

SKB - 20 people
SKI - 8-10
contractors - few
hundred

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Contribution to the NWTRB Full Board Meeting on
Task Force Studies and Performance Assessment

Report from Sweden

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1. Overview of the Swedish nuclear power and waste program

Caveat - This overview is not intended as an overall presentation of the Swedish nuclear power and waste program as would have been appropriate in a publication intended for the international nuclear waste community. I have emphasized features of the Swedish program which may be of particular interest for a US audience in the context of this NWTRB meeting

1.1 Sweden's nuclear power program

There are twelve nuclear power units in the Swedish electric power system. All have light water reactors. Nine are of the BWR type, three are PWRs. Their total net capacity is about 10 000 MWe. They deliver about 50 % of the electric power produced in Sweden. The nuclear plants are located at four sites as shown in fig 1.

The Swedish Parliament decided after a referendum in 1980 - in the wake of the Three Mile Island accident - that no more nuclear power units shall be added to our system and that no nuclear power reactor shall be operated beyond 2010. These decisions determine the total amount of spent fuel rather precisely. No other large scale substitute to nuclear power than fossil fuel plants has, however, emerged since that decision in spite of considerable R&D efforts. It therefore seems prudent to develop a waste management strategy which allows for an increased amount of spent fuel arising over an extended period of time.

In addition to the nuclear power plants we have had research and prototype power reactors and have a nuclear research center at Studsvik. They contribute to the amount of high-level or long-lived radioactive wastes which need to be disposed of but these contributions are by comparison not significant in amount or hazardous character.

1.2 Sweden's nuclear waste program

Studies in Sweden on management and disposal of spent fuel and high-level wastes date back to 1973 when the government commissioned an investigation of these matters by a group of parliamentarians and experts from nuclear research centres, nuclear industry and universities, the AKA-committee. This committee presented its findings in the spring of 1976. What the AKA-committee had seen as a long term R&D-effort got an early upswing when, after a shift in government in the fall of 1976, new legislation involving high level wastes was initiated, the so called Stipulation Act of 1977. This act stipulated that no new nuclear power reactors would be given fuelling permission until the owner could present a method for the handling and safe disposal of the spent fuel or of the reprocessing wastes from this fuel. It was not requested that a site for the disposal was pointed out. The owner must, however, show that such sites with the necessary qualities could be found within the country.

Two nuclear power units were near completion. Delays in their commissioning would have been very expensive. The nuclear utilities formed a task force, the KBS project group, connected with their daughter company SKBF (later renamed with the present acronym SKB). Its task was to describe a disposal system, make a safety assessment and support this assessment with technical and geological data. The KBS group completed this task within one year with the publication of the first KBS report.

This report was sent by the government on a national and international remit for comment and critique. Answers were received from around 50 Swedish and 20 international organizations among them the US National Academy of Sciences. The report was subsequently approved by the government as sufficient evidence that the spent fuel and ensuing high-level wastes could be safely managed and disposed of.

The first KBS report described a complete system for interim storage, transport and disposal of vitrified high-level wastes from reprocessing. Subsequent reports by the same project group, KBS-2

in 1978 and KBS-3 in 1983, deal exclusively with spent fuel as the waste to be disposed of, but at the time of the first report reprocessing was still an option for the Swedish utilities.

The Stipulation Act had consequences which the utilities, in retrospect, should find beneficial.

-They had to take the initiative and have kept it since.

-They had to devise a complete disposal system already at the start of their work with an interim fuel storage, transport facilities and a repository. This gave them the basis for a long ranging strategic plan on how to implement the necessary steps in the management of their spent fuel up to final closure of the waste repositories.

-They got approval of their concept for a repository as one way to reach the goal, a safe disposal system. This gave them a focus and a structure for their subsequent R&D work. They still had to assess alternative disposal methods but they could do this against an established reference, reviewed and accepted by large parts of the scientific community, the nuclear authorities and the government.

-A fee system was implemented to cover the costs of spent fuel management and decommissioning of the nuclear power plants. The fees are earmarked for this purpose and accumulated in a fund at the Bank of Sweden, separate from the government budget. SKB gets its expenses covered from the fund after authorisation by the Swedish Nuclear Power Inspectorate.

-The conceptual disposal system is used for cost estimates by which the fee is calculated. This introduces a measure of economic discipline on SKB's work. The long term total expenditures for the program must balance the long term total receipts of the fund. A requisite for a total budget is, of course, that an upper bound is set on the amount of waste to be managed within the budgeted disposal program.

In addition, the international remit resulted in widespread knowledge about the work done in Sweden and promoted participation in our work by experts from other countries. A noteworthy and for us very valuable example of such joint efforts was the participation from the US already in our first Stripa project.

