Table 4
Estimated Plutonium Production, High-Level Radioactive Waste Generation, and Atmospheric Radioactive Releases by the Chemical Separation Plants at Chelyabinsk-65, Tomsk-7, and Krasnoyarsk-26 in Russia (1992).

Isotope	Half-life (years)	RT-1 Chelyab'k-65 (Curies/y)	Tomsk-7 (Curies/y)	Kras'k-26 (Curies/y)
Atmospheric Releases:				
H-3	12.26	660	210	100
C-14	5730	40	23	12
Kr-85	10.72	810,000	450,000	230,000
I-131	0.022	-	3	2
Xe-131m	0.033	-	250	130
Xe-133	0.014	-	730	360
Remaining in High-Level Waste:				
Sr-90	29.3	7,700,000	3,300,000	1,600,000
Y-90m		7,700,000	3,300,000	1,600,000
Zr-95	0.18	2,700	95,000,000	47,000,000
Nb-95m		2,700	95,000,000	47,000,000
Tc-99	213,000	1,600	450	230
Ru-106	1.02	8,400,000	12,000,000	5,800,000
Rh-106m		8,400,000	12,000,000	5,800,000
I-129	1.6xE07	4.5	1.0	0.5
Ce-144	0.78	18,000,000	88,000,000	44,000,000
Pr-144m		18,000,000	88,000,000	44,000,000
Cs-137	30.17	10,000,000	3,600,000	1,800,000
Ba-137m		10,000,000	3,600,000	1,800,000
Np-237		4.5	1.5	0.78
Am-241	432.2	76,000	150	75
Am-242m	141	640	0.110	0.057
Am-243	7,370	830	0.024	0.012
Am(total)		77,000	150	75
Cm-242	162.9	32,000	170	340
Cm-243	28.5	1,100	0.003	0.001
Cm-244	18.11	85,000	0.051	0.025
Cm-245	8,500	9.0	-	-
Cm-246	4,780	0.97	-	-
Cm(total)		120,000	170	340

Recovered from processed fuel elements:

	MT/y	MT/y	MT/y
Np-237	0.035	-	-
U(Total)	114.*	2,310.#	1,155.#
Pu(Total)	1.04**	0.997##	0.498##

* 98.27% U-238; 1.254% U-235; 0.4499% U-236; 0.02417% U-234.
** 64.24% Pu-239; 20.11% Pu-240; 11.28% Pu-241; 2.952% Pu-242; 1.427% Pu-238.
# 99.33% U-238; 0.6566% U-235; 0.00919% U-236.
95.15% Pu-239; 4.605% Pu-240; 0.2395% Pu-241; 0.004406% Pu-242; 0.002958% Pu-238.

Table 4 Notes.

The data in Table 4 was calculated using a one group burnup code and the fission product spectra for U-235 and Pu-239 fission by thermal neutrons. The fission product spectra were taken from K.A. Varteressian and Leslie Burris, "Fission-Product Spectra From Fast and Thermal Fission of ^{235}U and ^{239}Pu," Argonne National Laboratory, ANL-7678, March 1970. The following additional assumptions were made:

Chelyabinsk-65:

(a) Fuel type: VVER;
(b) Initial fuel enrichment: 3.6% U-235, 0.0337% U-234, and 96.3663% U-238;
(c) Fuel burnup: 30,000 Mwd/MT;
(d) Fuel irradiation period: 3 years;
(e) Spent fuel cooling period prior to reprocessing: 3 years;
(f) Spent fuel processed: 120 MTHM;
(f) Recovery: 99% of the uranium and plutonium,[1] and 85% of the neptunium; and periodic recovery of other elements.
(g) No capture of Krypton-85, Carbon-14, or tritium (it is all release up the stack at the chemical separation plant);

[1] Ibid; Based on "Report by the Commission for Investigation of Environmental Situation in Chelyabinsk Region." (Decree by the President of the USSR, #RP 1283, January 3, 1991). Bukharin reports that in a June 27, 1991, Evgeniy Mikerin, then head of the Department of Isotope Separation, Reprocessing and Production Technology, MAPL told him that 99.9 percent of the plutonium is recovered and americium and curium are also extracted for further utilization.

Tomsk-7 and Krasnoyarsk-26:

(a) Reactor characteristics: Similar to Hanford B-Reactor;
(b) Number of reactors operating: 2 at Tomsk-7 and 1 at Krasnoyarsk-26;
(c) Reactor power level: 2000 Mw (thermal) each;
(d) Average Capacity factor: 0.8 each reactor
(e) Fuel: natural U (99.289% U-238; 0.711% U-235);
(f) Fuel burnup: 500 Mwd/MT;
(g) Fuel irradiation period: 62.5 full power days;
(h) Spent fuel cooling period prior to reprocessing: 120 days;
(i) Spent fuel processed: 2336 MTHM at Tomsk-7; 1168 MTHM at Krasnoyarsk-26;
(j) Recovery: 99% of the uranium and plutonium,[2] no neptunium;
(k) No capture of Krypton-85, Carbon-14, or tritium (it is all release up the stack at the chemical separation plant);
(l) Atmospheric releases of I-131, Xe-131m and Xe-133 were estimated from the Kr-85 release using the average release fractions for the Savannah River Site during the 8 year period 1971-1978.

[2] Ibid; Based on "Report by the Commission for Investigation of Environmental Situation in Chelyabinsk Region." (Decree by the President of the USSR, #RP 1283, 3 January 1991). Bukharin reports that in a June 27, 1991, Evgeniy Mikerin, then head of the Department of Isotope Separation, Reprocessing and Production Technology, MAPI, told him that 99.9 percent of the plutonium is recovered and americium and curium are also extracted for further utilization.

Table 5
Non-radioactive Chemical Waste Constituents From Chemical Separations[1]

Solvent

Trichloroethylene
Tri-n-butylphosphate
n-Undecane
n-Dodecane
n-Tridecane
n-Tetradecane
n-Pentadecane
$n\text{-}C_{22}H_{46}$–$nC_{34}H_{70}$
Kerosene
Carbon tetrachloride
Butylbenzylphthalate
Dicotylphthalate
Unknown phthalates

Volatile Solvents

Acetone
Methylene chloride
Chloroform

Carboxylic Acids

Docos-13en-oic acid
Hexanedioic acid
Hexadecanoic acid
Phthalic acid
Nonanedioic acid
Tetradecanoic acid
Pentanedioic acid
Octadecanoic acid
Hydroxybutanedioic acid
Butanedioic acid

Alkanes

nC_{23}-nC_{35}

Phthalate Esters

Dibutylphthalate
Dioctylphthalate

Chelating/complexing Agents

Citric acid
N-(2-Hydroxyethyl)ethylenediaminetriacetic acid (HEDTA)
Ethlyenediaminetetraacetic acid
Methane Tricarboxylic acid
Nitrilotriacetic acid (NTA)

Chelator Fragments

Ethylenediaminetriacetic acid (ED3A)
N-(2-Hydroxyethly)ethylenediamine-N'N'-diacetic acid (HEDDA)
N-(ethylene)ethylenediaminetriacetic acid (E_2DTA)
N-(2-Hydroxyethyl)iminodiacetic acid (HEIDA)
N-(2-Hydroxyethyl)-N'-(methyl)ethylenediamine-'N,N'-diacetic acid (MeHEDDA'A)
N-(methyl)ethylenediamine-N,N'-diacetic acid (MeEDD'A)
Imnodiacetic acid (IDA)

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[1] DOE, "Final Environmental Impact Statement on Disposal of High-Level, Transuranic and Tank Wastes, Hanford Site," DOE/EIS-0113, December 1987, p. A11.

Table 6
Occupational Radiation Exposures at Chelyabinsk-65(-40)
(Distribution of Employees According to Their Dose)[1]

	Installation A					Installation B				
	Percent of Employees				Average dose (rem)	Percent of Employees				Average doses (rem)
	<25	25-100	100-400	>400		<25	25-100	100-400	>400	
1948	84.1	11.1	4.8	-	19.6	-	-	-	-	-
1949	10.7	57.7	31.1	0.5	93.6	26.9	66.2	6.9	-	48.0
1950	52.2	47.2	0.6	-	30.7	21.5	42.0	36.0	0.5	94.0
1951	74.9	25.1	-	-	18.1	13.8	41.6	42.8	1.8	113.3
1952	83.9	16.1	-	-	14.9	21.8	57.0	21.2	-	66.0
	Percent of Employees				Average dose (rem)	Percent of Employees				Average dose (rem)
	<10	10-25	25-100	>100		<10	10-25	25-100	>100	
1953	37.8	41.5	18.4	2.3	19.6	25.3	25.4	47.3	2.0	30.7
1954	64.0	33.0	3.0	-	8.9	34.7	36.1	29.1	0.1	20.0
1955	61.8	33.7	4.5	-	9.5	29.8	36.7	33.2	0.3	21.3
1956	92.3	6.4	0.6	0.7	5.1	45.0	31.9	23.1	-	16.2
1957	98.1	1.9	-	-	4.2	37.5	36.9	25.5	0.1	17.5
1958	95.3	4.7	-	-	4.4	59.6	31.3	9.1	-	10.8
1959	99.7	0.3	-	-	3.3	75.7	21.1	3.2	-	14.7
	Percent of Employees				Average dose (rem)	Percent of Employees				Average dose (rem)
	<2.5	2.5-5.0	>5.0			<2.5	2.5-5.0	>5.0		
1960	57.5	29.3	13.2		2.7	14.2	25.8	60.0		15.2
1961	73.9	22.4	3.7		2.0	13.8	49.1	37.1		11.0
1962	65.0	31.4	4.0		2.3	16.6	32.5	50.9		7.6
1963	64.3	29.8	5.9		2.4	41.4	37.3	21.3		3.8
1964	55.7	27.8	16.5		3.0	66.4	29.3	4.3		4.1
1965	24.5	49.1	26.4		4.0	67.0	31.4	1.6		2.1
1966	25.5	52.4	22.1		1.7	56.7	41.3	2.0		2.4
1967	45.5	41.4	13.1		1.3	76.7	23.2	0.1		1.8
1968	55.0	38.7	6.3		1.1	76.3	23.7	-		1.8
1969	56.2	39.5	4.3		1.0	91.9	8.1	-		1.4
1970	36.9	49.7	13.4		1.4	85.6	14.4	-		1.6
1971	25.7	36.5	37.8		1.3	95.1	4.9	-		1.4
1972	69.7	26.8	3.5		1.1	97.9	2.1	-		1.3
1973	45.5	44.8	9.7		1.0	97.4	2.6	-		1.3
1974	95.1	4.9	-		1.0	98.9	1.1	-		0.6

[1] Boris V. Nikipelov, Andri F. Lizlov, and Nina A. Koshurnikova, "Experience with the first Soviet Nuclear Installation," *Priroda*, February 1990 (English translation by Alexander Shlyakhter).

Table 7a
Population Centers Along the Techa River[1]

Population Center	Distance (km)	Radiation Dose (rems) to those Evacuated	Remaining
Metlino*	7	160	
Techa-Brod*	18	130	
Novo Asanovo*	27	110	
Staro Asanovo*		110	
Nazarovo*		110	
N. Taskino*		90	
GP*		75	
Nadirovo*		60	
Nadirov*		55	
Most*		20	
Ibragimovo*	48	51	
Isaevo*		33	
Ferma (Farm) # 2*		31	
Muslyumovo	78		26
Kurmanovo*		16	
Karpino*		20	
Zamanila*		14	
Vetroduika*		18	
Brodokalmak	109		6.5
Panovo*			
Osolodka*			
Cherepanovo*			
Russkaya Techa	138		9.0
Baklanovo*			
Nizhnepetropavlovsk	152		11
Lobanovo			9.0
Anchugovo			10
Verkhnyaya Techa			11
Skiyagino			16
Bugaevo			10
Shutikhinskoye			4.0
Pershinskoe			6.0
Klyuchevskoye	202		3.5
Zatechenskoye	237		7.0
Dalmatovo			

* Population centers that were evacuated; only 21 (of 22 cited in the literature) could be identified on the chart.

[1] Data from a photograph of a chart on the wall at Mayak (ca. 1991). Population centers are identified in the order of their distance from the discharge point. Radiation doses for some villages could not be read from the photograph.

Table 7b
Organ Dose Estimates (External and Internal) for Inhabitants in Some Villages Along the Techa River[1]

Village	Distance from point of release, km	Effective dose equivalent, rem	Mean doses, Rem			
			red bone marrow	bone surfaces	large intestine	other tissues
Metlino	7*	140	164	226	140	127
Techa-Brod	18*	119	127	148	119	115
N. Asanovo	27*	100	127	190	104	90
Ibragimovo	48*	56	95	180	62	44
Muslyumovo	78	24	61	143	29	12
Brodokalmak	109	5.8	14	31	7	3.3
Russkaya Techa	138	8.2	22	53	10	3.7
Nizhnepetropavlovsk	152	10	28	68	13	4.3
Klyuchevskoye	202	3.6	8	18	2.6	2.2
Zatechenskoye	237	6.6	17	40	8.4	3.2

* Villagers were evacuated.

[1] G.I. Romanov, "Radioecological Conditions Accounted for the 1957 and 1967 Accidents and Production Activities of the Industrial Complex 'Mayak,'" paper presented at the International Radiological Conference, Chelyabinsk, Russia, 20-25 May 1992; and M.M. Kossenko, M.O. Degteva, and M.A. Petrushova, "Estimate of the Risk of Leukemia to the Residents Exposed to Radiation as a Result of a Nuclear Accident in the Southern Urals," *The PSR Quarterly*, Vol. 2, Number 4, December 1992, p. 192.

Table 8
The Average Annual Sr-90 and Cs-137 Concentration in the Techa River at the Mysiyumovo Settlement.[1]

Observation year	Sr-90 content (pCi/l)	Cs-137 content (pCi/l)
1951	40,000	510,000
1962	10,000	4,000
1964	3,000	250
1973	2,000	40
1978	1,500	36
1983	350	24
1988	420	40

[1] "Proceedings of the Commission on Studing the Ecological Situation in Chelyabinsk Oblast," (Ordered by President M. Gorbachev, Presidential Decree # RP-1283, 3 January 1991), ca. April, 1991, [translated into English], Vol. II, p. 51 (of the English translation).

