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CURRENT STATUS OF OPERATION, UTILIZATION AND REFURBISHMENT OF THE DALAT NUCLEAR RESEARCH REACTOR

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ABSTRACT

The reconstructed nuclear research reactor at Dalat, Vietnam has been put into operation sine March 1984. Up to present a cumulative operation time of 13,172 hrs at nominal power (500kW) has been recorded. Production of radioisotopes for medical uses, element analysis by using activation techniques, as well as fundamental and applied research with filtered neutrons are the main activities of reactor utilizations. The problems facing Dalat NRI are the ageing of the re-used TRIGA-MARK-II reactor components (especially the corrosion of the reactor tank), as well as the obsolescence of many equipment and components of the reactor control & instrumentation system. Refurbishment works are being in progress with the technical and financial supports from the government and the IAEA.

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1. *Background information. Reactor chracteristics (Fig. 1)*[1].

Reactor type: swimming pool, water-cooled, water-moderated, reconstructed from the TRIGA-MARK-2 reactor.

Criticality after reconstruction: 1-11-1983.

Nominal power: 500kW thermal.

Reactor core:

* Fuel assemblies: hexagonal, Russian type VVR-M2, U-Al alloy, 36% U-235 enrichment,
* Core loading: 89 fuel assemblies, 3576g U-235,
* Volume of active core: 64.9l, 55.2% water.

Reactor control: 7 control rods (2 safety, 4 shim, 1 regulating), total rod worth 17.5$.

Excess reactivity: original 9%, present: 3.6%.

Reflector: 25kg beryllium plus former TRIGA-MARK-II graphite reflector.

Thermal neutron flux at 500kW:

* At central neutron trap: 2.1×10^{13} n/cm^2/s,
* Average in reactor core: 4×10^{12} n/cm^2/s,
* At rotary specimen rack: 3×10^{12} n/cm^2/s.

Flow rate of cooling systems:

* primary: 50m^3/hr,
* secondary: 90m^3/hr.

Total operation time up to august 1993: 13,172hrs

Operation mode: 100hrs continuous run every three weeks.

2. *Problems.*

2.1 The ageing of the re-used TRIGA reactor components that are of 30 years old. An underwater telescope inspection undertaken in 1989 revealed a number of deep corrosion spots and pittings in many areas of the reactor tank. Since then, appropriate measures have been taken towards slowing down the corrosion rate and early detection of any invisible water leakage through the aluminum tank [2].

Concerning the fuel assemblies a regular radioactivity monitoring of air and reactor coolant water has not detected so far any anomaly related to the leakage of fission products. However, with more than 13,00C operating hours since 1984, the excess reactivity is curre n tly approaching its lower limit. A part of the core is planned to be replaced with new fuel assemblies. A reactor tank clean-up has also been planned to be performed during that reactor shut-down period for refuelling .

2.2 The obsolescence of many components of the reactor control and instrumentation system (RCIS) and its unreliability in tropical climatic conditions, the lack and/or non-availability of Russian-manufactured spare parts. Fig. 2 shows the failure statistics of the RCIS [3].

3. *PSA studies*

PSA studies relative to the protection function of the RCIS using fault tree techniques were conducted in the framework of an IAEA-supported CRP on research reactor probabilistic assessment. On the basis of the failure statistics recorded for subsystems of the RCIS through 9 years of reactor operation the most responsible blocs and units were identified.

4. *Refurbishment of the RCIS*

The refurbishment of the RCIS is currently being undertaken in the framework of an IAEA technical assistance project " Renovation of the Dalat RCIS". As the design principles and some important equipment (neutron detectors, electromechanical servodrivers etc) of the original RCIS are good according to the assesment of experts, these are preserved in the renovated version. Meanwhile, up to date equipment and components have been acquired for

- enhancing the reliability of the system,
- replacing the outdated equipment and instruments,
- reconstructing some units of the RCIS by preserving the same functional principles and modular design, but using modern and higher quality components,
- reserving as spare parts.

The reactor control room has been reconstructed with new control console. A project group with full time employees from the departments of nuclear reactor and nuclear electronics of the Dalat Nuclear Research Institute has been assigned to perform design, construction and installation works. Commissioning and final approval of the renovated RCIS by a high level authority are expected to be in early 1994.

5. *Refurbishment of other reactor systems*

The Dalat NRI has been undertaking also a government-supported project on refurbishment of the technology network, which includes the cooling tower, the systems of ventillation, open-air lighting and radiation and physical protection. The project objectives also include the clean-up of the reactor tank during shut-down periods for core refuelling and RCIS testing, the upgrading of the existing laboratory for reactor-water chemistry. Under this project a simple underwater telescope was manufactured by Hochiminh City Engineering University, providing an in hand visual instrument for observation ofthe extent of corrosion in the bottom area of the reactor tank. As a whole, the project is going behind schedule, and up to now only a few items have been completed.

6. *Reactor calculations*

A small group of reactor physicists from Dalat NRI and Hochiminh City Centre of Nuclear Techniques has been undertaking calculations of parameters, characteristics and neutron spectra of the Dalat NRR. A large reactor calculation codes pertinent to the hexagonal lattices, as being at the Dalat NRR, has been adapted to the PC. In the last years attention has been paid to the calculations of core burn-up and various fuel replacement options. The results will be directly used in the forthcoming core refuelling programme.