The infrastructure of facilities for nuclear waste which has been developed within the Swedish program is also illustrated in fig 1. We have a facility for interim storage of spent nuclear fuel, CLAB,

in operation since 1985. This can, after a planned expansion, accommodate all fuel from our nuclear power reactors. We have also a repository for low and intermediate level wastes, SFR, which is in operation since 1988. SFR is sized for all operational wastes from our reactors as well as radioactive wastes from other sources as industry and hospitals. CLAB and SFR are located at two of our nuclear power sites. All sites for nuclear power and nuclear wastes are at the coast of the Baltic Sea which greatly facilitates the transports of spent fuel and other nuclear wastes. SKB has also a purpose-built vessel, the Sigyn, for transports of spent fuel or reactor wastes from the nuclear power plants to CLAB and SFR respectively. This infrastructure allows for flexibility in the development and implementation of the disposal of the spent fuel.

It is self-evident but perhaps noteworthy that the KBS disposal system was initially designed, evaluated and approved without guidance from established standards and regulations for high-level waste disposal. The overriding criterion used in the evaluation was that the individual dose commitment caused by foreseeable leakage from the repository should be well below 0.1 mSv whenever it occurred. It is only recently (1993) that the Nordic authorities on radiation protection have issued criteria for spent fuel disposal. In this work they have had the benefit of experience gained over many years of research work on disposal in Sweden and elsewhere.

1.3 Spent fuel disposal concept

The disposal concept, which can be traced back already to the AKA-report, is illustrated in fig 2 and 3. The repository is designed as a configuration of long drifts and short side corridors excavated at a depth of about 500 meters below ground. Pits are drilled in the floors of the side corridors. The fuel containers are positioned in the pits embedded in clay.

The original design of the containers has recently been modified to the design shown in fig 4. The fuel is placed in a steel pressure vessel surrounded by a mantle of copper for corrosion protection. It is as yet unclear whether there will be any filling material around the fuel inside the steel vessel. The total amount of fuel will be about 7 800 tonnes counted as heavy metal content, if all the reactors are in use until 2010. The number of containers will be about 5 500 each holding 1.4 tonnes of fuel.

The safety principle of the disposal, in Sweden as everywhere, is to isolate the radionuclides from the biosphere by multiple, indepen-

dent barriers - the fuel matrix itself, the fuel container, the backfill and the rock.

An overriding objective for the KBS group in their first task was to get the earliest possible approval of the design of the disposal system. They had little time to collect and analyse data on properties of the bedrock and to assess the complex interactions of radionuclides with the groundwater and the rock. Therefore they designed the repository with a conventional lay out and with as durable disposal containers for the waste as they could devise. In this way they were less dependent on concurrence among experts from various geoscientific disciplines about the performance of our ancient crystalline bedrock as barrier to radionuclide migration.

Considerable efforts have since then been spent on studies of the barrier performance of the bedrock but the case for durable containers is as strong as it ever was. The bedrock contributes to the isolation of the radionuclides from man, but this contribution cannot be substantiated in its full extent since it is in practice impossible to obtain all the necessary data on the relevant properties of the bedrock.

1.4 Responsibility and regulation of spent fuel disposal in Sweden

Swedish legislation states that the owners of nuclear power plants have the responsibility, technically and financially, for the management and disposal of their spent nuclear fuel. The owners have, with the consent of the government, delegated the execution of the R&D work and implementation of the disposal to SKB. The government must, of course, assume the long term responsibility for the integrity of the repository site.

SKB is requested by law to submit its R&D-program every third year for review and comment to an authority designated by the government. The program shall outline all work needed to implement management and disposal of all the spent fuel up to and including sealing of the repositories, and present in more detail the R&D work planned for the nearest six years. In the course of the review the program is sent to a broad sample of concerned organisations, institutions and groups in Sweden with a request for their comments. The reviewing authority presents the results of its deliberations, based on its own expertise and received comments, in a report to the government. The government decides on the program bearing in mind that the decisions should not be in conflict with the interim term responsibility of SKB for the execution of the work. This triennial review started in 1986.

SKB will have to submit an EIS and a PSA for the encapsulation plant as well as for the repository. A preliminary EIS of the operational and post closure stages of disposal shall be submitted already with the application for permission to investigate in detail the prime candidate site for the repository.

The construction, operation and closure of the waste facilities are subject to licensing in analogy with the licensing requirements for nuclear power plants.

2. Swedish Nuclear Fuel and Waste Management Company's (SKB) proposed strategy

In the earlier programs, 1986 and 1989, SKB aimed at a full-sized repository to be built from 2010 onwards with start of disposal from 2020. The disposal would be ongoing up to about 2050 so that no fuel would have to be emplaced in the repository until 40 years had passed since it was irradiated in a reactor. The encapsulation facility would be built and tested between 2010 and 2020 for service from 2020 onwards. The R&D-program was still of a long range character.

