



Implementation of spent nuclear fuel disposal in Taiwan

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Abstract

Owing to the limited natural energy resources in Taiwan, the electricity generated from nuclear power plants is an important energy supply for domestic economic development. Presently, there are three twin unit nuclear power plants in operation with a total output of 5145 MW located at three different sites in Taiwan. Although the nuclear power plants can provide a convenient and reliable energy resource, the associated spent fuel disposal problem is a very challenging one, especially in terms of public acceptance of the final disposal site. In order to target this issue, Taiwan Power Company has conducted a long-term disposal program for the spent nuclear fuel from 1986 until the present. This paper presents a general overview regarding the implementation of the spent nuclear fuel disposal project in Taiwan.

Keywords: Spent nuclear fuel; Disposal

1. Introduction

At the beginning of 1978 the first commercial operation of a nuclear power plant commenced in Taiwan, since which time the stockpile of spent nuclear fuel has been increasing annually. The final disposal of spent nuclear fuel has therefore inevitably become an important issue of backend management.

Taiwan Power Company (TPC), which is the only nuclear power plant operator in Taiwan, began to conduct a final disposal program for spent nuclear fuel in 1986. The work of phases I and II of this program was completed in 1988 and 1991, respectively. On 20 August 1993, TPC contracted the Energy and Resources Laboratories (ERL) of

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the Industrial Technology Research Institute (which is a non-profit organization) to conduct the 'Spent Nuclear Fuel Disposal Program, Phase III', also called the 'Regional Investigation Stage', which is scheduled for a running period of 10 years. As of April 1996, the first-year task of Phase III was completed, and the second-year task is currently under execution by ERL. This paper discusses the activities and the implementation of this spent nuclear fuel disposal program.

2. Spent nuclear fuel management policy

The highest official authority of spent nuclear fuel management in Taiwan is the Radioactive Waste Administration (RWA) of the Atomic Energy Council. On 16 September 1988, the Executive Yuan (Cabinet) approved the RWA's Radioactive Waste Administration Policy. This policy is applicable to all types of radioactive waste and provides the guidelines for the management of radwaste-related activities in Taiwan. The principle outlines of this policy are as follows [1–3]:

1. The radioactive waste management programs must be carried out by adopting currently feasible technologies and be adapted to Taiwan's local conditions.
2. The radioactive waste producer must pursue possible ways to minimize the amount and volume of waste.
3. The radioactive waste producer must be responsible and bear costs for conducting the waste management programs.
4. The protection of the health and safety of the public and the quality of the environment must be warranted and the international conventions must be observed.
5. Continue to plan for the final disposal program of spent fuel and high-level radwaste, complete a preliminary feasibility study report, and an implementation program as soon as possible.

According to the above-mentioned outline No. 3, it is clear that the radioactive waste producer is responsible for solving its own waste disposal problem. Since TPC is the sole spent nuclear fuel producer in Taiwan, it plays an important role in resolving the domestic spent nuclear fuel disposal problem. Regarding the radioactive waste management issue, TPC recognizes the following [3]:

1. The problem generated by this generation should and must be solved by this generation.
2. Because radioactive waste is a long-term problem, funds must be collected.
3. Radiation and environmental protection are foremost concerns of the public, thus communication with the public is very important.
4. Backend operation requires technology and management, therefore it should be planned integrally and conducted in stages.

3. Development of spent nuclear fuel disposal program

TPC has conducted a series of programs on the spent fuel disposal issue during the past few years. From 1 May 1986 to 30 June 1988, TPC contracted domestic institutes,

