

# **„Eugene Wigner” Training Course for Reactor Physics Experiments, 2004**

## **General**

Supported by the 5th Framework Programme of the European Commission, the European Nuclear Engineering Network (ENEN) is preparing the future European Nuclear Education schemes, degrees and requirements. To fully utilise the benefits of international co-operation and to promote the knowledge of students in nuclear engineering a *training course* is being organised **starting at 27 April 2004**.

The language of the course is English. The main emphasis of the course is to *perform reactor physics experiments* on three different research- and training reactors in three different cities (Vienna, Prague, Budapest). The experimental work is preceded by theoretical lectures aiming to prepare the students for the experiments (Bratislava). The students' work will be evaluated, and upon success the students will get a certificate. The finally accepted credit (ECTS) value will be determined by the students' home university. The ENEN-recommended value is between 6 and 8 ECTS. The detailed description of the course will be given below.

This course is an upgraded result of a long-standing similar cooperation between the above-mentioned four institutions in Vienna, Prague, Bratislava and Budapest. The participation was opened to students of any European university in 2003, where 20 students of different countries and universities have already attended the course. The quality control and accreditation of ENEN assures that the acquired knowledge of the participants will fulfil the requirements of the European Nuclear Education and fits in the European ECTS system.

## **Participation**

The course is open to undergraduate and graduate students of *any European university*. However, basic knowledge of reactor physics theory is requested, and this knowledge has to be attested by a professor of the student's home university. The number of participants is limited to 20. The application is subject of a selection procedure, and may be refused, if the course is already fully booked, or if the selection committee decides so, due to any reason.

The application deadline is **28. February 2004** (as post stamp). The selection will be made till 15. March 2004. Each applicant will be informed about his/her acceptance and about the details of the payment (see below). The deadline for the payment is 2. April 2004.

The students wishing to participate should fill in the Application Form (Appendix I), provide the necessary attachments, and send them to the following address:

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### Cost of the course:

The cost of the course is **1800 €** which includes

- the tuition fee (lectures, technical tours and utilization of 3 research reactors);
- the textbooks;
- the accommodation during the time of the course;
- the welcome dinner;
- the transport tickets between the four countries during the course
- the transport tickets inside the cities from the accommodation place to the experimental facilities and back.

These are all organised centrally.

**Not** included are:

- the travel to the “starting place” (Bratislava, Slovak Republic) and back to his/her home country
- the cost of the meals (with the exception of the welcome dinner);
- visa (if necessary).

These have to be arranged and paid individually.

**Important note:** The organizers of the course do not accept liability for the payment of any cost or compensation that may arise from damage to or loss of personal property, or from illness, injury, disability or death of a participant while he/she is traveling to and from or attending the course. The participants are **well advised to take out insurance** against these risks.

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## DETAILED DESCRIPTION OF THE COURSE

### 1. Overall time-table

The participants will form 4 groups (denoted by A,B,C,D in the followings). On the first week all groups follow the preparatory theoretical courses in Bratislava, and a visit to an operating NPP and radioactive waste facility nearby. The second and third weeks the groups rotate between Vienna, Prague and Budapest, and perform the reactor-experiments. The following table shows it summarised:

Institute	27.04	28.04-29.04	30.04	01.05-02.05	03.05-07.05	08.05-09.05	10.05-14.05	15.05		
SUT Bratislava	Arrival, Opening	A,B,C,D	Visit to NPP	free program, travel	-	free program, travel	-	-		
INT Budapest	-	-	-		A,B		C,D	-		
AI Vienna	-	-	-		C		D	A	B	Evaluation
CVUT Prague	-	-	-		D		C	B	A	-

Groups C and D travel between Vienna and Prague on Wednesday (05.05), groups A and B do the same on Wednesday (12.05).

## **2. The theoretical courses:**

The theoretical lectures will be held in the lecture halls of Slovak University of Technology, Bratislava /STUB/ (Slovak Republic).