7. *Reactor utilizations*

7.1 *Radioisotope production*

Fig. 3 shows some statistics of reactor operation and utilizations. The radioisotope production is steadily increasing [4], and in the last two years, apart from radiopharmaceuticals, the Dalat NRR has began to supply radioisotopes as tracers for sediment and water transport studies (about 20Ci of I-131, Cr-51 and Sc-46 labelled sand). The long distancesbetween Dalat and population centres, where are located nuclear medicine departments, appreciably reduce the activity of radiopharmaceuticals during transportation.

7.2 *Applications of nuclear analytical techniques*

In the last years there has been increasing attention in Vietnam to environmental problems. The scientists at the Dalat NRR successfully take advantage of reactor-based analytical techniques in meeting the demands for multielement analysis of environmental objects. INAA is being applied in most cases, while PGNAA shows its advantage in the characterization of light elements, providing a method complementary to INAA techniques (Table I) [5,6]. Various radiochemical neutron activation techniques have also been well established. The combination of these analytical techniques ensures the characterization of about 40 elements in typical environmental objects, such as soil, plants, foods, sediments, fallout, aerosols, water etc.

Table I

Comparision of the capability of PGNAA with INAA in element characterization of environmental objects

Element	PGNAA	INAA
H, B, Cd, Gd	good	difficult, incapable
C, N, Si, P	capable	difficult, incapable
Al, Cl,K, Ca, Ti,Mn		
Fe, NI, Nd, Sm, Dy, Hg	capable, good	capable, good

The PGNAA experiments are carried out at the tangential beam port of the reactor. To improve the quality of the thermal neutron beam used in PGNAA, a single crystal silicon filter of 60 cm long was inserted in the beam tube. At the sample location a 1.5×10^{6} n/cm^{2}/s thermal neutron flux with R_{Cd}=200 is obtained and the gamma dose rate is less than 0.1R/hr. The single crystal silicon filter considerably improves the contrast of the prompt gamma spectra, as shown in Fig. 4a,b. The advantage of PGNAA in element characterization of biological objects can be seen from Fig. 5. As an illustration, Fig. 6 shows the concentrations of rare earth elements in bottom sediments collected at the estuaries of Mekong (in South Vietnam) and Red (in North Vietnam) rivers. The results are plotted in so-called REE patterns along with the patterns of typical coastal minerals and sands. Note that large differences between REE patterns of different coastal minerals in Fig. 6 make REE to become good alternative tracers in coastal sediment transport studies.

7.3 *Nuclear data measurements with filtered resonance neutrons*

Quasi-monoenergetic neutrons are being used for nuclear data measurements by inserting neutron filters in the piercing beam tube of the reactor. The neutron filters and the characteristics of filtered neutron beams are given in Table II. Fig. 7 shows the recoil proton

Table II

Filtered neutron beam characteristics

Neutron	Filter combination	Neutron flux ($n/cm^2/s$)	FWHM
Thermal	$98cmSi+10cmTi+50g/cm^2S$	$1.8x10^7$	
144keV	$98cmSi+10cmTi+0.4cmB_4C$	$1.2x10^7$	22keV
55keV	$98cmSi+50g/cm^2S+.4cmB_4C$	$4.x10^6$	8keV
25keV	Al+ Ti	$1.2x10^6$	

spectrum recorded by a hydrogen proportional counter in case of silicon filter [8]. By inserting additionnal resonance absorbers (B, S) quasi-monoenergetic neutron spectra can be obtained (after differentiation of the recoil proton spectra, Fig. 7), as shown in Fig. 8a,b. Filtered neutrons are being used for measurements of total neutron cross-sections by transmission technique [7], activation cross-sections and isomeric ratios by activation method, capture gamma-ray spectra by using Compton suppress and/or pair spectrometers. Fig. 9 shows the experimental set-up used in these measurements and as an illustration Fig. 10 presents the results of total neutron cross-sections measured with silicon filter.

This direction of fundamaental research is being conducted in cooperation with the Kiev Institute for Nuclear Research.

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[6] Pham Duy Hien et al., Proc. II Int. Workshop on NAA in Environment, Dubna, Oct. 1992.

