COST CALCULATIONS AT EARLY STAGES OF NUCLEAR RESEARCH FACILITIES IN THE NORDIC COUNTRIES - 7168

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NUCLEAR RESEARCH FACILITIES

The Nordic countries Denmark, Norway and Sweden, and to some extent also Finland, had very large nuclear research and development programs for a few decades starting in the nineteen fifties. Finland was in a special situation after the Second World War which impeded the actions to a certain extent.

After the Second World War, Norway was in a unique position in that it possessed heavy water that made it possible to build atomic piles using natural uranium. The first nuclear reactor in the Nordic countries, JEEP 1, was commissioned in Norway already in 1951. The Nordic countries became active participants when new international organizations were planned in the early fifties and it was in Norway that the first international nuclear conference was organized already in 1953.

The first Swedish nuclear research reactor, R 1, was located at the Royal Institute of Technology in Stockholm and was commissioned in 1954. The moderator consisted of heavy water supplied from Norway, and part of the fuel was domestic natural uranium.

Denmark acquired two reactors from the United States in 1956, and one from Great Britain in 1957. They all used enriched uranium. The homogeneous liquid reactor concept was studied for power generation purposes

Finland started its nuclear technology in 1956 by a subcritical pile, which used natural uranium as fuel and light water as moderator. The next step was the purchase in 1962 of a TRIGA reactor which uses enriched uranium fuel.

The programs in Denmark, Norway and Sweden included full fuel cycle activities, and much of the work was carried out in co-operation between the countries. Eventually, Denmark and Norway decided not to build any nuclear power plants while Finland and Sweden did. Today, only some of the nuclear research facilities are in use. Several have been decommissioned while others are at various stages of planning for shutdown. Work is presently in progress in Denmark on decommissioning of all of their nuclear facilities at Risø near Roskilde to green field conditions. In Sweden, decommissioning has just been completed for the Active Central Laboratory which was originally intended for pilot scale manufacturing of mixed oxide fuel.

RATIONALE FOR THE PRESENT WORK

In Finland and Sweden, planning for decommissioning is made under the requirements of the systems for funding, the purpose of which is to ensure that adequate funds are accumulated to cover all future costs.

It has been found in the associated review work that the existence of a nuclear power program is of limited value for cost calculations for old research facilities. Substantial differences exist with regard to existence and availability records, access to staff who designed and operated the facilities, approaches for design including its variations. It was also found that there are substantial common interests between owners of research facilities in different stages of decommissioning. This includes comparison between facilities, feedback of experience, and joint efforts to save resources.

These results prompted the Swedish Nuclear Power Inspectorate to take initiative to a Nordic co-operative project, the results of which are presently being reported internationally for the first time. The work is carried out under the auspices of The Nordic Nuclear Safety Research (NKS).

GOOD PRACTICE

Recommendations for decommissioning work as well as specific advice on cost calculations have been issued by the IAEA and the OECD/NEA. These documents form the framework for all the tasks carried out in our project. Moreover, from a systems analysis point of view, a decommissioning project can be rather complex with decisions having to be made from time to time based on incomplete information. Consequently, there is a need for compilations of what might need to be considered for planning and cost estimation purposes, and this is the rationale for the present description of good practice.

Radiological surveying. The cost for decommissioning is closely related to the presence, extent, character and distribution of remaining radioactivity. Frequently, the cost for decommissioning of a nuclear facility is a couple of order of magnitude higher than for a corresponding (hypothetical) non-radioactive plant. Moreover, the costs for radiological measurements and experts may be a considerable fraction of the total cost, maybe even more than half of the total project.

In practice, this may mean that considerable amounts of sampling, measurements and analyses need be made at the time of planning and cost estimation, and perhaps several decades before the actual decommissioning takes place. What really dictates the extent of work is that which is required for appropriate selections of techniques to be used and for estimations of the costs involved. The extent of measurements at the time of planning and cost estimations may be substantially reduced by utilization of radiological modeling. It is essential that the radiological surveying be tailored with respect to the features of the plant in question, and especially the radionuclide distributions.

Technical planning and methodology selection. The cost for decommissioning is closely related to the strategies and methods applied. A rational selection between alternatives cannot actually be made until costs can be compared.

