

Mobile nuclear laboratory for in-situ measurements in NPPs

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In-situ gamma- and alpha-spectrometry, neutron counting and gamma-dosimetry are utilized in Paks NPP Hungary since 1985 to assist maintenance operations as well as elimination of malfunctions with their consequences. Devices, methods are well applicable for the new generations of the future reactors as important additional safety measures.

Laboratory for Nuclear Safety and Techniques was established by the **University of Debrecen, Hungary** and **Quantechnologies Co** in 2005 to utilize the results of the basic research achieved earlier in the investigations of *fission, gamma-spectrometry* and related fields.

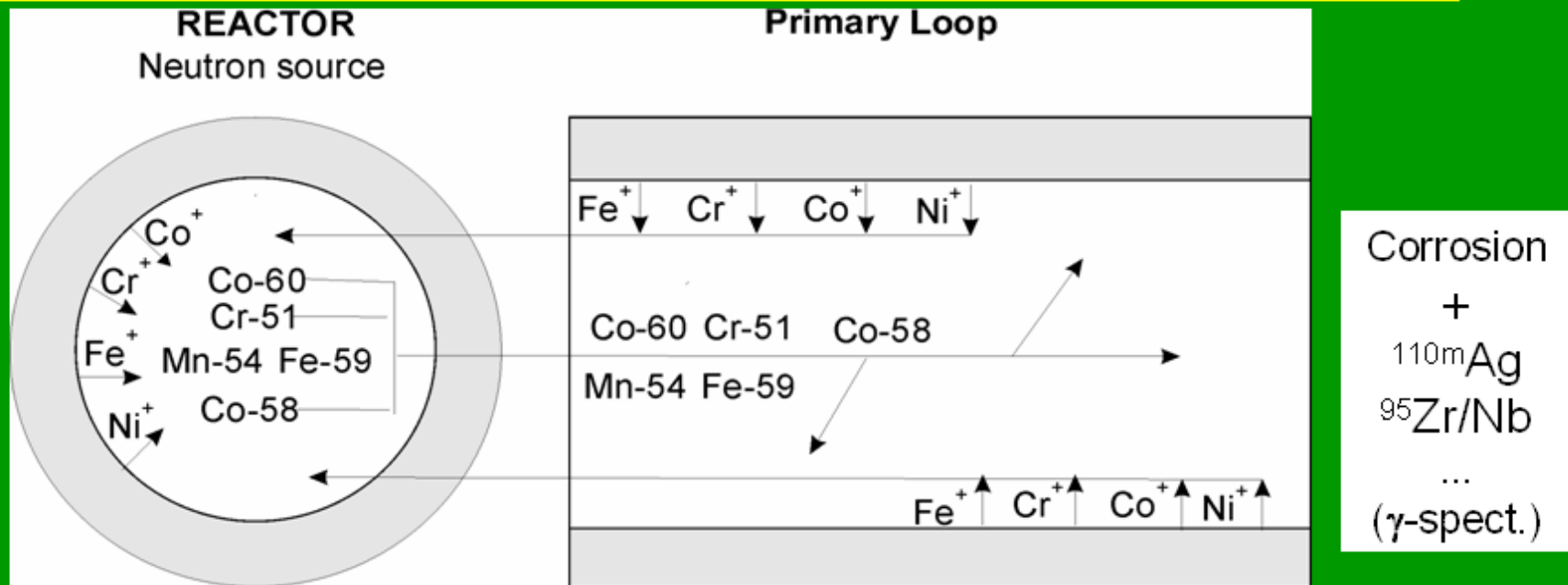
Isotope selective, non-destructive analysis is applied to determine the activity of *corrosion and erosion products* as well as *fission products*.

Measurements are carried out after the yearly shut-down with a cooling time ranging from several days to 3 weeks depending on the maintenance schedule.

Main primary pipes, ion exchangers, steam generators	}	regular measurements ~100 reactor–years
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Material transport in the primary circuit

SOURCE 1. Corrosion processes + neutron activation in the zone



SOURCE 2. Dehermetization of the fuel assemblies

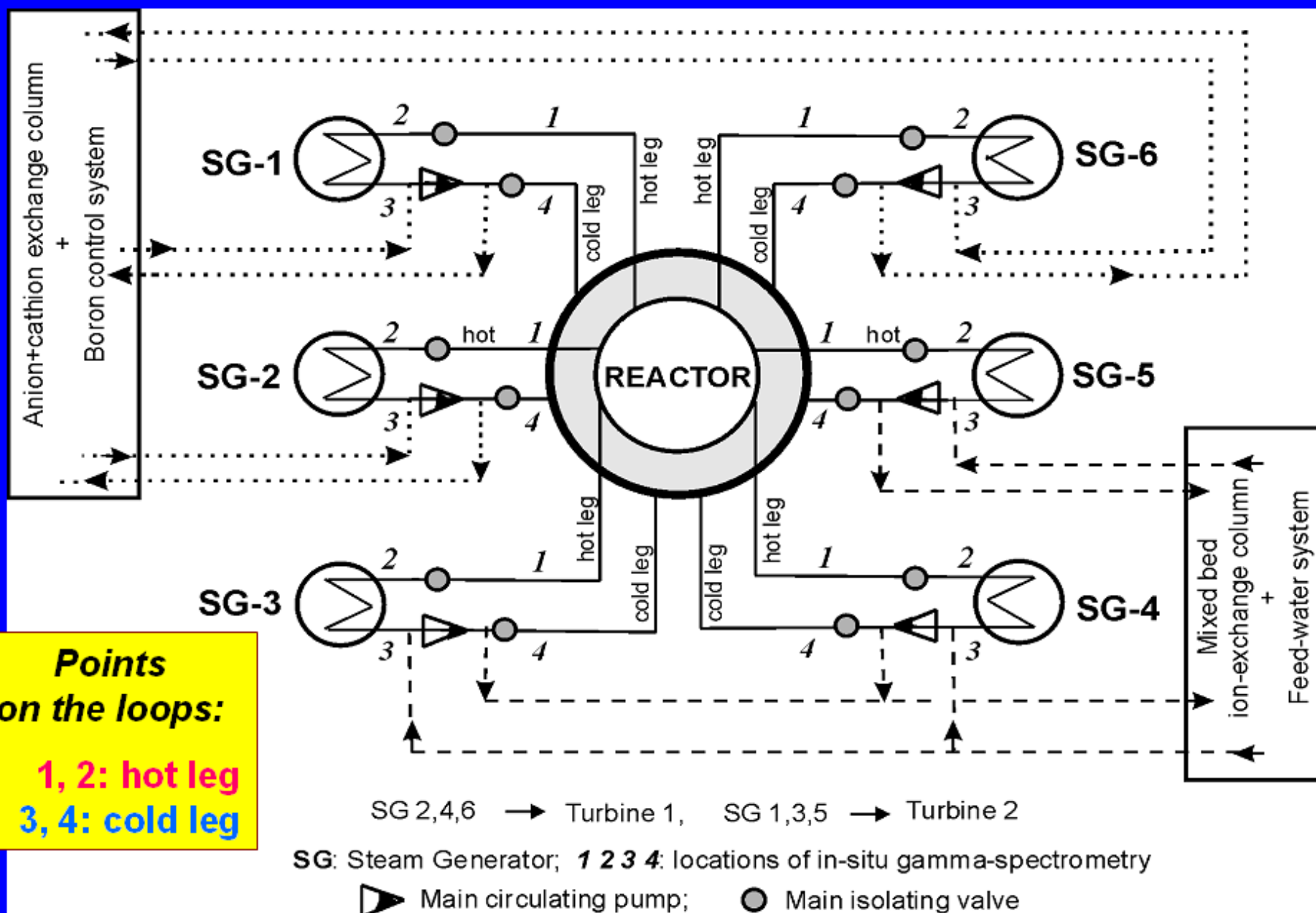
a) fission product nuclei: ⁹¹Y ⁹⁵Zr/Nb ¹⁰⁶Ru/Rh ¹²⁵Sb ^{131,133}I ¹³⁷Cs ¹⁴⁰Ba/La
¹⁴¹Ce ¹⁴⁴Ce/Pr ¹⁵⁵Eu ... (γ-spectrometry)

b) final nuclei from (n,γ)-reaction on fission products: ^{122,124}Sb ^{134,136}Cs ^{148m}Pm ... (γ)

c) trans-Uranium nuclides: ^{238,239,240}Pu ²⁴¹Am ^{242,244}Cm ... (α-spectrometry, n-counting)

+ Relocation / rearrangement of contamination within the primary circuit

Results: contamination, surface activity, gamma-dose ...



