The Jules Horowitz Nuclear Complex
A plat-form for Research and Development on Nuclear Fuel
and Materials for the 21st Century

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Abstract:

The CEA intends to build a Material Test Reactor at Cadarache (South of France). This reactor would be the central piece of a wider complex which would include experimental fuel fabrication, destructive and non destructive examinations, in-reactor on line measurement advanced methods and modelling. For 50 years this platform would provide the necessary knowledge to the nuclear industry, the safety authority and to the national decision makers.
This material test reactor called Jules Horowitz Reactor (JHR) could be a key facility for industry and the central component of the European Research Area on nuclear fission from 2010.
In this paper an overview of the research complex is given and a first approach of the development effort undertaken to meet the requirements in term of : "time to result, experimental cost, experiment quality and international co-operation. Finally are given several ways of technical development undertaken to meet the above requirements.

1- INTRODUCTION

Present European Community policy on nuclear energy is to undertake all the necessary actions to keep the nuclear option open should the circumstances change and make the utilisation of nuclear energy ineluctable. In this common policy the position of each state is very variable. However

- nuclear energy is currently providing 35% of the European electricity and this situation will be mechanically persistent for the next 30 years.
- the good management of resources, the security of energy supply and the environment preservation (green house effect) are general preoccupations to which nuclear energy would bring an efficient solution.

The main challenges in the next 50 years will be to give confidence in the decisions on the currently working reactors and their evolution, allow and give the reasons of future orientations toward innovative nuclear systems.

The operation of existing reactors and the definition of future orientations require an experimental nuclear reactors capacity which, in Europe will be more than 40 years old by 2010. These reactors may be then out of date from a technical, safety or economy viewpoint which will justify their progressive closing down. /Fig. 1/

To answer the needs of the European energy policy in the framework of the European research area, Europe should examine the possibility of introducing an international research infrastructure on nuclear fission. In view of its important nuclear industry and research organisation, France is well suited to host a scientific complex of this kind, open to the Union's scientific community and industry and matching the challenge of keeping nuclear research and development community alive in Europe. The JHR complex could be the mainstay of this research activity during the next 50 years.

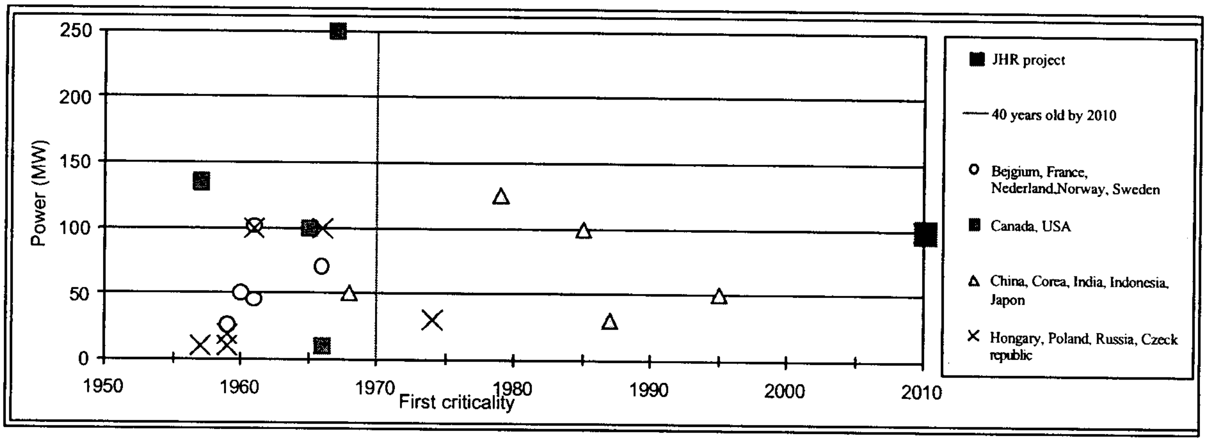
In synergy with the other development activities carried out by CEA this experimental complex could answer questions from:

- The international nuclear industry to build up the "technical-economic confidence" in existing reactors (examination and expertise), in their evolution (increased performance of the fuel, plant life extension and management) and in the evolution toward innovative nuclear systems. It should allow the utilities to assess and control the risk taken in their industrial choices and in their safety options. This is of interest for the system designers and the utilities, for the reactors and the fuel cycles evolution.
- The European and world policy makers to build up a "public confidence" in existing reactors and in future decisions related to nuclear energy. This is related to health concern, the good management and utilisation of resources, the security of energy supply and the environment preservation. It is intended to provide the policy makers with the technical information needed in the area of energy policies. It is worth noting that it is possible to share technical activities between countries with different energy policies (for instance plant life extension is equally important in Germany, France and Sweden).

