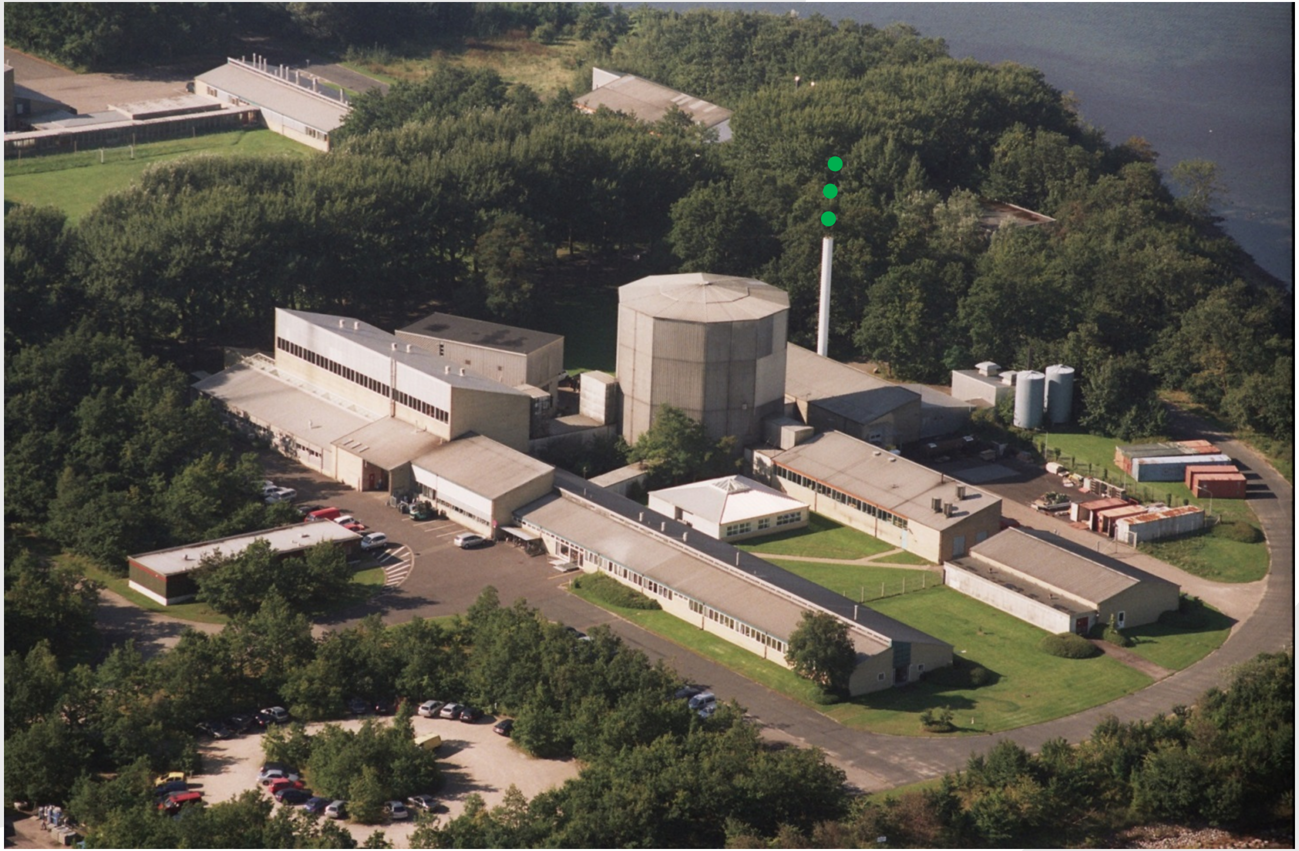
Upper estimates for effective doses from release of ^{36}Cl activity during plasma cutting of the DR3 reactor tank

