

# Neutron Measurement of Moisture in Mineral Matter. Modelling of the Gauge

Servo Kasi

Aalto University and home: Fi-01360 Vantaa, Finland

\*Corresponding author: Servo Kasi, Aalto University and home: Fi-01360 Vantaa, Finland.

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## Abstract

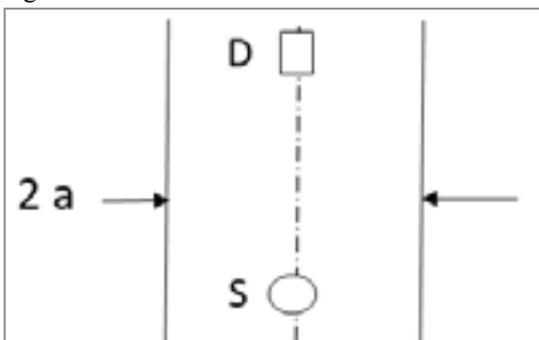
Neutron radiation can be used to measure moisture in mineral matter. The author has worked with neutron moisture gauge. This meter has source of fast (MeV) neutrons. The gauge detects thermal or epithermal down-slowed neutrons. For modelling Monte Carlo (MC) calculation has been done. The process has 2 MC-paths. One from the source down, and the other from detector up. They meet at a certain energy  $E$ . The first slowing-down density and second detection probably are multiplied and integrated to get the counting rate (the result of measurement). The first result of modelling is presented. Then spherical symmetry assumption is applied. It seems that cylinder assumptions should be used.

**Keywords:** Neutron Gauge, Moisture Measurement, MC-Calculation, Geometry Applications.

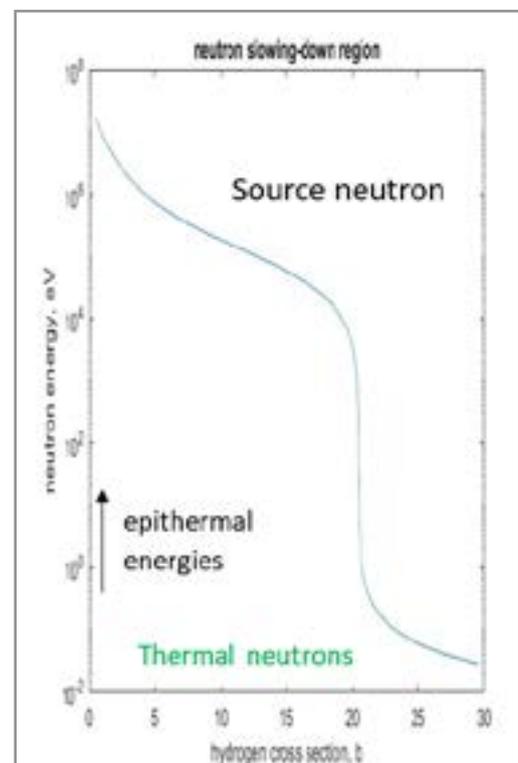
## Introduction

Neutrons have used to measure moisture in matters [1, 2, 3] Figure 1. In fact it is the content of hydrogen, which is determined. The energies of source neutrons are in MeV region, Figure 2. Hydrogen has the special property to slow down neutrons, because its mass is equal with the mass of neutron. The values of the cross section of hydrogen in Figure 2 I have taken from ENDF/B-VIII.1 -tabulations [4].

For the gauge I have made Monte Carlo (MC)- calculations [5], the first with Elliott [6] and the last ones with MatLab in my computer. In this paper I consider detection of epithermal neutrons, Fig. 2.



**Figure 1:** Essential parts of neutron gauge. S is the source and D detector of neutrons,  $2a$  is the outer diameter of the access tube.



**Figure 2:** Fast Neutrons Slow-down in Matter. Scattering Cross Section of Hydrogen is then Considerable.

In the gauge we have source of fast neutrons and detector of thermal or epithermal neutrons. In good moisture measurements one then considers the parameters: hydrogen content, density and absorption cross section of the matter. The most significant absorption is that of thermal neutrons. The hydrogen cross section  $\sigma_t = \sigma_s + \sigma_a$ . These are scattering and absorption cross sections.  $\sigma_a \ll \sigma_s$  during the slowing-down. Below 1 MeV other elements than hydrogen slow down negligibly. The most of gauges detects thermal neutrons.

### Calculus

In the calculations, at first, I supposed that S and D are points in infinite homogeneous medium and in spherical geometries. I took the AmLi source spectrum of neutrons [7] to pick up the energy for each neutron. The neutrons I follow downwards sequentially. They slow down into the energy  $E = 1$  keV.  $q_E$  is the slowing-down density at the energy E.