Whatever the future industrial policy choices it is absolutely necessary to make available to the international scientific community a scientific platform available to utilities, nuclear steam system suppliers, fuel fabricators, research organisations and safety authorities and on which commercial experiments (with one partner) or cost-shared experiments between several partners will be possible. The national and international openness of the platform is essential and it is foreseen that the programmes would be determined by a scientific committee including the relevant European or international institutions. International teams would be intermingled with permanent staff of similar scientific level.

JRH platform aim mainly to sustain nuclear industry by producing related knowledge. Of course, it can also answer complementary needs related to medical applications or to non nuclear industry requests.

Figure 1 : *First criticality of research reactors worldwide. European reactors will be more than 40 years old by 2010. Modern MTRs will be then belonging to Far East countries.*



2- SCOPE OF THE JHR PROJECT

It is intended here to promote the JHR platform at the level of a European Research infrastructure by guarantying a high efficiency level in the environment of the Cadarache site.

- Expertise from the experimental fuel fabrication to the interpretation of irradiation/examination results will form the surrounding complex of this material test reactor. It includes the preparation of fuel and materials samples (fuel fabrication and re-fabrication), the preparation of the irradiation devices (loop, boiler...) and their instrumentation (on-line measurements), their irradiation, the intermediate examinations (non destructive tests), the destructive and non-destructive post irradiation examinations.

- This platform is organised, of course, around a permanent group of material and fuel experts to provide a first interpretation of rough data and serve as an interface with national and international scientific teams and capitalise on the benefit of this scientific knowledge.

- The presence of these services on the same site and the efforts in non destructive testing will allow better management of the experiments which will reduce transportation, personal doses, the volume of destructive testing and wastes and therefore the cost of experiments. CEA is proposing to host this platform at the Cadarache research centre on which a synergistic effect is expected with CEA's other technical activities.

- The technical challenge is to set up a research complex which would be:
  - ☞ A common tool to several reactor types, including existing reactors, their evolution and the first studies on new types of reactors. These studies would lead to the determination of technical options of future demo reactors, fuel or systems. This platform could be used by utilities, nuclear steam system suppliers, fuel fabricators, research organisations and safety authorities and therefore its cost could be shared between countries, institutions or with the E.U.
  - ☞ A tool able to produce for 50 years relevant data for various foreseeable needs. This is depending on the scientific know how (interpretation, modelling, simulation...) surrounding the platform, the flexibility of the reactor to accommodate future evolution of research needs, the level of instrumentation and examination available on the platform to deliver in (or nearly) real time a large amount of quality data. The pertinence of the technical choices retained for the platform depends on the determination of a technical envelope (flux, volume, specific power, payload, instrumentation, types of irradiation rig...) and not on the similarity of the MTR with a determined reactor type.
  - ☞ An evolutionary device : flexibility is maximal under the constraint of a reasonable investment cost. Then, the choice of the technical characteristics will be based on a cost/quality optimisation.

3- EXPERIMENTAL CAPACITY OF THE PLATFORM

The ability to reliably predict in-reactor fuel and materials performance is an essential requirement for safety assessments, fuel design studies, reduction in operating margins, flexibility in fuel management and improved operating economics. Therefore the JHR platform will be mainly devoted to under irradiation tests of nuclear fuel and materials and global tests.

- Material studies: The goal is to understand phenomena occurring under irradiation and altering the chemical composition, the mechanical properties, the geometry and the corrosion behaviour under different parameters. This kind of study would allow, for instance, a proposal to the safety authority on plant life extension and management - PLEM - scheme or to decrease the personal doses on plants.

- Fuel studies: For the types of fuel currently used in power reactors and for innovative types of fuel, the challenge is to study in MTR reactor the basic thermo-mechanical and chemical mechanism involved in order to be able to extrapolate the fuel and cladding/matrix behaviour to higher burn-up or different physical conditions or transient regimes. The platform, because of its safety conception, will be able to study the fuel in abnormal and accidental conditions (with loss of fuel) in a far better way than currently possible in existing reactors. Such safety features will permit studies on very toxic isotopes like the actinides or some fission products.