Table 9
Radioactive Contamination in the Chelyabinsk-65 Reservoirs[1]

Reservoir Number	Area of the Reservoir (sq km)	Capacity of the Reservoir (million cubic m)	Composition of Radionuclides: Concentration in Water, ci/l					Composition of Radionuclides: Ground Deposits, Ci/kg		Accumulation, Ci		
			Sr-90	Cs-137	HTO	$\Sigma\alpha$	$\Sigma\beta$	Sr-90	Cs-137	In the Reservoir	In Ground Deposits	Overall
2	19	83	1.1×10^{-6}	4.5×10^{-6}	2.5×10^{-7}	?	--	1.3×10^{-6}	3×10^{-5}	2×10^{3}	18×10^{3}	20×10^{3}
3	0.5	0.75	1.6×10^{-6}	2.0×10^{-7}	1.4×10^{-6}	3×10^{-10}	--	1.4×10^{-4}	1×10^{-3}	2.6×10^{3}	15.4×10^{3}	18×10^{3}
4	1.3	4.1	1.7×10^{-7}	1.3×10^{-6}	5.2×10^{-7}	4.5×10^{-9}	--	4×10^{-6}	6×10^{-5}	1.7×10^{3}	4.2×10^{3}	6×10^{3}
6	3.6	17.5	3.7×10^{-10}	2×10^{-11}	1×10^{-6}	3.9×10^{-5}	--	3×10^{-7}	3.9×10^{-7}	2	300	300
9	0.25	0.4	1.7×10^{-3}	1.2×10^{-2}	5.3×10^{-5}	5.7×10^{-6}	1.9×10^{-2}	0.3	1.4	8.4×10^{6}	110×10^{6}	120×10^{6}
10	16.6	76	3.5×10^{-7}	8.6×10^{-6}	3.2×10^{-7}	1×10^{-11}	--	3.5×10^{-6}	1.5×10^{-1}	50×10^{3}	60×10^{3}	110×10^{3}
11	44	217	5.1×10^{-6}	2×10^{-11}	4.5×10^{-6}	2×10^{-12}	--	1.3×10^{-6}	1.3×10^{-7}	24×10^{3}	15×10^{3}	39×10^{3}
17	0.17	0.8	7×10^{-4}	4×10^{-6}	1×10^{-4}	1.2×10^{-3}	--	3.3×10^{-7}	3.3×10^{-2}	45×10^{3}	2×10^{6}	2×10^{6}

[1] "Proceedings of the Commission on Studing the Ecological Situation in Chelyabinsk Oblast," (Ordered by President M. Gorbachev, Presidential Decree # RP-1283, 3 January 1991), ca. April, 1991, [translated into English], Vol. I, p. 37 (of the English translation); B.V. Nikipelov, A.S. Nikiforov, O.L. Kedrovsky, M.V. Strakhov, and E.G. Drozhko, "Practical Rehabilitation of Territories Contaminated as a Result of Implementation of Nuclear Material Production Defence Programmes," (undated English translation ca. 1990); and tables given to Thomas B. Cochran by Victor N. Chukanov, USSR Academy of Sciences, Ural Department, Ecological Security Center, Sverdlosk, private communication, 13 April 1991.

Table 10
Characteristics of the Radioactivity Released in the 1957 Accident[1]

Radionuclide	Contribution to total activity of the mixture, %	Half-life	Type of radiation emitted
^{89}Sr	traces	51 d	β, γ
$^{90}Sr + {}^{90}Y$	5.4	28.6 y	β
$^{95}Zr + {}^{95}Nb$	24.9	65 d	β, γ
$^{106}Ru + {}^{106}Rh$	3.7	1 y	β, γ
^{137}Cs	0.036	30 y	β, γ
$^{144}Ce + {}^{144}Pr$	66	284 d	β, γ
^{147}Pm	traces	2.6 y	β, γ
^{155}Eu	traces	5 y	β, γ
$^{239,240}Pu$	traces	-	α

[1] B.V. Nikipelov, G.N. Romanov, L.A. Buldakov, N.S. Babaev, Yu.B. Kholina, and E.I. Mikerin, "Accident in the Southern Urals on 29 September 1957," International Atomic Energy Agency Information Circular, 28 May 1989.

Table 11
Land Contaminated by the 1957 Accident at Chelyabinsk-65[1]

Contamination Level (Ci Sr-90/km^2)	Area (km^2)
0.1 - 2	15,000 - 23,000
2 - 20	600
20 - 100	280
100 - 1000	100
1000 - 4000	17

Table 12
Solid Waste Burial Sites at Chelyabinsk-65[2]

KIND OF WASTE	NUMBER OF BURIAL SITES	VOLUME OF WASTE (1000 m^3)	WASTE ACTIVITY (Ci)	TOTAL AREA (ha)
Low- and Medium-level Waste	203	685.1	31.6×10^3	20.2
High-level Waste	24	41.3	12×10^6	1.1
Total	227	726.4	12×10^6	21.3

[1] G.N. Romanov and A.S. Vorovov, "The Radiation Situation After the Explosion," *Priroda*, May 1990, p. 50.

[2] "Proceedings of the Commission on Studing the Ecological Situation in Chelyabinsk Oblast," Vol. II, p. 27.

Table 13
Estimated Plutonium-Equivalent Production by the Five Graphite Reactors at Chelyabinsk-65

YEAR	CAPACITY	THERMAL ENERGY		PLUTONIUM EQUIVALENT	
		ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE
	(Mwt)	(1000Mwd)	(1000Mwd)	(kg)	(MT)
1948	100	8	8	7	0.0
1949	100	18	26	16	0.0
1950	250	64	91	55	0.1
1951	965	140	231	121	0.2
1952	2,515	407	638	350	0.5
1953	2,515	587	1,225	505	1.1
1954	3,165	890	2,115	766	1.8
1955	4,465	1,304	3,419	1,121	2.9
1956	4,465	1,304	4,723	1,121	4.1
1957	5,165	1,508	6,231	1,297	5.4
1958	6,565	1,917	8,148	1,649	7.0
1959	6,565	1,917	10,065	1,649	8.7
1960	6,565	1,917	11,982	1,649	10.3
1961	6,565	1,917	13,899	1,649	12.0
1962	6,565	1,917	15,816	1,649	13.6
1963	6,565	1,917	17,733	1,649	15.3
1964	6,565	1,917	19,650	1,649	16.9
1965	6,565	1,917	21,567	1,649	18.5
1966	6,565	1,917	23,484	1,649	20.2
1967	6,565	1,917	25,401	1,649	21.8
1968	6,565	1,917	27,318	1,649	23.5
1969	6,565	1,917	29,235	1,649	25.1
1970	6,565	1,917	31,152	1,649	26.8
1971	6,565	1,917	33,069	1,649	28.4
1972	6,565	1,917	34,986	1,649	30.1
1973	6,565	1,917	36,903	1,649	31.7
1974	6,565	1,917	38,820	1,649	33.4
1975	6,565	1,917	40,737	1,649	35.0
1976	6,565	1,917	42,654	1,649	36.7
1977	6,565	1,917	44,571	1,649	38.3
1978	6,565	1,917	46,488	1,649	40.0
1979	6,565	1,917	48,405	1,649	41.6
1980	6,565	1,917	50,322	1,649	43.3
1981	6,565	1,917	52,239	1,649	44.9
1982	6,565	1,917	54,156	1,649	46.6
1983	6,565	1,917	56,073	1,649	48.2
1984	6,565	1,917	57,990	1,649	49.9
1985	6,565	1,917	59,907	1,649	51.5
1986	6,565	1,917	61,823	1,649	53.2
1987	6,565	1,833	63,656	1,576	54.7
1988	6,000	1,752	65,408	1,507	56.3
1989	6,000	1,528	66,936	1,314	57.6
1990	4,000	803	67,739	691	58.3

Assumed reactor capacity factors for the first year:	0.4
second year:	0.6
subsequent years:	0.8

Table 14
Estimated Plutonium-Equivalent Production by the Heavy and Light Water Reactors at Chelyabinsk-65

YEAR	CAPACITY	THERMAL ENERGY		PLUTONIUM EQUIVALENT	
		ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE
	(MWt)	(1000 Mwd)	(1000 Mwd)	(kg)	(MT)
1950	250	37	37	35	0.0
1951	250	55	91	52	0.1
1952	250	73	164	69	0.2
1953	250	73	237	69	0.2
1954	250	73	310	69	0.3
1955	500	146	456	139	0.4
1956	500	146	602	139	0.6
1957	500	146	748	139	0.7
1958	500	146	894	139	0.8
1959	500	146	1,040	139	1.0
1960	1,000	292	1,332	277	1.3
1961	1,000	292	1,624	277	1.5
1962	1,000	292	1,916	277	1.8
1963	1,000	292	2,208	277	2.1
1964	1,000	292	2,500	277	2.4
1965	1,000	292	2,792	277	2.7
1966	1,000	292	3,084	277	2.9
1967	1,000	292	3,376	277	3.2
1968	1,000	292	3,668	277	3.5
1969	1,000	292	3,960	277	3.8
1970	2,000	438	4,398	402	4.2
1971	2,000	511	4,909	464	4.6
1972	2,000	584	5,493	526	5.2
1973	2,000	584	6,077	526	5.7
1974	2,000	584	6,661	526	6.2
1975	2,000	584	7,245	526	6.7
1976	2,000	584	7,829	526	7.3
1977	2,000	584	8,413	526	7.8
1978	2,000	584	8,997	526	8.3
1979	2,000	584	9,581	526	8.8
1980	2,000	584	10,165	526	9.4
1981	2,000	584	10,749	526	9.9
1982	2,000	584	11,333	526	10.4
1983	2,000	584	11,917	526	10.9
1984	2,000	584	12,501	526	11.5
1985	1,000	292	12,793	248	11.7
1986	1,000	292	13,085	248	12.0
1987	2,000	438	13,523	372	12.3
1988	2,000	511	14,034	434	12.8
1989	2,000	584	14,618	496	13.3
1990	2,000	584	15,202	496	13.8
1991	2,000	584	15,786	496	14.3
1992	2,000	584	16,370	496	14.7

Assumed reactor capacity factor for the first year: 0.4
second year: 0.6
subsequent years: 0.8

Table 15
Estimated Plutonium-Equivalent Production by the Five Graphite Reactors at Tomsk-7

YEAR	CAPACITY	THERMAL ENERGY		PLUTONIUM EQUIVALENT	
		ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE
	(Mwt)	(1000Mwd)	(1000Mwd)	(kg)	(MT)
1955	650	11	11	9	0.0
1956	650	100	111	86	0.1
1957	650	148	259	127	0.2
1958	1,950	399	658	343	0.6
1959	1,950	484	1,142	417	1.0
1960	2,630	732	1,874	629	1.6
1961	3,950	1,015	2,889	873	2.5
1962	3,950	1,084	3,973	932	3.4
1963	5,950	1,599	5,572	1,375	4.8
1964	5,950	1,690	7,262	1,453	6.2
1965	7,950	2,227	9,489	1,915	8.2
1966	7,950	2,274	11,762	1,956	10.1
1967	9,300	2,716	14,478	2,335	12.5
1968	9,300	2,716	17,194	2,335	14.8
1969	10,000	2,920	20,114	2,511	17.3
1970	10,000	2,920	23,034	2,511	19.8
1971	10,000	2,920	25,954	2,511	22.3
1972	10,000	2,920	28,874	2,511	24.8
1973	10,000	2,920	31,794	2,511	27.3
1974	10,000	2,920	34,714	2,511	29.9
1975	10,000	2,920	37,634	2,511	32.4
1976	10,000	2,920	40,554	2,511	34.9
1977	10,000	2,920	43,474	2,511	37.4
1978	10,000	2,920	46,394	2,511	39.9
1979	10,000	2,920	49,314	2,511	42.4
1980	10,000	2,920	52,234	2,511	44.9
1981	10,000	2,920	55,154	2,511	47.4
1982	10,000	2,920	58,074	2,511	49.9
1983	10,000	2,920	60,994	2,511	52.5
1984	10,000	2,920	63,914	2,511	55.0
1985	10,000	2,920	66,834	2,511	57.5
1986	10,000	2,920	69,754	2,511	60.0
1987	10,000	2,920	72,674	2,511	62.5
1988	10,000	2,920	75,594	2,511	65.0
1989	10,000	2,920	78,514	2,511	67.5
1990	8,000	2,709	81,222	2,330	69.9
1991	6,000	1,752	82,974	1,507	71.4
1992	4,000	1,552	84,526	1,335	72.7
1993	4,000	1,168	85,694	1,004	73.7

Assumed reactor capacity factors for the first year:	0.4
second year:	0.6
subsequent years:	0.8

Table 16
Estimated Plutonium-Equivalent Production by the Three Graphite Reactors at Krasnoyarsk-26

YEAR	CAPACITY	THERMAL ENERGY		PLUTONIUM EQUIVALENT	
		ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE
	(MWt)	(1000 Mwd)	(1000 Mwd)	(kg)	(MT)
1958	2,000	146	146	126	0.1
1959	2,000	365	511	314	0.4
1960	2,000	511	1,022	439	0.9
1961	4,000	730	1,752	628	1.5
1962	4,000	949	2,701	816	2.3
1963	4,000	1,095	3,796	942	3.3
1964	6,000	1,314	5,110	1,130	4.4
1965	6,000	1,533	6,643	1,318	5.7
1966	6,000	1,679	8,322	1,444	7.2
1967	6,000	1,752	10,074	1,507	8.7
1968	6,000	1,752	11,826	1,507	10.2
1969	6,000	1,752	13,578	1,507	11.7
1970	6,000	1,752	15,330	1,507	13.2
1971	6,000	1,752	17,082	1,507	14.7
1972	6,000	1,752	18,834	1,507	16.2
1973	6,000	1,752	20,586	1,507	17.7
1974	6,000	1,752	22,338	1,507	19.2
1975	6,000	1,752	24,090	1,507	20.7
1976	6,000	1,752	25,842	1,507	22.2
1977	6,000	1,752	27,594	1,507	23.7
1978	6,000	1,752	29,346	1,507	25.2
1979	6,000	1,752	31,098	1,507	26.7
1980	6,000	1,752	32,850	1,507	28.3
1981	6,000	1,752	34,602	1,507	29.8
1982	6,000	1,752	36,354	1,507	31.3
1983	6,000	1,752	38,106	1,507	32.8
1984	6,000	1,752	39,858	1,507	34.3
1985	6,000	1,752	41,610	1,507	35.8
1986	6,000	1,752	43,362	1,507	37.3
1987	6,000	1,752	45,114	1,507	38.8
1988	6,000	1,752	46,866	1,507	40.3
1989	6,000	1,752	48,618	1,507	41.8
1990	6,000	1,567	50,185	1,348	43.2
1991	6,000	1,168	51,353	1,004	44.2
1992	2,000	584	51,937	502	44.7

Assumed reactor capacity factors for the first year:	0.4
second year:	0.6
subsequent years:	0.8

Table 17
Estimated Tritium Production

YEAR	TRITIUM PRODUCTION (kg)	TRITIUM DECAY (kg)	TRITIUM INVENTORY (kg)	PLUTONIUM EQUIVALENT PRODUCTION (kg)	PLUTONIUM EQUIVALENT CUMULATIVE (MT)
1950	0.5	0.0	0.5	35	0.0
1951	0.7	0.0	1.2	52	0.1
1952	1.0	0.1	2.1	69	0.2
1953	1.0	0.1	2.9	69	0.2
1954	1.0	0.2	3.7	69	0.3
1955	1.9	0.2	5.4	139	0.4
1956	1.9	0.3	7.1	139	0.6
1957	1.9	0.4	8.6	139	0.7
1958	1.9	0.5	10.1	139	0.9
1959	1.9	0.6	11.5	139	1.0
1960	3.8	0.6	14.7	277	1.3
1961	3.8	0.8	17.7	277	1.5
1962	3.8	1.0	20.6	277	1.8
1963	3.8	1.1	23.3	277	2.1
1964	3.8	1.3	25.9	277	2.4
1965	3.8	1.4	28.3	277	2.7
1966	3.8	1.5	30.6	277	2.9
1967	3.8	1.7	32.8	277	3.2
1968	3.8	1.8	34.9	277	3.5
1969	3.8	1.9	36.8	277	3.8
1970	5.6	2.0	40.4	402	4.2
1971	6.4	2.2	44.6	464	4.6
1972	7.3	2.4	49.5	526	5.2
1973	7.3	2.7	54.1	526	5.7
1974	7.3	3.0	58.4	526	6.2
1975	7.3	3.2	62.5	526	6.7
1976	7.3	3.4	66.4	526	7.3
1977	7.3	3.6	70.1	526	7.8
1978	7.3	3.8	73.6	526	8.3
1979	7.3	4.0	76.9	526	8.8
1980	7.3	4.2	80.0	526	9.4
1981	7.3	4.4	82.9	526	9.9
1982	7.3	4.5	85.7	526	10.4
1983	7.3	4.7	88.3	526	10.9
1984	7.3	4.8	90.8	526	11.5
1985	3.4	5.0	89.3	248	11.7
1986	3.4	4.9	87.8	248	12.0
1987	0.0	4.8	83.0	0	12.0
1988	0.0	4.5	78.5	0	12.0
1989	0.0	4.3	74.2	0	12.0
1990	0.0	4.1	70.1	0	12.0
1991	0.0	3.8	66.3	0	12.0