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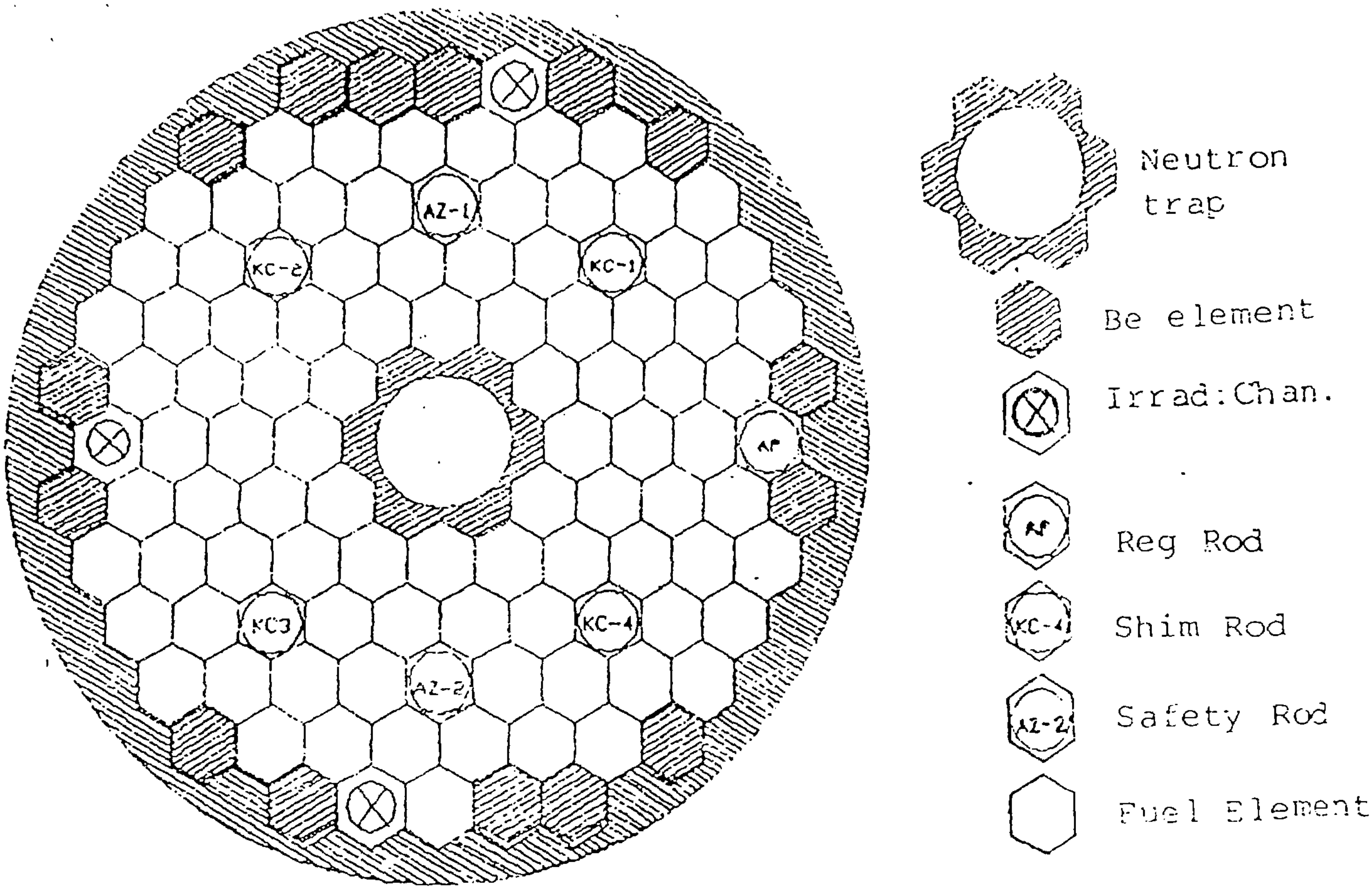
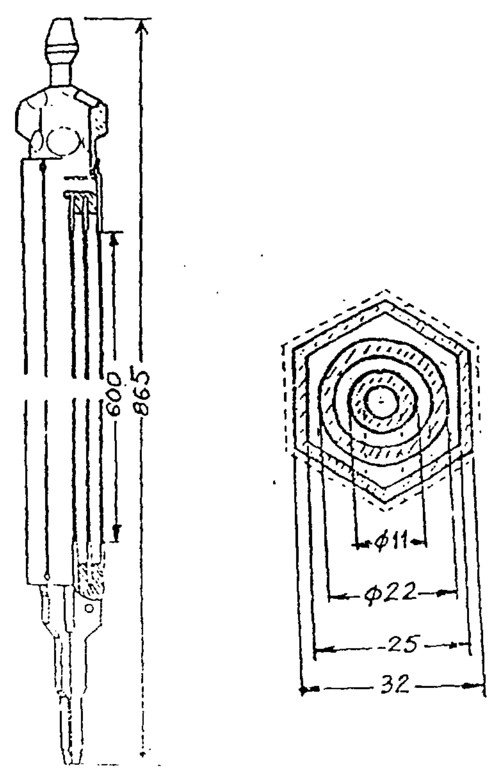


