CALIBRATION EXPERIMENTS OF NEUTRON SOURCE IDENTIFICATION AND DETECTION IN SOIL

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A method of detection of neutron source in soil is proposed and proved in the present paper by means of registration of neutrons in wells drilled close to laying of the source, a fundamental efficiency of method is shown and preliminary calculation estimates are carried out. Experiment, carried out in November, 2001 within the borders of the present work was carried out in vitro using the constant Pu-Be neutron source.

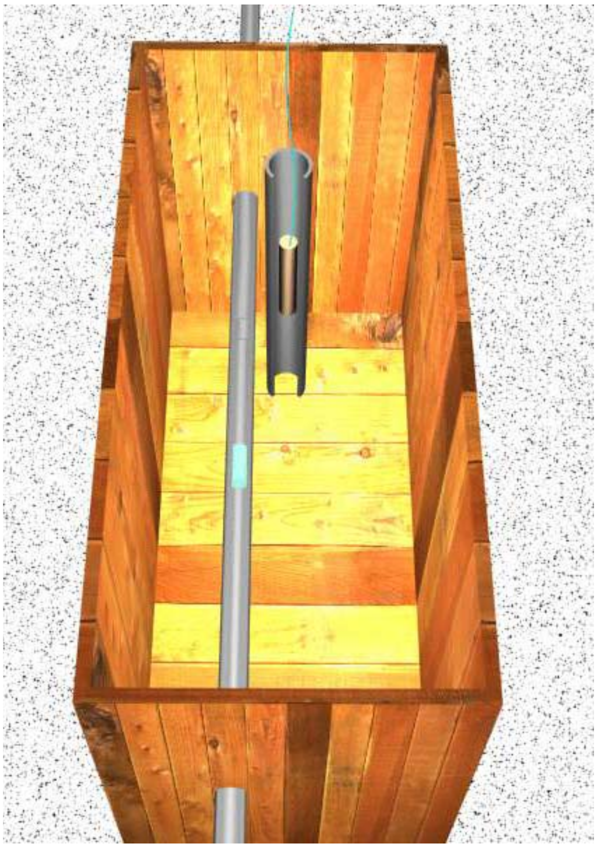

Fig.1. Appearance of empty measuring container. Location of SNM-18 detector in a borehole mock-up, both source pipes and construction with neutron source are shown.

Main goals of experiment:

1. Method of neutron source in soil detection sensitivity measurement.
2. Minimal source activity and maximal range at which the source can be surely detected estimation.
3. Obtaining of experimental results to verify calculational methods.
4. Investigation of influence of water contents, presence of heterogeneous bodies and neutron source spectrum on sensitivity of method.

Sand with investigated chemical composition was used as soil, its density was measured. Possibility of varying of sand humidity and modeling of heterogeneities (stone, cavities filled with water or air), changing neutron source location relatively detector were provided. Researches were carried out for “dry” sand containing 0.3 mass percents of water, “moist” and “wet” sand, containing 3.8 and 8.1 mass percents of water correspondingly.

Proposed construction may be considered as a benchmark assembly for the calculational codes verification.

1. Experimental conditions.

The experiment was carried out in vitro at the specially designed borehole mock-up.

Measuring container is filled with sand. Appearance of empty container with installed pipe – borehole mock-up and a device for moving of a neutron source is given at Fig.1. Borehole mock-up is a pipe of aluminum with outer diameter of 95mm and wall thickness of 7.5mm is installed vertically at full height of container. SNM-18 neutron detector is located inside borehole mock-up.

Special construction provides centering of detector in a borehole mock-up, at that error of reproduction of its position makes ±5mm in height and ±1mm in radius.

In a central plane of a container two aluminum pipes were laid one inside another. Outer pipe – casing pipe – 38mm in diameter, wall thickness 2mm. Inside, along casing pipe's axis second pipe was located – 30mm in diameter, wall thickness 1.5mm. In its center a constant Pu-Be source of neutrons with power of ~1.61×10^6 n/s is consequently fastened.