SKB had in its third program report in 1992 made a subtle but significant change in the customary title of the report. It used to be called "SKB R&D-Programme" but was now called "SKB RD&D-Programme". R and the first D stand for the usual Research and Development but the last D stands for Demonstration. SKB's program has advanced from mainly generic research and development work to an implementing phase including "demonstration" of their chosen method of disposal. This third program report represents a milestone in the evolution of SKB's work

Following an advice initially given by the earlier National Board for Radioactive Waste and endorsed by the government in its resolution on the 1989 program, SKB has changed its earlier plans and decided to implement the disposal of the spent fuel in steps rather than in an once-and-for-all full scale disposal. SKB has further concluded that the time is ripe for starting the implementation of the first step, a repository in demonstration scale, i.e. 5 to 10 % of the full fuel load. This has far reaching consequences. SKB had to select and get approval for the method of disposal. SKB had to decide on the design of the spent fuel disposal container and the repository and SKB must start the procedure to obtain approval for a repository site.

The government had in its resolution on the 1989 R&D-Programme stated that " one of the premises for further research and development activities should be that a final repository for nuclear waste and spent nuclear fuel shall be able to be put into operation gradually with checkpoints and opportunities for adjustments. In the next R&D-programme under the Act on Nuclear Activities, SKB should explore the possibilities of including a demonstration-scale final repository as a step in the work of designing a final repository."

SKB comments in its RD&D-Programme 92 - "In the planning of the present RD&D programme SKB considered this possibility of building and commissioning the repository in stages. The result is that SKB finds that a demonstration phase has considerable advantages. The present programme thereby calls for completion of the research, development and demonstration work by first building the final repository as a deep repository for demonstration deposition of spent nuclear fuel. When the demonstration deposition has been completed, the results will be evaluated before a decision is made whether or not to expand the facility to accomodate all the waste. This plan also makes it possible to consider whether the deposited waste should be retrieved for alternative treatment. The latter option means that it must be possible to retrieve deposited fuel during the period the facility is being operated for demonstration purposes. The siting process is only affected to a limited extent by whether the planning applies to a deep repository for demonstration deposition or to a complete deep repository. The requirements on background information from SKB in the different phases (pre-investigation, detailed investigation, construction of repository) are essentially the same."

SKB explains in some detail the advantages it has found with a demonstration step in the development of a full scale repository

" The most important reasons for SKB's plan to build a repository for demonstration deposition is that this makes it possible to demonstrate the following, without the necessity of making what are sometimes described and perceived as definite decisions:

- the siting process with all its technical, administrative and political decisions,
- the process and the methods for step-by-step investigation and characterization of the deep repository site,
- system design and construction,
- full-scale encapsulation of spent fuel,

- the handling chain of spent fuel from CLAB to deposition in the repository,
- the operation of a deep repository,
- the licensing of handling, encapsulation and deep disposal, including the assessment of long-term safety,
- (retrievability of the waste packages).

Beyond this it is also possible to study the condition of the barriers a given shorter or longer time after deposition. This is, however, something that preferably can and should be investigated with non-radioactive material in the Äspö Hard Rock Laboratory, which is under construction at Simpevarp approximately 20 km north of Oskarshamn.

The long-term safety of the final repository cannot be demonstrated through field tests. Allowability in this respect must always be based on a technical-scientific assessment of the performance of the repository over a long period of time. However, the background information that is gathered in conjunction with the construction of the deep repository for demonstration deposition allows a safety assessment to be performed based on site-specific 'full-scale' data.

The reason SKB is planning a demonstration deposition is not doubts as to the feasibility and safety of the deep disposal scheme. The plan should be viewed as an expression of an awareness of and respect for the fact that the solution of the nuclear waste problem arrived at by the R&D work needs to be demonstrated concretely to concerned people in society far beyond the circle of experts for confidence-building purposes. It is SKBs opinion that a demonstration deposition of spent nuclear fuel with full freedom of choice for the future is a good way to enlist broad support for the method of disposing of the nuclear waste.

The planned demonstration deposition also means that the present-day generation is deciding for a span of time that roughly corresponds to its own active time, leaving it up to the next generation to make its own decision with as much background information as possible."

In the new strategy is included that an encapsulation plant for the spent fuel will be built adjacent to CLAB for test operation before the year 2010 and for full-scale operation from 2020, that two sites are selected for initial investigations of the bedrock and that one of these sites is selected for detailed investigations before 2000, and that demonstration disposal is started around 2008. The time schedule is shown in fig 5.

3. Comments on the SKB strategy by KASAM and others

The authority responsible for the review of the SKB RD&D-Programme 92 was the Swedish Nuclear Power Inspectorate which solicited comments from other Swedish authorities concerned with SKB's plans and from universities, technical institutes, scientific academies, counties and municipalities hosting nuclear power sites, and private citizen groups. KASAM made an independent review which was submitted directly to the government.

