

NOBLE GASES RELEASE AFTER UNDERGROUND NUCLEAR EXPLOSIONS

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USSR Underground Nuclear Tests

Emplacement mine working	First test	Final test
Explosion in the tunnel	October 11, 1961	October 24, 1990 Total: 245 tests
Explosion in the shaft	January 15, 1965	October 19, 1989
		Total: 251 tests



Radioactive Noble Gases Release

- The release of gases during the nuclear explosion depends on:
 - - the depth of burial the nuclear device (scaled depths $m/kt^{1/3}$);
 - -safety of the stemming complex,
 - -the content of moisture, carbonates and organic substances in the rock.
- The choice of test location should be made with consideration for the physical and chemical properties of local rock: a rock with the minimal gas content, and absence of tectonic faulting and technogenic cracks in the enclosing rocks.



Radiation situation criteria for UNE

- **CCE - (completely contained explosion)**
- - an underground nuclear explosion of complete internal action accompanied by the formation of an underground cavity with a respective compaction, fragmentation, and cracking of rock around it, but the rock block prevents the release of gaseous products.

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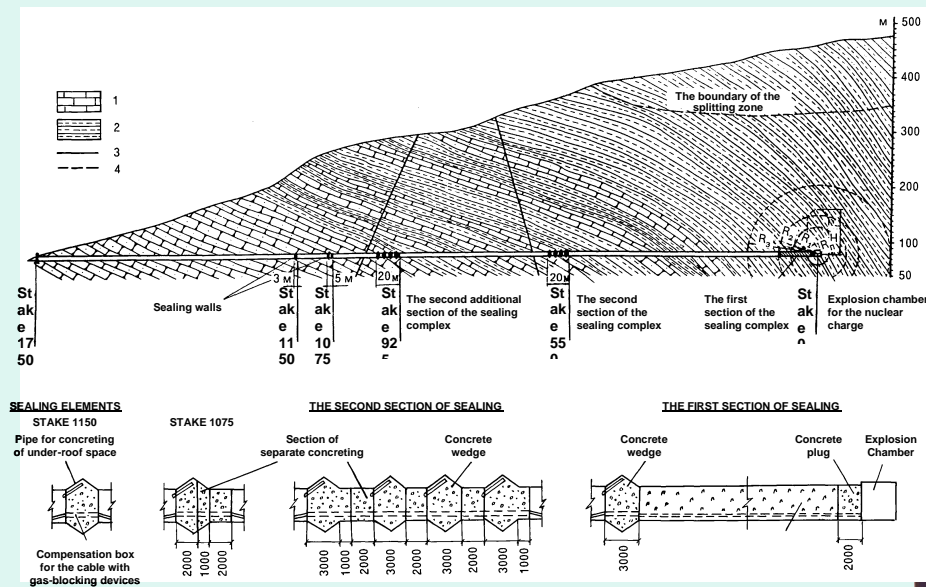
Radiation situation criteria for UNE

ICE (RNG) - (incompletely contained explosion)

- -an explosion of complete internal action accompanied by joining of fissured and spalled zones on the earth surface in the explosion epicentral area and by a ventilation, as a rule, insignificant (slight) release to the atmosphere of short-lived noble gases radionuclides (RNG): Kr-85m ($T_{1/2}=4.5\text{h}$), Kr-87 ($T_{1/2}=76.3\text{min}$), Kr-88 ($T_{1/2}=2.84\text{h}$), Xe-131m ($T_{1/2}=11.9\text{d}$), Xe-133 ($T_{1/2}=5.2\text{d}$), Xe-133m ($T_{1/2}=2.2\text{d}$), Xe-135 ($T_{1/2}=9.09\text{h}$), etc.



Tunnels of the Former Semipalatinsk Test Site



Standard mine tunnel with the stemming complex.

- 1 – quartz sandstones; 2 – mica shales; 3 – tectonic cracks;
- 4 – forecasted zones of the explosion mechanical impact:
- R_c – cavity radius, R_1 – radius of fracturing zone,
- R_2 – radius of macrocracks zone, R_3 – radius of microcracks zone.



