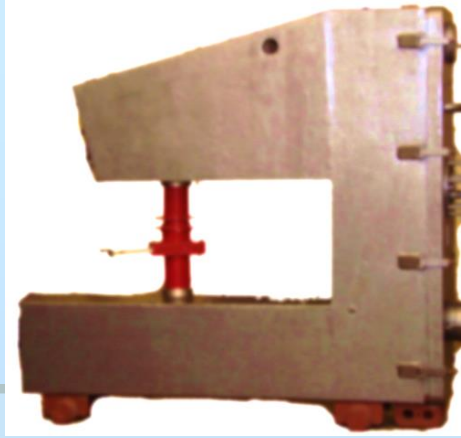
IAEA 60 Years
Atoms for Peace and Development

Replacing the isotopic radiation sources in thickness measurement on X ray

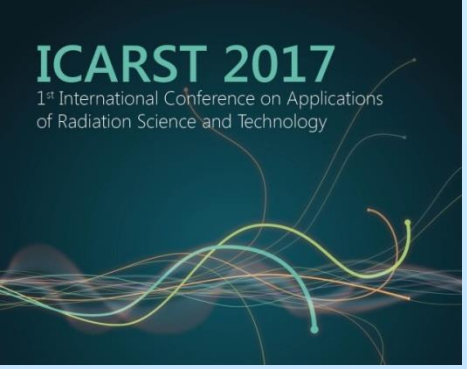
Artemiev B., Artemyev I.

Moscow, Russia

Abstract



Currently, there is a tendency in the industry by refusing isotopic radiation sources in favor of the X-ray machines. This is due to several factors, chief among them radiation safety and maintenance problems, movement and disposal of gamma-ray sources. Compared to the gamma ray source devices have a number of disadvantages. The spectral energy distribution and therefore change in the spectrum as the radiation passes through the controlled material. Instability of radiation compared with gamma sources. All this complicates the use of X-ray sources for the thickness measurement of materials with different chemical compositions.



Radometric method

The task of the radiation method is that it is necessary to compensate for the nonlinearity of the attenuation of the probe radiation, for a large number of alloys of different chemical composition. When using isotope radiation sources, the attenuation function is simple and is described by the expression:

$$I = I_0 e^{-\mu l \rho}$$

Where:

I - is the intensity of the radiation incident on the detector in the presence of a controlled object;

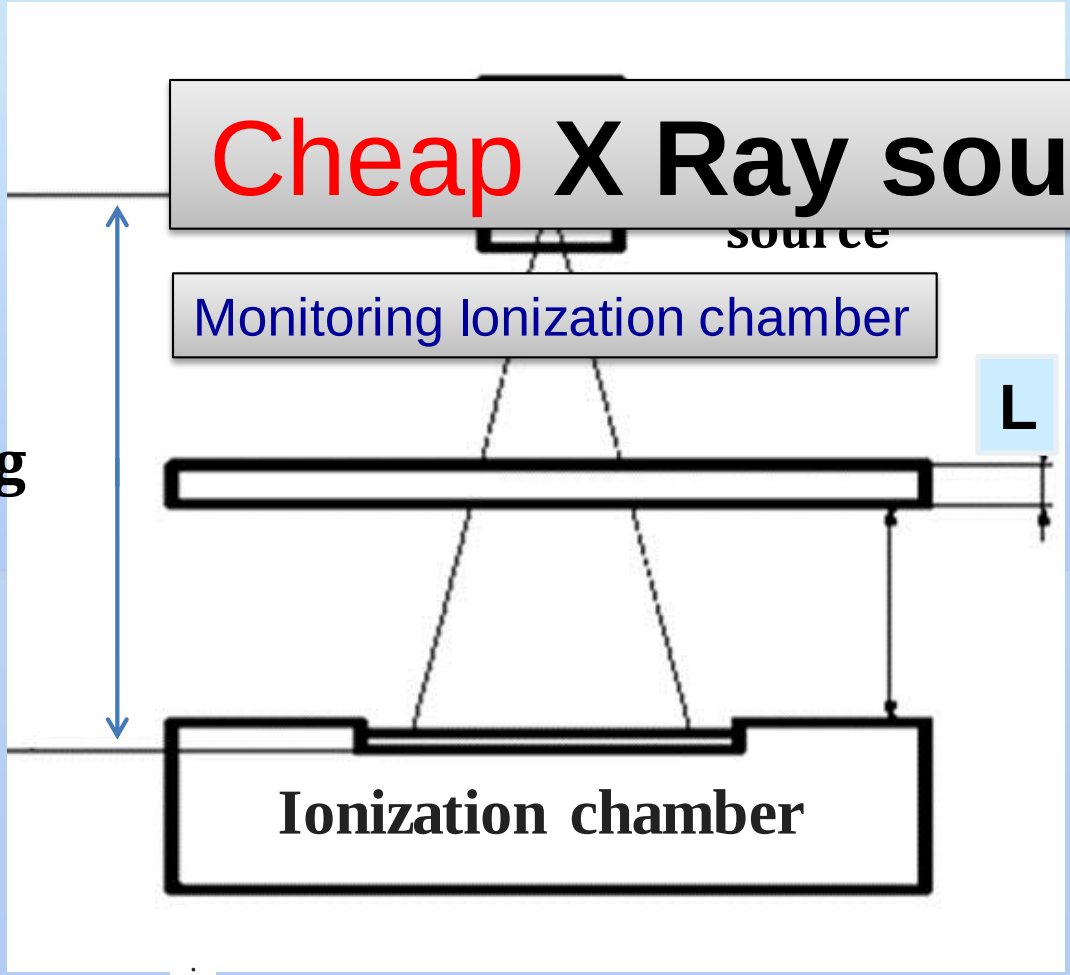
I_0 - radiation intensity in the absence of a controlled object;