The RD&D-program has two main parts, the demonstration program and the program for supporting R&D. The demonstration part concerns SKB's new strategy which includes a decision on the repository design, the spent fuel container design and the procedure to obtain approval of a repository site. The R&D part includes the program for performance assessment and for supporting research including the Hard Rock (underground) Laboratory, HRL, which is under construction at Äspö near the CLAB interim fuel storage. The HRL is of particular interest as SKB plans to construct a module of the KBS repository there - a side corridor with deposition pits in the floor. This will be used to test the handling, emplacement and initial performance of dummies of the disposal container. HRL is also useful for testing methods for the detailed investigations which will be made at the candidate site for the repository. The demonstration program and the R&D program, especially the HRL program, need to be linked by a well considered time schedule.

The reviewers, of course, addressed both parts of the program. The comments on SKB's new strategy cannot be summarised in isolation from comments on the R&D since an opinion about the strategy is influenced by the reviewer's opinion about the maturity of the supporting research.

Many reviewers observed that the new strategy was not yet well integrated with the R&D work. It had obviously been decided late in the interval between this and the last program. SKB presented their arguments for the demonstration scale disposal but did not describe how this project would interact with the supporting research program e.g. how it would interact with, benefit from, and eventually supersede the HRL. Nor did SKB expound what lessons they foresaw they might learn from the demonstration step except those related to the licensing procedure.

SKB's new strategy to develop the disposal in steps was, nevertheless, approved almost unanimously. This consensus was somewhat

surprising since a phased approach to disposal is a novelty even internationally. It was pointed out that the licensing must be as stringent as for a full sized repository. Some reviewers questioned the term "demonstration". They meant that this first step should be called step one and nothing else since SKB had not indicated any other difference between this step and the next than its size. The majority conclusion among the reviewers was that the demonstration repository would ultimately be sealed as built if lessons learned would only be of minor importance for safety. At the same time it was regarded as important for the credibility of the learning aspect of the demonstration that the repository design allows for retrieval and that retrieval is demonstrated as part of the effort.

Even if favourable to the idea of a stepwise implementation of disposal some critical reviewers expressed distrust about SKB's motives. They believed that SKB had adopted the stepwise approach as a way to allay opposition against their work rather than as a way to learn and at the same time leave options open for the future.

Some concern was expressed about SKB's choice of disposal method. Not that it was necessarily a poor choice but rather that a choice was made at all at this stage. Even if the design formally only aimed at a small scale repository, the general feeling was that the first design would hardly be exchanged for a substantially different design if the experience would come out as reasonably good. Some reviewers wanted more studies of alternatives to the KBS design, in particular studies of disposal in deep boreholes. The logical conclusion of an approval of a stepwise approach and concern about the method to be used in the first step is, of course, a recommendation not to rush the demonstration step. That was also the conclusion reached by some reviewers.

Another disputed decision by SKB was the new container design. In the earlier design molten lead was poured into the cylindrical container to fill the void around the fuel assemblies. The long slender fuel pins with their thin cannings would then be exposed to hot molten lead. It was felt that this increased the risk for mishaps in the production and ensuing dispersal of radioactivity. The lead filling has on the other hand the acknowledged merit that it will delay substantially the leakage of radionuclides out of the container in case the copper mantle were to be penetrated by water. This dilemma of potential risks for the workers in the encapsulation facility and for man in a distant future was commented. SKB was urged by several reviewers, among them the Swedish Radiation Protection Institute and KASAM, to give as much attention to the

performance assessment of the pre-closure as the post-closure period.