Jens Søgaard-Hansen
Danish Decommissioning
Roskilde, Denmark

NSFS Conference 2019, 10th – 14th June, Helsinki, Finland

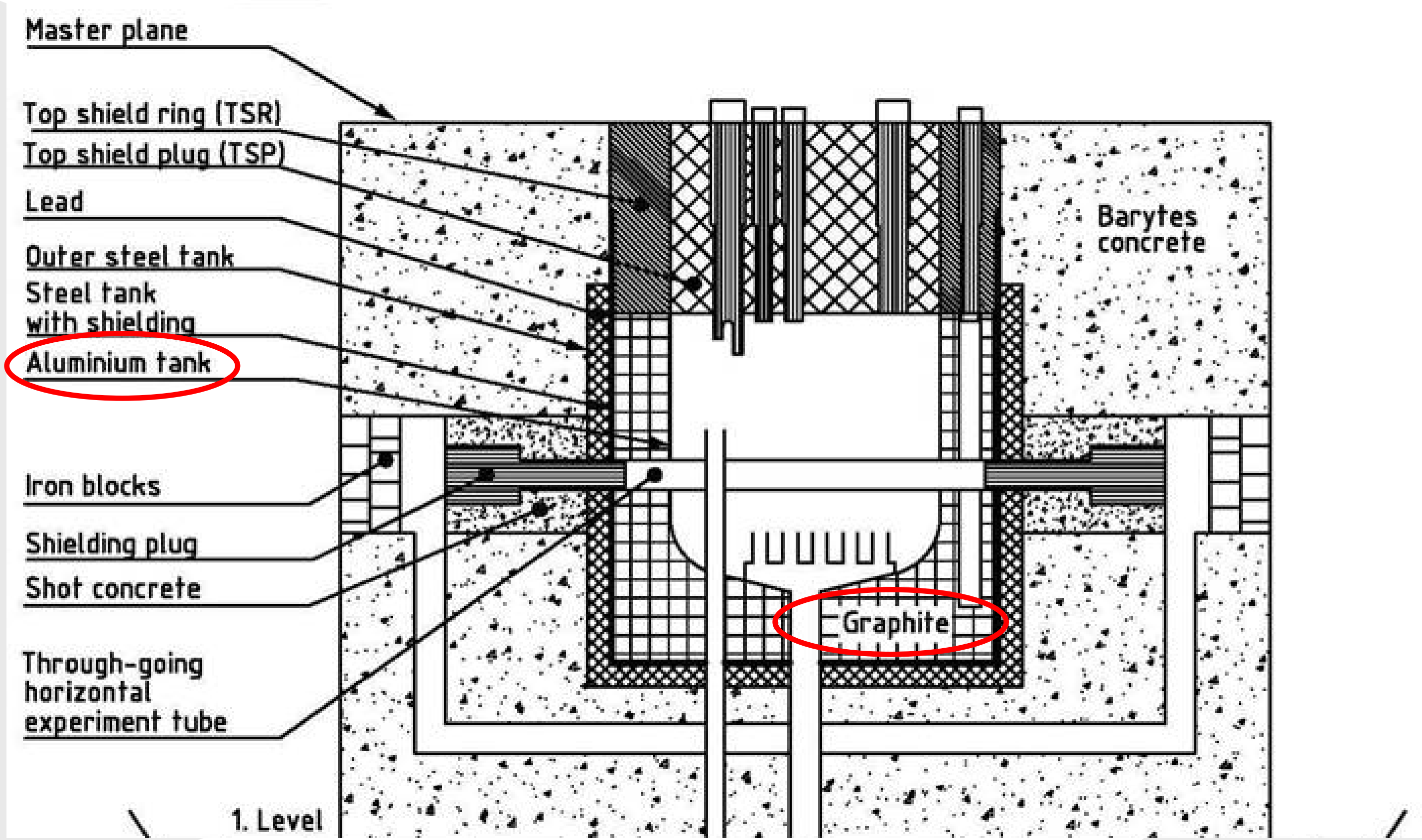
DANSK DEKOMMISSIONERING

DR3 (Danish research Reactor 3)
Under decommissioning since 2012



DANSK DEKOMMISSIONERING

Schematic vertical cross section



DANSK DEKOMMISSIONERING

Plasma cutting of the reactor tank

Gas mixture (% vol.):
He: 77
N: 20
CO_2: 3

No O_2 !