Nuclear Tests at Semipalatinsk Test Site

Distribution of completely contained explosions conducted at the Semipalatinsk Test Site according to radiation situation

Test type	Number of explosions	CCE	ICE (RNG)
Explosion in the shaft	127	56 (44 %)	71 (56 %)
Explosion in the tunnel	209	126 (60 %)	83 (40 %)

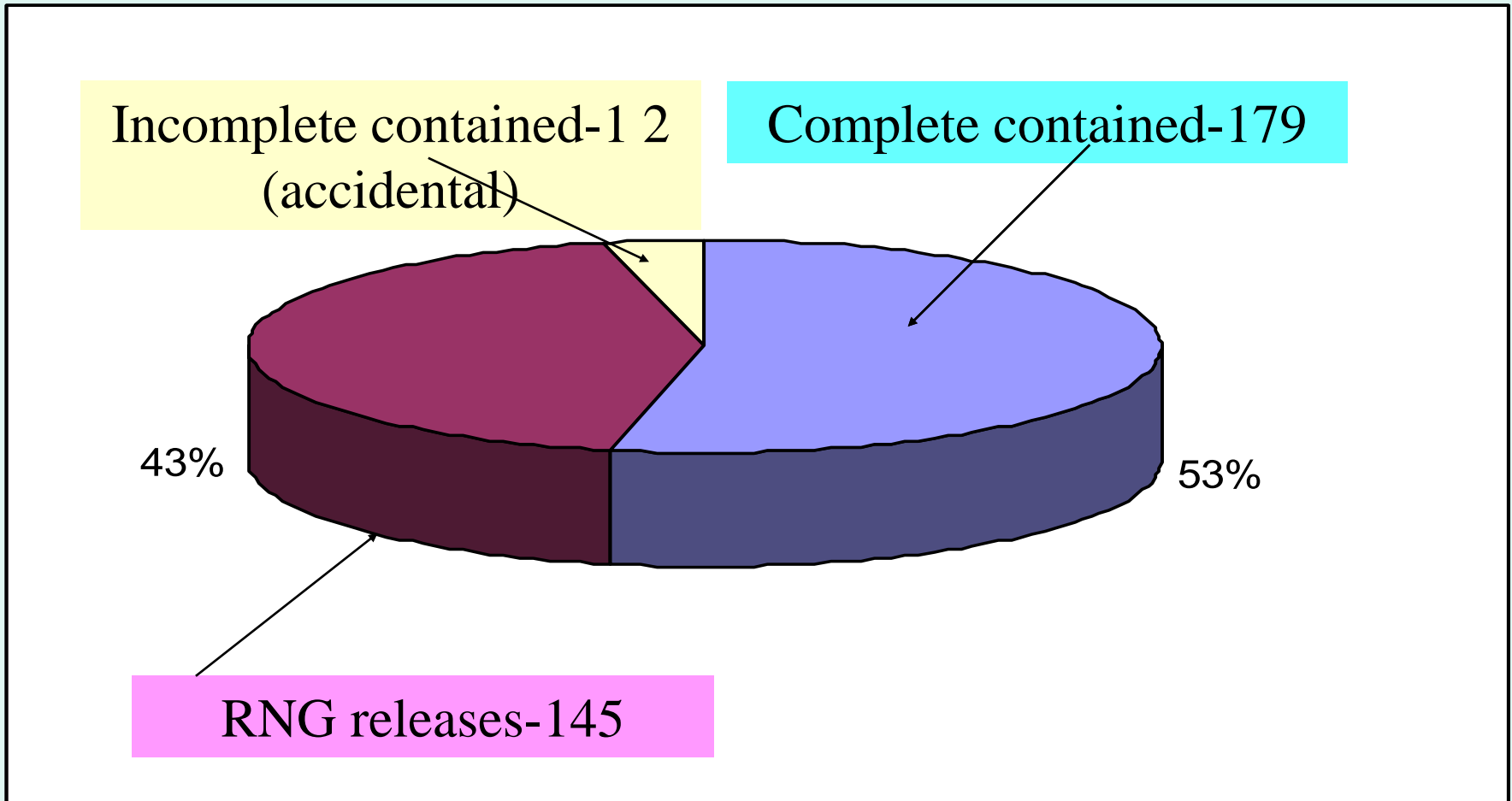


RNG Release at Semipalatinsk Test Site

- In explosions of ICE type both early-time RNG release (up to ~ 1 h) and late-time release from 1 to 28 h after explosions were observed.
- Sometimes gas seepage lasted for several days (release lasted), and it depending on atmospheric pressure and air temperature it occurred through either the tunnel portal or epicentral zone.
- In tunnel tests radioactive gas release occurred through cracks in the epicentral area, less commonly through the test tunnel portal.
- In shaft tests - gas release occurred through the head of test shaft, cracks in epicentral area, intercable spacegas amplifying pipeline.