4. Excerpts from the government decision on SKB RD&D-Programme 92

The government in its decision on the SKB RD&D Programme 92

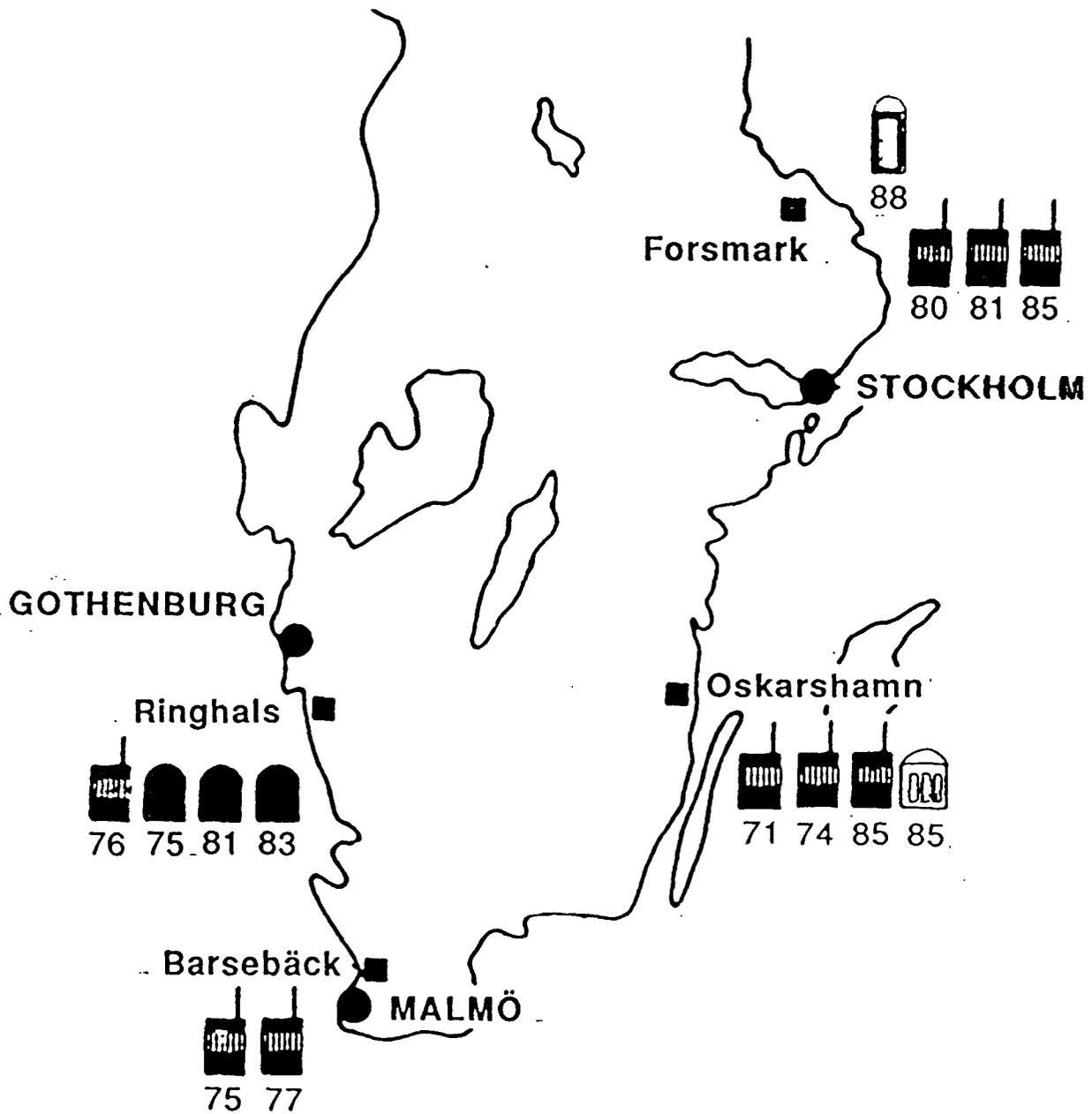
- shared the opinion expressed by the Swedish Nuclear Power Inspectorate and KASAM that the phased approach to a full disposal that SKB had described has considerable advantages even if the long term properties of the repository cannot be demonstrated,
- emphasized that SKB should not commit itself to any specific management and disposal method until a thorough and coherent safety and radiation protection analysis had been presented, even if the KBS 3-concept would be a reasonable choice for demonstration deposition.

The government decided that SKB shall complement RD&D-Programme 92 with

- accounts of the criteria and methods on which a selection of sites for disposal can be based,
- a schedule for presentation of design specifications for the encapsulation facility and the repository,
- a schedule for presentation of the performance and safety analyses that SKB prepares,
- an analysis of how different measures and decisions taken by SKB influence later decisions in the disposal program.

SKB shall further give successive accounts to the Swedish Nuclear Power Inspectorate of changes in the time schedules which were presented in RD&D-Programme 92.

Nuclear Power Facilities in Sweden



-  BWR in operation
-  PWR in operation
-  CLAB, Central Facility for intermediate storage of spent fuel in operation
-  SFR, Final Repository for Reactor Waste