Fig. 1a Cross-sectional view of reactor core



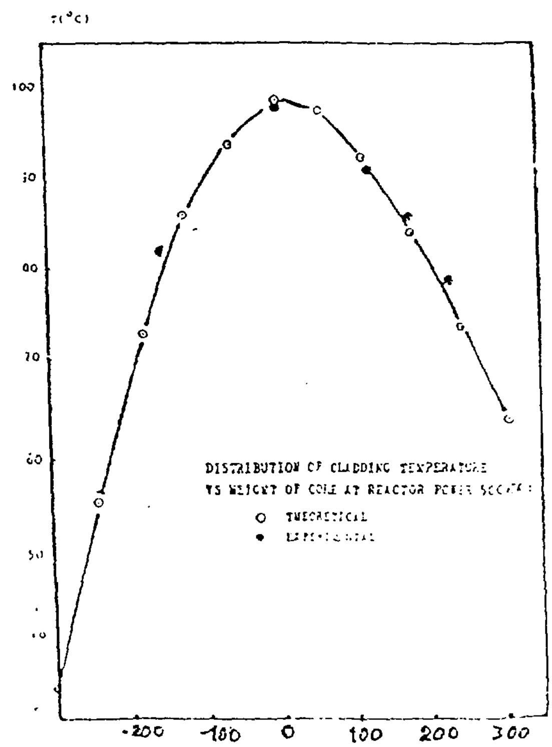
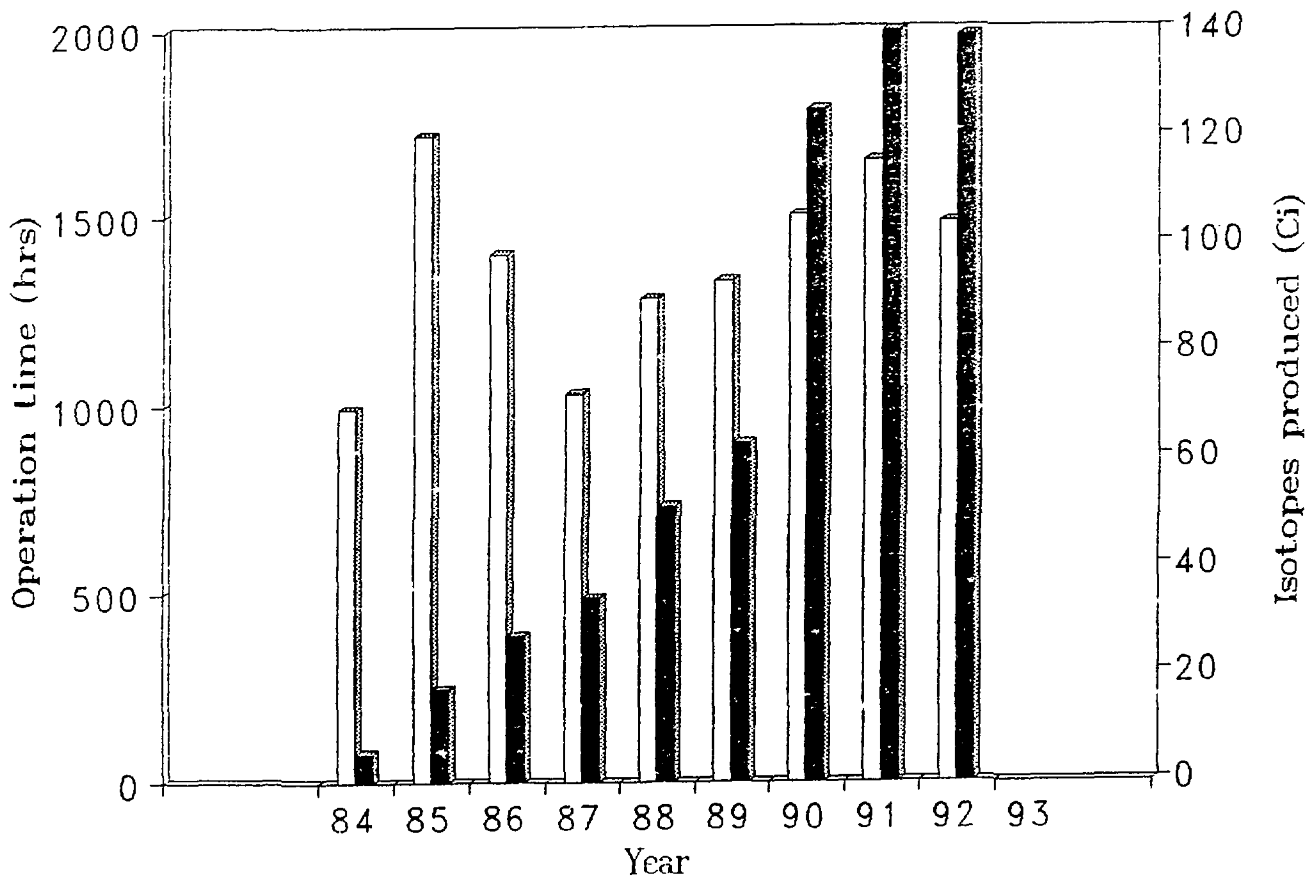


