supply unit, data processing unit, commutation and interface transformation unit, indication and alarm elements, server on IBM PC basis and software. Installed system was officially commissioned in May 2011 at railway scales of enterprise, where the initial radiation control of incoming metal scrap rakes place. From this time up to now a lot of cases of elevated radiation level in the scrap coming from Kyrgyzstan and Kazakhstan were detected by radiation control system, the most frequent cause of alarms being $^{226}$Ra radionuclide. In all cases of alarms caused by radioactive materials in contaminated scrap the performers of the present project of INP AS RU conducted additional radiation research and issued expertise conclusions. Thus the radiation control system elaborated and manufactured in INP proved its reliability in detection of radioactive substances and in prevention of radiation contamination of metal products.

## ON CALIBRATION OF RADIOACIVE SOURCES AND THEIR CERTIFICATION

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While using radioactive sources the problem of their activity determination and certification arises. This problem was solved in frames of method elaborated in INP nuclear instrument making division. For measurement of activity of the sample $\gamma$ - $\gamma$ coincidence method was used. Prompt $\gamma$ - quanta are accompanying the fission process and their registration permits to state the fission act and determine the activity of the source. Let's consider the measurement procedure of activity of arbitrary sample with mass $m = 1$ g. for $^{60}_{27}Co$. The decay scheme is shown on Fig.1 with energy 1.3325 and 1.17324 MeV.

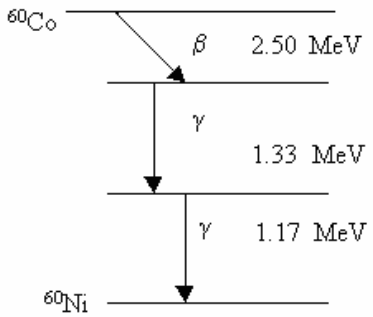


Fig.1. Decay of $^{60}$ with production of two γ-quanta

Knowing half-life of $^{60}_{27}Co$ it's easy to determine its specific radioactivity:

$$A_R = \frac{dN}{dt} = \frac{N_A \ln 2}{\mu_A T_{1/2}} \approx 4.166 \cdot 10^{13}\ g.^{-1} s.^{-1} \qquad (1)$$

where $\mu_A = A = 60\ \frac{g.}{mole}$, $N_A$ - Avogadro's number, $T_{1/2}$ - half-life (Tab.1.).

Tab.1. Characteristics of $^{60}$Co according decay according Fig.1

| **Nucleus** | $T_{1/2}, \beta$, **years** | $T_{1/2}, \gamma$, **years** | $E_\beta$, **keV** | $E_\gamma$, **MeV** |
|---|---|---|---|---|
| $^{60}$Co | 5.273 | -- | 317.88 | 1.33250; 1.17324 |

For source with mass $m = 1$ g we get absolute activity:

$$A_m = m \cdot A_R = 4.166 \cdot 10^{13}\ Bq \approx 1.126 \cdot 10^3\ Ci \quad (2)$$

The most probable decay channel of $^{60}_{27}Co$ is characterized by cascade emission of two $\gamma$ - quanta in characteristic time $\tau \sim 10^{-11}$ s. If time resolution of counters $t >> \tau$, it is possible to use $\gamma$ - $\gamma$ double coincidence scheme for source activity measurement. Let's consider radioactive source $^{60}_{27}Co$ (Fig.2) located on distance $r$ from 2 detectors with effective measurement square $S = 100\,\text{cm}^2$.

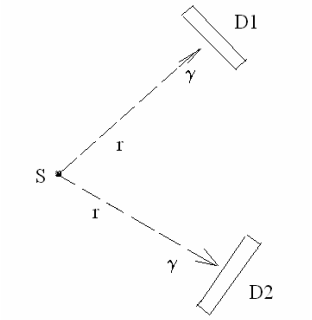


Fig.2. Location of detectors D1and D2 in relation to $^{60}$C source

The probability of one $\gamma$ - quantum registration is:

$$P_{\gamma 1} = \frac{S}{4\pi r^2}\varepsilon_{eff}, \quad (3)$$

where $\varepsilon_{eff}$ effectiveness of $\gamma$ - quantum detection. Then probability of double $\gamma$ - $\gamma$ coincidence detection is:

$$P_{\gamma-\gamma} = 2\left(\frac{S}{4\pi r^2}\right)^2 \varepsilon_{eff}^2, \quad (4)$$

provided identity of detectors. Then the number decay per time unit:

$$N_{\gamma-\gamma}(reg) = 2A_m\left(\frac{S}{4\pi r^2}\right)^2 \varepsilon_{eff}^2 \quad (5)$$

If measurement time of source activity is $t$, then the number of events of $\gamma$ - $\gamma$ coincidences registered is:

$$N_{\gamma-\gamma}(t) = 2A_m\left(\frac{S}{4\pi r^2}\right)^2 \varepsilon_{eff}^2 \cdot t \tag{6}$$

And the activity as follows is:

$$A_m = \frac{N_{\gamma-\gamma}(t)}{2\left(\frac{S}{4\pi r^2}\right)^2 \varepsilon_{eff}^2 \cdot t} \tag{7}$$

At parameters selected $r = 100\ c.,\ t = 60\,s\ and\ \varepsilon_{eff} = 0.2$, we get from (6) :

$$N_{\gamma-\gamma}(t = 60s) \approx 3.426 \cdot 10^7 \text{ events.} \tag{8}$$

Let's note the number of events is proportional to source mass and at small masses the demands to measurement precision increase. The measurement precision besides systematic error of detector parameters has measurement error of $\gamma$ - $\gamma$ coincidence events due to background. In these cases the number of events related to fission of source matter should be determined with background correction. This procedure is done by subtracting the number of registered events of $\gamma$ - $\gamma$ coincidences without the source. The schemes of $\gamma$ - $\gamma$ coincidences practically exclude the background influence but non-zero probability of hitting two random $\gamma$ - quanta in two detectors exists. This probability easily is estimated as $P \sim \left(\Delta t / t\right)^2$, where $\Delta t$ - detector time resolution and $t$ - measurement time and simple calculation gives: $P \approx 2.9 \cdot 10^{-16}$.

## SEMIEMPIRICAL X-RAY FLUORESCENCE TECHNIQUE FOR DETERMINING COMPONENTS OF ALLOYS

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For the determination of alloy composition the semiempirical technique of X-ray fluorescence using intensities of characteristic K- and L-lines requires some tabular data of the elements– fluorescence yield, ratio Kα/Kβ-lines, absorption edge jump ratio, yield probability of a characteristic line of an analyzed element, mass absorption and mass attenuation coefficients and et al. These data obtained theoretically with the use of various techniques for L-lines [2, 3] in different tables differ < 5 % for elements with Z > 20. The aim was to select the most accurate table data for L-line at semiempirical determination of alloy components [1] taking the alloys with the known contents of components. For this purpose we took alloys of Au-Cu-Ag, Mo-Re and W-Mo in which only L-lines of W, Re and Au elements appear under excitation by Am-241 source. Proper choice of the most exact values from the above mentioned tabulated data is presented on the example of Au-Cu-Ag alloy with the known content of components: Au (58.3 %) - Cu (33.7 %) - Ag (8.0 %). The alloy spectrum excited by Am-241 source is shown in Fig.1. The known edge jumps of absorptions for L III - level of 8 elements were taken from tables [2, 3] to find their dependence on Z as seen in Fig.2.