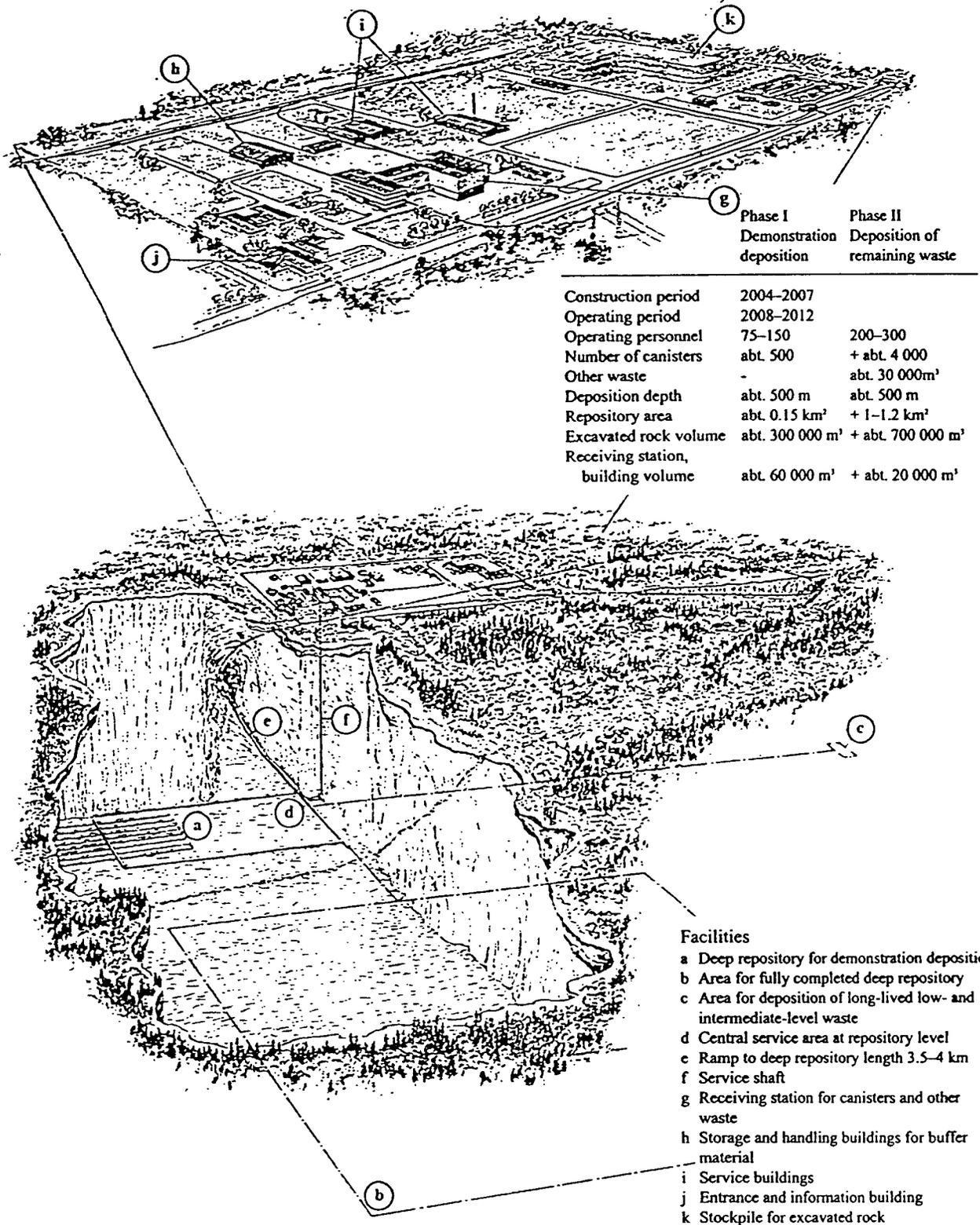


Figure 9-2. Plan of possible design of a deep repository. About 10% of a complete repository as marked in the figure is built for demonstration deposition.

Figure 2. Repository layout (from RD&D-Programme 92).

