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SAFETY TEST FACILITIES - STATUS, NEEDS, FUTURE DIRECTIONS

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ABSTRACT

A survey is given of the in-pile programs which are presently or in the near future being performed in the DeBeNe-area and in France. Only those in-pile programs are considered which are dealing with severe accidents that might lead to disruption of major parts of the core. By comparing the needs with the goals of the present programs points are identified which are not sufficiently well covered up till now. The future procedure is described: The existing facilities will be used to the largest possible extent. Whenever it is necessary, upgrading and improvement will be foreseen. Studies of a Test Facility allowing the transient testing of large pin bundles should be continued. The construction of such a facility in Europe in the near future however seems premature.

1. INTRODUCTION

During the past 10 years the construction of prototype LMFBR reactors and demonstration plants has been started all over the world. The safety of these plants has mainly been guaranteed by conservative design measures.
During the same period significant progress has been made in the field of fast reactor safety R+D. Nevertheless, we need additional efforts in this area because of the following reasons:

- the presently available information should be broadened and strengthened,
- additional information should be gained in order to reduce unnecessary conservatism in later commercial LMFBR's,
- alternative designs of components should be investigated in order to find out whether safety still can be improved.

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2.1.2 FUEL PIN BEHAVIOUR PRIOR AND UP TO CLAD FAILURE

The course of the accident is strongly influenced by the fuel behaviour prior to clad failure. Phenomena to be investigated are:
- thermal expansion of the fuel,
- transient fuel swelling,
- movement of molten clad material,
- release of fission gases and/or fission products prior to melting or at melting,
- internal fuel motion,
- time and location of clad failure.

For most of these phneomena in-pile investigations are clearly necessary. One-pin experiments in a prototypic environment as far as temperature distributions in the fuel, cladding and coolant are concerned, probably are sufficient. The test pins themselves should have prototypic dimensions especially as far as the length is concerned. Different kinds of pin design are of interest. The linear heat rating as well as the burn-up reached during pre-irradiation are important parameters.

A large number of experiments dealing with these problems have already been performed in the past. Additional tests will be performed in the frame of current programs. The main goal of these tests is to improve the prototypicality and to investigate design specific questions.

2.1.3 BEHAVIOUR OF FUEL AND STEEL AFTER CLAD FAILURE

The following phenomena are of special interest in this phase of the accident:
- molten fuel enters in a channel which might be voided or not,
- fuel coolant ineraction,
- fuel and steel masses undergo extended motion and eventually will partially or totally freeze at the upper or lower parts of the core.

Permanent removal of fuel out of the core region is the final shut down mechanism, and so a good knowledge and description of material movement phenomena is of special importance.
Large efforts have been made in the past and will be undertaken in the future to investigate most of these problems by out-pile experiments. In any case however, in-pile experiments seem to be desirable to confirm the out-pile results. Most of these in-pile experiments ask for multipin geometry; some are asking even for multi-subassembly geometry. Linear heat rating and burn-up stages are important parameters to be varied.

2.1.4 FORMATION OF POOLS

According to our todays knowledge the most probable course of an CDA does not lead to an energetic disassembly but rather leads to the formation of pools formed out of a fuel/steel mixture.
Important phenomena of such a configuration are:
- melt through processes in still existing subassembly structures,
- crust and blockage formation,
- pool internal heat transfer phenomena and heat transfer to the surrounding structures,
- formation of critical configurations as consequence of pool collapse etc.

2.2.2 PIN-TO-PIN-PROPAGATION

Fast Pin-to-Pin-Propagation today is considered as very unlikely. This follows from theoretical considerations, out-pile experiments as well as in-pile experiments. However, the in-pile experiments up to now have been made using fresh pins only. It is felt that these tests have to be repeated using preirradiated pins. Slow propagation cannot be excluded with certainty. Under these circumstances detection of blockages preferably done by DND becomes important. Development and improvement of these detection methods are asking for in-pile experiments.

