Guidance on Applying the Measurement Methods Matrix (MMM) in Using Comparison Results to Support CMCs

In the interest of supporting the calibration and measurement capabilities (CMCs) published by National Measurement and Designated Institutes (NMIs and DIs) on the Key Comparison Database (KCDB), the Consultative Committee on Ionizing Radiation Section II [CCRI(II)] developed a generic groupings table of radionuclides called the MMM. Using these groupings, CCRI(II) and corresponding technical committees in the Regional Metrology Organizations (RMOs) might leverage a select set of comparisons to support a wider range of CMCs for the measurement of radionuclides. The MMM has been designed for used by the NMIs and DIs.

For the official rules to CMC claims, refer to the latest "Rules for entering CMC Claims in Ionizing Radiation Metrology" located on the BIPM website:
https://www.bipm.org/en/committees/cc/ccri/publications

This document is meant to be used as a tool for evaluating CMCs but should not be construed to imply traceability of radionuclides, which still requires an unbroken chain of comparisons or calibrations against an appropriate standard.

- Radionuclides have been categorized by a primary measurement method (column in the MMM) as appropriate for a specific nuclide.

- Each method is described by the geometry, detector type, radiation, and detection mode. The relative difficulty of measuring a specific nuclide by the indicated method (without consideration of source preparation issues) is denoted by a color-coded system: "red" for the most difficult, "yellow" for the moderately difficult, and "green" for the least difficult. It should be noted that a "red" nuclide by one method may be indicated as "green" by another.

- Several primary methods may be used for a given radionuclide; the application of more than one method for verification and confidence in results, as appropriate, is encouraged.

- In general, results from a comparison of a radionuclide indicated as red for a given primary measurement method may be used to support the calibration and measurement capability (CMC) claims for other nuclides of the same type (presuming similar decay complexities and measurement challenges) by that measurement method (i.e., other red, yellow and green-indicated nuclides for that method). Results from a comparison of a nuclide indicated as yellow will support claims for the yellow and green-indicated nuclides, and that of a green-indicated nuclide will support CMCs of only green-indicated nuclides by the same method. CMCs should, in all cases, be claimed only for those radionuclides measured by the submitting laboratory.

- A comparison result of a radionuclide measured by a specific primary method generally will not be supportive of claims for that radionuclide measured by other primary methods.

- As comparisons are generally not undertaken for secondary methods specifically, a similar matrix for those methods is not practical. Extension of primary comparison results to support CMCs of secondary methods may be possible with demonstration of traceability of those methods to the primary method used in the comparison; the uncertainties would be expected to be greater than those achieved in the initial, primary-method comparison.

- When a secondary method is used in the context of a comparison, the results for that comparison can support the CMCs of only that nuclide as measured by that method.

Generic Groupings of the Radionuclides for Primary Methods: To Establish Key Comparisons to Underpin MRA CMCs in Radioactivity

