The linkup of mono-elemental solutions to the SI using INAA: a measurement procedure and the achievable uncertainty

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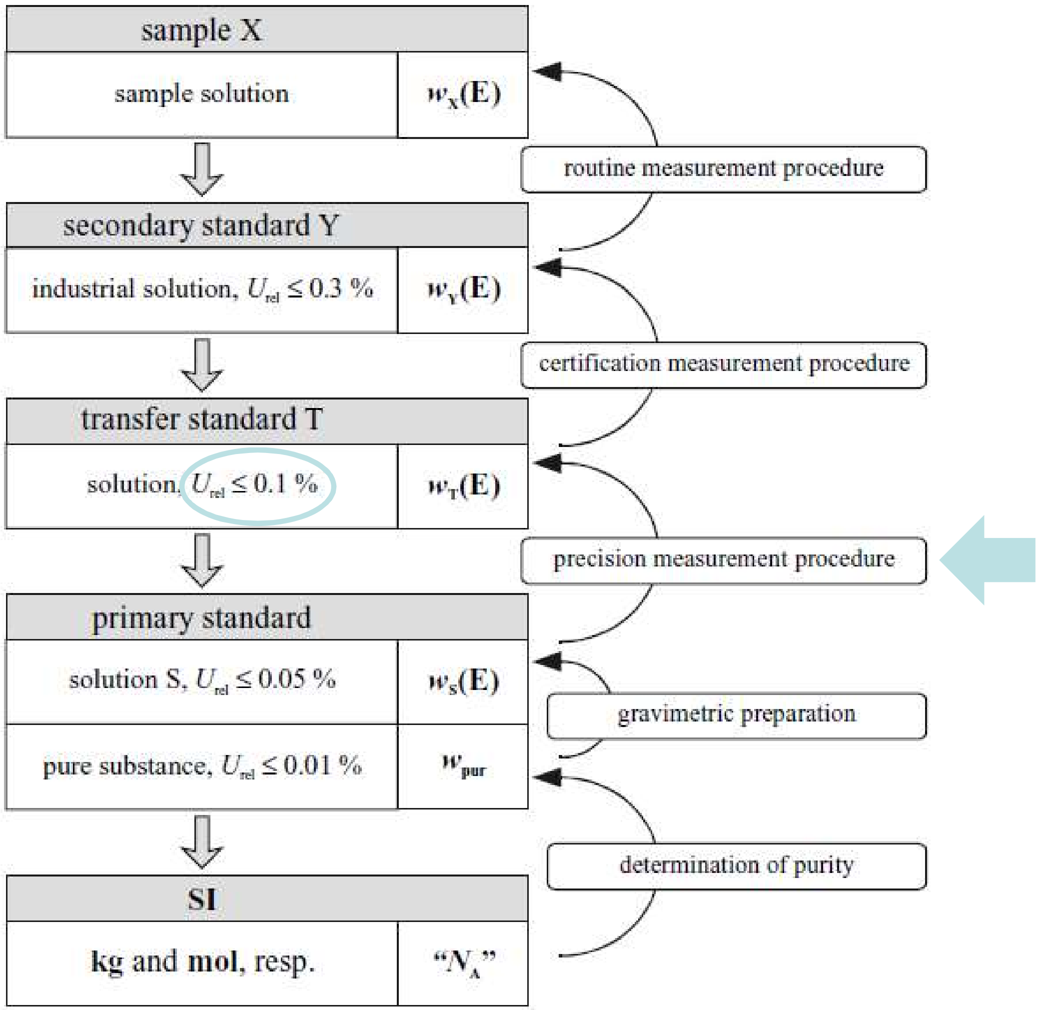
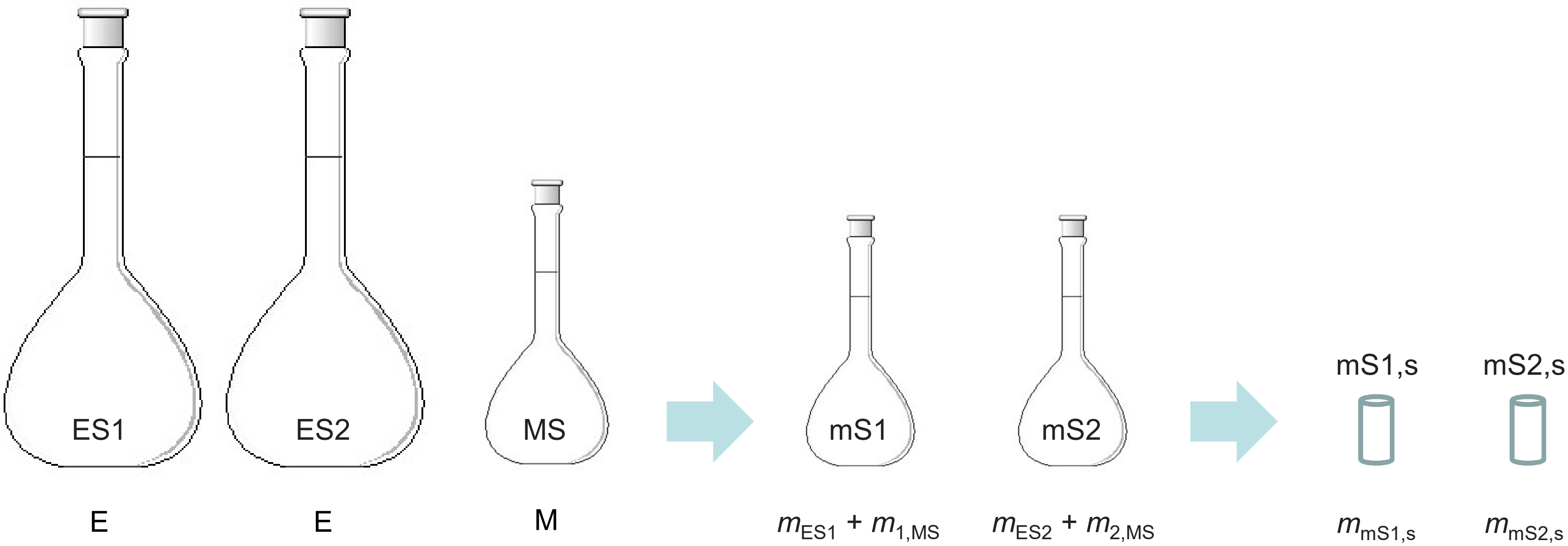
Traceability chain for elemental analysis



