



DIRECTION DE LA RECHERCHE TECHNOLOGIQUE

CEA/GRENOBLE

DEPARTEMENT DES TECHNOLOGIES POUR LES ENERGIES NOUVELLES  
SERVICE MATERIAUX ET PROCEDES  
LABORATOIRE SIMULATION ET MECANIQUE DES MATERIAUX

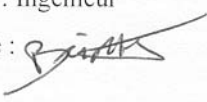
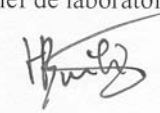
Le 8 mars 2002

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***HTR-E – WP1 Work Plan Report***  
***Deliverable n°1***



***Laurent Briottet***

| Version | Rédaction                                                                                                                                 | Vérification                                                                                                                                        |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| A       | Nom : Briottet<br>Fonction : Ingénieur<br>Signature :  | Nom : Burlet<br>Fonction : Chef de laboratoire<br>Signature :  |



**EUROPEAN COMMISSION**

**5th EURATOM FRAMEWORK PROGRAMME 1998-2002**

**KEY ACTION : NUCLEAR FISSION**

**HTR-E**

**High-Temperature Reactor Components and Systems**

**CONTRACT N°**  
**FIKI-CT-2001-00177**

**WP1 WORK PLAN REPORT**

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Deliverable n°1

[illegible]

|                 |                                                                     |            |      |
|-----------------|---------------------------------------------------------------------|------------|------|
|                 | <b>Helium Turbine</b>                                               | <b>CEA</b> |      |
|                 |                                                                     | Rev : A    | 2/20 |
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|                              | Helium Turbine    | CEA     |      |
|                              |                   | Rev : A | 3/20 |
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## 1. Objective of the Work Package

The general objectives of WP1 of the HTR-E program are to determine the critical issues, to assess and demonstrate the potential of success for the design of the helium turbine, mainly based on two concepts : power turbine (GT-MHR), high pressure compressor turbine (PBMR).

## 2. Description of the tasks

The contractual objective of the Work Package is to produce 10 deliverables (with deliverables 3 and 7 split in 2 reports), which are identified D1 to D10.

### 2.1 Deliverable D1

Present document.

### 2.2 Deliverable D2 (task 1.1)

The title of the document is "Design use, system review, integration and In-Service Inspection and Repair".

A comparison of the different options proposed in the GT-MHR and PBMR type reactors. The reasons of such design options will be identified and discussed. The objective is to provide specifications concerning the turbines, including also system review, ISIR and safety classification.

The organisation of the document can be found in table 1.

### 2.3 Deliverable D3 (task 1.2)

The title of the document D3a is "Review of existing technologies from past HTR experience and other industries".

The objective of the document is to review the technological choices proposed in past experiences.

Since Aubert&Duval is a sub-contractor, they will provide a document concerning "Materials and manufacturing of turbine discs" : D3b.

The organisation of these documents can be found in table 2.

### 2.4 Deliverable D4 (task 1.3.1)

The title of the document is "HHV data and turbine inlet thermal insulation".

The objective of this document is to provide the data concerning the HHV test loop. Recommendations concerning the design of the thermal insulation at the turbine inlet and the hot gas duct will be provided.

The organisation of the document can be found in table 3.

### 2.5 Deliverable D5 (task 1.3.2)

The title of the document is "EVO design data and measurements for specified load cases".

The objective of this document is to provide the data concerning the EVO helium loop.