Nr	App.	Nuclide	4P-BP/AP-PC/PP/LS/SP-GR-NA/GH-CO/AC	4P-XR/AE-PC/PP/LS/SP-GR-NA/GH-CO/AC	4P-AP-LS-00-00-HE	4P-BP/AP/XR/AE-NA/CS-00-00-HE	4P-PH-NA-00-00-HE	4P-BP/AP-PP-00-00-HE* (**most emitting an alpha particles, accompanied by emission of gamma photons)	4P-XR/AE-PP-00-00-HE	SA-A-P-PS-00-00-00	4P-BP-PC/PP/LS-GR-NA-CT/AT	4P-A-P/BP/PH/AE/XR-LS-00-00-CN	4P BP-LS-00-00-TD** (**pure-beta emitting nuclides only)	4P-BP-CD-00-00-TD** (**Čerenkov Counting in LS channel)	4P-AP/BP/PH/AE/XR-LS-00-00-TD*** (***all not pure-beta emitting nuclides)	4P-AP/BP/PH/AE/XR-CD-00-00-TD*** (***TDCR with Čerenkov counting, no1 pure-beta emitting nuclides)	4P-BP-PP-00-00-HE****** (******pure-beta emitting nuclides only)	4P-BP-PC-00-00-IG	??-XR/AE/PO-??-00-00-??	??-GR-??-00-00-??	4P-??-PC/PP/LS/SP-??-NA/GH-CO/AC/CT/AT (DS)*	4P-??-LS-00-00-CN/TD (DS)*	4P-??-PP-00-00-HE (DS)*	SA-??-PS-00-00-00 (DS)*	4P-??-PC-00-00-IG (DS)*
			α or β coincidence/ anticoincidence	x-ray or Auger coincidence/ anticoincidence	α-particle high efficiency liquid scintillation	α or β or x-ray or Auger NaI(Tl) or CsI	photons NaI(Tl) high efficiency	α or β high efficiency proportional counter	x-ray or Auger proportional counter high efficiency	Defined solid angle α-particle with PIPs detector	β-particle proportional counter or liquid scintillation with γ-ray efficiency tracing	α or β or photon or Auger or x-ray CIEMET/NIST	β-particle (pure) TDCR	β-particle (pure) TDCR with Čerenkov counting in the LS channel	α or (mixed) β or photon or Auger or x-ray TDCR	α or (mixed) β or photon or Auger or x-ray TDCR with Čerenkov counting in the LS channel	β-particle (pure) high efficiency proportional counter	β-particle internal gas counting	Any geometry x-ray or Auger or positron by any detector and mode	Any geometry γ-ray by any detector and mode	DELAYED STATE 4π any radiation coincidence methods	DELAYED STATE 4π any radiation scintillation methods	DELAYED STATE 4π any radiation high efficiency methods	DELAYED STATE defined solid angle any radiation	DELAYED STATE 4π any radiation internal gas counting
1	ENV	H-3										3	2					1							
2	RES	Be-7		3					1																
3		Be-10										0.6													
4	MDD	C-11					1					2							3						
5	ENV, RES	C-14									3	1	1					1							
6	MDD	F-18	2				1	2				0.6			3										
7	DCA	Na-22	1				1					0.6													
8	DCA	Na-24	0.5				3	2				2													
9	ENV	Al-26	2									2													
10	MDT, RES	P-32									1.5	0.7	1.5				1.5								
11	MDT, RES	P-33									1.5	1	1				1.5								
12		Si-32																							
13		S-35									3	1	1				3								
14	ENV,MDD,FOF	Cl-36									1.5	0.7	1				2								
15		Ar-37																	3						
16	ENV	K-40										0.8													
17	MDD,WAS,FOF	Ar-41																2							
18	ENV,WAS,FOF	Ca-41										6							3						
19		K-42	1					1				2													
20		Ca-45									2	2	2				2								
21		Sc-46	1				2	3				3													
22		Ca-47/Sc-47																			1.5	3			
23		Sc-47	0.6					3				3													
24	DCA	Cr-51		1								3													
25		Mn-52		1.5								2													
26		Mn-53																							
27	DCA	Mn-54		0.7								3			2										
28	DCA	Fe-55							6			3			2				4						
29	RES	Mn-56	0.7				3	2				2			2										
30		Co-56		0.8			1					3			3										
31		Co-57		1					3			2			2										
32		Co-58		1.2								2			2										
33		Fe-59	1			3						2	2												
34		Ni-59							2						?										
35	DCA	Co-60	0.4				2					1			1										
36		Ni-63									3	1	1												
37	MDD,MDT	Cu-64	2	2								1.2													
38		Cu-67					1																		
39		Zn-65		1								3			2										
40	MDD	Ga-67		2			5														2	3			
41	MDD, DCA	Ge-68/Ga-68	1.5					1.5							1.5				6		1.5	1.5			
42		Se-75		2			1														2	3			
43		As-76	1																			2			
44		Br-82	1																			2			
45	DCA	Sr-85		1																		3			
46	ENV	Kr-85																2							
47		Rb-86	1.2					2														2			
48		Rb-87																				1.4			
49		Sr-87m					3													3					
50	DCA	Y-88		0.8			2															1.5			
51	MDT	Sr-89									2		1				2					0.6			
52		Zr-89																							
53	MDT	Sr90/Y90										0.6	1								2		2		
54	MDT	Y-90									2		0.4				2					0.4			
55		Mo-93																							
56		Zr-93																							
57		Nb-93m																	5			0.7			
58		Nb-94	1																			1.5			
59		Nb-95	0.4																			2			
60		Tc-95m/Tc-95		1.5																	3				
61		Zr-95				8															4				
62	MDD	Mo-99																			1				
63	ENV, MDD (impu	Tc-99									2		1									1			
64	MDD	Tc-99m		2																3					
65	MDT	Ru-103	2																		2				
66		Pd-103							3						6						3		3		
67		Ru/Rh-106	1.5			2															0.7				
68		Ag-108m																			3				
69	DCA	Cd-109							2			?									1.5	1			
70		Ag110m	1				0.6														1				
71		Ag-111	1																						
72	MDD	In-111		1.5			0.4		0.4						1.5							1.5			
73		Cd-113m											?		?										
74		In-113m																		3					
75	DCA	Sn-113		2.5		3									?						2.5				
76		I-123		1.4								?			2							2.5			
77		Te-123m																		3					
78	MDD	I-124		2																		2			
79		Sb-124	2				3	4														1.5			
80	MDD, MDT	I-125		3		2			3						2.5				1.5	1.5		2.5			
81		Sb-125	2																		2				
82		Xe-127																3							
83		I-129	3												2							2			
84		Cs-131							3										3						
85	MDT	I-131	0.7						2												0.7	1			
86		Xe-131m																3							
87		Te-132/I-132	2																		2				
88	DCA	Ba-133		1.2			0.4															2			
89	MDD	Xe-133																2.5							
90		Cs-134	1.2				0.6	3														0.6			
91		Cs-137	1.5			1.5									?						1.5	1.5	1.5		
92	DCA	Ce-139		0.8			1.2								2							3			
93		Ba-140/La-140	1			2															1		2		
94		La-140	1																			2			
95	DCA	Ce-141	1					3														3			
96		Ce/Pr-144	1.2					4													1.2				
97		Pm-147									2		1.5				4					1			
98		Gd-148			1					2															
99	DCA	Eu-152		1.2			1															1			
100	DCA	Gd-153		2																		2			
101	MDT	Sm-153	1.2					3							1							1			
102		Eu-154	0.8				2	3														1			
103		Eu-155	0.8					4														2			
104		Tb-160	1																			1			
105	MDT	Ho-166	2					2														1			
106	DCA	Ho-166m	1				0.5						1		1							1			
107		Er-169	1.5																			1.5			
108	MDT	Yb-169		1.2			1															1			
109		Tm-170	2					2														1.5			
110		Yb-175																							
111		Lu-176	2				0.4															1.5			
112	MDT	Lu-177	1					3							1							0.8			
113		Hf-181					2														0.8		2		
114		Ta-182	1				2	3														2			
115		W-185									2						2					1.5			
116	MDT	Re-186	1.5					3							2							0.8			
117	MDT	W-188/Re-188													?						1.4		2.5		
118	MDT	Re-188	1.2					2														1.5			
119	MDT	Ir-192	1				0.6															0.6			
120		Au-195		1.5																		2			
121		Hg-197		3																		2			
122	MDT	Au-198	0.7					2														2			
123		Au-199	1.5																			1.5			
124	MDD	Tl-201		1.5																		3			
125		Tl-202		2																		2			
126		Hg-203	1				4	4														3			
127		Pb-203		1.5																		3			
128		Tl-204									2.5		1				2					1			
129		Bi-207					2														2				
130		Po-208			1.5																2		2	2	
131		Tl-208	3																			2			
132		Po-209			1.5			2																	
133		Pb-210						3													2	1			
134		Po-210			1.5			2		2															
135		At-215																							
136	ENV	Rn-222													?								3	3	
137		Ra-223	1									1	1												
138		Ra-224			3					3															
139		Ac-225																							
140		Ra-226																			4		2	1.2	
141		Ac-227																			5			4	
142		Th-227	1																						
143		Ac-228																			2				
144		Ra-228/Ac-228																			3				
145		Th-228+d																			4		3	3	
146		Th-229			2			2		2					3										
147		Th-230			1			2		2															
148		Pa-231																							
149		Th-232			2			2		2															
150		U-232			1			2		2															
151	ENV	Pa-233	1.5					3														3			
152		U-233			1			2		2															
153		Th-234(/Pa-234)						4													2				
154		U-234			1			2		2															
155		U-235			1																3		3	1	
156		U-236			4			2		4															
157		Np-237																			1.5	0.6	2	1.5	
158		Pu-238	1		1			2		0.5															
159		U-238/(Th,Pa)																			3	2	3	4	
160		Pu-239			1			2		2															
161		Pu-240			1			2		2															
162		Pu-241										2	2												
163	DCA	Am-241	0.8		1			2		0.5					?										
164		Cm-242	1		1			2		2															
165		Pu-242	2		1			2		2															
166		Am-243																			2	1	3	1	
167		Cm-243						3		3		2													
168		Cm-244	2		1			2		1															

