NUCLEAR WEAPONS EFFECTS

HANDBOOK

A collection of the graphs, nomograms, and tabulated data most frequently used by the Radiological Scientific Officer.

PREFACE

This handbook was compiled in an effort to simplify the use of the basic text used on Radiological Scientific Officers courses, i.e., The Effects of Nuclear Weapons, 1962 (reprint edition, 1964).

The Effects of Nuclear Weapons is an excellent reference book and will continue to be used for RSO courses. However, students have frequently commented upon the difficulty of quickly locating the graphs and tables which they regularly use for preparing their weapons effects estimates; a single computation may require reference to several graphs, each located in a different chapter in the text. Therefore, those data most frequently used by the RSO have been extracted from The Effects of Nuclear Weapons and re-assembled in this handbook in subject groups more closely related to the normal order of use.

To complete the usefulness of this handbook, data from one or two other sources have been inserted in some sections and a full section of "useful relationships", containing selected mathematical tables, conversion factors, etc., is included.

Users must remember that this handbook contains only selected data; it is not a full and complete manual of nuclear weapons effects. It must be used therefore, in conjunction with its source documents, in which the various phenomena are discussed and explained and which define or qualify the order of reliability of some of the data.

TABLE OF CONTENTS

SECTION A - BLAST & SHOCK

A-3 continued

SECTION B - THERMAL RADIATION & EFFECTS

B-1 EMISSION, TRANSMISSION & DELIVERY

SECTION C - INITIAL NUCLEAR RADIATION

SECTION D - RESIDUAL NUCLEAR RADIATION & FALLOUT

SECTION A - BLAST & SHOCK

A-1 AIR BLAST

Figures 3.67a & b. Peak overpressures on the ground for a 1-kiloton burst (high and low-pressure ranges)

The curves in Figs. 3.67a & b show peak overpressures on the ground as a function of distance from ground zero and height of burst for a 1 KT burst in a standard sea-level atmosphere. The broken line separates the regular reflection region from the Mach region and indicates where the triple point is formed. The data are considered appropriate to nearly-ideal target conditions.

SCALING:

The height of burst and the distance from ground zero to which a given peak overpressure extends scale as the cube root of the yield, i.e.,

$$\frac{d}{d_1} = \frac{h}{h_1} = W^{1/3}$$

where, for a given overpressure, d_1 and h_1 are distance from ground zero and height of burst for 1 KT and d and h are the corresponding distance and height of burst for W KT.

METHOD:

Given the yield W and any two of height of burst h overpressure p, or distance d, to find the unknown, proceed as follows.

To find distance.

1. Calculate scaled height of burst: $h_1 = \frac{h}{W^{1/3}}$

2. From Fig. 3.67a or b, using scaled height h_1 and the given overpressure p, determine the scaled distance d_1 at which p is produced.

3. Convert scaled distance to actual distance: $d = d_1 W^{1/3}$

To find overpressure:

1. Calculate scaled height as above.

2. Calculate scaled distance: $d_1 = \frac{d}{W^{1/3}}$

3. Using h_1 and d_1, read off p from Fig. 3.67a or b.

To find height of burst:

