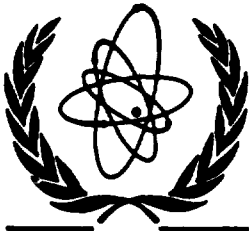


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**STATUS REPORT OF THE PROGRAM ON  
NEUTRON BEAM UTILIZATION  
AT THE DALAT NUCLEAR RESEARCH REACTOR**

Vuong Huu Tan  
Nuclear Data Sector, Nuclear Research Institute  
Dalat, Vietnam

August 1996

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**ABSTRACT**

The thermal reactor is an intense source not only of thermal neutrons, but also intermediate as well as fast neutrons. Using the filtered neutron beam technique at steady state atomic reactor allows receiving the neutrons in the intermediate energy region with the most available intense flux at present. In the near time at the Dalat reactor the filtered neutron beam technique has been applied. Utilization of the filtered neutron beams in basic and applied researches has been an important activity of the Dalat Nuclear Research Institute (DNRI). This report presents some relevant characteristics of the filtered neutron beams and their utilization in nuclear data measurements, neutron capture gamma ray spectroscopy, neutron radiography, neutron dose calibration and other applications.

**I. INTRODUCTION**

The research reactor IVV-9 of the Dalat Nuclear Research Institute (DNRI) after the completion of its renovation and upgrading from the previous TRIGA reactor has been operating at its power level of 500 kW since 1984 [1]. From that time the research program on effective utilization of horizontal experimental channels of the reactor was conducted. For this purpose investigations on physical characteristics of the reactor; neutron spectra and fluxes at these channels; safety conditions in their exploitation have been carried out. However, before 1988 the reactor was mainly used for isotope production and neutron activation analysis

and no beam channels were utilized. From 1988 the filtered thermal neutron beam at the tangential channel No.3 was extracted using a single crystal silicon filter and used for prompt gamma neutron activation analysis (PGNAA), neutron radiography (NR) and transmission experiments (TE), In 1990 we began the program for extracting filtered quasi-monoenergetic keV neutron beams at the piercing horizontal channel No.4 using the neutron filter technique. Utilization of these filtered neutron beams in nuclear data measurements and applied researches has been carried out.

**Table 1**

*Main characteristics of the filtered thermal neutron beam*

Composition of the filter assemblies	$\phi(\text{th})$ n.cm <sup>2</sup> .s <sup>-1</sup>	$\phi(E > 1\text{MeV})$ n.cm <sup>-2</sup> .s <sup>-1</sup>	R(Cd/Au)	I(gamma) (R/h)
No filter	5.8x10 <sup>7</sup>	4.5x10 <sup>5</sup>	5	4
80 mm C + 50mm Pb	1.2x10 <sup>7</sup>	3.5x10 <sup>4</sup>	12	1.8
80 mm C + 100 mm Pb	5.5x10 <sup>6</sup>	1.2x 10 <sup>4</sup>	19.5	0.8
Comp. No 2 +366 mm Si	3.5x10 <sup>6</sup>	n x 10 <sup>1</sup>	77.5	0.22

## II. THE FILTERED NEUTRON BEAMS AT THE DALAT REACTOR

Up to now at the Dalat reactor two horizontal experimental channels were utilized. On the tangential channel the filtered thermal neutron beam was extracted, its characteristics with some filter assemblies are shown in Table 1 [2].

In the piercing channel No.4 some kinds of neutron filters such as Si, Al, Fe, S, Ti, B have been installed to produce quasi-monoenergetic neutrons of 24 keV, 25 keV, 55 keV, 75 keV, 144 keV as well as thermal neutrons. The fluxes and other characteristics of these filtered neutron beams are given in Table 2 [3].

### III. UTILIZATION OF THE FILTERED NEUTRON BEAMS

#### 3.1. Neutron Physics and Nuclear Data [3]

In the keV energy region filtered beams are the most intense neutron sources which can be used to obtain neutron data for reactors and other applications. The following experiments have been carried out at the Dalat reactor:

- Total neutron cross section measurements for  $^{238}\text{U}$ , Fe, Al, Pb on filtered neutron beams of 144 keV, 55 keV, 25 keV and evaluation of average neutron resonance parameters from experimental data.

- Gamma ray spectra from neutron capture reaction of some reactor materials on filtered neutron beams of 55 keV and 144 keV.

- Average neutron radiative capture cross sections of  $^{238}\text{U}$  for 55 keV and 144 keV neutrons.

- Isomeric ratio of  $^{82\text{m,g}}\text{Br}$  created in the reaction  $^{81}\text{Br}(n,\gamma)^{82}\text{Br}$  for 55 keV and 144 keV neutrons.

- Other investigations such as average resonance capture measurements,  $(n,2\gamma)$  reaction, etc.

**Table 2**

*The characteristics of filtered neutron beams at the channel No. 4*

Neutron	Filter combination	$\Phi(\text{n}/\text{cm}^2.\text{s})$	$R_{\text{cd}}$ or FWHM
Thermal	98cm Si + 10cm Ti + 35g/cm <sup>2</sup> S	$1.8 \times 10^7$	143
144 keV	98cm Si + 10cm Ti + 0.2g/cm <sup>2</sup> B <sup>10</sup>	$1.2 \times 10^7$	22 KeV
55 KeV	98cm Si + 35g/cm <sup>2</sup> S + 0.2g/cm <sup>2</sup> B <sup>10</sup>	$4.0 \times 10^6$	8 KeV
25 KeV	102.3cm Al + 0.2g/cm <sup>2</sup> B <sup>10</sup>	$1.2 \times 10^6$	
24 KeV	20cm Fe + 20cm Al + 25g/cm <sup>2</sup> S + 0.2g/cm <sup>2</sup> B <sup>10</sup>	$1.0 \times 10^6$	
75 KeV	45g/cm <sup>2</sup> S + 0.2g/cm <sup>2</sup> B <sup>10</sup>	$1.1 \times 10^6$	