Scheme of the primary circuits in VVER-440 reactors and the assay points

Gamma-spectrometry

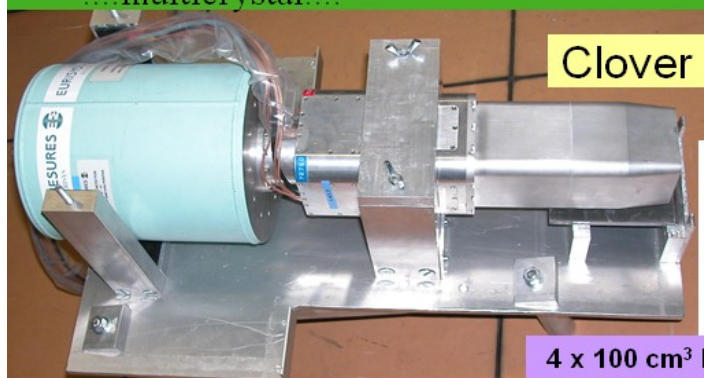
HPGe detectors

mobile,
multiorientation

....single crystal....

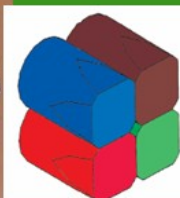


....multicrystal....



Clover

„add-back“



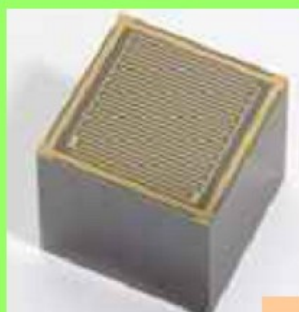
4 x 100 cm³ HPGe crystal

E_γ MeV	„400“/“100“ efficiency ratio at 25 cm
0,5	4,6
1,0	5,5
1,5	5,8
2,0	6,1

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Gamma-spectrometry

High temperature semiconductor detector



$V=1,5 \times 1,5 \times 1 \text{ cm}^3$



CdZnTe

Coplanar Grid layout



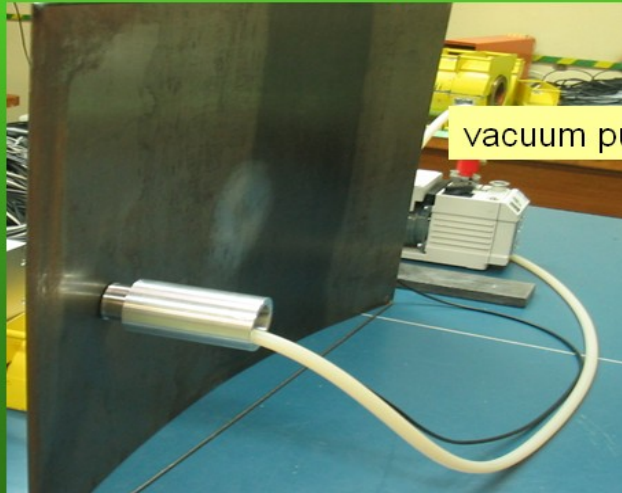
NaI(Tl) scintillation detector

Alpha-spectrometry

Si surface barrier detector:
PIPS
 =Passivated Implanted Planar Silicon

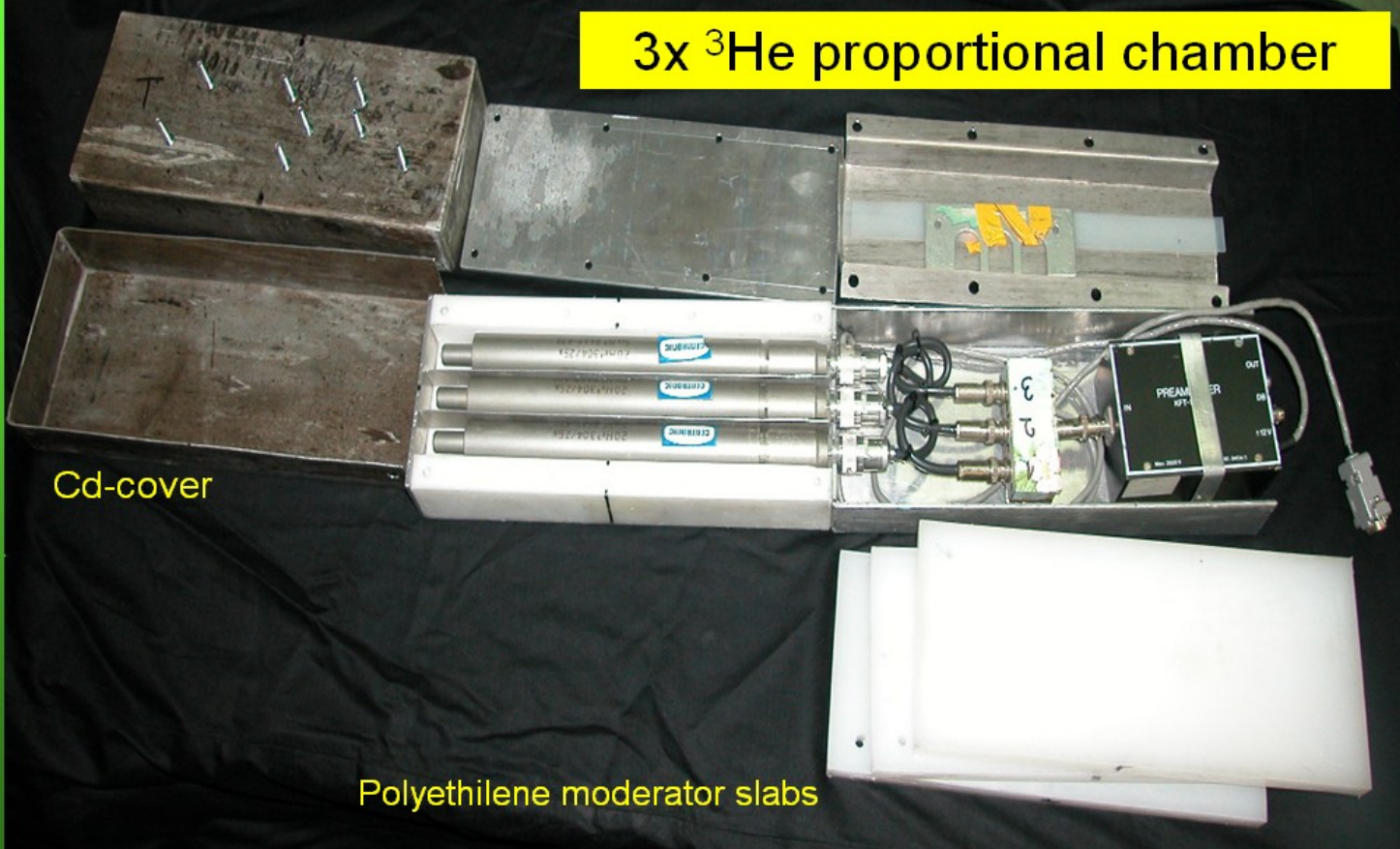


Rugged,
 touchable,
 cleanable surface



Neutron - counting

3x ^3He proportional chamber



Cd-cover

Polyethylene moderator slabs

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Other detectors

Gamma- and neutron-dose rate meters

GM-tubes

Field survey meter, gamma + neutron

Scintillation neutron detectors



PC-controlled devices:
USB, RS232, interface;
 μ -controller, ...

