Evaluation of Surface Contamination – Proposal for Revision of ISO Standard 7503

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- Proposed structure of ISO standard 7503
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Importance of surface contamination evaluation

Direct measurement of surface contamination

Importance of surface contamination evaluation

Indirect measurement of surface contamination

Comparison of limits and guideline values for surface contamination in Bq/cm^2

Radio-nuclide	Group (ANSI)	Screening level	Limit		Guideline value
		CLEARANCE (ANSI)	*TRANSPORT (IAEA)* Averaging area: 300 cm^2		*CLEARANCE (Switzerland)* Averaging area: 100 cm^2
Ra-226	1	0.1	0.4	0.04	1
Th-228		0.1	4	0.4	0.1
Th-232		0.1	4	0.4	0.1
Am-241		0.1	0.4	0.04	0.3
Co-60	2	1	4	0.4	3
Ag-110m		1	4	0.4	10
Eu-152		1	4	0.4	10
U-238		1	0.4	0.04	1
Na-24	3	10	4	0.4	3
Cl-36		10	4	0.4	3
I-131		10	4	0.4	3
Pu-241		10	4	0.4	10
H-3	4	100	4	0.4	1000
C-14		100	4	0.4	30
S-35		100	4	0.4	30
Fe-55		100	4	0.4	300

Existing structure of ISO standard 7503

ISO 7503-1, First edition 1988-08-01
Evaluation of surface contamination - Part 1:
Beta-emitters (maximum beta energy greater than 0.15 MeV) and alpha-emitters

ISO 7503-2, First edition 1988-08-01
Evaluation of surface contamination - Part 2:
Tritium surface contamination

ISO 7503-3, First edition 1996-11-15
Evaluation of surface contamination - Part 3:
Isomeric transition and electron capture emitters, low energy beta emitters (maximum beta energy less than 0.15 MeV)

Proposed structure of ISO standard 7503

ISO 7503-1
  Evaluation of surface contamination - Part 1: Direct method

ISO 7503-2
  Evaluation of surface contamination - Part 2: Indirect method

Proposed content of ISO 7503-1 Direct method

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2 Normative references
3 Definitions
4 Methods for evaluating surface contamination
5 Instrumentation
6 Calibration
7 Calculation of calibration factors
8 Measurement
9 Calculation of the activity per unit area
10 Applicability of the different calibration factor types
11 Examination of applied surface contamination evaluation method
12 Test report
Annexes

Proposed content of ISO 7503-1 Direct method

6 Calibration
6.1 Basic methods
6.2 Calibration sources
6.3 Calibration geometry
6.4 Calibration procedure
6.5 Calculation of the instrument efficiency

7 Calculation of calibration factors
7.1 Calibration factor for the evaluation of surface contaminations of a single radionuclide (single-source calibration)
7.2 Calibration factor for the evaluation of surface contaminations of a single radionuclide (multisource calibration)
7.3 Calibration factor for the evaluation of surface contaminations of a radionuclide mixture

Reference sources for multisource calibration

Nuclide	Radiation type	Emission probability	Radiation energy [keV]			
			For all α emitters			
Am-241	alpha	1.0	5390 – 5490			
			Energy regions for β emitters (mean energy)			
			40 - 70	70 - 140	140 - 400	>400
C-14	beta	1.0	50			
Tc-99	beta	1.0		85		
Cl-36	beta	0.98			250	
Sr-90/Y-90	beta	1.0 each			190	940
			Energy regions for γ emitters			
			5 - 15	15 - 90	90 - 300	>300
Fe-55	gamma	0.28	6			
I-129	gamma	0.78		32		
Co-57	gamma	0.96			124	
Cs-137	gamma	0.85				660
Co-60	gamma	2.0				1200

