**“RE-REVISED VERONIKA GRID:**

**ADVICE FROM SARNET SOURCE TERM, 25/09/2006”**

The Source Term group provided comments in May 2006, at the request of CEG-SAM, on the initial VERONIKA proposal concerning fission product release from VVER fuel at high temperatures, this included tests in hydrogen/argon and steam/argon atmospheres. One concern of the ST group was that the series should include some tests with air/argon atmospheres, which would coordinate well with ruthenium release and transport studies being performed in the Source Term area. In response to this comment the Russian colleagues provided a revised proposal in which tests involving an air atmosphere completely replaced those with steam. At the CEG-SAM meeting in September 2006 it was felt that this revised matrix went too far in the direction of an air atmosphere, so that some tests with steam should be re-introduced to improve the balance of the proposal (action 10/8 refers). The present document constitutes a response to this action. It is a consensus based on a proposal by IRSN, Annex 1, taking into account the views of ST partners whose individual comments are given in Annex 2.

1. **Introduction**

VERONIKA is a proposed Separate Effect Test (SET) programme associated with analytical work intended to give reliable results on fission product (FP) release from highly-irradiated VVER fuel (~60 GWd.t-1) along with fuel micro-structure evolution in severe accident conditions, in oxidizing and reducing environments for a wide list of FPs including short half-life isotopes.

This programme will help in understanding FP behaviour in highly-irradiated LWR fuel under severe accident conditions and will be useful for development/validation of mechanistic models. It is designed as an analytical programme with very well-controlled conditions, simplifying the interpretation of results. In addition, for each test, the evolution of the high burn-up fuel microstructure will be studied by pre- and post-test microanalyses of samples (SEM, EPM, etc., perhaps SIMS or XRD).

The VERONIKA tests would be performed following the global scheme presented in the following figure. This figure must be considered only as an illustration. Indeed, the exact scenario of each test (temperatures, beginning of gas phase injection, exact gas phase composition, etc.) have to be defined accurately later.

1. **Test Matrix**

The programme would be divided in two parts. Basically, as a whole, tests foreseen involve about 3 atmospheres at 3 temperatures and 2 fuel conditions (bare fuel/ fuel segment). This sums to 18 tests so it seems that dividing these into two sets and look at mainly one fuel condition and then another is the most practical way to go.

This would mean a majority of bare fuel tests in one half. The 2nd half would then be mainly the fuel segment tests.

A first unit of 8 bare fuel tests will demonstrate the fission products (FP) behaviour in a fuel submitted to conditions representative of severe accidents and chosen to correspond to interesting steps regarding their physico-chemical changes. In addition these analytical tests will allow reliable validation (and further developments) of the mechanistic models implemented in MFPR, which is one goal of the VERONIKA programme. Additionally, before launching the 2nd series of tests, 2 tests with fuel segment would be interesting to quantify to what extent the cladding may act on restraining FP release (especially inhibiting Ru oxidation).

The second unit of mainly fuel segment tests would demonstrate the effect of cladding, which is seen as modifying the gas access, the gas phase composition by clad oxidation (and modifying the fuel oxygen potential), and the FP behaviour by possible interactions with the clad materials (mechanical effects of clad on the fuel are not explicitly considered). Three complementary tests with bare fuel are however planned in this second series in order to cover additional atmosphere conditions which can be “seen” by the bare fuel (see §4).

Both series of data will be very important to give the basic FP thermophysical and thermochemical data in irradiated fuel at elevated temperatures and also to show the effect of cladding on restraining FP release.