The organisation of the document can be found in table 4.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                       |                       |      |
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| <p><b>2.6 Deliverable D6 (task 1.4)</b></p> <p>The title of the document is "HTR-M results analysis and recommendations".</p> <p>The objective of this document is to provide the results and recommendations from HTR-M, to compare them with the recommendations provided in Deliverable 2. Suggestions concerning the possible coatings for turbine blades will also be displayed.</p> <p>The organisation of the document can be found in table 5</p> <p><b>2.7 Deliverable D7 (task 1.5)</b></p> <p>It has been decided to split this task into two subtasks leading to two deliverables 7a and 7b.</p> <p>The title of the document D7a is "Design study of the turbine and compressor".</p> <p>From the bibliographical results and from the analysis of previous experiences, the objective of this document is to provide preliminary geometries for the turbine discs and blades, as well as the thermal fields through these components. These outputs will be necessary to perform the numerical simulations of tasks 2.1 and 2.2.</p> <p>An analysis and definitions of the general layout of the compressors will also be provided.</p> <p>The organisation of the document can be found in table 6.</p> <p>The title of the document D7b is " Thermal insulation at the turbine inlet ".</p> <p>A design of the thermal insulation at the turbine inlet will be proposed, supported by FEM calculations.</p> <p>The organisation of the document can be found in table 7.</p> <p><b>2.8 Deliverable D8 (task 2.1)</b></p> <p>The title of the document is "Thermal and thermo-mechanical analysis".</p> <p>From the results obtained in task 1.5, thermomechanical FEM simulations will be performed in order to analyse the stress fields in the disks and blades.</p> <p>The organisation of the document can be found in table 8.</p> <p><b>2.9 Deliverable D9 (task 2.2)</b></p> <p>The title of the document is "Aerodynamic design-CFD calculations".</p> <p>CFD calculations will be performed to optimised the shape of the blades for typical operating conditions.</p> <p>The organisation of the document can be found in table 9.</p> <p><b>2.10 Deliverable D10 (task 2.3)</b></p> <p>The title of the document is "Experimental test program definition".</p> <p>The objective of this document is to provide an experimental test program that should be performed to assess the proposed options and geometries concerning the turbine and compressor. The capability to carry out these tests on existing test loops will also be analysed.</p> <p>The organisation of the document can be found in table 10.</p> |                       |                       |      |

### 3. Definition of the tasks of each partner

The partners involved in the Work Package are :

- ◆ Framatome ANP France (1),
- ◆ CEA (2),
- ◆ FZJ (5),
- ◆ EA (6),
- ◆ VKI (11),
- ◆ EVO (13) (sub contractor),
- ◆ A&D (14) (sub contractor)
- ◆ Framatome GmbH (15)

The proposal of the repartition of the budget by document and partner is the following :

|                | D1 | D2  | D3 | D4  | D5 | D6 | D7    | D8   | D9 | D10 | Total |
|----------------|----|-----|----|-----|----|----|-------|------|----|-----|-------|
| FRA (1)        |    | 6.8 |    |     |    |    |       |      |    |     | 6.8   |
| CEA (2)        | 1  |     | 6  |     |    |    |       | 8.5  |    | 1   | 16.5  |
| FZJ (5)        |    | 1   | 2  | 4.8 |    |    |       |      |    |     | 7.8   |
| EA (6)         |    | 2   |    |     |    | 2  | 3+3.8 | 3.1  |    |     | 13.9  |
| VKI (11)       |    |     |    |     |    |    | 3     |      | 6  | 1   | 10    |
| EVO (13)       |    |     |    |     | 4  |    |       |      |    |     | 4     |
| A&D (14)       |    |     | 3  |     |    |    |       |      |    |     | 3     |
| FANP GmbH (15) |    |     |    |     |    |    | 5     |      |    |     | 5     |
| Total          | 1  | 9.8 | 11 | 4.8 | 4  | 2  | 14.8  | 11.6 | 6  | 2   | 67    |

Remarks :

1. The numbers in the columns are man months.
2. The volume reserved for each partner are approximately the same as those in the proposal reference, at the exception of :
  - Partner 16 (BDT) decided to cancel its contribution in WP1.
  - Partner 15 (FANP GmbH) is introduced in the work package to make part of the work previously proposed by BDT in task 1.5b : 5 man months. Partner 6 (EA) will also perform calculations concerning the inlet turbine thermal insulation in task 1.5b : 3.8 man months. These two new contributions concern the deliverable D7b. This subtask will begin in March 2002 and will end in December 2003.
  - The contribution of the subcontractor Aubert&Duval is reduced from 5 to 3 man months.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                       |         |      |
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Helium Turbine</b> | CEA     |      |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                       | Rev : A | 7/20 |
| <ul style="list-style-type: none"> <li>• The task concerning deliverable 8 will begin in January 2003 instead of January 2004 as previously proposed.</li> </ul> <p>The repartition of the manpower per year is given in table 11.</p> <p><b>4. Identification of the interfaces with the other Work Packages</b></p> <p>The main input deliverables coming from the other workpackages are listed in the tables 1 to 9, related to the different documents. These interfaces are connected to WP6 Helium purification and to HTR-M and HTR-M1 "Materials".</p> <p><b>5. Future meetings</b></p> <p>The next meeting will be held the 5th November 2002 at Juelich or Framatome ANP (Paris).</p> |                       |         |      |