Calibration procedure

Calculation of the instrument efficiency

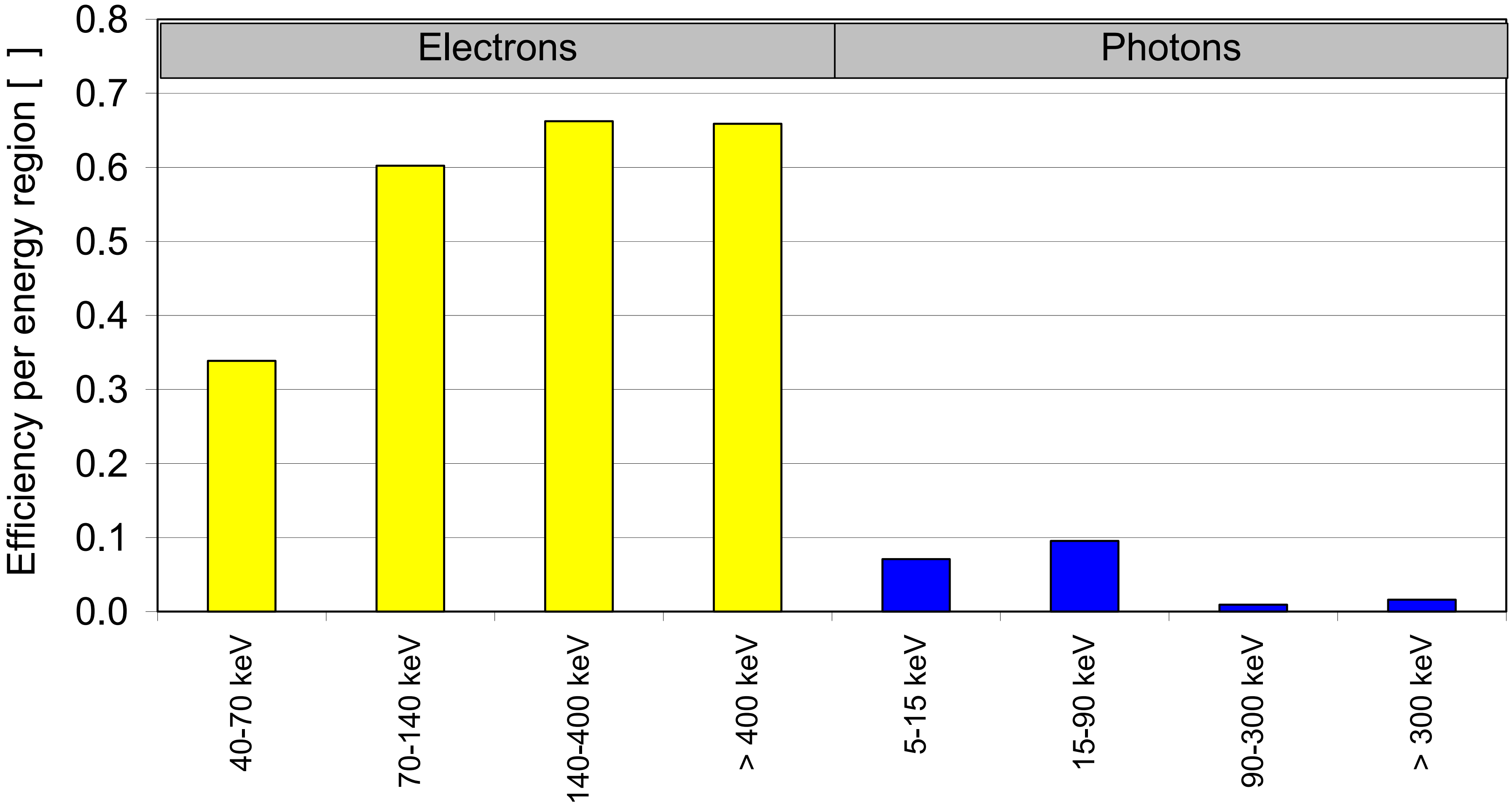
$$\varepsilon_{i,j} = \frac{r - r_B}{q_{2\pi,j}}$$

r = measured total count rate from the reference source [s^{-1}]

r_B = background count rate [s^{-1}]

$q_{2\pi,j}$ = surface emission rate for radiation type j of the calibration source [s^{-1}].

Example of instrument efficiency profile



Calibration factor for the evaluation of surface contaminations of a single radionuclide (multisource calibration)

$$C_{ms,n} = \frac{1}{A \times \sum_{j} \left(\varepsilon_{\mathrm{i},\mathrm{j}} \times \varepsilon_{d,j} \times \varepsilon_{s,j} \right)}$$

where

in case of no requirement for averaging the instrument reading:

A = W = sensitive detector window area [cm^2], and

in case of a requirement for averaging the instrument reading:

A = A_{GV} = active calibration source area equal to the averaging area for the surface contamination guideline value [cm^2]

$\varepsilon_{i,j}$ = instrument efficiency for a given energy and radiation type j [ ]

$\varepsilon_{d,j}$ = emission probability of a given radionuclide n for the radiation type j [ ]

$\varepsilon_{s,j}$ = efficiency of the contamination source of radionuclide n [ ].

