Studsvik

The Metal Recycling Process and its Nuclide Distribution

Per Lidar, Maria Lindberg, Arne Larsson and Patrik Konneus

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Agenda

- Introduction
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  - Purpose
  - Goal
- Metal recycling process
- Material differences in nuclide distribution
- Results, nuclide distribution in ingots
- Literature comparison
- Conclusion

Background

- Increasing documentation requirements for disposed secondary waste remaining after treatment for free release
- Large conservatism in assigned nuclide vectors for radioactive waste intended for treatment for free release by melting
  - Poor forecasting capabilities
- Dismantling work during decommissioning could be better optimized with
  - Less conservative nuclide vectors
  - Better knowledge of the real outcome from melting
  - More waste could therefore be subject for treatment and free release

Purpose

- Investigate the real nuclide distribution in ingots melted at Studsvik and its secondary waste in order to
  - Obtain a good characterization of the inventory
  - Support the free release process of the ingots
  - Create less conservative and more precise nuclide vectors including the secondary waste
  - Give better guidelines to decommissioning projects and dismantling work

Goal

- Establish an accepted formula for the nuclide distribution during the melting process
- Revise the WAC for the Melting facility to allow for a wider scope of waste to be treated for free release

Introduction – Expected nuclide vectors

- NPP BWR and PWR primary circuit standard operation without significant fuel failures
  - Dominant contaminants activation products are Co-60, Ni-63 and Fe-55
- NPP with fuel failure history
  - Also fission products such as Cs-137, Sr-90, and certain alpha emitting nuclides have to be considered as a significant part of the nuclide inventory
- Fuel factories
  - Uranium isotopes and its progeny
  - TRU-elements and activation products (mainly for MOX plants)
- Research facilities (LWR, HWR, Spallation sources)
  - A wide combination of nuclides can exist

Metal recycling process

- Melting is suitable for low level waste with all types of contaminations
  - Both short lived and long lived nuclides can be treated
  - Nuclides in vapor phase at room temperature lead to special requirements for the off-gas treatment
- Established techniques and facilities available
- International recommendation exists
  - EC RP89
- Melting facility at Studsvik since 1987
  - Licensed capacity 5 k tonne per y
  - Induction furnaces

Carbon and stainless steel

- Co, Mn, Fe, Ag and Ni isotopes are closely linked to the steel matrix and stays therefore to a high degree
- Heavy alpha isotopes (U, Am, Pu) will end up in the slag to a high degree
- Nuclides which evaporates at the actual temperature are transferred to the slag or the dust (Cs etc.)

Aluminium

- Co stays in the metal
- Heavy alpha isotopes (U, Am, Pu) stays in the metal to a high degree
- Nuclides which evaporates at the actual temperature are transferred to the slag or the dust