## Table 1 Deliverable 2

### DELIVERABLE 2

Title "Design use, system review, integration and In-Service Inspection and Repair"

**Schedule** January 2002 – December 2002

**Responsible** Framatome-ANP (1)

**Partners** FZJ (5), EA (7)

### DOCUMENT ORGANISATION

| INDEX                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | RESPONSIBLE                | INPUT NEEDED                                                                                                    | DATE                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-----------------------------------------------------------------------------------------------------------------|----------------------------------|
| General principles                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                            |                                                                                                                 |                                  |
| Feed-back from GT-MHR, PBMR, system review and ISIR giving : <ul style="list-style-type: none"> <li>Specifications for design of the turbine.</li> <li>The components description (rough description)</li> <li>The technical options and the reasons for these choices</li> <li>Thermal and hydraulic data : steady state and transient conditions</li> <li>He impurities (including recommendations for Co contents for disc and blades)</li> <li>System review and ISIR</li> <li>Safety classification</li> </ul> |                            |                                                                                                                 |                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Framatome-ANP</b>       | Possibility to get information from PBMR team using the agreement between HTR-TN and PBMR team, and from GT-MHR | July 2002                        |
| GT-MHR                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>Framatome-ANP</b>       |                                                                                                                 | Draft available in Oct 2002      |
| PBMR                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>EA+FZJ</b>              |                                                                                                                 | Draft available in Oct 2002 (EA) |
| He impurities                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>Framatome-ANP + FZJ</b> | HTR-E - WP6<br>He impurities                                                                                    | In final document                |

|                                    |                       |                       |                                                                                          |
|------------------------------------|-----------------------|-----------------------|------------------------------------------------------------------------------------------|
|                                    | <b>Helium Turbine</b> | <b>CEA</b><br>Rev : A | 9/20                                                                                     |
|                                    |                       |                       |                                                                                          |
| <b>INDEX</b>                       | <b>RESPONSIBLE</b>    | <b>INPUT NEEDED</b>   | <b>DATE</b>                                                                              |
| Conclusion: synthesis of documents | <b>Framatome-ANP</b>  |                       | <u>Draft</u> : Nov 2002<br>on SINTER for partner comments<br><br><u>Final</u> : Dec 2002 |

|  |                       |                       |       |
|--|-----------------------|-----------------------|-------|
|  | <b>Helium Turbine</b> | <b>CEA</b><br>Rev : A | 10/20 |
|--|-----------------------|-----------------------|-------|

## Table 2 Deliverable 3

### DELIVERABLE D3

Title "Review of existing technologies from past HTR experience and other industries"