**3) Temperatures**

The values of temperature (as well as that for the ramp) are considered as representative of severe accidents and chosen to correspond to interesting steps regarding the behaviour of FP, particularly T1=1400°C and T2=1700°C. Concerning the highest one (T3), the group proposes to fix it later in the project, but suggests that it should be higher than 2000°C and less than 2300°C. It is indeed interesting for bare fuel to investigate FP behaviour up to 2300°C in hydrogen and steam atmosphere, while it is less interesting under air conditions as it is expected that most of Ruthenium would have been released before reaching this temperature in that case. Moreover, between 2000K and 2500K, there would not be a significant change on partial pressure of Ru species (see P. Taylor's SARNET report P1), i.e. on Ru release kinetics. For fuel rod segments, 2300°C may be a too high temperature for oxidizing conditions as we know from the FZK tests made by J. Stuckert et al. for the COLOSS project that non-irradiated UO2 & Zr has completely reacted at 2000°C in 15mins, and within 5mins at 2300°C. Similar ‘pot’ tests at ITU (also for COLOSS) with irradiated fuel & cladding segments needed 5 mins to destroy them at 2000°C. Thus with Zircaloy metal present we do not need to go beyond 2000°C or 2100°C at 30 mins.

**4) Atmospheres**

Atmospheres involved during accident progression are mainly: steam, hydrogen (when there is steam starvation), steam/hydrogen mixture, air/steam mixture (air ingress). In order to investigate analytically atmosphere effect on fuel and FP behaviour, the group suggests looking mainly at steam, hydrogen, air for bare fuel 1st series. To go further in the investigation of “reactor situations”, as one main issue regarding Ru release in air ingress scenario is the competing effect between cladding oxidation and Ru release (i.e. Ru oxidation); tests with air/steam mixture and steam/hydrogen have to be considered in the 2nd series. Moreover, in the reactor case, the cladding may not be fully oxidised, thus a test with a partially-oxidised cladding prior to the release phase may be suggested in the 2nd series as well (to be more prototypic). However, this will be limited to the intermediate temperature to avoid large fuel relocation. This could be the spare test in the 2nd matrix.

**5) Proposed grids (consensus)**

PART 1 (from to to to+ 3 years)

|  |  |  |  |
| --- | --- | --- | --- |
| ***Test number*** | ***Sample type*** | Gas phase | ***Test temperature (°C)*** |
| 1 | Bare fuel | H2O/Ar | 1700b |
| 2 | Bare fuel | H2/Ar | 1700b |
| 3 | Bare fuel | H2O/Ar | 1400a |
| 4 | Bare fuel | H2O/Ar | T3c |
| 5 | Bare fuel | H2/Ar | 1400a |
| 6 | Bare fuel | H2/Ar | T3c |
| 7 | Bare fuel | Air/Ar | 1400a |
| 8 | Bare fuel | Air/Ar | 1700b |
| 9 | Fuel rod segment | H2O/Ar | 1700d |
| 10 | Fuel rod segment | Air/Ar | 1700d’ |

1. *: the samples are fuel fragments and the test consists of simple ramp (1K/s) up to 1400°C maintained one hour.*
2. *: the test consists of the test (a) followed by a ramp (1K/s) up to 1700°C maintained 30 minutes.*
3. *: the same than (b) but the second ramp ends at T3>2000°C maintained 30 minutes.*
4. *: in this case samples are fuel pellets in their original cladding ant the test is identical to (b)*

*(d’) : idem (d) but with air.*

PART 2 (from to+ 3 years to to+ 5.5 years)

|  |  |  |  |
| --- | --- | --- | --- |
| ***Test number*** | ***Sample type*** | Gas phase | ***Test temperature (°C)*** |
| 11 | Fuel rod segment | H2O/ H2 | 1400 a1 |
| 12 | Fuel rod segment | H2O/ H2 | 1700 b1 |
| 13 | Fuel rod segment | H2O/ H2 | T3c1 |
| 14 | Fuel rod segment | H2O/Ar | 1400e |
| 15 | Fuel rod segment | H2O/Ar | T3f |
| 16 | Fuel rod segment | Air/Ar | 1400e’ |
| 17 | Fuel rod segment | Steam/Air | 1400 or 1700 |
| 18 | Bare fuel | H2O/ H2 | 1400 a2 |
| 19 | Bare fuel | H2O/ H2 | 1700 b2 |
| 20 | Fuel rod segment | spare  | spare |