Table 18
Pilot and Semi-Commercial U-Pu Fuel Production Bays

BAYS (PRODUCTION)	LOCATION	OPERATION TIME	PURPOSE	FUEL COMPOSITION & ITS PRODUCTION PROCESS	TYPE OF Pu USED	CAPACITY
Laboratory lines, bays	Sci. Res. Inst. for Inorganic Materials, Moscow	Early 1950s to present day	Preparation of experimental fuel specimens, fabrication of individual fuel elements	Delta-Pu alloys; PuO_2;$(U,Pu)O_2$ & other different methods	Military	
Pilot bay	"Mayak," Chelya-binsk-65	1060s to 1970s	Manufacture of pellets and pilot fuel elements for fast research reactors	Pu alloys; PuO_2	Military	Total mass of Pu used 1 ton
Pilot complex	Sci. Res. Inst. for Atomic Reactors, Dimi-trovgrad	1985 to present day	U-Pu fuel production, fabrication of fuel elements & assemblies for fast reactor testing	$(U,Pu)O_2$;Elec-trochemical granulation & vibrocompaction of fuels	Military & energy producing	40-50 FAs*/an-num, fuel fab-rication bay (350 kg Pu)
Semi-commercial plant "Zhemchug"	"Mayak," Chelya-binsk-65	1986-1987	U-Pu fuel production for fast reactor testing	$(U,Pu)O_2$; sol-gel process	Military (from BN reactors)	35 kg Pu/ annum (for 5 FAs)
Semi-commercial "Granat"	"Mayak," Chelya-binsk-65	1988 to present day	U-Pu fuel production for fast reactor testing	$(U,Pu)O_2$;ammonia granulation of coprecipitated U & Pu compounds	Military	70-80 kg Pu/annum (for 10 FAs)

Semi-commercial plant "Pakat"	"Mayak," Chelya-binsk-65	1988 to present day	U & Pu dioxide pellet manufacture, fabrication of fuel elements for fast reactor testing	$(U,Pu)O_2$ produced by both mechanical stirring of individual U & Pu oxides & sol-gel process, ammonia granulation, carbonate	Military	10 FAs/ annum (70-80 kg Pu)
Semi-commercial complex for mixed fuel production (1 line)	"Mayak," Chelya-binsk-65	50% ready production	U-Pu fuel production, pellet manufacture, fuel element & assembly fabrication for use in commercial fast reactors	$(U,Pu)O_2$ pro-duced by U and Pu coprecipitation	Energy producing and military	5-6 t Pu/annum
Semi-Commercial complex for mixed fuel production (2 line)	"Mayak," Chelya-binsk-65	Project develop-ments	U-Pu fuel production, pellet manufacture, fuel element and assembly fabrication for use in VVER type reactors	$(U,Pu)O_2$ pro-duced by U and Pu coprecipitation	Miltary & energy producing	5-15 t Pu/annum

* FAs: fuel assemblies

Table 19
Research and Commercial Reactor Tests of Pu-Containing Fuel

REACTOR	TIME OF TESTING	FUEL TYPE AND PRODUCTION PROCESS	TESTING SCALE
BR-2	1956	Pu metal	~ 20 kg Pu
BR-5 (BR-10)	from 1959	PuO_2	~ 150 kg Pu
IBR-2	1965	PuO_2	~ 100 kg Pu
IBR-30	from 1957	Pu metal	~ 100 kg Pu
Crit. facility BFS (Ph.En.Inst.)	from 1960s	Pu metal	750 kg Pu
BOR-60	from 1975	1.$(U,Pu)O_2$:electrochemical granulation & vibrocompaction of fuels	hundreds kg Pu
	from 1973	2.$(U,Pu)O_2$:mechanical strirring of individual oxides & pelletizing	tens kg Pu
	from mid-1980s	3.$(U,Pu)O_2$:co-precipiatation by carbonate and ammonia processes and pelletizing	up to 10 kg Pu
BN-350	from 1980	1.$(U,Pu)O_2$:mechanical coprecipitation, granulatation and pelletizing	10 FAs*
	1990-1992	2.$(U,Pu)O_2$:ammonia coprecipitation, granulation, pelletizing	100 fuel elements
BN-600	from 1990	$(U,Pu)O_2$:ammonia co-precipita-tion, granulation, pelletizing	8 FAs
MIR	from 1992	$(U,Pu)O_2$:co-precipitation by carbonate & ammonia & pelletizing (Thermal reactor fuel containing 5% mass Pu)	2 fuel elements and 3 ampules

* FAs: fuel assemblies

Table 20
Versions of Pu Utilization in the Nuclear Fuel Cycle

REACTOR TYPE	Pu UTILIZATION SCHEDULE	Pu INVENTORY, MT	
		Initial Inventory (MT/reactor)	Makeup (MT/y)
BN-350	Loading of whole core	~1.5	0.6
BN-600	50% loading of core*	1.1-1.2	0.6
BN-800	Loading of whole core	2.3	1.6
VVER-1000	1/3 loading of core	1.0	0.35
	Loading of core	3.0	1.0

* On condition the reactor core is updated.

Table 21
Uranium Mining Areas[1]

DISTRICT/ LOCATION	DEPOSITS	TYPE OF DEPOSIT	KNOWN URANIUM RESOURCES, MTU
Uranium ore districts			
Russia			
Streltsa	Streltsovskoye Tulukuyevskoye Yubileinoye Novogodnee Dal'nee	vein/stockwork in volcanic complexes	124,000
Stavropol	Beshtau * Bykogorskoye *	vein/stockwork	3,300
Ukraine			
Kirovograd	Michurinskoye Severinskoye Vatutinskoye Yuzhnoye Kalinovskoye Lozovatskoye	metasomatic stockwork in albatites	82,400
Krivoi Rog	Pervomaiskoye * Zheltovodskoye * Devladovo * Bratskoye *	metasomatic stockwork in albatites	30,800
Kazakhstan			
Zacaspiysk	Melovoye Tomakskoye Tasmuran Taybagar	vein/stock in volcanic complexes	64,400
Pribalkhash	Botaburum Kyzylsay Kurday Dzhideli	fish-bone detritus	121,900

[1] "Uranium Raw Material Base," JPRS-UEQ-93-002.

Kokchetavsk	Ishimskoye * Balkhashinskoye * Manybay * Vostok Grachevskoye Zaozernoye Tastykolskoye	vein/stock in folded regions	99,200
	Semisbay	sandstone	
Uzbekistan			
Kyzylkum	Uchkuduk Surgaly Ljavljakan Beshkak Bukinay Kanimesh	sandstone	165,300
	Rudnoye Koscheka Dzhantuar	black shales	
Karamazar *	Alatanga Chauli Maylikatan Taboshar Adrasman Maylisu Shaptar Maylisay	vein/stock in volcanic complexes	20,000
Uranium bearing areas (all in Russia)			
Zauralsk	Dolmatovskoye Dobrovolskoye	sandstone	16,400
Yeniseysk	Labyshevskoye	vein-stockwork	7,600
	Primorskoye Ust-Uyuk	sandstone	
Vitimsk		sandstone	23,700
Onezhsk	Padma	black shales	2,000
Far Eastern	Lastochka	vein/stockwork	3,900
Central Trans-baikalian (Chita)	Olovskoye Gornoye Berezovoye	vein/stockwork	20,700
	Stepnoye	sandstone	

* -- resources are partially or wholly exhausted.

Table 22
Principal Uranium Production Centers[1]

REPUBLIC	PRODUCTION FACILITY AND LOCATION	OPERATIONS AND ASSOCIATED URANIUM-ORE DISTRICTS	ESTIMATED CAPACITY, MTU3O8/y
Russia	Priargunsky Mining and Chemical Combine (Krasnokamensk, Chita area)	Processing of ore from the Strelitsa district. By-product recovery of molybdenum.	4,000
Ukraine	Vostochny Mining and Processing Combine (Zheltye Vody)	Processing of ore from the Kirovograd and Krivoi Rog districts.	2,000
Kazakhstan	Joint Stock Production Association Kascor (Actau)	Processing of ore from the Zacaspiysk district. By-product recovery of scandium, rare earth elements and phosphates.	3,000
	Tselinny Mining and Chemical Combine (Stepnogorsk)	Processing of conventional ore and ISL slurries from the Kokchetavsk and Pribalkhash districts. By-product recovery of phosphates and molybdenum.	3,000
Kyrgyzstan	Production Association Yuzhpolimetal (Kara Balta, Beshkek)	Processing of ISL slurries from the Pribalkhash district. By-product recovery of molybdenum. Production of uranium may be terminated.	5,000
Uzbekistan	Navoinsky Mining and Metallurgy Combine (Navoi)	Processing of conventional ore and ISL slurries from the Kyzylkum district. Recovery of molybdenum, scandium and precious metals.	8,000
Tajikistan	Vostochny Rare Metal Industrial Combine (Khodzhent)	Processing of conventional ore and ISL slurries from the Pribalkhash and Kyzylkum districts. Production of uranium is terminated	4,500

[1] "*Uranium In The New World Market: Supply And Demand 1990*," Uranium Institute, 1991; D. Garrow, "Uranium Supply Potential, Central Asian Republics;" Marc Humphries, "The CIS Role in World Mineral Markets," *CRS Report to the Congress*, 18 May 1993.

Table 23
Estimated Uranium and SWU Requirements for Soviet-Built Power Reactors

TYPE (number)	ENRICHMENT, %	AMOUNT OF FUEL, MT/y	SWU REQUIREMENTS, x 10^6 SWU/y[1]	EQUIVALENT OF NATURAL URANIUM REQUIREMENTS, MTU/y[2]
RBMK-1000 (15.5)[3]	2.4	586[4]	1.383	2,992
VVER-440 (26)	3.6	330[5]	1.512	2,683
VVER-1000 (18)	4.4	334[6]	2.014	3,327
BN-350/600 (1/1)	20-25	6	0.229	300
Naval and research reactors (tens)	mostly HEU	1.5[7]	from HEU stock[8]	from HEU stock

[1] Assuming 0.3% tail assay.

[2] Neglecting conversion and enrichment losses, which are on the order of 0.5%.

[3] Includes 13 RBMK-1000 and two RBMK-1500 rated at 1250 Mw_e.

[4] Assuming a capacity of 3200 Mw_t, a burnup of 20 Mwd/kgU, and the average load factor of 0.647, a 1000-MWe RBMK reactor consumes 37.8 MTU/y.

[5] Assuming a capacity of 1375 Mw_t, a burnup of 28.6 MWd/kgU, and average load factor of 0.723, a VVER-440 consumes 12.7 MTU/y. Currently, VVER-440s are being transferred from a 3 to a 4 year-fuel life with increase in burnup to 40 MWd/kg. At a burnup of 40 MWday/kgU and the same load factor, a VVER-440 reactor consume 9.1 MTU/y.

[6] Assuming a capacity of 3000 Mw_t, a burnup of 40 Mwd/kgU, and an average load factor of 0.677, a VVER-1000 consumes 18.5 MTU/y.

[7] E. Mikerin, Workshop in Rome, June 1992.

[8] Interview with E. Mikerin, Moscow, 19 May 1992.

Table 24
Soviet-Designed Power Reactors Operating and Under Construction[1]

	VVER-440	VVER-1000	RBMK	OTHERS	UNDER CONSTRUCTION[2] (% complete)
RUSSIA					
Novovoronezh	2	1			
Kola	4				
Balakovo		4			
Tver' (Kalinin)		2			1 VVER-1000 (70)[3]
Kursk			4		1 RBMK-1000 (60)
St. Petersburg			4		
Smolensk			3		
Beloyarskaya				BN-600	
Bilibino				4 x 12 MWe[4]	
UKRAINE					
Rovno	2	1			1 VVER-1000 (70)
Zaporozhye		5			1 VVER-1000 (90)
South Ukraine		3			
Khmel'nitsky		1			1 VVER-1000 (90)
Chernobyl			2		
Ignalina, Lithuania			2x1,250 MWe		
Actau, Kazakhstan				BN-350	
OUTSIDE THE FORMER SOVIET UNION					
Bulgaria	4	1			1 VVER-1000
Hungary	4				
Czechoslovakia	8				6 VVER-440 and 2 VVER-1000
Finland	2				

[1] The acronyms, Russian names and English translation of the reactor names are as follows:
VVER – "Vodo-Vodyanoy Energeticheskiy Reactor" (water-water power reactor);
RBMK – "Reactor Bolshoy Moschnosti Kipyaschiy" (high power boiling reactor);
AST – "Atomnaya Stantcia Teplovaya" (heat atomic station);
BN – "[reactor na] Bystrykh Neitronakh" (fast neutrons reactor).

[2] Construction of some reactors (not included in the table) that have been stopped, but which the Russian Federation has order resumption of construction include: Balakovo VVER-1000 Unit 5 (30%), Rostov VVER-1000 Unit 1 (80%), South Urals BN-800 Unit 1 (10%), and Voronezh AST-500 (80%) The prospects for completion of these reactors remains uncertain.

[3] The local government voted to allow operation of Tver' VVER-1000 unit 3 (70%-complete), but to stop construction of Tver' VVER-1000 unit 4 (30% complete).

[4] A heat and power reactor.

Table 25
Research Reactors

OPERATOR (location)	NAME	POWER, kW	ENRICHMENT (%)/AMOUNT OF FUEL (kg)	COMMENTS
Russia				
Kurchatov Institute (Moscow)	MR	40,000	90/2.	
	WWR-2	3,000	10/	
	IR-8	8,000	90/1.06	
	IIN-3M Hydra	10	90/2.4	Uranium-salt solution reactor. Used for development of low-power passive safety reactors.
	Argus	50	21/2.8	The core is UO_2SO_4 solution surrounded by a graphite reflector. The reactor is used for neutron activation and radiographic analysis, production of nuclear filters, non-destructive testing, and production of short-life radioisotopes.
	F-1	24	natural uranium/ tons	
Moscow Engineering and Physics Institute (MEPI)	IRT-A MEPI	2,500	90/1.3	
	IRT MEPI	10,000		
Institute of Physics and Power Engineering (Obninsk)	BR-10	8,000	90% HEU or Pu /120.84	Fast reactor. Used for validation of core design and new fuel concepts.
	BFS (Big Physical Stand)[1]		750 kgPu	Subcritical assembly. Used for research on MOX fuel and reactor -core design.
NIIAR (Dimitrov-grad)	RBT-10/2	10,000	63/18.4	RBT reactors are used for research on reactor materials under continuous irradiation with relatively small flux intensities.
	RBT-10/1	10,000	63/18.4	
	RBT-6	6,000	63/18.4	

[1] V. Murogov, "Energy Conversion of Weapons Plutonium", Proceedings of the International Workshop on Reprocessing of Nuclear Fuel, Storage And Disposition Of Civilian And Military Plutonium, 14-16 December 1992, Moscow.