2.3.3 SUBASSEMBLY TO SUBASSEMBLY PROPAGATION

Two possibilities of SA to SA-propagation can be thought of: a mechanical propagation and a thermal one. By and large a mechanical propagation nowadays is ruled out. Even the arbitrary assumption of a violent FCI presumably does not lead to intolerable mechanical effects in the neighboured subassemblies.

This has been proven by out-pile experiments using materials which simulate fresh or low irradiated steel. The same test for embrittled materials simulating highly irradiated steel still has to be made. In the field of thermal propagation the knowledge is much less advanced. The phenomena to be investigated are very similar to the problems discussed under item 2.1.4. Consequently also in this case multi-pin or even multi-subassembly in-pile experiments are needed. However, no power burst capability is needed for this kind of experiments.

2.3 EXTRAPOLATION OF EXPERIMENTAL RESULTS TO REACTOR CONDITIONS

Despite the fact that the above listing of physical phenomena is not complete, it becomes clear that there is a high number of possible experimental conditions. Both the number of physical phenomena and the number of reactor core conditions to be simulated are large. There is therefore no hope to examine all situations by in-pile experiments only. Rather a combination of out-pile and in-pile experiments is needed. Furthermore the development of theoretical models and computer codes is extremely important in order to reach an understanding of the basic phenomena. As reactor conditions probably never can be simulated in all details, this deep understanding of basic phenomena and development of computer models are needed to apply the experimental results to reactor conditions. From this it follows that the theoretical interpretation must accompany the experimental efforts.

3. PRESENT STATUS OF IN-PILE PROGRAMS

For the investigation of the above problems large programs presently are underway in Germany, France and the Netherlands. Detailed technical descriptions are given during this conference /6/, /7/, /8/. Therefore only a short summary is presented in this paper. The main test reactors which are available for safety tests are the CABRI and the SCARABEE reactors at Cadarache, the BR2 at Mol and the HFR reactor at Petten.

In the first two experiments which have been performed in spring 1977 and spring 1978 the blockages were formed out of steel spheres in a cage of 4o mm length. For the third experiment which will be run early in 198o UO_2 spheres will be used. The results of the first experiments are discussed during this conference /6/. However, two items should be mentioned also here. The experiments clearly showed that

- there si no fast pin-to-pin-propagation to the whole fuel element,
- fuel pin failures generate extremely clear DND signals allowing under reactor conditions automatic or reactor operators intervention.

It is planned to extend the present program by roughly 5 to 6 experiments to be performed from 1981 to 1983. Two different kinds of experiments are under consideration:

1. Experiments with a central heat generating blockage with irradiated pins (i.e. a repetition of the present program using irradiated pins). A total number of 2 experiments are foreseen.
2. Meltdown experiments of a 37-pin bundle. Investigation of dispersive fuel behaviour as well as thermal propagation phenomena shall be made. Three experiments are planned. Fresh and irradiation fuel pins shall be used.

The irradiated fuel pins for this so-called Mol 7C follow-on program will be taken from KNK II. Standard KNK II pins do have the necessary high enrichment of about 85% and prototypical dimensions. Furthermore pins are available having two different enrichments which are needed to flatten the power distribution in the test bundle.
The feasibility study of this program is presently under investigation. The study will be finished at the end of the year.

3.4 SCARABEE

Like CABRI the Scarabee-reactor is a swimming-pool-type reactor. The driver core consists of MTR plate elements. The thermohydraulic and power density characteristics which can be obtained in the central sodium loop are typical for power reactor conditions.

The reactor has already been used between 1971 to 1974 to investigate the behaviour of single pins or small pin bundles up to 7 pins under various coolant disturbances.

The following accident conditions were investigated:

- local blockages
- total blockage at the inlet of the cooling channel
- slow power transients
- pump run down incidents without shut down.

Fresh test pins have been used in this phase of the experimental program. The interpretation of these experiments has been performed as a joint venture between KfK, UKAEA and CEA. The results are reported during this conference /8/.

However, despite the large number of experiments, not all parameters which could be investigated in the available facilities are covered by the present programs. Some of them are of growing importance. To give an example: in the Cabri program up to now it was not planned to investigate the behaviour of fuel pins having hollow pellets. From the Pinex-2 experiment, performed 2 years ago, it became clear that such fuel pins might offer valuable inherent safety characteristics. We are now considering the possibilities of adding this kind of experiments to the Cabri-program.