*(a1, b1, c1)* : *the scenario of tests is identical to a, b and c respectively but in this case the gas phase composition is mixed, for example 25mg/s for H2O and 0,3 mg/s for H2)*

*(a2, b2) idem than tests a1,b1 but with bare fuel*

1. *idem (a) but with fuel rod segments*
2. *idem ( c) but with fuel rod segments*

*(e’) idem (e) but with air*

*(f’) idem (f) but with air*

**6) Concluding Remarks**

The CEG-SAM is invited to consider these comments, and in particular the revisions to the test matrices to cover the conditions of temperature, oxidising potential, and presence or absence of cladding, in its discussions leading to the production of the final VERONIKA proposal to ISTC.

Tim Haste (PSI), Patrice Giordano (IRSN) and Luis Herranz (CIEMAT) – editors

based on technical contributions from R Dubourg (IRSN), K Trambauer (GRS), D Bottomley (JRC/ITU), I Nagy (AEKI), Y Dutheillet (EdF), N Davidovich (ENEA) and D Ohai (INR).

06 October 2006

**ANNEX 1 : IRSN proposal of a re-revised matrix**

Early in April we received from CEG-SAM an ISTC project proposal VERONIKA that concerns fission product release from high burn-up fuel in different atmospheres. We were requested to supply comments on it and we assembled our comments into a consolidated document, transmitted to CEG-SAM.

Last week, a revised proposal by RIAR Dimitrovgrad was presented at the CEG-SAM meeting: Russian colleagues took into account our comments, but they over-reacted to one of them (please read for more details B. Clément's report here below).

We are asked by CEG-SAM to give again a SARNET advice on this matter, quite quickly.

In order to speed the review process, please find here attached a "re-revised" test matrix consistent with the CEG-SAM last meeting discussion: this re-revised matrix does not add any test to the Russian proposal, but substitutes some "fuel rod cladded test" with bare fuel H2O tests, so that in Part 1, the 3 atmospheres (reducing- oxidizing- highly oxidizing) will be addressed.

Could you please quickly give me your comments on it? Has anyone any better ideas on this short timescale ? In case of no reply before 22nd of September, I will consider that there is no objection from you to this re-revised proposal.

**“RE-REVISED VERONIKA GRID- 15/09/2006”**

VERONIKA is considered as an ensemble of experiments giving reliable results on fission products release from highly irradiated VVER fuel (~60GWd.t-1) along with fuel micro-structure evolution in severe accident conditions, in oxidizing and reducing environments for a wide list of fission products including short half-life isotopes.

This programme will help in understanding fission products behaviour in highly irradiated LWR fuel under severe accident conditions and will be useful for development/validation of mechanistic models. It is designed as an analytical program with very well controlled conditions, simplifying the interpretation of results. In addition, for each test, the evolution of the high burn up microstructure will be given by pre and pos-test microanalyses of samples (SEM, EPMA…perhaps SIMS or XRD).

Following previous recommendations from SARNET members, RIAR modified the grid of experiments, including many tests in air conditions. The new grid presented by RIAR during the last CEG-SAM meeting included such tests in air but in too much amount because now no tests in steam conditions were foreseen during the first part of VERONIKA program and it was agreed the collaborators of VERONIKA members of CEG-SAM will prepare a proposal of grid, in relation with SARNET group.

The VERONIKA tests are performed following the global scheme presented in the following figure.

As already proposed the programme might be divided in two parts for each of which the following possible grids are proposed.

It is considered that the first part of the programme has significant chances to be accepted whereas the second part is more uncertain.

Thus, the tests considered as high priority are placed in the first part.

In addition, the values of temperature (as well as that for the ramp) are considered as representatives of severe accidents and chosen to correspond to interesting steps regarding the behaviour of fission products and the highest one (2300°C) will avoid too much fuel degradation.

Also, the effect of cladding is seen as modifying the gas access, the gas phase composition by clad oxidation (and modifying the fuel oxygen potential), and the fission products behaviour by possible interactions with the clad materials (mechanical effects of clad on the fuel are not explicitly considered).