Kipphardt et al. Accred Qual Assur (2006) 10: 633-639

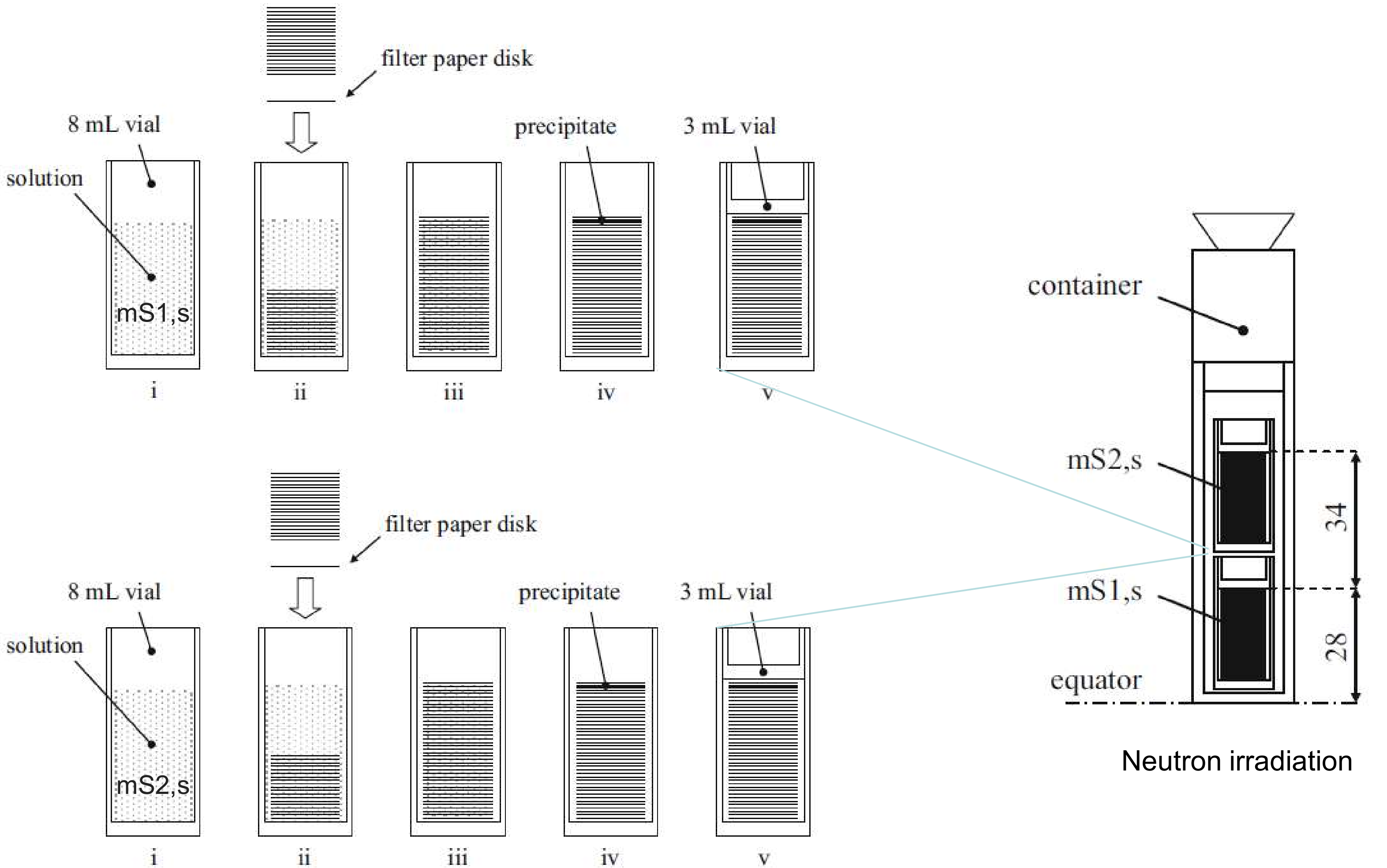
Measurement procedure



E	→	Mo	^{98}Mo (n,γ) ^{99}Mo, ^{99m}Tc	$t_{1/2} \cong 66$ h, $E_\gamma = 140.5$ keV
M	→	Co	^{59}Co (n,γ) ^{60}Co	$t_{1/2} \cong 5.3$ y, $E_\gamma = 1173.2$ keV, 1332.5 keV

$$\tau = \frac{w_{ES1}(E)}{w_{ES2}(E)} = \frac{m_{ES2}}{m_{ES1}} \frac{m_{1,MS}}{m_{2,MS}} \frac{C_{mS1,s}(t_{d\,mS1,s})}{C_{mS2,s}(t_{d\,mS2,s})} \frac{C_{M-mS2,s}(t_{d\,M-mS2,s})}{C_{M-mS1,s}(t_{d\,M-mS1,s})} \beta_R \, \kappa_{td} \, \kappa_{M-td}^{-1} \, \kappa_{ss} \kappa_{M-ss}^{-1} \, \kappa_{sa} \kappa_{M-sa}^{-1} \, \kappa_{g} \kappa_{M-g}^{-1} \, \kappa_{\varepsilon} \kappa_{M-\varepsilon}^{-1}$$