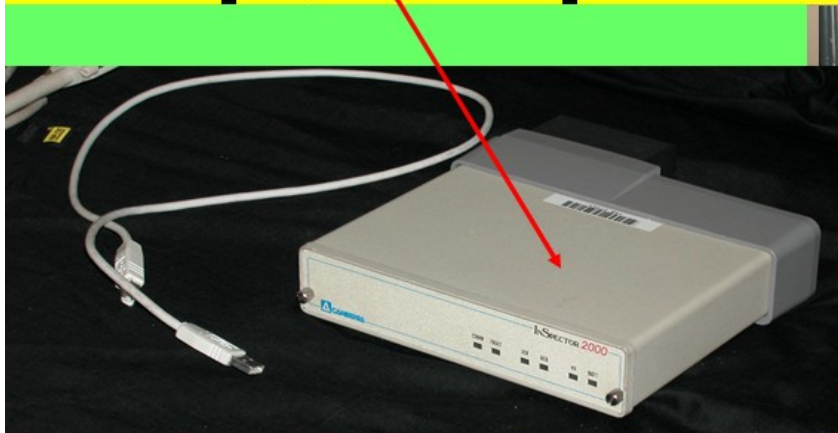


Electronics, data acquisition

[HV, LV]; [Amplifier] + [ADC] + PC

[HV, LV]; [Digital Signal Processing] + PC

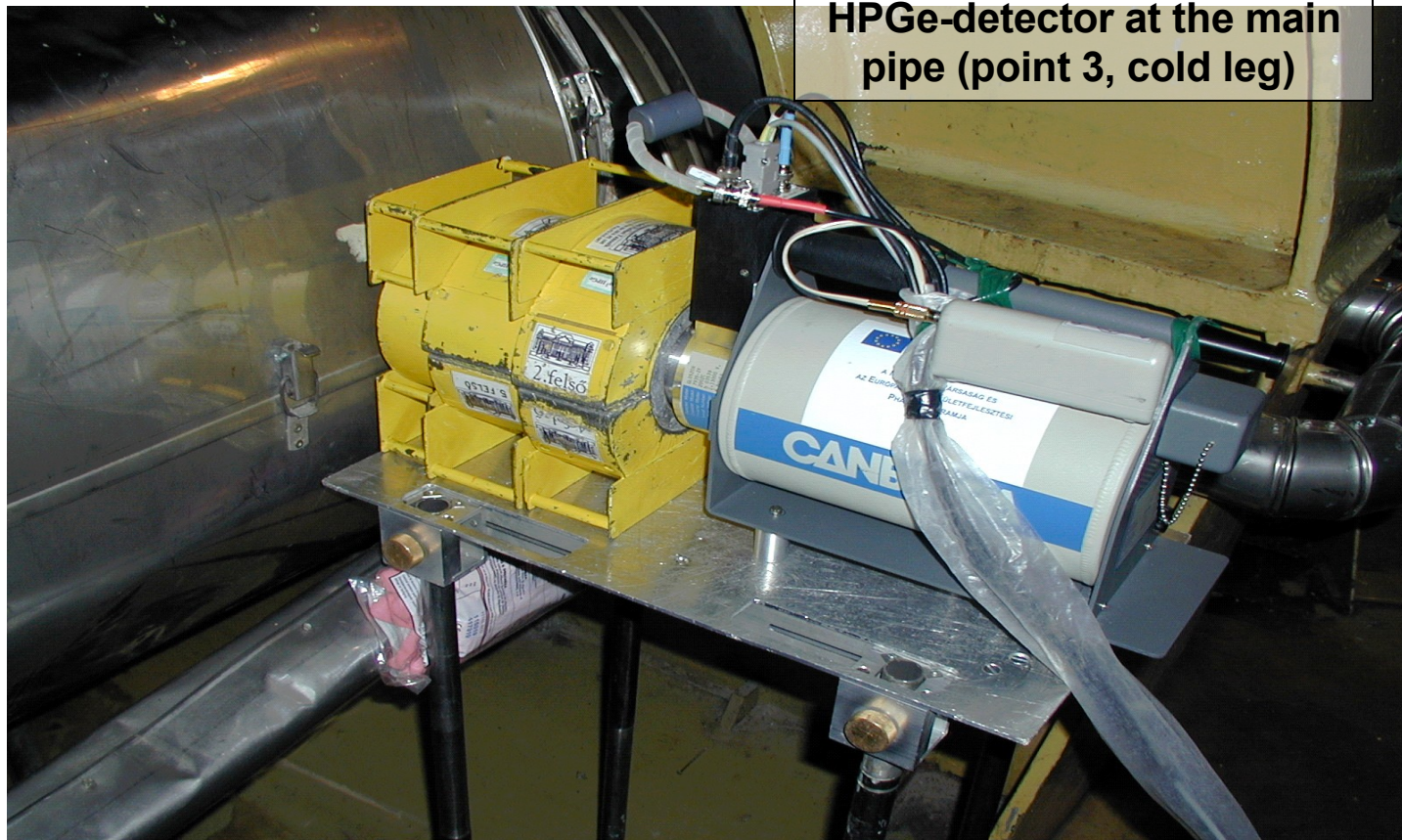
[HV, LV + DSP] + PC



Scalers; timers; coinc/anticoinc
units; pulse generators;
digital oscilloscope, ...

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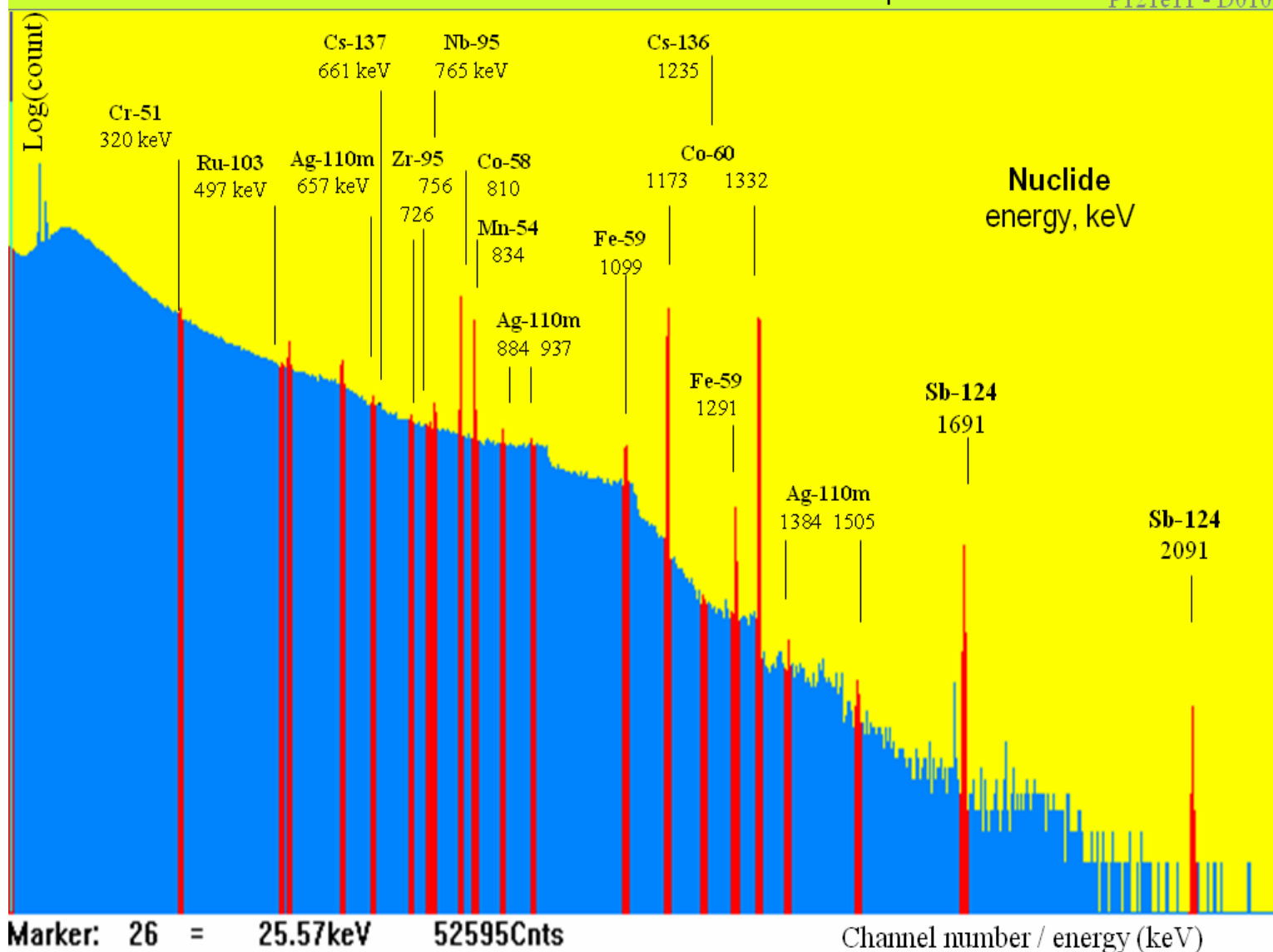
HPGe-detector at the main pipe (point 3, cold leg)