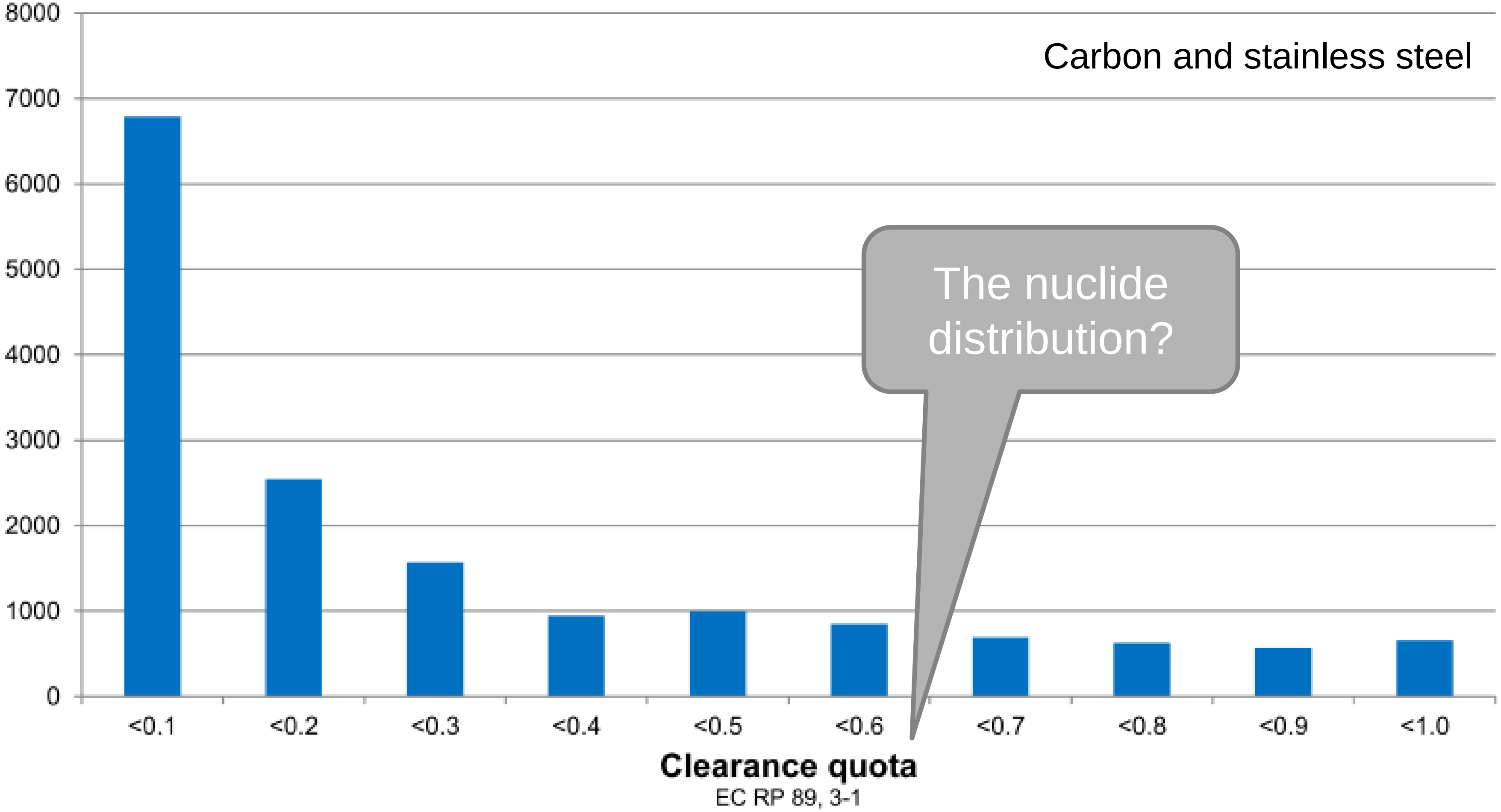
Lead

- Most isotopes can be removed from the metal
- Co end up in the slag
- Certain nuclides such as Ag-108m are hard to separate in the melting process
- Heavy alpha isotopes (U, Am, Pu) ends up in the slag to a high degree
- Nuclides which evaporates at the actual temperature are transferred to the slag or the dust
- Special personnel safety case when handling lead melting!

Overview– most important nuclides [1]

Nuclide	Mode (α β γ)	$T^{1/2}$	Steel (%)	Slag (%)	Dust (%)	Other (%)
H-3	β	12.33 y				
C-14	β	5730 y	27-100	0-1	0-2	0-73 (offgas)
Mn-54	β + γ	312 d	24-100	1-75	0-5	0
Co-60	β + γ	5.27 y	20-100	0-1	0-80	0
Zn-65	β + γ	244 d	0-20	0-1	80-100	0
Sr-90	β	28.79 y	0-20	95-100	0-10	0
Ag-108m Ag-110m	β + γ β + γ	418 y 249 d	75-100	0-1	0-25	1 (bottom)
Sb-125	β + γ	2.76 y	60-100	0-20	10-40	0
Cs-137	β + γ	30.07 y	0	0-5	95-100	0
U-234 U-235 U-238	α α + γ α (+ γ)	2.4E+5 y 7.0E+8 y 4.5E+9 y	0-1	95-100	0-5	0
Pu-238 Pu-239	α α	87.7 y 24 110 y	0-1	95-100	0-5	0
Am-241	α + γ	432 y	0-1	95-100	0-5	0

Histogram over conditionally cleared ingots 2005-2012. Approx. 10 000 tonne



Results, nuclide distribution in ingots

Material category	Weight, tonne	Measured nuclide content, % of total activity*								
CS and SS	27 749	Co-60	Mn-54	Sb-125	Cs-137	Zn-65	Ag-110m	Ru-106	Total alpha	Others
		96%	1.1%	0.7%	0.7%	0.5%	0.3%	0.3%	0.3%	0.5%
					(MDA)					
Aluminium	772	Co-60	Zn-65	Uranium	Mn-54	Cs-137	Cr-51	Na-22	Sb-125	Others
		62%	11%	6.4%	5.6%	4.6%	4.2%	1.4%	1.1%	2.8%
Lead	395	Sr-90	Ag-110m	Cs-137	Co-60	Ag-108m	Am-241	Pu-239	Sb-125	Others
		52%	17%	5.8%	5.5%	5.0%	3.9%	3.1%	1.3%	6.3%

*) MDA values included from gamma / alpha spectrometry.

