THE STATUS OF THE GERMAN AF-PROGRAM AND THOUGHTS TOWARD A NATIONALLY AND INTERNATIONALLY COORDINATED TERMINATION OF THE PROGRAM

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ABSTRACT

The activities under the German AF-Program primarily concentrate at present on the establishment of the fabrication technology for LEU fuel elements on the basis of uranium silicide (U_3Si_2). In the meantime, the technical facilities for the individual process steps have been largely provided and, for the major part, have already been integrated into the future series production line. The conversion studies for the German research reactors planned to be converted from HEU to LEU currently aim at determining the operation- and licensing-specific data (in part already available) required primarily for the licensing applications. Such an application has already been filed for the Geesthacht reactors so that it is highly probable that one research reactor in Germany will be converted to LEU operation in 1988.

Since there are only about two years left until the official end of the AF-Program, the procedure for terminating the program is being considered at present. Relevant views developed in the past as well as thoughts towards a coordinated procedure for terminating the international RERTR activities will be presented.

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1. INTRODUCTION

At last year's international RERTR meeting in Gatlinburg, Tennessee, USA, it was reported that the German AF-Program had been updated by a second addendum taking extensive account of the results of international RERTR activities. On this occasion, the reasons for this new updating[1] were outlined, the goals of current and future work were described and the status reached as well as the future research priorities were illustrated (see /1/). As is generally known, the program was mainly updated to extend the period by another three years from the end of 1986 to the end of 1989 so that, among other things, the German AF-Program will continue to be the official liaison address for international cooperation.

In early 1987, the formal decisions on program updating were finally made relating to the type and scope of activities still to be carried out and above all to the time and cost requirements for such work. Section 2. below contains the most relevant information and also briefly deals with the status reached (fall 1987).

Section 3. describes the procedure for terminating the German activities. It was evolved by a working group of the German AF-Program meeting at regular intervals. Furthermore, thoughts ("suggestions") towards the possible procedure for a coordinated termination of current worldwide activities will be presented, such coordination being achieved at an early stage between the different national RERTR programs and the international organizations concerned.

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[1] A first addendum to the AF-Program had already been made in 1983.

2. CURRENT WORK, INFORMATION ON PROGRAM OPERATION, GOALS AND STATUS

For the AF-Program 10 separate major tasks were defined in late 1979 which were to be handled by five program partners (two industrial companies, three large national research laboratories) with the aim to produce the prerequisites for converting research reactors from HEU to LEU fuel cycles (five tasks each for industry and national research centers). Up to the present and this will not be changed any more, another five major tasks to be operated by industry have been added. In total, 15 major tasks have been or are still being handled, although the number of tasks running in parallel has always been < 10. Seven of the 15 separate tasks belong to the field of fuel and fuel element development, including the establishment of the associated fabrication technology, and four each to the fields of fuel qualification by irradiation and post-examination as well as HEU-LEU conversion studies. Eight major tasks have already been completed to date with minor residual activities being continued after completion of the tasks as part of newly commenced work especially concerning fuel and fuel element technology.

The seven major tasks under way at present are distributed between the following three areas of activity:

- 3 fuel and fuel element technology,
- 3 fuel and fuel element qualification and
- 1 HEU-LEU conversion studies.

The attached schedule (Fig. 1) gives a survey of the priorities of the three areas of activity and their handling in terms of time. It may be seen that the essential work can be completed by the end of 1988 and final activities will only be carried out in 1989 for fuel and fuel element qualification as well as the establishment of the LEU fabrication technology.

The costs of the program amount to DM 57.6 million. The major portion of this sum equalling approx. 77 % (DM 44.3 million) was already raised by the end of 1986. Approximately 54 % (DM 31.0 million) of these costs are allocated to the industrial tasks and the remaining 46 % (DM 26.6 million) to activities

carried out by the national research centers. On the whole, there has been a tendency towards ever increasing expenditure on industrial work. Original program planning initially provided for a share of about 30 % for industry which had already increased to about 50 % in the first addendum to the AF-Program in 1983. Approximately 75 % of the expenditure for industry is covered by special funds from the Federal Ministry for Research and Technology. The remainder is borne by industry itself, although the respective self financing of the individual tasks varies between 0 and 50 %. The funds for the tasks handled by the research centers are provided through their basic financing.