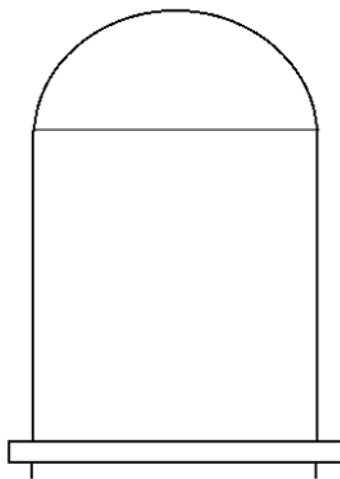


Gamma-spectrum measured at a primary circuit location

open collimator

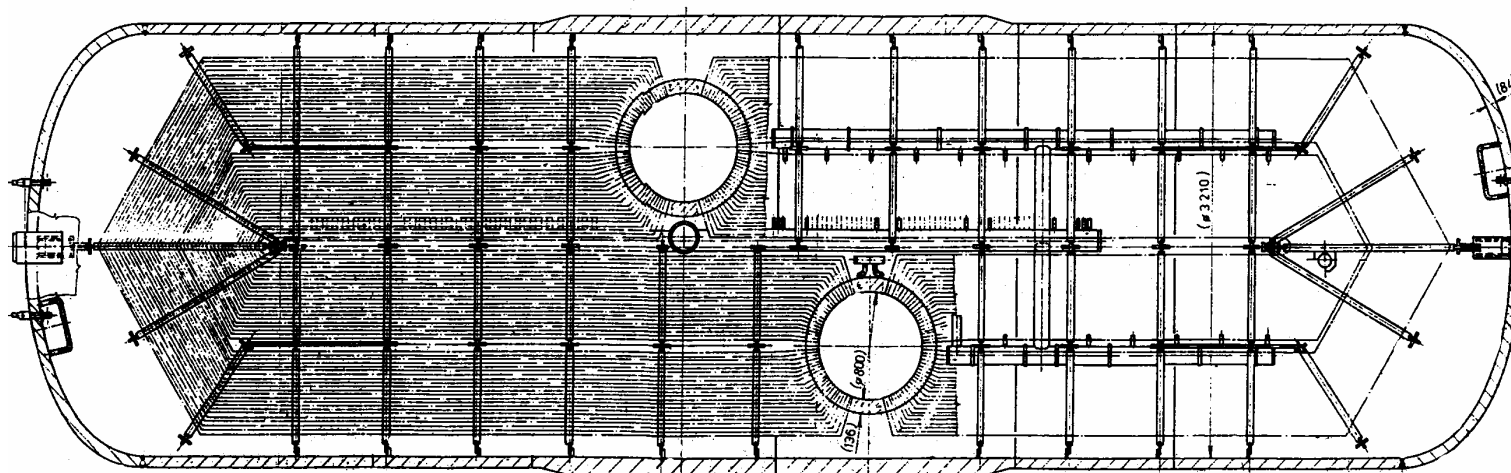
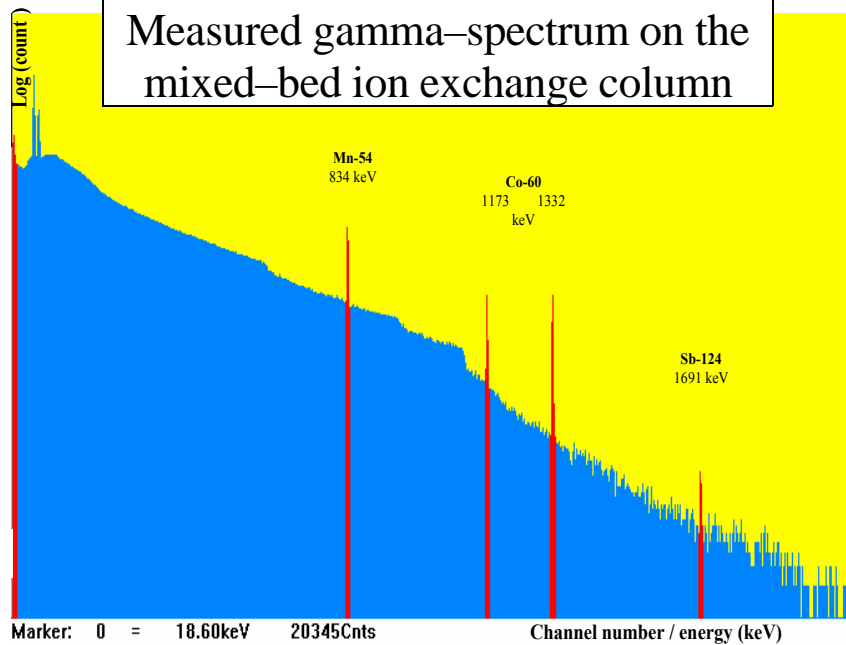
P121e11 - D010





position	height cm
— 1. —	135
— 2. —	120
— 3. —	105
— 4. —	90
— 5. —	75
— 6. —	60
— 7. —	45
— 8. —	30
— 9. —	15
— 10. —	0