- Studies on reactor systems or safety analysis: the platform will be able to provide rigs devoted to a given reactor type, such as water (P&BWRs...), gas (HTR, fast breeders...) molten salt, or even liquid metals (sodium, led-bismuth....) with their own environment (temperature, pressure...).

Because of the complexity of the phenomena studied, the knowledge on these is embodied in codes to provide best estimate predictions of fuel and materials behaviour in extrapolated conditions (higher burn-up, different temperature, pressure, integrated flux...). One important goal is a comprehensive description of fuel and materials behaviour in both normal and off-normal conditions.

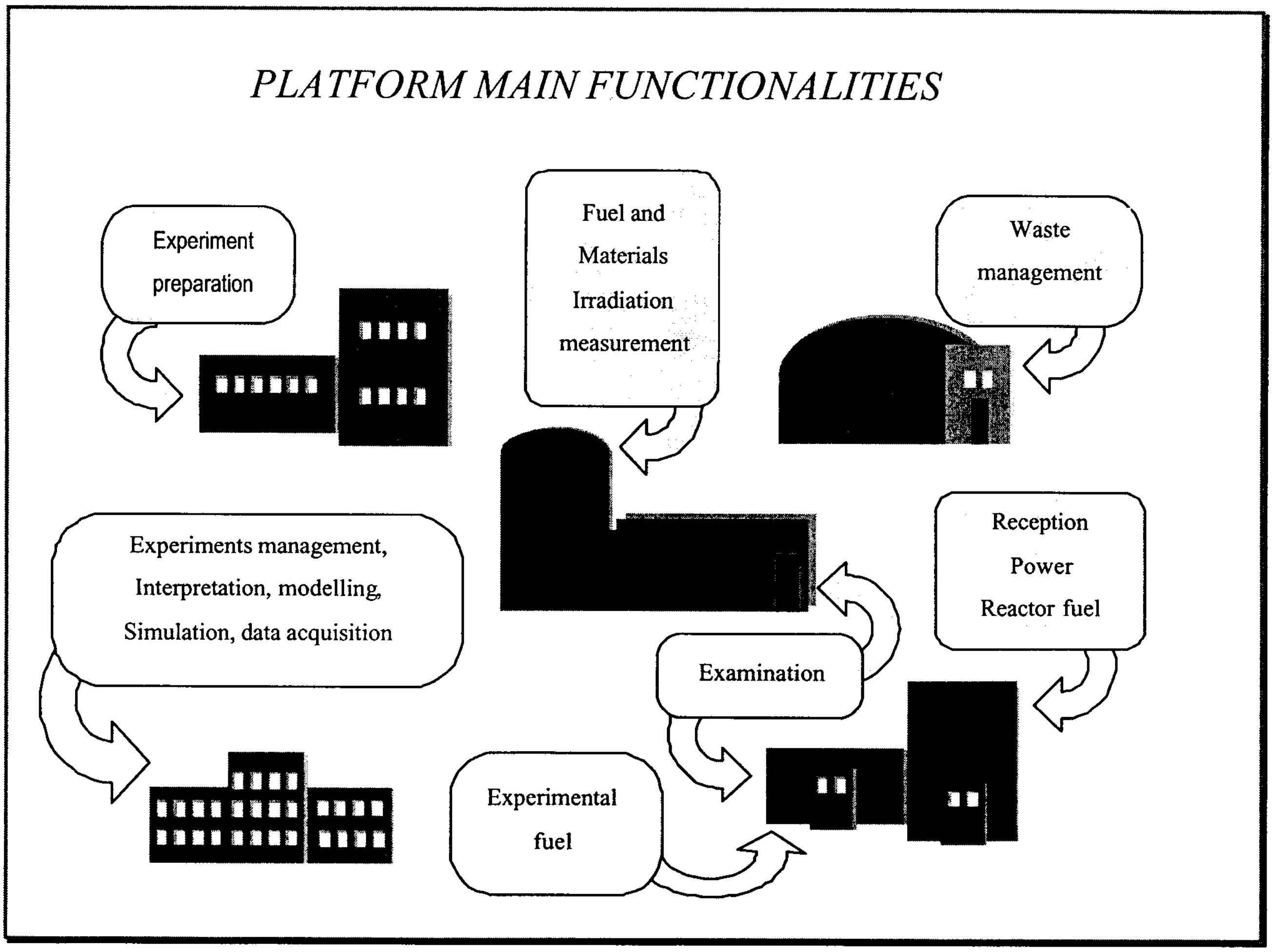
It is worth noting that, on one hand, such prediction is much dependant on the quality of measurements and examinations therefore great effort is being made to modernise the equipment foreseen for the platform; on the other hand, to cover the wider irradiation conditions important improvements are foreseen to adapt to specific irradiation conditions (increase of the irradiation flux by a factor 2 to 4).