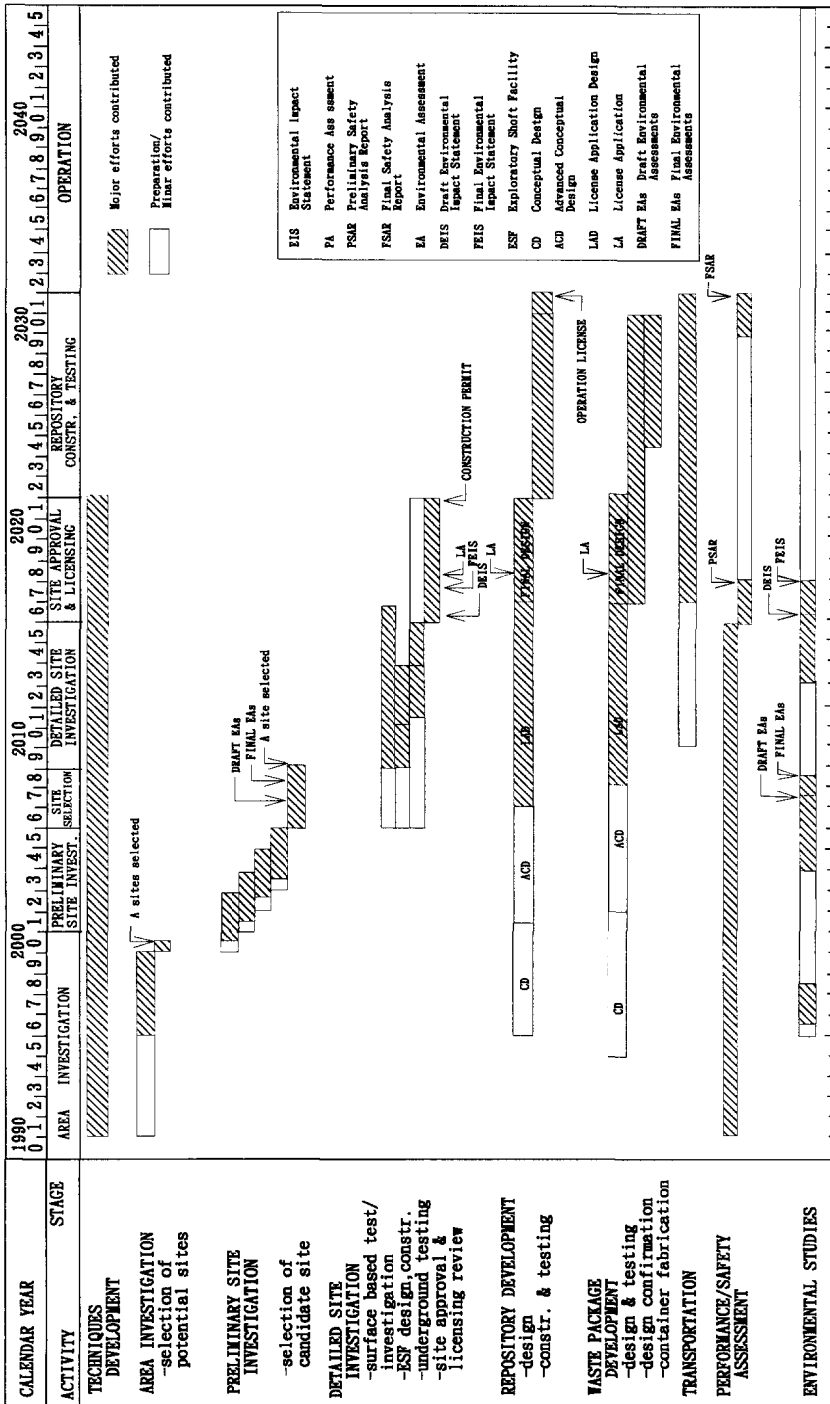


Fig. 1. Proposed schedule for the long-term spent fuel disposal program [4].

including the Institute of Nuclear Energy Research (INER), the Energy and Resources Laboratories (ERL) and the Central Geological Survey (CGS), to cooperatively execute the 'Spent Nuclear Fuel Long-Term Disposal Program, Phase I Project'. The main purpose of the Phase I project was to study the siting criteria, siting investigations and design concept on the final disposal site. The general concept for planning the final disposal of spent nuclear fuel in this study was based on the deep geological disposal method which is widely accepted by the international community.

Upon completion of the Phase I project, only the basic concept and the knowledge for understanding the spent nuclear fuel disposal problem were established. Thus, from November 1988 to June 1991, TPC contracted the INER, ERL, CGS and National Tsing-Hwa University to conduct the 'Spent Nuclear Fuel Long-Term Disposal Program, Phase II project'. There were two major tasks for the Phase II project: '1. Plan a long-term program for the spent nuclear fuel disposal. 2. Perform a preliminary geological investigation for screening the potential disposal sites.' For the long-term planning task, it focused on the full-scale R & D and engineering aspects, program management and decision-making process, quality assurance, required expertise and equipment, public acceptance, literature and information collection and dissemination, and international cooperation. At the end of the Phase II project, a long-term program had been completed as a guideline for the disposal of Taiwan's spent nuclear fuel. This program was planned to start from 1991 and terminate at 2031. There are six major stages involved in this long-term program, and the main objectives of each stage are given as follows [4]:

1. Regional Investigation (1991–2000).
 - 1.1. To complete regional investigation of four areas and prioritize 4–6 potential sites.
2. Preliminary Site Investigation (2001–2005).
 - 2.1. To complete preliminary investigation of 4 potential sites.
3. Site Selection (2006–2008).
 - 3.1. To select 1–3 favorable candidate sites.
4. Detailed Site Investigation (2009–2015).
 - 4.1. To conduct a detailed investigation (i.e., borings, exploratory shaft excavation and in-situ testing) of the candidate sites.

Table 1
Costs for overall program (in NT dollars) [5]

Item	Cost (million)	%
(1) Central administration	828	1.1
(2) Research and development	5,014	6.4
(3) Transport	4,963	6.3
(4) Encapsulation station and final repository for spent fuel	67,899	86.2
Total	78,704	100.0

Costs are estimated at a discounted value of 3.5% real rate of interest.

At the exchange rate of May 1990, NT\$ 4.54 Per Sweden SEK.

The total cost is approximately equivalent to 3,000,000,000 US dollars (1 US\$ = 26.5 NT\$).

5. Site Approval and Licensing (2016–2021).
 - 5.1. To apply for approval and a license for construction of the selected candidate site as the repository site.
6. Repository Construction and Testing (2022–2031).
 - 6.1. To complete the construction and operation of the repository before the end of 2031.

Besides the investigation, selection and construction of the repository, other aspects such as technique development, waste package development, performance/safety assessment and environmental studies are also included in this long-term program. Fig. 1 illustrates the major objectives and milestones of this proposed program [4]. The estimated total cost for this overall program is approximately 78,704,000,000 NT dollars and is equivalent to 3,000,000,000 US dollars (see Table 1 [5]).

4. Implementation status of spent nuclear fuel disposal program

Based on the proposed plan presented in Fig. 1, TPC contacted the ERL, INER and CGS to arrange a task force for the implementation of the regional investigation stage (also termed the Phase III project) of this project. The detailed activities and milestones proposed in the regional investigation stage are shown in Fig. 2 [4]. It reveals that the regional investigation stage is a 10 year task with 7 major activities including: personnel training and the introduction of techniques, equipment acquisition, technique development, area investigation, performance assessment, environmental studies and socio-economic studies.

Within this 10 year time frame of the regional investigation stage (see Fig. 2), the actual investigation work will not commence until the sixth year. Thus, for management purposes, TPC sectioned this stage into the first 4-year task and the second 6-year task. The main objectives of the first 4-year task are:

1. Perform personnel training to reserve the valuable human resource for this long-term spent nuclear fuel disposal program.
2. Develop and introduce geoscience technologies and equipment for conducting the regional investigation.
3. Conduct research on thermal properties of potential host rocks, buffer and backfill materials, and on radionuclide transportation and retardation.
4. Establish the generic capability of performance and safety assessment.
5. Establish the quality assurance system to ensure the work quality.
6. Establish the information inquiry system to facilitate relevant information exchange.
7. Complete the preparation work for implementation of the later regional investigation task.

On 20 August 1993, TPC engaged ERL to conduct a project of ‘Spent Nuclear Fuel Long-Term Disposal Program – Phase III Regional Investigation Project – The First Year of 4-Year Task’ with the assistance of INER. Based on the first 4-year’s objectives described above, 6 working items were identified and executed in this first year project. They are personnel training, technique and equipment introduction, quality assurance,

