RADIOLOGICAL EFFECTS OF MULTIPLE ATOMIC BOMB DETONATIONS

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1. General Considerations

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The original reports by Dr. Nicholas M. Smith, Jr. on Project Gabriel (November 12, 1949 and November 5, 1951) concluded that 10^5 nominal bombs could be exploded without resulting in large-scale disasters from secondary effects. This conclusion was based on assumptions of high air bursts and some distribution of bursts in space and time, and was derived from considerations of the immediate as well as delayed effects of radiation and of strontium ingestion resulting from widespread fall-out. The Gabriel reports have been extended through a staff study to consider more localized regional effects which might result from the tactical use of atomic weapons under various weather conditions.

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2. Long-Range Effects of High Air Bursts

2.1 *A basic figure* for the calculations is that a fraction 5×10^{-9} of each bomb will fall out per square mile -- a figure which allows for a local variation of ten times over the observed average. Stokes' Law is considered not to be valid for sub-micron particles of bomb debris, with the result that fall-out cannot be accurately calculated. Ranger data indicated a fractional fall-out between 5×10^{-9} and 5×10^{-11} per square mile. More elaborate Buster studies indicated an average fractional fall-out of 4×10^{-9} per square mile over the United States. If the debris were distributed uniformly over the north temperate zone, the average would be 5×10^{-9} per square mile.

2.2 <u>External radiation</u> hazard due to the debris from 10^5 nominal bombs would not be lethal. The total dose to a man standing in an atmosphere (5 miles high and 2×10^7 square miles area) containing all the debris from 10^5 nominal bombs would amount to only about 6 r. The dose to a man standing on the earth's surface on which all the debris had fallen out would receive an initial dose rate (after 50 hours) of 1.26 r/hr and an integrated dose of 315 r over a lifetime. This would entail some shortening of life and significant genetic changes.

2.3 <u>Inhalation dose</u> to the lungs from the contaminated atmosphere mentioned in paragraph 2.2 might amount to 90 rem in the first week, and less thereafter. Because the lungs can tolerate several thousand rep, this dose is not consequential. Carcinogenic effects have not been demonstrated for small isolated radioactive particles in the lungs, but the accumulation of large numbers of radioactive particles might constitute a hazard which cannot be dismissed.

2.4 <u>Ingestion</u> of radioactive strontium is an important (but not necessarily the controlling) factor in considering long-range hazard due to bomb debris, and produces its estimated mid-lethal effect when 7×10^5 nominal bombs are exploded. This number is calculated from the assumptions that: (1) strontium-90 is more toxic than other fission products or plutonium; (2) the mid-lethal dose is 10 micrograms of Sr^{90} fixed in the skeleton; (3) 200 people derive their food per square mile of arable land; (4) the proportion of strontium in the square mile of soil which finds its way into 200 human
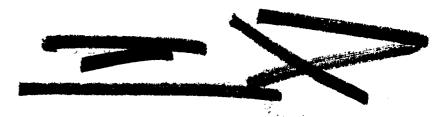
skeletons is 10^{-3}. These aspects as well as factors of biologic concentration need much more study and experimentation.
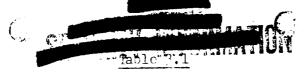
2.5 <u>Conclusion.</u> By the above discussion involving long-range radiation and ingestion hazards, 10^5 nominal bombs is believed to be a reasonably safe number, with an uncertainty factor of 10--100.

3. <u>Localized and Regional Effects Resulting from Tactical Use</u>

3.1 <u>Near Surface Bursts</u>

3.11 Experience with tower, surface and underground bursts indicates that a large fraction of the total radioactivity (of the order of half) is plated on materials which are swept up from the ground and deposited within relatively short distances. The active areas are the crater, an adjacent area downwind, and a more remote area some miles downwind into which particles of sizes of the order of 75 microns will fall.

Data from Trinity and Jangle are extrapolated, as shown in Table 3.1, on the basis of the following assumptions:

(a) Activity is proportional to energy yield.

(b) Dusts for a 13-KT shot will go twice as high as in Jangle, and for a 20-KT shot 2.25 times as high as in Jangle (to give results comparable to Trinity).

(c) Principal mode of fall-out is gravitational.

(d) Atmospheric conditions are as in Jangle.