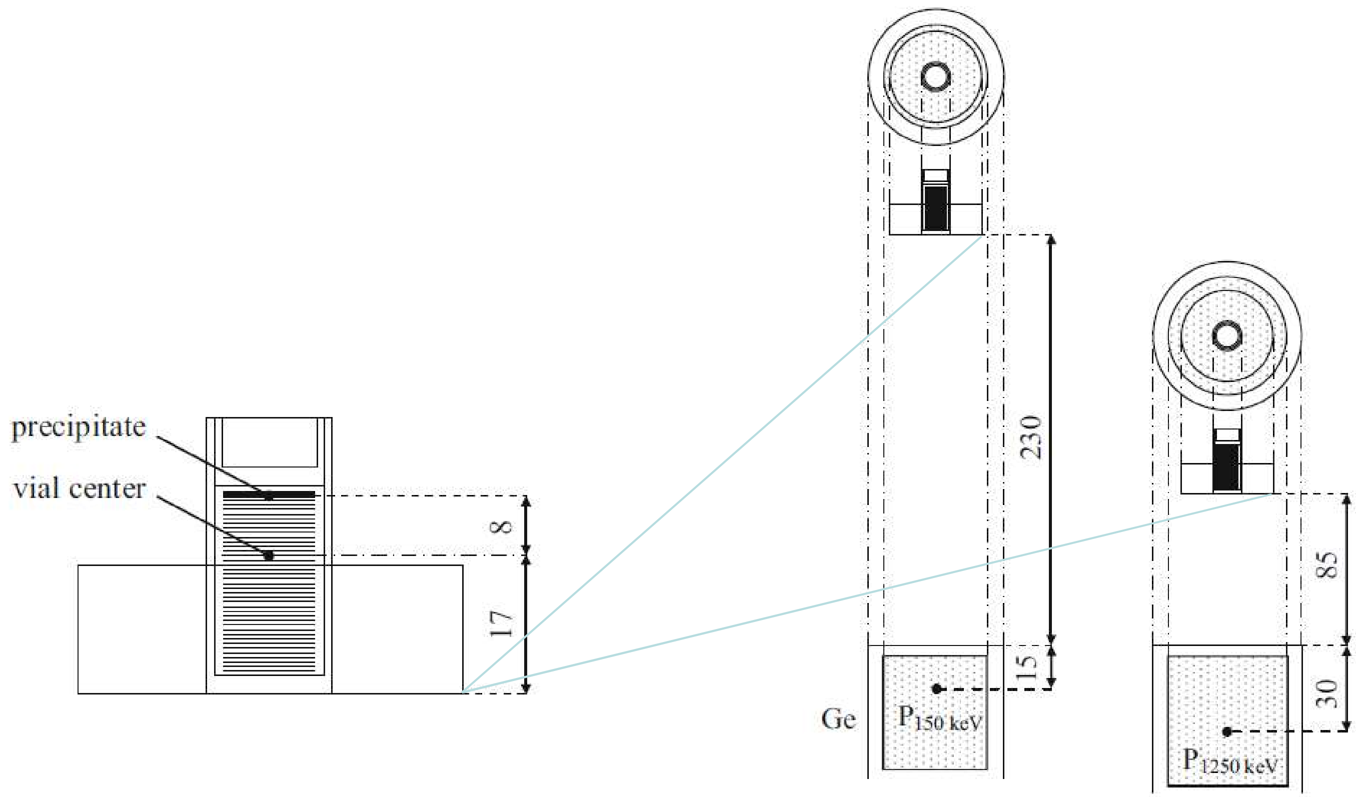
Sample preparation and neutron irradiation