### 3.2. *Applied Neutron Capture Gamma Ray Spectroscopy [2,3]*

- Design and arrangement of the Compton-suppressed and pair spectrometer for neutron in-beam researches.
- Development of prompt gamma neutron activation analysis (PGNAA) technique using the filtered thermal neutron beam in combination with the Compton-suppressed spectrometer for analyzing Fe, Co, Ni, C in steel samples; Si, Ca, Fe, Al in cement samples; Gd, Sm, Nd in uranium ores; Sm, Gd in rare earth ores; etc.
- Utilization of the PGNAA method for investigating the correlation between boron and tin concentrations in geological samples as a geochemical indication in exploration and assessment of natural mineral resources; analyzing boron in sediment and sand samples to complement reference data for river samples.
- Utilization of the PGNAA method for comparing boron concentrations in natural ginsengs and in callus ginsengs obtained by the plant tissue culture technique to choose the suitable culture medium, the quantity of trace elements needed to add as well as to apply some relevant procedure of tissue culture process; for determining the nitrogen concentration in various categories of animal food.
- Development of the PGNAA method for in-vivo activation analysis of essential elements Ca, Cl, N and P in the whole body and of the toxic elements Cd, Hg in a body organ for medical diagnosis of various diseases.
- Development of the spectrometer of summation of amplitudes of coinciding pulses for  $(n,2\gamma)$  reaction research and for measuring activity of activated elements with high possibility of cascade transitions.

### 3.3. *Other Applications [2,3]*

- Development of neutron radiography method as a NDT technique for various kinds of objects such as electrical and electronic products, mechanical devices, etc.
- Utilization of the filtered neutron beams for research on estimation of the radiobiological effectiveness (RBE) of different energy neutrons and on calibration of neutron dosimeters.
- Utilization of transmission measurements on the thermal neutron beam for determining thermal neutron absorption cross section of samples from drillholes in oil and gas exploitation and for determining boron content distribution along glass tubes used in the electric fluorescent lamp industry.
- In the world neutron scattering techniques have been used very effectively for the structure analysis of superconductors, magnetic materials, actinides, monolayer molecules, martensite alloys, ceramics,...; and for studying various excitations in the condensed matter such as spin-wave of heavy fermion system,

magnetic scattering and photon of the pseudo two-dimensional materials, lattice dynamics of super ionic conductors and martensite alloys, ... In the framework of the program on neutron beam utilization of the Dalat Nuclear Research Reactor we have proposed an IAEA Project on the Small Angular Neutron Scattering (SANS) Facility for the period 1996-2000. The SANS facility will be effectively used in research of molecular biology; for a structural analysis of homopolymer in block copolymer microdomains which is very interesting problem in morphology of the polymer mixtures and for studying microstructure of Co-Cr thin films which is a promising material for magnetic recording with higher recording density, etc.

#### **IV CONCLUSION AND DISCUSSION**

The neutron filter technique has been used at the Dalat reactor and produced quasi-monoenergetic neutron beams which have a relatively high neutron flux density despite the low reactor power and a low photon contribution. These beams and other scientific equipment have been used for research on neutron physics and nuclear data, and for applications in sciences and life. Many new investigations can be conducted on the filtered neutron beams such as nuclear structure research, boron neutron capture therapy, etc. In order to improve the quality of our results and to open new research the facility and spectrometers have to be upgraded and equipped. In conclusion we can say that beside research and applications our filtered neutron beams, research equipment and methods are basic for training scientific and engineering personnel at the service of the future National Atomic Power Program.

#### **ACKNOWLEDGEMENTS**

The author and the staff of Nuclear Data Sector (Applied Nuclear Physics Dept., DNRI) are grateful to Prof. Pham Duy Hien and Dr. Tran Ha Anh for their continuous interest and valuable advices in research on utilization of the filtered neutron beam at the Dalat reactor. We would like to thank the Dalat Nuclear Research Institute, Vietnam National Research Programs on Nuclear Science and Technology 50A, KC-09 and for Fundamental Sciences for the financial support in development and utilization of the filtered neutron beams at Nuclear Data Sector (Applied Nuclear Physics Department, DNRI). The fruitful cooperation of Drs Murzin A.V. and Litvinski L.L. from Kiev Nuclear research Institute (Ukraine) in the field of neutron filters is highly appreciated.



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## APPENDIX 1

### RESEARCH CONTRACTS OF THE PROGRAM ON NEUTRON BEAM UTILIZATION AT DNRI

1. Exploitation of the Dalat Nuclear Research Reactor for the period 1984-1985  
Chief Scientific Investigator: Prof. Pham Duy Hien
2. Exploitation of the Dalat Nuclear Research Reactor for the period 1986-1990  
Chief Scientific Investigator: Prof. Pham Duy Hien
3. Utilization of Horizontal Experimental Channels of the Dalat Nuclear Research Reactor for the period 1991-1995  
Chief Scientific Investigator: Dr. Vuong Huu Tan
4. Exploitation of Neutron Beams at the Dalat Nuclear Research Reactor for the period 1996-2000  
Chief Scientific Investigator: Dr. Vuong Huu Tan

## APPENDIX 2

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- on Research Reactor Utilization, Lucas Heights, Sydney, Australia, 26 April to 13 May 1994.
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