The summation index j refers to the radiation type.

Recommended values for ε_s

Type of particle and energy range (MeV)	ε_s	Comment
Beta ($E_{\beta max} \geq 0.4$ resp. $E_{\beta mean} \geq 0.14$)	0.5	for beta-emitters and isomeric transition emitters
Beta ($0.15 < E_{\beta max} < 0.4$ resp. $0.04 < E_{\beta mean} < 0.14$)	0.25	for beta-emitters and isomeric transition emitters
Alpha	0.25	Conservative value for: – layers up to saturation thickness homogeneously contaminated – wipe test samples

Calculation of the activity per unit area for surface contaminations of a single radionuclide

The activity per unit area $A_{s,n}$ of fixed and removable contamination of a single radionuclide n on the surface being checked, expressed in Bq cm^{-2}, in relation to the measured count rate, is given by the equation:

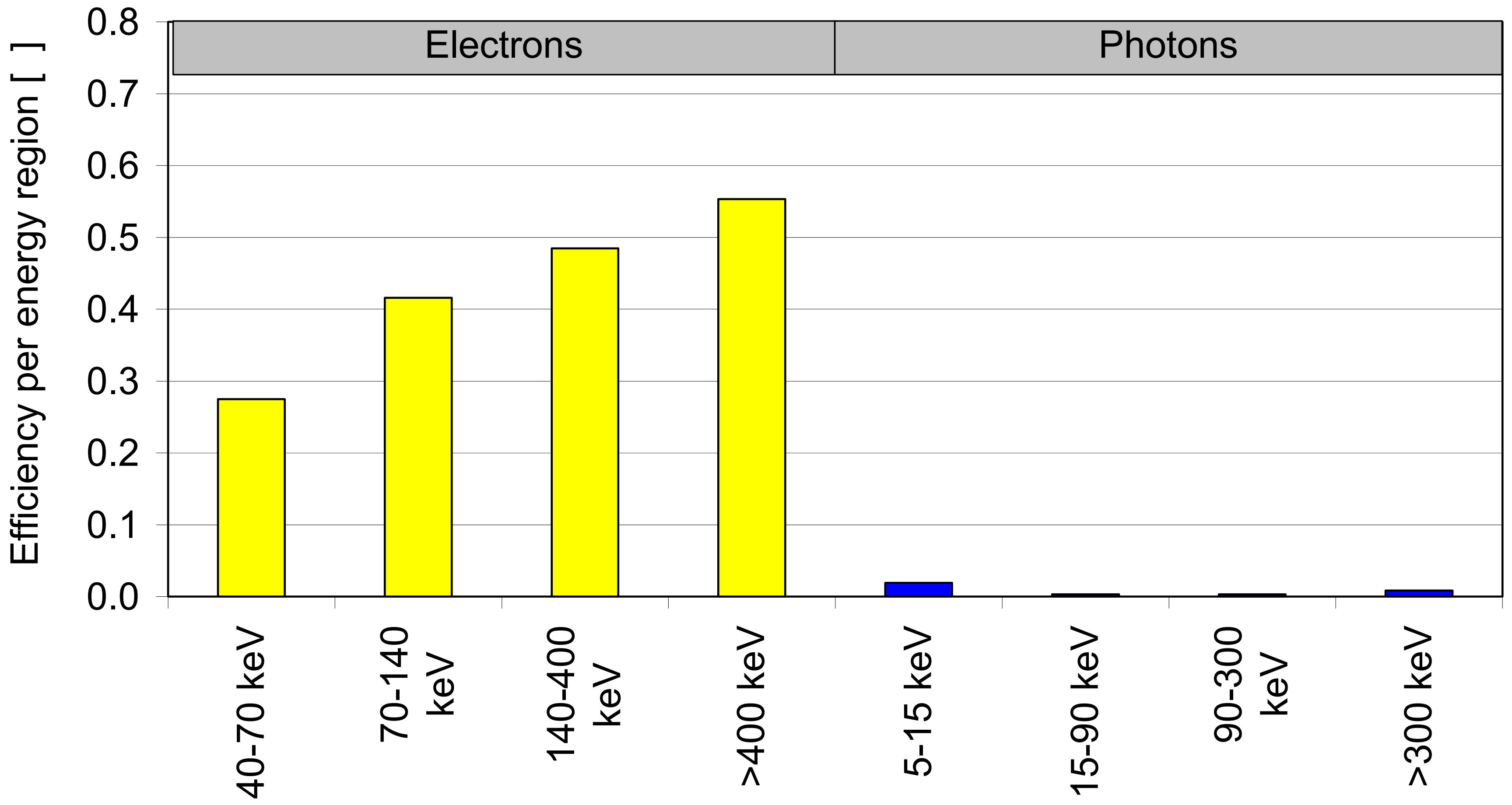
$$A_{s,n} = C_{ms,n} \times \left(r - r_B\right)$$

