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Title

NOMOGRAMS FOR OVERPRESSURE, FIREBALL RADIUS AND THERMAL ENERGY OF NUCLEAR WEAPONS

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Summary

The effects of nuclear explosions have been known for more than three decades, and phenomena that emit the largest portions of energy are the overpressure (blast wave) and thermal radiation. Nomograms are presented that quickly provide first-cut estimates of the emitted peak-exposure levels. These levels are then related to (1) the resulting damage effects of various structures and materials and (2) the biological effects on humans and animals.

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GLOSSARY

cal	Calories
cm	Centimeter
km	Kilometer
kt	Kiloton
lb/in. ²	Pounds per square inch
m	Meter
Mt	Megaton
P _{MAX}	Maximum overpressure
psi	Pounds per square inch

SECTION I
INTRODUCTION

For more than 30 years it is known that the phenomena associated with nuclear weapon detonations have included ionizing radiation, electromagnetic pulse (EMP) effects, thermal radiation, overpressure and seismic waves. The characteristics of these phenomena are well documented in the literature, and one of the more accessible books is written by Samuel Glasstone.* The nomograms on overpressure and thermal energy contained in this article are based on the data presented by Glasstone. However, new information is included concerning a "visibility" factor.

Nuclear weapons are similar to the more conventional types in so far as their destructive action is due mainly to blast or shock. However, there are several basic differences between nuclear and high-explosive weapons. First, nuclear explosions can be many thousands of times more powerful than the largest conventional detonations. Second, a fairly large porportion of the energy in a nuclear explosion is emitted in the form of light and heat, generally referred to as "thermal radiation". It is capable of causing skin burns and starting fires at considerable distances. Third, the nuclear explosion is accompanied by highly penetrating and harmful invisible rays, called the "initial nuclear radiation". Finally, the substances remaining after a nuclear explosion are radioactive, emitting similar radiations over an extended period of time. This is known as the "residual radioactivity".

The following paragraphs discuss two nomograms useful in visualizing the destructive aspects of nuclear explosions. These nomograms deal with the two phenomena delivering the largest energy fractions of the explosion yields, i. e., overpressure (included in blast and shock delivering 50%) and thermal radiation (35%).

* Samuel Glasstone, The Effects of Nuclear Weapons, United States Atomic Energy Commission, Superintendent of Documents, US Government Printing Office, Washington, D. C., April 1962.

SECTION II
OVERPRESSURE AND FIREBALL RADIUS

2.1 USEAGE OF NOMOGRAM

Nomograms are graphical representations that allow quick and convenient computation of an unknown from a set of given, known parameters. Figure 1 is a nomogram that enables estimation of the maximum overpressure and fireball radius from the yield (in tons of explosive force) and distance of a nuclear weapon. As an example it is desired to know the overpressure for a 20 kiloton (kt) weapon at a distance of 1 km from the detonation. By drawing a straight line from the 1-km point on the "range" scale to the 20 kt point on the "yield" scale, the intersects on the "maximum overpressure" scale is approximately 7 lb/in.² for the condition of a surface burst, or 14 lb/in.² for a burst occurring at optimum burst height. The fireball radius is found by drawing a horizontal line between the "yield" scale and the "maximum fireball radius" scale; for this example the maximum average fireball radius is approximately 0.24 km where the maximum burst height for negligible early fallout (radiation) is approximately 0.19 km (80% of maximum fireball radius). It is emphasized that this nomogram is useful in estimating any one of the parameters if the other two are known.

2.2 DAMAGE AND OVERPRESSURE

Damage to various types of structures as a function of overpressure intensity is listed in table form in Figure 1. The structures range from glass windows to buried concrete arches, the most resistant to overpressure damage. Two relative descriptions of damage are given: (1) light, where the structure can readily be repaired; (2) heavy, where the structure is beyond or nearly beyond repair.

2.3 BIOLOGICAL EFFECTS

A table is also given in Figure 1 that relates effects to humans and animals as a function of maximum overpressure (P_{MAX}). If the maximum overpressure is greater than 5 lb/in.² (side-on or reflected overpressure), more than 1% of the exposed population will experience ruptured eardrums. Similarly, if P_{MAX} is greater than 45 lb/in.², then better than 99% of the population will have ruptured eardrums. Overpressure ranges are also described for biological effects such as lung hemorrhage and the expected death rate (resulting largely from high yield weapons). The lower and upper limits on P_{MAX} correspond to the percentages of the exposed population that will experience a given destructive biological effect (in this case 1% and 99% boundaries).

NOTE: MIN. BURST HEIGHT FOR NEGLIGIBLE EARLY FALLOUT
IN EMERGENCY CASE IS '80% OF MAX. FIREBALL RADIUS.