PART 1 (from to to to+ 3 years)

|  |  |  |  |
| --- | --- | --- | --- |
| ***Test number*** | ***Sample type*** | Gas phase | ***Test temperature (°C)*** |
| 1 | Bare fuel | H2O/Ar | 1700b |
| 2 | Bare fuel | H2/Ar | 1700b |
| 3 | Bare fuel | H2O/Ar | 1400a |
| 4 | Bare fuel | H2O/Ar | 2300c |
| 5 | Bare fuel | H2/Ar | 1400a |
| 6 | Bare fuel | H2/Ar | 2300c |
| 7 | Bare fuel | Air/Ar | 1400 a |
| 8 | Bare fuel | Air/Ar | 1700 b |
| 9 | Fuel rod segment | H2O/Ar | 1700d |
| 10 | Fuel rod segment | Air/Ar | 1700d’ |

1. *: the samples are fuel fragments and the test consists of simple ramp (1K/s) up to 1400°C maintained one hour.*
2. *: the test consists of the test (a) followed by a ramp (1K/s) up to 1700°C maintained 30 minutes.*
3. *: the same than (b) but the second ramp ends at 2300°C maintained 30 minutes.*
4. *: in this case samples are fuel pellets in their original cladding ant the test is identical to (b)*

*(d’) : idem (d) but with air.*

PART 2 (from to+ 3 years to to+ 5.5 years)

|  |  |  |  |
| --- | --- | --- | --- |
| ***Test number*** | ***Sample type*** | Gas phase | ***Test temperature (°C)*** |
| 11 | Bare fuel | H2O/ H2 | 1400 a1 |
| 12 | Bare fuel | H2O/ H2 | 1700 b1 |
| 13 | Bare fuel | H2O/ H2 | 2300 c1 |
| 14 | Fuel rod segment | H2O/ H2 | 1400 a2 |
| 15 | Fuel rod segment | H2O/ H2 | 1700 b2 |
| 16 | Fuel rod segment | H2O/ H2 | 2300c2 |
| 17 | Fuel rod segment | H2O/Ar | 1400e |
| 18 | Fuel rod segment | H2O/Ar | 2300f |
| 19 | Fuel rod segment | Air/Ar | 1400e’ |
| 20 | Fuel rod segment | Air/Ar | 2300f’ |

*(a1, b1, c1)* : *the scenario of tests is identical to a, b and c respectively but in this case the gas phase composition is mixed, for example 25mg/s for H2O and 0,3 mg/s for H2)*

*(a2, b2, c2) idem than tests above but with fuel rod segments*

1. *idem (a) but with fuel rod segments*
2. *idem ( c) but with fuel rod segments*

*(e’) idem (e) but with air*

*(f’) idem (f) but with air*

**ANNEX 2 : SARNET MEMBERS’ COMMENTS**

**GRS (K. Trambauer)**

I completely support the new revision of the test matrix. I checked the grid as you can see on the app. table. For a complete variation of the 3 different parameters (Bare fuel/rod segment x gas composition x temperature) 24 tests would be required. the 4 missing tests are

- one for bare fuel + air + 2300°C

- three for rod segment + H2 + 3 temp.

These excluded tests are of less interest, since changes of FP release rates under air conditions are more relevant for lower temperatures and changes of FP release rates under hydrogen conditions are more relevant if no metallic material is present.

Furthermore the distribution of the tests to the first and second phase is reasonable for me (about equal number of tests for H2/H2O/Air and two additional tests for rod segments).

