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LOS ALAMOS SCIENTIFIC LABORATORY

of

THE UNIVERSITY OF CALIFORNIA

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January 25, 1950

ATOMIC WEAPON DATA
SIGMA CATEGORY 1
per R.D. ... 9/4/81

This document consists of 20 pages

[redacted]

DADDY POCKETBOOK

A summary of lectures by Edward Teller

written by Harris Mayer,

with illustrations by George Gamow.

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ABSTRACT

The basic ideas behind the design and use of Daddy are presented in this pocketbook in a somewhat conversational tone. The nuclear reactions and energy transformations in the main charge are discussed, followed by sections on fusing, delivery, and the gross effects of the explosion.

I. INTRODUCTION

This Report gives a review of the processes in Daddy, i.e., in a bomb powered by the thermonuclear reaction of deuterium. It is essentially a summary of two lectures given by Edward Teller, with illustrations by George Gamow, before the Technical Council. [redacted] The fuse will be discussed later (Section IV).

Once a portion of the main charge is ignited, the thermonuclear reaction [redacted] Eventually, much of the energy appears in blast.

II. THE NUCLEAR REACTIONS

[redacted]

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There are other possible secondary reactions, e.g., $He^3 + He^3$, but these are unimportant in Daddy.

Ranges of the fast charged particles[1], r, and mean free paths, λ, of the fast neutrons[1] emitted are indicated in Fig. 1 by positions along the distance scale.

The rate of the nuclear reactions (1) and (2) per unit volume is

$$R_{D(D,n)} = (1/2)\, N_D^2\, \overline{(\sigma v)}_{D(D,n)} \quad , \tag{7}$$

$$R_{D(D,p)} = (1/2)\, N_D^2\, \overline{(\sigma v)}_{D(D,p)} \quad , \tag{8}$$

where N_D is the deuteron density and $\overline{\sigma v}$ is the product of the relative velocities v and the reaction cross section σ appropriately averaged over the velocity distribution in collisions for a deuteron gas at a temperature T_N. Similarly, for reactions (3), (4), and (5) the rates are

$$R_{DT} = N_D N_T \overline{(\sigma v)}_{DT} \quad , \tag{9}$$

$$R_{DHe^3} = N_D N_{He^3} \overline{(\sigma v)}_{DHe^3} \quad , \qquad (10)$$

$$R_{TT} = (1/2) N_T^2 \overline{(\sigma v)}_{TT} \quad , \qquad (11)$$

where N_T is the triton density and N_{He^3} the density of He^3 (tralpha) particles.

The relevant cross sections have been measured (LA-581, LA-582). At low energies, they essentially follow a Gamow penetration formula.

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III. ENERGY TRANSFORMATION IN DADDY

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IV. IGNITION OF THE MAIN CHARGE

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V. DELIVERY OF DADDY

The tremendous explosive power of Daddy prohibits its delivery by ordinary manned bombers, for the bombers could hardly avoid being knocked out by the blast from the very weapon they deliver. Thus, long-range guided missiles are required.

What limitations does Daddy impose on the design of its carrier?

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[2] S. Frankel, LA-551 (April 15, 1946).

A special problem with Daddy is the necessity of keeping the liquid deuterium and tritium below the boiling point (about 20° K). Heat would leak in through the best Dewar walls at the rate of about 55 cal/sec. Moreover, the tritium present generates heat in its β-decay at the rate of 0.078 cal/gm·sec. Of course, a refrigerator could be carried along with Daddy, even in the guided missile. Alternatively, the evaporation of liquid hydrogen (heat of vaporization 108 cal/gram at 20° K) from a jacket surrounding the main charge could provide cooling. Only about 2 kg of hydrogen per hour of cooling would be required. Even in a flight of 10 hours, then, the weight and volume of the coolant would be negligible compared to that of the main charge. We conclude that cooling puts no additional requirements on the missiles designed to carry Daddy.