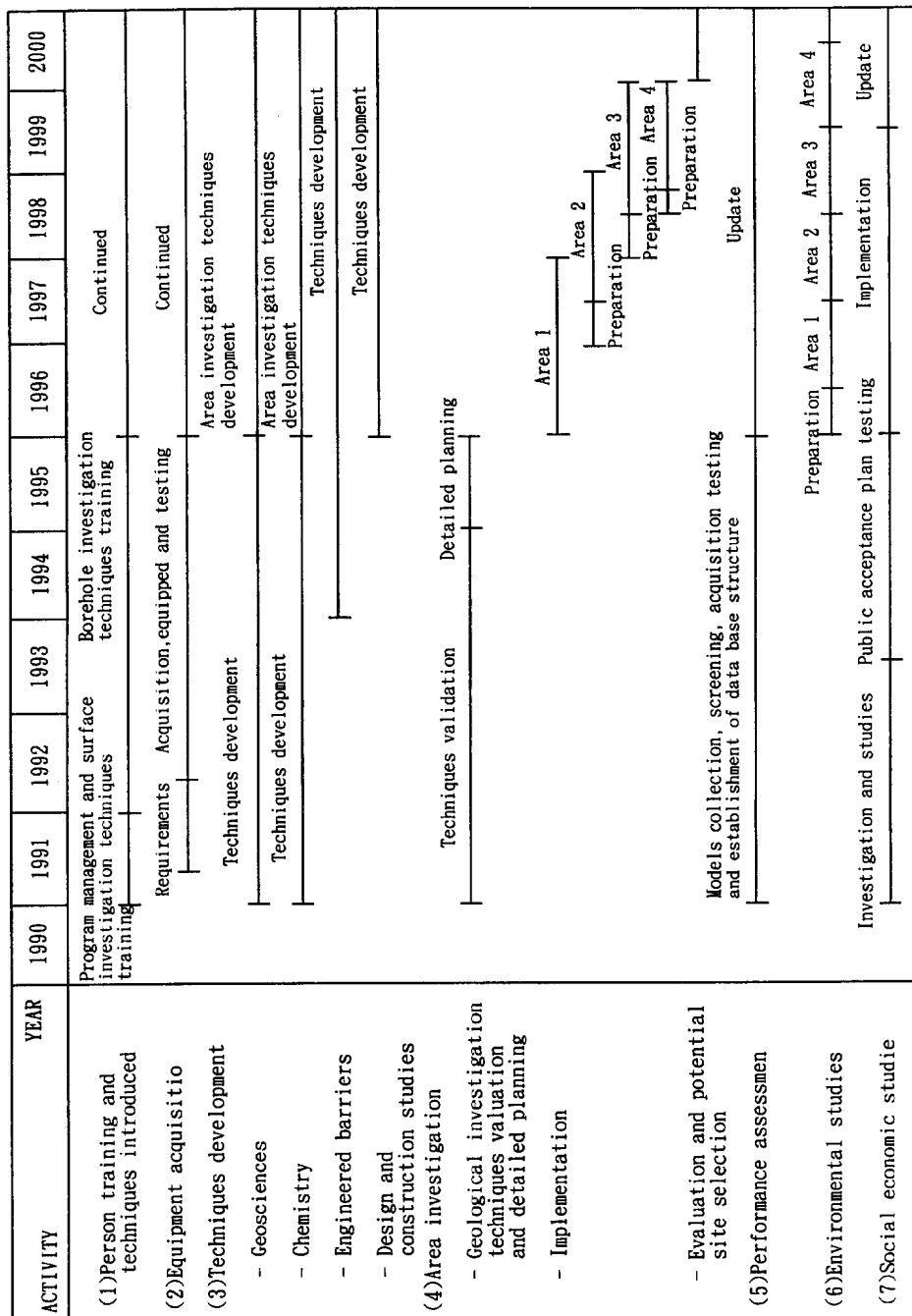


Fig. 2. Proposed plan for the regional investigation stage of the spent fuel disposal program [4].