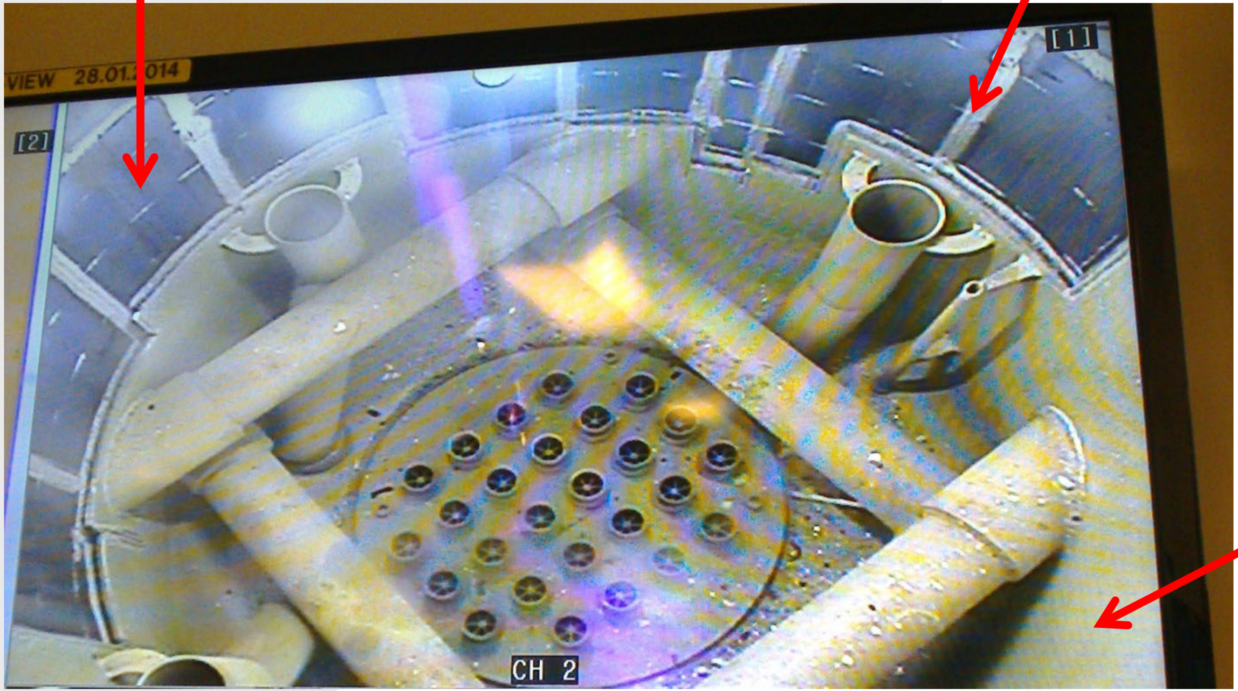
Plasma temperature:
~ 20000 K

DANSK DEKOMMISSIONERING

Half way through the cutting