	MIR-M1	100,000	90/2.3	Water cooled and moderated, beryllium-reflector reactor. Used for tests of fuel rods and assemblies, validation of core designs for power, propulsion, and research reactors.
	BOR-60	60,000	45-90% HEU or Pu	A power reactor (3-loop sodium-cooled fast reactor). Fueled with UC or UC+PuC fuel. Used for research and tests of fuel compositions, rods and assemblies, reactor materials, safety of fast reactors, technology of sodium coolant, and design of steam-generators.
	SM-2	100,000	90/11.0	Used for irradiation of reactor materials; production of isotopes of trans-plutonium elements; neutron-activation analysis.
Yekaterinburg	IVV-2M	15,000	90/1.7	
Institute of Nuclear Research (Dubna)	IBR-30	30	90/	
Technology Research Institute (St.Petersburg)	WWR-M Gatchina	18,000	90/1.0	
	PIK physical model	0.1	90/19.4	
Norilsk Mining Combine (Norilsk)	WWR-TS	12,000	36/3.5	Used for assaying metal ore.
Institute of Experimental Physics (VNIIEF, Arzamas-16)	BIGR.			Uranium-graphite fast reactor.
	BR-1			Uranium-metal alloy fast reactor.
	VIR-2M			Intermediate-energy neutron reactor. The core is uranium salt solution.
				Reactors are used for research on resistance of materials to effects of radiation, safety, solid-state physics, radiobiology as well as for development of radiation-resistant radio-electronic components.
Ukraine				
Institute for Nuclear Research	WWR-M Kiev	10,000	36/1.36	
High marines School (Sevastopol)	WWR-M	200	36/4	Used for training purposes.[2]

[2] William C. Potter, *Nuclear Profiles of the Soviet Successor States* (Monterey, CA: Monterey Institute of International Studies, May 1993). Potter also reports a subcritical assembly at Sevastopol.

Kazakhstan				
NPO "Luch"	IGR			Impulse, graphite-moderated reactor.
	IVG.1M			Impulse, water-cooled reactor with beryllium reflector. Both IGR and IVG are capable of producing high neutron fluxes and uniquely suitable for research on reactor safety in transient conditions.[3]
	RA			High-temperature, gas-cooled (hydrogen as working gas) reactor. Used for research on nuclear propulsion for space applications.
Institute of Nuclear Physics (Almaty)	WWR-K Alma-Ata	10,000	36/5.2	Shut down in 1988 because of revision of the seismic standards after the Chernobyl accident of 1986. Possible restart in 1993-94.
Other republics				
Institute of Nuclear Physics (Riga, Latvia)	IRT-2 Riga	5,000	90/2.5	
Institute of Atomic Energy (Minsk, Belarus)	IRT-M Minsk	4,000	90/4	Shut down in 1988. Possible restart for training purposes.[4]
Paldisky naval base (Estonia)	Paldiski-1 and Paldiski-2			Russia-owned reactors which were used for training purposes. Shut down in 1990.[5]
Institute of Nuclear Physics (Tbilisi, Georgia)	IRT-M Tbilisi	8,000	90/4	Shut-down in 1990.
Nuclear Physics Institute (Tashkent, Uzbekistan)	WWR-CM Tashkent	10,000	90/4	

[3] O. Bukharin's interview with an official from the Kazakh National Nuclear Research Center, 5 May 1993.

[4] Potter, *Nuclear Profiles*. The Institute of Atomic Energy may also house two critical assemblies.

[5] Ibid.

Table 26
Head Organizations Involved in Research On Utilization of Plutonium

NAME	LOCATION	RESEARCH AREA
Bochvar's Institute of Inorganic Materials (VNIINM)	Moscow	-- Research on MOX powders. -- Technology of fabrication of pelletized MOX fuel. -- Radiochemical research.
Institute of Physics and Energy (FEI)	Obninsk	-- Basic research. -- Concept of a reactor core with MOX fuel. -- Thorium nuclear fuel cycle. -- Actinide transmutation.
Institute of Atomic Reactors (NIIAR)	Dimitrovgrad	-- Pyroreprocessing. -- Fabrication of MOX fuel by vibrocompaction.
Khlopin's Radium Institute	St.Petersburg	-- Radiochemical research. -- Coordination of research on MOX fuel in VVER reactors.
Production Association Mayak	Chelyabinsk-65	-- Fabrication of MOX fuel.

Figure 1
All-Russian Research Institute of Experimental Physics (Arzamas-16) at Sarova

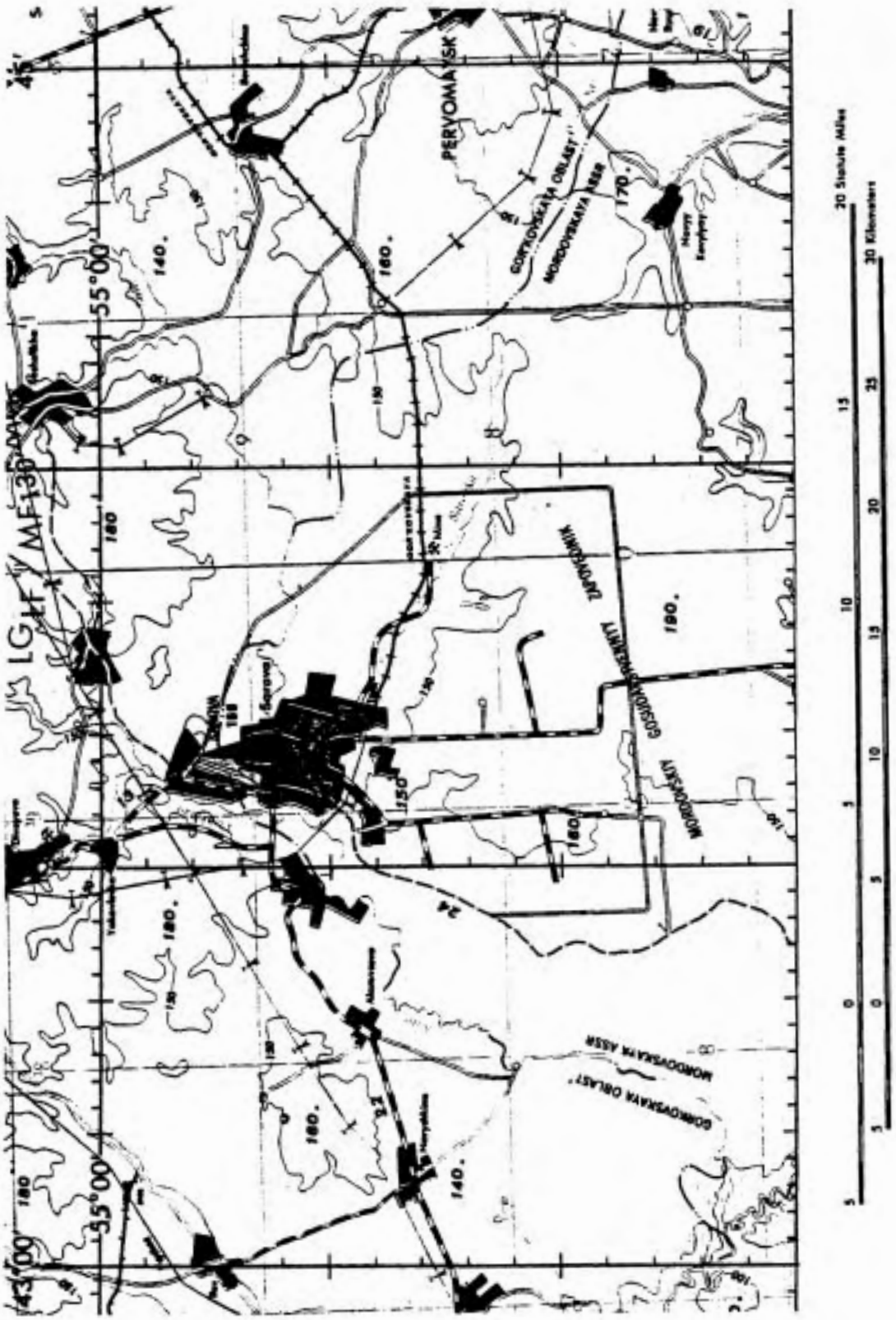


Figure 2
All-Russian Scientific Research Institute of Technical Physics (Chelyabinsk-70)
Between lakes Sinara and Silash, North of Kasli; and
Chelyabinsk-65 at Lake Kyzyltash, East of Kyshtym

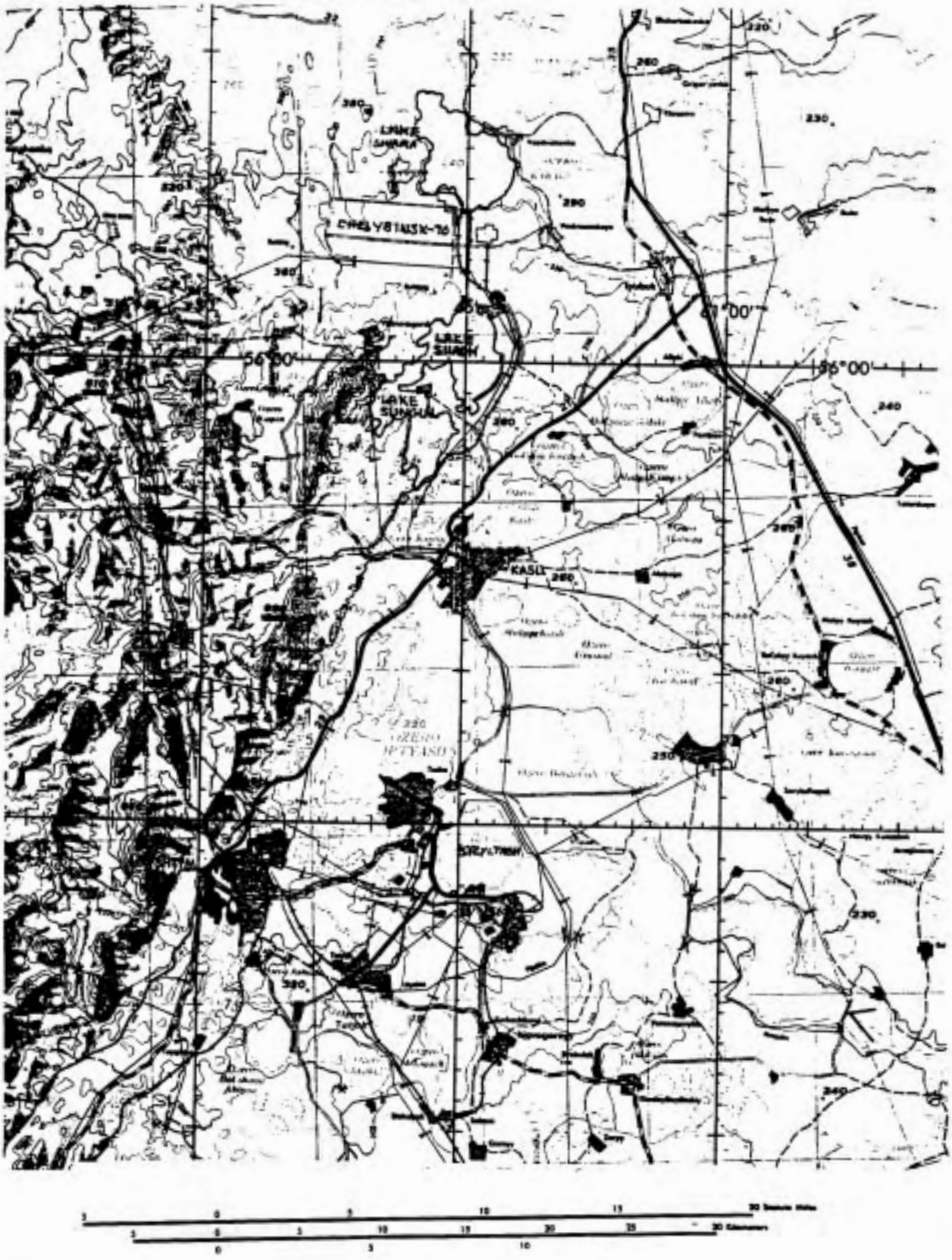
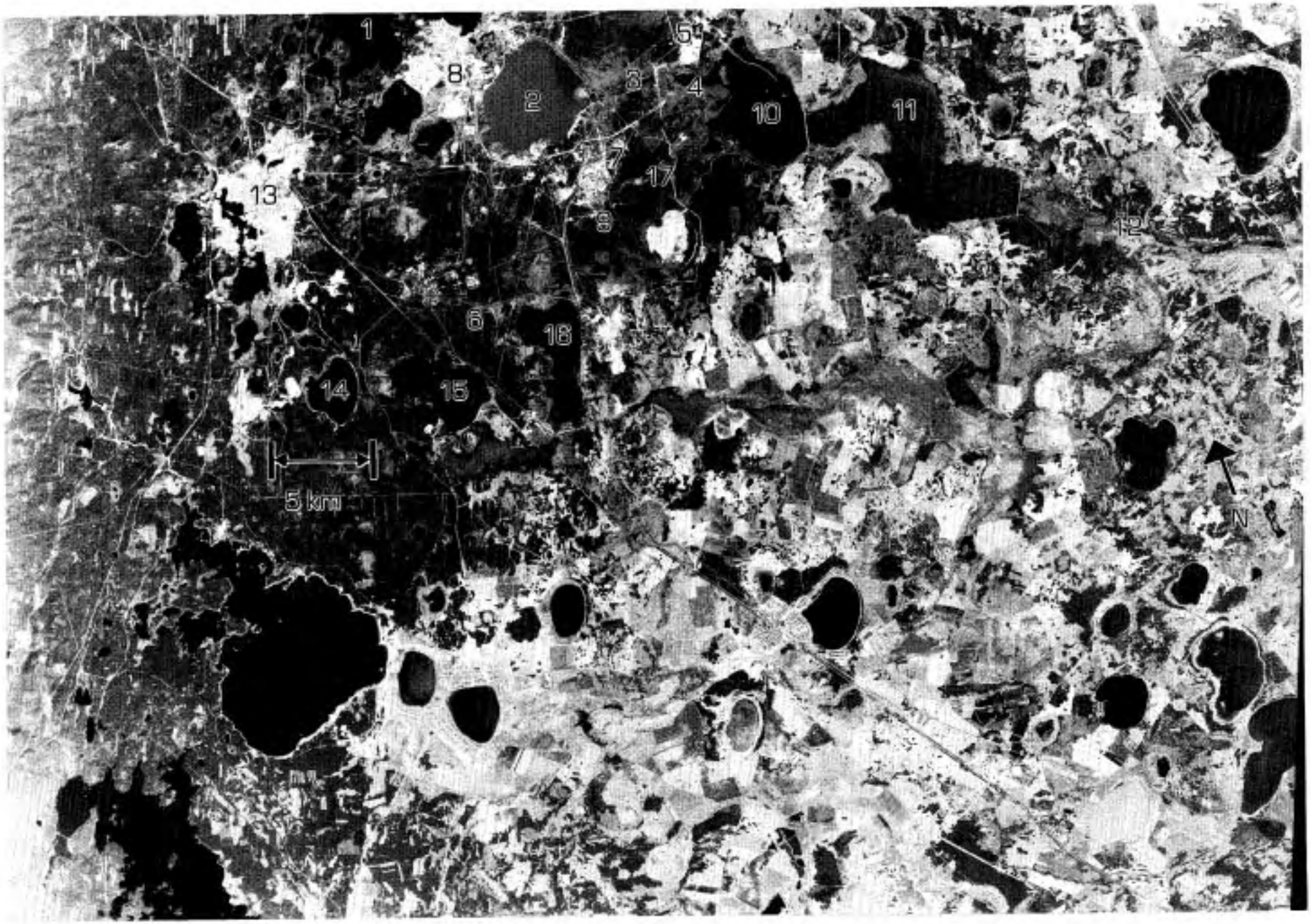


