RESULTS OF THE GERMAN ALTERNATIVE FUEL CYCLE EVALUATION AND FURTHER EFFORTS GEARED TOWARD DEMONSTRATION OF DIRECT DISPOSAL

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ABSTRACT

In a comparative study initiated by the German Federal Ministry for Research and Technology which was carried out by Karlsruhe Nuclear Research Center in the period from 1981 to 1985, direct disposal of spent fuel was contrasted to the traditional fuel cycle with reprocessing and recycle. The results of the study did not exhibit decisive advantages of direct disposal over fuel reprocessing. Due to this face and legal requirements of the German Atomic Energy Act, the cabinet concluded to continue to adhere to fuel reprocessing as the preferred version of "Entsorgung". But the door was left ajar for the direct disposal alternative that, under present atomic law, is permissible for fuel for which reprocessing is neither technically feasible nor economically justified. An ambitious program has been launched in the Federal Republic of Germany (FRG), geared to bring direct disposal to a point of technical maturity.

BACKGROUND

The way Germany is dealing with the nuclear fuel cycle and waste management can be characterized briefly by two prominent facts: the commitment to closing the nuclear fuel cycle through fuel reprocessing and, secondly, the ongoing geologic investigation of the Gorleben salt dome which represents one of the most advanced projects in the world to establish a repository for high-level waste from the commercial nuclear program. All steps at the back end of the nuclear fuel cycle are referred to as "Entsorgung" in German and this term will be used henceforth in this presentation. To illustrate how direct disposal became the supplementary way of Entsorgung, one has to go back to the end of the 1970s.

In May 1979, the project of a 1,400 MT/yr fuel-reprocessing plant had been cancelled for political reasons. In the aftermath of this decision, the heads of both the federal government and the states agreed on a more cautious approach to the entire Entsorgung question: Reprocessing should go forward as a matter of priority but on a smaller scale. At the same time, there was to be a major comparative study of fuel reprocessing and direct geologic disposal of spent fuel, enabling a judgement by 1985 whether or not direct disposal might offer decisive advantages.

RESULTS OF THE COMPARATIVE ASSESSMENT

The comparative assessment of both Entsorgung options was carried out by KfK's Project Group Alternative Entsorgung. It was based upon quantification of the criteria technical feasibility, radiological safety, economics, safeguards, and uranium utilization for which the following results were obtained[1].

Technical Feasibility

In contrast to fuel reprocessing, packaging of spent fuel for direct disposal has not yet been demonstrated. However, most process steps in a conditioning plant such as remote welding of casks and handling of heavy loads are common practice in nuclear technology.

Each Entsorgung alternative requires an underground repository with specific technical features. For both types of repository, the level of technical features. Apart from a test emplacement of spent fuel in the USA which does not seem to be representative, handling and emplacement of high-active packages has not yet been demonstrated on a large scale for either Entsorgung variant. Dry drilling of 0,5-m-diam 300-m-deep boreholes-the reference emplacement concept for vitrified waste in the FRG-is not state-of-the-art yet in salt mining. And the necessity to have this array of boreholes properly aligned-the spacing amounts to about 30 to50 m-might bring about additional technical complexity. On the other hand, the lowering through the transport shaft and the underground handling of heavy loads of 60 Mg and more in connection with direct disposal of spent fuel has not been demonstrated either.

Radiological Safety

With respect to radiological safety, individual as well as collective doses were used as performance criteria for both Entsorgung variants whereby the front end activities and the nuclear power plant were to be included in the evaluation. Individual doses from routine operation to both the work force and the general public were found to be well within the limits as defined by the German radiation protection ordinance. Even for the highest exposed individual in the vicinity of the model reprocessing plant, the dose is below this limit by a wide margin and amounts to about 0.1 mSv/yr (10 mrem/yr).

