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TECHNOLOGY TRANSFER WITHIN THE KFA/NUCLEBRÁS COOPERATIVE PROGRAM "THORIUM UTILIZATION IN PWRs"

NUCLEBRÁS/CDTN - 524/86 Março 1986

CENTRO DE DESENVOLVIMENTO DA TECNOLOGIA NUCLEAR

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TECHNOLOGY TRANSFER WITHIN THE KFA/NUCLEBRÁS COOPERATIVE PROGRAM "THORIUM UTILIZATION IN PWRs"

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1. Introduction

It is a general trend in the area of advanced technologies that beside the transfer of the technology itself also the transfer of know-how for related R&D work is required and attempted. This provides the accepting country with deeper understanding of the transferred technology, enables active participation in adoptions to the specific conditions of this country and provides possibilities for further independent activities in this area.

The cooperative R&D program on "Thorium Utilization in Pressurized Water Reactors" between NUCLEBRAS/CDTN on the Brazilian side and KFA-Jülich with the participation of the companies KWU and NUKEM on the German side aims at improvement of the knowledge on this subject and contributes to fullfill in practice 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 has been motivated by the fact known from numerous R&D activities, among others in Brazil and Germany, that thorium based fuels can provide better resource utilization in thermal reactors compared with the conventional uranium based fuels. The thorium fuel cycle technology is, however, not so mature as to permit well based feasibility statements in this area. By using the standard PWR as a reference plant an efficient way has been chosen for demonstration of the technological feasibility by concentration on the problems specific for the thorium fuel cycle, providing also a way for assimilation of the LWR-fuel cycle know- how. At the same time, the potential of the standard PWR with respect to the advanced fuel cycles is being investigated for this particular case.

2. Program Results

In the program Phase 1 (1979 through 1983) the technological basis for further work on $(Th,U)O_2$ fuel has been established and the principal feasibility of the chosen fuel cycle concept has been proven.

In the current Phase 2 the main objectives are the demonstration of the $(Th,U)O_2$ fuel, initiation of the development of $(Th,Pu)O_2$ fuel and extension of the status of the knowledge in spent fuel treatment. The demonstration of the $(Th,Pu)O_2$ fuel should follow in Phase 3.

The results achieved up to now show that $(Th,U)O_2$ and $(Th,Pu)O_2$ fuel can be inserted in unchanged fuel assemblies in a standard PWR in both 3 and 4 years cycle (Fig. 1, 2). The advanced fuel fabrication process based on pellet pressing of kernels of ex-gel origin provides $(Th,U)O_2$ fuel satisfying PWR specifications. This fuel, under irradiation testing since end of 1983, shows good irradiation performance in a good agreement with the model predictions (Fig. 3, 4). Transfer of $(Th,U)O_2$ fuel fabrication technology to $(Th,Pu)O_2$ fuel by means of Cerium as a Pu-substitute has been initiated. No basic problems have been identified up to now. In the area of reprocessing the results on laboratory scale show that PWR thorium fuel can be reprocessed using the known flow sheets.
The detailed results of this common effort have been jointly published in scientific meetings as well as in form of reports.

3. Cooperation and Technology Transfer Aspects

The transfer of R&D techniques presents the other main objective of the program. The three program phases aim not only at different levels of R&D effort as mentioned above but also at different levels of cooperation and know-how transfer (Fig. 5). In the initial phase the major flow of know-how has been directed from Germany to Brazil mostly in connection with long term Brazilian delegations to Germany. With the upgrading of the CDTN/NUCLEBRAS laboratories, implementation of computer programs and production and quality assurance techniques the share of new development by CDTN has been [illegible] increasing. The communication of the working results has been done by close person to person contacts, exchange of the reports and by short term delegations, as well as by direct participation of R & D personnel on the activities within other partner's departments. In the present program phase an equillibrized participation on novel R & D is attempted whereas in the following phase far-reaching independency of NUCLEBRAS/CDTN complemented by close cooperation on special problems is envisaged.

An example of such a joint activity in fuel development area is presented in Fig. 6. In order to investigate the stability of the production process simultaneous fabrication of the ex-gel-kernels by NUCLEBRAS and NUKEM and pellet pressing at NUCLEBRAS, KWU and NUKEM were performed. At the same time, by extensive comparison of analytical methods and characterization procedures the quality control scheme will be verified.