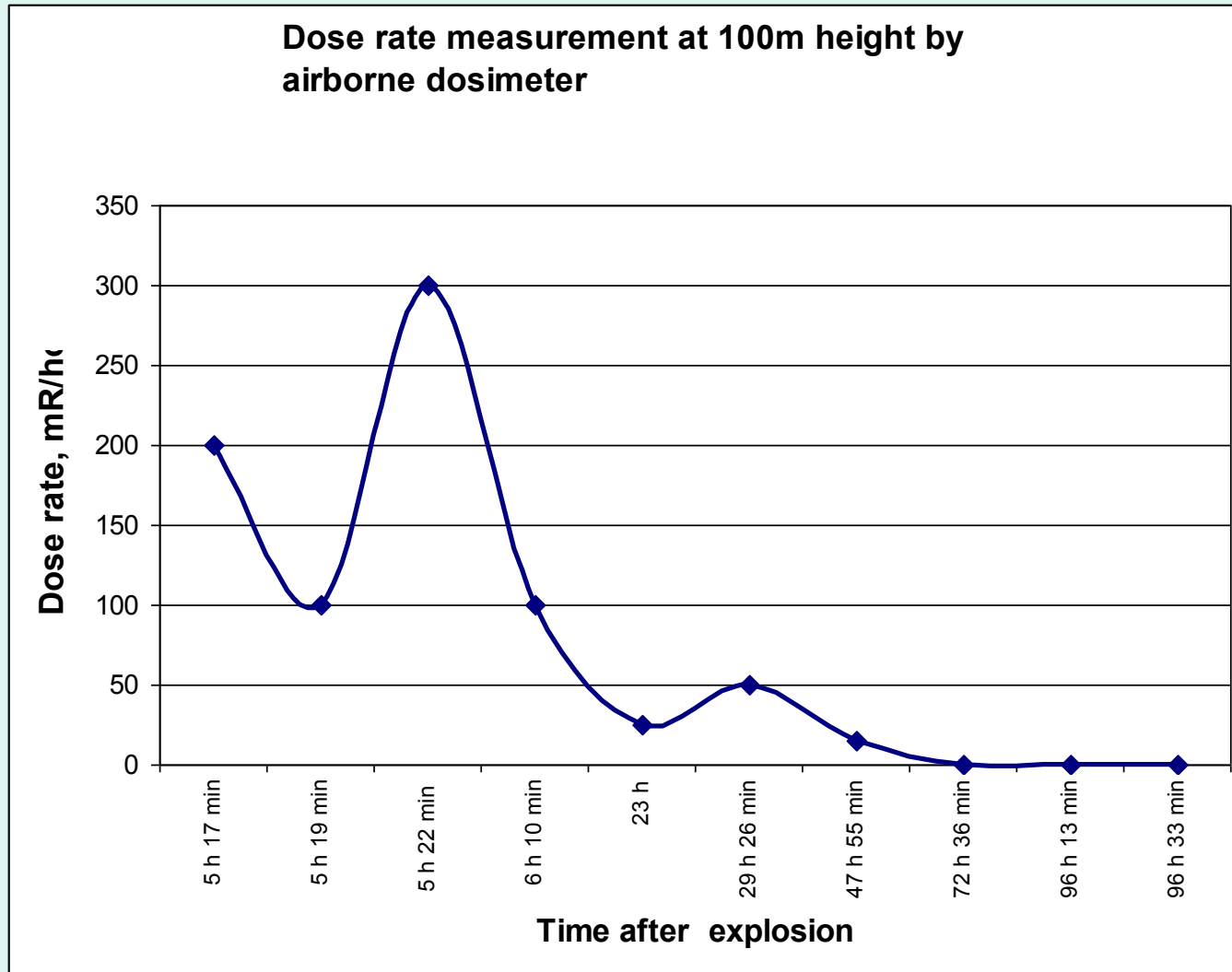


Contained Explosions Conducted at STS as Radiation Situation





RNG Release from epicentral area of the explosion in in the Shaft -1366 (STS, February, 1989).





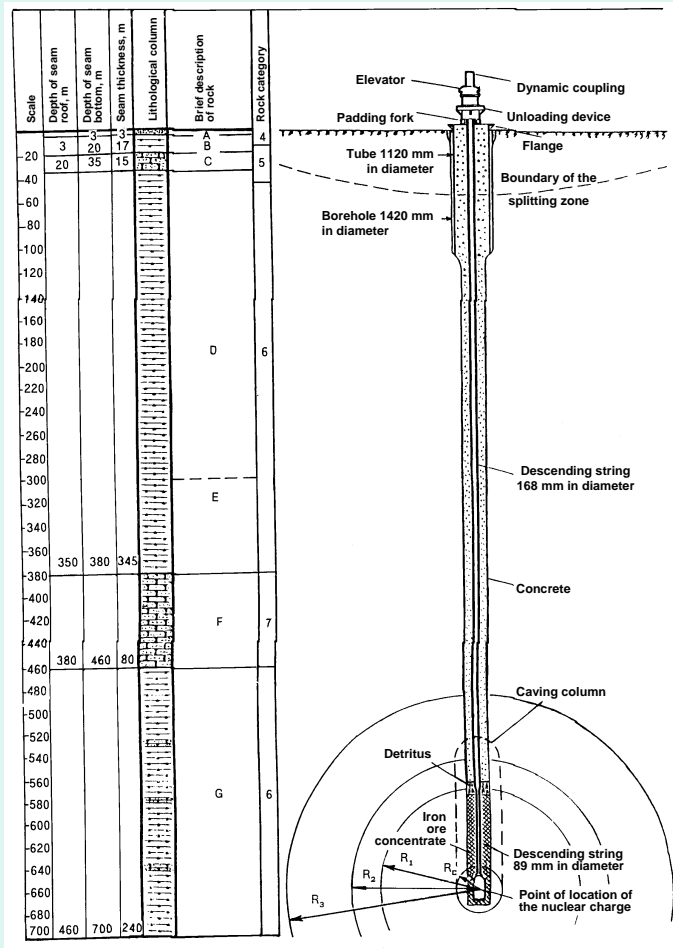
Nuclear Tests at Novaya Zemlya Archipelago

- 39 nuclear tests had been conducted at the Novaya Zemlya Test Site (6 from them - in shafts) .
- After 11 tests RNG spreaded beyond the NZ Site`s boundaries (offsite).
- Total activity of RNG released from one test was higher than 10^4 Ci ($3.7 \cdot 10^{14}$ Bq)
- Maximum total activity did not exceed 10^7 Ci (1 test).
- If total RNG activity was less than 1000 Ci ($3.7 \cdot 10^{13}$ Bq), RNG were not detected beyond the NZ Site`s boundaries