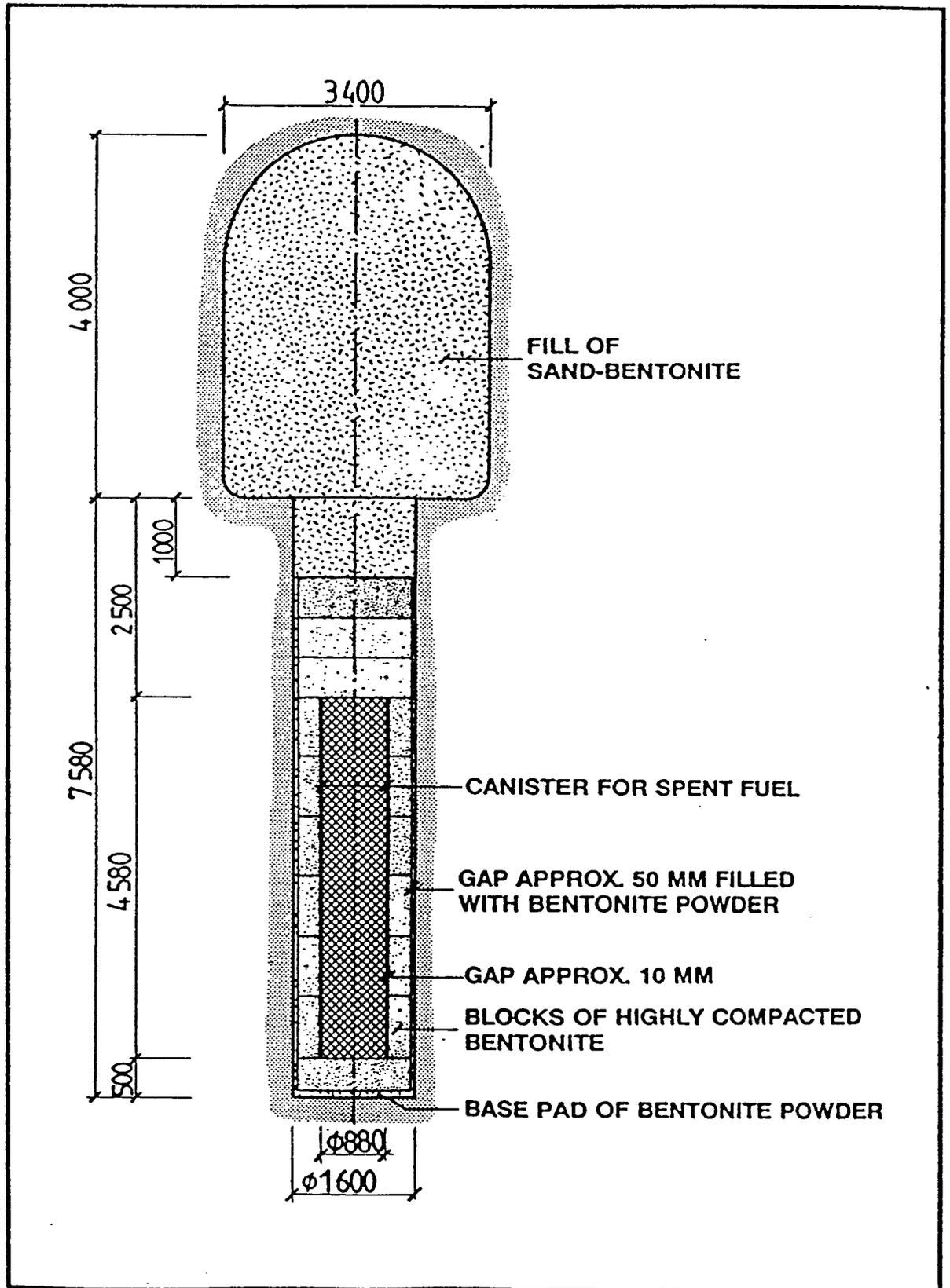


Figure 3. Position of fuel container in repository

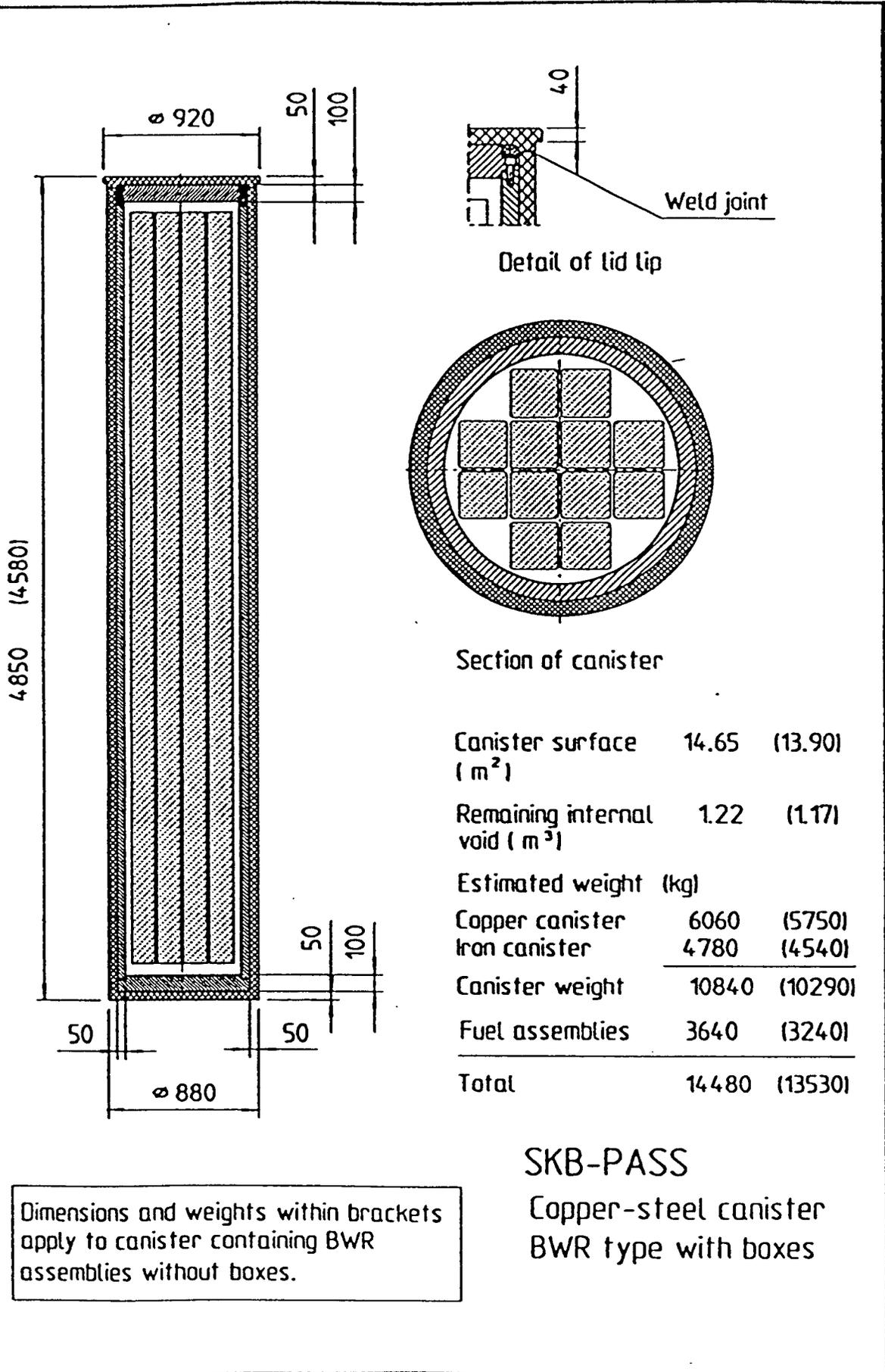


Figure 4. New design of fuel container