### ***2.1 Survey of research reactors and associated systems***

(3 hours lecture, Prof. Villa)

Survey of research reactors' use (overview, reactor utilisation in physics, chemistry, medicine, biology, training purposes and industrial applications)

Selected systems and components

- Fuel elements for research reactors
- Safety and control systems (including control rod and neutron detectors)
- Cooling and ventilation systems
- Experimental facilities

### ***2.2 Data evaluation techniques (related to the practical exercises)***

(3 hours lecture, Prof. Z. Szatmáry)

- Principles of parameter estimation
- Maximum likelihood method, the method of least squares
- Some illustrative examples
- Solution of the least squares equations
- Statistical properties of the estimated parameters (expectation value, standard deviation, etc.)
- Confidence intervals
- Goodness of fit tests

### ***2.3 Radiation protection and dosimetry***

(3 hours lecture, Prof. Zagyvai)

- Physical and biological dose – definitions, units, interpretations
- Harmful effects of ionizing radiations on human body – deterministic and stochastic effects
- Structure of health physics regulations (laws, decrees, guidelines, standards) for limiting the emission and immission of radioactivity
- Sources of radioactivity in the environment – natural and artificial radionuclides, management of radioactive wastes
- Measurement techniques associated with the determination of external and internal dose
- Migration of radioactivity in environmental media, role of environmental monitoring
- Activity of health physics services at workplaces

### ***2.4 Detectors of radiation***

(2 hours lecture, Prof. M. Miglierini)

- Principles of detection.
- Gas-filled detectors. Ionisation chambers, proportional-, GM-counters.
- Scintillation detectors. Scintillators, photomultipliers.
- Semiconductor detectors.
- Detectors of neutrons.

## **2.5 Instrumentation for nuclear measurements**

(2 hours lecture, Dr. Sz. Czifrus)

- Single-channel analyser
- Multichannel analyser
- Multiscaler mode
- Differential- and integral discriminators
- Coincidence devices

## **2.6 Nuclear measuring methods**

(2 hours lecture, Dr. Sz. Czifrus)

- Alpha spectrometry
- Gamma spectroscopy (energy calibration, efficiency, evaluation of spectra)
- Neutron activation analysis

## **2.7 Nuclear Safety**

(2 hours lecture, Prof. Slugeò)

- General information about nuclear safety
- Defence in depth (accident prevention and mitigation)
- Safety culture
- Legislative rules
- Physical protection
- Safeguards at research reactors
- Application of nuclear safety at research reactors
- Emergency preparedness

Time-table of the Bratislava-part:

27 <sup>th</sup> April (Tuesday)	14:00 -	Arrival, occupying accommodation
	19:00	Opening ceremony, common dinner
28 <sup>th</sup> April (Wednesday)	08:00 – 16:30	Theoretical lectures (12:00-13:00 lunch-break)
29 <sup>th</sup> April (Thursday)	08:00 – 16:30	Theoretical lectures (12:00-13:00 lunch-break)
30 <sup>th</sup> April (Friday)	08:00 – 16:30	Technical tour to Bohunice NPP and Radwaste Storage facility
1 <sup>st</sup> May (Saturday)		Free program (excursion, barbecue, etc.)

### **3. Reactor experiments in Budapest:**

The reactor experiments will be performed at the 100 kW training reactor of the Institute of Nuclear Techniques /INT/ of the Budapest University of Technology and Economics /BUTE/ (Budapest, Hungary).

#### ***3.1 Neutron activation analysis***

Analysis of environmental samples by comparison with standard reference materials.

#### ***3.2 Measurement of delayed neutron parameters and determination of uranium concentration***

Half lives and relative intensities of some delayed neutron groups are determined, then the  $^{235}\text{U}$  concentration of a depleted uranium sample is estimated by comparing the delayed neutron intensities in the sample of interest and in uranium standard.

#### ***3.3 Exercise on reactor operation and control***

The students learn and practice the operation and control of the reactor at different power levels.

#### ***3.4 Determination of the diffusion length of thermal neutrons in graphite***

The measurement is performed in the thermal column of the reactor, by activation method.

#### ***3.5 Measurement of the reactivity importance of neutron absorbers***

The reactivity importance of a perturbation is studied as a function of its position in the active core.