With respect to long-term safety of both types of repository, neither vitrified HLW nor spent fuel will contribute to dose burdens according to the accident scenario assumed for the post-operational phase of the repository. Due to heat generation, the room closure rate is so high that access to the waste is rendered impossible for the brine. Only in these sections of the repositories where low-level waste is emplaced, interaction between brine and waste is hypothetically possible, leading to maximum individual exposures of about 0.1 mSv in both cases, notwithstanding the higher amounts of plutonium in a spent fuel repository.

Results in terms of collective doses per unit electricity generated can be summarized as follows: If the overall fuel cycles are considered, direct disposal scores better than the fuel cycle based on fuel reprocessing. For the work force the total dose differs by about 15%, for the population by a factor of 2. The collective doses to the general public are composed of small individual doses that are only a minor fraction of the natural background radiation. Although the existence of one radiation source does not provide a basis for the justification of a different source, natural radiation can be used to "give perspective"[2]. Therefore, the difference between both fuel cycles was not judged decisive.

Economics

The economic analysis was based on the two fuel cycles centering around a fuel-reprocessing and a spent fuel conditioning plant, respectively, both with a capacity of 700 Mg/yr and, further, in each case, the repository whose capacity was to last 50 years. All these facilities were assumed to go operational in the year 2000. Transports, fuel supply, and Pu/U-credits were also taken into consideration. The resultant overall total, expressed as levelized unit costs of Entsorgung in deutsche mark (DM) per kilogram of heavy metal (HM) discounted to the year 2000, amounts to DM 1,592/kg HM for the reprocessing version. Totalling DM 1,112 kg HM, direct disposal proves less costly than the reprocessing fuel cycle by a margin of 30%. It has to be pointed out, though, that the reference spent fuel packaging concept was not cost-optimized.

Another economic aspect, uranium requirements in the respective fuel cycles, was quantified for a medium-size German nuclear program with a final capacity of about 50 GW. Annual uranium savings through fuel reprocessing can approach 35% after nuclear capacity has reached a constant level, whereas for growing generating capacities they remain below about 25%. Cumulative savings up to the beginning of the next century are even smaller.

Safeguards

Current safeguards measures are capable of providing effective safeguards for aboveground facilities of both direct disposal and the reprocessing fuel cycle. Safeguards measures consist of material accountancy and physical inventories. Containment and surveillance are used as supplementary measures at sensitive points.

The fissile material content in wastes from the reprocessing fuel cycle is diluted in such a way that recovery can be ruled out. Therefore, wastes from this fuel cycle are likely to meet the criteria for termination of safeguards prior to their disposal, and safeguarding a repository for this type of wastes will prove unnecessary. On the other hand, in the case of spent fuel elements, such termination and a categorization as "waste" is not readily achievable. In addition, there is no clear evidence that spent fuel disposed of in the repository is totally irretrievable.

The conditioning plant and the repository for spent fuel are both a novelty for which no reference facilities exist. It is likely that new safeguards measures will be developed in the near future so that these types of facilities can also be safeguarded effectively. As Canada, Sweden, and the USA are expected to implement direct disposal of spent fuel, an international solution of unresolved issues will be at hand when necessary.

Political Evaluation

There were two major boundary conditions to be taken into account by the federal government when evaluating the findings of the comparative assessment: the German Entsorgung Policy of 1979 quoted in the introductory section defines the scope of the licensing requirements for new nuclear power plants with respect to Entsorgung. In one passage it is clearly spelled out that beginning January 1, 1985, initial operating licenses of new nuclear power plants will be granted only under the stipulation that the site selection process for facilities of either one of the Entsorgung variants has been concluded. Second, in the FRG Atomic Energy Act, the priority of recovery of fissile material over removal of spent fuel is stressed. Therefore, implementation of direct disposal would make mandatory an amendment of the Atomic Energy Act. It is obvious that, based on direct disposal of spent fuel, evidence of ensured Entsorgung could not be given during the period of time required to amend the Act. This would eventually lead to a shutdown of nuclear power plants.