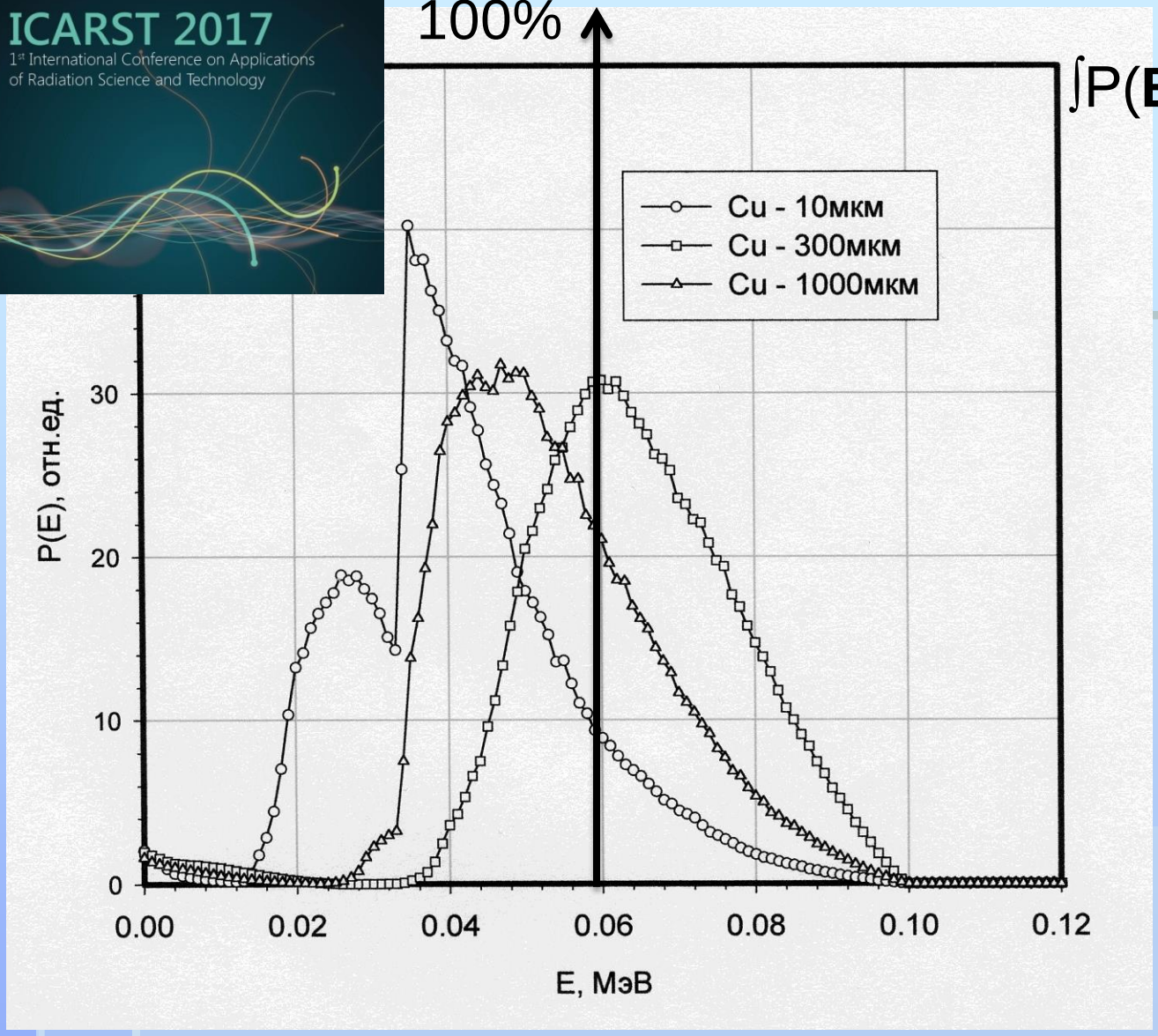
μ - is the linear attenuation coefficient that depends nonlinearly on the material of the object and on the energy of the probing radiation;

L - is the thickness of the monitored object;

ρ - is the density of the material.

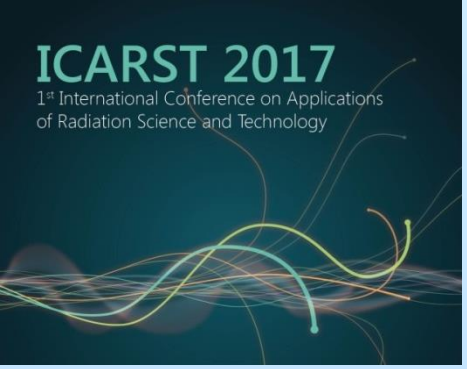
Diagram of the radiation measuring chain gauge





$$\int_0^\infty P(\mathbf{E})d\mathbf{E}=1$$

The distribution function of the absorbed energy of X-rays in an ionization chamber (filled with xenon at a pressure of 1 atmosphere). The curve is mapped from normalization condition.