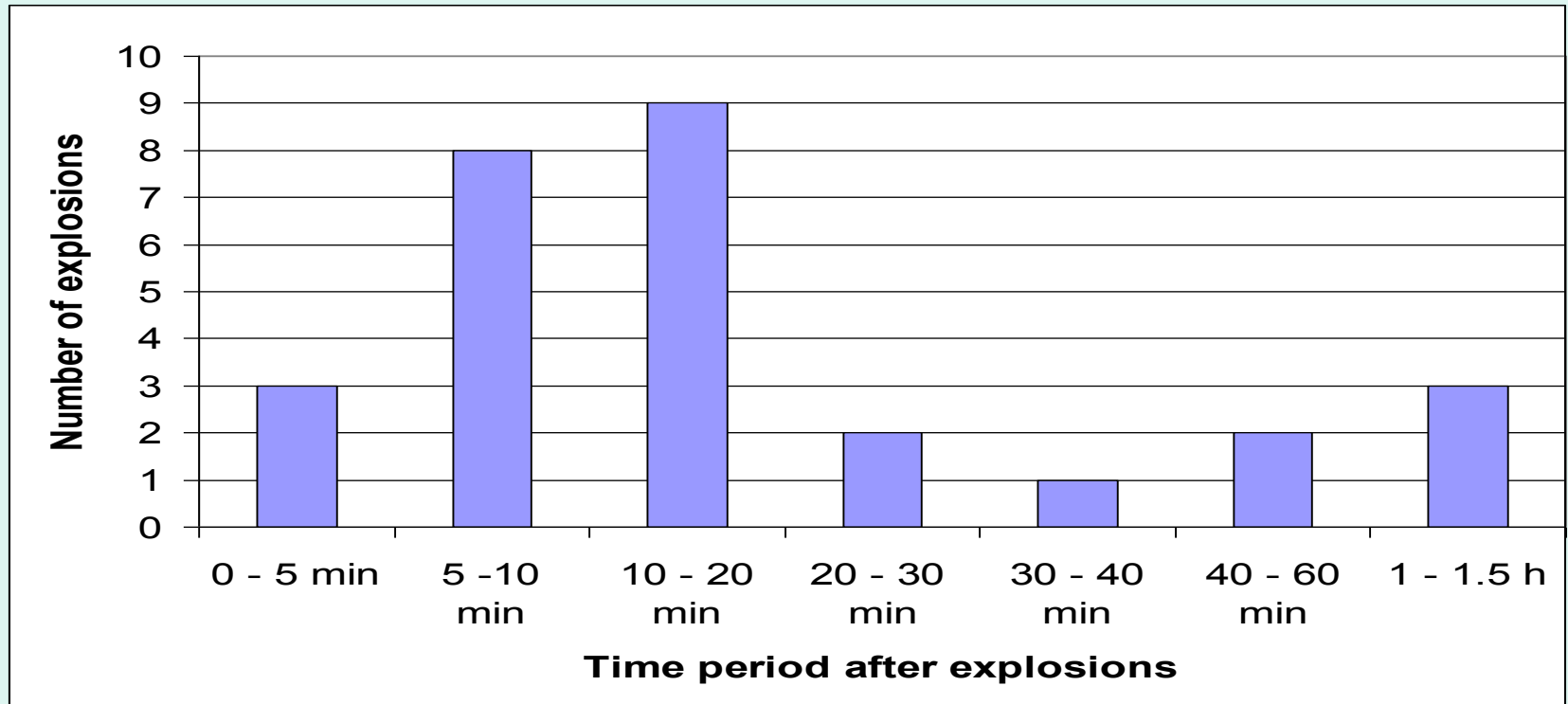


Test in the Shaft



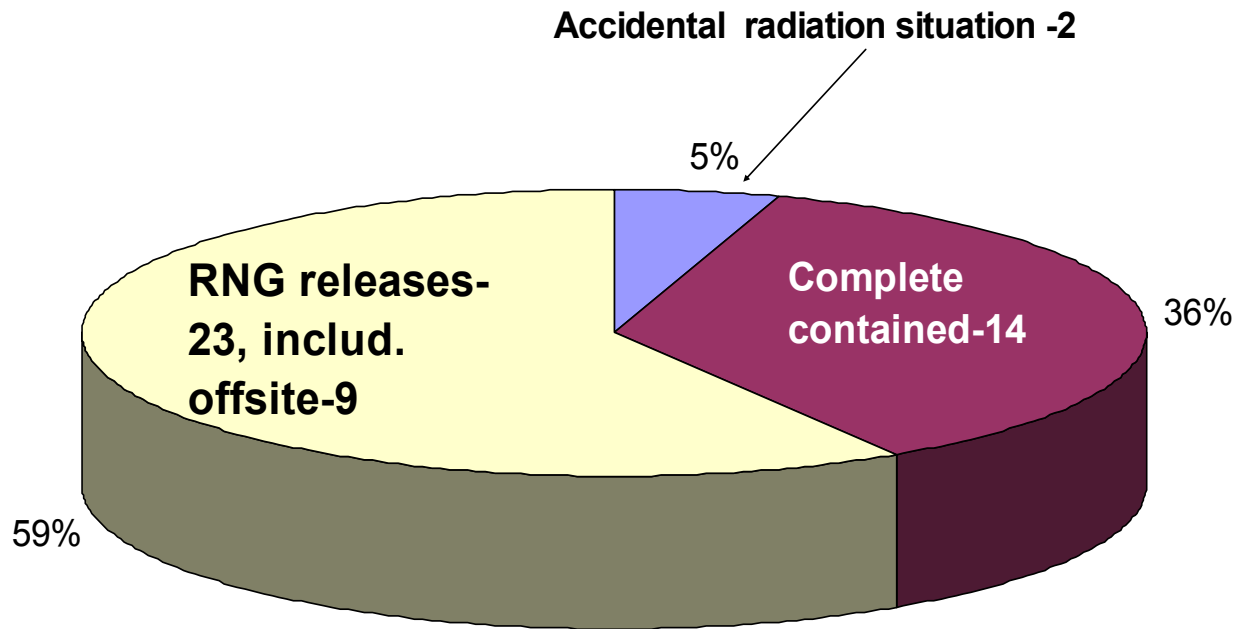


Beginning Time of RNG Release after UNE`s at Novaya Zemlya Test Site





Contained Explosions Conducted at NZ Site as Radiation Situation





RNG Release at the Peaceful Nuclear Explosions (PNE)

- 39 nuclear explosions with a yield W ranging from 2 to 23 kt TNT in vertical holes (shafts) at the depth of 400-1000 m had been conducted under the Core Seismic Sounding Program. No release of RNG was observed in 22 explosions.
- In a some cases a low-pressure seepage of radioactive gases occurred through both: the space between metallic casing of shaft and rock ("Globus-3", "Batolit-1"), and cracks in stemming complex of shafts ("Takhta-Kugulta", shaft "2Tk" on the Site "Lira").



**Characteristics of gas seepage after some
underground nuclear explosions in the rock salt at "Galit" Site**

Parameter	Explosions in Shaft		
	A-I	A-II-1	A-VIII
Name	A-I	A-II-1	A-VIII
Date	1966	1968	1979
Depth, m	161	600	995
Yield, kt TNT	1.1	27	65
Beginning of seepage, min	12	30	45
Duration of seepage	20 days	9 days	26 hours
Paths of release	Cracks in epicentral zone	Cracks in epicentr al zone	From crash heads of shaft
Summary RNG activity, Ci, (%)	$1.9 \cdot 10^5$ $(3.5 \cdot 10^{-4} \%)$	$5.4 \cdot 10^6$	$4 \cdot 10^6$
Volumetric activity of ^{133}Xe , GBq/L, (Ci/L)	-	3.7 (0.1)	37 (1.0)

“Galit” Site (Kazakhstan), Technical Site of the A-II-1 Shaft (modern view)





PNE for the Apatite Ore Ragging

- Radiation situation in peaceful nuclear explosion epicentral area in the Quelporr mountain (Khibiny) massif, object "Dnieper-2" (Kola Peninsula, 1984), kept being a background one for 8 hours after explosion.
- Low-pressure release of RNG with irregular character began later (late-time seepage) and continued for 10 days. Radioactive gases seepage occurred along the cracks at the epizentral area of the mountain surface.

the comprehensive nuclear-test-ban treaty
putting an end to nuclear test explosions

Thank you!

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