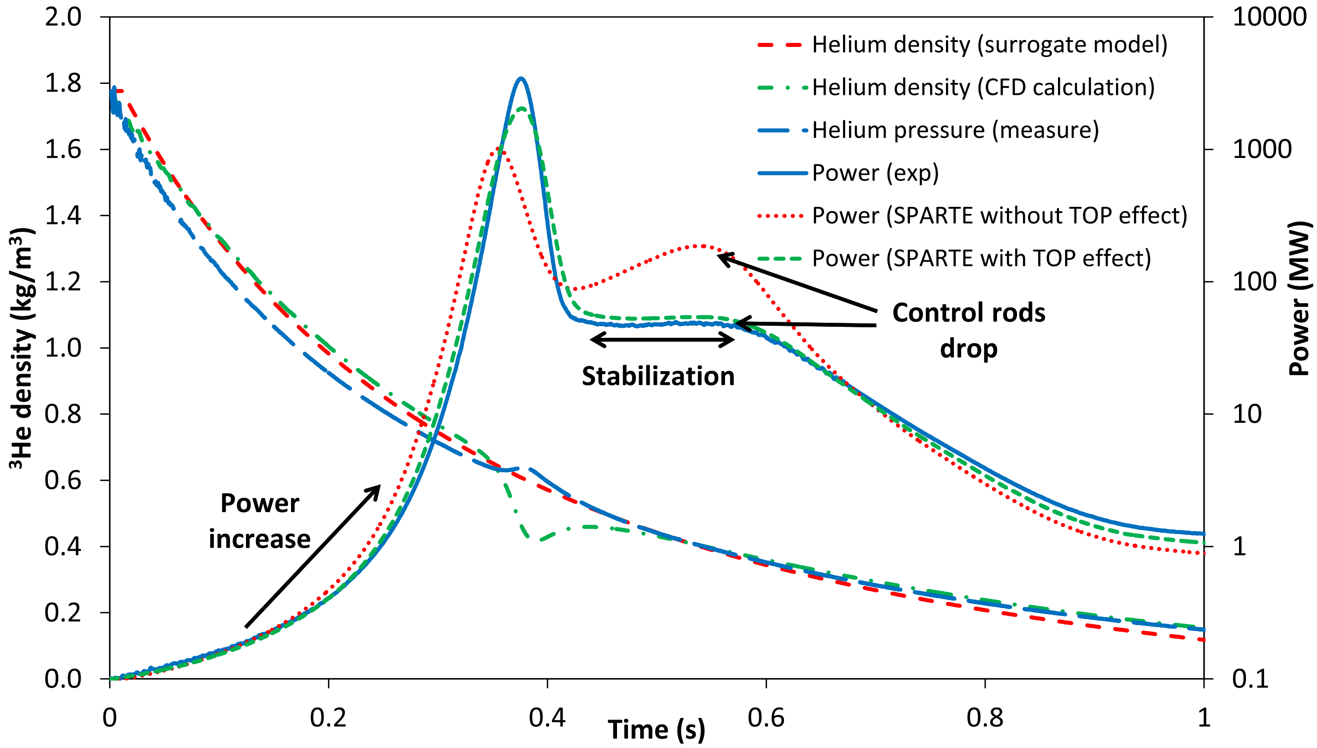


Fig. 10. Comparison of measured CABRI power transient and power transients calculated with density surrogate model and CFD calculation including TOP effect—case of low flow rate channel depressurization.

D. Surrogate Model Including Top Effect

The last progress on this paper is the building of a surrogate model of TOP effect and its implementation in the SPARTE code. We can observe on density curves computed by reverse kinetics with experimental power transients that the TOP effect is observable over a threshold on the power of approximately 100 MW. Four models, based on power transients data and CFD simulations, were built in order to simulate the TOP effect. There is a pair of surrogate model for the depressurization by the high flow rate channel and a pair for the low flow rate channel. There are of two types as follows.

- The first ones are references depressurization without TOP effect.
- The second ones are density deviations generated by the power transient.

The 50 CFD calculations abovementioned were used to make the references depressurization models in addition to the density evolutions computed by reverse kinetics on approximately 50 commissioning tests. Only the points with a power under 100 MW were used for the reference models. The goal of this model is to evaluate the time after opening knowing the rate of depressurization and the parameters of the depressurization. The parameters of the reference surrogate models are as follows:

- initial ^{3}He pressure;
- aperture of the control valve;
- purity of the gas;
- initial temperature;
- rate of depressurization ($d_{^3\mathrm{He}}(t) - d_0/d_{\min} - d_0$).