The main parameter of the radiometric system is energy of the X-ray quantum **E**.

$$\mathbf{E} = \int_0^{U_a} E_0 \, dE$$ - full spectrum of radiation source

Using the X-ray apparatus as the radiation source, we have a continuous spectrum, in contrast to the mono lines of isotope sources and, according to the traditional approach, we take

$\mathbf{E}_{эф} = 2 / 3 \, U_a$

Where: U_a is the voltage at the anode of the X-ray tube,

$\mathbf{E}_{эф}$ - is the effective energy of quantas.

The next parameter of the system is the exposure dose D, the value of which depends on the anode current of the tube $\mathbf{I_a}$ and the anode voltage $\mathbf{U_a}$, and the exposure time.

$$k_0 = \frac{\Delta d \Delta \mu}{\chi_N} \Phi P \sqrt{N S_Д \eta \chi_N}$$

Where :

N - The number of incident quanta per measurement on the surface of a unit area;

η - Efficiency of detecting quanta by a detector;

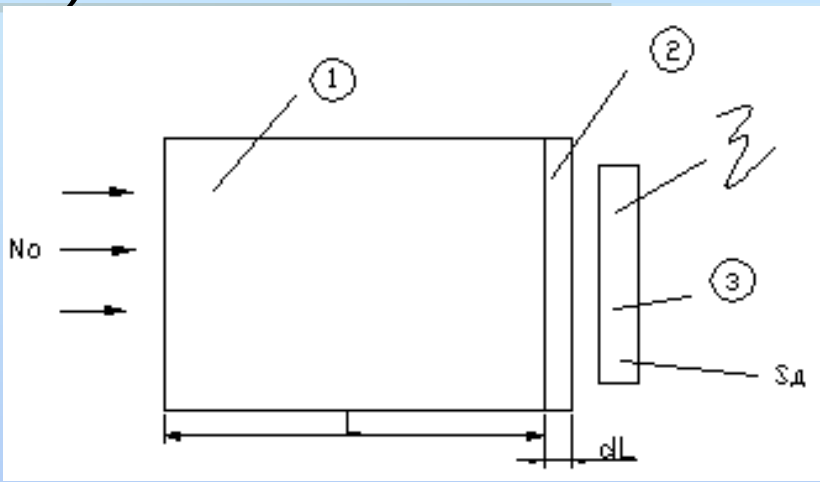
$$\Delta D = N_0 S\partial e^{-\mu d} \eta\chi_N - N_0 S\partial e^{-\mu d+\Delta d} \eta\chi_N = N_0 S\partial \eta\chi_N (1-e^{-\mu\Delta d})$$

$$\frac{\Delta d \Delta\mu}{\chi_N}$$ Radiation contrast; Taking into account the tendency $(E^2) \to 0 \quad к \to 1$

ΦP – The scattering function is

$$\Phi P = 1 - \exp(-\frac{F\sqrt{S_Д}}{f_k h_\varepsilon})$$

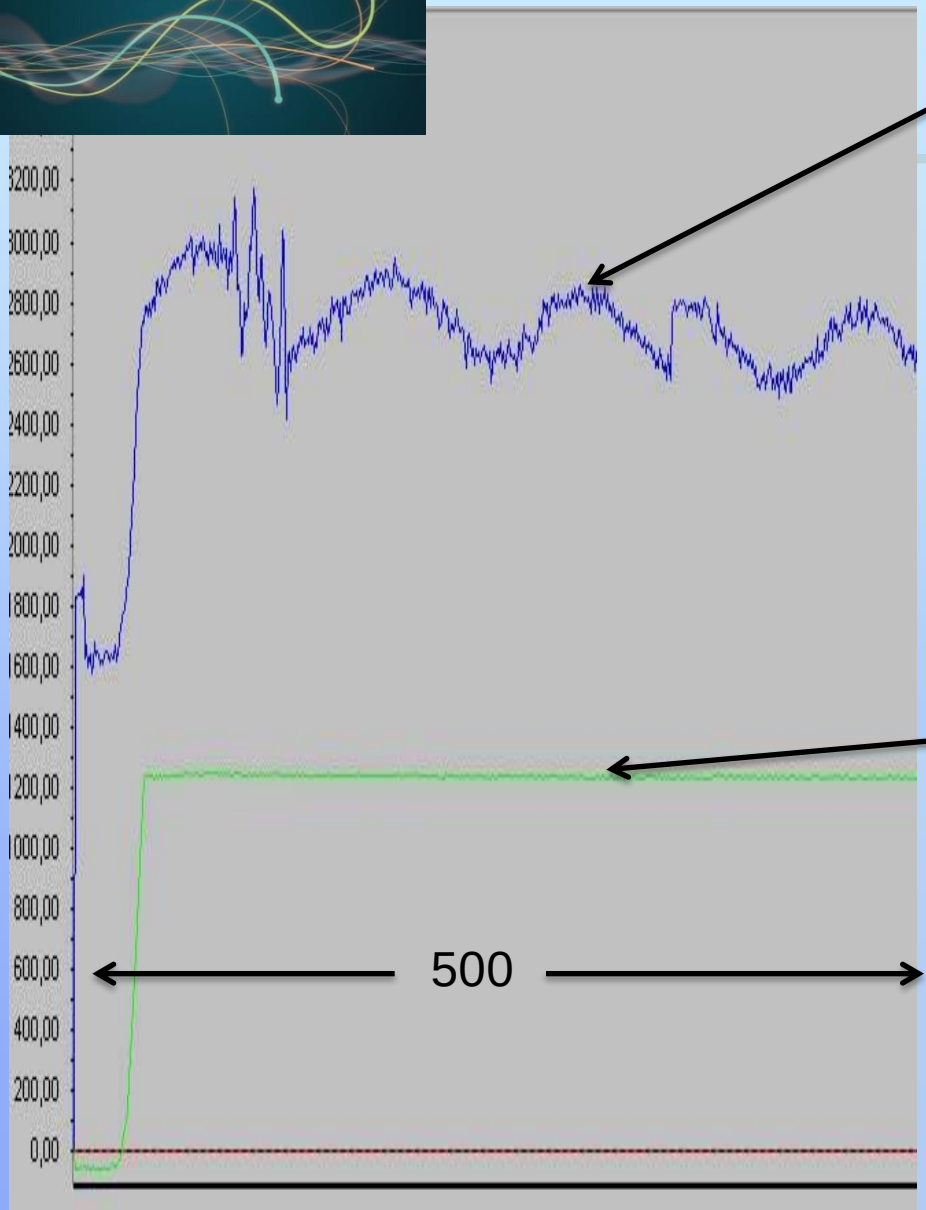
Its value tends to 1.