Example of a multisource calibration for I-131

- Determination of instrument efficiency
- Radionuclide data treatment

  Preparation of beta and photon emission probabilities $\varepsilon_{d,\beta}$ and $\varepsilon_{d,\gamma}$
- Calculation of the summation term of the calibration factor formula
- Calculation of calibration factor and instrument net count rate for the guideline value

Efficiency profile for the calibrated instrument



Preparation of beta and photon emission probabilities $\varepsilon_{d,\beta}$ and $\varepsilon_{d,\gamma}$

Radionuclide	Half-life	Unit	Radiation type	Energy	uE	Intensity	uI	40-70 keV	70-140 keV	140-400 keV	> 400 keV	5-15 keV	15-90 keV	90-300 keV	> 300 keV
I-131	8.0207	d	beta part.	69.36	0.19	2.1	0.03	2.1	0	0	0				
I-131	8.0207	d	beta part.	86.94	0.2	0.651	0.023	0	0.651	0	0				
I-131	8.0207	d	beta part.	96.62	0.2	7.27	0.1	0	7.27	0	0				
I-131	8.0207	d	beta part.	191.58	0.23	89.9	0.8	0	0	89.9	0				
I-131	8.0207	d	beta part.	283.24	0.23	0.48	0.01	0	0	0.5	0				
I-131	8.0207	d	E AU K	24.6	0	0.6	0.04	0	0	0	0				
I-131	8.0207	d	E AU L	3.43	0	5.1	0.4	0	0	0	0				
I-131	8.0207	d	E CE K	45.6236	0	3.5	0.3	3.5	0	0	0				
I-131	8.0207	d	E CE K	249.744	0.005	0.252	0.017	0	0	0.3	0				
I-131	8.0207	d	E CE K	329.928	0.005	1.55	0.2	0	0	1.6	0				
I-131	8.0207	d	E CE L	74.7322	0	0.46	0.04	0	0.46	0	0				
I-131	8.0207	d	E CE L	359.036	0.005	0.246	0.022	0	0	0.2	0				
I-131	8.0207	d	gamma	80.185	0	2.62	0.04					0	2.62	0	0
I-131	8.0207	d	gamma	177.214	0	0.27	0.004					0	0	0.27	0
I-131	8.0207	d	gamma	284.305	0.005	6.14	0.07					0	0	6.14	0
I-131	8.0207	d	gamma	325.789	0.004	0.274	0.022					0	0	0	0.274
I-131	8.0207	d	gamma	364.489	0.005	81.7	0.8					0	0	0	81.7
I-131	8.0207	d	gamma	503.004	0.004	0.36	0.004					0	0	0	0.36
I-131	8.0207	d	gamma	636.989	0.004	7.17	0.1					0	0	0	7.17
I-131	8.0207	d	gamma	642.719	0.005	0.217	0.005					0	0	0	0.217
I-131	8.0207	d	gamma	722.911	0.005	1.77	0.03					0	0	0	1.77
I-131	8.0207	d	X KA1	29.779	0	2.56	0.16					0	2.56	0	0
I-131	8.0207	d	X KA2	29.458	0	1.38	0.09					0	1.38	0	0
I-131	8.0207	d	X KB	33.6	0	0.91	0.06					0	0.91	0	0
I-131	8.0207	d	X L	4.11	0	0.57	0.18					0	0	0	0
I-131								**0.0560**	**0.0838**	**0.9243**	**0.0000**	**0.0000**	**0.0747**	**0.0641**	**0.9149**