1. Calculate scaled distance as above.

2. From Fig. 3.67a or b, using d_1 and p, read off scaled height h_1.

3. Convert scaled height to actual height: $h = h_1 W^{1/3}$

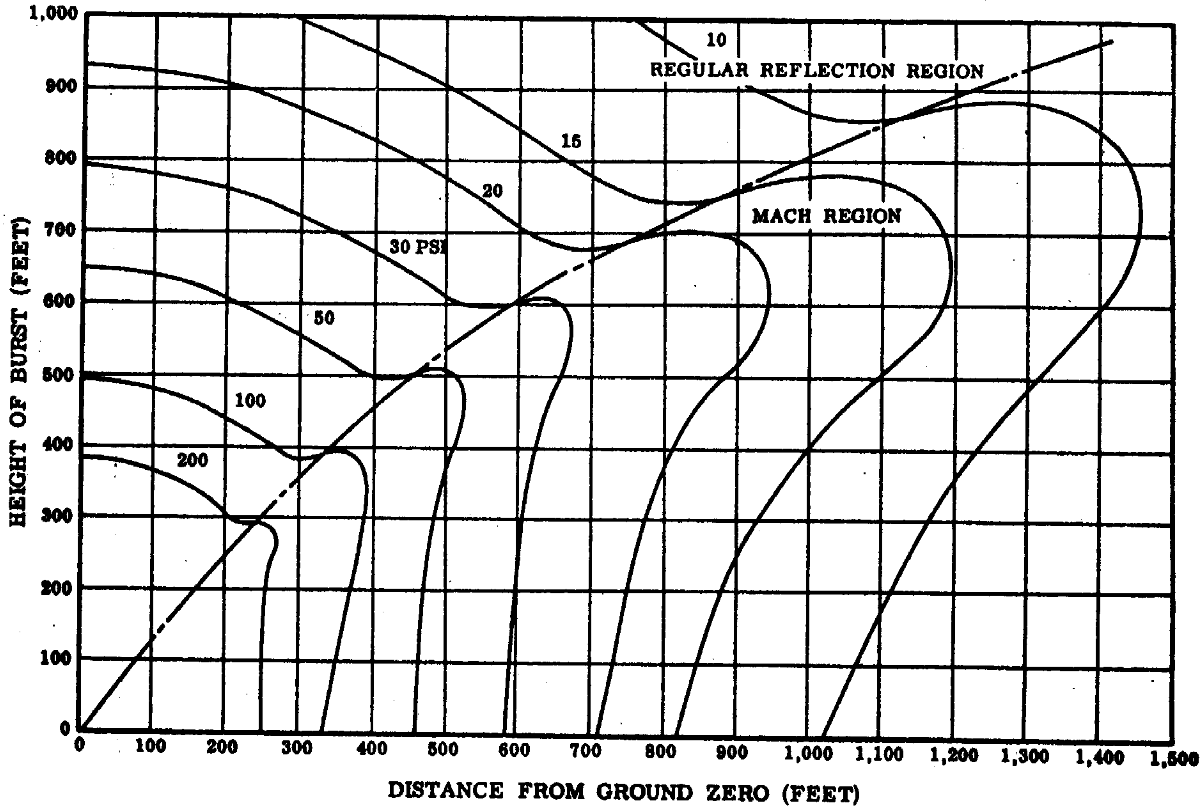

Figure 3.67a. Peak overpressures on the ground for a 1-kiloton burst (high-pressure range).