The technical definition of the platform will start by 2002 and will be open to wide collaboration. A key challenge of the preliminary design are the flexibility and the evolution possibilities of the platform. For instance:

- The reactor will be a water pool type reactor equipped with a tank. The core structures will be dismountable to adjust the specific power (neutron flux) to the level requested or to respond to the needs in terms of irradiation volume.
- Several high flux positions, undisturbed by the environment (control rods, other experiments...) will be managed to accept well instrumented experiments needing very steady irradiation conditions for specific modelling purpose.

In parallel CEA is opening an analysis on the necessary evolution of its hot labs.

4- THE PLATFORM CONCEPT



The platform will essentially be composed of the following functionalities:

- The fuel experimental fabrication lab,
- the reception zone devoted to non-destructive testing, dismantling, dispatching of samples and when necessary fission gas sampling,
- a re-fabrication zone where irradiated fuel samples are instrumented for re-irradiation
- an experimental fuel fabrication lab,
- a scientific zone where samples are prepared for physical examination (MEB, TEM, EPMA, Gamma Spect.....) or chemical analysis (Burn-up, fission gas...),
- the reactor where a group in charge of the rig design and instrumentation will prepare the irradiations according to the management group requirements,
- the reactor and its hot cells where non-irradiated experiments are received and where non destructive testing can be carried out primarily as an intermediate examination (an effort will be made on the rig design and on the examination tool to be able to carry out these examinations during the shut down period and put the irradiation back under irradiation at the next cycle) , they are: Neutron-radiograph, X ray tomography, micro-acoustic examination, clad-gap measurements... The hot cells attached to the reactor are also foreseen to handle failed fuel (UO_2, MOX, Actinides) from failed fuel studies or safety experiments. A facility devoted to on-line measurement of gaseous fission products will also be connected to the reactor,
- the experiment management group acting interactively with the data acquisition unit and the interpretation/modelling /simulation group to design, monitor the experiments, conduct the irradiation and decide on examinations (intermediate and final)...,
- the connection to the waste management unit and buffer cells for fuel and materials management.

ADVANTAGES OF THE PLATFORM CONCEPT

The platform composed of interlinked units on the same site will have the advantage of developing all the steps of the experimental process under the same umbrella. In addition the concept should be able to:

- **Shorten drastically the "time to result"**

  This will be obtained by eradicating the "bottle necks" on the material fluxes and developing dedicated transportation means between units (water channels, pneumatic rabbits...).

  A second way will be to replace, each time it is possible, destructive examinations by non-destructive examinations. In this way a special effort will be made on the development of non destructive investigation methods (Neutron radiograph, X rays, micro-accoustic....) at the reactor, in the hot cells attached to the reactor and at the hot laboratory to keep the destructive examinations for very specific purposes.

  A third way will be on the irradiation rig design. Rigs will have to be easily disconnected from their irradiation position, transferable to another position or to an examination position when the examination is not possible "in situ". The aim will be to carry out intermediate examination during a standard shut down period and put the rig back under irradiation at the next irradiation cycle.

An expected side effect of this policy will be an important decrease of the experimental cost, the personal doses and the amount of waste.

- **Decrease the experimental cost**

  The directions given above on transportation, non-destructive examinations and rig design will have an automatic effect on the cost of experiments (less transportation by cask, less destructive examinations, less wastes, less personal doses and less time wasted...).
  In addition it is expected to decrease the cost of experiments by sharing the cost in international programmes without excluding bilateral programmes when commercial interests are involved.