Preparation

Neutron irradiation

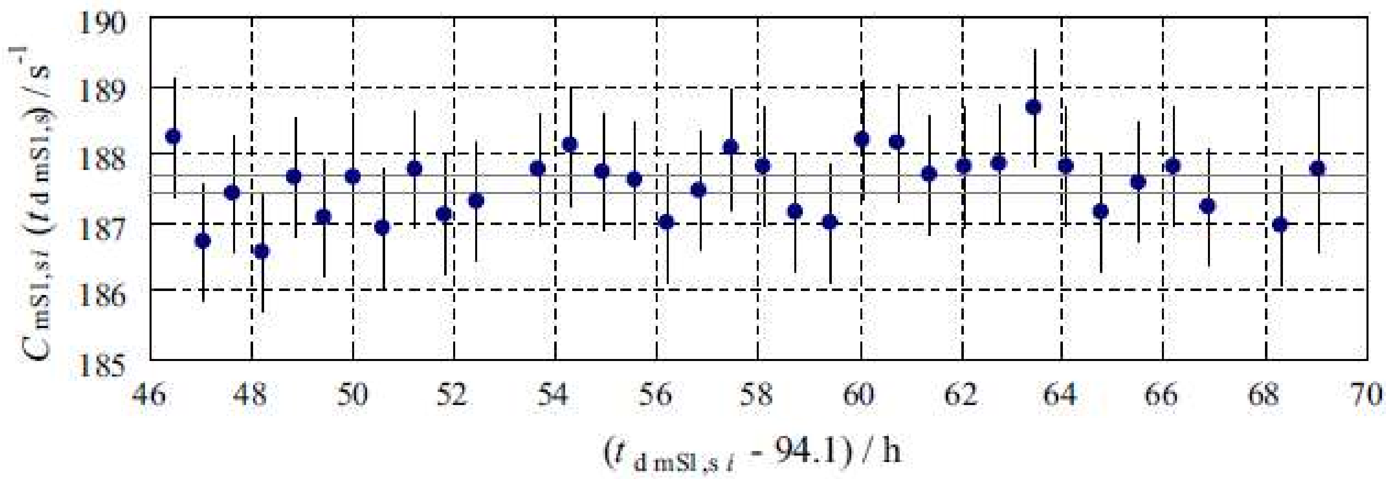
Gamma spectrometry

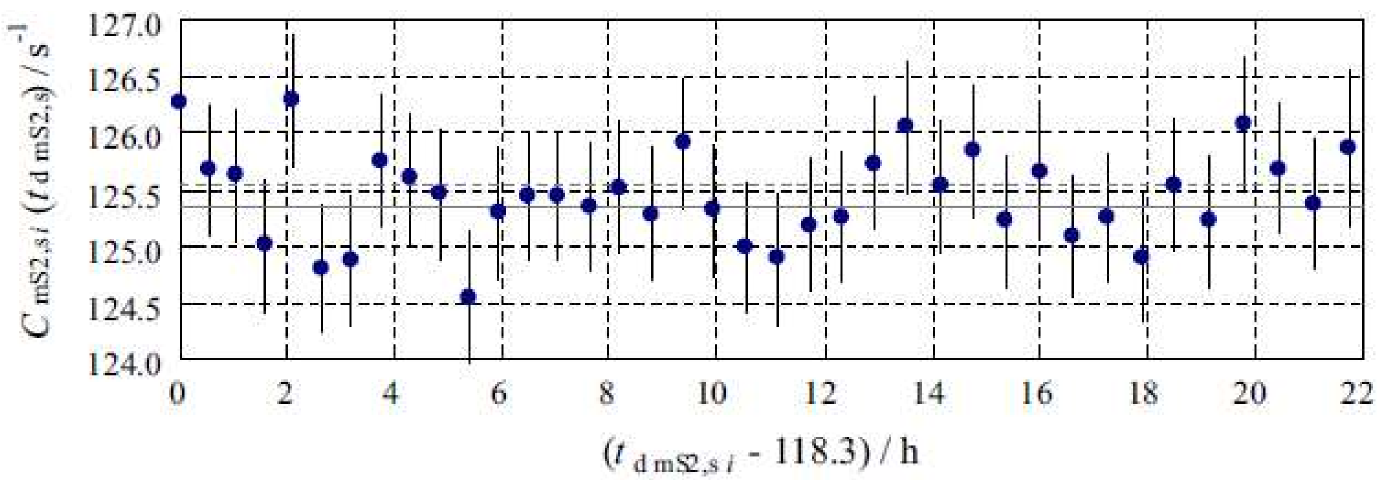


^{99}Mo, ^{99m}Tc
140.5 keV

^{60}Co
1173.2 keV
1332.5 keV

140.5 keV ^{99}Mo,^{99m}Tc count rates





Result and uncertainty budget

Table 2 Uncertainty budget of the measured ratio τ

Quantity X_i	Unit $[X_i]$	Value x_i	Standard uncertainty $u(x_i)$	Index %
$m_{1,\mathrm{MS}}$	g	0.12572	0.00004	0.0
$m_{2,\mathrm{MS}}$	g	0.12572	0.00004	0.0
m_{ES1}	g	27.03259	0.00006	0.0
m_{ES2}	g	27.03259	0.00006	0.0
$C_{\mathrm{mS1,s}}/C_{\mathrm{mS2,s}}$	1	1.49490	0.00065	0.0
$C_{\mathrm{M-mS2,s}}/C_{\mathrm{M-mS1,s}}$	1	0.85708	0.00055	0.1
β_{R}	1	1.000	0.010	22.8
κ_{td}	1	0.77554	0.00000	0.0
$\kappa_{\mathrm{M-td}}$	1	0.99452	0.00000	0.0
$\kappa_{\mathrm{ss}}\ (\kappa_{\mathrm{M-ss}})^{-1}$	1	1.00000	0.00000	0.0
$\kappa_{\mathrm{sa}}\ (\kappa_{\mathrm{M-sa}})^{-1}$	1	1.00000	0.00000	0.0
$\kappa_{\mathrm{g}}\ (\kappa_{\mathrm{M-g}})^{-1}$	1	1.00000	0.00000	0.0
κ_{ε}	1	1.000	0.009	18.5
$\kappa_{\mathrm{M-\varepsilon}}$	1	1.000	0.016	58.5
Y	$[Y]$	y	$u_{\mathrm{c}}(y)$	
τ	1	0.999	0.019	100.0