Figure 3
Reservoirs and Lakes at Chelyabinsk-65
(overleaf)

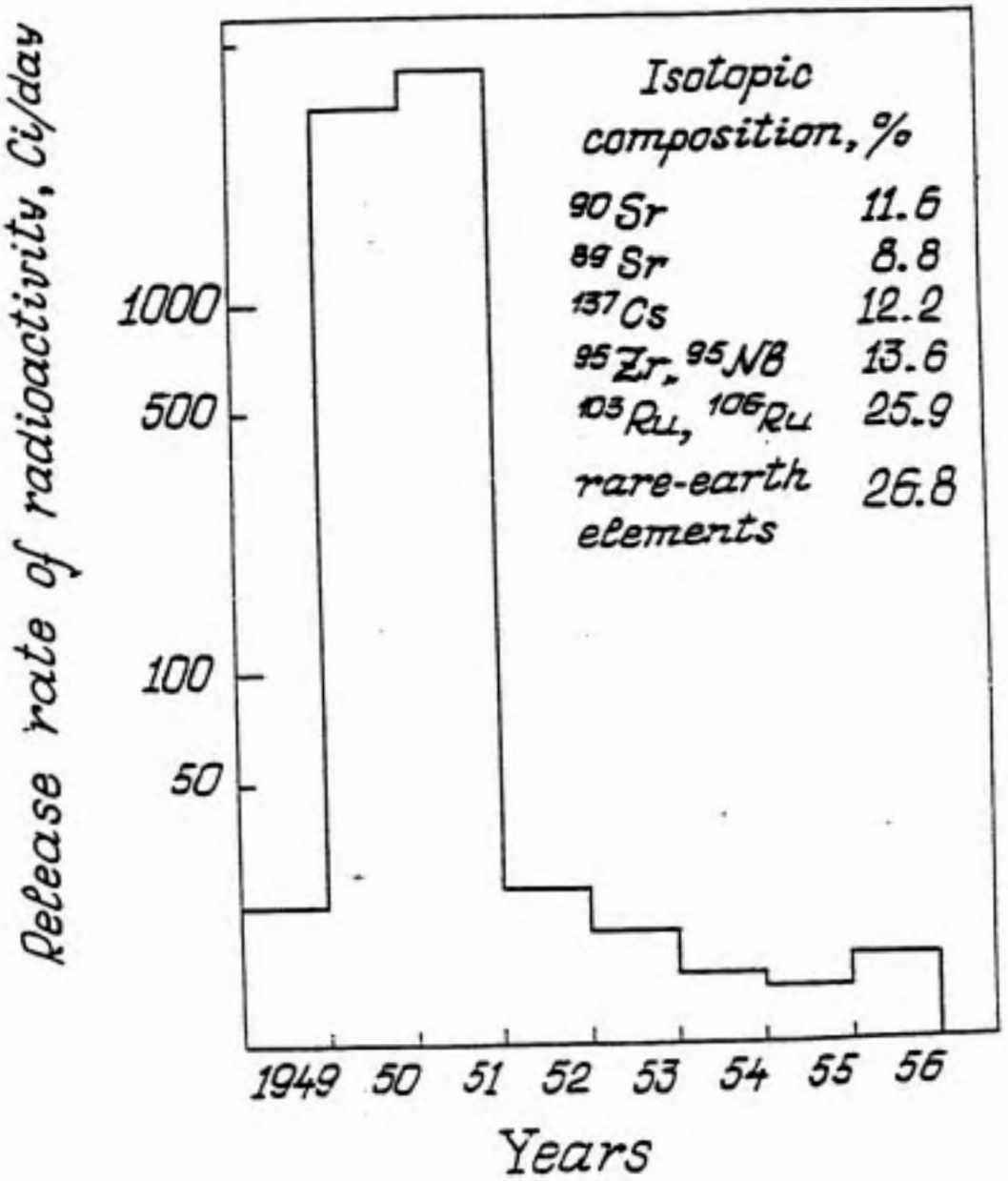
Legend

1. Lake Irtyash (Reservoir Number 1)
2. Lake Kyzyltash (Reservoir Number 2)
3. Reservoir Number 3
4. Reservoir Number 4
5. South Urals Project (Construction of 3 BN-800 reactors)
6. Lake Number 6
7. Chelyabinsk-65 Reactor Area
8. Ozersk (Chelyabinsk-65 Residential Area)
9. Lake Karachay (Reservoir Number 9)
10. Reservoir Number 10
11. Reservoir Number 11
12. Techa River
13. Kyshtym
14. Lake Bol'shaya Akulya
15. Lake Akakul'
16. Lake Ulagach
17. Lake Staroe Boloto (Old Swamp)


1
8
2
3
5
4
10
11
7
17
13
9
12
6
16
14
15
5 km
N

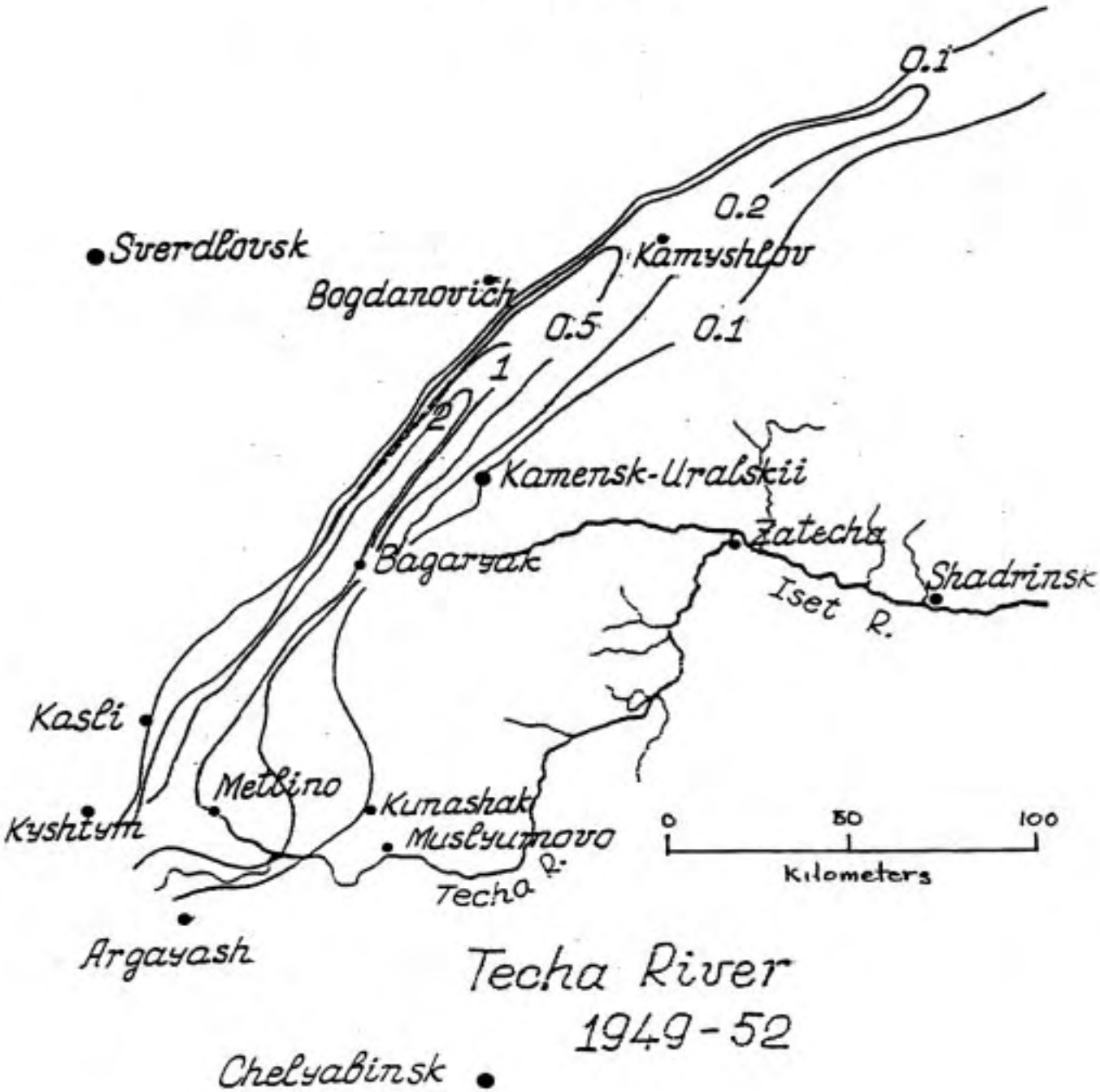

canal
1
2
3
4
10
11
17
9
Techa River
canal

Figure 4
Radioactivity Discharged into the Techa River, 1949-1956[1]



[1] Mira M. Kossenko, Marina O. Degteva, and Nelly A. Petrushova, "Estimate of the Risk of Leukemia to Residents Exposed to Radiation as a Result of a Nuclear Accident in the Southern Urals," *The PSR Quarterly*, Vol. 2, Number 4, December 1992, p. 189.

Figure 5
Radioactive Fallout from the 1957 Accident at Chelyabinsk-65[1]
(contours in Ci/km²)



[1] G.N. Romanov and A.S. Vorovov, "The Radiation Situation After the Explosion," *Priroda*, May 1990, p. 50; also in Mira M. Kossenko, Marina O. Degteva, and Nelly A. Petrushova, "Estimate of the Risk of Leukemia to Residents Exposed to Radiation as a Result of a Nuclear Accident in the Southern Urals," *The FSR Quarterly*, Vol. 2, Number 4, December 1992, p. 168.

Figure 6
Areas in and around Chelyabinsk-65 Contaminated by Cesium-137 (Ci/km²)

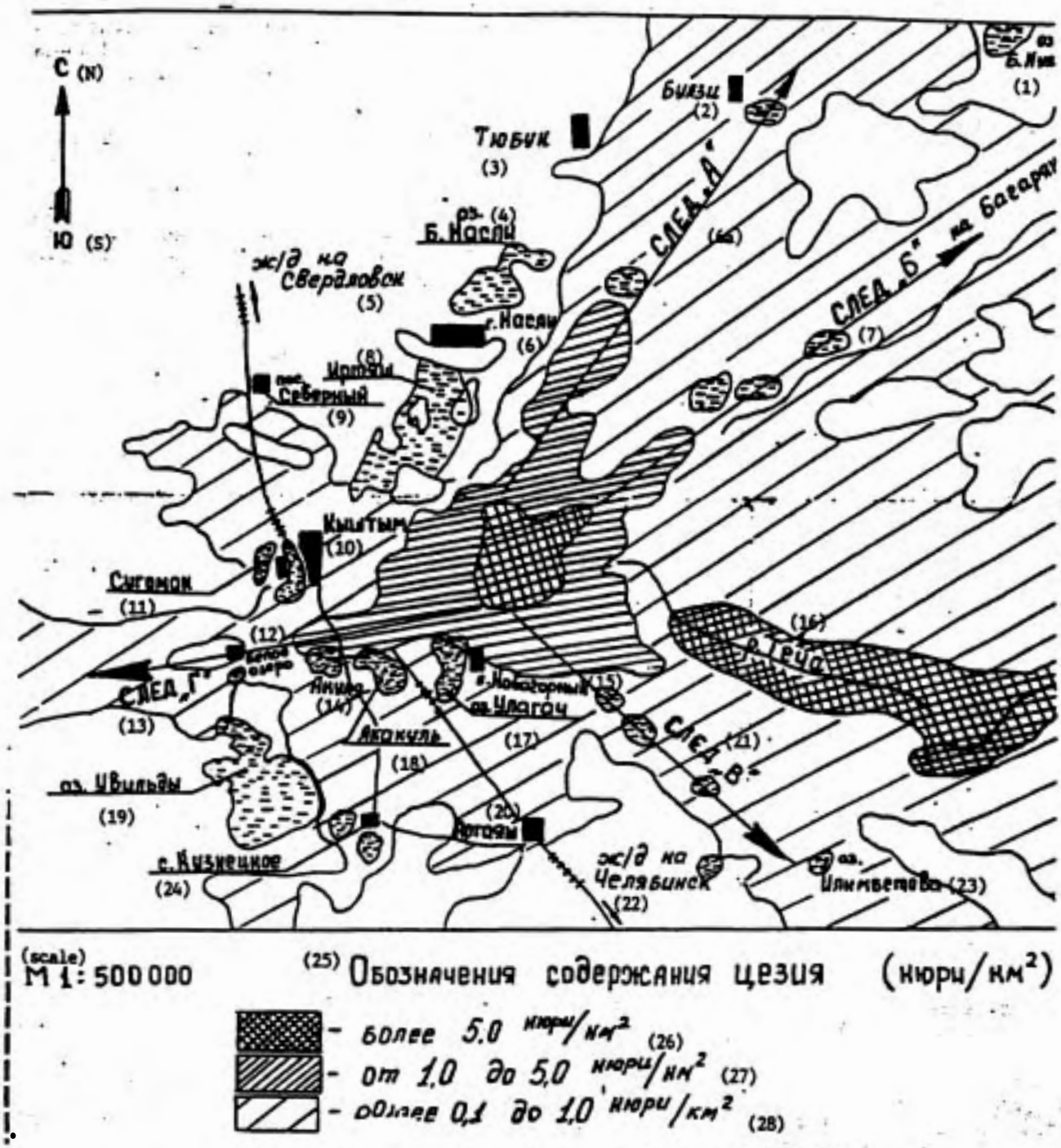


Diagram of Contamination of the Area by Cesium 137 (Ci/km²)

Key: 1. Lake B. Nuya; 2. Bulzi; 3. Tyubuk; 4. Lake B. Nasli; 5. railroad to Sverdlovsk; 6. Nasli; 6a, trail A; 7. trail B to Bagaryak; 8. Irtyash, 9. Severnyy; 10. Kyshtym; 11. Sugomak; 12. Beloye ozero (White Lake); 13. trail D; 14. Akulya; 15. Novogornyy; 16. Techa River; 17. Lake Ulagach; 18. Akakul; 19. Lake Uvildy; 20. Argayash; 21. trail C; 22. railroad to Chelyabinsk; 23. Lake Ilimvetava; 24. Kuznetskoye; 25. cesium content (Ci/km²); 26. more than 5.0 Ci/km²; 27. 1.0 to 5.0 Ci/km²; 28. 0.1 to 1.0 Ci/km²

Appendix 1.
Glossary of Key Figures in the Soviet/Russian Nuclear Program

Adamsky, Viktor B.--Born 1923. A senior member of the Tamm/Sakharov theoretical department at Arzamas-16. Was in charge of what Sakharov calls the "Big Bomb," presumably the 150 megaton device exploded on 30 October 1961, at one-third its yield, and at least three more times during an August through December 1962 series at smaller fractions of its yield.