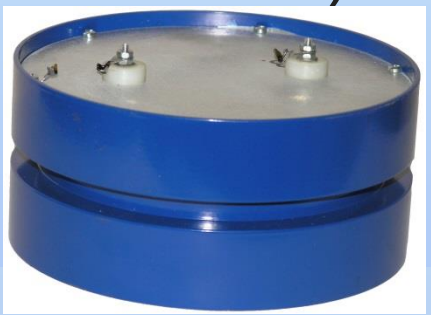
The probability of detecting a change in the thickness of test object when changes are made either by thickening or thinning, under the condition of a Gaussian distribution of the fluctuations, has the form to

$$f(k_0) = 1 - \frac{1 - \frac{1}{\sqrt{2\pi}} \int_{-k_0}^{+k_0} \exp(-\frac{1}{2} k_0^2) dk_0}{2}$$

Transition process



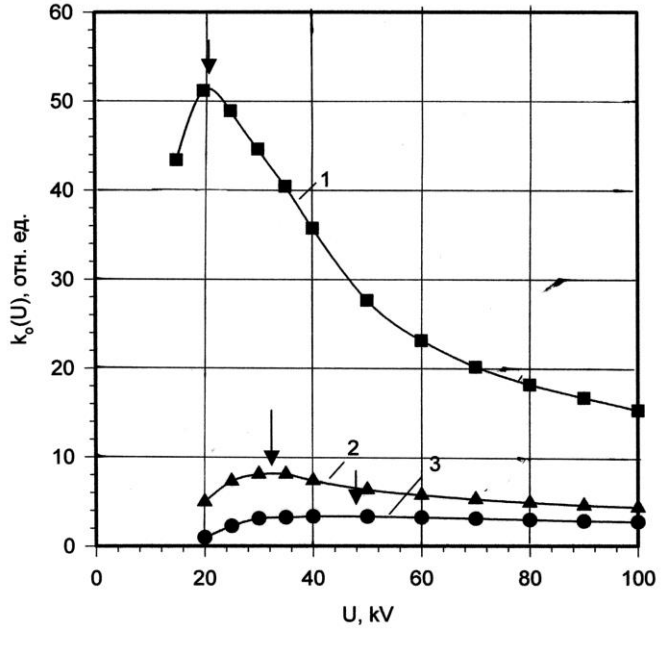
The signal from the camera when the thickness gauge is turned on (the amplitude is doubled), at a thickness of the monitored object 1200 μm Cu alloy M1 and voltage at the anode 100 kV (time 5000 ms).



Transfer function of the modified thickness gauge after the measurement result is normalized to the reference camera signal.