The program has a joint management. Mutually agreed interacting working programs and common progress reports strengthen the cooperative character.
The program covers a wide spectrum of activities including the nuclear core design, fuel design and fabrication, irradiation testing and spent fuel treatment. External institutions are involved if needed. Therefore, extensive excercise of R & D management of a complex program can be considered as another benefit from this cooperation.

The program performance up to now has been judged to be positive. The major factors which contributed to this judgment are presented in the following Fig.7.

The program has been oriented towards the standard commercial PWR system. Therefore, the involvement of the German industrial participants KWU in all program areas and NUKEM in the fuel development area has been essential because of their know-how potential, R & D experience and strictly problem oriented treatment of the tasks.

The assimilation of the LWR fuel cycle technology has been strongly enhanced by the fact that the R & D activity for an advanced type of the fuel had to satisfy the well known requirements of an existing reactor system. The necessary modifications and adaptions in the standard methods such as computer programs including the input data, production process steps as well as the quality control require their deep understanding. All these modifications are checked again for the application to the standard PWR.

The motivation of the R & D personnel has been strongly increased by the challenge of the novel activities, differing in some respect strongly from the previously known ones. Some problems, particularly in the fuel development area, were not to be solved easily. As a consequence, the typical R & D sequence of trying, finding of basic solutions and optimizing has been extensively excercised.

The definition of so called master goals, preferably hardware ones, linked to as many program areas as possible, contributed to coordinating of the work and performance measurement. As an example of such a goal should be mentioned the "start of irradiation of short rods with $(Th,U)O_2$ fuel satisfying PWR specifications". Here, practically all departments had to contribute and the performance was easily measurable by the standards or specifications.

The creating and support of direct, partly informal, links between technical personnel of all partners working on one subject contributed to a timely and extensive information exchange. The positive role of working visits should be stressed here.

The close cooperation has lead to the detailed recognition and understanding of the capabilities of the other partners including internal interdependencies and regulations. This helped substantially what the management aspects and the performance of the work are concerned (Fig. 8).

4. Conclusion

The results of the cooperative R & D program "Th-Utilization in PWRs" performed by KFA and NUCLEBRAS under participation of KWU and NUKEM show that thorium based fuel can be inserted in unmodified fuel assemblies into standard PWR of KWU design. Successfull transfer of technology in the area of R & D on nuclear fuel cycle from Germany to Brazil presents another benefit of this joint effort.

0.80 5	1.08 2	0.88 3	1.17 2	0.94 4	0.99 3	0.97 3	0.91 1
	1.00 3	1.00 3	0.96 3	1.24 2	0.91 4	0.99 3	0.90 1
		0.94 4	1.25 2	1.01 4	1.23 2	1.00 3	0.87 1
			1.12 3	1.22 2	0.92 3	1.06 2	0.68 1
				0.89 4	1.01 3	0.99 1	
					1.21 1	0.73 1	

0.80	AVERAGE POWER IN FA
5	IRRADIATION PERIOD

Fig. 1: Power distribution at beginning of cycle
Th/HEU-core, 4 batch once-through equilibrium

1.12	1.37	1.01	0.90	0.78	0.96	1.00	0.94
5	2	4	3	4	3	4	1
	1.33	1.16	0.89	0.79	0.91	1.34	0.97
	2	2	3	4	4	1	1
		0.98	0.91	0.79	0.97	1.22	0.91
		3	3	4	4	2	1
			0.81	1.02	1.15	1.10	0.67
			4	3	3	2	1
				1.17	1.31	0.92	
				3	2	2	
					1.26	0.71	
					1	1	

1.12	AVERAGE POWER IN FA
5	IRRADIATION PERIOD

Fig. 2: Power distribution at beginning of cycle
Th/Pu core, 4 batch once-through equilibrium