Material differences, melting results

- Carbon and stainless steel
  - Total amount melted 27 700 tonne
  - Includes ingots for direct free release and under decay storage
  - Nuclide distribution in ingots
    - Co-60 >95% of all activity
  - Since Co-60 is totally dominant nuclide and Cs-137 is important to measure, it was decided to concentrate the detailed study on Co-60 and Cs-137
    - 5 200 tonne included for the relation of nuclides in ingots / slag / dust

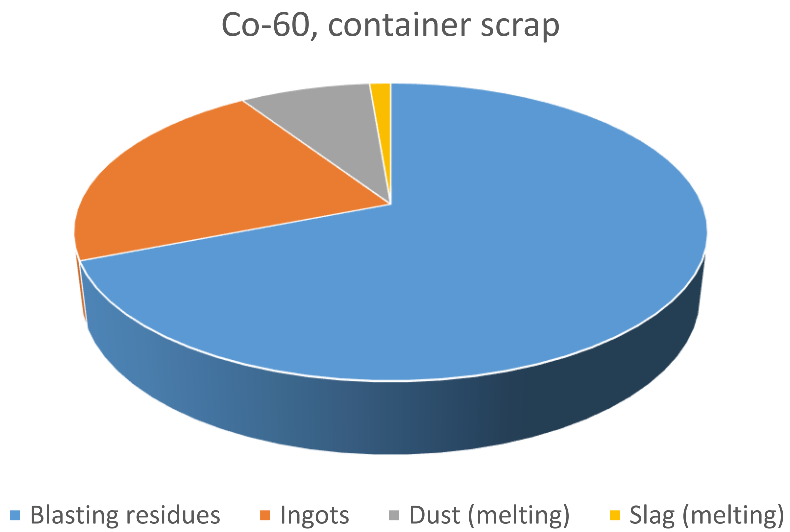
Material differences, metals recycling

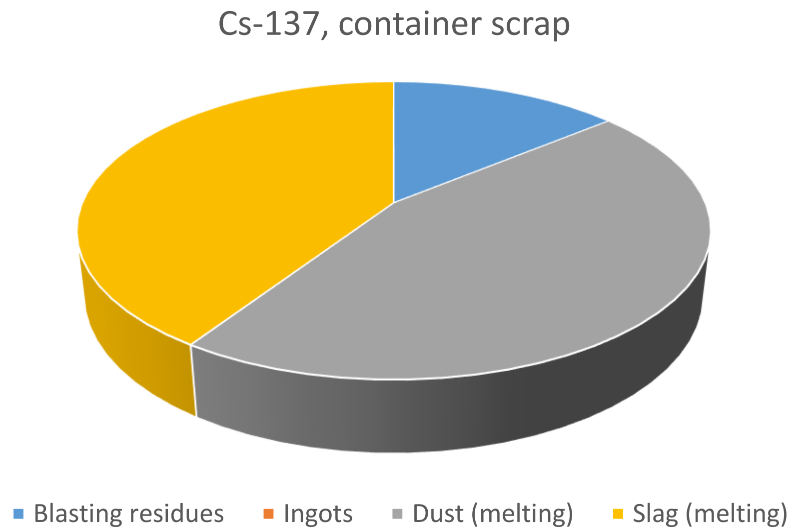
- Carbon and stainless steel
  - 5 200 tonne from different LWRs
  - Median levels adds up to 100% reasonably well

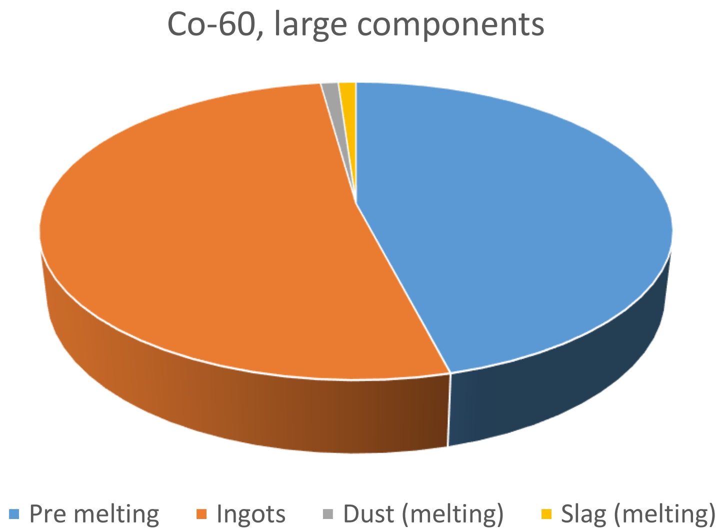
Co-60.				
Container scrap		Max	Min	Median
Blasting residues		91%	18%	69%
Melting fraction	Ingots	92%	29%	67%
	Dust	58%	6%	24%
	Slag	14%	2%	4%
Large components		Max	Min	Median
Pre melting fraction		82%	14%	46%
Melting fraction	Ingots	99%	88%	97%
	Dust	7%	0%	2%
	Slag	6%	1%	2%