Aleksandrov, Anatoliy Petrovich--Born 13 February 1903 in Tarashchi near Kiev. Graduated from Kiev University in 1930. Aleksandrov replaced Kapitsa in 1946 as director of the Institute of Physical Problems after Kapitsa refused to participate in the atomic weapons program. He directed it until 1955. Part of the Tamm group. Worked with Kurchatov on development of the first production reactors. Responsible for isotope separation using thermal diffusion. Designer of early graphite production reactors and the later Chernobyl type RBMK reactors. On 15 May 1960 he became director of the I.V. Kurchatov Institute of Atomic Energy. Academician; elected on 23 October 1953; elected President of the Academy of Sciences on 25 November 1975, and served in that capacity until he was replaced by Guriy Marchuk on 16 October 1986.

Alexandrov, Gen. Anatoly Sergeevich--On Beria's staff and later Vannikov's deputy at the First Main Directorate. From 1946 to 1951 he helped administer the bomb program. Was director of Arzamas-16 from 1951 to 1955. According to Sakharov, Alexandrov was fired, ostensibly because of an affair with a woman working in a foreign embassy. The authorities claimed she was a spy, but in fact she was a double agent working for the KGB. The true cause was probably a conflict with Zernov who had been promoted and was Alexandrov's superior.

Alfyorov, Vladimir Ivanovich--Helped prepare first test in 1949. Was director of Arzamas-16 beginning in 1951, possibly after the dismissal of Anatoly S. Alexandrov. Later, was director of the first nuclear warhead production plant, presumably Sverdlovsk-45. Later became director of the 6th Main Directorate (nuclear weapons production) of the MMB and after Zernov died in 1964 became deputy minister. Retired in 1968.

Alikhanov, Abram Isaakovich--Born 5 March 1904 in Tbilisi; died 8 December 1970 in Moscow. Appointed to the weapons program at the suggestion of A.F. Ioffe. In 1949 Alikhanov and his colleagues put into operation the first nuclear reactor with a heavy-water moderator in the USSR. Director of the Thermodynamic Laboratory, 1945-1968. Principal constructor of the Serpukhov high energy accelerator. Academician; elected full member in 1943.

Altshuler, Lev Vladimirovich--Born 1913. Experimental physicist at Arzamas-16 from 1947. Co-authored a report in 1949 that provided the experimental basis and calculations for a more efficient design that would be tested in 1951 as "Joe 2" and "Joe 3."

Antropov, Pyotr Yakovlevich--A former Minister of Geology, Antropov was made the head of the Second Main Directorate, a special "semi-ministry" (like the First) of the Council of Ministers in 1946 to oversee the extraction and enrichment of uranium.

Artsimovich, Lev Andreyevich--Born 25 February 1909 in Moscow; died 1 March 1973. Graduated from Belorussian University, 1928. From 1930-1944 worked at the Physicotechnical Institute. From 1944 worked at the Institute of Atomic Energy. Responsible for isotope separation using electromagnetic separation. Leader of pioneering work on thermonuclear physics. Academician; elected 23 October 1953. Awarded Hero of Socialist Labor, 1969; Lenin Prize 1958; State Prizes 1953 and 1971.

Averin, Alexander Nikitovich--Born in 1946, Averin was graduated from the Moscow Physical-Technical Institute in 1970, and has worked at Chelyabinsk-70 for the last 22 years. He holds a doctorate in Science and is deputy head of the Explosion Physics Department. His fields of expertise include: the properties of matter under high pressure and high-speed dynamic processes, such as impacts, phase transitions, cumulation, explosive techniques and technologies.

Avrorin, Yevgeniy Nikolaevich--Born 11 July 1932; graduated from Moscow State university in 1954; worked at Arzamas-16 from March-August 1955. Since its establishment in 1955, Avrorin has worked at Chelyabinsk-70, where he is currently the Scientific Director. Elected corresponding member of the General Physics and Astronomy Department, Academy of Sciences, 23 December 1987. Theoretical physics with interests in the fields of physical processes under high pressures and temperatures, nuclear and neutron physics, inertial confinement fusion, and disarmament.

Babayev, Yuri Nikolayevich--Born 21 May 1928; died 6 October 1986. Graduated from Moscow University in 1950 at the age of 22, went to work for at Arzamas-16 in 1951 and worked on the nuclear weapons program. Was a junior member of a team that was secretly awarded the Stalin Prize in 1953. In 1959 was given Lenin Prize, in 1962 Hero of Socialist Labor. In 1962 was given rank of senior research worker at an unidentified institute. The official obituary published in *Izvestia*, identified him as a"major scientist, an outstanding specialist in the field of nuclear physics and atomic technology."

Barulin, Anatoly Yegorovich--Born in 1936 and graduated from the Moscow Physical Engineering Institute in 1960, Barulin has a doctorate in Science. He has worked at Chelyabinsk-70 since 1960 and is the Chief Designer of the Institute (for fiber optics). His experience includes work in the fields of fiber-optic networks, technology and equipment for fiber production, control systems, cyrogenic machines, and laser thermonuclear experiments.

Belugin, Vladimir Aleksandrovich--Born 30 March 1931 in Leningrad (now St. Petersburg). Director (1993) of Arzamas-16.

Beria, Lavrenti Pavlovich--Born 29 March 1899, Merkheuli, near Sukhumi in Georgia; died 23 December 1953, Moscow. Brought to Moscow in 1934 as deputy to Nikolay Yezhov, the head of the People's Commissariat for Internal Affairs (NKVD; Soviet secret police). Yezhov was shot and Beria became head of the secret police, retaining the position from 1938 to 1953. In 1941 he became deputy prime minister of the USSR, and during World War II, he was a member of the State Defense Committee. He was made a marshall of the USSR in 1945. He was also a member of the Central Committee of the Communist Party from 1934, and of the executive policy-making committee, the Politburo from 1946. Beria was director of atomic bomb program from 1943 to 1953. Some of his assistants that oversaw the atomic bomb program were: Nikolai I. Pavlov, Lt. Gen. Osetrov, Pavel Yakovlevich Meshik, Col. Valery Evstafievich Rukavitsyn, Col. Vasily Ivanovich Detnyov, and Gen. V.A. Makhnev.

Bochvar, Andrei Anatol'yevich--1902-1984. Member of the Academy of Sciences in 1946, Lenin Prize in 1961, State (Stalin) prizes in 1941, 1949, 1951, and 1953. Headed a department at Chelyabinsk-40 (now Chelyabinsk-65), responsible for processing plutonium and fabricating the sub-critical fissile masses for a bomb. Director of the All-Union Scientific Institute of Organic Materials.

Bogolyubov, Nikolay Nikolayevich--Born 21 August 1909. Mathematician and theoretical physicist. Part of the Tamm group. Leading scientist at Arzamas-16. Former Academician Secretary of the Mathematics Department, from July 1963. Academician; elected to the Physical Mathematical Sciences Department (now Nuclear Physics Department) of the Academy of Sciences 23 October 1953. Former Director of the Joint Institute for Nuclear Research in Dubna, from 1965.

Bolyatko, Viktor Anisimovich--born 1906, and joined the CPSU in 1929. He was killed in an automobile accident in 1965 when he was chief of a Main Administration (probably the 12th) of the Ministry of Defense. The only industrial minister to sign his obituary was Ye.P. Slavsky.

Boychuk, Yefim Vasilevskiy--1918-1991. Chief of the 12th Main Administration, 1974 to 1985.

Brish, Arkady Adamovich--A chief designer at Arzamas-16

Brokhovich, Boris V.--Among the first 300 people to arrive at Chelyabinsk-40 (now Chelyabinsk-65) in 1946. Electrical Engineer; Chief Engineer at the 501-Reactor, 24 May 1952--1 July 1954; Director of Plant 156 (three reactor complex) 12 July 1963--18 May 1971; Director of Chelyabinsk-65 (formerly Chelyabinsk-40) 1971--ca. 1991. Hero of Socialist Labor; Lenin Prize, 1960; State Prize laureate, 1954.

Chernyshev, Alexander K.--Born 23 October 1945. In 1992 Deputy scientific director of Arzamas-16.

Davidenko, V.--Part of the design team at Arzamas-16, responsible for the development of the neutron generator.

Dmitriev, Nikolai Alexandrovich--Born 1924. Mathematician; disciple of Academician Kolmogorov. Colleague of Sakharov's at Arzamas-16. Did calculations on the "Third Idea." Child prodigy.

Dudochkin, Yevgeniy Konstantinovich--Born 8 June 1940. Senior official with Fifth Department, under Gorobets, responsible for nuclear warhead production facilities (warhead assembly, fissile material storage, etc.) within the Department of Defense Industry, Ministry of Atomic Energy.

Dollezhal', Nikolai Antonovich--Born 27 October 1899. Head designer of the first atomic reactor. A chief designer of naval reactors. Academician, 1962. Member of the Physical Technical Problems of Power Engineering Department, and the Mechanics and Control Processes Department. Stalin Prize, 1952; Lenin Prize, 1957.

Drozhko, Yevgeny Gordeevich--Candidate of Technical Sciences and Chief Engineer at Chelyabinsk-40 (now Chelyabinsk-65) in 1989.

Dukhov, Lt. Gen. Nikolai Leonidovich--Born 26 October 1904; died 1 May 1964 (of leukemia). Was drafted in July 1948 into the atom bomb program and was the right hand man on the engineering side to Kurchatov. Deputy head of the scientific effort at Arzamas-16. In 1932-1948 he was chief designer at the Kirov plant in Leningrad, where during World War II he designed the Stalin tank. In early 1954 he was moved to the ICBM program where he headed a design bureau. Three times a Hero of Socialist Labor in 1945, 1949 and 1954; Lenin Prize in 1960.

Dzekun, Yevgeniy G.--Chief Engineer of the Radiochemical Plant, "Mayak" Production Association (Chelyabinsk-65) in 1991.

Faykov, Yuriy Ivanovich--First deputy chief designer at Arzamas-16 in 1992; doctor of technical sciences.

Fedorov, Ye.--1910-1981. According to 3 May 1990 *Izvestiya* he once worked at the test site in Novaya Zemlya. Academician, Chief Scientific Secretary of the Academy of Sciences.

Feoktistov, Lev Petrovich--Physicist-theoretician. Part of the Tamm group. From 1955 to 1973 was in charge of a department, then a division and finally became deputy scientific director at Chelyabinsh-70. From 1973 to 1990 worked at the Kurchatov Institute of Atomic Energy (IAE)

Feoktistova, Ekaterina Alekseevna--Born c. 1920. A colleague of Sakharov's. Since September 1947 worked in A.F. Belyaev's laboratory. Sent to work at Chelyabinsk-70 in 1955 and was put in charge of a laboratory studying high explosives.

Fetisov, Victor Ilich--In 1990 was Deputy Director of the Mayak Production Association (Chelyabinsk-65).

Fishman, David Abramovich--Head of the design department at Arzamas-16 in the period around 1961

Flerov, Georgii Nikolaevich--Born 2 March 1913 in Rostov-on-Don. Died 19 November 1990. From 1938-1941 was on the staff of the Physicotechnical Institute. From 1941-1943 was in Soviet Army. From 1943-1960 on staff of Institute of Atomic Energy. Worked at Arzamas-16. In 1960 made director of Nuclear Reactions Laboratory of the Joint Institute for Nuclear Research in Dubna, after having worked there since 1953. In 1940 Flerov together with L.I. Rusinov showed that more than two neutrons are emitted during the fission of a uranium nucleus. In the same year together with K.A. Petrzhak, Flerov discovered the spontaneous fission of heavy nuclei. Noticed articles on nuclear energy had disappeared from American, British, and German publications in the early 1940s. As a consequence he wrote letter to Stalin in April 1942 alerting him to the urgency of solving the "uranium problem." This prompted renewed interest by the Soviets in developing an atomic bomb. From 1960 to 1988 he was director of the Laboratory of Nuclear Reactiopns (now the Flerov Laboratory of Nuclear Reactions) at the Joint Institute for Nuclear Research.

Frank-Kamenetskiy, David Albertovich--A leading theoretical physicist at Arzamas-16, arriving there in 1946. Associate of Zeldovich. Left Arzamas in 1956 to work at LIPAN (Kurchatov Institute).

Fuchs, Klaus--born 29 December 1911, died 28 January 1988. A German-born physicist in the U.S. fission and fusion weapons program at Los Alamos who was convicted of being a Soviet spy. Emigrated first to Britain and then went to Los Alamos during World War II. After the war he returned to Britain and worked at Harwell, a nuclear research center near Oxford. From 1941 on he carried out espionage for the Soviet Union until his arrest in February 1950. He served nine years of a 14-year sentence and returned to East Germany where he resumed a scientific career.

Fursov, V.--Assistant to Kurchatov who helped with the design of the F-1 pile and who helped oversee the construction of Chelyabinsk-40 as Kurchatov's main representative.

Gavrilov, Viktor Yulianovich--born c. 1920; died early 1970s. Colleague of Sakharov's at Arzamas-16. Later became a molecular biologist. Headed radiobiological department.

Gerasimov, Vladimir Ivanovich--Successor to Ye.V. Boychuk as Chief of the 12th Main Administration, 1985-1992.

Ginzburg, Vitaly Lazarevich--Born 4 October 1916. Graduated from Moscow University in 1938. First to propose the use of lithium deuteride in thermonuclear weapons; Sakharov said that "The first two ideas [about the H-bomb] were those proposed by Vitaly Ginzburg and myself in 1948." Member of the Department of Theoretical Physics of the P.N. Lebedev Institute of Physics of the Soviet Academy of Sciences (FIAN). Part of the Tamm group; became department head when Tamm died on 12 April 1971. Academician; elected to General Physics and Astronomy Department of the Academy of Sciences on 1 July 1966. Also a member of the Nuclear Physics Department.

Gorobets, Boris Valentinovich--Currently (1993) Chief of Sixth Department, Nuclear Weapons Production, Department of Defense Industries, Ministry of Atomic Energy.

Grechishnikov, Vladimir Fyodorovich--one of the first weapon designers. Died at the age of 41 while deputy chief designer of Chelyabinsk-70. Was responsible for the design of the lenses of the first bomb. Hero of Socialist Labor.

Gurevich, Isaak Izrailevich--Born 13 July 1912 in Riga. Graduated from Leningrad University in 1934. From 1934-1945 worked at the Radium Institute. In 1941, with Zeldovich and Khariton, determined the critical mass of U-235. Since 1945 at the I.V. Kurchatov Institute of Atomic Energy. Corresponding Member of the Academy of Sciences, 1968. Main work in neutron physics, reactor theory and the properties of muonium.

Ioffe, Abram Fedorovich--Born 29 October 1980; died 14 October 1960. Graduated Munich University, 1905. Founder and Director of the Physics Institute of the Soviet Academy of Sciences (FIAN)in 1918. Recommended I.V. Kurchatov as the man to head the Soviet Union's atomic bomb development program.

Ivanov, Vitaliy Mikhailovich--Senior official of the Fifth Department, Nuclear Weapons Development and Testing, Department of Defense Industry, Ministry of Atomic Energy.

Izrael, Yuriy Antoniyevich--Born 15 May 1930. According to 3 May 1990 *Izvestiya,* he once worked at the test site in Novaya Zemlya. Elected corresponding member of the Oceanology, Atmospheric Physics and Geography Department, Academy of Sciences on 26 November 1974.

