CENTRO DE DESENVOLVIMENTO DA TECNOLOGIA NUCLEAR

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assunto: RELATÓRIO ANUAL DO PROGRAMA DE UTILIZAÇÃO DO TÓRIO EM PWR - 1988	programa: UTILIZAÇÃO DO TÓRIO EM PWR	
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resumo:

Durante o ano as atividades do programa se orientaram para o encerramento ordenado do mesmo, o que se deu formalmente em 30.06.1988, conforme decisão do Comitê de Coordenação, em sua 9ª (e última) Reunião, realizada no CDTN, em 10.08.88, com a presença dos membros alemães do Comitê, Dr.P.Engelmann (do KFA Jülich) e Dr.H.Märkl (da Siemens/Divisão KWU).

As atividades técnicas do CDTN no período se restrigiram à conclusão:

- da avaliação dos testes de irradiação de varetas de $(Th,U)O_2$ realizada no reator de testes FRJ-2 (KFA),
- do programa de demonstração da tecnologia de obtenção de pastilhas de $(Th,U)O_2$, incluindo a elaboração de procedimentos, e
- da análise neutrônica de acidente postulado de ruptura de tubulação de vapor em PWR de 1300 MWe com núcleo Th/Pu.

Realizou-se, no CDTN, a 14ª (e última) Reunião de Gerência do programa, nos dias 8-14.04.1988, com a presença dos representantes do KFA Jülich (Dr.V.Maly) e da Siemens/Divisão KWU (Dr.M.Peehs), este também representando a NUKEM (Dr.M.Hrovat não pôde comparecer por motivo de saúde). Esta reunião marcou o encerramento das atividades técnicas do CDTN no âmbito do programa.

Em adição às atividades técnicas foi dada especial ênfase à documentação adequada dos trabalhos realizados no período 1979/88, isto é, durante toda a duração do programa, através da elaboração do Relatório Final do programa, em duas versões, uma para divulgação e outra - completa-, de difusão restrita.

É apresentado, no Anexo, o "Resumo Executivo" do Relatório Final. O Relatório Final para divulgação está sendo impresso no KFA-Jülich e o Relatório Final completo, de difusão restrita, será impresso na Siemens/Divisão KWU.

AGRADECIMENTO:

O Gerente brasileiro do programa deixa, aqui, registrado seu agradecimento ao empenho de todos os companheiros do CDTN que contribuiram decisivamente para o sucesso alcançado pelo "Programa de P&D sobre a Utilização do Tório em PWR", assim como aos companheiros alemães do KFA Jülich, da NUKEM e da Siemens/Divisão KWU. A convivência com todos que participaram do programa, nestes quase 10 anos de trabalho conjunto e cooperativo, será certamente inesquecível. Ao contrário, espero que sejam esquecidas pelos companheiros as falhas do Gerente, em particular os ocasionais "estouros".

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ANEXO

RESUMO EXECUTIVO DO RELATÓRIO FINAL

0. EXECUTIVE SUMMARY

0.1. Introduction

The cooperative R & D Program on "Thorium Utilization in Pressurized Water Reactors" was carried out by NUCLEBRAS/CDTN on the Brazilian side and KFA-Juelich with the participating companies Siemens UB KWU and NUKEM on the German side. It was directed towards the improvement of knowledge in this field and actually aimed at fulfilling the "Governmental Agreement on Cooperation in the Field of Science and Technology" from 1969 and the "Memorandum of Understanding between KFA and NUCLEBRAS" from 1978.

The program was motivated by the fact, determined in numerous R & D activities, including those in Brazil and Germany, that thorium fuels can improve the resource utilization in thermal reactors and may supplement conventional uranium-based fuels. The thorium cycle technology was, however, not so mature as to permit well-founded feasibility statements in this area.

The original objectives of the program running since mid 1979 were

a) to analyze and prove thorium utilization in pressurized water reactors;

b) to design PWR fuel elements and core for the Th-fuel cycle;

c) to manufacture, test and qualify Th/U and Th/Pu fuel elements under operating conditions;

d) to study the spent fuel treatment and to close the thorium fuel cycle by reprocessing spent Th-containing PWR fuel assemblies.