Fig. 1c Fuel surface temperature distribution

Fig. 1b Fuel element
type VKR-M2

Fig. 3 Reactor operation and isotope production statistics



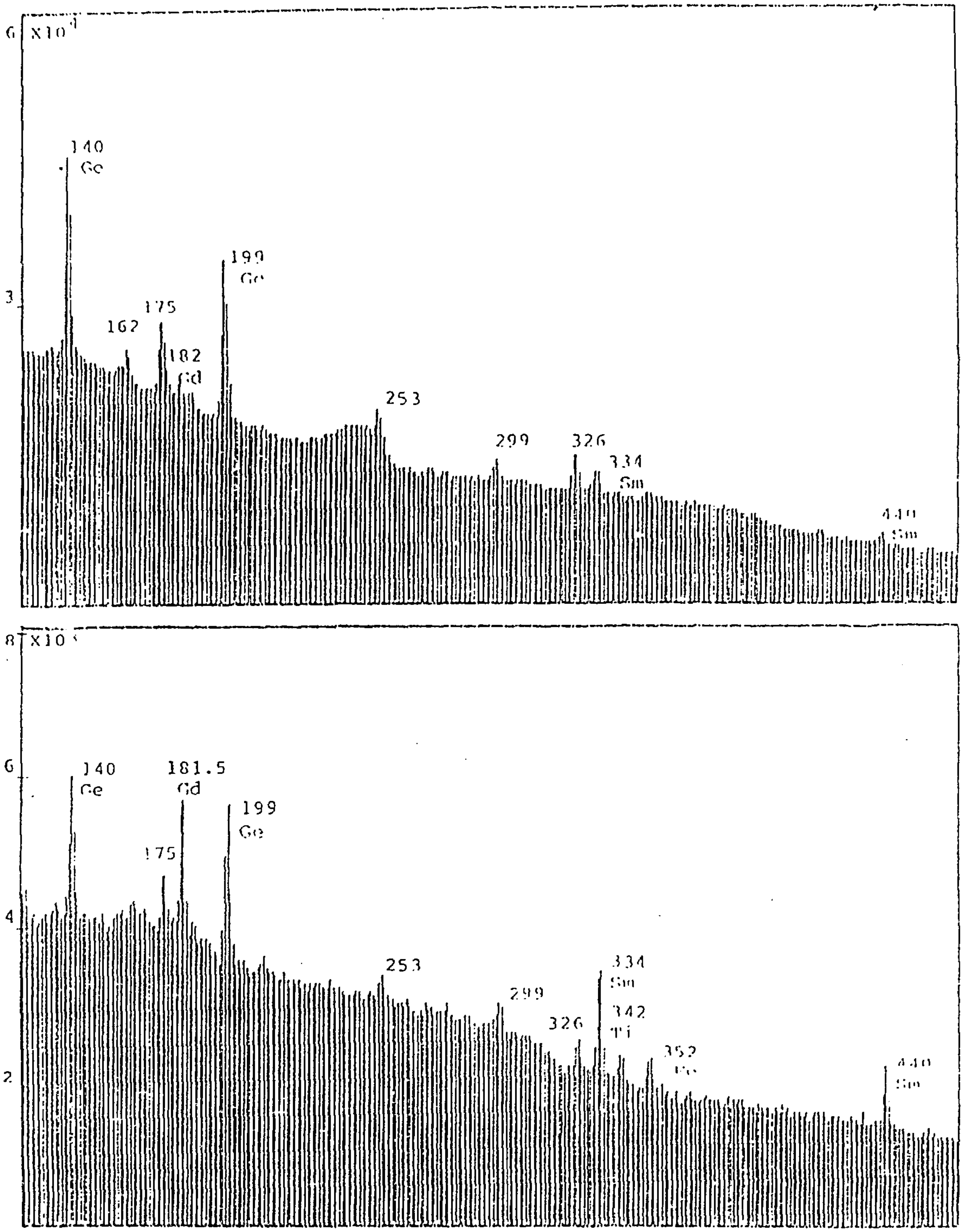


Fig. 4: . Portions of the prompt gamma spectra of a rock sample containing REE irradiated by the neutron beams (a) - without the filter; (b) - with a 60 cm long silicon filter.