- **Improve the experiments interpretation.**

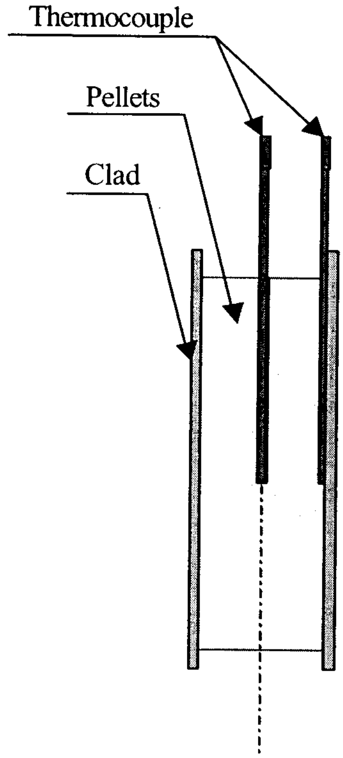
  The fast communication between the different units on the same site and the development of different non destructive methods will provide the possibility of measuring the same parameter by different means, thereby decreasing the level of uncertainty on data.
  For instance:
  - Burn-up calculation can be confirmed either by gamma spectrometry or by Neodymium isotopic measurement.
  - The fission gas release can be measured on line, by non destructive methods during shut down periods and at the end of the irradiation or by destructive method (piercing).
  - Length change of fuel column or cladding can be measured on line by specific sensors or by non destructive methods during shut down period (length measurement, X-Ray, neutron radiograph, acoustic methods) however it should be noticed that on-line measurement can have specific applications e.g. when this measurement is used as an indicator of fuel-clad interaction (clad failure or simple interaction) the measurement has to be performed on-line.
  - Temperature measurement of fuel and clad has no alternative method and has to be performed on-line.

The benefit of this organisation will likely be to obtain 80% of the experimental results in real time or within a short period after the end of the experiment. Sharing needs and requirements at the international level will provide a real opportunity to optimise the overall efficiency of the experimental capability.

5- EXAMPLES OF DEVELOPMENT FORESEEN FOR THE PLAT-FORM

Several examples are given hereafter, some of the methods described have been already used, others are completely new but in each case there is a challenge and the subject of our future developments will be to improve this techniques.

Fuel Temperature measurement

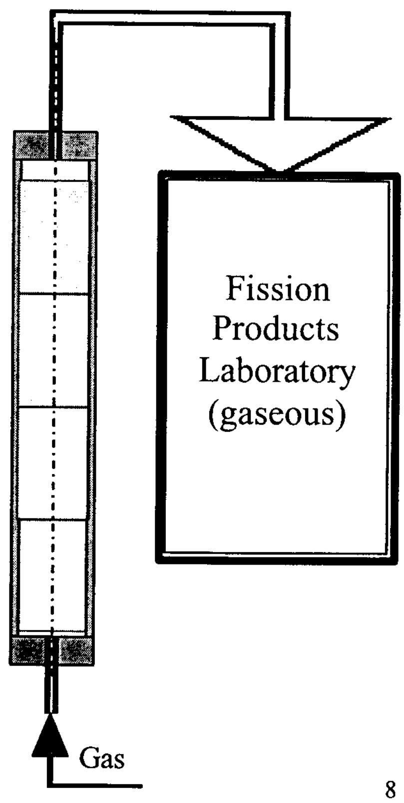


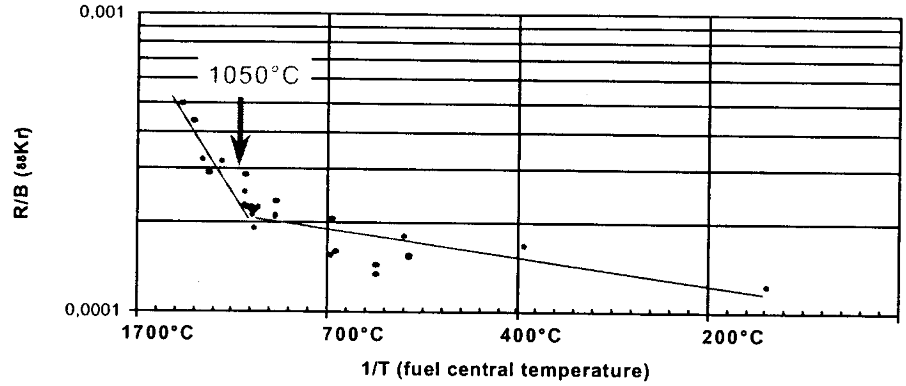
The rig and instrumentation laboratory attached to the reactor will develop methods to implant thermocouples in the fuel and the clad to measure the temperature gradient in the fuel on un-irradiated or irradiated (for instance in a power reactor) fuel. The instrumentation will be carried out either at the fuel fabrication lab (un-irradiated) or in the hot lab (irradiated). This instrumented fuel will then be irradiated to the designed burn-up.
This measurement is a key measurement and for instance the diffusion equation applied to fission gas release is strongly dependant on the temperature. When correlated to other measurements like fission gas release and burn-up this measurement derives a series of fundamental characteristics of the fuel.