The transfer of R & D methodology for the PWR fuel cycle presented the other main objective of the program.

The program was directed by the Coordinating Committee (CCM) consisting of two representatives from each participating country. The program managers, who met once or twice a year, jointly formulated the working program and supervised the progress. Task managers were assigned by each participating organization and shared the technical responsibility.

The program was planned to run in three phases. In the program phase 1 (1979 through 1983) the technological basis for further work on (Th,U)O2 fuel for PWR was established and the feasibility of the chosen fuel cycle concept was proven in principle.

In the Phase 2 the main objectives were the demonstration of the feasibility of PWR (Th,U)O2 fuel, nuclear core design and initiation of the development of (Th,Pu)O2 fuel and improving knowledge on spent fuel treatment. The demonstration of the (Th,Pu)O2 fuel was intended to follow in Phase 3.

In the course of time, the objectives and scope of the program were adapted to the actual needs in the contributing countries. The effort was concentrated more on the development of the fuel fabrication, its qualification and testing as well as on the transfer of R & D know-how in this area. The activity related to the spent fuel treatment was reduced, in particular when the advantageous features of the once-through Pu/Th fuel cycle with high burnup were confirmed.

Phase 2 of the program was focussed on the intended irradiation of a pathfinder fuel assembly in a Brazilian power reactor. It was also recognized that the major benefits in the Th-PWR application result from the Th/Pu fuel. Since Brazil decided not to reprocess spent PWR fuel, the most beneficial Th application was no longer a short term issue. Thus due to a Brazilian priority decision the partners agreed to terminate the program at a pre-determined decision point in the middle of Phase 2.

0.2. Technical Results

Nuclear core design and strategy

The program covered major portions of the PWR fuel cycle including the relevant parts of nuclear core design. The Siemens standard 1,300 MWe-PWR was used as the reference reactor, also providing a good basis for the know-how transfer. First, Siemens' standard nuclear core design codes were adapted for the use of thorium and validated. The results of nuclear core design show that the present design Siemens-type PWR can accomodate Th-based fuels without any changes or restrictions in the fuel assembly or core design. Operation of the reactor in three and four batches was investigated in open and closed fuel cycles. Moreover, partial core load with Th-fuel and successive switch over from U to Th fuel is also practicable. Beside the determination of optimum shuffling patterns, basic three-dimensional safety

calculations also show sufficient safety margins. Th/Pu based fuels show a possibility of extending the burnup even beyond the 4-year cycle operation.

In the strategy field beside the code development, the accompanying studies of thorium cycle potential have also provided insight into the possible introduction of Th-fuels in the long-term reactor strategy in Brazil.

Fuel technology

The merging of the standard LWR pelletizing process with the chemical ex-gel process developed for the HTR fuel was successfull. The combination of a chemical ex-gel conversion process resulting in calcined unsintered (Th,U)O2 kernels, with a mean diameter of about 0.2 mm, with standard pelletizing techniques using a somewhat adapted compaction pressure, provided (Th,U)O2 fuel pellets with adequate homogeneity, microstructure and geometrical shape, satisfying the usual PWR specifications. These pellets have been reproducibly manufactured in Germany and Brazil in kg charges and the results confirmed in a round robin test. In most steps of the production process standard equipment could be used. Thus, no major difficulties are expected for scale-up from pilot scale to production capacity.

The transfer of knowledge to the (Th,Pu)O2 fuel production was performed on a laboratory scale using cerium as a substitute for plutonium. The dust-free ex-gel fabrication process is particularly attractive for this application. Results on a laboratory-scale investigation indicate that the master-mix fuel concept can also be realized.