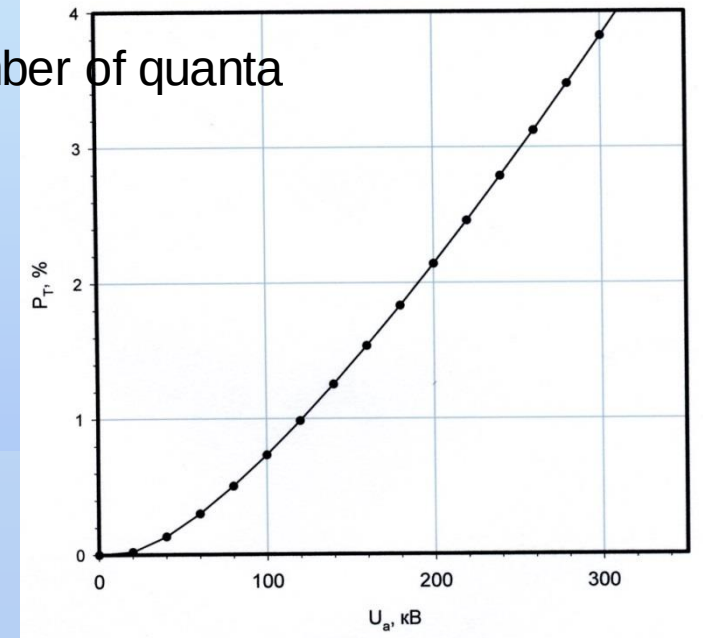
Optimum anode voltage for thicknesses

h_{Fe} , мм	$U_{опт}$, кВ	$U_{опт}=3/2E_{опт}$ ($\mu(E_{опт})xH_{Cu}=2$), кВ
0.01	24	18
0.1	32	18
0.2	47	18



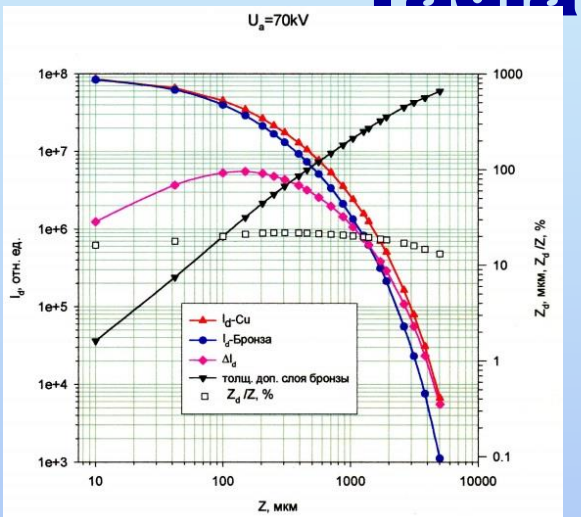
Dependence of the signal-to-noise ratio on the anode voltage for various process filters

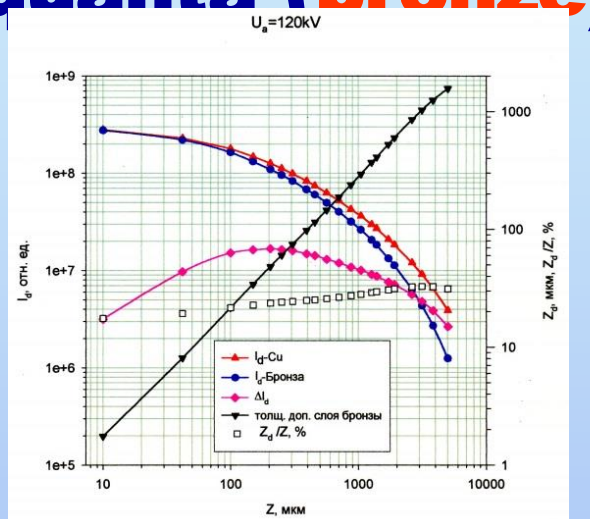
Number of quanta

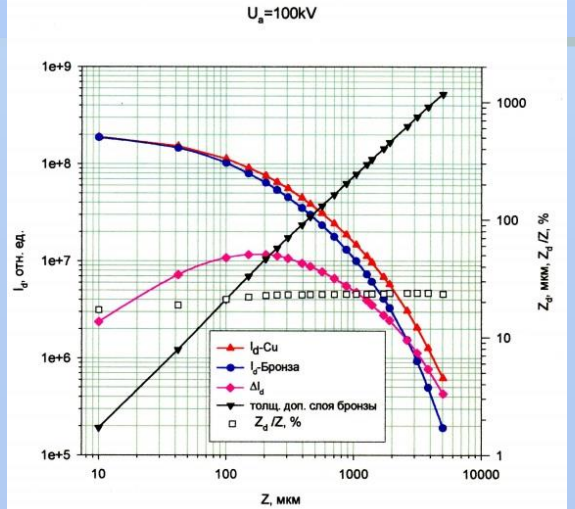


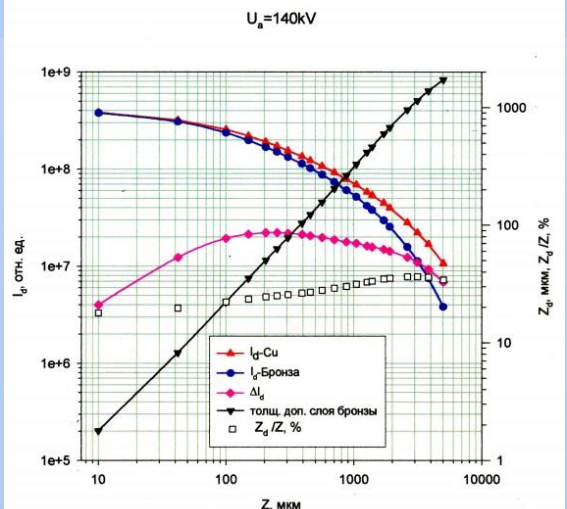
Dependence of the quantum return of the tube on the supply voltage