Sand was used as a soil. Its chemical composition was explored and all of its components with content no less than 1% were identified. Attention was paid to neutron absorbing materials, mainly boron and rare-earth elements. The results of analysis of sand composition are given in Table 1.

Table 1. "Dry" sand composition.

Element	Contents, %	Comment
SiO_2	87.5…91	
Mg	5	
Al	1	
Fe	1…2	
Ca	0.5 … 1	
Na	0.5	
K	1 … 3	
Ti	0.05 …0.1	
B	Not found	Method sensitivity (0.001…0.01)%
Cd. Bi. Be	Not found	Method sensitivity <0.001%
S	Not found	Method sensitivity <(0.3 … 0.5)%
Rare-earth materials	Not found	Method sensitivity <0.01%

Three series of measurements with various contents of water in sand were carried out: 0.3 mass percents (further as "dry" sand), 3.8 mass percents (further as "moist" sand), 8.1 mass percents (further as "wet" sand). While loading "moist" and "wet" sand four samples of mixture were taken to measure water contents in sand from various levels of container. Weights of sand were taken from these samples and a change of weight was measured during warming-up of each weight, thus allowing to calculate water amount in sand.

Stone (photo at Fig.2) and water- and air-filled cavities were used as heterogeneities. Stone chemical composition and water contents analysis was carried out. The results of stone composition analysis are given in table 2.

Table 2. Stone chemical composition.

Element	Contents, %	Comment
Mg	25.95	Stone type – chrysotyl $Mg_2Si_2O_5(OH)_4$ Stone mass (1810±5) g Density 2.4 g/cm^3
Si	20.6	
O	1.45	
H	52.0	
B	Not found	Method sensitivity 0.001…0.01
Cd. Bi. Be	Not found	Method sensitivity <0.001
S	Not found	Method sensitivity <0.3 … 0.5
Rare-earth materials	Not found	Method sensitivity <0.01

Cavity was modeled with common plastic 1.5 liter bottle. Air cavity – empty bottle, water cavity – bottle filled with water. Pouring-in and draining of water were carried out through two hoses, thus bottle location in experiment for one sand load did not vary.

Heterogeneities location in the experimental container is given at Fig.3. We estimate reproducibility of heterogeneity location after sand reload as ±2 cm.

Fig.2. Stone photo.
Next to stone a matchbox is located.

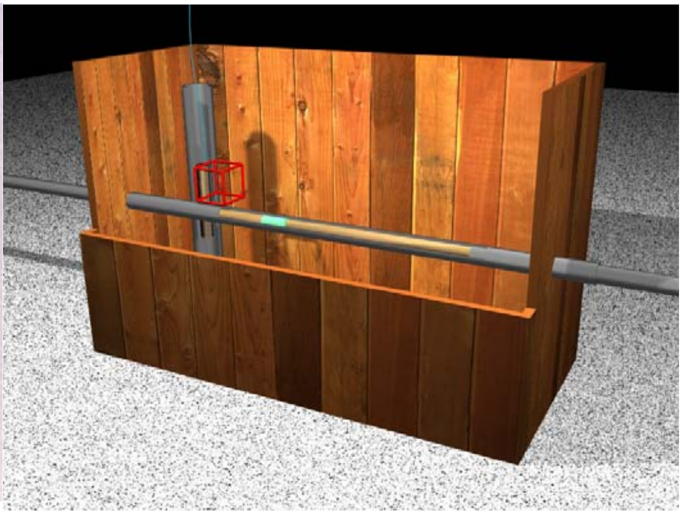

Fig.3. Heterogeneities location in the experimental container.

2. Calculations results.

Obtained experimental results were verified by means of MCNP calculating program (developed by LANL). MCNP code allows to create three-dimensional models of objects and to calculate tasks of neutron transport by means of Monte-Carlo method.