Fuel design and modelling

Data and models for the thermal and mechanical fuel rod design were derived from theoretical considerations and experimental results for the newly developed oxidic Th-fuels for use in standard PWR fuel design. Design values were successfully verified by predicting the fuel behaviour in irradiation experiments performed in the FRJ-2 reactor at KFA, Juelich. Good agreement between predicted and measured values was reached. On this basis the design of a test fuel assembly for the Angra-1 reactor was prepared including the licensing report for the experimental fuel.

Irradiation testing

The irradiation testing of the newly developed fuel was performed in FRJ-2 reactor up to 10 MWd/kgHM under conditions covering the loads of a PWR. The ex-gel (Th,U)O2 fuel behaviour satisfied the requirements. Extensive post-irradiation examination and evaluation of the series of experiments provided a comprehensive data base for further development effort and substantially improved knowledge on in-pile fuel behaviour.

On the basis of these experiments an irradiation program up to four cycles for four segmented rods and one full scale rod with burnups up to 45 MWd/kgHM was prepared on the basis of a pathfinder fuel assembly approach for a commercial power reactor including the preparation of the licensing documents.

Spent fuel treatment

Computer calculations based on newly developed methods were performed in order to indentify differences between Th and U based fuels in storage performance. The intermediate and direct final storage does not present additional problems in comparison with the standard UO2 fuel.

Laboratory investigations on reprocessing spent thoria fuel were focussed mainly on work with unirradiated fuel. To a limited extent hot laboratory work on dissolution was performed. The application of presently known reprocessing techniques for thoria fuels to the fuels developed in this program seems possible.

0.3. Program Evaluation

R & D progress

The results of the program confirm in detail that the newly developed thoria based fuels can be used in present PWRs of KWU design. No changes in the fuel assembly and in the core design are needed. This holds both for (Th,U)O2 and (Th,Pu)O2 fuels in 3 and 4 batch operation. The latter fuel shows high burnup potential beyond the four-cycle scheme. In this case the inserted fissile Pu is strongly depleted and the once-through put-away cycle becomes very attractive.

The fuel manufacturing was developed on a pilot scale for kg-amounts of (Th,U)O2 using adequate spin-off from fully established HTR and LWR fuel manufacturing. Due to the understanding of the key process parameters and using mostly standard equipment, full-scale production seems feasible after a short development period.

The status of the (Th,U)O2 fuel testing and modelling permits a design of pathfinder fuel test which can be subjected to licensing. This would be a necessary step before insertion of (Th,U)O2 fuel on a large scale.

As far as the technology development and transfer for the Th/U fuel are concerned, the program objectives were accomplished.

However, large scale demonstration of Th/U fuel in a power reactor, fabrication and qualification of Th/Pu fuel as well as closing the fuel cycle would require substantially more effort than presently desirable.

For (Th,Pu)O2 fuel a basic knowledge considering the requirements for the transfer from the (Th,U)O2 fuel fabrication technology was developed. The assessment of the back end of the fuel cycle shows that Zircaloy-4 clad PWR fuel can be handled in the storage regardless of the specific ceramic fuel included.

Cooperation and technology transfer

The contents of the final report and numerous joint publications and reports confirm that successful cooperation and technology transfer took place in the course of this program.

In the first phase of the program the build up of the research capacity in the nuclear fuel technology area at NUCLEBRAS/CDTN resulted in steadily increasing Brazilian participation in the R & D effort. In the second program phase each partner's contribution consisted in delivering his share of the work package in a balanced way.

The technology transfer is documented in the technical part of the report. This transfer was enhanced by the fact that in most areas techniques used for a standard UO2-fuelled PWR had to be modified thus requiring an active understanding and assimilation of the R & D know-how.

So far as the nuclear core design and the technology development and transfer for the Th/Pu fuel is concerned, the original program objectives were accomplished.

Conclusions

The utilization of thorium in PWRs presents a long term option providing in some respects interesting results. The most attractive application for Th-based fuels at present is the use of recycle plutonium in extended burnup once-through fuel cycle.

From the point of viw of cooperation and technology transfer, the program experience shows the importance of using hardware oriented goals, clear definitions of required outputs and sufficient communication including joint work on interacting tasks.