The TOP effect is a deviation of the rate of depressurization during the transient. It happens a few milliseconds before the power peak and finishes few milliseconds after corresponding to the threshold of 100 MW. A sensitivity study helped to find the best parameters for the deviation computing:

- initial ^{3}He pressure (higher pressure implies a larger deviation);
- aperture of the control valve (smaller aperture implies a larger deviation);
- time difference with the power peak (the maximum deviation appears just after the peak).

The implementation of the TOP effect in the SPARTE code needed the creation of new Fortran functions including the surrogate models. The TOP effect modeling needs a reiteration process. The first step consists in doing the same calculation as before replacing the surrogate model of density evolution by the new reference one based on calculation and experimental data. The power transient curve is needed to recalculate the density curve including the TOP effect. We observed that four steps of calculation are sufficient for convergence (maximum power, peak time, and FWHM).

We can observe on Fig. 11 the comparison between the model and the experiment on a case of simple depressurization by the low flow rate channel. The TOP effect surrogate model well represents this phenomenon and allows us to

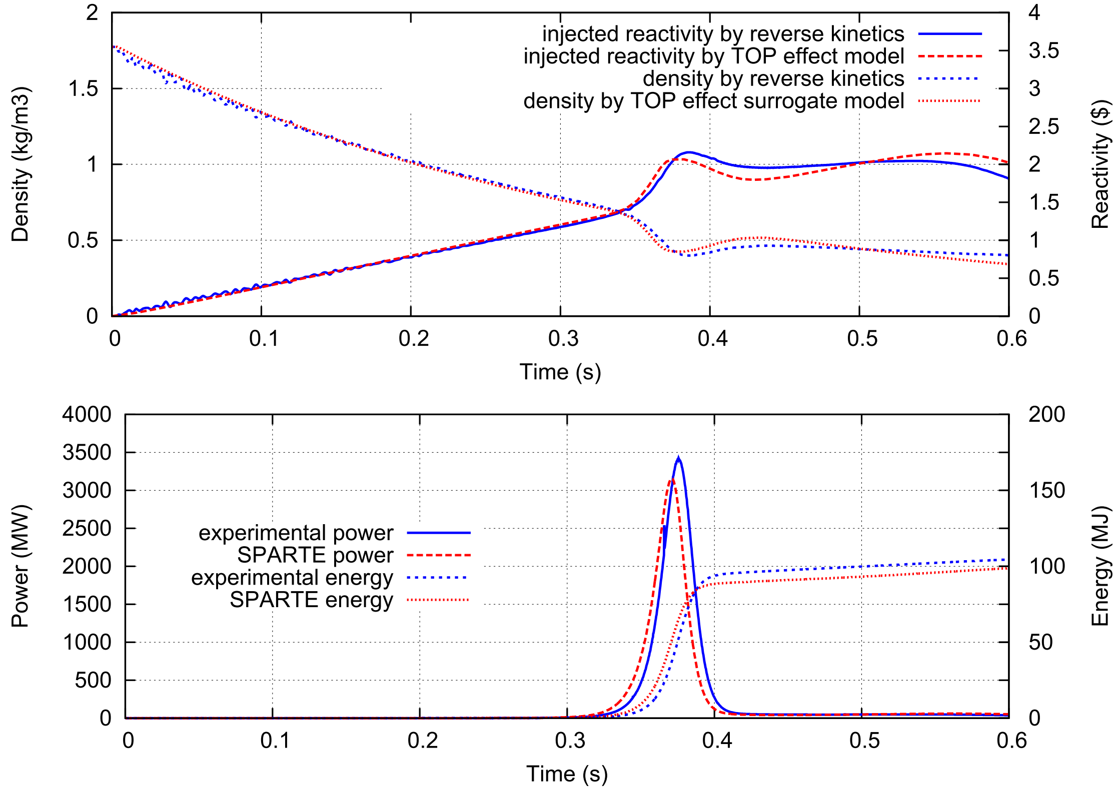


Fig. 11. Experimental/calculation comparison for ^{3}He density and core power including the TOP effect surrogate model.

evaluate with a good precision the power transient. As we can see, the power peak appears a little too soon in the simulation. It is because of the uncertainty on the depressurization curve. The simulated depressurization is a bit faster than the one calculated by reverse kinetics of the measured power.

VI. Conclusion

This paper points out differences between measured pressure and ^{3}He density in transient rods. It shows that the gas density evolution is slower than pressure evolution because of temperature changes in the rods. Surrogate models were developed in order to replace old models based on analytical solution of the problem (with simplification of the geometry). The study demonstrates that the ^{3}He density evolution is different if core power is boosted due to gas heating by neutron/^{3}He interactions. This effect, called TOP effect, affects density evolution by increasing depressurization speed during the transients. It explains some difficulties in the CABRI power transients prediction. Surrogate models were just developed in order to be used in the future power transients calculations and uncertainty studies.

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