(DS)* = delayed state or active daughter

Acronyms for radioactivity measurement methods as used in the Generic Groupings Table

D.F.G. Reher, IRMM, 2001-12-11; updated 2005-10-18 (lk)

Geometry	*acronym*
4π	4P
defined solid angle	SA
2π	2P
undefined solid angle	UA

Detector	*acronym*
proportional counter	PC
press. prop counter	PP
liquid scintillation counting	LS
Cerenkov detector **	CD
NaI(Tl)	NA
Ge(HP)	GH
Si(Li)	SL
Ge-Li	GL
CsI	CS
ionisation chamber§	IC
grid ionisation chamber§	GC
bolometer	BO
calorimeter	CA
plastic scintillator	SP
PIPS detector	PS

Radiation	*acronym*
positron	PO
beta particle	BP
Auger electron	AE
Conversion electron	CE
Bremsstrahlung	BS
Gamma ray	GR
X - rays	XR
alpha - particle	AP
mixture of various radiation	MX
*Photon**	*PH*

Mode	*acronym*
efficiency tracing	ET
internal gas counting	IG
CIEMAT/NIST	CN
sum counting	SC
coincidence	CO
anti-coincidence	AC
coincidence counting with efficiency tracing	CT
anti-coincidence counting with efficiency tracing	AT
triple-to-double coincidence ratio counting	TD
high efficiency	HE
selective sampling	SS

*this notation not used in earlier versions

§ indicates that these methods are not addressed by the generic tables as they are secondary methods, which are not included here.