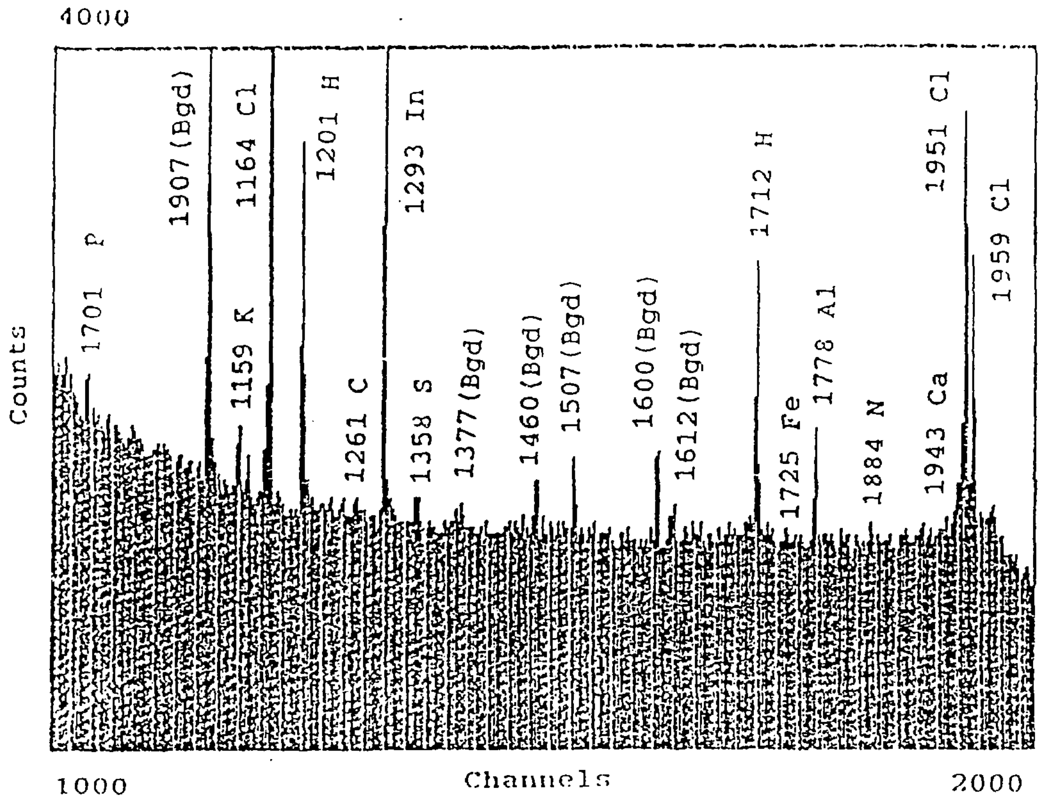


Fig.5a : A portion of the prompt gamma spectrum of the