For a final GRS position, I have to contact my colleagues in Cologne. If you don't get further comments, please consider this mail as the GRS position.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Test #*** | ***Sample*** | Gas | ***T (°C)*** | ***bare*** | ***segm.*** | ***H2/Ar*** | ***H2O/Ar*** | ***Air/Ar*** | ***H2O/H2*** | ***1400*** | ***1700*** | ***2300*** |
| 1 | Bare fuel | H2O/Ar | 1700b | **X** |  |  | **X** |  |  |  | **X** |  |
| 2 | Bare fuel | H2/Ar | 1700b | **X** |  | **X** |  |  |  |  | **X** |  |
| 3 | Bare fuel | H2O/Ar | 1400a | **X** |  |  | **X** |  |  | **X** |  |  |
| 4 | Bare fuel | H2O/Ar | 2300c | **X** |  |  | **X** |  |  |  |  | **X** |
| 5 | Bare fuel | H2/Ar | 1400a | **X** |  | **X** |  |  |  | **X** |  |  |
| 6 | Bare fuel | H2/Ar | 2300c | **X** |  | **X** |  |  |  |  |  | **X** |
| 7 | Bare fuel | Air/Ar | 1400 a | **X** |  |  |  | **X** |  | **X** |  |  |
| 8 | Bare fuel | Air/Ar | 1700 b | **X** |  |  |  | **X** |  |  | **X** |  |
| 9 | Rod segment | H2O/Ar | 1700d |  | **X** |  | **X** |  |  |  | **X** |  |
| 10 | Rod segment | Air/Ar | 1700d’ |  | **X** |  |  | **X** |  |  | **X** |  |
| 11 | Bare fuel | H2O/ H2 | 1400 a1 | **X** |  |  |  |  | **X** | **X** |  |  |
| 12 | Bare fuel | H2O/ H2 | 1700 b1 | **X** |  |  |  |  | **X** |  | **X** |  |
| 13 | Bare fuel | H2O/ H2 | 2300 c1 | **X** |  |  |  |  | **X** |  |  | **X** |
| 14 | Rod segment | H2O/ H2 | 1400 a2 |  | **X** |  |  |  | **X** | **X** |  |  |
| 15 | Rod segment | H2O/ H2 | 1700 b2 |  | **X** |  |  |  | **X** |  | **X** |  |
| 16 | Rod segment | H2O/ H2 | 2300c2 |  | **X** |  |  |  | **X** |  |  | **X** |
| 17 | Rod segment | H2O/Ar | 1400e |  | **X** |  | **X** |  |  | **X** |  |  |
| 18 | Rod segment | H2O/Ar | 2300f |  | **X** |  | **X** |  |  |  |  | **X** |
| 19 | Rod segment | Air/Ar | 1400e’ |  | **X** |  |  | **X** |  | **X** |  |  |
| 20 | Rod segment | Air/Ar | 2300f’ |  | **X** |  |  | **X** |  |  |  | **X** |
| Selected |  |  |  | **8+3** | **2+7** | **3+0** | **4+2** | **3+2** | **0+6** | **3+4** | **5+2** | **2+4** |

1. *: the samples are fuel fragments and the test consists of simple ramp (1K/s) up to 1400°C maintained one hour.*
2. *: the test consists of the test (a) followed by a ramp (1K/s) up to 1700°C maintained 30 minutes.*
3. *: the same than (b) but the second ramp ends at 2300°C maintained 30 minutes.*
4. *: in this case samples are fuel pellets in their original cladding ant the test is identical to (b)*

*(d’) : idem (d) but with air.*

 *(a1, b1, c1)* : *the scenario of tests is identical to a, b and c respectively but in this case the gas phase composition is mixed, for example 25mg/s for H2O and 0,3 mg/s for H2)*

*(a2, b2, c2) idem than tests above but with fuel rod segments*

1. *idem (a) but with fuel rod segments*
2. *idem ( c) but with fuel rod segments*

*(e’) idem (e) but with air*

*(f’) idem (f) but with air*

**AEKI (I. Nagy)**

Regarding the "RE-REVISED VERONIKA GRID" we discussed the part1 section and have been found quite right and does not need any significant change viewing the main concept. Have a good success and work also.

**EDF (Y. Dutheillet)**

Firstly, I appreciate the effort made by our Russian colleagues to take into account most of the remark. It seems that the discussions at the last ISTC meeting were fruitful, but I could not attend it unfortunately. Please find herewith my comments.

Grid matrix

It is said that the effect of cladding is seen as modifying the gas access, the gas phase composition by clad oxidation (and modifying the fuel oxygen potential), and the fission products behaviour by possible interactions with the clad materials (mechanical effects of clad on the fuel are not explicitly considered).