As expected, the main share of approx. 48 % of the costs (DM 27.6 million) is accounted for by the development of the LEU fuel and fuel element technology. About 43 % is spent on work for fuel and fuel element qualification by the centers (DM 24.8 million) which, however, contains a high neutron cost fraction. The remainder of about 9 % (DM 5.2 million) is required for HEU-LEU conversion calculations including plant- and licensing-specific studies.

2.1 Fuel Technology

It was reported in /1/ that intensified efforts have already been under way since 1984 to find technically optimized and low-cost solutions for the six essential process steps[2] for the production of LEU-MTR fuel elements using uranium silicide fuel. It was shown that particularly great efforts are required for developing and establishing the processes needed for these steps because work does not only relate to the development and future selection of suitable methods, but especially also to their integration into the overall process for the series production of LEU-MTR fuel elements. In addition, this work is aimed at incorporating into the fabrication process all the testing required for quality assurance in such a way that a smooth flow of production is ensured as far as possible, that component parts not produced to specification are identified in time and rejected or recirculated into the process without major

[2] Fuel conversion, melting of the fuel, fuel powder production, preparation for rolling the plates, plate manufacture by rolling and fuel element assembly.

outlay and that the scope of testing on the finished fuel element can be reduced as far as possible.

Information in detail (see also /2/).

The essential aim in fuel conversion is to reduce the dust release as far as possible in order to avoid increased radiation exposure of the operating personnel. For this purpose, the concept of a hydrofluorinating fluid bed with integrated powder transport was developed. The preparations for installing this new system, including the evaluations by the Technical Control Board (TÜV), have been largely completed by now so that the system can be put into operation. For melting the fuel, the induction process has proved suitable so that it was also possible here to set up the necessary technical facilities. Essential efforts have been and are still being directed at the development and establishment of suitable methods and devices for fuel powder production. For this purpose, a comminution in two steps (coarse and fine) has proved to be promising. Appropriate facilities aimed at furnishing fuel powder of a specified grain size (fine grain fraction < 25 %) in as few passages as possible have been developed to a stage where efforts concentrate primarily on the establishment of a continuously working multistep comminution plant suitable for series production. While the technical system developed already satisfies the requirements for coarse comminution, technical alternatives are still being examined for the fine comminution device.

For the remaining three fabrication steps it has been largely possible to create the technical prerequisites and make the required adaptations so that new facilities of the LEU fabrication line have in part already been set up. The technical systems are currently being tested for the series trial production of 78 LEU fuel elements for converting the Geesthacht research reactors from HEU to LEU operation.

2.2 Fuel Qualification

Within the scope of the AF-Program, LEU fuel plates and elements have been tested in Germany, primarily in Geesthacht and Jülich. A total of 25 Plates of reduced size have been tested in special irradiation devices. The irradiations

and the results of post-examinations already available were respectively are being discussed by E. Groos, /3/, W. Krull, /4/, and G. Thamm /5/. Post-examinations have only been started just recently for the irradiation of five plates with increased fine grain fraction in Geesthacht and for the second irradiation campaign in Jülich which recently had to be discontinued prematurely at a moderate burn-up of only about 1.2 x 10^{21} f/cm^3 due to increased activity releases into the cooling water of the irradiation device. The concluding post-examinations of the first irradiation campaign in Jülich (see /5/) have once more corroborated the different irradiation behavior of U_3Si_2 and U_3Si already reported by G. L. Hofman and L. A. Neimark in /6/ and /7/. At burn-ups up to 2 x 10^{21} f/cm^3 and even above, U_3Si_2 (with densities up to 5 gU/cm^3) was found to exhibit only minor swelling (well below 10 %) and moderate changes in the fuel microstructure under irradiation. The blister temperature thresholds are generally also above 500 °C and thus more favorable than for U_3Si fuels. The latter show substantially greater volume increases (20 to 30 %) under irradiation even before reaching the so-called break-away threshold and also considerably greater changes in the fuel microstructure which is characterized by considerable swelling and by the interlinkage of individual fuel particles as well as by the concentration of fission gas bubbles. This adverse behavior of U_3Si is also retained in the uranium silicide mixed fuel (U_3Si_{1-2}), so that the dimensional and microstructural stability of this fuel must be basically regarded as inferior to that of U_3Si_2.