Bowen's Kale sample

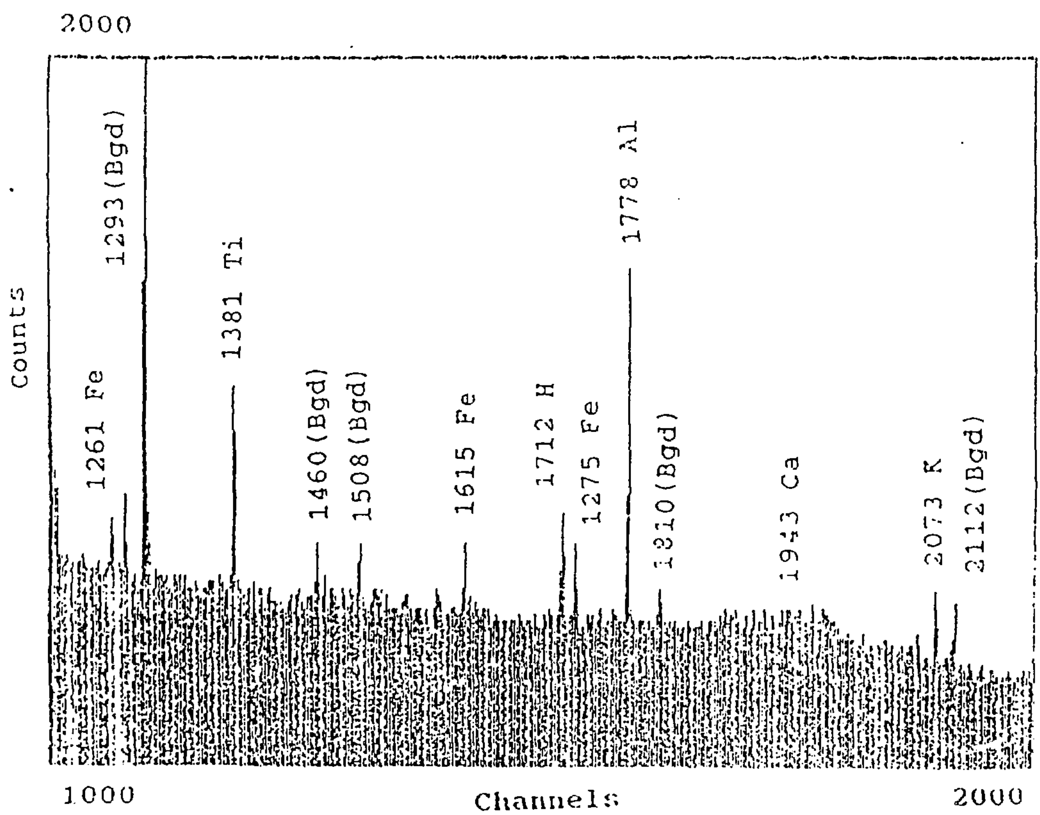
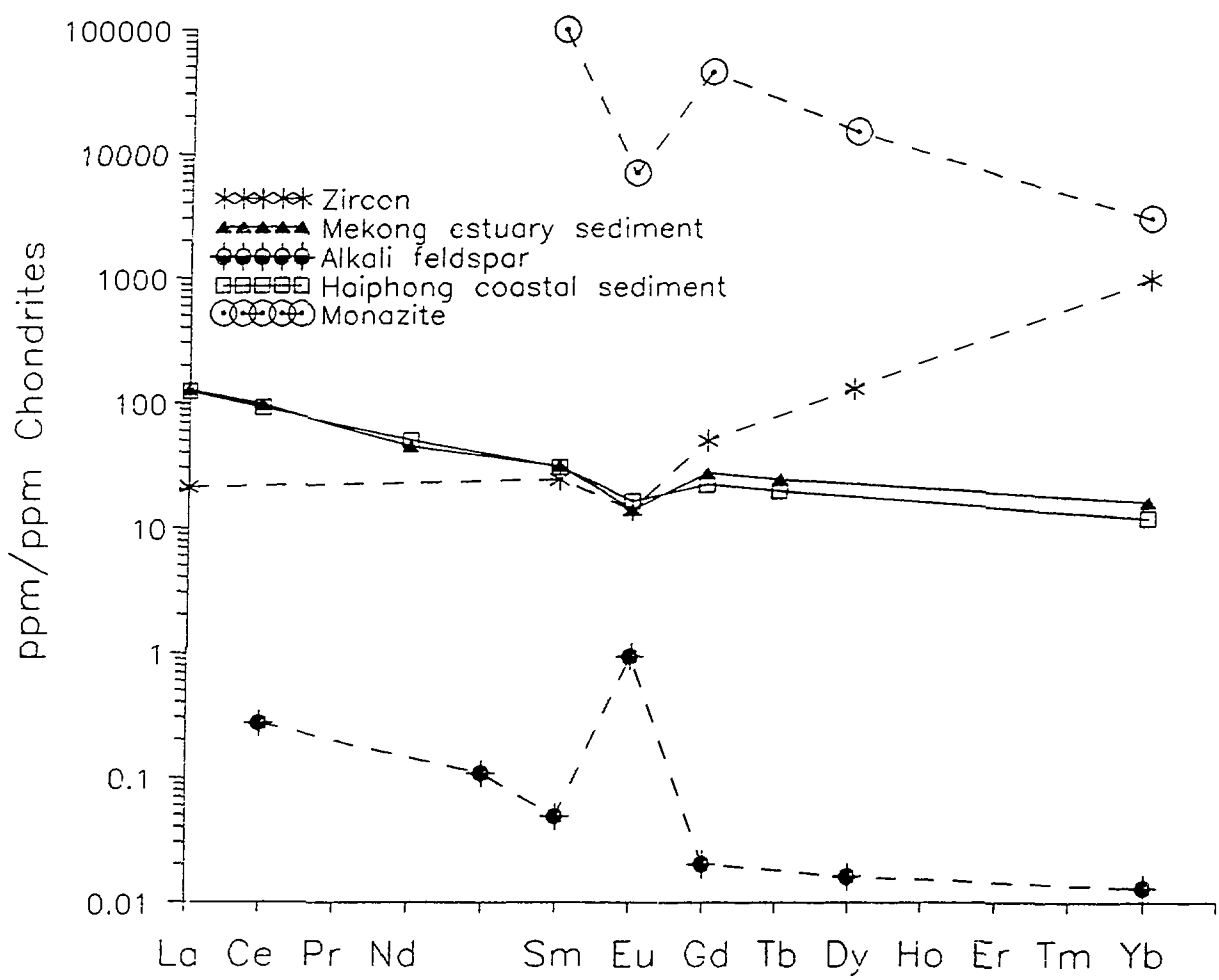