** changed to CD March 2016

Common Terms for Primary Methods in the

Measurement Methods Matrix

Matrix Column	Noted in Matrix	Common Nomenclature
4P-BP/AP-PC/PP/LS/SP-GR-NA/GH-CO/AC		**Coincidence/anticoincidence** counting (beta or alpha-particle emitting radionuclides) in approximately 4πι geometry
4P-XR/AE-PC/PP/LS/SP-GR-NA/GH-CO/AC		**Coincidence/anticoincidence** counting (x ray or Auger-electron emitting radionuclides) in approximately 4πι geometry
4P-AP-LS-00-00-HE		**High efficiency** (liquid scintillation) counting (alpha particle-emitting radionuclides)
4P-BP/AP/XR/AE-NA/CS-00-00-HE		**High efficiency** (NaI(Tl) or CsI detector in approximately 4πι geometry) counting (beta or alpha particle, or x ray or Auger-electron emitting radionuclides)
4P-PH-NA-00-00-HE		**High efficiency** (Na(Tl) detector in approximately 4πι geometry) counting (photon-emitting radionuclides)
4P-BP/AP-PP-00-00-HE*	nuclides emitting beta or alpha particles, accompanied by emission of gamma photons	**High efficiency** (pressurized proportional counter in approximately 4πι geometry) counting (beta or alpha-particle emitting radionuclides producing photons)
4P-XR/AE-PP-00-00-HE		**High efficiency** (pressurized proportional counter in approximately 4πι geometry) counting (x ray or Auger-electron emitting radionuclides)
SA-AP-PS-00-00-00		**Defined Solid angle** alpha-particle counting using a PIPS detector
4P-BP-PC/PP/LS-GR-NA-CT/AT		**Coincidence/anticoincidence** counting with efficiency tracing (beta particle-emitting radionuclides) in approximately 4πι geometry
4P-AP/BP/PH/AE/XR/CE-LS-00-00-CN		**CIEMAT/NIST** liquid scintillation counting (all radiations)
4P-BP-LS-00-00-TD**	pure-beta emitting nuclides only	**TDCR** (pure beta particle-emitting radionuclides)

4P-BP-CD-00-00-TD**	Cerenkov Counting in LS channel	**TDCR using Cerenkov** counting in LS channel (pure beta-particle emitter radionuclides)
4P-AP/BP/PH/AE/XR/CE-LS-00-00-TD***	all nuclides other than pure-beta emitters	**TDCR** (all other than pure beta-particle emitting radionuclides)
4P-AP/BP/PH/AE/XR-CD-00-00-TD***	TDCR with Cerenkov counting, nuclides other than pure-beta emitters	**TDCR using Cerenkov counting** (all other than pure beta-particle emitting radionuclides
4P-BP-PP-00-00-HE****	pure-beta emitting nuclides only	**High efficiency** (pressurized proportional counter in approximately 4πι geometry) counting (pure beta particle emitters)
4P-BP-PC-00-00-IG		**Internal gas** (proportional counter) counting (beta particle-emitting radionuclides) in approximately 4πι geometry
??-XR/AE/PO/CE-??-00-00-??		X ray, Auger, conversion electron or positron emitting radionuclides, **any other primary counting method**
??-GR-??-00-00-??		Gamma ray emitting radionuclides, **any other primary counting method**
4P-??-PC/PP/LS/SP-??-NA/GH-CO/AC/CT/AT (DS)*	Delayed state	**Coincidence/anticoincidence** methods, delayed state radionuclide decay
4P-??-LS-00-00-CN/TD (DS)*	Delayed state	**Liquid scintillation** (CIEMAT/NIST or TDCR) methods, delayed state radionuclide decay
4P-??-PP-00-00-HE (DS)*	Delayed state	**High efficiency** (pressurized proportional counter in approximate 4 pi geometry) method, delayed state radionuclide decay
SA-??-PS-00-00-00 (DS)*	Delayed state	**Defined Solid angle** counting methods, delayed state radionuclide decay
4P-??-PC-00-00-IG (DS)*	Delayed state	**Internal gas** counting methods, delayed state radionuclide decay