Geometry of the *ion exchange column*

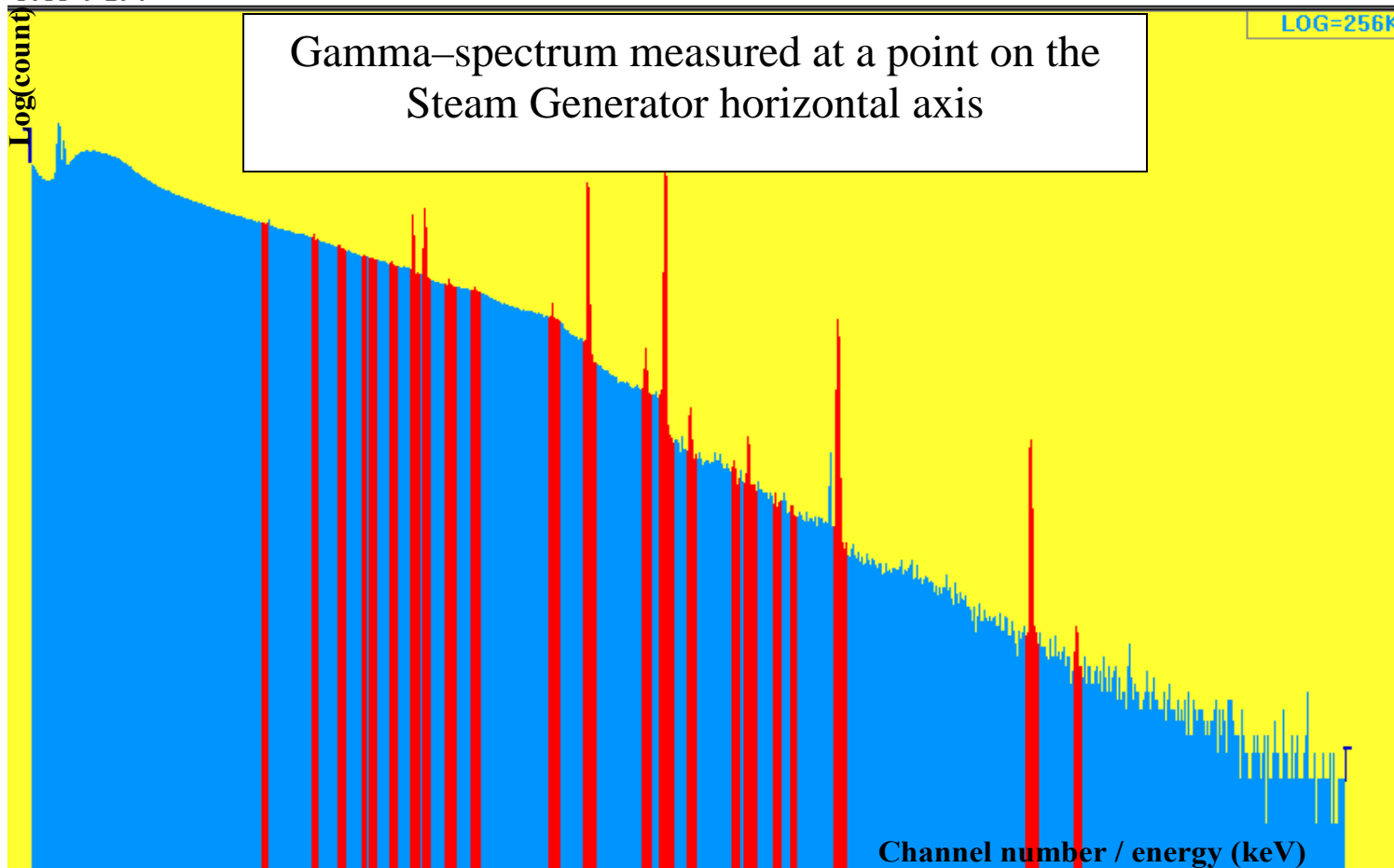


Steam Generator

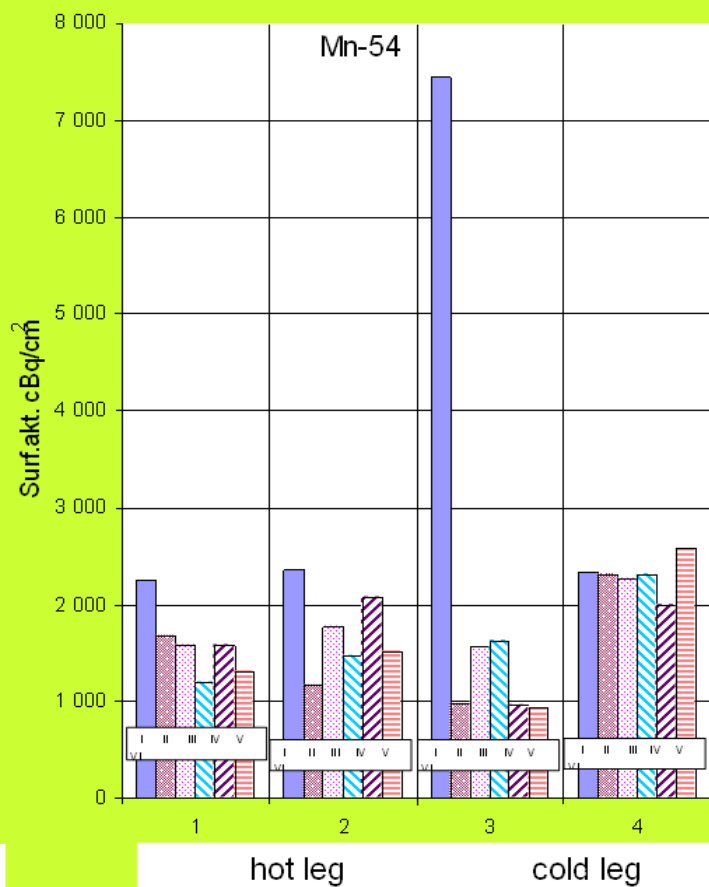
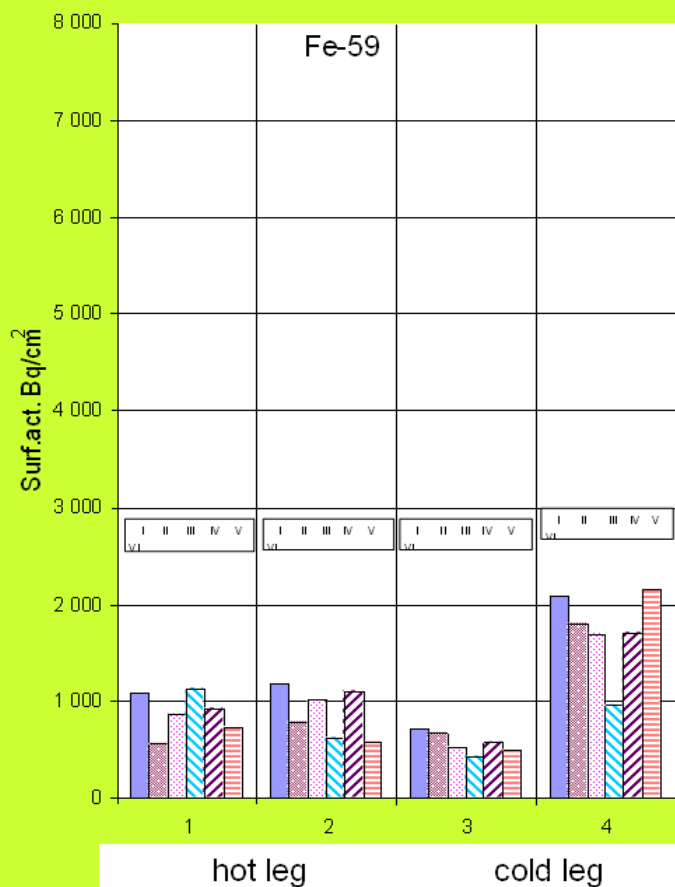
8189 : 274

Gamma-spectrum measured at a point on the Steam Generator horizontal axis

LOG=256K

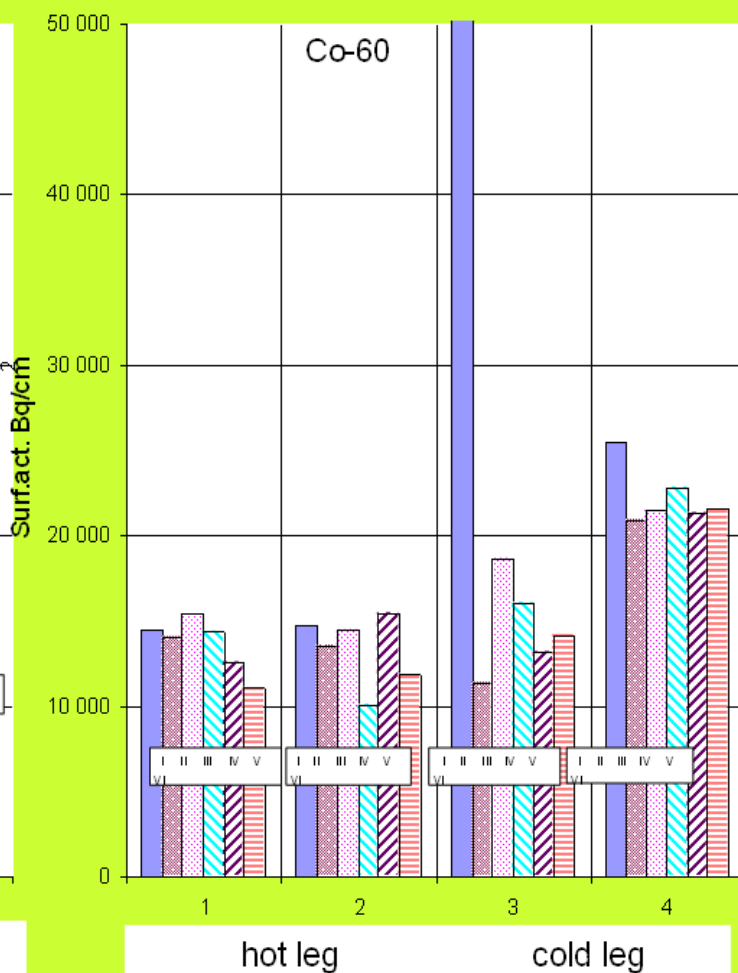
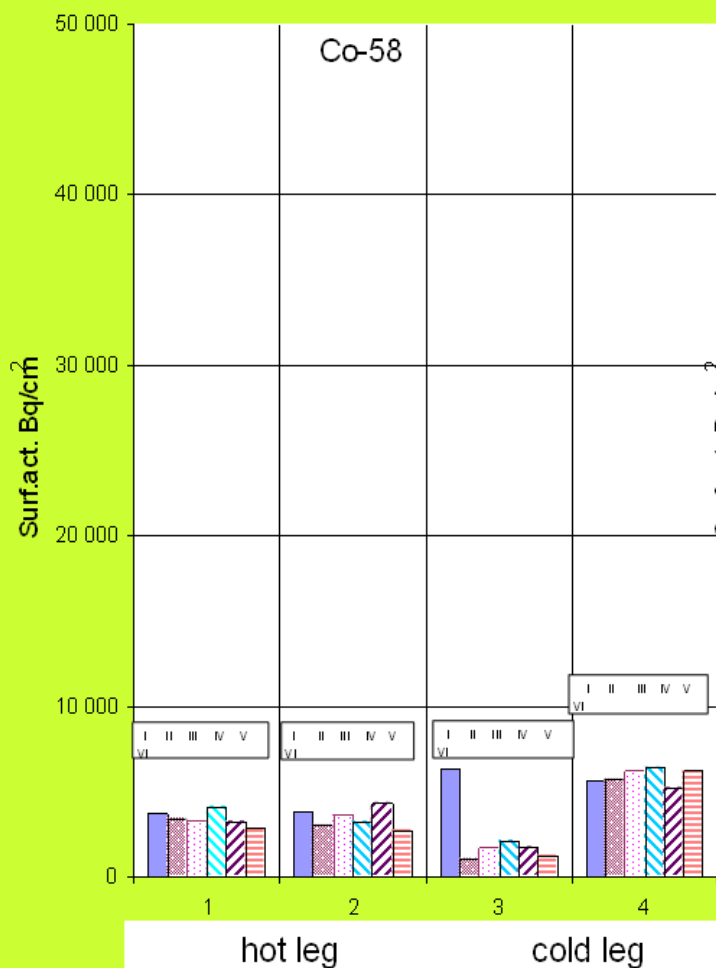


Surface activities at the hot and cold leg points of I.-VI. loops, 1.