Test irradiations with LEU fuel elements have been completed successfully, above all in Geesthacht with U_3Si_2 fuel elements which had a prototype character for the conversion from HEU to LEU envisaged there. In part of the test irradiations carried out with LEU-U_3O_8 elements in Geesthacht and Jülich it has been possible to exceed without failure the maximum burn-ups possible in HEU operation.

2.3 Reactor Conversions

As is generally known (see /1/), reactor conversion studies are being

essentially carried out in two steps in the Federal Republic of Germany. They comprise

- basic studies for a reference core predefined by the operator, followed by
- operating- and licensing-specific studies which are, in part, predefined by the requirements of the procedure for HEU-LEU conversion licensing.

With one exception, the basic studies have been completed for the reactors to be converted from HEU to LEU operation. The essential data and steps for the conversion process in Geesthacht, Jülich and Munich have therefore been determined. Basic studies for a LEU element with high fuel load (Geesthacht design) are still under way for the BER-II in Berlin. Since the licensing application for HEU-LEU conversion was already filed in late 1986 for the research reactors in Geesthacht, the operating- and licensing-specific studies are most advanced for this case. In this connection, for example, special core configurations deviating significantly from the reference core of the basic calculations were examined with respect to their influence on the power density form factors as well as on the fission product and total activity inventories (see also /4/). Licensing is expected for Geesthacht in late 1987/early 1988 so that in all probability the first research reactor in Germany will be converted to operation with LEU fuel in 1988.

The conversion to LEU of the FRJ-2 (DIDO) in Jülich requires a modification of the fuel element design. Prior to a conversion to LEU operation the licensing authority demanded test irradiations with three HEU and LEU elements each of the new design (roll-swaged design; RS) and then first of all a conversion to RS elements in HEU followed by a prolonged operational test phase. The final conversion from HEU to LEU will therefore not take place before 1990.

If the Munich reactor (FRM) should be replaced in the early nineties by a modern powerful (20 MW) beam tube reactor with a very compact cylindrical core (see /8/), it would not then be necessary to convert the current core from HEU to LEU.

As far as the BER-II is concerned, practical preparations for HEU-LEU conversion will only be commenced after completion of the current reconstruction measures for a power increase (5 → 10 MW) and for the operation of a modern Cold Source, so that conversion will probably take place not before 1990.

3. NATIONALLY AND INTERNATIONALLY COORDINATED TERMINATION OF THE RERTR ACTIVITIES

The German AF-Program has been oriented from the very beginning towards close international cooperation. Prior to the final defination of the program goals and of the procedure for reaching these goals, German representatives were already engaged in various INFCE and IAEA working groups so that the program was optimally oriented to internationally recognized requirements. Especially the recommendations and criteria evolved by INFCE (Working Group 8c) to reduce the poliferation risk for research reactors became a basis for the program. Moreover, the objectives and procedure were coordinated with representatives of the American RERTR program, before the AF-Program was officially launched, and close cooperation was agreed upon from the very beginning. If, therefore, coordination with international partners played a significant role when the program was initiated, this should definitely also be the case upon termination of the program after more than eight years of successful international cooperation.

The following will give a brief description of the views prevailing in Germany and of the procedure for terminating the AF-Program, and thoughts will be presented concerning an internationally coordinated approach at terminating all the activities currently still under way. As to the latter point, it is intended to utilize this year's RERTR meeting to get acquainted with the attitudes and intentions of the international RERTR partners and start discussing the further joint procedure.

3.1 Views in Germany

Considering the results obtained under the AF-Program and also from international activities and looking at the work under way and still to be carried out in the future, there appears to be no need at present to continue RERTR activities beyond the end of the eighties within the scope of a program supported by the German Federal Government.