**Schedule** *July 2002 –June 2003*

**Responsible** *CEA (2)*

**Partners** *FZJ (5), A&D (14)*

### DOCUMENT ORGANISATION

| INDEX                                                                                                                                                                            | RESPONSIBLE               | INPUT<br>NEEDED | DATE                                                                                       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-----------------|--------------------------------------------------------------------------------------------|
| General principles                                                                                                                                                               |                           |                 |                                                                                            |
| <ul style="list-style-type: none"> <li>Components description</li> <li>Technical options and reasons for these choices</li> </ul> from past HTR experiences and other industries |                           |                 |                                                                                            |
| Past HTR experiences<br>Zr coatings (blades)                                                                                                                                     | <b>FZJ</b>                |                 | Draft available in May 2003                                                                |
| Other industries<br>aeronautic<br>gas turbine<br>steam turbine                                                                                                                   | <b>CEA</b>                |                 | Draft available in May 2003                                                                |
| Materials and manufacturing for turbine discs : 1 report                                                                                                                         | <b>Aubert &amp; Duval</b> |                 | <u>Final D3b</u> : June 2003                                                               |
| Conclusion: synthesis of documents                                                                                                                                               | <b>CEA</b>                |                 | <u>Draft</u> : May 2003 on SINTER for partner comments<br><br><u>Final D3a</u> : June 2003 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Helium Turbine | CEA          | Rev : A                                                                  | 11/20 |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                         |  |  |  |                                    |     |  |                                                                          |
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| <div>Table 3<br/>Deliverable 4</div> <div>DELIVERABLE 4</div> <div>Title "HHV data and turbine inlet thermal insulation"</div> <div>Schedule July 2002 – June 2003</div> <div>Responsible FZJ (5)</div> <div>DOCUMENT ORGANISATION</div> <table><tr><th>INDEX</th><th>RESPONSIBLE</th><th>INPUT NEEDED</th><th>DATE</th></tr><tr><td>General principles</td><td></td><td></td><td></td></tr><tr><td>HHV data will concern :<ul style="list-style-type: none"><li>materials</li><li>turbine design options description</li><li>operational experiences and problems encountered</li></ul>Recommendations for turbine inlet thermal insulation.<br/>Recommendations for hot gas duct design.</td><td></td><td></td><td></td></tr><tr><td>Conclusion: synthesis of documents</td><td>FZJ</td><td></td><td>Draft : May 2003 on SINTER for partner comments<br/><br/>Final : June 2003</td></tr></table> |                |              |                                                                          |       | INDEX | RESPONSIBLE | INPUT NEEDED | DATE | General principles |  |  |  | HHV data will concern : <ul style="list-style-type: none"><li>materials</li><li>turbine design options description</li><li>operational experiences and problems encountered</li></ul> Recommendations for turbine inlet thermal insulation.<br>Recommendations for hot gas duct design. |  |  |  | Conclusion: synthesis of documents | FZJ |  | Draft : May 2003 on SINTER for partner comments<br><br>Final : June 2003 |
| INDEX                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | RESPONSIBLE    | INPUT NEEDED | DATE                                                                     |       |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                         |  |  |  |                                    |     |  |                                                                          |
| General principles                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                |              |                                                                          |       |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                         |  |  |  |                                    |     |  |                                                                          |
| HHV data will concern : <ul style="list-style-type: none"><li>materials</li><li>turbine design options description</li><li>operational experiences and problems encountered</li></ul> Recommendations for turbine inlet thermal insulation.<br>Recommendations for hot gas duct design.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                |              |                                                                          |       |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                         |  |  |  |                                    |     |  |                                                                          |
| Conclusion: synthesis of documents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | FZJ            |              | Draft : May 2003 on SINTER for partner comments<br><br>Final : June 2003 |       |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                         |  |  |  |                                    |     |  |                                                                          |

## Table 4 Deliverable 5

### DELIVERABLE 5

Title " EVO design data and measurements for specified load cases"

**Schedule** *July 2002 – December 2003*

**Responsible** *EVO (13)*

### DOCUMENT ORGANISATION

| INDEX                                                                                                                                                                                                                                                                                                                                                    | RESPONSIBLE | INPUT NEEDED | DATE                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|--------------|---------------------------------------------------------------------------------------|
| General principles                                                                                                                                                                                                                                                                                                                                       |             |              |                                                                                       |
| <p>The data concerning the EVO experimental cogeneration power plant will address the following points :</p> <ul style="list-style-type: none"> <li>materials</li> <li>turbine design options description</li> <li>discs and blades geometry</li> <li>stress and temperature fields</li> <li>operational experiences and problems encountered</li> </ul> |             |              |                                                                                       |
| Measurements from specified load cases will be displayed                                                                                                                                                                                                                                                                                                 | <b>EVO</b>  |              | December 2002                                                                         |
| Conclusion: synthesis of documents : 1 document in english                                                                                                                                                                                                                                                                                               | <b>EVO</b>  |              | <u>Draft</u> : Nov 2003 on SINTER for partner comments<br><br><u>Final</u> : Dec 2003 |

## Table 5 Deliverable 6

### DELIVERABLE 6

Title "HTR-M results analysis and recommendations"

**Schedule** *January 2003 – December 2003*

**Responsible** *EA (6)*

### DOCUMENT ORGANISATION

| INDEX                                                                                                                                                                                                                                                                                                                                            | RESPONSIBLE | INPUT NEEDED               | DATE                                                                                         |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|----------------------------|----------------------------------------------------------------------------------------------|
| General principles                                                                                                                                                                                                                                                                                                                               |             |                            |                                                                                              |
| <p>This task will provide the analysis of the main conclusions drawn within the HTR-M program, specially concerning :</p> <ul style="list-style-type: none"> <li>materials</li> <li>database</li> <li>process</li> </ul> <p>taking into account the design recommendations from D2 and D3</p> <p>Suggestions on possible coatings for blades</p> |             | HTR-M results<br>D2 and D3 |                                                                                              |
| Conclusion: synthesis of documents                                                                                                                                                                                                                                                                                                               | <b>EA</b>   |                            | <p><u>Draft</u> : Nov 2003 on SINTER for partner comments</p> <p><u>Final</u> : Dec 2003</p> |

