Discussion of the Steel Screening Results

Gerd Heusser for Task Group 11

G. Heusser
GERDA Collabor. meeting
Ringberg, Feb. 12-14, 2007

composition [%] of 1.4571 (X6CrNiMoTi17-12-2) according to DIN EN 10088				
C	Cr	Ni	Mo	Ti
≤ 0.08	16.5 - 18.5	10.5 - 13.5	2.0 - 2.5	≥ 5 x C ≤0.70

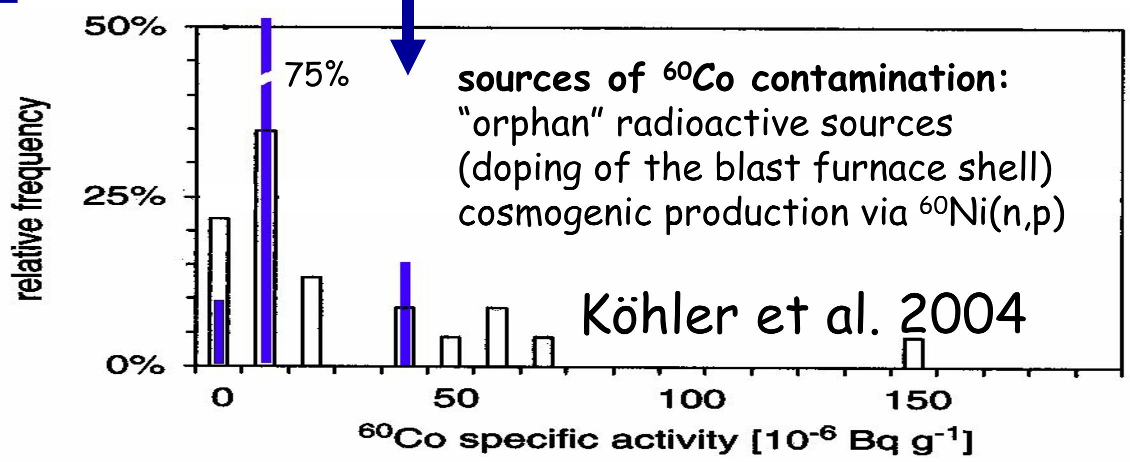
Steel 457.1	**activity [mBq/kg]**					
sample	**primordial**				**man made**	**cosmogenic**
heat plate **kg # hours**	^{226}Ra	^{228}Th	^{228}Ra	^{40}K	^{60}Co	^{7}Be
5991 495466-2 54,0 D1 70.5	2.9 1.0	5.1 1.0	≤ 2.9	≤ 3.9	6.5 0.5	
494257 347106-2 61.3 D2 95.2	≤ 2.0	≤ 1.9	≤ 3.4	≤ 4.5	14.2 0.6	34.6 5.3
493553 320308-3 57.3 D3 161.2	≤ 0.84	1.1 0.4	≤ 3.3	≤ 3.3	15.1 0.5	
493554 20311+AF 39.96 D4 36.1	≤ 2.2	≤ 2.6	≤ 4.5	≤ 6.2	14.4 1.0	
492217 91856 40.6 D5 101.3	≤ 1.2	≤ 1.1	≤ 2.6	≤ 2.8	11.6 0.5	
495895 ? 20 mm 49.38 D6 253.3	≤ 0.6	≤ 0.8	≤ 1.4	≤ 1.7	16.7 0.4	
496895 ? 25 mm 52.48 D7 99.4	≤ 1.3	≤ 1.0	≤ 4.1	≤ 6.8	17.1 0.7	

measurements at Heidelberg

GeMPI measurements at LNGS (Matthias Laubenstein)