graphite

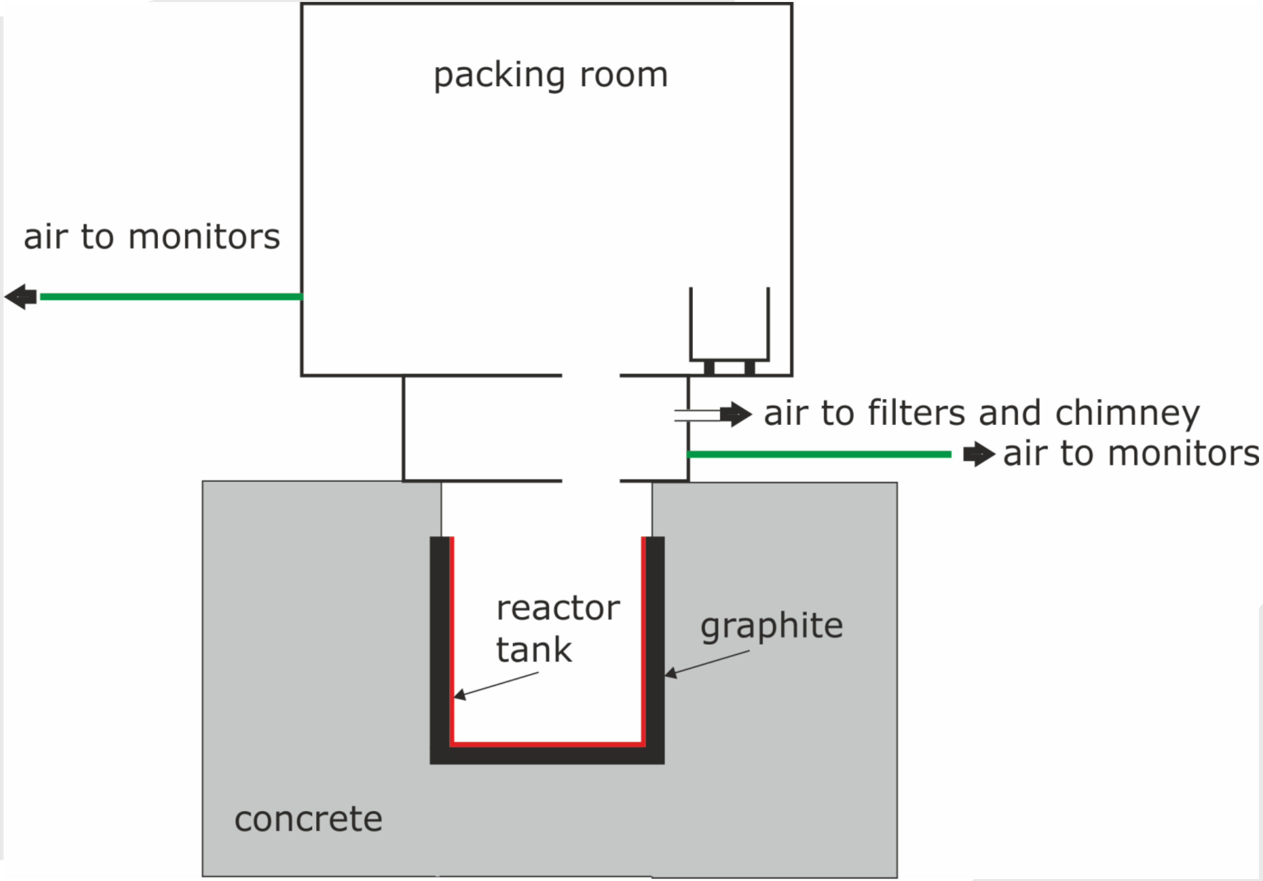
deposited (condensed) tank material



reactor tank (Al)