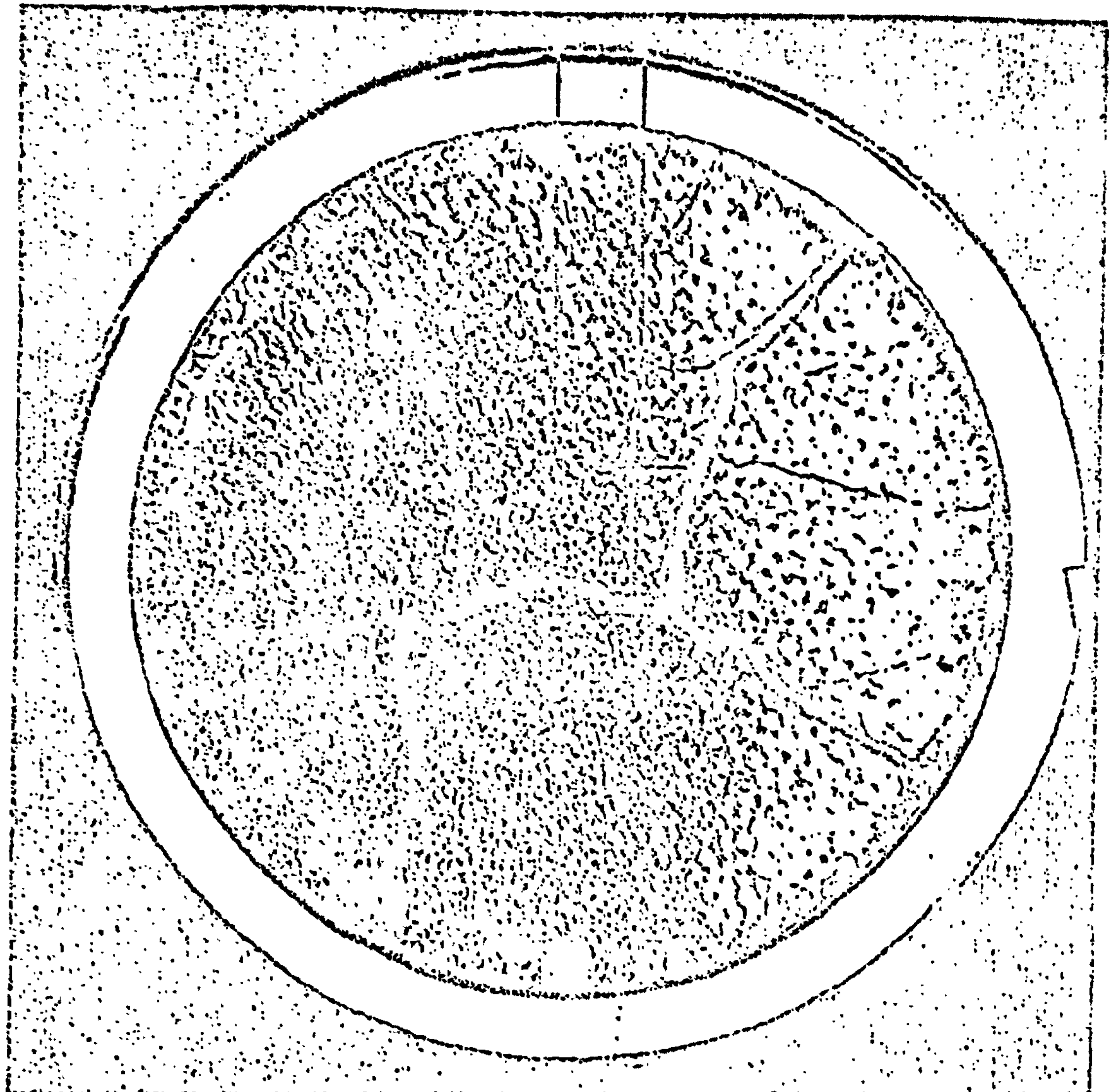

Fig. 3: $(Th,U)O_2$ fuel pellet irradiated up to 10 MWd/kg_{HM}

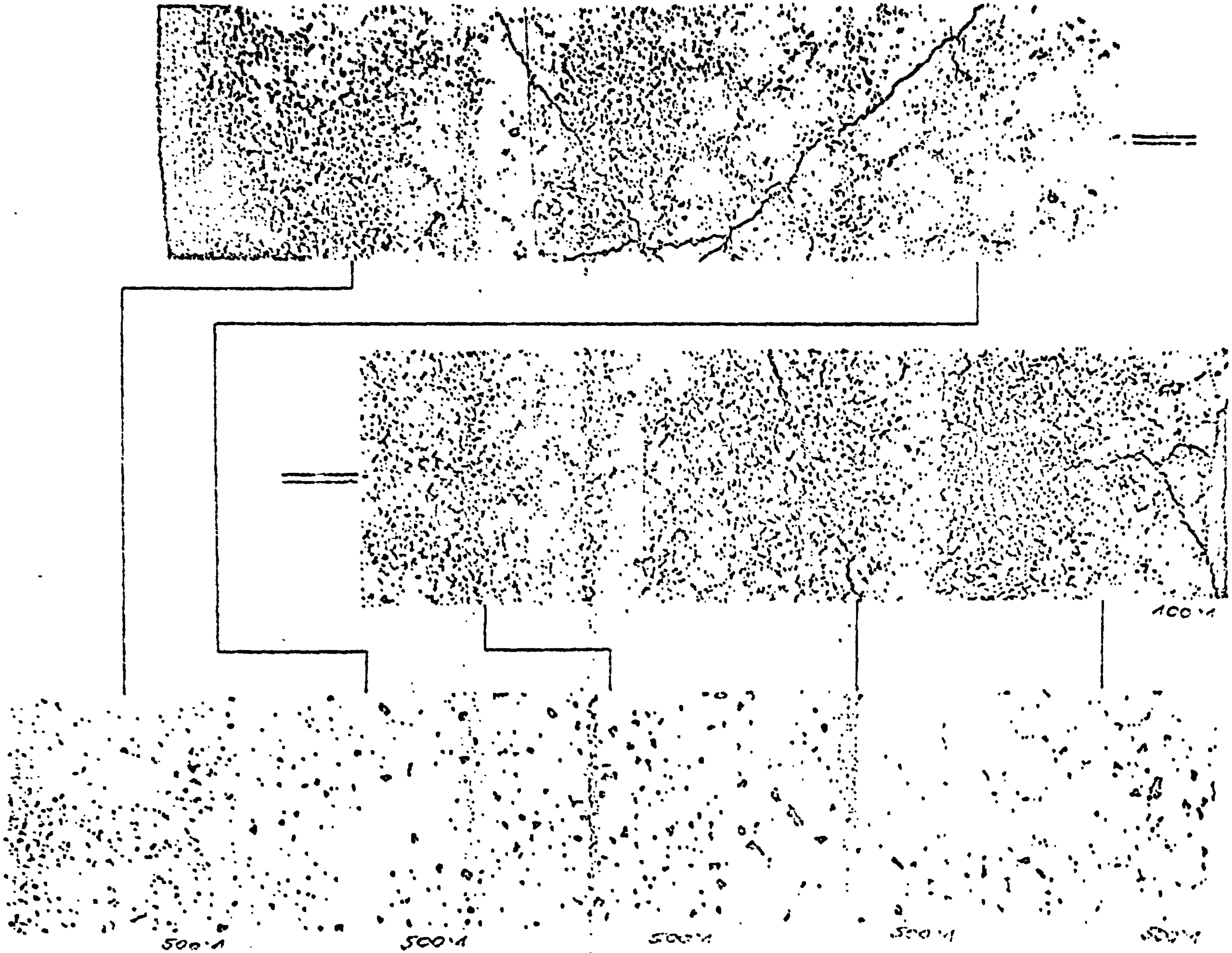

Fig. 4: Magnifications of the pellet cross-section

Phase 1	Phase 2	Phase 3
1979 - 1983	1984 - 1989?	beyond 1989
Feasibility	Optimization	Demonstration
Equalizing of R&D status	Complementary R & D	common R & D on special problems
know-how from Germany to Brazil	know-how both ways	know-how both ways