Figure 5. New time schedule (from RD&D Programme 92).

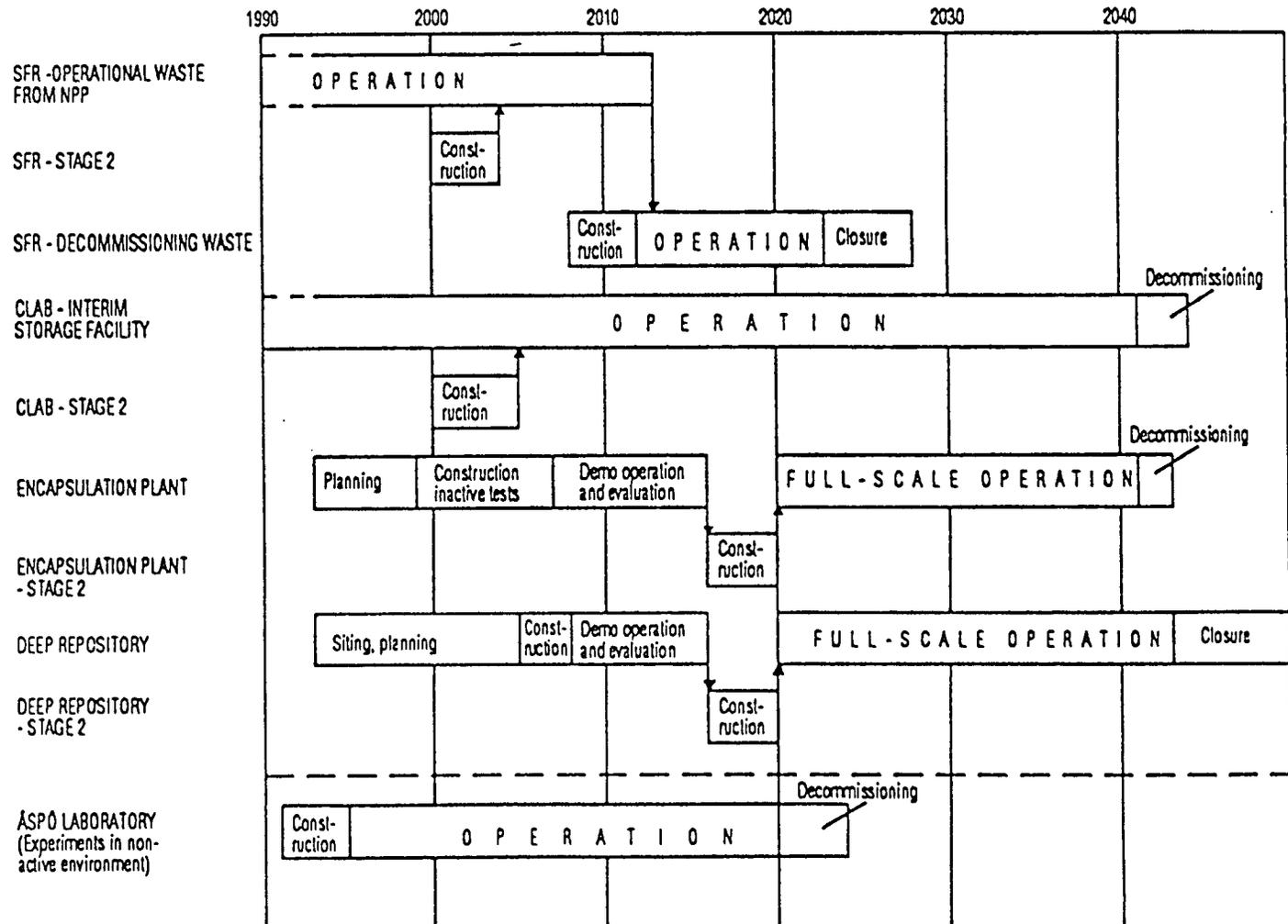


Figure 1-2. Approximate timeschedule – facilities for management of the waste products of nuclear power.