The most immediate guided-missile prospect is the "Snark", which is being developed by Northrop Aircraft Company for delivery of ordinary fission weapons. This is a subsonic carrier with range of 5000 miles. By slight changes of design the warhead compartment of the "Snark" could be enlarged to accommodate Daddy, without prejudice to the aerodynamic characteristics. A diagram of the "Snark" showing the warhead compartment is given in Fig. 5. Daddy can also be carried by supersonic missiles such as "Navajo", being developed by North American Aviation, or "Triton" being developed by the Applied Physics Laboratory of Johns Hopkins University; these can be launched, respectively, from a B-36 or a submarine at a distance of 1000 miles from the target. These missiles are in an advanced stage of development and will certainly be ready for use before Daddy itself.

VI. EFFECTS

The effects of Daddy depend on the total energy released. If we assume that the D-D reaction produces tritons and tralphas in equal numbers, and that the tritons immediately react with deuterium

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FIG. 5 ADAPTATION OF SUBSONIC GUIDED MISSILE "SNARK" FOR DADDY (RANGE - *5000 MILES*)

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The explosion of a 40-megaton Daddy in an air burst[3] (1 to 3 miles above ground) would cause a blast wind whose positive phase lasts from 10 to 15 seconds. Overpressure would be as much as 20 psi 9000 yards from the center of the explosion, with wind velocities of 300 mph. Following the outward-going blast wind would be strong inward currents, as air rushed back to fill the vacancy left by the rising column of hot gases resulting from the explosion. These after-winds would have velocities of 100 mph at 20,000 yards from the center of the explosion, and higher velocities closer.

Accompanying the blast would be a heat wave of some 40 seconds' duration containing, roughly, one-third of the energy released. The heat could char wood at 20 miles and cause first-degree skin burns on unprotected personnel at 17 miles.

Additional effects of the explosion would be the release of nuclear radiations--neutrons and gamma-rays--and the formation of an enormous quantity of induced radioactivity.

Damage effects in a typical city due to the explosion of a 40-megaton Daddy are illustrated in Fig. 6. The accompanying table also gives these results.

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[3] The figures quoted on Daddy effects are taken from the report of F. Reines and B. R. Suydam, LAMS-993 (Nov. 18, 1949).