In the reactor case, the cladding will not be fully oxidised, thus I would have prefer a few test with a partially oxidised cladding prior to the release phase (to be more prototypic). However, this will be limited to the intermediate temperature tests to avoid heavy fuel relocation. I believe that one main issue regarding Ru release in air ingress scenario is the competing effect between cladding oxidation and Ru release (i.e. Ru oxidation).

For air ingress scenario, the entering mixture is made of steam and air. That is, tests for cladding oxidation are considered with such a mixture. In VERCORS tests (RT8 I guess), there has been a test with diluted oxygen concentration to avoid any hydrogen hazard. I think that a test with a mixture could be considered in the second phase maybe (?).

It seems that the fuel rod segments have their counter parts in the bare fuel situation except for the Air/Ar one at 2300°C. Any reasons?

I understand that these remarks may be slightly out of the analytical scope of the VERONIKA program but I think it will have to be addressed some time (in the complementary VERDON programme?). However the proposed matrix in VERONIKA is valuable to increase our database on fission product release.

**ENEA (N. Davidovich)**

If the last version for the test-matrix is that in the tables here below, I understand they have already solved the problem of having too many experiments in air environment and none for steam.

Yves (Dutheillet) wonders that fuel rod segments have their counter parts in the bare fuel situation except for the Air/ar at 2300°C and I see the fuel rod segment in air at 2300 C is considered in the second part. I think it could perhaps be better performing these two tests (bare fuel and fuel rod segment in air at 2300 C, or better 2000 C?) within the first series, as the second series is not sure to be approved and oxidising effects are more relevant at higher temperatures (and consequently longer exposition to the environment), both for fuel and cladding. So I suggest exchanging test number 10 with number 20 and performing test number 8 at 2000 C instead of 1700 C, if there is not some experimental reason for doing otherwise. (I mean if we cannot have both 1700 and 2300 C tests for these conditions, it might be better doing them at 2000 C instead of 2300 C, to avoid excessive fuel degradation).

**ITU (D. Bottomley)**

Following Nora (Davidovich)'s remarks about the highest temperature, I attach a memo about this as I should have noted earlier that this is likely to be excessive for cladded material. I also feel Yves's remarks about the importance of cladding material are also valid. However the main point is to have a 'clear' matrix with an obvious objective,

David

**VERONIKA TEST MATRIX**

- ITU Commentary on the 15th Sept. Re-Revised Matrix from RIAR

& remarks from EdF & ENEA

After the last 2 commentaries I would like to ‘step into the ring’ and make a comment for the SARNET & CEG-SAM people.

**1) Test Matrix**

Firstly the matrix as it stands does not have a very good look about it. Basically with 20 tests in two halves then we are looking for a unit of 10 tests that will demonstrate something. If we have 3 atmospheres at 3 temperatures (and 2 fuel conditions) then this is 18 tests so it seems that dividing it into two halves and look at one fuel condition and then another is the most practical way to go.

This would mean 9 bare fuel (or fuel segment) tests in one half plus one spare test to be chosen at a later stage. The 2nd half would then be the fuel segment (or bare fuel) tests for 3 temperatures and 3 atmospheres plus one spare test to be decided later.

**2) Temperatures**

At the moment, the temperatures are 1400°C, 1700°C & 2300°C, but in fact Nora Davidovich’s remark about the necessity to go so high is actually very relevant. For bare fuel perhaps it can give some diffusion data, but for the cladded material we know from the FZK tests made by J. Stuckert et. al. for the COLOSS project that non-irradiated UO2 & Zr has completely reacted at 2000°C in 15mins, and within 5mins at 2300°C. Similar ‘pot’ tests at ITU (also for COLOSS) with irradiated fuel & cladding segments needed 5 mins to destroy them at 2000°C. Thus with Zircaloy metal present we do not need to go beyond 2000°C or 2100°C at 30 mins. I would therefore suggest that the 3 temperatures be 1400, 1700 & 2000°C (or 2100°C).