Calculation of the summation term of the calibration factor formula

Calculation scheme for the summation term:

	40-70 keV	70-140 keV	140-400 keV	> 400 keV	5-15 keV	15-90 keV	90-300 keV	> 300 keV
Instrument efficiency ε_i	0.275	0.416	0.485	0.553	0.019	0.003	0.003	0.009
Emission probability ε_d	0.0560	0.0838	0.9243	0.0000	0.0000	0.0747	0.0641	0.9149
Contamination source eff. ε_s	0.25	0.25	0.5	0.5	0.5	0.5	0.5	0.5
Product of indiv. columns	0.0039	0.0087	0.2241	0.0000	0.0000	0.0001	0.0001	0.0041

The number products formed for the individual columns are added up to give the summation term:

$$\sum_j \left(\varepsilon_{\mathrm{i},\mathrm{j}} \times \varepsilon_{d,j} \times \varepsilon_{s,j}\right) = 0.241$$

Calculation of calibration factor and instrument net count rate for the guideline value

With the averaging area of 100 cm^2 for the surface contamination guideline value the multisource calibration factor for I-131 becomes:

$$C_{ms,I-131} = \frac{1}{A_{GV} \times \sum_{j} \left(\varepsilon_{\mathrm{i,j}} \times \varepsilon_{d,j} \times \varepsilon_{s,j} \right)} = 0.041 cm^{-2}$$

For the surface contamination guideline value $GV_{I\text{-}131}$ of 3 Bq cm^{-2} the instrument net count rate $r_{GV,I\text{-}131}$ becomes:

$$r_{GV,\mathrm{I\text{-}131}} = \frac{GV_{\mathrm{I\text{-}131}}}{C_{ms,\mathrm{I\text{-}131}}} = 73 s^{-1}$$

Calibration factor for the evaluation of surface contaminations of a radionuclide mixture

The calibration factor C_m for a given radionuclide mixture m with known radionuclide contribution to the mixture is calculated according to:

$$C_m = \frac{1}{\sum_{n=1}^{N} \frac{f_n}{C_{ss,n}}}$$

or

$$C_m = \frac{1}{\sum_{n=1}^{N} \frac{f_n}{C_{ms,n}}}$$

where

$C_{ss,n}$ = single-source calibration factor for a given radionuclide n [cm^{-2}]
$C_{ms,n}$ = multisource calibration factor for a given radionuclide n [cm^{-2}]

f_n = fraction of nuclide n in the mixture ($\sum_{n=1}^{N} f_n = 1$) [ ].

Comparison of calibration factors for direct and indirect method

$$C_{ms,n} = \frac{1}{A \times \sum_j \left(\varepsilon_{\mathrm{i,j}} \times \varepsilon_{d,j} \times \varepsilon_{s,j}\right)}$$

$$C_{ms,n} = \frac{1}{S \times F \times \sum_j \left(\varepsilon_{\mathrm{i,j}} \times \varepsilon_{d,j} \times \varepsilon_{s,j}\right)}$$

S = wiped area [cm^2]
F = removal factor [ ].
If the removal factor F is not determined experimentally, a conservative value of F = 0.1 shall be used.

Summary

The sound metrological basis given in the revision proposal for ISO standard 7503 is necessary to fulfill the demands outlined in the

Scope

- This international standard applies to the evaluation of contamination on surfaces in terms of activity per unit area by direct and indirect methods of measurement.
- This international standard also applies to the evaluation of surface contamination by direct and indirect methods of measurement in compliance with guideline values or limits of surface contamination levels given in national legislations or international conventions.

Summary

Scope continued

- This standard can be used for nuclear material transportation, laboratory and equipment/installation control and for clearance of materials/equipment.
- This international standard applies to alpha-, beta-, isomeric transition and electron capture emitters.

Outlook

Status of ISO standard 7503 revision process:

- At present, Part 1 “Direct method” and Part 2 “Indirect method” are *Working Drafts* of Working Group 17 of ISO/TC 85 SC 2.
- Beginning of October, the two drafts have been submitted to AFNOR for circulation for two months as *Committee Drafts* for ballot. A decision is not yet known.