**Time-table** of the experiments at INT-BUTE from 5 to 9 May, and from 12 to 16 May 2003 for the two groups (Gr.1, Gr.2) of students.

	<b>Monday,</b> 3 (10) May	<b>Tuesday</b> 4 (11) May	<b>Wednesday</b> 5 (12) May	<b>Thursday</b> 6 (13) May	<b>Friday</b> 7 (14) May
8.30- 12.30 am.	<b>Gr.1:</b> <i>Delayed neutrons...(3.2)</i> <b>Gr.2:</b> <i>Reactor operation (3.3)</i>	<b>Gr.1:</b> (10:00-13:30) <i>n-activ. analysis (3.1)</i> <b>Gr.2:</b> <i>Reactivity importance...(3.5)</i>	<b>Gr.1:</b> <i>Reactor operation (3.3)</i> <b>Gr.2:</b> <i>Diffusion length...(3.4)</i>	<b>Gr.1:</b> <i>Diffusion length...(3.4)</i> <b>Gr.2:</b> <i>Delayed neutrons...(3.2)</i>	<b>Gr.1:</b> <i>Reactivity importance...(3.5)</i> <b>Gr.2:</b> (10:00-13:30) <i>n-activ. analysis (3.1)</i>
14.00 - 17.00 pm.	<b>Gr.2,Gr.1:</b> <i>Preparation and evaluation of the report</i>	<b>Gr.2,Gr.1:</b> <i>Preparation and evaluation of the report</i>	<b>Gr.2,Gr.1:</b> <i>Preparation and evaluation of the report</i>	<b>Gr.2,Gr.1:</b> <i>Preparation and evaluation of the report</i>	<b>Gr.2,Gr.1:</b> <i>Preparation and evaluation of the report</i>

#### **4. The reactor experiments in Vienna:**

The reactor experiments will be performed at the Triga Reactor Facility of the Atominstitut der Österreichischen Universitäten (Vienna, Austria).

##### ***4.1 Thermal neutron flux measurement:***

Thin Au foils are irradiated in the TRIGA core at 10 W both Cd-covered and uncovered in different radial and axial positions. The radial and axial neutron flux distribution is determined from these Cd-difference measurements.

##### ***4.2 Influence of void coefficient on reactor power***

At 10 W reactor power a small container with different air volumes is pulled axially through the reactor core while the reactor is in automatic operation mode. The influence of volume and position in the core on reactivity is determined.

##### ***4.3 Critical experiment***

Ten fuel elements are removed from the reactor core and consecutively reloaded. The neutron count rate is measured after each step. At each step measurements are performed with all control rods up and then down. Criticality is reached with all control rods up after reloading of five fuel elements.

##### ***4.4 Determination of the neutron absorption cross section according to the danger coefficient method***

After reactivity calibration of the reactor with a known absorber, several unknown materials are inserted in the same core position. From the reactivity response of the reactor conclusions are made on the absorption cross section of the unknown materials.

##### ***4.5 Reactivity values of fuel elements in different core positions***

While the reactor is on automatic control with 10 W, one fuel element is removed from each of the five fuel ring positions. The movement of the regulating rod compensates the loss of reactivity. From the rod position difference and using the rod calibration curve the reactivity value of the fuel element in different core positions can be determined.

##### ***4.6 Reactor power calibration and temperature coefficient of reactivity***

The reactor is operated at 10 W, rod positions, water- and fuel temperature is noted, then the reactor power is raised to 100 kW, again the values are noted. From the difference in rod position and fuel temperature the fuel temperature coefficient can be determined. Then the reactor is operated for 90 min only with convection cooling and the increase of water temperature is monitored. Comparing the temperature increase with the value from a previous calibration the thermal reactor power can be determined.

##### ***4.7 Demonstration of a prompt critical power excursion (requires only a short time)***

Due to the strong negative temperature coefficient of reactivity TRIGA reactors allow prompt critical excursion to 1000 times the normal power mode without any damage to the core. This is demonstrated using a pneumatic rod which is removed promptly from the critical core, typical power levels of 250 to 300 MW are reached for a time period of about 40 ms.

Each group of students perform these experiments during two days (Monday-Tuesday, and Thursday-Friday respectively, see the overall time-table).