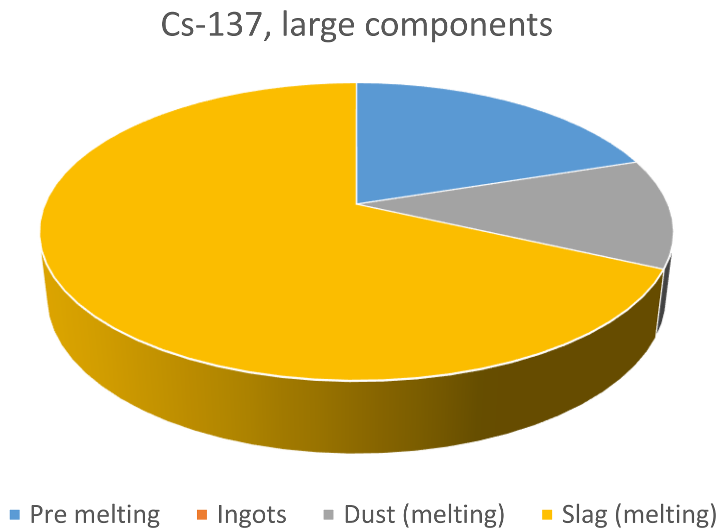
Cs-137				
Container scrap		Max	Min	Median
Blasting residues		16%	1%	14%
Melting fraction	Ingots	0%	0%	0%
	Dust	70%	23%	57%
	Slag	77%	30%	52%
Large components		Max	Min	Median
Pre melting fraction		35%	10%	20%
Melting fraction	Ingots	0%	0%	0%
	Dust	29%	10%	15%
	Slag	90%	71%	85%

CS and SS, 5200 tonne LWRs, cont.









CS and SS, 5200 tonne LWRs, cont.

For the metal recycling process

- Co-60
  - Melting in combination with blasting and pre melting actions is effective.
- Cs-137
  - Melting is the outstanding most effective individual step, and can be used in combination with blasting and pre melting actions

Material differences, metals recycling

- Al
  - Total amount melted 800 tonne
  - Nuclide distribution
    - Co-60 dominating with >60%
    - Top six corresponds to 95%

Material differences, metals recycling

- Lead
  - Total amount melted 400 tonne
  - All ingots free released
  - Nuclide distribution
    - Sr-90 dominating with >50%
    - Top six corresponds to 89%
    - More ingots needed to sort out normal vs. unusual cases

Literature comparison

1. NCRP (2002). Managing Potentially Radioactive Scrap Metal, NCRP Report No 141, NCRP, Bethesda, MD.
   - Table 6.2, Applicable for steel
   - Large uncertainty for some nuclides (combined information from different sources)
2. QUADE, U. and MÜLLER, W. (2005). Recycling of radioactively contaminated scrap from the nuclear cycle and spin-off for other application, Rev. Metal. Madrid Vol. Extr. (2005) 23-28.
   - Table 1, Applicable for steel
   - Detailed nuclide distribution for many nuclides

Literature comparison, CS and SS

Nuclide	Ref.	Note	Steel (%)	Slag(%)	Dust (%)	Other (%)
Co-60	[1]		20-100	0-1	0-80	0
	[2]		88	11	1	0
	Container	Min - Max	29-92	2-14	6-58	0
	Container	Median*	70	4	26	0
	LC	Min – Max	88-99	1-6	0-7	0
	LC	Median*	96	2	2	0
Cs-137	[1]		0	0-5	95-100	0
	[2]		<1	60	40	0
	Container	Min - Max	0-0	30-77	23-70	0
	Container	Median*	0	47	53	0
	LC	Min - Max	0-0	71-90	10-29	0
	LC	Median*	0	85	15	0

*) Median value re-scaled to 100% total sum

Conclusions

- Carbon and stainless steel
  - Co-60
    - Totally dominating measured nuclide in the ingots (>95%)
    - Confirmed literature data regarding relationship between ingots, slag, and, dust
- Aluminium
  - Co-60 dominating with >60%
- Lead
  - All ingots free released

Conclusions, cont.

- Investigated the real nuclide distribution in ingots melted at Studsvik and its secondary waste
  - Obtained a good characterization of the inventory
  - Supported the free release process of the ingots
  - Created less conservative and more precise nuclide vectors including the secondary waste
  - Able to give better guidelines to decommissioning projects and dismantling work
- Important step in order to develop improved models for the nuclide distribution during the melting process
- Supporting both waste generators and disposal organizations in their optimization work

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