A similar situation can be seen in the field of low rated pins. Fuel pins located in the outer regions of the reactor and having lower linear heat ratings are expected to show differences in the transient behaviour compared to pins having high linear heat ratings. Again experiments of this kind are not foreseen in the Cabri program up to now.

In addition a large number of rather small but well posed experiments aiming at special physical details needed for the complete understanding of the integral experiments seem to be necessary. Examples of this kind of problems are transient fuel swelling, fission gas release, heat transfer between fuel and gap under transient conditions etc. The feasibility of all these investigations is not questioned but these additional experiments are of course time and cost consuming. Nevertheless, it should be stated that as much additional use as possible should be made of existing facilities.

4.2 IMPROVEMENT AND UPGRADING

The programs which are presently in a planning stage partly need considerable improvement and modifications of the respective facility. This is especially true for the Mol 7C follow-on and the Scarabee-N program.

For both programs for instance a reliable fuel motion detection device would be of extremely high value. In the case of ER2 the use of a device like a hodoscope or Coded Aperture Imaging System certainly is not possible, therefore we are presently considering the feasibility of using in-core detectors. In the case of Scarabee similar considerations are underway. Another problem is caused by the fact that irradiatied pins of nearly prototypic dimensions shall be used. The standard KNK-II pins having a fissile length of 600 mm can not be introduced into the present Mol 7C loop. Therefore either the design of the loop has to be changed or the pins have to be shortened. Additional difficulties will arise from the reassembly of irradiated pins to bundles and their instrumentation. All these investigations and modifications will need a time period of about 2 years. Taking into accout the fact that the experimental programs themselves need in addition about 3-4 years, we have to face the situation that the currently planned programs by and large will not be finished prior to 1985. Consequently a large amount of financial support as well as manpower will be needed for these programs in the years to come.

We can see that at least part of the information can be gained from the currently planned programs in the area of whole core accidents for all the important phenomena. However, there are two important open points. Neither in the BR2 nor in the Scarabee reactor the transient behaviour of large pin bundles can be tested if there is a significant power rise. Furthermore problems in the behaviour of boiling pools cannot be examined if multi-subassembly configurations are needed.

A similar situation exists in the field of the Single Subassembly Event: Local boiling as well as detection of blockages and pin-to-pin propagation pheomena can probably be examined sufficiently in the Mol 7C and Scarabee-N programs. On the other hand, only part of the information concerning thermal Subassembly-to-Subassembly propagation can be expected. Again multi-subassembly configuration would be desirable.

Accordning to the above there are basically two items which are not covered by the current or the planned programs: the testing of large pin bundles under severe power transients and testing of multi-subassembly configurations under quasi-steady state conditions or moderate power transients.

Facing this situation we have to ask ourselves whether we have to start the construction of a new test facility in the near future or not. In Germany and in France we came to the conclusion that at the present time the construction of such facilities would be premature despite the open points mentioned above. The main reasons for this statement are as follows:

- the results of the current in-pile programs should be available when the decisions on new facilities is made. Only when these results are known can a relation between the amount of effort and the amount of additional information to be expected from new facilities be established.
- The same requirement exists for the results of the present out-pile experiments. While probable not all of the information can be gained from out-pile tests, we are quite confident that the out-pile results will improve our knowledge significantly. For instance at the KfK an out-pile program has been started in the frame of which the transient behaviour of large pin bundles up to 169 pins will be investigated. The pins are filled with thermite and by using a special technique can be ignited coherently. Material movement is visualized by high speed X-ray cinematography. First results of this program will be reported during this conference /11/.
- We are not sure whether the CDA accident will play the same dominant role in the future as it was the case in the past. There is a tendency in our countries that the CDA should no longer be a quasi-design basis accident in the future. This goal will be supported by additional engineered safeguards and inherent safety measures like inherent shut down systems, low void cores etc. /9/, /10/.

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