In its decision of January 23, 1985, the federal government felt that it best complied with the legal requirements by adhering to reprocessing and recycle as the preferred version of Entsorgung. The government was vindicated in its decision by the findings of the Entsorgung comparison which did not exhibit decisive advantages of direct disposal over fuel reprocessing.

In its new policy statement, the cabinet also stated that direct disposal was permissible only for fuel for which reprocessing was neither technically feasible nor economically justifiable. By that, the cabinet left the door ajar not only for direct disposal of fuel from the German HTGR-program but also for certain types of LWR fuel: the government said that direct disposal appeared realizable and that work to bring it to a point of technical maturity would continue.

In the second part of my presentation, I will deal with the main efforts geared to demonstrated direct disposal in the FRG.

FRG ACTIVITIES ON SPENT FUEL DISPOSAL

During the direct disposal R&D-program which has lasted from 1981 to 1985 and included the aforementioned comparison, no aspects have been unearthed that would call into question the basic licensibility of direct disposal. However, especially the mining authorities have pointed out that the feasibility of direct disposal is to be demonstrated before a license for industrialscale deployment could be granted. The current planning for a repository in the Gorleben salt dome does not take into account the emplacement of large spent fuel packages with lengths and weights up to about 6 m and 60 Mg, respectively. Even a small number of spent LWR fuel elements intended for direct disposal in the Gorleben salt dome whose sole purpose has always been to accomodate reprocessing waste, could entail major changes in both the aboveground and underground design of the repository. Therefore, in order to cope with all future licensing requirements, the following program will be carried out prior to 1992 so that the schedule requirements for the Gorleben repository can be met. The main thrust of the program will lie with the demonstration and test program that is to be performed mainly in the Asse underground laboratory by KfK and DBE, the German repository company, as well as BGR and GSF.

1) Direct Disposal Demonstration and Test Program: Simulation of shaft transport for service loads up to 80 Mg; construction and test of equipment for transport and handling of heavy canisters in the repository, emplacement of electrically heated heavy canisters and study of the backfill material; handling of small canisters loaded with spent fuel.

2) Experimental Program: leaching of spent fuel; retention of fission gases by backfill material.

3) Systems Analysis "Dual-Purpose-Repository".

The accompanying experimental program is mainly directed to better understanding the complex mechanism of spent fuel leaching in an environment of salt, brine, and iron at elevated temperature and pressure. This will eventually help to model the source term for a postclosure accident scenario.

Systems Analysis "Dual-Purpose Repository"

After the governmental decision of early 1985, DWK, the German fuel cycle company, picked a site in Bavaria and applied for a license to build a two-metric-tons-a-day reprocessing plant and other allied surface facilities. In the meantime, the first partial construction permit has been issued, ensuring completion of the fuel cycle for Germany LWRs by the mid-1990s. But a gap on the order of 200 MT/yr of unreprocessed spent fuel will remain even for a moderate nuclear program of approximately 30 GW generating capacity. DWK is about to prepare documents for a conditioning and encapsulation plant for spent fuel that are going to be submitted to the licensing authority of Lower Saxony in 1986.

Beside the aforementioned demonstration of underground disposal, work to bring direct disposal to technical maturity must include optimization of all aboveground as well a subsurface process steps. Starting-point of such an analysis is a certain mix of spent fuel that is going to be disposed of directly and reprocessed, respectively. A ratio of 200 to 500 Mg of spent fuel was deemed realistic for the second half of the 1990s and will, therefore, be used as a starting-point. Under the boundary condition of one common repository for both reprocessing waste and conditioned spent fuel, an optimized system for direct disposal will be determined by chosing from among a variety of aboveground and underground concepts. These concept variations are generated by varying cooling times prior to disposal, by conceiving different conditioning and canister concepts, and finally by taking into consideration a number of repository design alternatives and emplacement techniques. The set of system parameters with which the optimization is going to be started is compiled in Table I. Further details on possible package design variations are given in Table II. It must be emphasized that the large version of the canister for spent fuel which served as a reference for the Entsorgung comparison will probably differ markedly from the one under development right now: While for former held only three intact LWR fuel elements, there are indications that the newly designed canister will accommodate rods of up to eight LWR fuel elements and the spherical, tennis ball-sized fuel elements from the German HTGR-