**3) Atmospheres**

I spoke of 3 Atmospheres so I would suggest that we look at steam, steam/air mixture and air as the most relevant given the interest in air ingress. The spare test in each matrix could be a test in H2 in order to check diffusion values of the fission products in stoichiometric fuel matrix for the models.

**4) Technical remarks**

We should not let the remark that the second half of the project might not get funded affect our judgement. This has left everyone fighting for their top priority, and this shows itself in a muddled matrix where nobody is happy, and more likely to run into difficulty. So long as the project has a clear ‘vision’ and achieves most of its objectives then there is no reason why the whole project should not get funded (Indeed, the project requires a lot of time to perform (5 years) so there is plenty of time to evaluate the results and find the 2nd half funding.

The re-revised test matrix part 1 was (as at 15th Sept 06):

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|  |  |  |  |
| --- | --- | --- | --- |
| Test No | Sample Type | Gas Phase | Test Temperature/°C |
| 1 | Bare Fuel | H2O/Ar | 1700 |
| 2 | Bare Fuel | H2Ar | 1700 |
| 3 | Bare Fuel | H2O/Ar | 1400 |
| 4 | Bare Fuel | H2O/Ar | 2300 |
| 5 | Bare Fuel | H2/Ar | 1400 |
| 6 | Bare Fuel | H2/Ar | 2300 |
| 7 | Bare Fuel | Air/Ar | 1400 |
| 8 | Bare Fuel | Air/Ar | 1700 |
| 9 | Fuel rod segment | H2O/Ar | 1700 |
| 10 | Fuel rod segment | Air/Ar | 1700 |

I would thus propose that the test matrix for the 1st part would be **either** *all bare fuel* **or** *all* *segmented fuel* as follows.

|  |  |  |
| --- | --- | --- |
| **Test No** | **Gas Phase** | **Test Temperature/°C** |
| 1 | H2O/Ar | 1400 |
| 2 | H2O/Ar | 1700 |
| 3 | H2O/Ar | 2000 |
| 4 | H2O/H2 | 1400 |
| 5 | H2O/H2 | 1700 |
| 6 | H2O/H2 | 2000 |
| 7 | Air/Ar | 1400 |
| 8 | Air/Ar | 1700 |
| 9 | Air/Ar | 2000 |
| 10 | Spare (possibly in an additional atmosphere H2/Aror replication of a VERDON test ) | 1400 or 1700 |

The Test Matrix Part 2 would then be an identical matrix but for the other fuel condition

I would start off with the segmented fuel matrix as I appreciate Yves Dutheillet’s argument that EdF needs data for the real or realistic reactor case, also for Dimitrovgrad (RIAR) it would give them more time to prepare and characterize the bare fuel (average piece size distribution plus microscopy of typical pieces) created by their ‘cladding lift-off’ process.

But I also appreciate that the data coming from the bare fuel will also be very important to give the basic FP diffusion data in irradiated fuel at elevated temperatures and also to show the effect of cladding on restraining FP release (eg inhibiting Ru oxidation).

Finally and most importantly, if the project has two clear test matrices that both individually and jointly important, then I feel there is every reason for both parts of the project to be funded.

I hope these comments are of use to the SARNET & CEG-SAM members and a good basis to make a concrete proposal, as RIAR have asked for.

David Bottomley

22nd Sept. ‘06

**INR (D. Ohai)**

Dear Patrice,

I think that the VERONIKA project is beneficial for the enrichment of the FPR data base in SA conditions with additional information for high burn-ups. But I have a technical observation on the ZrO2 crucible used in oxidizing tests (VERONIKA Proposal Goryachev. ppt, pag. 14). It is well known that by oxidizing, the UO2 sintered pellets self-disintegrate. The resulted powder covers down part of pellet, reducing free surface, diminishing air ingress on pellet surface. The problem can be resolved by interposition of a grid between the pellet and the Y2O3 insulating plate.

Sincerely yours,

Dumitru

15 September 2006