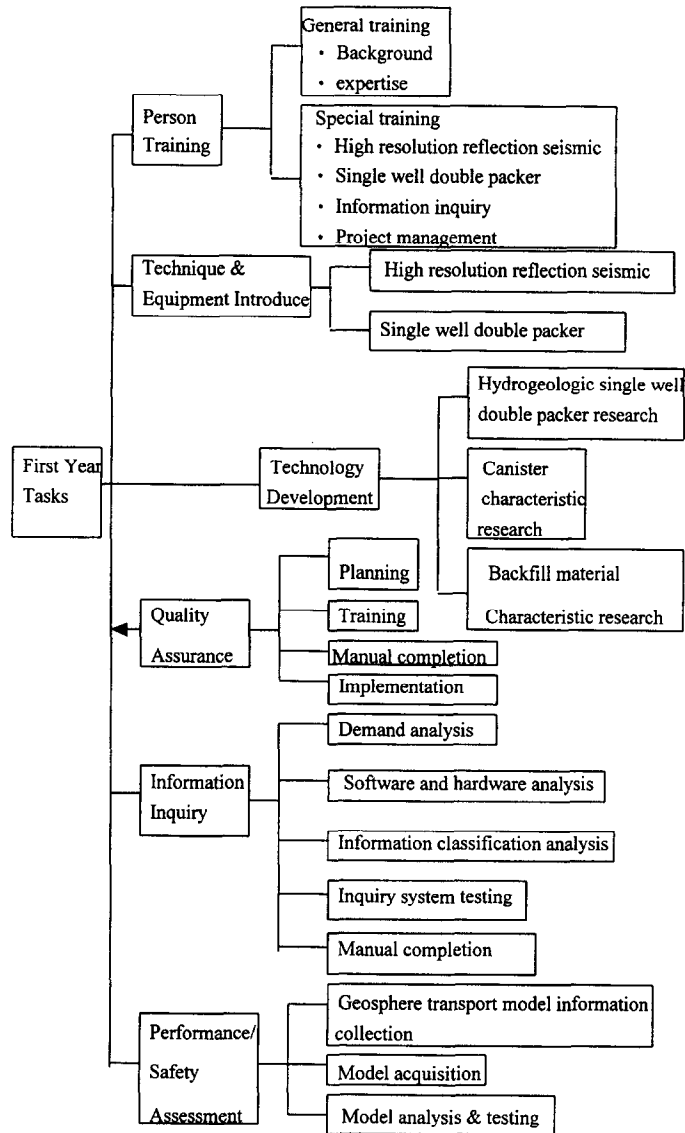


Fig. 3. Work breakdown structure of first year of the 4-year task.

technique development, information inquiry and performance/safety assessment. Among these items, only performance/safety assessment was conducted by INER, whereas all the others were conducted by ERL.

The major work breakdown structure of these items is illustrated in Fig. 3. It indicates that the first year's tasks are mainly to conduct the preparation work for the actual

regional investigation tasks which are scheduled six years later. The main achievements of the first year project are:

1. Complete background and professional training programs for relevant personnel to upgrade their capability and performance.
2. Acquire the high resolution seismic reflection data reduction system and the single-well double-packers equipment to meet the needs of regional investigation.
3. Implement the quality assurance program to ensure the work quality and performance.
4. Develop the high resolution seismic reflection exploration technique and hydrogeologic single-well double-packers technique to establish localized and self-sustained regional investigation technologies.
5. Set up an information inquiry system to facilitate relevant information exchange.
6. Study the SWIFT model to establish the capability of conducting performance and safety assessment.

Currently, this first year project has already been completed and a more detailed description regarding the activities performed and results achieved in this project is available in Ref. [6].

In May 1995, the second year project of the 4-year task proposed by ERL was formally approved by TPC. The working items for the second year project are very similar to the first year's. However, in the second year project the actual field tests (i.e., high resolution seismic reflection test and single well double-packer test) of various investigation technologies which were established in the first year project will be executed to evaluate their performances, and a special training team has been organized for a 6-week overseas training program to study advanced knowledge regarding the final disposal of spent nuclear fuel. Also, the long-term program for spent nuclear fuel disposal which was planned in the Phase II project will be evaluated and revised by considering the current status and the actual time schedule. The major tasks to be completed in the second year include the following:

1. Organize a core group and carry out a 6-week overseas training program.
2. Select testing places and conduct field exercises of high resolution seismic reflection and hydraulic packer testing techniques.
3. Modify the project quality assurance program and complete the integration of the QA plan with ISO 9000.
4. Enlarge the reference database regarding the spent nuclear fuel management and develop international channels for information exchange.
5. Review the long-term plan and make recommendations for revision.
6. Establish a control mechanism or an organization function to ensure the program integrity.

5. Program characteristics and potential difficulties

As the major spent nuclear fuel generator and regulated by the radioactive waste administration policy, Taiwan Power Company becomes the responsible party for the safe disposal of domestic spent nuclear fuel. From 1986 up to the present time, TPC has

contracted several domestic institutes including INER, ERL, and CGS to conduct various phases of the spent nuclear fuel disposal program. The general concept for planning the final disposal of spent nuclear fuel in this program is based on the deep geological disposal method which is widely accepted by the international community.