Steel 457.1	activity [mBq/kg]													
sample	primordial radionuclides						man made		cosmogenic radionuclides					
Supplier	^{226}Ra	^{234m}Pa	^{235}U	^{228}Th	^{228}Ra	^{40}K	^{137}Cs	^{60}Co	^{7}Be	^{54}Mn	^{58}Co	^{56}Co	^{46}Sc	^{48}V
Ilsenburg	≤ 1.3	≤ 94	≤ 2.6	≤ 0.2	≤ 2.6	≤ 2.8	0.77 0.43	45.0 2.1	≤ 3.9	1.3 0.4	0.67 0.34	≤ 0.32	≤ 0.35	0.30 0.11
Ilsenburg	≤ 0.24	≤ 12	≤ 0.63	≤ 0.11	≤ 0.86	≤ 0.93	≤ 0.16	14.0 0.1	≤ 3.0	1.5 0.1	0.99 0.12	0.17 0.06	0.24 0.06	0.36 0.07
Ilsenburg	≤ 0.35	≤ 38	≤ 1.5	≤ 0.27	≤ 1.1	≤ 1.1	≤ 0.39	13.0 0.6	13.6 2.5	1.4 0.2	0.59 0.20	≤ 0.42	≤ 0.31	0.40 0.12
Ugine	≤ 0.74	≤ 45	≤ 1.5	≤ 0.41	≤ 1.0	≤ 1.1	≤ 0.26	13.8 0.7	≤ 5.7	0.92 0.24	0.56 0.23	≤ 0.62	≤ 0.54	0.27 0.11
Acroni	≤ 13	≤ 41	≤1.9	5.1 0.5	≤ 3.0	≤ 1.7	≤ 0.36	20 1	9.6 2.9	2.0 0.3	0.71 0.26	≤ 0.71	≤ 0.67	0.31 0.13
Acroni	1.0 0.6	54 16	2.5 1.5	1.5 0.2	1.0 0.5	≤ 0.81	≤ 0.1	18.3 0.7	4.8 1.7	1.7 0.2	0.69 0.16	0.28 0.10	0.47 0.14	0.22 0.09
Acroni	3.9 1.6	≤ 56	≤ 3.9	5.2 0.5	1.9 1.0	≤ 1.7	≤ 0.6	42.1 1.9	≤ 5.9	1.6 0.3	0.54 0.27	≤ 0.6	0.61 0.26	0.39 0.13

Ilsenberg: electric arc melting
Acroni: electric arc melting
+ vacuum oxygen decarboration