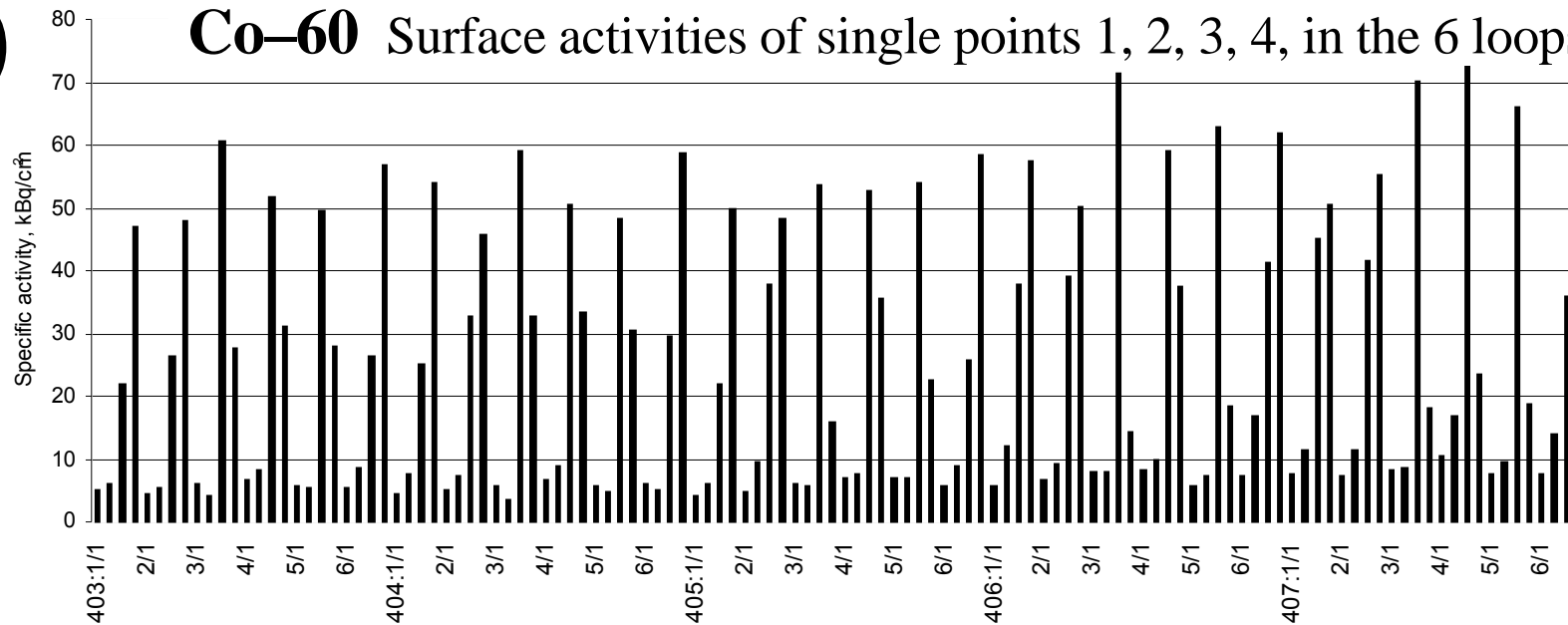
One-year results

Surface activities at the hot and cold leg points of I.-VI. loops, 2.



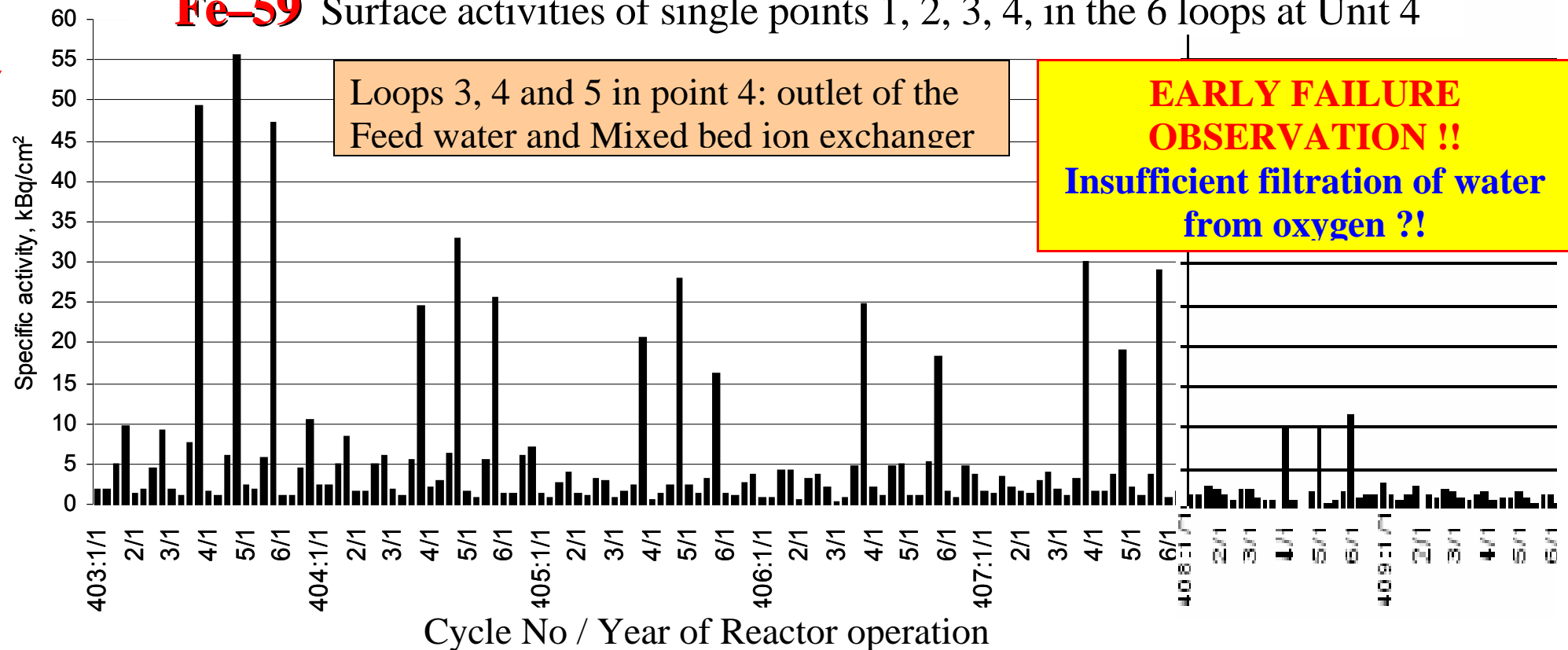
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Co-60 Surface activities of single points 1, 2, 3, 4, in the 6 loops at Unit 4



History of
Reactor
Operation
for
many years
(cycles) by **data
collection and
evaluation**

Fe-59 Surface activities of single points 1, 2, 3, 4, in the 6 loops at Unit 4

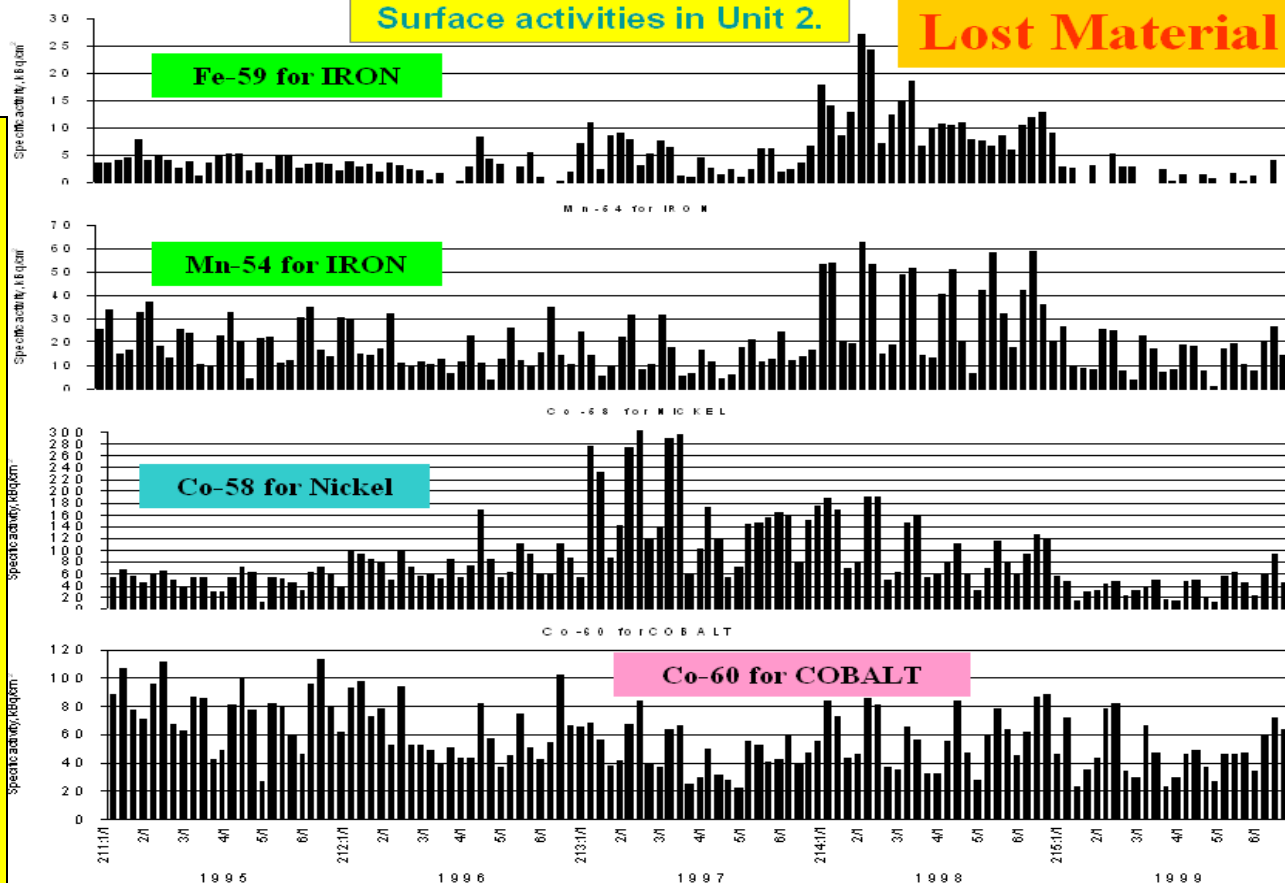


Loops 3, 4 and 5 in point 4: outlet of the
Feed water and Mixed bed ion exchanger

**EARLY FAILURE
OBSERVATION !!**
Insufficient filtration of water
from oxygen ?!

Surface activities in Unit 2.