The safe disposal of spent nuclear fuel in a geologic repository is a challenging task in Taiwan. This statement may be equally true for other countries which are striving to arrest the nuclear waste disposal program. Owing to the nature of radioactive materials and the complexity of safety measures, some inherent characteristics of spent nuclear fuel disposal programs can be observed. Conspicuously, they are: (1) a long period of time, (2) a wide diversity of technology, (3) interdisciplinary complexity and integration, (4) a large amount of data and information, and (5) high cost.

These characteristics entail potential difficulties that are foreseeable in the implementation of the spent nuclear fuel disposal program in Taiwan, for example:

- Owing to the long duration of the program, the importance of the spent nuclear fuel disposal issue loses its priority in the public consensus and support.
- Owing to the long duration of the program, participants' career planning often interrupts the program's goal setting. The preservation and the passing-on of relevant knowledge and experience are difficult.
- Self-centered arguments between disciplines cause a great burden on the program coordination.
- Over-emphasis of the research nature of an individual task, and overlooking the importance of the application purpose for achieving the goals.
- Mis-handling the data and information generated, and losing track of data or information resources.
- The high cost and the remote goal-setting draw hesitation from the administration with regard to continuous support to the program.

6. Summary and conclusion

As the major spent nuclear fuel generator and regulated by the radioactive waste administration policy, Taiwan Power Company becomes the responsible party for the safe disposal of domestic spent nuclear fuel. From 1986 up to the present time, TPC has contracted several domestic institutes including INER, ERL, and CGS to conduct various phases of the spent nuclear fuel disposal program. The general concept for planning the final disposal of spent nuclear fuel in this program is based on the deep geological disposal method which is widely accepted by the international community.

In the phase I project (1986–1988), only the basic concept and the knowledge for understanding the spent nuclear fuel disposal problem were established. In the phase II project (1988–1991), a long-term program was proposed as a guideline for the development of Taiwan's spent nuclear fuel disposal program. This long-term program was scheduled to begin from 1991 and end in 2031.

On 20 August 1993, TPC contracted ERL to conduct a 'Spent Nuclear Fuel Long-Term Disposal Program – Phase III Regional Investigation Project – The First Year of 4-Year Task' with assistance from INER. This declared that Taiwan's spent

nuclear fuel disposal program was formally proceeding into the regional investigation stage (i.e., Phase III project). Six major working items were executed in this first year project. They were personnel training, the introduction of techniques and equipment, quality assurance, technique development, information inquiry and performance/safety assessment.

As of April 1996, this first year project had already been completed and the second year of the 4-year task is currently being implemented by ERL with the assistance of INER. Basically, the first and second years' tasks were mainly to conduct preparation work for the actual regional investigation work which will be executed in the future.

The long-term program for the final disposal of Taiwan's spent nuclear fuel is characterized by long duration, technical complexity, and high cost. There is no doubt that the program's success requires the participants' devotion and commitment, and advanced skills in coordination and integration. In order to minimize the cost and time required for the implementation of this program, a domestic research team has to be organized to investigate various available technologies and accumulate sufficient expertise to adopt the technologies from abroad most suitable to Taiwan's environment. Besides the above issues, another consideration for the successful implementation of this program in Taiwan is the public acceptance of the program. In particular, the opposition of local residents and political pressure may jeopardize the final selection and construction of the site for spent nuclear fuel disposal in Taiwan. Thus, most importantly, the program needs stable and continuous support, both financially and politically.

References

- [1] Atomic Energy Council of the Republic of China, *Radioactive Waste Administration Policies*, Taipei, Taiwan [in Chinese].
- [2] P.C. Chyen et. al., *Taipower's Nuclear Backend Management Programs* (Taiwan Power Company, 1992).
- [3] Chao-Chi Huang and Chao-Ming Tsai, *Introduction to the Outlines of Radwaste Administration Policy of the Republic of China*, Int. Conf. on Environmental Issues and Management of Waste in Energy and Mineral Production, 27–29 August 1990, pp. 31–38.
- [4] Institute of Nuclear Energy Research, *Executive Summary of Spent Nuclear Fuel Disposal Program Phase II Project*, May 1991.
- [5] Institute of Nuclear Energy Research, *Program Plan of Spent Nuclear Fuel Disposal Program Phase II Project*, May 1991.
- [6] Cy.C. Chen, Shoung Ouyang and Ching-Hwa Lee, 'An Introduction of Spent Nuclear Fuel Long-Term Disposal Program – Regional Investigation – The First Year of 4-year Task', submitted for publication [in Chinese].