DANSK DEKOMMISSIONERING

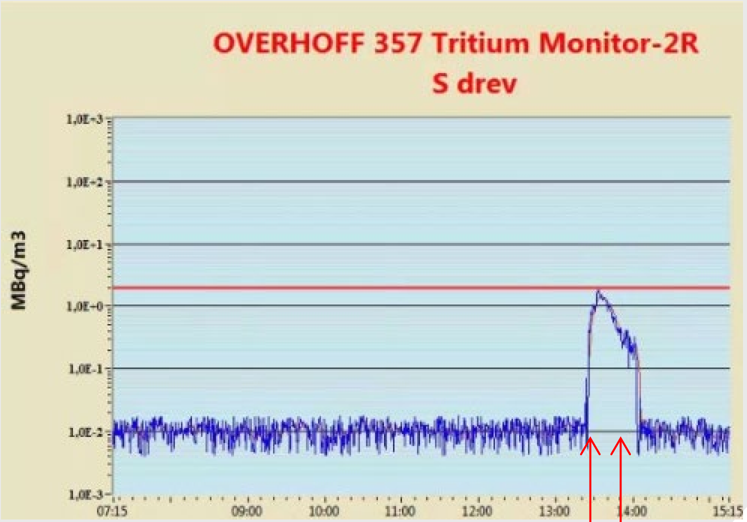
Air-monitoring



DANSK DEKOMMISSIONERING

Air-monitoring

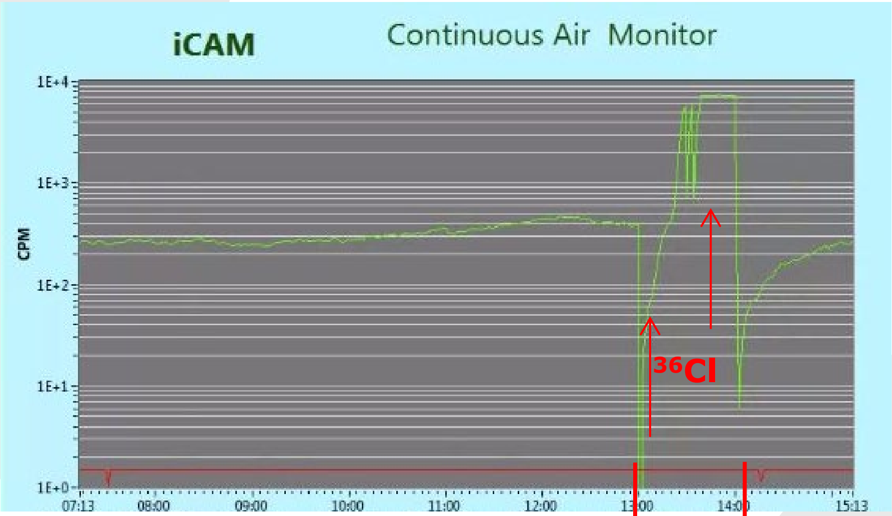
gas



^{36}Cl

^{3}H

particulates on filter



change of filter

Filter from air-monitor dissolved and ^{36}Cl identified.
^{36}Cl identified in a freezing trap water sample from released air.

DANSK DEKOMMISSIONERING

Origin of ^{36}Cl

- direct neutron activation of stable ^{35}Cl
- direct neutron activation of stable ^{39}K
- indirect neutron activation from ^{34}S

Origin of ^{35}Cl

- present in the raw carbon material
- leftover from a pre-irradiation chlorine gas treatment of the graphite at high temperatures

DANSK DEKOMMISSIONERING

Upper estimate for release of ^{36}Cl activity

$$Q = F_p \cdot T \cdot \bar{C}_{^{36}Cl} \cdot k$$

Q : released activity

F_p : flow rate of air to chimney

T : plasma cutting time

$\bar{C}_{^{36}Cl}$: average concentration of ^{36}Cl in air to gas monitor

k : air flow model parameter (k=1 or k=20)

DANSK DEKOMMISSIONERING

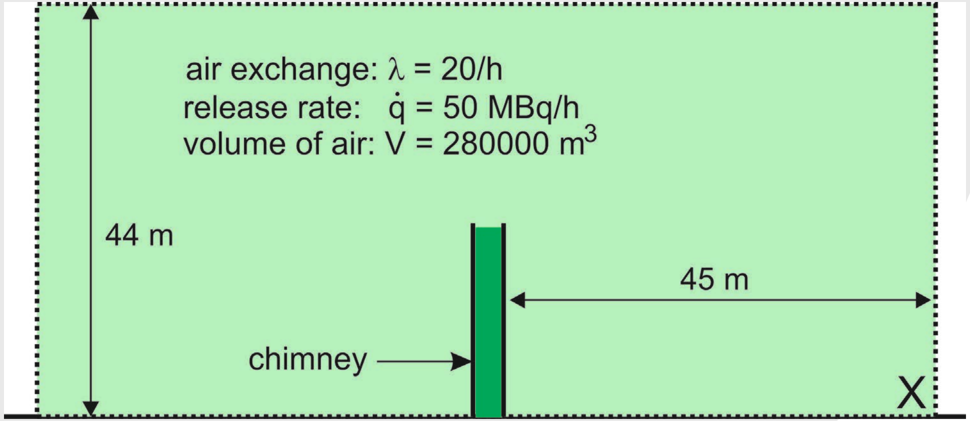
<u>Upper</u> estimates for releases of ^{36}Cl activity

Date (2017)	Release [MBq]	Uncertainty [MBq]	Date (2017)	Release [MBq]	Uncertainty [MBq]
24th Feb.	17	17	3th July	16	4
8th Mar.	3,2	3,2	4th July	114	28
28th Apr.	38	38	5th July	69	17
3th May	42	42	24th Aug.	79	20
4th May.	7,3	7,3	25th Aug.	202	50
5th May	26	26	28th Aug.	322	322
8th May	12	12	29th Aug.	168	42
9th May	4,0	4,0	30th Aug.	70	18
10th May	8,6	8,6	28th Sep.	71	18
15th May	8,3	8,3	29th Sep.	23	6
18th May	57	57	2th Oct.	17	4
22th May	139	139	3th Oct.	15	4