While modeling the experiment, calculational configuration was set maximally close to real. A wooden box was located on a concrete floor. The box was filled with sand with various humidity. Borehole pipe with a neutron detector mock-up was located vertically on a longitudinal axis of the box. In a central plane of the box a channel for moving neutron source was set.

Fig.4,5 show comparative results of experiments and calculations for various humidity of sand, filling the box.

Fig.6,7 show comparative results of experiments and calculations for various types of heterogeneities, located between neutron source and detector.

Values, obtained in calculations exceed values obtained in experiments. Such difference can be explained with peculiarities of registration system. However, on introduction of correction coefficients, MCNP calculation results surely describe experiment.

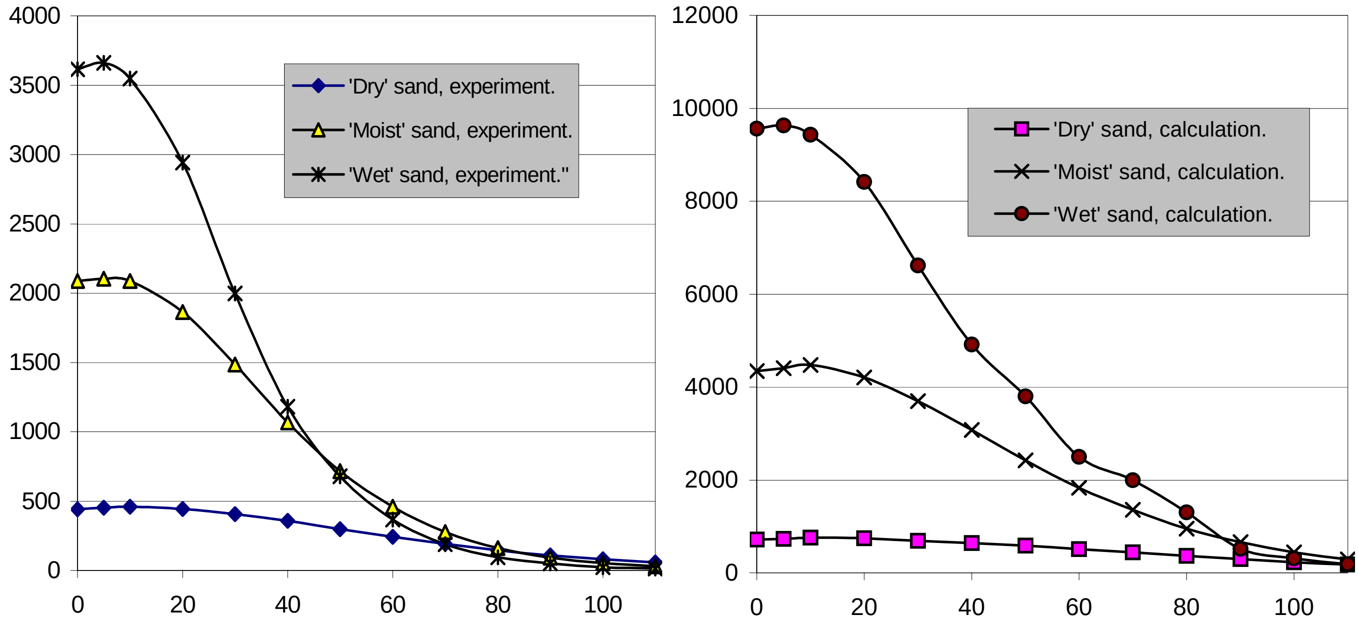

Fig.4,5. Experimental and calculational soil humidity detector counts dependencies. Plutonium-Berillium neutron source. Horizontal: source-detector range; vertical: detector counts at 100 sec.