TYPE OF STRUCTURE	DAMAGE & OVERPRESSURES	
	LIGHT	HEAVY
BURIED CONCRETE ARCH	120-160 PSI	220-280 PSI
BURIED STEEL ARCH	30- 40 PSI	45- 60 PSI
SEISMIC STRUCTURE	10.0 PSI	35.0 PSI
REINFORCED CONCRETE	7.0 PSI	25.0 PSI
ORDINARY HOUSE	1.0 PSI	5.0 PSI
GLASS WINDOWS	.02 PSI	1.0 PSI

P-MAX* PSI	PROBABLE BIOLOGICAL EFFECT
5-45	1-99% RUPTURE EARDRUM
15-25**	THRESHOLD LUNG MEMORRHAGE
35-65**	1-99% MORTALITY

* SIDE-ON OR REFLECTED OVERPRESSURE
** APPLIES ONLY TO FAST RISING PRESSURES OF LONG DURATION

MIN. BURST HEIGHT
FOR NEGLIGIBLE
EARLY FALLOUT

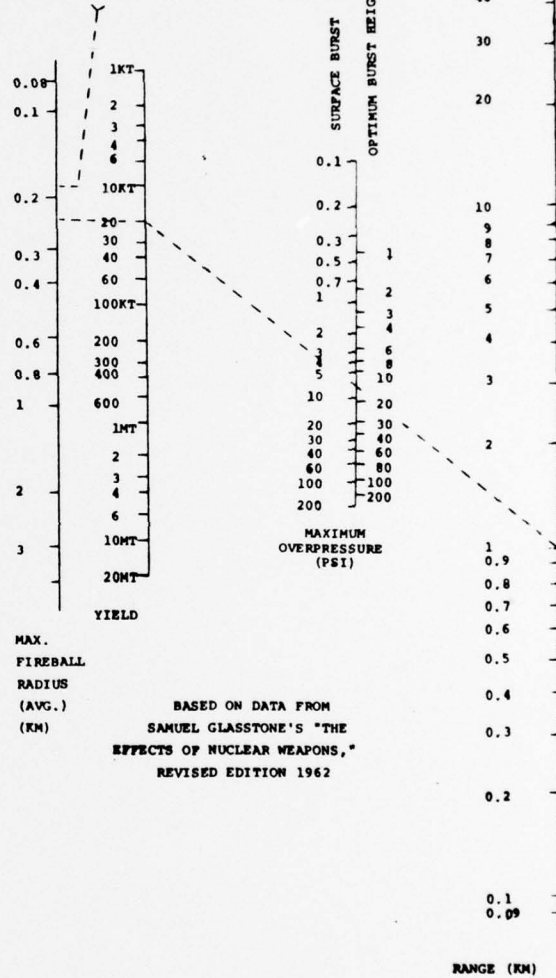


Figure 1. Nomogram for Overpressure and Fireball Radius

SECTION III
THERMAL ENERGY

3.1 USEAGE OF NOMOGRAM

Thermal energy as a function of distance from the nuclear explosion is estimated using Figure 2 for a given visibility factor and weapon yield (tons of explosive force). As an example it is desired to estimate the thermal radiation for a 100-kt explosion at 10 km on a very clear day. The transmittance through the atmosphere is found by drawing a straight line between scale 1 (visibility) and scale 2 (range in km); the transmittance is read on scale 3 (approximately 0.4). Then, a straight line is drawn between 10 km on scale 4 and the 0.4 transmittance on scale 5 to find the intersect on scale 6. Between this intersect (scale 6) and 100 kt on scale 7, another straight line is drawn to find the thermal radiation (cal/cm^2) on scale 8, i. e., about $2 \text{ cal}/\text{cm}^2$. Again, it is noted that this nomogram is useful in estimating any one of the parameters given the other three.

3.2 IGNITION OF MATERIALS

The amount of thermal radiation required to start fires with various types of materials is listed in table form in Figure 2. The materials for which test data is given are paper, some organic materials (wood and grass) and some types of cloth.

3.3 BIOLOGICAL EFFECTS

First degree burns are minor skin injuries similar to a sunburn with no blistering and will likely be experienced with a thermal radiation exposure of 1 to $2 \text{ cal}/\text{cm}^2$. Second degree burns involve blistering and can be serious if the face or extensive parts of the body are exposed. This is experienced with a thermal radiation exposure of 5 to $10 \text{ cal}/\text{cm}^2$. The extent of the injury is very much dependent upon the individual's skin tolerance to thermal energy and the shielding effect of clothing (tightness of weave and color).