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| <p style="text-align: center;"><b>Table 6</b><br/><b>Deliverable 7a</b></p> <p>DELIVERABLE 7a</p> <p>Title "Design study of the turbine and compressor"</p> <p><b>Schedule January 2003 – December 2003</b></p> <p><b>Responsible EA (6)</b></p> <p><b>Partners VKI (11)</b></p> <p>DOCUMENT ORGANISATION</p> <table> <tr> <th>INDEX</th><th>RESPONSIBLE</th><th>INPUT NEEDED</th><th>DATE</th></tr> <tr> <td>General principles</td><td></td><td></td><td></td></tr> <tr> <td> <p>To provide from the previous results a critical review and recommendations on possible improvements based on the two following projects (GT-MHR and PBMR)</p> <ul style="list-style-type: none"> <li>Preliminary geometries for the turbine discs and blades</li> <li>The thermal fields likely to be present on these components depending on the options</li> <li>Integration and ISIR</li> </ul> <p>To perform an analysis of the general layout of the compressors.</p> <p>To define the future works for deliverables 8 and 9 and the proposed geometries to be investigated</p> </td><td></td><td>WP6, D2, D3, D4, D5</td><td></td></tr> <tr> <td>Mechanical analysis</td><td><b>EA</b></td><td>D2</td><td>Draft available in Oct 2003</td></tr> <tr> <td>Aerodynamic analysis</td><td><b>VKI</b></td><td>D2</td><td>Draft available in Oct 2003</td></tr> <tr> <td>Compressor and turbine layout</td><td><b>VKI</b></td><td>D2</td><td>Draft available in Oct 2003</td></tr> <tr> <td>Conclusion : synthesis of documents</td><td><b>EA</b></td><td></td><td> <p>Draft : Nov 2003 on SINTER for partner comments</p> <p>Final : Dec 2003</p> </td></tr> </table> |                       |                       |                                                                                | INDEX | RESPONSIBLE | INPUT NEEDED | DATE | General principles |  |  |  | <p>To provide from the previous results a critical review and recommendations on possible improvements based on the two following projects (GT-MHR and PBMR)</p> <ul style="list-style-type: none"> <li>Preliminary geometries for the turbine discs and blades</li> <li>The thermal fields likely to be present on these components depending on the options</li> <li>Integration and ISIR</li> </ul> <p>To perform an analysis of the general layout of the compressors.</p> <p>To define the future works for deliverables 8 and 9 and the proposed geometries to be investigated</p> |  | WP6, D2, D3, D4, D5 |  | Mechanical analysis | <b>EA</b> | D2 | Draft available in Oct 2003 | Aerodynamic analysis | <b>VKI</b> | D2 | Draft available in Oct 2003 | Compressor and turbine layout | <b>VKI</b> | D2 | Draft available in Oct 2003 | Conclusion : synthesis of documents | <b>EA</b> |  | <p>Draft : Nov 2003 on SINTER for partner comments</p> <p>Final : Dec 2003</p> |
| INDEX                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | RESPONSIBLE           | INPUT NEEDED          | DATE                                                                           |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |                     |  |                     |           |    |                             |                      |            |    |                             |                               |            |    |                             |                                     |           |  |                                                                                |
| General principles                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                       |                       |                                                                                |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |                     |  |                     |           |    |                             |                      |            |    |                             |                               |            |    |                             |                                     |           |  |                                                                                |
| <p>To provide from the previous results a critical review and recommendations on possible improvements based on the two following projects (GT-MHR and PBMR)</p> <ul style="list-style-type: none"> <li>Preliminary geometries for the turbine discs and blades</li> <li>The thermal fields likely to be present on these components depending on the options</li> <li>Integration and ISIR</li> </ul> <p>To perform an analysis of the general layout of the compressors.</p> <p>To define the future works for deliverables 8 and 9 and the proposed geometries to be investigated</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                       | WP6, D2, D3, D4, D5   |                                                                                |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |                     |  |                     |           |    |                             |                      |            |    |                             |                               |            |    |                             |                                     |           |  |                                                                                |
| Mechanical analysis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>EA</b>             | D2                    | Draft available in Oct 2003                                                    |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |                     |  |                     |           |    |                             |                      |            |    |                             |                               |            |    |                             |                                     |           |  |                                                                                |
| Aerodynamic analysis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <b>VKI</b>            | D2                    | Draft available in Oct 2003                                                    |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |                     |  |                     |           |    |                             |                      |            |    |                             |                               |            |    |                             |                                     |           |  |                                                                                |
| Compressor and turbine layout                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>VKI</b>            | D2                    | Draft available in Oct 2003                                                    |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |                     |  |                     |           |    |                             |                      |            |    |                             |                               |            |    |                             |                                     |           |  |                                                                                |
| Conclusion : synthesis of documents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>EA</b>             |                       | <p>Draft : Nov 2003 on SINTER for partner comments</p> <p>Final : Dec 2003</p> |       |             |              |      |                    |  |  |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |  |                     |  |                     |           |    |                             |                      |            |    |                             |                               |            |    |                             |                                     |           |  |                                                                                |