Essential reasons are:

- It may be assumed that all candidate fuels for the LEU operation of research reactors have been examined in the past and that completely novel and promising fuels still unknown today do not exist.
- The fabrication technology for the uranium fuels to be used for LEU operation is either already available (UAl_x, U_3O_8) or the studies for establishing this technology have reached the final stage (U_3Si_2).
- After the very extensive qualification of fuels by test irradiations with plates and fuel elements and by post-examinations, including work under way, there appears to be no need for any further qualification testing in Germany.
- The conversion studies under the AF-Program have entered a stage where only plant-specific and regulatory issues have to be dealt with. These studies accompanying the licensing procedure are supported under the AF-Program insofar as they are of a "standard nature". Activities in this field extending beyond 1988 are largely a concern of the research reactor operator and do not require any special national program.
- Only in exceptional cases the Federal Ministry for Research and Technology will support scientific/technical development programs of the present type for a period exceeding five years. The extension of the program period to a total of 10 years brought about by the program updating described in Section 2. should be regarded as the upper limit which can hardly be exceeded any more.

The above reasons for terminating the AF-Program are to be discussed (see also Section 3.3) with the international RERTR partners. In the event of any areas being identified for which a continuation of certain activities beyond the end of the eighties is required, the present partners to the German AF-Program will certainly be available for further international cooperation when needed.

It will have to be examined very closely, however, whether this would require another extension of the program period.

3.2 Planned Procedure for Terminating the AF-Program

As pointed out in Section 2., seven of the 15 major tasks of the AF-Program are still being operated at present. As in the case of those already completed, the responsible AF-Program partner has to prepare a final report upon completion of these tasks. This report comprises the regularly submitted semi-annual reports, a summary of the activities and results with a target/performance comparison concerning the project goals as well as the cost and time required. As far as applicable, recommendations are also made which, in the past, primarily referred to a continuation of work found to be necessary in other (newly adopted) tasks of the program. In the present phase of program termination, the partners responsible for the projects are expected to make recommendations concerning e. g. specific limits of fabrication and use (such as maximum volumetric loading in the fuel and thus uranium density or upper limit for average and local burn-up). In addition, however, any activities should also be referred to which are meaningful and desirable from the specialists' point of view to support the work so far performed. The final reports shall be submitted within the quarter following project termination.

An overall final report will be eventually prepared for the AF-Program corresponding to those for the individual tasks as far as the form and the contents are concerned to be submitted within the first six months after termination of the program. It is also intended to prepare an English-language version serving the purposes of information and especially also further coordination with the international RERTR programs.

3.3 Thoughts Concerning an Internationally Coordinated Termination of the RERTR Programs

As already mentioned at the beginning of this section, the Federal Republic of Germany is by no means considering an independent attempt at termination, an analogous to the launching and later updating of the program. The Federal Government rather considers it necessary not only to coordinate at a very early

stage the procedure for terminating German activities, but also to reach agreement with all major partners in the other RERTR programs about the termination of the international programs. To this end, a special advisory group could be set up at the IAEA to which one representative each of the national RERTR programs would be delegated. The essential task of the advisory group should be to coordinate the procedure for terminating the RERTR programs, to determine the activities still required in completion of individual work, to clarify and define the possibilities of handling such activities and finally to prepare a synoptic report in the end phase.

This report could be largely compiled on the basis of the national final reports. A summary of the results obtained and a target/performance comparison should be included by analogy to the national final reports. Of course, this report should also contain special recommendations e. g. for operators whose HEU-LEU conversion is still to be implemented. The IAEA advisory group should be assisted by special expert groups in the following fields:

1. fuels and LEU fabrication technology
2. fuel qualification
3. reactor conversions
4. safety and licensing issues

Moreover, this group of experts should commence work at a very early stage (in 1988) so that the results derived by them and especially recommendations for the IAEA advisory group will be available, if possible, as early as late 1989.

It may be expected that another 1 - 2 international RERTR conferences will have to be held even after termination of the RERTR programs.