Izraileva, Revekka--Born c. 1920. Mathematician. Colleague of Sakharov's at Arzamas-16.

Kapitsa, Petr Leonidovich--1894-1984. Born Kronstadt. Studied and worked at Cambridge University, 1921-1934. Academician, 1939. In 1945 refused to work on the atomic bomb program because of differences with Beria.

Keldysh, Mstislav Vsevolodovich--Born 10 February 1911 in Riga; died 1978. Academician in 1946; President of the Academy of Sciences, 1961-1975, replacing A.N. Nesmeyanov.

Khandorin, G.--Director of the Siberian Chemical Combine (Tomsk-7) since at least 1990.

Khariton, Yuliy Borisovich--Born 27 February 1904 in St. Petersburg. Graduated from the Leningrad Polytechnic Institute in 1925. From 1926-1928 studied at the Cavendish Laboratory in England under Rutherford and received a PhD. In 1939, with Y. B. Zeldovich, was the first to calculate the chain reaction of uranium fission. Part of the Tamm group. Scientific director of Arzamas-16 from its foundaing in 1946, until 1992. With Sakharov and Zeldovich one of the three principal developers of the Soviet hydrogen bomb. Elected a member of the Nuclear Physics Department, Academy of Sciences

on 23 October 1953. Awarded the title of Hero of Socialist Labor in 1949, 1953, and 1956.

Khlopin, V.G.--1890-1950. Director of the Radium Institute in Leningrad from 1939. First scientific director of Chelyabinsk-40 (now Chelyabinsk-65). Hero of Socialist Labor, 1949; State Prizes 1943, 1946, and 1949.

Kikoin, Isaak Konstantinovich--Born 28 March 1908 in Malye Zhagory; died December 1984. In 1943 worked at the Kurchatov Institute of Atomic Energy. Responsible for isotope separation using gaseous diffusion. He was head of the isotope enrichment department and involved in uranium enrichment in the Urals. Hero of Socialist Labor 1951. Elected a member of the Academy of Sciences 23 October 1953.

Koblov, Petr Ivanovich--In 1991 a deputy chief designer at Chelyabinsk-70.

Komarovskiy, Aleksandr Nikolaevich--1906-1973. State Security official, graduated from the Moscow Institute of Transport Engineering, 1928. In 1930s directed construction of the Moscow-Volga canal. Chief of the Construction Department of the NKVD. During World War II in charge of military construction resources of the Ministry of Defence. Hero of Socialist Labour, 1949.

Komelkov, V.--Head of the department at Arzamas-16 responsible for producing kryton triggering devices.

Konovalov, Vitaliy Fedorovich--Born 1932. Minister of the Ministry of Atomic Power and Industry (now the Ministry of Atomic Energy (formerly the Ministry of Medium Machine Building) until August 1991; First Deputy Minister of Atomic Energy, March 1992-present.

Kozlov, Boris Isakovich--A colleague of Sakharov's at Arzamas-16. Designed the device exploded on 27 September 1962. Acting Director of Caspian Mining and Metallurgical Complex (PGMK) ore administration, responsible for mining and refining of uranium ore; a defense plant under the MMB, 1989- .

Kryuchenkov, Vladimir Borisovich--Kryuchenkov was born in 1948 and was graduated from the Moscow Physical Engineering Institute in 1972 with a doctorate in Science. In 1972, Kryuchenkov joined Chelyabinsk-70 and is currently head of the Experimental Physics Department. Kryuchenkov is an expert in diagnostics of dense high-temperature plasma, laser-plasma soft x-ray sources, plasma spectroscopy, and laser fusion.

Kurchatov, Igor Vasilyevich--Born 12 January 1903 in Sim (now in Asha Region, Chelyabinsk Oblast); died 7 February 1960 in Moscow. The son of a surveyor Kurchatov graduated in 1923 from Crimean University in physics and math. In 1925 he began at the Physicotechnical Institute under A. F. Ioffe. He was head of the Soviet nuclear weapons program. In 1943 he founded and was head of what later became known as the Institute of Atomic Energy. Since 1960 it has been known as the Kurchatov Institute of Atomic Energy. He is buried at the Kremlin Wall. The 104th element, Kurchatovium is named for him, though there is a competing claim that the element should be called Rutherfordium. Awarded the title of Hero of Socialist Labor three times, in 1949, 1953, and 1954.

Lavrentyev, Mikhail Alekseyevich--Born 1900; died 1980. A leading theoretical physicist at Arzamas-16, arriving there in 1946. Academician (1946), vice president of the Academy of Sciences, 1957-1975, and a leading organizer of the Academy's Siberian branch. Close scientific adviser to Khrushchev. Created the science city at Novosibirsk.

Lebedev, Valeriy Aleksandrovich--born 1941, Director of the Mining and Chemical Combine (Krasnoyarsk-26) beginning in 1989 - to date.

Ledenyov, Boris Nikolaevich--From 1955 was head of gas-dynamics division at Arzamas-16. From 1959 to 1961 was chief designer at Chelyabinsk-70, and from 1961 to 1964 was Director.

Litvinov, Boris Vasilyevich--Born 12 November 1929 in Voroshilovgrad, Ukraine. The current first deputy scientific leader of Chelyabinsk-70. Chief Designer of the institute; professor; member of the Russian Academy of Sciences; graduated in 1953 from the Moscow Institute of Engineering and Physics.

Lominskiy, Georgii Pavlovich--Born 1918; died 1988. Lt.-Gen. of aviation. From July 1948 to 1951 was in charge of test areas of Arzamas16. From 1951 tp 1955 he was head of the safety department. From 1955 to 1961 he was a deputy director of Chelyabinsk-70 on general issues and from 1961 to 1964 was chief engineer. From 1963 to 1986 he was director of Chelyabinsk-70.

Malenkov, Georgii Maksimil'ianovich--8 January 1902-23 January 1988. Member of the State Defence Committee, 1941-1945. Deputy Prime Minister, 1946. Prime Minister March 1953 to February 1955. Lost to Khrushchev in power struggle.

Mal'sky, Anatoly Yakovlevich--central participant in the 1949 and 1951 atomic tests. From 1953 was a director of the nuclear warhead prodcution

facility at Arzamas-16. Soon after was promoted to chief engineer at the Sverdlovsk-45 warhead prodcution facility, and in 1955 became the director.

Malyshev, Vyacheslav Aleksandrovich--Born 16 December 1902 in Ust'-Sysol'sk, now Syktykar; died 20 February 1957 in Moscow. Wartime head of Soviet tank production program. Vice-chairman of the Council of People's Commissars, 1940-1944. As Minister of Ministry of Medium Machine Building from June 1953-1955, assumed responsibility for the nuclear weapons program from Beria following Stalin's death. Buried at the Kremlin Wall.

Matveyev, Sergei Nikolaevich--Since September 1947 deputy head of test preparartions. From 1953 to his retirement he was head of the department.

Meshcheryakov, Mikhail Grigoryevich--Born 4 September 1910. Graduated Leningrad University. Radium Institute, 1937-1947. Deputy Director of Institute of Atomic Energy, 1947-1948. Deputy head of the first Main Directorate, helped administer activities at Arzamas-16 from 1946 to 1953. Became member of the USSR Academy of Sciences, 1953; Professor, Moscow University, 1954, Joint Institute of Nuclear Research, Dubna. Two State Prizes (1951, 1953). Three Orders of Lenin.

Mikhailov, Victor Nikitovich--Born 1934. Graduated with distinction from the Moscow Engineering Physics Institute. Graduate student in theoretical physics under Academician Ya. B. Zeldovich at Arzamas-16. Director of the Institute of Impulse Technology. Deputy Director, Ministry of Atomic Power and Industry (formerly the Ministry of Medium Machine Building) until March 1992, when he was promoted to Minister of Atomic Energy. Had himself appointed Scientific Director of Arzamas-16 in 1992.

Mikerin, Yevgeniy Ilich--Currently, and prior to 1989, Head of Fourth Department, Isotope Separation, Reprocessing, and Production Technology, Ministry of Atomic Energy (and formerly Ministry of Atomic Power and Industry); in charge of isotope production (production reactors and uranium enrichment), chemical separation, nuclear waste management, and plutonium and uranium componemt manufacturing - activities conducted at Chelyabinsk-65, Tomsk-7, and Krasnoyarsk-26.

Molotov, Viacheslav Mikhailovich--9 March 1890-November 1986. Became Stalin's most trusted and faithful aide. Prime Minister, 1930-1941, Minister of Foreign Affairs, 1941-1949, 1953-1957. A Politburo and GKO member, supervised the early stages of the atomic bomb program, but lost control of the program to Beria in 1945.

Morozov, Igor Pavlovich--Born in 1939 and graduated from Kharkov Polytechnic Institute in 1961 with a degree in mechanical engineering, Morozov is the Deputy Chief Engineer of the Mining and Chemical Combine (Krasnoyarsk-26). He holds a doctorate in Science and his fields of expertise include: development of test systems, automatization of production processes, management of developments.

Muzrukov, Boris Glebovich--Born 1904; died 1979. Defense industry official. Combine (Chelyabinsk-40) director during its construction in 1946 and until 1955; director of Arzamas-16 from 1955 to 1974. Awarded the title of Hero of Socialist Labor twice, in 1943 and 1949; Lenin Prize in 1962. Sakharov calls him "one of the great captains of industry."

Nechai, Vladimir Zinovyevich--Born 5 May 1936 in Alma Ata, Kazakh. Nuclear weapons R&D work since about 1960. Director General of Chelyabinsk-70 since 1986.

Negin, Yevgeniy Arkad'yevich--Born 1921. From 1955 was deputy scientific director at Arzamas-16, and since 1958 chief warhead designer. Lt. General and Academician with the Mechanics and Control Processes Department, since 15 March 1979. Working at Arzamas-16 by 1949, though worked in group with E.I. Zababakhin since August 1947. He witnessed his first nuclear test in 1953, and attended virtually all subsequent nuclear tests by Arzamas-16 afterwards, and was scientific leader at about half of them. Hero of Socialist Labor.

Nekrutkin, V.M.--designer of smaller diameter implosion device ("Joe 2").

Nikipelov, Boris V.--Born 2 August 1931. Worked at Mayak Chemical Combine (Chelyabinsk-65; formerly Chelyabinsk-40) from 1955 to about 1985; Chief Engineer. First Deputy Director, Ministry of Atomic Energy and Industry (formerly Ministry of Medium Machine Building, and now Ministry of Atomic Energy) until March 1992. Advisor to the Minister of Atomic Energy for international relations, chemical separation, and nuclear waste management March 1992 to present.

Nikitin, Boris Alekandrovich--Worked with Kurchatov during the early weapon development period. Engineer responsible for developing the technology to extract plutonium from the F-1 pile. Corresponding member of the Academy of Sciences.

Nikitin, Vladislav I.--In 1991-1992 the deputy director of Chelyabinsk-70.

Nikolskii, Boris Petrovich--Born 1900; died 1990. Worked with Kurchatov during the early weapon development period. Full member of the Academy of Sciences.

Novikov, S.A.--A leading scientist at Arzamas-16.

Ovsyannikov, L.V.--A leading scientist at Arzamas-16.

Pavlov, Nikolai Ivanovich--Born c. 1917; died ? Appointed in 1943 representative of the Central Committee and Council of Ministers at Laboratory No. 2 (subsequently the Kurchatov Institute of Atomic Energy). Served as Chairman of the State Testing Commission for nuclear weapons in the late 1950s. Guided work at Arzamas-16 from 1946 to 1953. In 1951 became deputy chief of the First Main Directorate and in 1953 became chief of the 5th Main Directorate of MMB.

Pavlovskiy, Aleksandr Ivanovich--Born 27 June 1927. Died 12 February 1993. Physicist. After graduating from Kharkov University in 1951, went to work at Arzamas-16 the same year and worked in G.N. Flerov's group. Was a protegé of Sakharov. Just prior to his death he was Deputy Chief Scientist and Head of the Fundamental and Applied Physics Department at Arzamas-16.

Pervukhin, Mikhail Georgiyevich--Born 1904. During the War Deputy Chairman of the Council of People's Commissars. Minister of Chemical Industry in the early 1950s and First Deputy Chairman of the Council of Ministers from 1955 to 1957. Minister of Medium Machine Building, May-July 24, 1957. Ambassador to German Democratic Republic, 1958-1962.

Petrosyants, Andronik Melkonovich--born 1906. Was an official with the Ministry of Medium Machine Building, 1955-1962. Chairman of the State Committee for the Use of Atomic Energy. Headed the investigation team that examined the Chernobyl disaster.

Petrzhak, Konstantin A.--In 1940 with G.N. Flerov discovered the spontaneous fission of uranium.

Pishchepov, Aleksandr Ivanovich--In 1990 was Deputy Director for Procedures at the Mayak Production Association (Chelyabinsk-65).

Pomeranchuk, Isaak Iakovlevich--Born 20 May 1913 in Warsaw, died 14 December 1966 in Moscow. Graduated from the Leningrad Polytechnic Institute in 1936. From 1940-1943 worked at the Institute of Physics and from 1943-1946 at the Institute of Atomic Energy. In 1946 he joined the staff of the

Institute of Theoretical and Experimental Physics and also became a professor at the Moscow Physical Engineering Institute. Made an important contribution to the theory and development of the first nuclear reactors in the USSR. Corresponding Member of the Academy of Sciences, 1953; Academician, 1964. Awarded: State Prize, 1950, 1952; Order of Lenin; Lenin Prize

Romanov, Gennady N.--Chief of Experimental Research Station, "Mayak" Production Association (Chelyabinsk-65) in 1991.

Romanov, Yuri Alexandrovich--Born 1926. Theoretical physicist. A colleague of Sakharov's from 1948 to 1955. First worked at Arzamas-16, arriving there in 1950 with Sakharov; then in 1955 was sent to work at Chelyabinsk-70. Since 1970 was in charge of the theoretical division at Chelyabinsk-70. Hero of Socialist Labor.

Ryabev, Lev Dmitriyevich--Born 1928. In 1957 he graduated from the Moscow Engineering and Physics Institute. Was deputy chief engineer, deputy director, and director of a Gorky-area scientific research institute of the Ministry of Medium Machine Building. From 1984 he was deputy and from June 1986 first deputy of the Ministry. At the end of 1986 he was appointed Minister of Medium Machine Building. Currently he is Principal Advisor to the Minister.

Sadovskiy, Mikhail Aleksandrovich--Born 6 November 1904. In 1949 he was deputy director of the Institute of Chemical Physics and responsible for the nuclear test site at Semipalatinsk. According to 3 May 1990 *Izvestiya,* he once worked at the test site in Novaya Zemlya. Director of the Institute of Physics of the Earth until he retired about 1988. Academician; elected member of the Geology, Geophysics, Geochemistry, and Mining Sciences Department of the Academy of Sciences in 1 July 1966.

Sakharov, Andrei Dmitriyevich--Born 21 May 1921; died 14 December 1989. Worked at Arzamas-16 from March 1950 until his clearance was revoked in July 1968. He departed Arzamas-16 on 14 September 1969. With Khariton and Zeldovich one of the three principal developers of the Soviet hydrogen bomb, responsible for the "First" and "Third Idea." Became Academician in the Physical and Mathematical Sciences Department on 23 October 1953. After Tamm's departure in 1954, became the head of the second theory department at Arzamas-16. Awarded the title of Hero of Socialist Labor three times (1953, 1956, and 1962), and won the Lenin Prize, the USSR State Prize, and the 1975 Nobel Prize for Peace.