From the present European experience, future developments will be on decreasing uncertainties of the measurement by, for instance, treating the contact/gap problems between the sensor and the fuel.

The fission product laboratory

The first fission product laboratory was developed in Grenoble beside the Siloë Reactor and has been used in many experiments /1/ /2/ /3/ /4/. The same type of lab will be built beside the Jules Horowitz reactor to measure on-line fission gas release. This irradiation will be possible in parallel on several fuel samples and correlated to other parameters such as temperature, type of fuel, specific power.../5/ /6/ and enable a comparison of the main characteristics of different types of fuel such as densification, fission gas release according to temperature, swelling, behaviour during ramps...The type of results obtained are illustrated below /5/:

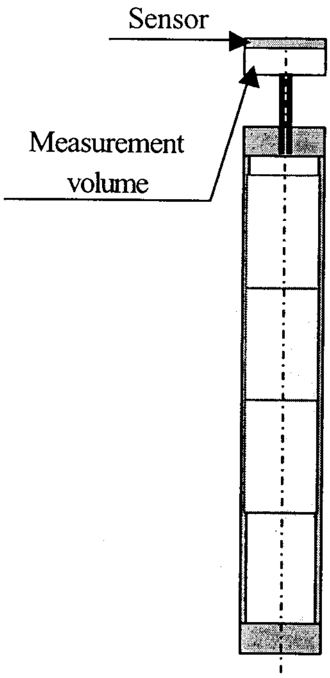




Release/born ratio for fission gas according to 1/T (T: fuel central temperature)

From the experience accumulated in Grenoble the new lab. will take into account the improvement of the transfer function between the experiment and the lab (transfer time).

<u>On-line gas pressure measurement</u>

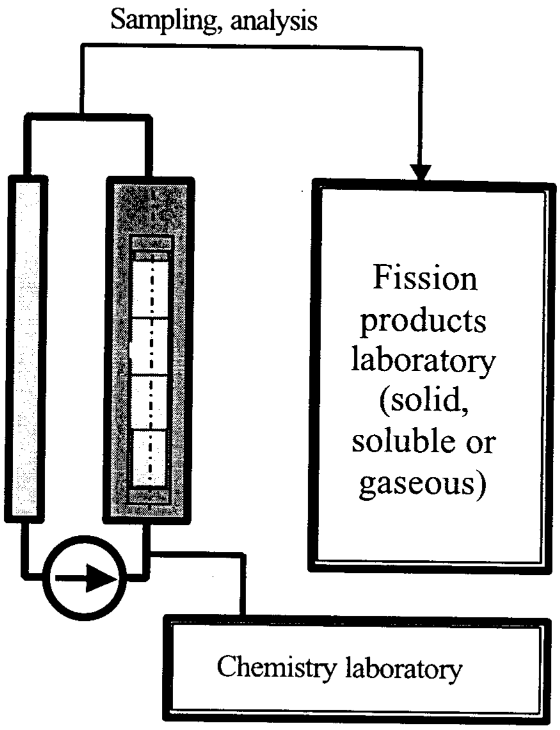


New R&D has been undertaken on-line gas pressure measurement. This new sensor should also be able to give an indication of the gas composition. Correlated to temperature and burnup this measurement is fundamental to any serious fuel modelling. Used together with gamma spectrometry the system will be able to give information on the fission gas release mechanism.