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AF – PROGRAM

Schedule

(status 09.1987)

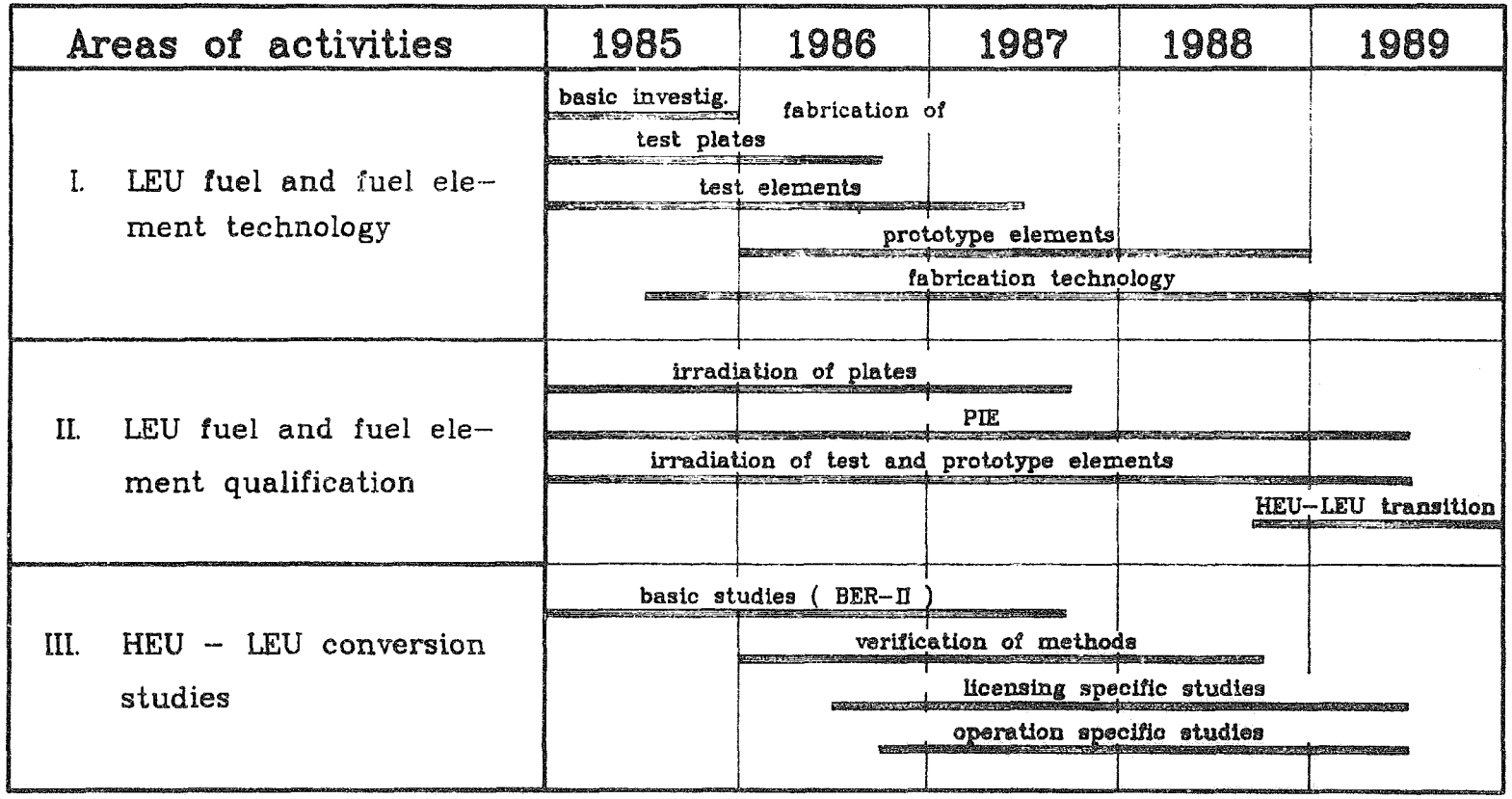

Fig. 1