## Table 7 Deliverable 7b

### DELIVERABLE 7b

Title "Thermal insulation of the turbine inlet"

**Schedule** *March 2002 – December 2003*

**Responsible** *Framatome-ANP GmbH (15)*

**Partners** *EA (6)*

### DOCUMENT ORGANISATION

| INDEX                                                                                                                             | RESPONSIBLE           | INPUT NEEDED                                       | DATE                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------|-----------------------|----------------------------------------------------|---------------------------------------------------------------------------------------|
| General principles                                                                                                                |                       |                                                    |                                                                                       |
| To provide a design of the thermal insulation at the turbine inlet.                                                               |                       |                                                    |                                                                                       |
| Design of the thermal insulation at the turbine inlet                                                                             | <b>Framatome GmbH</b> |                                                    | Primary design in July 2002<br>Final draft in June 2003                               |
| FEM analyses of the thermal insulation at the turbine inlet.<br>Mechanical analysis of the stability in case of depressurisation. | <b>EA</b>             | P,T in accidental conditions (provided by Fra ANP) | Draft available in Oct 2003                                                           |
| Conclusion : synthesis of documents                                                                                               | <b>Framatome GmbH</b> |                                                    | <u>Draft</u> : Nov 2003 on SINTER for partner comments<br><br><u>Final</u> : Dec 2003 |

## Table 8 Deliverable 8

### DELIVERABLE 8

Title "Thermal and thermo-mechanical analysis"