There are many reasons why the knowledge needed may be incomplete. Plant prerequisites include design and operation history as well as data from radiological surveying. Uncertainty that cannot readily be resolved beforehand should call for preparedness to shift methodology whenever warranted based on upcoming information. It may be observed that successful projects are associated with compiling and sharing experience with other facilities and projects.

Financial risk identification and evaluation. Experience shows that cost drivers frequently come as surprises during the course of the execution of a decommissioning task and thereby give rise to overruns. It is thus imperative that they be identified, preferably during the planning stages, but otherwise as early as possible. In practice, the cost drivers can be identified in many different ways. E g, methodologies for risk identification and assessment are applicable in this regard.

TECHNIQUES FOR COST CALCULATIONS

Textbooks explain that there are two principally different types of methodology for cost estimates, and these are referred to as comparison and detailed summation methods, respectively.

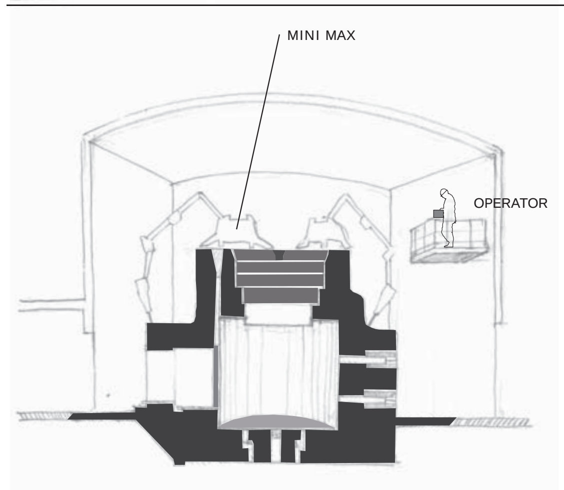
- Comparison with incurred costs for parts of facilities already erected
- Summation based on known volumes together with costs per unit

At early stages, the detailed summation method gives rise to large systematic errors since only a fraction of the terms to be summarized may be identified. Consequently, the comparison method is recommended for such situations, and in the first stage it can be expected to deliver a precision of +50/-30 %. Similarly, at the last stage of cost calculations, when detailed planning and supplier information is available, the detailed summation method can be applied with a typical precision of +/- 5 %.

It should be noted in this regard that cost calculations for nuclear research facilities are particularly treacherous for several reasons, e g:

- Plans for decommissioning may not exist
- The facilities were not designed or operated for decommissioning
- The facilities are small (i e investigations are costly vs total cost)
- The facilities are very different in character
- The types of contamination are different
- Regulations for construction and operation were less strict than today
- Incomplete documentation of design, operation and incidents
- Institutional memory may have been lost

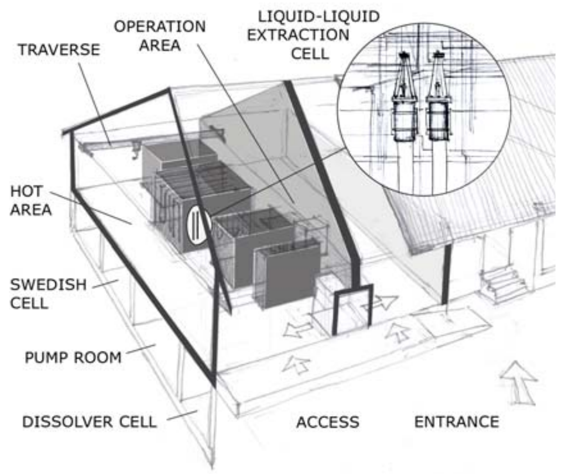
Thus, in order for a precision of ± 20 % to be achieved at early stages, incurred costs will have to be used extensively for the comparison method, and detailed cost-affecting features for the summation method.



The R1 research reactor in Sweden was moderated by heavy water and used natural uranium fuel. It started operations in 1954, was closed in 1970, and decommissioning was completed in 1981. The reactor was located in crystalline rock at the Royal Institute of Technology in Stockholm, Sweden. The decommissioning was carried out by Studsvik. There was still ample access to people who had worked in the facility. Extensive information searches and plant visits were made in the planning stage.