TABLE I

Reference System for
Optimization of Direct Disposal

	DISPOSAL PACKAGE	TIME OF EMPLACEMENT[c]	EMPLACEMENT CONCEPT
HLW[a]	200-L-CANISTER	40	300-M BOREHOLES
MLW(Q)[a]	400-L-DRUM	7	300-M BOREHOLES
SF	Ø1.6-M, 5.5-M SFP[b]	30	5MX4M TUNNELS

[a] High-level vitrified waste and heat-generating medium-level waste from reprocessing
[b] Spent fuel package
[c] Years after discharge from LWR

TABLE II

Characteristic Data
of LWR Disposal Packages

	SPENT FUEL PACKAGE LARGE	SPENT FUEL PACKAGE SMALL	HLW PACKAGE
LENGTH (M)	5.5	1.33	1.33
DIAMETER (M)	1.6	0.43	0.43
WEIGHT (MG)	65	1.0	0.5
NUMBER OF FUEL ELEMENTS	3-8	0.5	2.2
HEAT LOAD (KW)[a]	2.5-6.5	0.4	2.0
SURFACE DOSE RATE (MRAD/H)[a]	<200	10^6	10^8
EMPLACEMENT CONCEPT	TUNNEL	BOREHOLE	BOREHOLE

[a] 10 years after discharge from LWR

program. This increase in payload will-among other things-positively affect the economics of spent fuel conditioning. Emplacement of this large package will be exclusively on the floor of emplacement tunnels while, on the other hand, the small version of the spent fuel package which has the same outer dimensions as the package holding vitrified HLW, can also be disposed of in vertical boreholes.

The set of repository alternatives that is subject to optimization will include a combination of tunnel as well as horizontal borehole concepts. Emplacement tunnels and boreholes will be located either in different sectors of the model salt dome or in one common sector. Emplacement of heavy spent fuel packages in tunnels will even be studied for tunnels being arranged at different levels with about 150 m in between. To ensure that certain design limits are observed-e.g., an upper limit of 200°C was assumed as a working hypothesis for the temperature of the surrounding rock salt-conceptual design of the various repository and emplacement concepts will be accompanied by geothermal and thermomechanical calculations.

Analysis of the overall system reaches from spent fuel conditioning, aboveground interim storage and transport to the various disposal concepts. The pros and cons of the system variants will be determined by quantifying the criteria "expenditure until technical maturity", "radiological safety during routine operation", "long-term safety of the repository", and "cost".

The final evaluation will also include the areal requirements of the disposal concepts and aspects of international safeguards. This study if scheduled to be terminated by late 1988 and in-depth analysis of the two most promising systems is foreseen for the two subsequent years.

In a final diagram, Fig. 1, the sequence of analysis steps is described. Based upon the results of the overall analysis, PTB, the Germany company in charge of disposal, will be in a position to include eventual modifications in its design of the Gorleben repository.

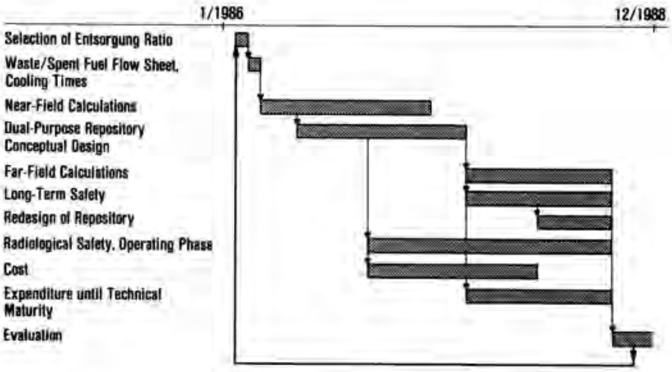

Fig. 1. Systems Analysis Dual-Purpose Repository.

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