**Schedule** *January 2004 – December 2005*

**Responsible** *CEA (2)*

**Partners** *EA (6)*

### DOCUMENT ORGANISATION

| INDEX                                                                        | RESPONSIBLE   | INPUT NEEDED                            | DATE                                                                                  |
|------------------------------------------------------------------------------|---------------|-----------------------------------------|---------------------------------------------------------------------------------------|
| General principles                                                           |               | Numerical codes interactions (mesh,...) |                                                                                       |
| To perform thermal and thermomechanical analysis of the proposed geometries. |               | D2, D7                                  |                                                                                       |
| Thermomechanical calculations on rotating discs and on blades.               | <b>CEA/EA</b> |                                         | Draft available in Oct 2005                                                           |
| Assessments concerning the damage on these elements (creep, fatigue,...)     | <b>CEA/EA</b> |                                         | Draft available in Oct 2005                                                           |
| Conclusion : synthesis of documents                                          | <b>CEA</b>    |                                         | <u>Draft</u> : Nov 2005 on SINTER for partner comments<br><br><u>Final</u> : Dec 2005 |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Helium Turbine | CEA                                                                                     | Rev : A                                                                     | 17/20 |       |             |              |      |                    |  |  |  |                                                                                                                                                                                |  |    |  |                                     |     |                                                                                         |                                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-------|-------|-------------|--------------|------|--------------------|--|--|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|----|--|-------------------------------------|-----|-----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| <div>Table 9<br/>Deliverable 9</div> <div>DELIVERABLE 9</div> <div>Title "Aerodynamic design-CFD calculations"</div> <div>Schedule January 2004 – April 2005</div> <div>Responsible VKI (11)</div> <div>DOCUMENT ORGANISATION</div> <table><tr><th>INDEX</th><th>RESPONSIBLE</th><th>INPUT NEEDED</th><th>DATE</th></tr><tr><td>General principles</td><td></td><td></td><td></td></tr><tr><td>The shapes of the blades of typical compressors + turbine stages will be optimised by means of CFD calculations.<br/><br/>Confirmation that foreseen performances can be reached</td><td></td><td>D7</td><td></td></tr><tr><td>Conclusion : synthesis of documents</td><td>VKI</td><td>Geometry limitations due to mechanical integrity are provided by EA (iterative process)</td><td>Draft : March 2005 on SINTER for partner comments<br/><br/>Final : April 2005</td></tr></table> |                |                                                                                         |                                                                             |       | INDEX | RESPONSIBLE | INPUT NEEDED | DATE | General principles |  |  |  | The shapes of the blades of typical compressors + turbine stages will be optimised by means of CFD calculations.<br><br>Confirmation that foreseen performances can be reached |  | D7 |  | Conclusion : synthesis of documents | VKI | Geometry limitations due to mechanical integrity are provided by EA (iterative process) | Draft : March 2005 on SINTER for partner comments<br><br>Final : April 2005 |
| INDEX                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | RESPONSIBLE    | INPUT NEEDED                                                                            | DATE                                                                        |       |       |             |              |      |                    |  |  |  |                                                                                                                                                                                |  |    |  |                                     |     |                                                                                         |                                                                             |
| General principles                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                |                                                                                         |                                                                             |       |       |             |              |      |                    |  |  |  |                                                                                                                                                                                |  |    |  |                                     |     |                                                                                         |                                                                             |
| The shapes of the blades of typical compressors + turbine stages will be optimised by means of CFD calculations.<br><br>Confirmation that foreseen performances can be reached                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                | D7                                                                                      |                                                                             |       |       |             |              |      |                    |  |  |  |                                                                                                                                                                                |  |    |  |                                     |     |                                                                                         |                                                                             |
| Conclusion : synthesis of documents                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | VKI            | Geometry limitations due to mechanical integrity are provided by EA (iterative process) | Draft : March 2005 on SINTER for partner comments<br><br>Final : April 2005 |       |       |             |              |      |                    |  |  |  |                                                                                                                                                                                |  |    |  |                                     |     |                                                                                         |                                                                             |

## Table 10 Deliverable 10

### DELIVERABLE 10

Title "Experimental tests program definition"

**Schedule** *January 2004 – April 2005*

**Responsible** *CEA (2)*

**Partners** *VKI (11)*

### DOCUMENT ORGANISATION

| INDEX                                                                                                                                                                                                                                  | RESPONSIBLE | INPUT NEEDED                                                                                        | DATE                                                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| General principles                                                                                                                                                                                                                     |             |                                                                                                     |                                                                                           |
| Guidelines for an experimental test program required to assess the feasibility of the turbine and compressor.<br><br>Capability to perform these tests in air or in helium in HTTR or HTR10 test loops or He system loop in Cadarache. |             | Possibility to get information from HTTR and HTR10 using the agreement between HTR-N and INET/JAERI |                                                                                           |
| Definition of aerodynamic tests                                                                                                                                                                                                        | <b>VKI</b>  |                                                                                                     |                                                                                           |
| Definition of mechanical tests                                                                                                                                                                                                         | <b>CEA</b>  |                                                                                                     |                                                                                           |
| Conclusion : synthesis of documents                                                                                                                                                                                                    | <b>CEA</b>  |                                                                                                     | <u>Draft</u> : March 2005 on SINTER for partner comments<br><br><u>Final</u> : April 2005 |

**Table 11**  
**Manpower per year**

|                | Year one | Year two | Year three | Year four | Total |
|----------------|----------|----------|------------|-----------|-------|
| FRA (1)        | 6.8      |          |            |           | 6.8   |
| CEA (2)        | 4        | 4        | 4          | 4.5       | 16.5  |
| FZJ (5)        | 4        | 3.8      |            |           | 7.8   |
| EA (6)         | 4        | 6.8      | 0.5        | 2.6       | 13.9  |
| VKI (11)       |          | 3.5      | 5.5        | 1.0       | 10    |
| EVO (13)       | 1.5      | 2.5      |            |           | 4     |
| A&D (14)       | 1.5      | 1.5      |            |           | 3     |
| FANP GmbH (15) | 2        | 3        |            |           | 5     |
| Total          | 23.8     | 25.1     | 10         | 8.1       | 67    |

The numbers are in man months.

## Table 12 Schedule

[illegible]