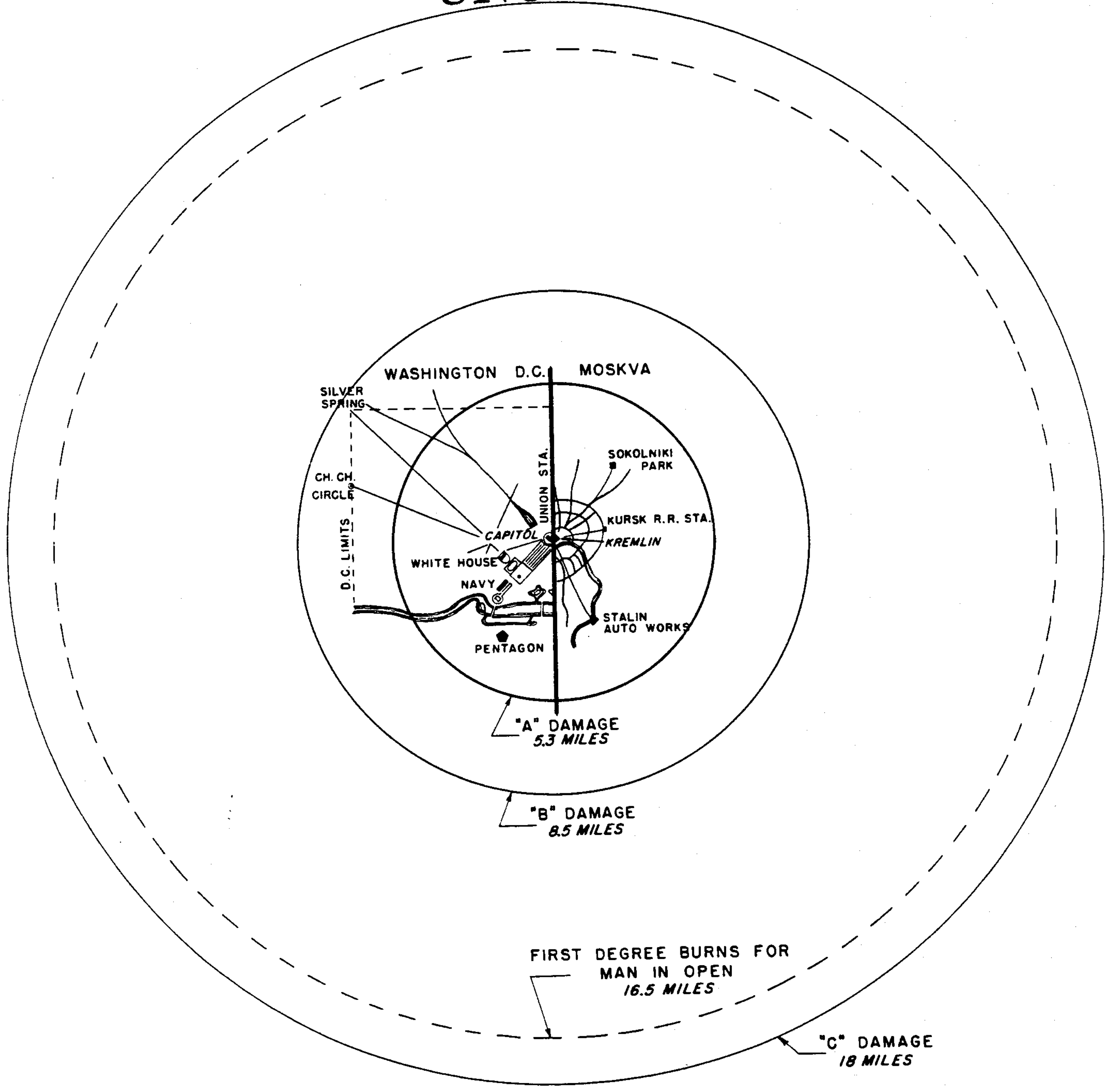

FIG. 6 DAMAGE RADII OF DADDY
(40 MEGATONS – 1 1/2 MILE HIGH AIR BURST)

Overpressure (psi)	Area (square miles)	Type of Damage*
20	90	A
10	170	A-B
8	210	B
2-4	1000	C

*For conventional structures:
A - complete demolition
B - irreparable damage
C - severe but reparable damage

From the military point of view, there are two important features of Daddy, compared to fission weapons. The first concerns accuracy of delivery. The expected error with present guided missiles is about 5 miles. Now, fission bombs of 40-kilotons yield have a destructive radius of 1.5 miles, the 40-megaton Daddy of 15 miles. Demolishing a localized target by guided missiles armed with fission bombs would require a lucky hit; armed with Daddy, it would be hard to miss.

The second feature concerns the size of the military forces needed to achieve a given strategic mission. The damage area due to Daddy is 100 times that due to a fission weapon. From this consideration alone, an air force equipped with Daddy would, therefore, require only one-hundredth the number of delivery devices compared to one equipped solely with fission bombs. Other tactical and strategic considerations would certainly make this ratio less favorable for Daddy, but even a small saving in this direction is important, since this is a recurrent item of expense in years of peace as well as in time of war.

APPENDIX

GLOSSARY OF NOTATION FOR FIGURE 3

$\dot{\epsilon}_N$ = energy production per unit time per unit volume due to nuclear processes.

ρ = density of deuterium in main charge.

ρ_o = normal liquid deuterium density ($\rho_o = 0.14$ gm/cm^3).

N_D = number of deuterons per unit volume.

Z_D = deuteron atomic number.

M_D = deuteron mass.

m = electronic mass.

∇^2 = Laplacian operator.

N_Z = number of nuclei of atomic number Z per unit volume.

σ_o = Thompson cross section for the electron (0.665 barns).

R = radius of main charge.

J = external radiation flux, energy per unit area per unit time.