	<b>Monday (Thursday)</b>	<b>Tuesday (Friday)</b>
8.00 am -5.00 pm.	Flux measurement (4.1), n-absorption cross-section determination (4.4), Reactivity values (4.5)	Critical experiment (4.3), Void coefficient (4.2), Power calibration (4.6), Pulse demonstration (4.7)

## **5. The reactor experiments in Prague:**

The reactor experiments will be performed at the research reactor facility of the Czech Technical University in Prague /CTU/ (Czech Republic).

### ***5.1 Properties of neutron detectors for nuclear reactor control***

Neutron gas detectors for the experiments at the VR-1 reactor, dead-time and differential characteristic of the neutron detector SNM-10, measuring the differential characteristic and setting the optimum of the discrimination level, measuring the dead-time by using the two-source and maximum rate methods

### ***5.2 Measurements of reactivity by various methods (source jerk, rod drop, Greenspan)***

Introduction into the measurements of reactivity, definition and units, reactivity measurements in the subcritical state by Source jerk method (using quickly moveable external neutron source), reactivity measurements in the supercritical reactor by Positive period method, Rod Drop method (control rod worth measurement)

### ***5.3 Calibration of control rods***

Introduction into the calibration of control rods, differential and integral characteristic of the control rod, Inverse rate method, Mutual calibration method

### ***5.4 Study of nuclear reactor dynamics***

Mathematical model of the research reactor dynamics, study of the reactor response to the negative / positive / periodical reactivity change, study of the influence of the bubbly boiling to the VR-1 reactor operation, simulation of the selected operating statuses of the power reactor of the WWER type: approaching to the critical state with modeling of the dilution of boric-acid concentration and change the operating group of the control rods

### ***5.5 Start-up and operation of the VR-1 reactor***

The start-up of the reactor, the operation of it in manual as well as automatic mode, the changes of the power (increasing, decreasing), the shutdown of the reactor for various reasons can be demonstrated, and various inspections and checks of the digital control and safety system

***5.6 Digital control systems of research reactors*** Introduction into the digital control and safety system of the VR-1 reactor is based on the microprocessor with the relay emergency chain, short description of the main parts of the digital control and safety system: measuring, safety and communication channels, the peripheral channel, control desk

Each group of students perform these experiments during two days (Monday-Tuesday, and Thursday-Friday respectively, see the overall time-table).

	<b>Monday (Thursday)</b>	<b>Tuesday (Friday)</b>
9.00 am - 16.00 pm.	Neutron detectors (5.1), Digital control systems (5.6) Reactor operation (5.5)	Reactivity measurement (5.2), Control rod calibration (5.3), Reactor dynamics (5.4)

**APPLICATION FORM****Parameters of the home university**

Univ. name:.....

Responsible person's name and title:.....

Mailing address:.....

Tel:..... Fax:.....

**Applicants data**

Name:..... First name:.....

Place and date of birth:.....

Mailing address:.....

Tel:..... Fax:.....

Email:..... Univ. ID-code:.....

Hereby I apply for participation in the „Eugene Wigner Training Course on Reactor Physics Experiments 2004” organised on a European level, following the request of ENEN. I accept that my application is subject of a selection procedure, and may be refused, if the course is already fully booked, or if the selection committee decides so, due to any reason. I understand that my travels to the course and back, my insurances, and the acquisition of the necessary visa have to be arranged and paid individually if I will be selected for participation.

The followings are attached:

- 1) A Curriculum Vitae (English knowledge must be stated)
- 2) A list of courses followed during the university studies. A short description of the content of the following courses: mathematics, reactor physics and radiation protection.
- 3) A letter of recommendation signed by a responsible professor of the sending institute (preferably, but not necessary an ENEN participant). Your theoretical background in reactor physics should be explicitly mentioned in this letter.
- 4) A declaration stating the number of credits (ECTS) which will be acknowledged in the home university upon successful completion of the course (signed duly by a responsible professor of the home university)
- 5) A statement about my intention how the costs of my participation will be covered (own sources, home university, grant, fellowship, etc.).

Date.....

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signature