Fig.5b : A portion of the prompt gamma spectrum of the SL-1 sediment sample

Fig. 6 Rare-earth element patterns. Data for zircon, akali feldspar and monazite are taken from : S. R. Taylor and S. M. McLennan, The Continental Crust: its Composition and evolution, Blackwell Scientific Publications, 1985.



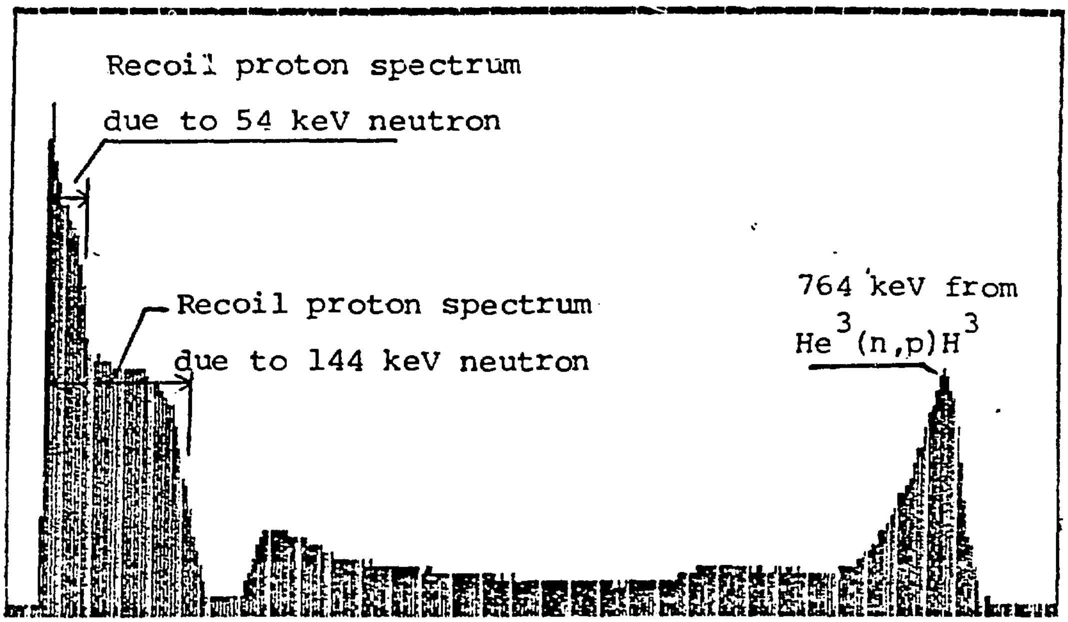


Fig. 7 . *Total energy spectrum from recoil proton detector.*

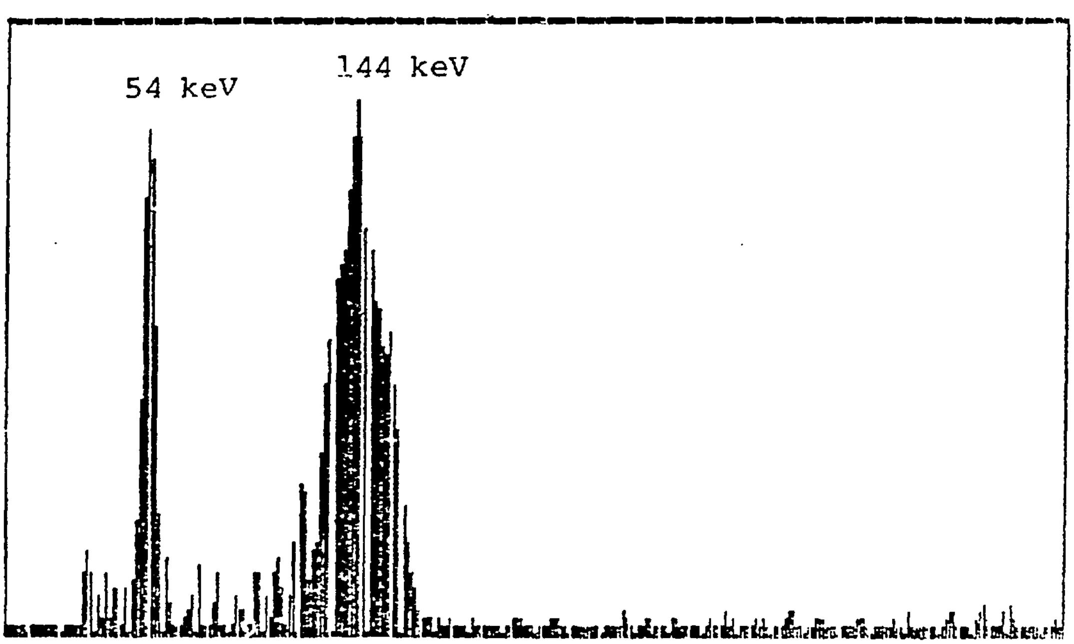


Fig. 8 . *Neutron beam differential spectrum.*

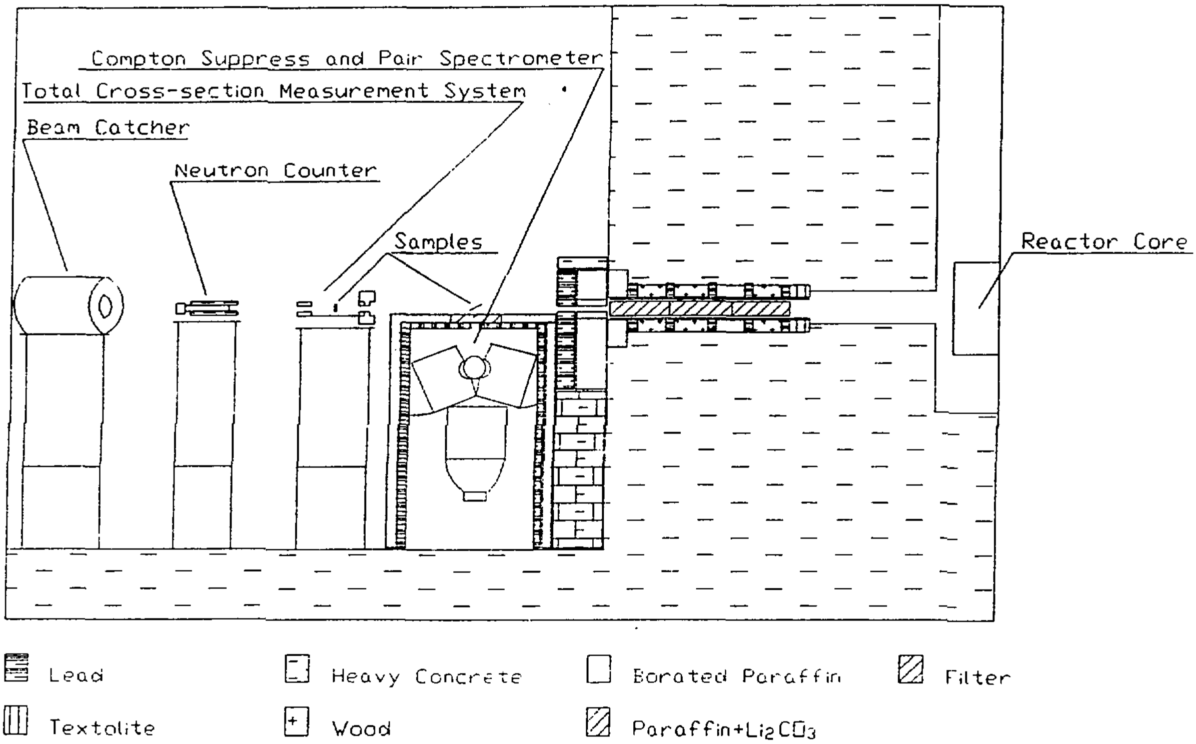


Fig. 9 Experimental setup at the piercing beam port No.4 of Dalat nuclear reactor.

Fig.10 Thickness dependence of the experimental cross−section
(1)− 55 keV, (2)− 144 keV