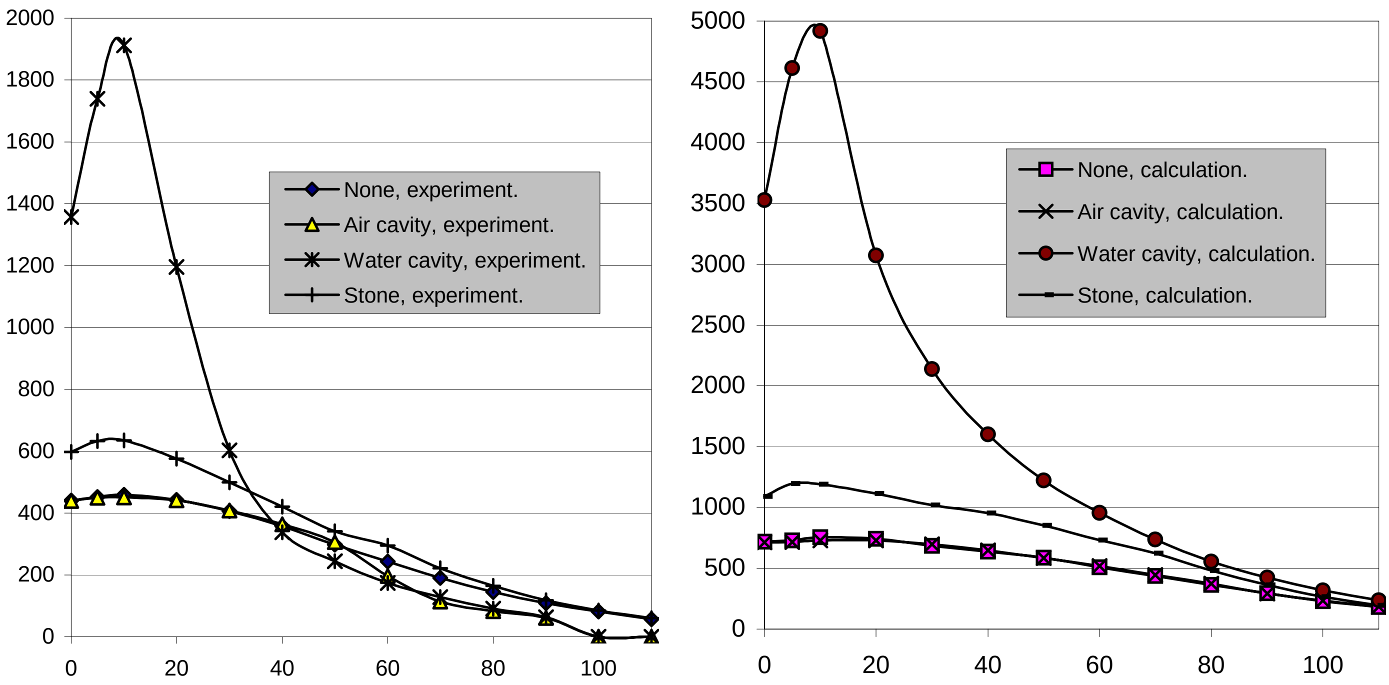

Fig.6,7. Experimental and calculational heterogeneities detector counts dependencies. “Dry” soil. Plutonium-Berillium neutron source. Horizontal: source-detector range; vertical: detector counts at 100 sec.

Conclusion.

1. Main objectives of calibration experiment were achieved:
   - Influence of water and heterogeneities in soil on method's sensitivity was explored.
   - Experimental results suitable for calculational methods verifications were obtained
2. Experimental data obtained is reliable, contain no inexplicable aperiodicities and at the level of qualitative analysis correspond to a physical meaning.
3. Succeeded in creation of calculational model, able to model process of neutron source in soil location at the qualitative level.
4. Calculations results correspond to the experimental results, excess of calculation results over the experimental results is explained with peculiarities of experimental parameters registration system.
5. It is expedient to continue experiment-calculated explorations to improve method of neutron source detection in soil:
   - for more exact determination of neutron source depth,
   - to estimate form of a source,
   - to develop and verify algorithm of neutron source form calculation on the results of measurements in several real wells surrounding the source,
   - to increase sensitivity,
   - to enhance registration system.