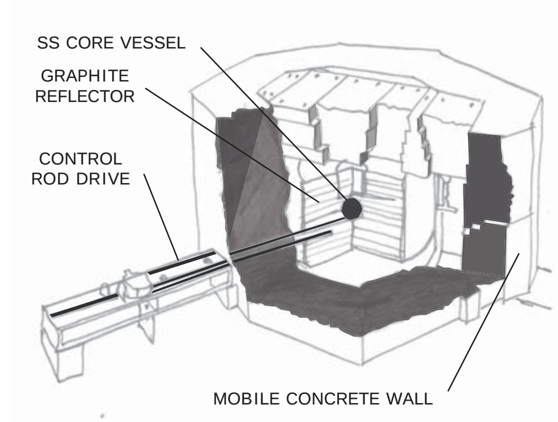
The coring and sampling of the graphite reflector was limited for occupational health reasons. This caused an underestimation of the dose and a cost rise.

A timber handling machine was modified with a pneumatic hammer and remote controls. This made the work much more efficient and saved dose as well as costs. This experience was actually the inception of the use of robots for demolition.



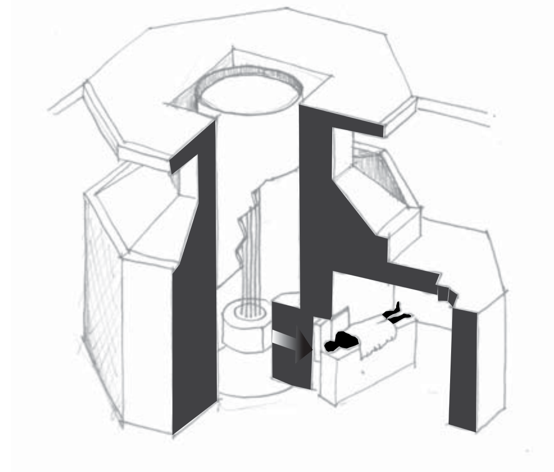
The uranium fuel reprocessing plant in Norway was commissioned in 1961 and taken out of operation in 1968. It was decommissioned partially in 1982 and fully in the period 1989 – 1993. The work comprised more than 6 000 meters of piping and a total of 50 tanks, evaporators and extraction columns. It was located at the IFE facilities in Kjeller at the outskirts of Oslo, and it was IFE who carried out the decommissioning project. The project was carried out while there was still institutional memory left from the time of operation. This was fortunate since one of the lessons learned was that it is important to conserve all essential written information and drawings.

The project was very well documented, partly within the NKS co-operative framework. Valuable advice is given on how to best handle various partially modified standard tools and on how to manage such that the motivation of the staff is maintained throughout.



The DR1 reactor at what is now called Risø National Laboratory, Technical University of Denmark – DTU. It was commissioned in 1957, taken out of service in 2001 and decommissioned by Danish Decommissioning in 2004-05. The reactor was a thermal homogeneous reactor with an output of 2 kW. The fuel was 19,9 % enriched uranium in the form of uranyl sulfate dissolved in light water. The core comprised a spherical vessel having a diameter of 0,32 m.

Existing records have been compiled and used. The project has utilized information from similar facilities by literature studies, plant visits and by using consultants. The approach has been to use the summation method for calculation in combination with a weighing scheme for the complexity and difficulty of each task. The PRICE computer code from UKAEA has been used, and the experience is that it is very suitable for the purpose.



The TRIGA research reactor at VTT in Finland has been in operation since 1962. The uranium fuel is enriched to 20 % and it is moderated by light water. The power output is 0,25 MW. The present operation is mainly for Boron Neutron Capture Therapy.

Planning for decommissioning including cost estimation is required under the Finnish law. Much of the material for this work is obtained from the circle of present and previous owners of TRIGA reactors. These reactors belong to a stage in the nuclear technology development when design features were becoming generic or standardized and many reactors were manufactured with similar designs, thus making co-operation between the operators particularly valuable. Detailed descriptions of completed projects are available in the open literature. Such information together with careful planning has helped in grossly meeting the various targets set at similar facilities.