These assumptions lead to the conclusion that the fall-out pattern will be geometrically similar to that of Jangle, of twice the linear dimensions and four times the area for a 13-KT shot.
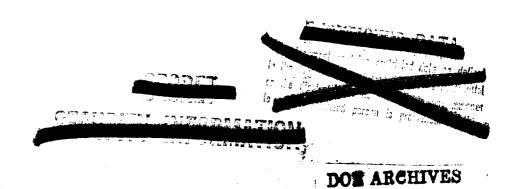
Table 3.1

Extrapolation of Fall-out Patterns from 1.2 KT Jangle Shots to 13 KT and 20 KT Near-Surface Bursts, under Similar Topographical and Meteorological Conditions

Area	Dimensions and Distance	Time	Radiation Levels (r/hr) Maximum	Average	Integrated Dose (r) Maximum	Average
JANGLE Crater	S, 94 ft	H+24		100		12,000
	U, 280 ft	H+15d		4		
Adjacent hot area	U, 2mi X 120°	H+1	500		2500	
		H+24	6		720	
Remote hot area	U, center at 13 mi 8mi X 5mi	H+1	33	3-4	165	15-20
13 KT Crater	Diameter 500ft	H+24		100		12,000
		H+15d		4		
Adjacent hot area	4mi X 120°	H+½	3,000	1,200	7,500	3,000
		H+1	1,250	500	6,250	2,500
		H+24	30	12	3,600	1,440
Remote hot area	25 mi 125 mi²	H+2	50	5	500	50
20 KT Crater	Diameter 600ft	H+24		100		
		H+15d		4		
Adjacent hot area	4.5mi X 120°	H+½	3,500	1,400	8,800	3,500
		H+1	1,500	600	7,500	3,000
		H+24	38	15	4,500	1,800
Remote hot area	30 mi 150 mi²	H+2	60	6	600	60

Note: We believe these estimates are accurate within order of magnitude, but refinement is impractical because of variations in soil, topography and meteorology.
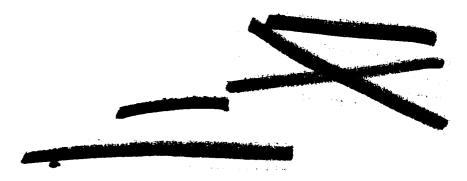
3.12 <u>Conclusion.</u> Considering the three hot areas resulting from a near-ground burst, it appears that personnel would be excluded from the crater for many days. Fall-out in good weather over about 17 square miles adjacent to a 13-KT burst (or 21 for 20 KT) would result in integrated doses of several thousand r, with levels high enough to limit use of the area for some days. It is unlikely that any serious personnel damage would result from the remote area of fall-out about 25 miles away, with the possible exception of beta ray burns from particles falling directly on the skin. Tactical use of multiple bombs under these conditions would lead to limited areas of significant contamination.

3.2 <u>Fall-out With Snow or Rain</u>

3.21 It is assumed (without sufficient actual evidence) that snow and probably rain will remove debris almost completely from air in which these precipitations are formed, and probably from air through which they fall. Table 3.2 was calculated, showing maximum possible fall-out due to weather conditions as an atomic cloud spreads through a 10° wedge. Under extreme weather conditions, the wash-out from a 13-KT bomb would be potentially lethal to a large fraction of the inhabitants in an area of considerably less than 100 square miles (taking 400 r as the mid-lethal dose).

Table 3.2 Dose from Complete Fall-out at Time H + t.

t (hrs)	Activity (curies)	Distance* from Zero (miles)	Diameter of Cloud (miles)	Area of Cloud (mi²)	Concentration of Activity from Complete Fall-out at Time t (c/mi²)	Initial Dose Rate (r/hr)	Integrated Dose** (r)
1	4×10^9	20	3.4	11	3.6×10^8	1500	7500
2	1.8×10^9	40	6.8	40	4.5×10^7	190	1000
3	1.1×10^9	60	10.2	104	1×10^7	42	630
4	0.8×10^9	80	13.6	190	4.2×10^6	17.6	350
5	0.58×10^9	100	17.0	290	2×10^6	8.4	210
6	0.45×10^9	120	20.4	416	1.1×10^6	4.6	138
7	0.40×10^9	140	23.8	575	7×10^5	2.9	100
8	0.33×10^9	160	28	785	4.2×10^5	1.8	72
9	0.29×10^9	180	30.5	935	3.1×10^5	1.3	58
10	0.25×10^9	200	34	1150	2.2×10^5	0.9	45
11	0.22×10^9	220	37.5	1415	1.5×10^5	0.6	33
12	0.20×10^9	240	41	1650	1.2×10^5	0.5	30

* Wind Velocity Assumed 20 m/hr.
** Assuming continuous exposure to this surface concentration until it has decayed to negligible value.

3.22 Note: Since the preparation of Table 3.2, Col. Benjamin Holzman
(now at the War College) has discussed with us a somewhat similar,
but extended, approach. He obtained actual wind trajectories
taken at 12-hour intervals over a period of a week, and originating
at a point in central Germany. Extending each trajectory until
precipitation was encountered, then calculating fall-out as in
Table 3.2, he shows a pattern of fall-out. The obvious extension
of this method is to prepare such a pattern for each of the four
seasons, and thereby obtain a probability pattern. Precipitation
data are available for much of Northwestern Europe.

3.23 Note: The highest wash-out obtained during Buster-Jangle was 8+
curies per square mile at Rochester, New York. The lowest level
recommended by the Noyes Panel for Radiologic Warfare is 3 mega-
curies per square mile.