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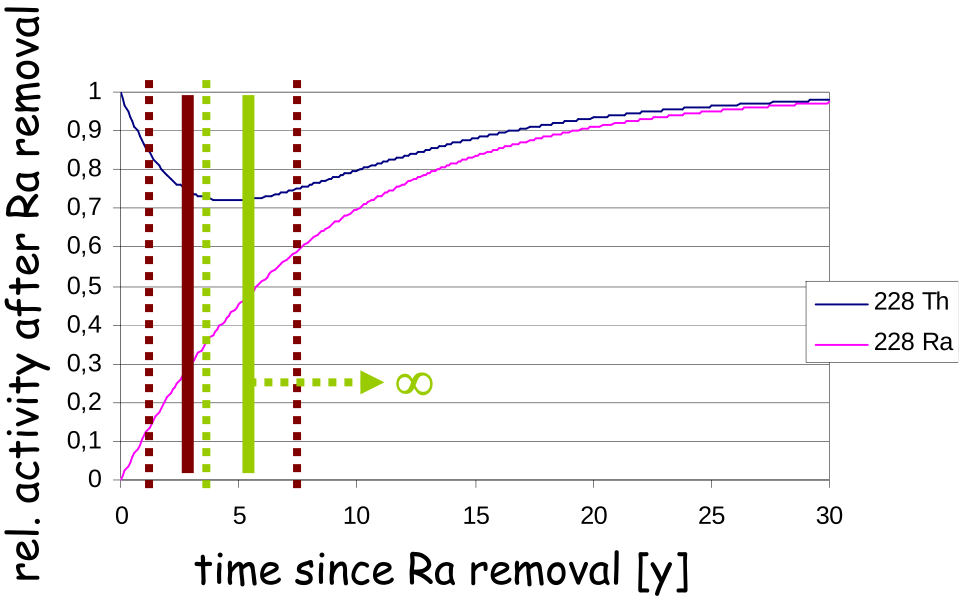
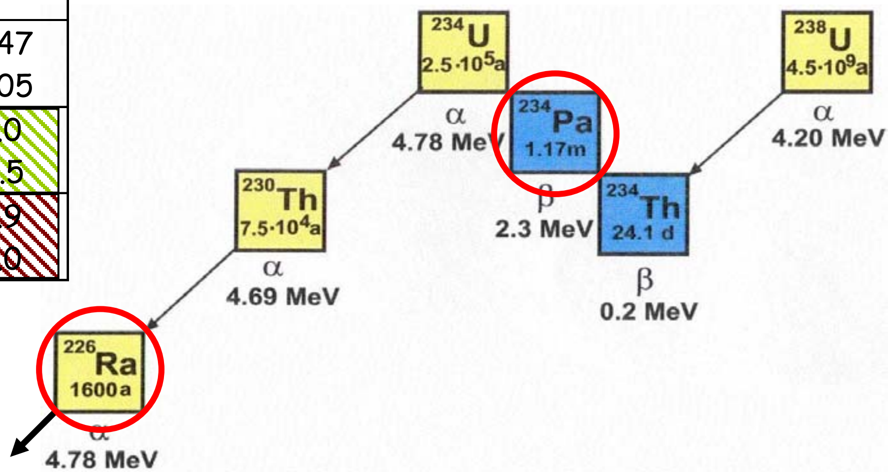
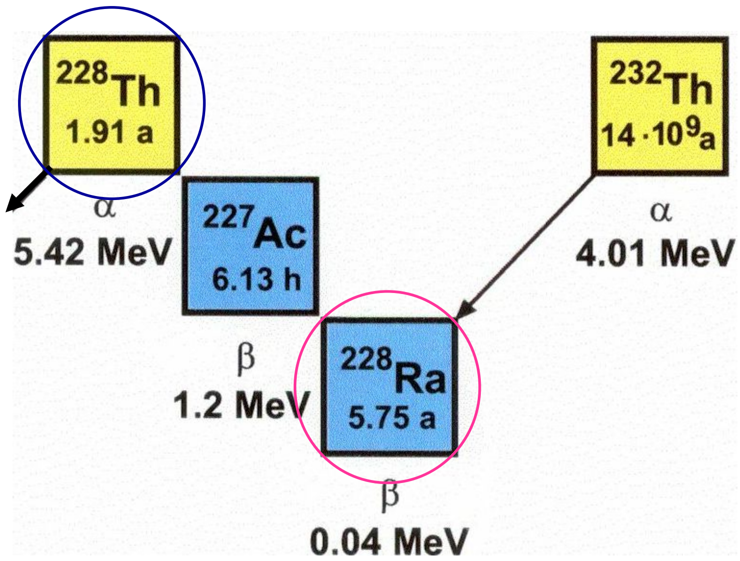
sample heat kg · # · plate hours	^{226}Ra	^{234m}Pa	^{235}U	234m / 226	^{228}Th	^{228}Ra
old ship steel 47.29 · 1017	0.15 0.02	5.7\$ 1.4	0.30\$ 0.08	38 11	0.46 0.07	0.47 0.05
254533 · 56754 53.15 · G5 · 230.4	1.0 0.6	54* 16	2.5* 1.5	54 36	1.5 0.2	1.0 0.5
255772 · 71459 55,0 · G7 · 144.5	3.9 1.6	≤ 56	≤ 3.9	≤ 10-24	5.2 0.5	1.9 1.0

\$ (4.6 ± 1.1) E-10 g/g U - (5.2 ± 1.4) E-10 g/g U
* (4.4 ± 1.3) E-9 g/g U - (4.4 ± 2.6) E-9 g/g U







increase of ^{228}Th activity in the course of GERDA !