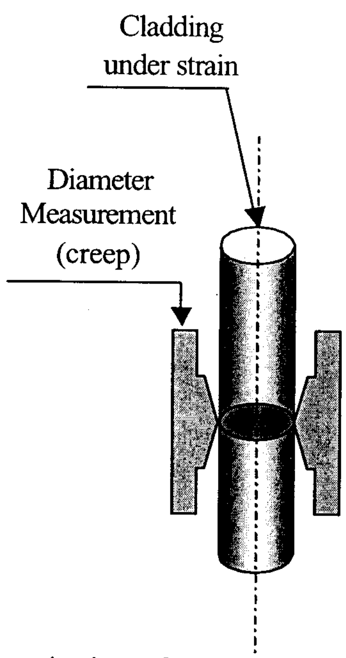
Our challenge is now to adapt this sensor to nuclear conditions and carry out, on a routine basis, correlation with fuel temperature measurements. Some possible progress are toward the partial pressure measurement.

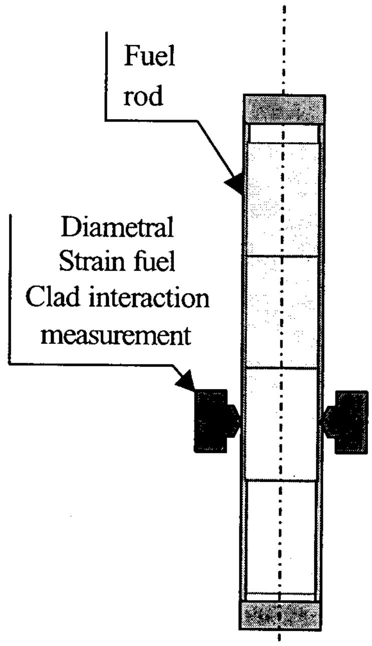
Failed fuel irradiation

Fuel failure studies (ramp, LOCA...) will be considered. The fission products and actinides release in the primary circuit will be possible through the fission products laboratory. The parameters influencing the release will be studied with the help of the chemistry lab. Which will modify, on demand, the water parameters (temperature, pressure and also Oxygen potential, pH....) /7/ /8/



On line diameter measurements /9/ /10/





The determination of the fuel-clad interaction either in steady state, abnormal (ramp) or is of utmost importance to determine "the margin to failure". To acquire this knowledge it is necessary to study both the cladding material and the fuel behaviour (clad + fuel).

The reactor high flux will allow a fast accumulation of "damage" and the samples will be analysed either by non destructive methods (creep) and ultra-sound (Poisson coef., Young modulus) or by destructive examination. Developments are underway to perform measurements directly on the rig.

Diameter measurement of the fuel rod have already been performed in the Siloe Reactor. It is very essential to modellers to quantify the fuel strain during irradiation. A new development is now under development to perform this measurement during specific events (ramp).

This measurement when performed under irradiation and during a transient is a challenge and International co-operation is certainly wished on this subject.

Non destructive examination

The non-destructive examination devices on the reactor and in the examination zone will allow to check the quality of on-line measurements. For instance if the fission gas release is studied during a power ramp, the fission product lab. And the gamma spectrometry will validate the on-line measurement. The gamma-spectrometry would allow to check the burn-up and in turn the linear power reached.

6- CONCLUSION

The ambition to build a modern nuclear experimental platform open to Europe and the world is based on the necessity to sustain nuclear R&D competence and research capabilities. It is a necessary condition to provide confidence in industrial and public decisions on nuclear energy.

Modern development in nuclear R&D requires an improvement of on-line measurement. In addition wastes and transportation are a burden and should be dramatically minimised. It would also be a great mistake to forget that Nuclear R&D is expensive and therefore should be treated as a "business" which means customer satisfaction on the "time to result", the quality of the final product, and the cost which means, inter alia, to work in international programmes.

Without forgetting about our own shortcomings on re-fabrication, instrumentation, on-line measurement and development of non-destructive methods...It is now essential that the willingness to modernise fuel and materials R&D exists. The building of a new reactor gave the kick off of the process and an important effort in R&D will be undertaken on new sensors, non destructive examinations, on-line measurements....

In this process international co-operation should play a central role. The Jules Horowitz platform will be an open international project for the initial investment, the experimental programme, the construction and the R&D; with that in mind we have recently initiated a European Programme called "Future E.U. Needs in Materials Research Reactors" (FEUNMARR) and this programme has been now accepted.

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