Dependences of changes in chemical corrections on the thickness of the material and the effective energy of the probing radiation quanta (bronze)

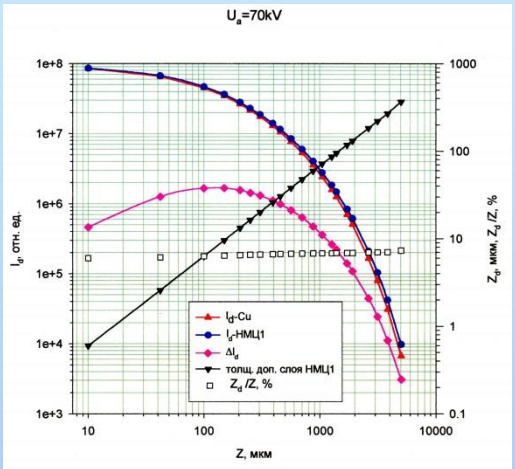


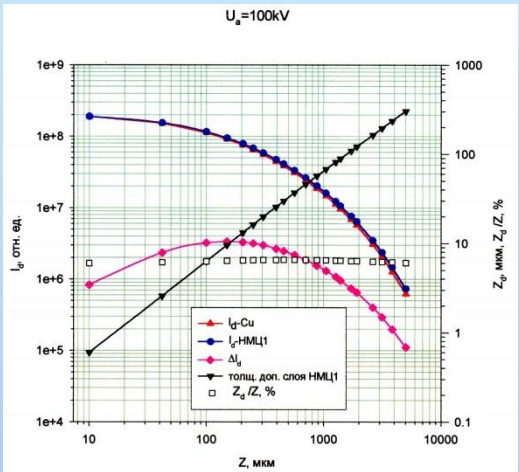


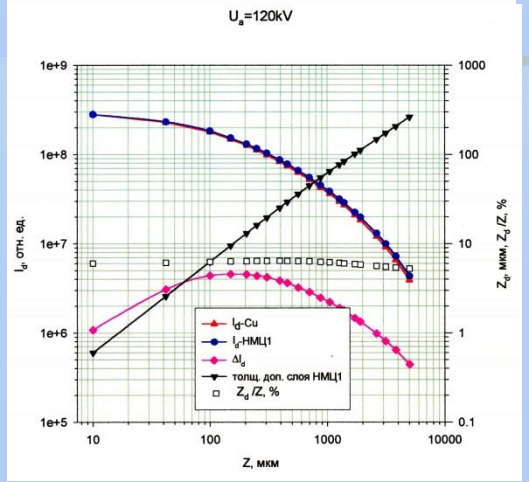


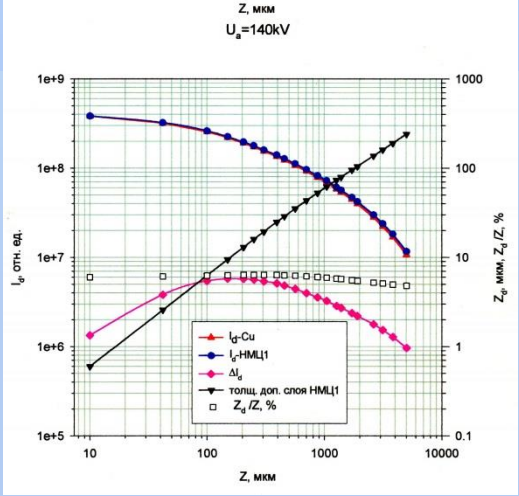


Dependences of changes in chemical corrections on the thickness of the material and the effective energy of the probing radiation quanta (NMC1)

