Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research

Pneumatic transport system REGATA-2 for automation of activation analysis at the IREN facility, FLNP JINR

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Introduction

The IREN facility at the Frank Laboratory of Neutron Physics (FLNP) of the Joint Institute for Nuclear Research (JINR) is used for experiments to determine elemental composition of various samples by neutron activation analysis (NAA). Pneumatic transport system (PTS) REGATA-2 was implemented to automate the delivery of containers with samples to the irradiation position and back.

Components of the REGATA-2 pneumatic transport system

1.

1. One of the PTS's component is a box with a loading and unloading station. A polyethylene transport channel with a length of about 40 meters starts from the box.

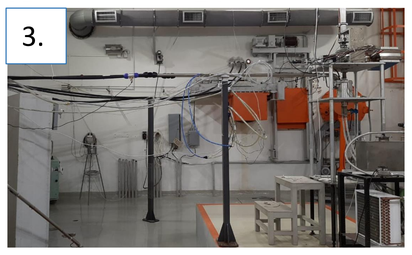
2. The transport channel divides into three channels using splitters. The first splitter branches off the pipeline leading to the horizontal irradiation channel G. The second one separates the vertical channels N1 and N2.

3. In the target hall three transport channels are fixed on supporting columns. The transport channels end with irradiation channels made of stainless steel.

4. The irradiation channels are fixed on an adjustable structure called a truss close to the neutron moderator. The irradiation position is located 5 cm below the top of the moderator in the point of maximum energy release.

2.

3.

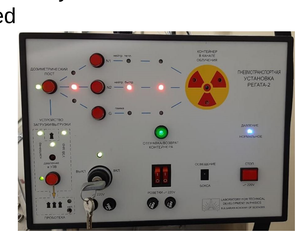


4.

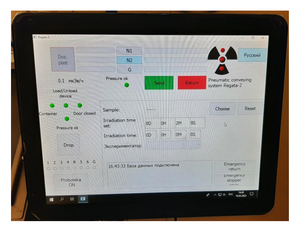
Modernization

1. Solving the problem with the container presence sensor at the irradiation position.
2. Solving the problem of overheating for the exhaust solenoid valve.
3. Replacement of the old electromechanical control panel with a modern touch control panel.
4. Information exchange with the neutron activation analysis database was implemented