Sazhnov, Vladimir K.--Director of Radiochemical Plant, "Mayak" Production Association (Chelyabinsk-65) in 1991.

Semenov, Nikolai Nikolayevich--Born 15 April 1896; died 1986. Born in Saratov, graduated from Petrograd University in 1917. From 1920-1931 worked at Leningrad Physicotechnical Institute. Corresponding Member of the Academy of Sciences, 1929; Academician, 1932. In 1931 became Director of the Institute of Chemical Physics. Was responsible for the "polygon" (the nuclear test site) at Semipalatinsk in 1949, when the Soviets tested their first atomic device. Vice President of the Academy of Sciences 1963-1971. Shared Nobel Prize in Chemistry (1956) with Sir Cyril Hinselwood for parallel research on chemical reaction kinetics. Awarded: Hero of Socialist Labor, 1966; seven Orders of Lenin; State Prize, 1941, 1949; Order of the Red Banner of Labor.

Semyonov, Nikolai Anatol'evich--Born 1918; died 28 January 1982. First Deputy Minister of Medium Machine Building from 1971 to his death. He joined the nuclear weapon program in 1948 and rose to become director of a the Mayak Combine (Chelyabinsk-40/65) before his transfer to the MMB in 1971. Received Hero of Socialist Labor, Lenin Prize, State Prize.

Sen'kin, Aleksandr Nikolaevich--One of the current Chief Designers at Chelyabinsk-70.

Shchelkin, Kirill Ivanovich--Born 17 May 1911; died 8 November 1968. Graduated from the Crimean Pedagogical Institute in Simferopol in 1932. Main works were devoted to the physics of combustion and explosion. From March 1947 was Khariton's deputy at Arzamas-16. Head of a department at Arzamas-16 responsible for the development of explosive shaped charges. Previously at the Institute of Chemical Physics. Served as the first scientific director of Chelyabinsk-70 from 1955 at its founding, until 1960. Corresponding member of the Academy of Sciences. Three times a Hero of Socialist Labor, in 1949, 1953, and 1956.

Simonenko, Vadim Aleksandrovich--Born 8 November 1939. Graduated in 1962 from Moscow Engineering Physical Institute; Head of Theoretical physics department at Chelyabinsk-70 where he has worked since 1961.

Slavskiy, Yefim Pavlovich--Born 7 November 1898 in Makeevka, Ukraine. died 1991. Trained as a metallurgical engineer. The first Chief Engineer at Chelyabinsk-40 (now Chelyabinsk-65) in 1946. In charge of metallurgical extraction and processing aspects of the early bomb program. Deputy, then First Deputy Minister of Medium Machine Building, 1953-1957. Replaced Pervukhin as Minister of MMB, 1957-1963. Chairman, State Production Committee for MMB, 1963-1965. Minister of MMB, 1965-1986. Received Hero of Socialist Labor, 1949, 1954 and 1962; Lenin prize 1980; State Prizes 1949 and 1951.

Tamm, Igor Evgenievich--Born 8 July 1895 in Vladivostok; died 12 April 1971 in Moscow. Created a school of theoretical physics to which many well-known Soviet scientists belonged. In June 1948 appointed head of a special nuclear bomb research group at the Physics Institute of the Soviet Academy of Sciences (FIAN). He and Sakharov proposed in 1950 that a hot plasma in a magnetic field be used to obtain a controlled thermonuclear reaction. Left Arzamas-16 in 1954 (after the August 1953 test) to return to Moscow. Won the Nobel Prize in Physics in 1958. Elected a member of the Academy of Sciences on 23 October 1953.

Thiessen, A.--German scientist captured by the Russians at the end of the war who succeeded in producing a suitable barrier for isotope enrichment by gaseous diffusion.

Timofeev, Lt. Gen. Nikolai Ivanovich--In charge of the Ministry of Defence construction units which built the facilities at the Semipaltinsk test site ("N 2").

Tolstikhin, Oleg T.--Deputy Director, "Mayak" Production Association (Chelyabinsk-65) in 1991.

Trutnev, Yuri Alekseyevich--Born 2 November 1927. Sakharov says that he made "significant contributions" to understanding "the Third Idea." He is currently first deputy scientific director of Arzamas-16. Elected as a corresponding member of the Nuclear Physics Department of the Academy of Sciences on 26 June 1964 (now a full member), and became a full member of the Russian Academy of Sciences in 1991. A Hero of Socialist Labor.

Tsukerman, Veniamin Aronovich--From 1947 until the present headed a laboratory on X-ray research, and methods of neutron and gamma-radiation recording.

Tsyrkov, Georgi Alexandrovich--From 1955 to 1960 a deputy chief designer at Chelyabinsk-70. Then chief engineer of the Fifth Main Directorate of MMB, and later became the head. Then head of the department of defense industry within the Ministry of Atomic Power and Industry (formerly the Ministry of Medium Machine Building). This department was responsible for the design laboratories, including Arzamas-16, Chelyabinsk-70, the test sites, and the warhead fabrication plants. In March 1992 appointed Head of the Fifth Department, Warhead Design and Testing in the newly created Ministry of Atomic Energy. Hero of Socialist Labor.

Turbiner, Vladimir Alexandrovich--the first leader of the design group which in 1946 designed a one-fifth size mock up of a bomb that was shown to

Stalin. The actual bomb detonated 1949 bore no relationship to this early model. In March 1948 he was dismissed.

Vannikov, Boris L'vovich--Born 7 September 1897 in Baku; died 22 February 1962 in Moscow. From 1942-1946 was People's Commissar of Munitions. In 1949 he was head of the First Main Directorate of the Soviet Council of Ministers, the provisional designation given the agency responsible for the entire atomic program. It was subsequently renamed the Ministry of Medium Machine Building, and Vannikov was First Deputy Minister from 1953-1958. Three times Hero of Socialist Labor, 1942, 1949, 1954; State Prize 1951, 1953.

Vasilyev, Dmitri Ch.-- First director of Chelyabinsk-70 from 1955 until his death in early-1961.

Velikhov, Yevgeniy Pavlovich--Born 2 February 1935. Currently (1993) Vice President (for Physical and Mathematical Sciences Section since November 1977) of the Russian (formerly Soviet) Academy of Science; and Director of Kurchatov Institute of Atomic Energy since 1988. The first President of the Soviet Nuclear Society. Formerly Chairman of the Armed Services Subcommittee of the Defense and State Security Committee of the USSR Supreme Soviet.

Vernadskiy, Vladimir Ivanovich--1863-1945. Geochemist and scientific administrator. Founded and headed the State radium Institute, 1921-1939. In the 1930s organized and headed various commissions; heavy water (1934), isotopes (1939).

von Ardenne, Manfred--German nuclear scientist who went to work for the Russians after the end of the war. Headed up a team of German scientists who were working on the problem of isotope separation.

Voronin, S.--Chief Designer at Arzamas-16, 1993.

Yangel, M. - Worked at Chelyabinsk-70.

Yegorov, Nikolay Nikolaevich--Physicist, Deputy Minister of Atomic Energy (Minatom) responsible for uranium enrichment, production reactors, plutonium and other isotope production, chemical separation, and radioactive waste management, March 1992- present. From 1965-1992, worked at Krasnoyarsk-45.

Yegorov, Nikolai Pavlovich--was probably a deputy to V.A. Bolyatko in the 12th Main Administration. Died in 1976.

Yemelyanov, Vasiliy Semenovich--Born 12 February 1901. Joined nuclear project in September 1945, as deputy to Boris L. Vannikov. Various unknown posts between 1946 to 1957. From 1957-1960, Head, Main Board on the Use of Atomic Energy, USSR Council of Ministers. From 1957-1959 was permanent USSR representative at the International Atomic Energy Administration. 1960-1962 was Chairman, State Committee on the Use of Atomic Energy. Accompanied Khruschev to U.S. in 1959. Awarded: Stalin Prize, 1942, 1950; Order of Lenin; Hero of Socialist Labor, 1954.

Zababakhin, Yevgeny Ivanovich--Born 16 January 1917; died December 1984. From March 1948 to June 1955 was leader of a theoretical group. In 1955 became deputy scientific director of Chelyabinsk-70. In 1960 was made scientific director until his death in 1984. A classmate of Sakharov's at Moscow University. Joined Air Force Academy in 1941, graduated with rank of captain. Main works are on hydrodynamics and explosions. Corresponding Member of the Academy of Sciences, 1958; Academician, 1968. Hero of Socialist Labor, 1953; Lenin Prize, 1958, State Prize, 1949, 1951, 1953.

Zakharenkov, Alexander Dmitrievich--An early scientist at Arzamas-16. From 1946-1955 was leader of a group and head of a laboratory. From 1968 to 1989 chief designer at Chelyabinsk-70.

Zavenyagin, Avraamii Pavlovich--Born 14 April 1901 in Uzlovaia; died 31 December 1956 in Moscow. Colonel general in the army and main aide to Beria in supervising the postwar nuclear weapons program. Worked with Kurchatov during the early weapon development period (see *Pravda,* March 4, 1989). Worked at Arzamas-16, arriving there in 1946. Deputy Minister of Medium Machine Building 1953-1955. Minister of Medium Machine Building from February 1955 replacing Malyshev. In 1955-1956 organized Chelyabinsk-70. Twice Hero of Socialist Labor, 1949 and 1954. Buried at the Kremlin Wall. Was project director for the research team of German scientists immediately after the war, that were located near Sukhumi on the Black Sea.

Zeldovich, Yakov Borisovich--Born 8 March 1914 in Minsk; died 2 December 1987. One of the founders of the modern theory of combustion, detonation, and shockwaves. His work with Khariton (1939-1941) were of great importance in solving the problem of the use of nuclear energy. An important paper with Khariton was delivered at the Conference on Questions of the Physics of the Atomic Nucleus held in Kharkov, November 15-20, 1939 and published later that year. In his *Memoirs* Sakharov said that his task, with the Tamm group, was initially to verify and refine the calculations produced by Zeldovitch's group at the Institute of Chemical Physics. Sakharov said that he now believes that the design developed by the Zeldovich group for the hydrogen bomb was directly inspired by information acquired through

espionage, though he has no proof. Zeldovich was initially responsible for theoretical research at Arzamas-16, arriving there in 1946. With Khariton and Sakharov one of the three principal developers of the Soviet hydrogen bomb. Academician; elected full member of the Academy of Sciences in 1958. Awarded the title of Hero of Socialist Labor three times, in 1949, 1953, and 1956.

Zernov, Pavel Mikhailovich--Born 1905; died 1964. First administrator (Director) of Arzamas-16 from 1946 to 1951, then deputy chairman of the First Main Administration, 1951-1953, and Deputy Minister of the Ministry of Medium Machine Building, 1953-1964.

Zubarev, Dmitri--Theoretical physicist who worked with Zavenyagin and with German scientists near Black Sea. Was transferred to Arzamas-16 where he remained until 1953.

Zysin, Yuri Aronovich--Born c. 1920; died 1987. A colleague of Sakharov's. Sent to work at Chelyabinsk-70 in the mid-1950s.

* The Soviet government awarded a several types of prizes to citizens who made contributions to the state. The most prestigious award was the Lenin Prize (1925-1935 and 1957-), followed by the State Prize (since 1967). The Stalin Prizes awarded from 1940 to 1952 were converted to State Prizes. The Hero of Socialist Labor was instituted in 1938. By 1971, 16,000 had been given the award but only 105 had won it more than once. Many of the very infrequent three-time winners have been associated with the nuclear weapons program; e.g., N.L. Dukhov, Y.B. Khariton, I.V. Kurchatov, A.D. Sakharov, K.I. Shchelkin, Ye.P. Slavsky, B.L. Vannikov, and Y.B. Zeldovich.

Appendix 2
Flerov Letter to Stalin, April 1942

Dear Iosif Vassarionovich:

Ten months have already elapsed since the beginning of the war, and all the time I have felt like a man trying to break through a stone wall with his head.

Where did I go wrong?

Am I overestimating the significance of the "uranium problem"? No I am not. What makes the uranium projects fantastic are the enormous prospects that will open up if a successful solution to the problem is found. I have to make a reservation from the very beginning. Perhaps I am not right—in research there is always as element of risk, more so with uranium that anything else. Let us imagine for a minute, however, that we have "succeeded" with uranium. True this will not bring about a revolution in technology, as the projects of the prewar months showed but then a veritable revolution will occur in military hardware. It may take place without our participation—due simply to the fact that now, as before, the scientific world is governed by sluggishness.

Do you know, Iosif Vassarionovich, what main argument has been advanced against uranium? "It would be too good if the problem could be solved. Nature seldom proves favorable to man."

Perhaps being at the front, I have lost all perspective of what science should deal with at present, and the long term problems, like that of uranium, must be postponed until the after the war. I think we are making a big mistake. The greatest follies are made with the best intentions.

All of us want to do all we can to rout the nazis, but there is no need for such hurry-scurry, no need to deal only with problems that come under the term "pressing" military objectives.

Well and, finally, maybe I am taking too much upon myself. All letters which you, Iosif Vassarionovich, receive may be divided into two groups. In the first there are letters with proposals which can, in their authors' view, help the struggle against the nazis. In the second there are the same proposals, but the implementation of these proposals is linked to some changes in the position of the author himself.

Now, I find it very difficult to write, knowing that the "sober" approach can be rightfully applied to me. What is Flyorov raging about over there? He dealt with science, was called up to the army, wants to get out of it and, using uranium as a pretext, has been showering letters upon all and sundry with disapproving comments on Academicians.

Now, for the solution of the question I consider it necessary to call a conference, which should be attended by Academicians Ioffe, Fersman, Vavilov, Khlopin and Kapitsa, Academician of the Ukrainian Academy of Sciences [Alexsandr Il'ich] Leipunsky, Professors Landau, Alikhanov, Artsimovich, Frenkel, Kurchatov, Khariton and Zeldovich, Doctors Migdal and Gurevich. It is also desirable to invite K. A. Petrzhak.

I ask an hour and a half for the report, and your presence, Iosif Vissarionovich, either in person or by default, is most desirable.

Generally speaking, now is not the time to arrange such scientific tournaments but personally, I see this as the only means to prove that I am right and have the right to deal with uranium—because other means—personal talks with A. F. Ioffe, letters to Comrade Kaftanov have brought about no results and are simply being passed over in silence. I have received no reply to my letter and five telegrams to Comrade Kaftanov. When discussing the plan of the Academy of Sciences, they probably spoke about everything but uranium.

This is that wall of silence which I hope you will help me break through, because this is my last letter, whereupon I lay down arms and wait till the problem has become solved in Germany, Britain or the USA. The results will be so overriding it won't be necessary to determine who is to blame for the fact that this work has been neglected in our country, the Soviet Union.

All of this is being done in such a skilful manner that we shall not even have formal grounds against anyone. No one anywhere has ever said that the nuclear bomb is unfeasible and yet there is the opinion that this task belongs to the realm of science fiction.

Therefore my first request, on whose fulfillment I insist, is to receive from all candidates to the future conference written considerations concerning the feasibility of the uranium problem. The conclusion should include a reply concerning the figure which should be used to assess the probability of solving the problem. For those conference participants who will consider their erudition insufficient for a written conclusion, this question may be ignored, but they are not relieved of the duty of attending the conference.

Source: *Moscow News*, No. 16, 1988.

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