Now also another MC-calculation is needed. Neutron comes to the detector. There is an event. The neutron has had a path. You can follow the path. This is MC calculation upwards in energy. You calculate the paths of the so-called pseudo-neutrons. In the first calculation the epithermal detection in D was selected, and the energy goes upwards. At E I find the value for  $\Phi^*_E$ , the adjoint or may be called the quantity of detection or the value of pseudo-

neutrons. Now in a scattering event the energy and weight of pseudo-neutron grows. For hydrogen scattering  $E_2 = E_1/r$ . r is random number (0...1]. The first adjoint MC program MCNA is from the year 1971 [8]. In Neutron 50 a Conference in 1982 in UK Cambridge I shew the idea of 2 particle clouds: one from the source,  $q_E$ , and the other from the detector, the detection probability  $\Phi^*_E$ . We calculate the distributions of  $q_E$  and  $\Phi^*_E$  and integrate their multiplication

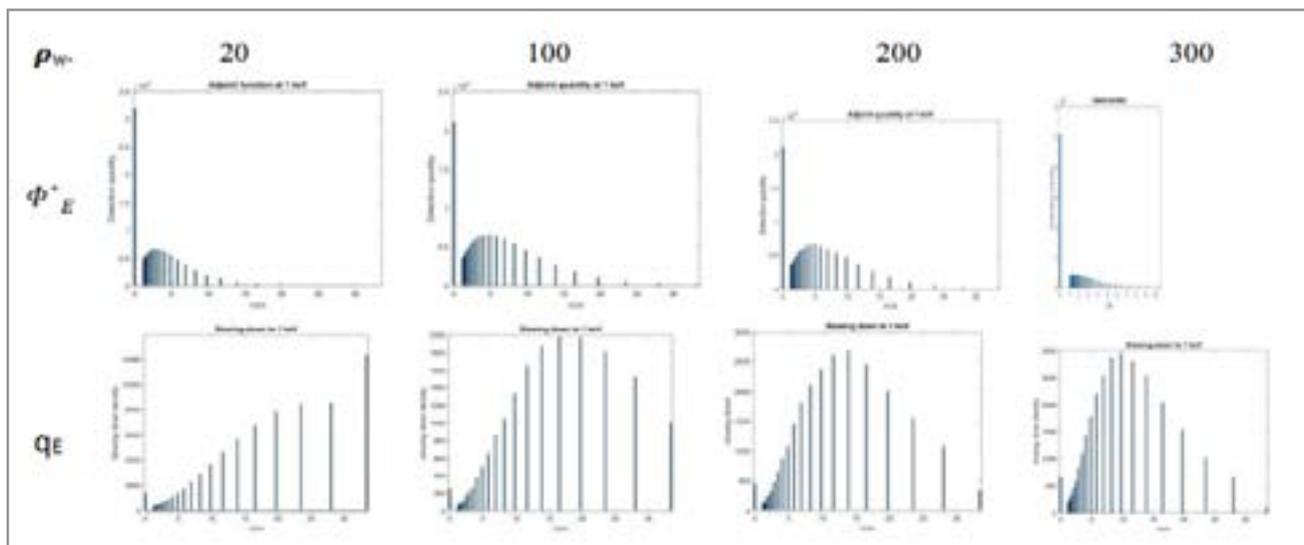
$$C = \int_V \int_{4\pi} \Phi^*_E(r, \Omega) q_E(r, \Omega) d\Omega dr$$

in order to get the counting rate C [9]. V must be large enough. The unite vector  $\Omega$  of direction has the 3 components u, v and w,  $u^2 + v^2 + w^2 = 1$ . They are cos-functions against x, y, and z axes, respectively [5]. In my calculation  $\Omega$  has 6 directions of w around the direction of r. I tried to find  $q_E$  and  $\Phi^*_E$  for  $a = 2.3$  cm and over that, and shew those distributions  $\Phi^*_E$  and  $q_E$  (Figure 3) in

ISRP 16 Symposium 2024 in Lisbon.

### Results

I supposed, that point S and D are in infinite soil. Around the points there are shells. But the shells from S and from D do not coincide. Therefore I set the distance  $d = SD = 0$ . I try to find the good shell radii. Now  $r = 0, 1.19, 1.42, 1.69, 2.02 = a, 2.40$ , etc.

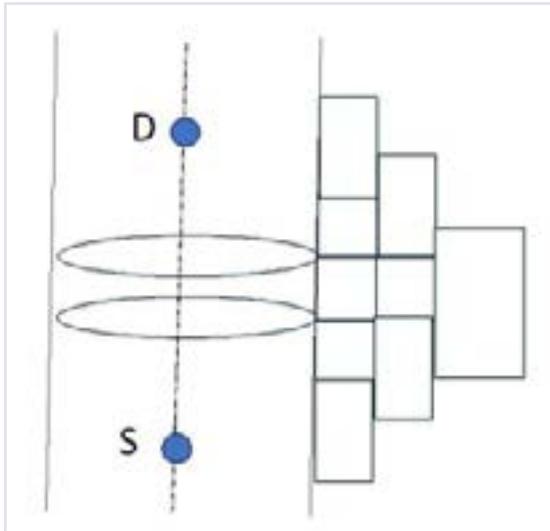


**Figure 3:** The First Distributions  $\Phi^*_E$  and  $q_E$  for Comparing.  $\rho_w$  is Water Content in kg/m<sup>3</sup>. In Figures the Horizontal Variable r is the Same in Both (and all) Rows.

### Conclusion

**It seems to select:** E to be higher, is better. E depends on  $\rho_w$ . Because the bad distributions and, maybe spherical models, the

integration for C was not valid to make. The spherical geometry now does not seem.



**Figure 4:** Rings Around the Tube. Each Ring has its Own  $r$ .

#### Applicable

1. I have continued in cylindrical geometry. Further I have the epithermal detection.
2. The model of thermal detection gauge should be calculated, too.

3. The components S and D are mostly cylindrical.

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