The input quantities x_i are given in the text. The index column gives the relative contributions of $u(x_i)$ to the combined standard uncertainty, $u_{\mathrm{c}}(y)$, of τ

$$\beta_{\mathrm{R}} = \frac{1+\frac{\alpha_{Q}\,Q_{0,E}(\alpha)}{f_1+Q_{0,E}(\alpha)}}{1+\frac{\alpha_{Q}\,Q_{0,E}(\alpha)}{f_1(1+\alpha_1)+Q_{0,E}(\alpha)}}$$

$$\kappa_{\varepsilon} = \frac{(d_{\mathrm{Mo}} + \Delta d_{\mathrm{Mo2}})^2}{(d_{\mathrm{Mo}} + \Delta d_{\mathrm{Mo1}})^2}$$

$$\kappa_{M-\varepsilon} = \frac{(d_{\mathrm{Co}} + \Delta d_{\mathrm{Co2}})^2}{(d_{\mathrm{Co}} + \Delta d_{\mathrm{Co1}})^2}$$

Approaching the target 0.1% expanded uncertainty

$$\alpha_Q = \frac{Q_{0,EM}(\alpha) - Q_{0,E}(\alpha)}{Q_{0,E}(\alpha)}$$

Q_0 (^{98}Mo) = 53.1(33)

Q_0 (^{59}Co) = 1.993(60)

$\alpha_Q \cong -0.96$

Q_0 (^{98}Mo) = 53.1(33)

Q_0 (^{116}Sn) = 56.3(11)

$\alpha_Q \to 0$

$u(\beta_R) \downarrow$

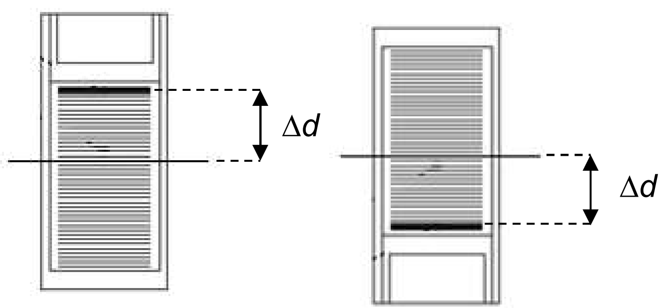
Δd_{Mo1}

Δd_{Mo2}

Δd_{Co2}

Δd_{Co1}

$$\sqrt{\frac{C_{rsu}(t_d)}{C_{usd}(t_d)}} = \frac{d - \Delta d}{d + \Delta d}$$



$u(\kappa_\varepsilon) \downarrow$

$u(\kappa_{M\text{-}\varepsilon}) \downarrow$

Thank you for your attention