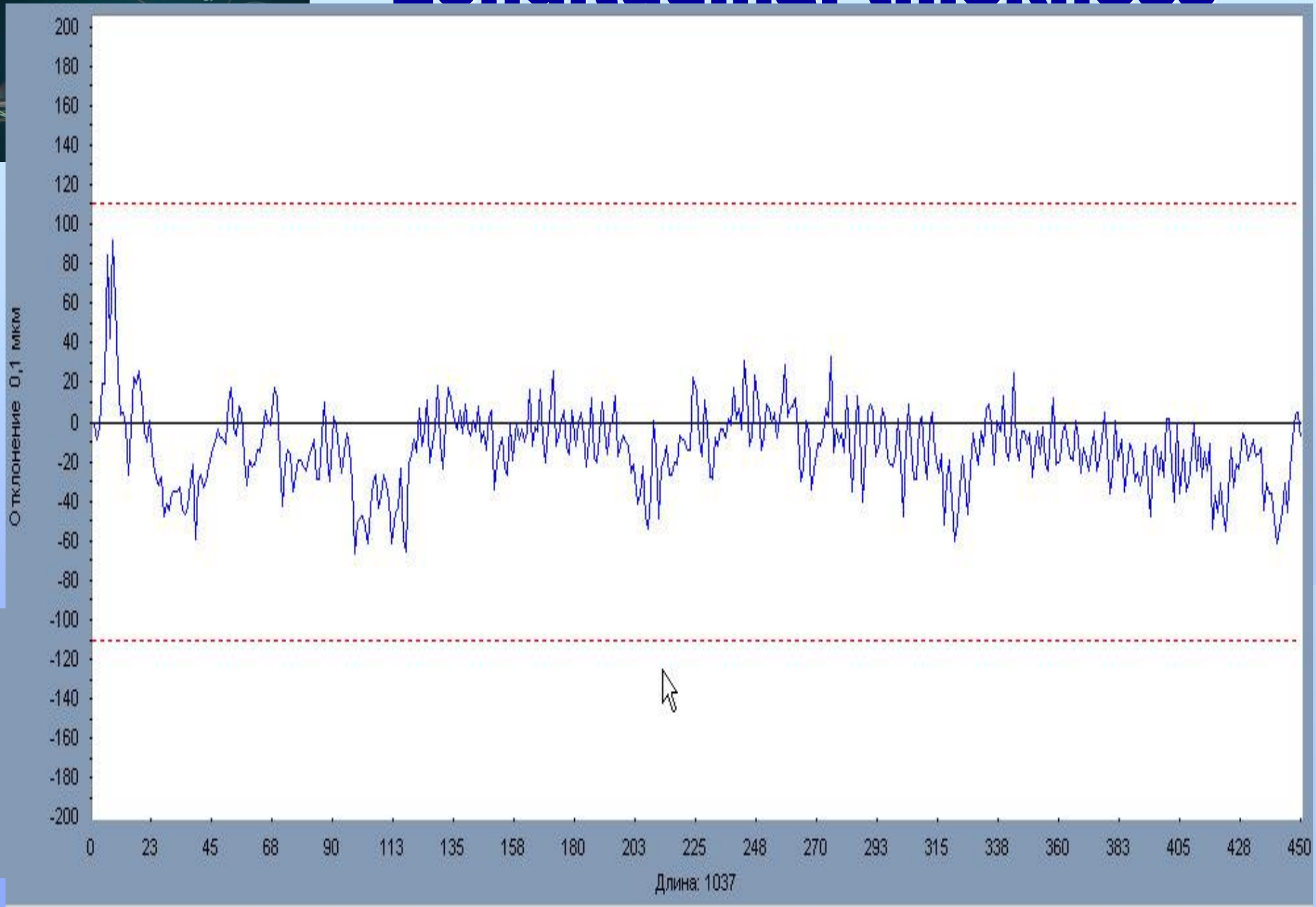








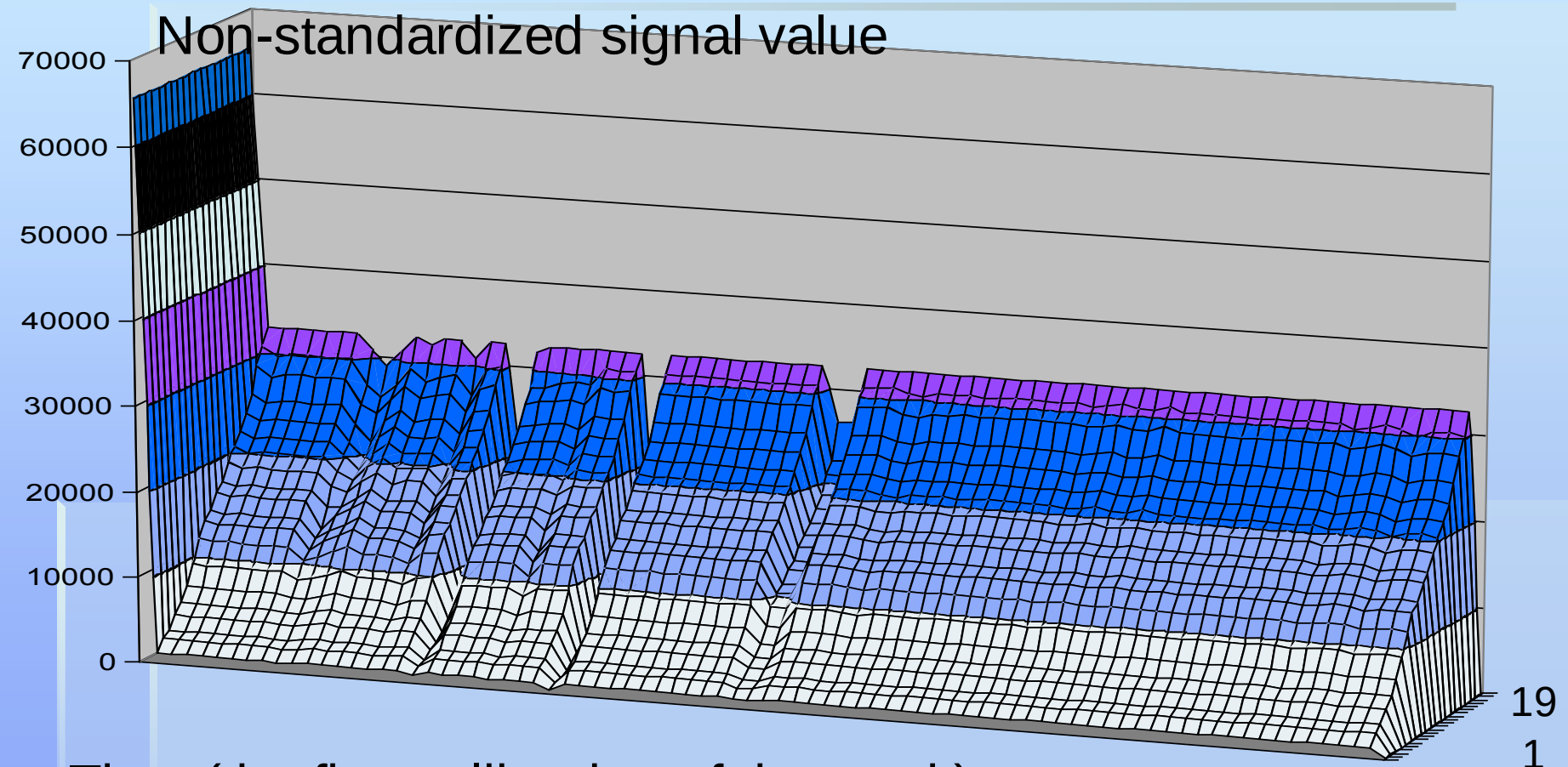
Longitudinal thickness



Results

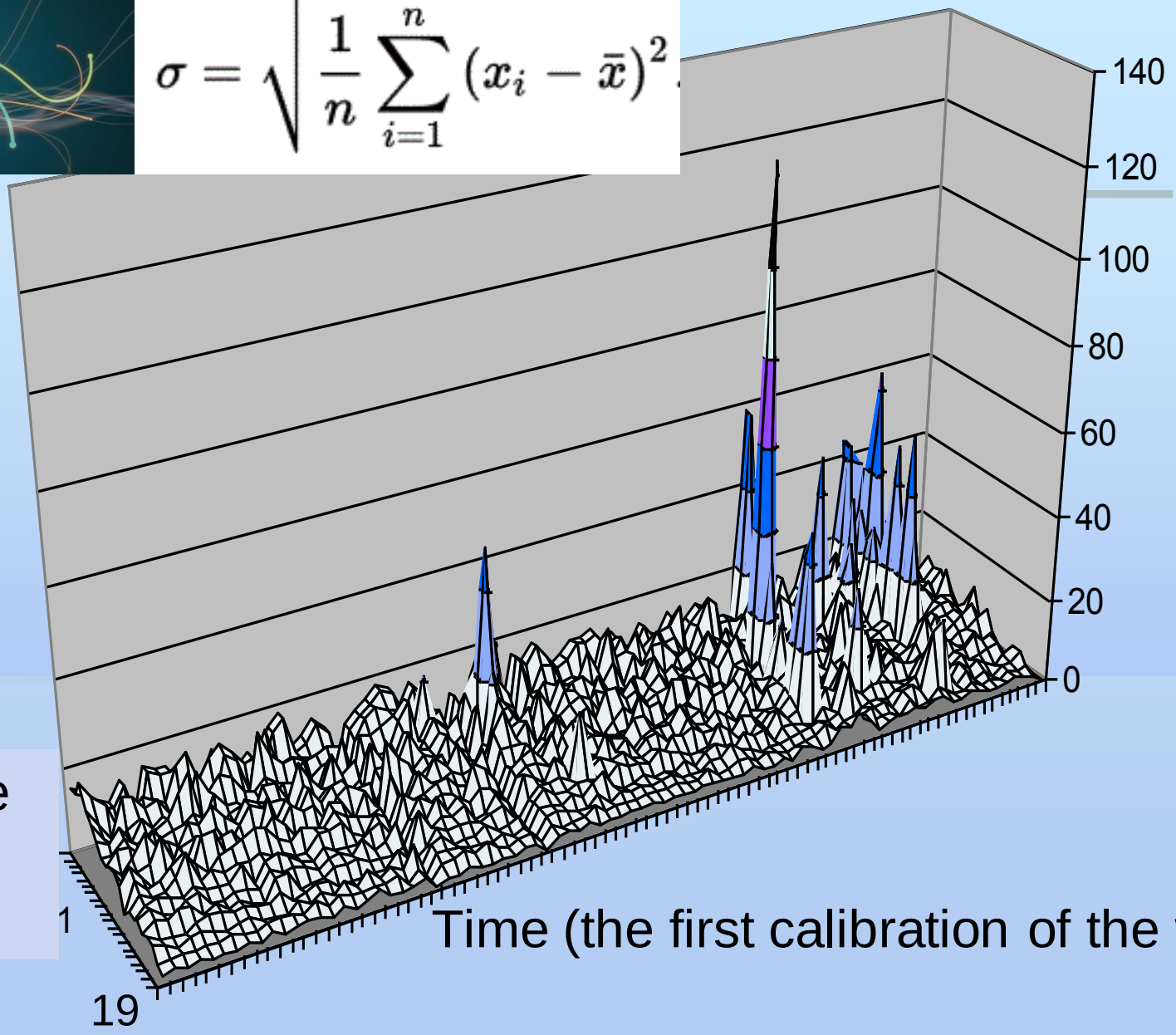
For the production of rolled products with a thickness of less than 0.2% of the nominal value, it is necessary to ensure a rigid stabilization of the radiation flux both in energy and in current and dynamically change the corrections to the chemical composition of the material during the rolling process, which is impossible without the use of the proposed solution.

Calibration



Root-mean-square deviation

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$



Reference Samples
19 pieces

Thank you for your attention!