Fig. 5: Program Phases

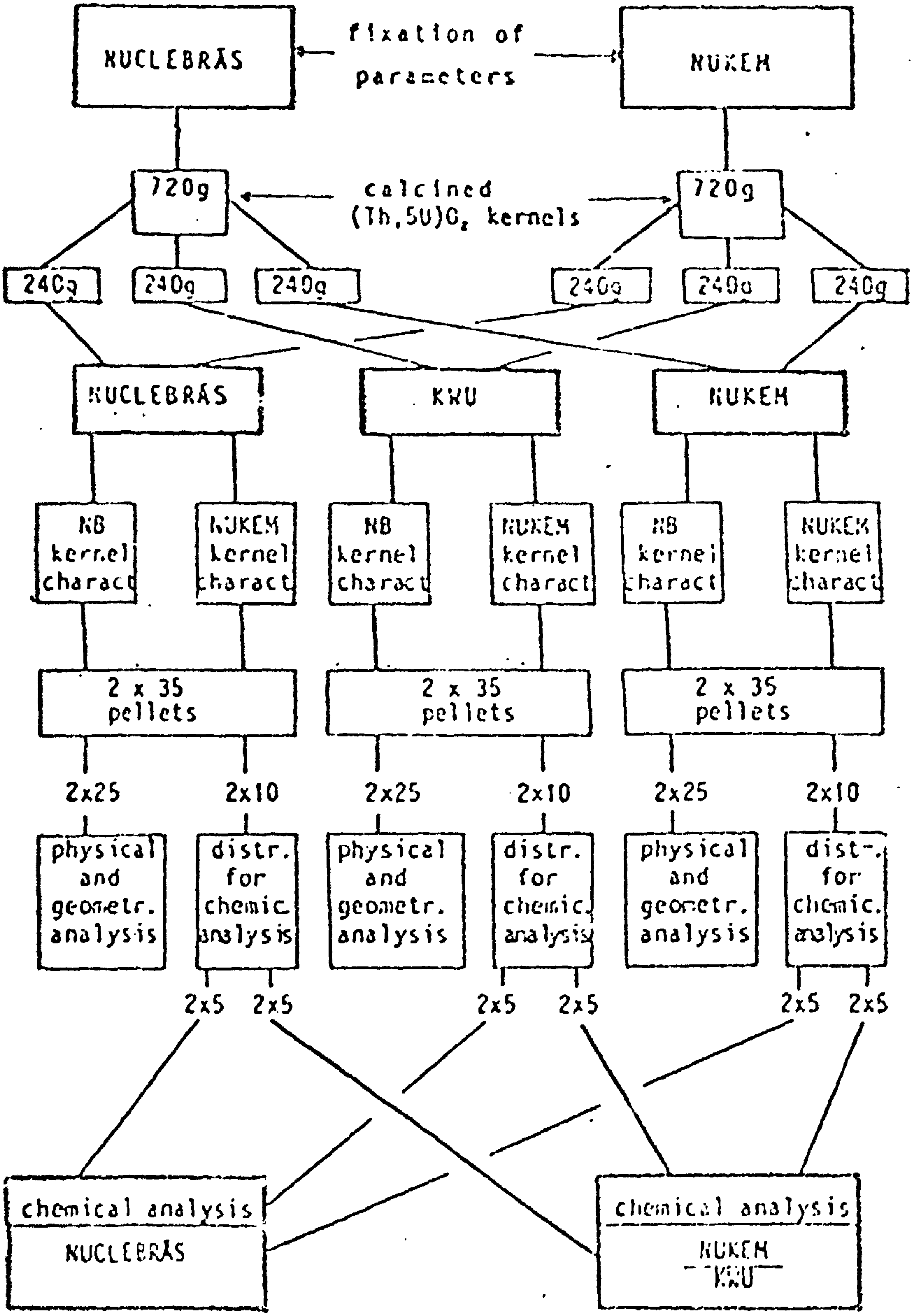

Fig. 6: Round Robin Test

- joint program steering and management including interacting working programs
- clear formulation of goals oriented on the requirements of a standard PWR-system
- intensification of know-how transfer by modifying standard procedures and programs
- motivation of personnel by novel research activities competing with known ones
- enhancing of the cooperation and integration of program effort by introducing hardware oriented master goals
- flexible means for information exchange

Fig. 7: Major factors for program success

- intensive and verifiable know-how transfer
- detailed recognition of the capabilities of other program partners
- creation of durable contacts between the participating personnel

Fig. 8:

Program benefits from standpoint of technology transfer