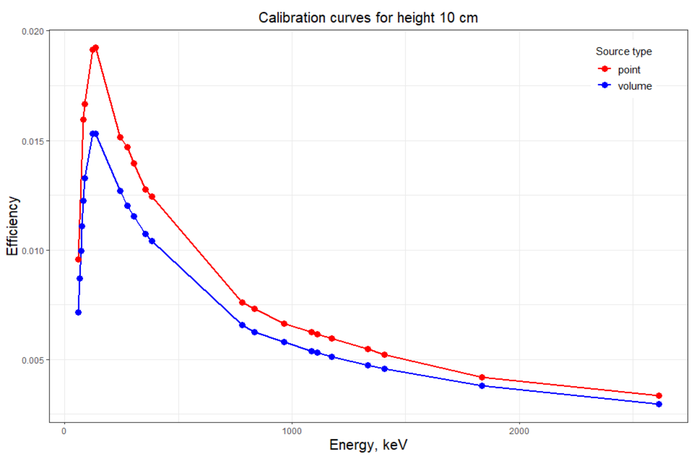
Old control panel



New touchscreen

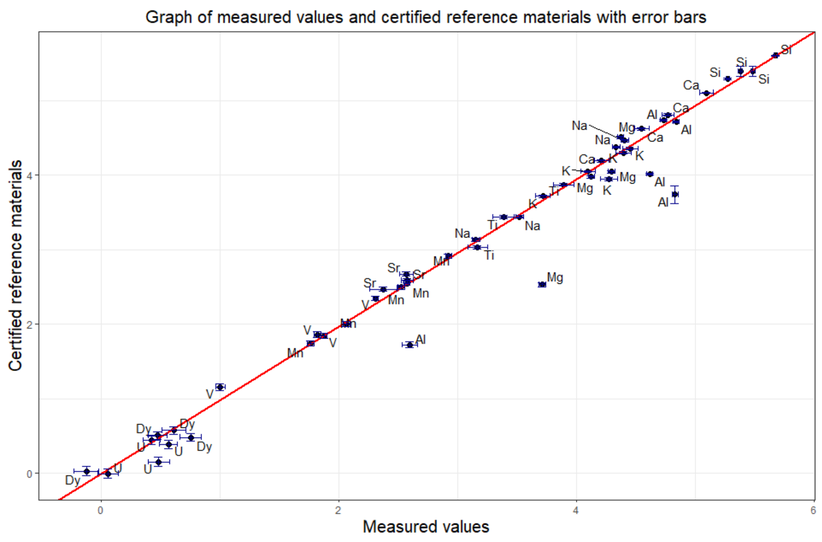


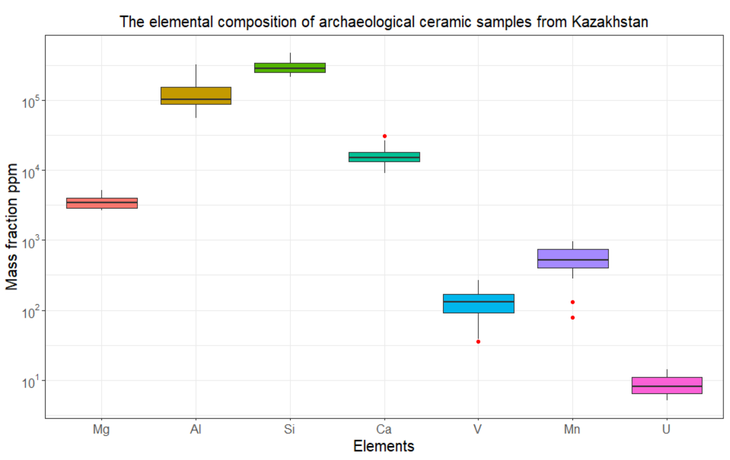
Neutron activation analysis



The ANGLE software was used for efficiency calibration transfer from gamma rays point source to volumetric one.
The figure shows calibration curves. The blue curve demonstrates the efficiency calibration for a point source for a 10 cm height above the detector surface. Red color – the efficiency calibration for a volumetric source for the same height. Calculation was made with following parameters: type of sample – soil, sample height – 15 mm, height of polyethylene container – 42.5 mm, inner and outer container diameters – 17.4 and 24 mm.

IAEA proficiency test samples were investigated using NAA. The obtained mass fractions showed good compliance with certified reference materials. However, certain samples exhibit deviations in the mass fractions of two elements: Al and Mg. The causes that could have led to these discrepancies are being explored. Probably the mass fractions of these elements have changed due to long storage without appropriate conditions.





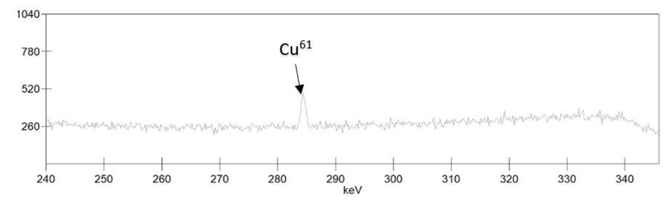
Investigations of ceramics samples found on the territory of Kazakhstan was carried out by short-lived isotopes. 17 samples, 4 standard samples and 2 flux monitors were irradiated sequentially for 40 minutes each. As a result, 7 elements were found. Earlier studies of the elemental composition by long-lived isotopes were carried out at the IBR-2 reactor with the same samples. So the present experiment significantly expanded information about elemental composition of ceramic artifacts.

Gamma activation analysis

The goal of the experiment was a qualitative elemental analysis using gamma activation.

The copper sample was irradiated. Lines from ^{61}Cu isotope were detected when analyzing the spectra.

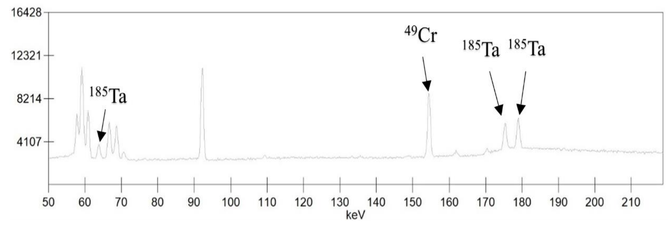
- $Cu^{63}(\gamma - 2n)\ Cu^{61}$



Irradiation results of the 50C standard			
Element	Mass fraction according to the passport,%	Isotopes	Detection with GAA
As	0.0225	-	
Cr	4.128	Cr^{49}	+
Cu	0.0792	-	
Mn	0.3417	Mn^{52m}, Mn^{56}	
Mo	0.0821	-	
N	0.0117	-	
Ni	0.0686	Ni^{57}	+
P	0.0222	-	
S	0.006	-	
Si	0.3102	Al^{29}	
Sn	0.0183	-	
V	1.158	V^{52}	
W	18.445	Ta^{185}	+

The 50C NIST standard reference material was irradiated. It is chips of tungsten, chromium, and vanadium steel. Peaks of several isotopes were detected, among which Ta^{185}, Cr^{49} and Ni^{57} can be confidently attributed to the results of gamma reactions.

- $W^{186}\ (\gamma - n, p)\ Ta^{185}$
- $Cr^{50}\ (\gamma - n)\ Cr^{49}$
- $Ni^{58}(\gamma - n)\ Ni^{57}$



The fragment of plaster from the Saviour Church on Nereditsa (12th century) was irradiated.

Peaks of several isotopes were detected, among which K^{43}, Fe^{53}, and Zr^{89m} isotopes can be confidently attributed to the results of gamma reactions.

- $Ca^{44}\ (\gamma - n, p)\ K^{43}$
- $Fe^{54}\ (\gamma - n)\ Fe^{53}$
- $Zr^{90}\ (\gamma - n)\ Zr^{89m}$

Experiment results for a plaster from the Saviour Church on Nereditsa		
Element	Isotopes	Detection with GAA
Fe	Fe^{53}	+
Al	Al^{29}	
Ca	K^{43}	+
Cs	Cs^{126}	
Sc	Sc^{47}	
Nd	Nd^{137}	
Zr	Zr^{89}	+
Co	Co^{56}, Co^{64}	
Zn	Zn^{75}	

Conclusions

1. REGATA-2 PTS was implemented at the IREN facility.
2. PTS has been modernized.
3. NAA experiments to determine the elemental composition of samples by both long-lived and short-lived isotopes with the half-life of approximately one minute or more were carried out using PTS.
4. The results of neutron activation analysis of IAEA proficiency tests samples demonstrate good convergence with the passport data.
5. Archaeological ceramic samples from Kazakhstan were studied by NAA method using PTS, which allowed to obtain data on the main macroelements.
6. The qualitative elemental analysis was carried out using gamma activation.

References

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