Dating of steel production ?

Neuschütz D. et al., Distribution ratios after electric arc furnace melting of contaminated steel

	distribution [%] estimated from partition ratios experimental	
radionuclid	steel melt	slag + dust
^{60}Co	98	2
^{60}Co	88	12
^{137}Cs (CsCl)	-	> 99
^{137}Cs (CsX)	< 1	100
^{226}Ra	-	100
^{226}Ra	3.2	96.8
^{235,238}U	1.3	98.8
^{231,234}Th*	1	99

* U. Quade, ASME 2001

Most likely U/Ra desequilibrium in steel originates from additives in the iron/steel convertion

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Steel 457.1	**activity [mBq/kg]**					
sample	**cosmogenic radionuclides**					
$T_{1/2}$ →	^{7}Be 53.3 d	^{54}Mn 312.2 d	^{58}Co 70.9 d	^{56}Co 77.3 d	^{46}Sc 83.8 d	^{48}V 16.0 d
production channel →	spallation	$^{56}Fe(n,p2n)$	$^{58}Ni(n,p)$ $^{60}Ni(n,p2n)$	$^{58}Ni(n,p2n)$	spallation on Cr/Ni	spallation on Cr/Ni
G1	≤ 3.9	1.3 0.4	0.67 0.34	≤ 0.32	≤ 0.35	0.30 0.11
G2	≤ 3.0	1.5 0.1	0.99 0.12	0.17 0.06	0.24 0.06	0.36 0.07
G3	13.6 2.5	1.4 0.2	0.59 0.20	≤ 0.42	≤ 0.31	0.40 0.12
G4	≤ 5.7	0.92 0.24	0.56 0.23	≤ 0.62	≤ 0.54	0.27 0.11
G5	9.6 2.9	2.0 0.3	0.71 0.26	≤ 0.71	≤ 0.67	0.31 0.13
G6	4.8 1.7	1.7 0.2	0.69 0.16	0.28 0.10	0.47 0.14	0.22 0.09
G7	≤ 5.9	1.6 0.3	0.54 0.27	≤ 0.6	0.61 0.26	0.39 0.13
mean		1.5	0.68	0.23	0.44	0.32
Chondrites*	800	1700	160	60	140	300
Chondrites/steel		1130	240	260	320	940

* mean of meteorites Neuschwanstein and Moravka

$$A = PR(1-e^{-\lambda t})$$

$$PR_{54Mn} \cong 4.5\ mBq/kg$$

→ $t \cong 40$ d

$PR_{58Co} \cong 0.4\ mBq/kg$ at 2 mwe

W. Hampel PhD Thesis 1974

Measurement of production rates by sea level exposure of one of the steel samples

Cosmogenic* and primordial concentrations in Cu			
radionuclide	**halflife**	**activity [μBq/kg]**	
cosmogenic		exposed	unexposed
^{56}Co	77.31 d	230 ± 30	
^{57}Co	271.83 d	1800 ± 400	
^{58}Co	70.86 d	1650 ± 90	
^{60}Co	5.27 y	2100 ± 190	< 10
^{54}Mn	312.15 d	215 ± 21	
^{59}Fe	44.5 d	455 ± 120	
^{46}Sc	83.79 y	53 ± 18	
^{48}V	15.97 d	110 ± 37	
primordial			
^{226}Ra (U)	1600 y	< 35	< 16
^{228}Th (Th)	1.91 y	< 20	< 19
^{40}K	1.277x10^{9} y	< 120	< 88

dominating cosmogenic activity at start of GERDA

* saturation activity scaled after exposure at LNGS surface for 270 d

summary

- Low activity steel discovered – important for low level community
- Increase of ^{228}Th with time should be considered
- Dating of modern steel production possible ?
- Cosmic ray exposure of steel can be estimated

Highly sensitive Ge-spectrometry is a very powerful tool

The gain in sensitivity by applying GERDA technology
will open new fields