Lost Material



Activity profile on the mixed-bed ion exchange column

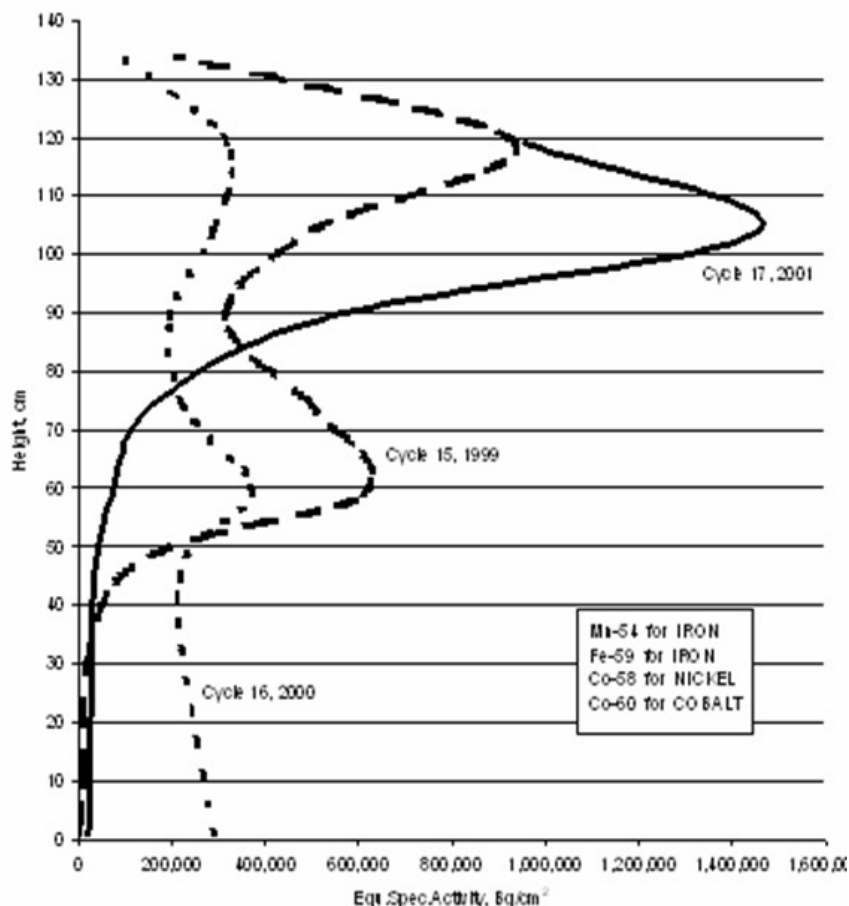
Mixed-bed ion
exchange column

Activity
profile for
summed
corrosion
isotopes
as a
function of
time/cycle

Height
cm
Position
No

134	1
119	2
104	3
89	4
74	5
59	6
44	7
0	10

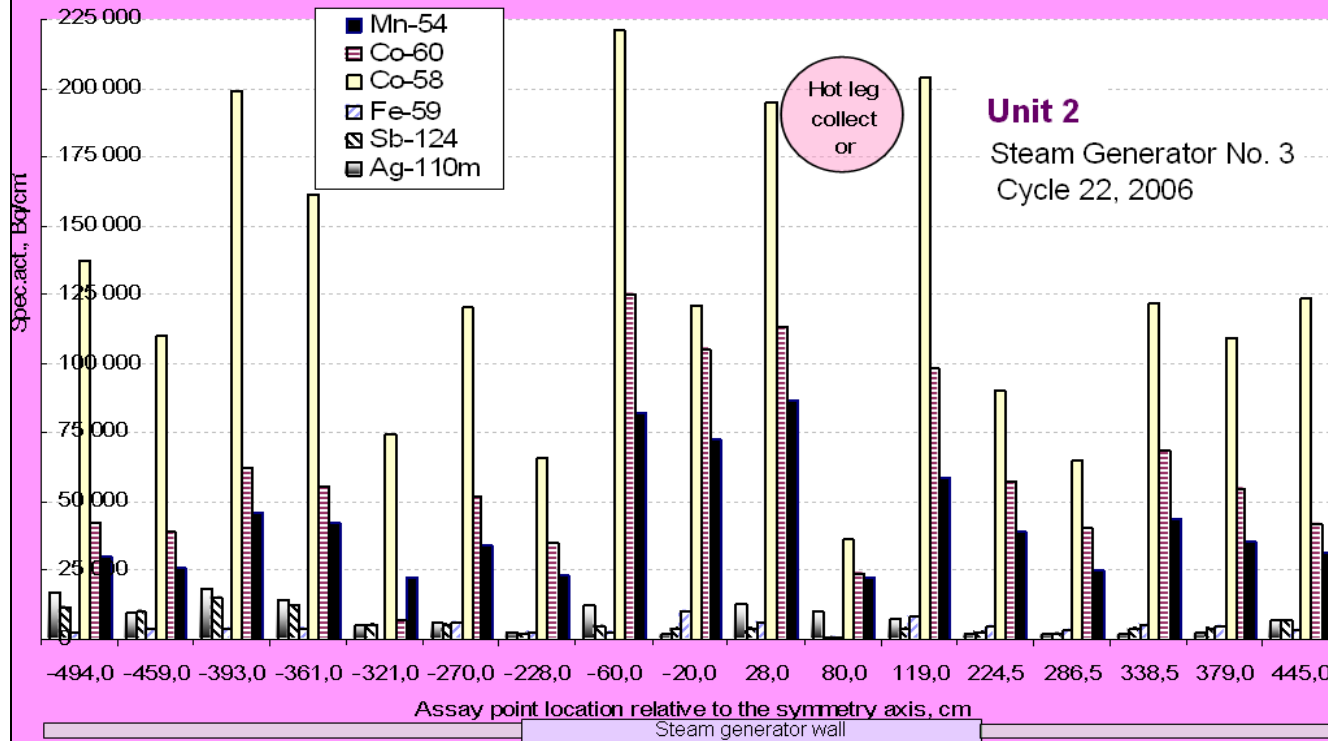
Mn-54, Fe-59, Co-58, Co-60 summed activity
Block 2



Activity profile for total corrosion product activity along the vertical axis of the mixed-bed ion exchange column

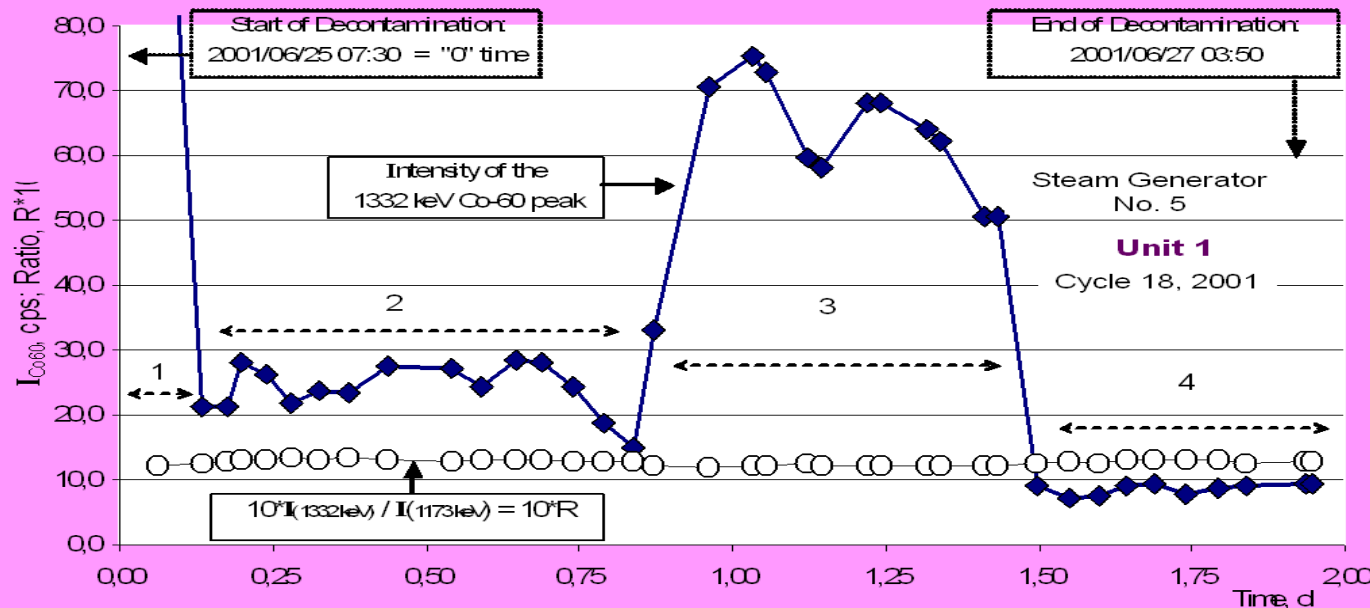
Steam Generator:

Activity profile determination of isotopes by in-situ gamma-septctrometry



Spatial distribution of the corrosion nuclides along the horizontal axis of the Steam Generator

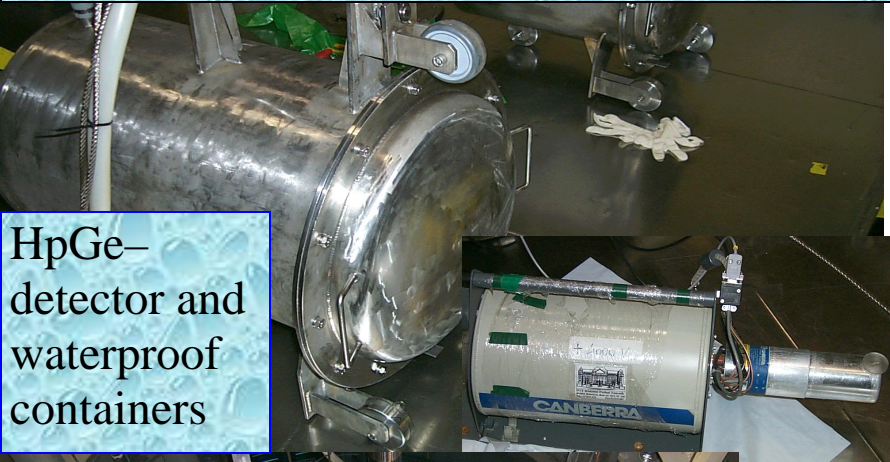
Investigation of the decontamination process by in-situ gamma-septctrometry



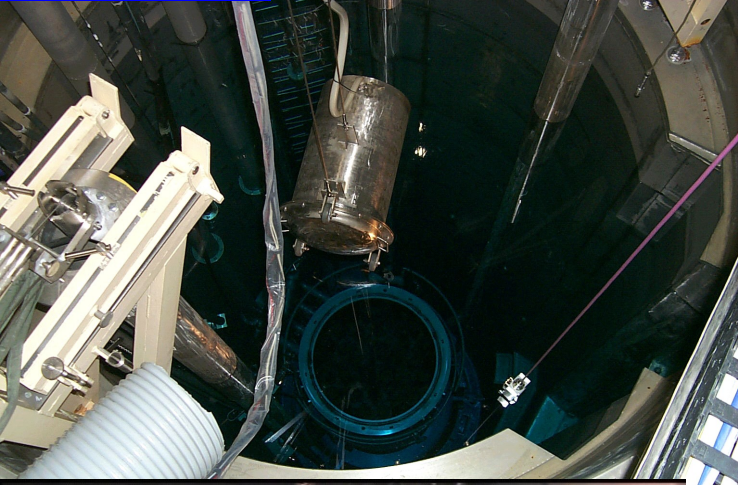
Time behavior of Co-60 (Ni) contamination during the decontamination procedure of a Steam Generator

Special Nuclear Techniques for Handling Malfunctions, Incidents

Under water gamma-spectrometry

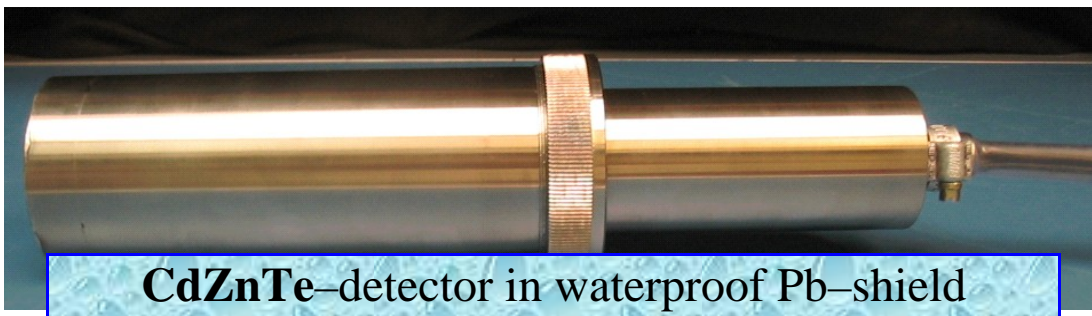
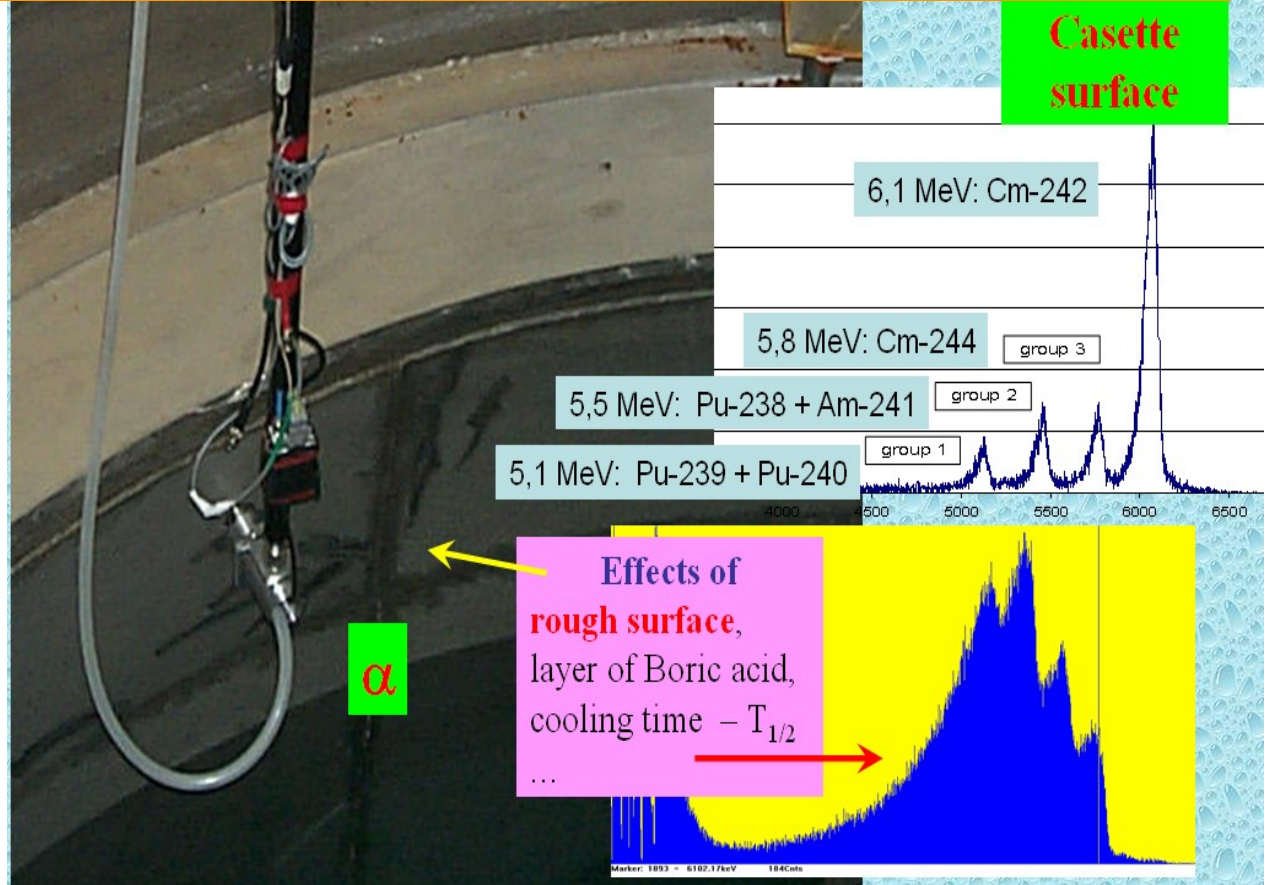


HPGe-detector and waterproof containers



„Submarine” in Technical Pool to investigate contamination of under water surfaces

PIPS alpha-detector with preamplifier fixed to the pool surface (or cassette wall) by vacuum to determine transuranium activities.



CdZnTe-detector in waterproof Pb-shield