Sum: 2,7 ± 0,4 GBq

DANSK DEKOMMISSIONERING

<u>Upper</u> estimates for effective dose (no-wind)



$$C(t) = \frac{\dot{q}}{V \cdot \lambda} \cdot (1 - e^{-\lambda \cdot t})$$

$$I = 1{,}2\ \mathrm{m}^3\ /\mathrm{h}$$

$$e_{50} = 0{,}007\ \mu\mathrm{Sv}/\mathrm{Bq}$$

$$E_{50}(T) = \int_0^T \frac{\dot{q}}{V \cdot \lambda} \cdot \left(1 - e^{-\lambda \cdot t}\right) \cdot I \cdot e_{50}\, dt \approx \frac{\dot{q} \cdot T \cdot I \cdot e_{50}}{V \cdot \lambda}$$

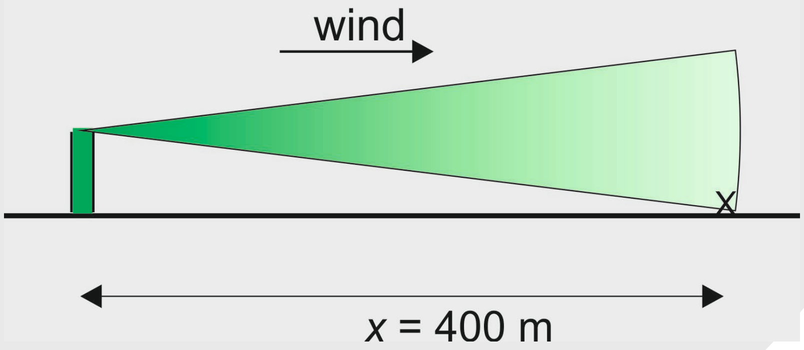
$E_{50}(5\mathrm{h}) = 0{,}5 \mu\mathrm{Sv}$ (release of 250 MBq)

================

DANSK DEKOMMISSIONERING

Upper estimates for effective dose (windy weather, gaussian plume model)

wind speed: v = 5m/s
release rate: $\dot{q}$ = 50 MBq/h
atmosperic stability: neutral



$$C(x) = \frac{\dot{q}}{\pi \cdot \mathrm{v} \cdot \sigma_y(x) \cdot \sigma_z(x)}$$

$$E_{50}(T) = C(400\ \mathrm{m}) \cdot I \cdot e_{50} \cdot T = \frac{\dot{q} \cdot I \cdot e_{50} \cdot T}{\pi \cdot \mathrm{v} \cdot \sigma_y(400\ \mathrm{m}) \cdot \sigma_z(400\ \mathrm{m})}$$

$E_{50}(5\mathrm{h}) = 0{,}02\mu\mathrm{Sv}$ (release of 250 MBq)

===============

DANSK DEKOMMISSIONERING

^{36}Cl in grass samples

DANSK DEKOMMISSIONERING

Estimates of release of ^{36}Cl based on grass samples

Sample	Model	Released ^{36}Cl activity (detection limit) [MBq]
Close	No-wind, deposition velocity: 10^{-3} m/s	0,5
Away	Windy conditions deposition velocity: 10^{-3} m/s	1 (wind towards point of sampling)

DANSK DEKOMMISSIONERING

Estimate of release of ^{36}Cl based on ^{3}H measurements

Period	^{3}H release		^{36}Cl release
	Freezing trap concentrations [GBq]	^{3}H-monitor readings [GBq]	From difference in ^{3}H-release [GBq]
Cutting days with the best flow model	58 ± 3	81 ± 18	0,42 ± 0,33

DANSK DEKOMMISSIONERING

Conclusions

- Plasma cutting of DR3 reactor tank (with graphite behind) liberated ^{36}Cl from the place of cutting
- Chlorine is a leftover from pre-irradiation threatment of graphite
- Liberated ^{36}Cl was both in particulate and in gaseous form
- Gaseous ^{36}Cl can be released to the surrounding
- Conservative upper limit for released ^{36}Cl activity was estimated from gas monitor readings
- Conservative effective doses to persons in the surroundings from release of ^{36}Cl were $< 1\ \mu Sv$
- Grass samples could not confirm that activity has been released to the surroundings
- ^{3}H in freezing trap could indicate ^{36}Cl release to surroundings

DANSK DEKOMMISSIONERING


Thank you for your attention