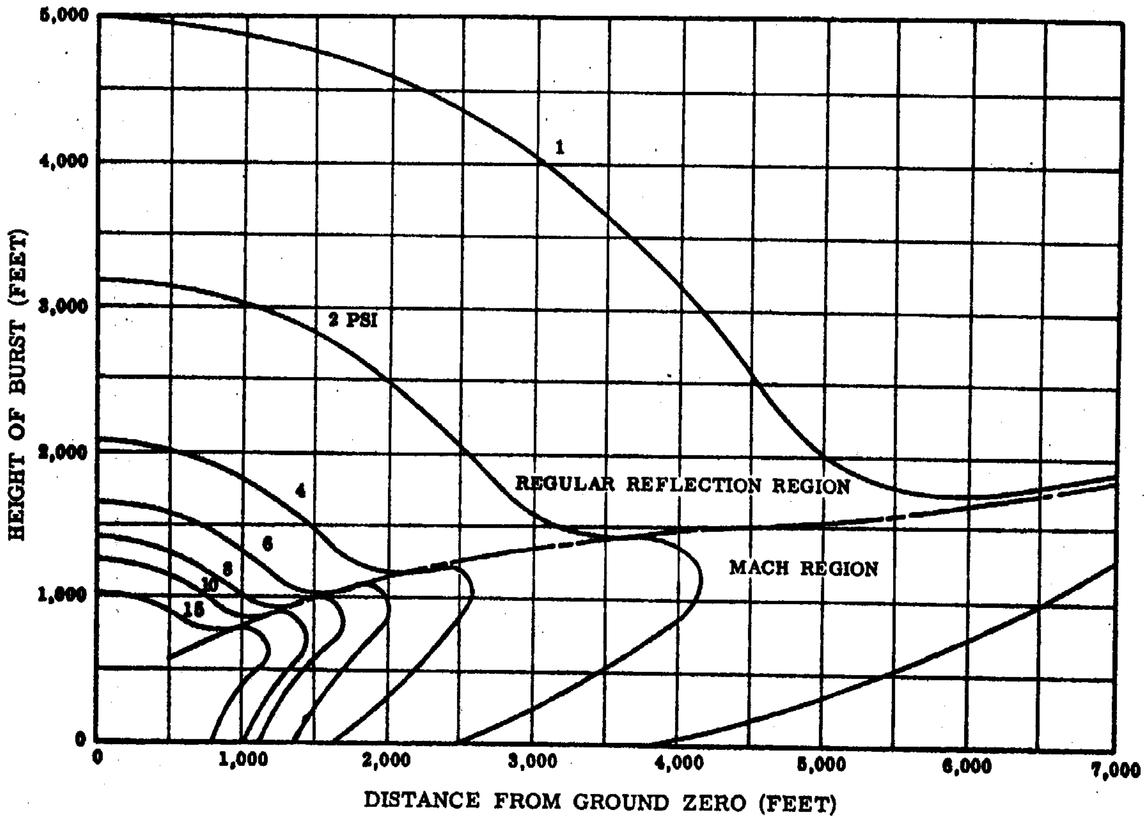

Figure 3.67b. Peak overpressures on the ground for 1-kiloton burst (low-pressure range).

(from Effects of Nuclear Weapons, 1964, pp 137, 139)

Figure 3.68. Horizontal component of peak dynamic pressure for 1-kiloton burst.

The curves in Fig. 3.68 show the horizontal component of peak dynamic pressure on the ground as a function of distance from ground zero and height of burst for a 1 KT burst in a standard sea-level atmosphere. The data are considered appropriate for nearly-ideal target conditions.

SCALING: as for Figs. 3.67a & b.

Figure 3.69. Positive phase duration on the ground of overpressure and dynamic pressure for 1-kiloton burst.

The curves in Fig. 3.69 show the duration on the ground of the positive phase of the overpressure and of the dynamic pressure (in parentheses) as a function of distance from ground zero and height of burst in a standard sea-level atmosphere. The curves are considered appropriate for nearly-ideal surface conditions.

SCALING:

The required relationships are $\frac{d}{d_1} = \frac{h}{h_1} = \frac{t}{t_1} = W^{1/3}$

where d_1, h_1, and t_1 are the distance from ground zero, the height of burst, and duration, respectively, for 1 KT; and d, h, and t are the corresponding distance, height of burst, and duration for W KT.

EXAMPLE:

GIVEN: A 160 KT explosion at a height of 3,000 feet.

FIND: The positive phase duration on the ground of (a) the overpressure, (b) the dynamic pressure at 4,000 feet.

SOLUTION: The corresponding height of burst for 1 KT is

$$h_1 = \frac{h}{W^{1/3}} = \frac{3,000}{(160)^{1/3}} = 550 \text{ feet},$$

and the corresponding diatance from ground zero is

$$d_1 = \frac{d}{W^{1/3}} = \frac{4,000}{(160)^{1/3}} = 740 \text{ feet}$$

(a) From Fig. 3.69 the positive phase duration of the overpressure for a 1 KT at 740 feet from ground zero and a burst height of 550 feet is 0.18 second. The corresponding duration of the overpressure positive phase for 160 KT is, therefore,

$$t = t_1 W^{1/3} = 0.18 \times (160)^{1/3} = 1.0 \text{ second ANSWER}$$

(b) From Fig. 3.69, the positive phase duration of the dynamic pressure for 1 KT at 740 feet from ground zero and a burst height of 550 feet is 0.34 second. The corresponding duration of the dynamic pressure positive phase for 160 KT is, therefore,

$$t = t_1 W^{1/3} = 0.34 \times (160)^{1/3} = 1.8 \text{ second ANSWER}$$

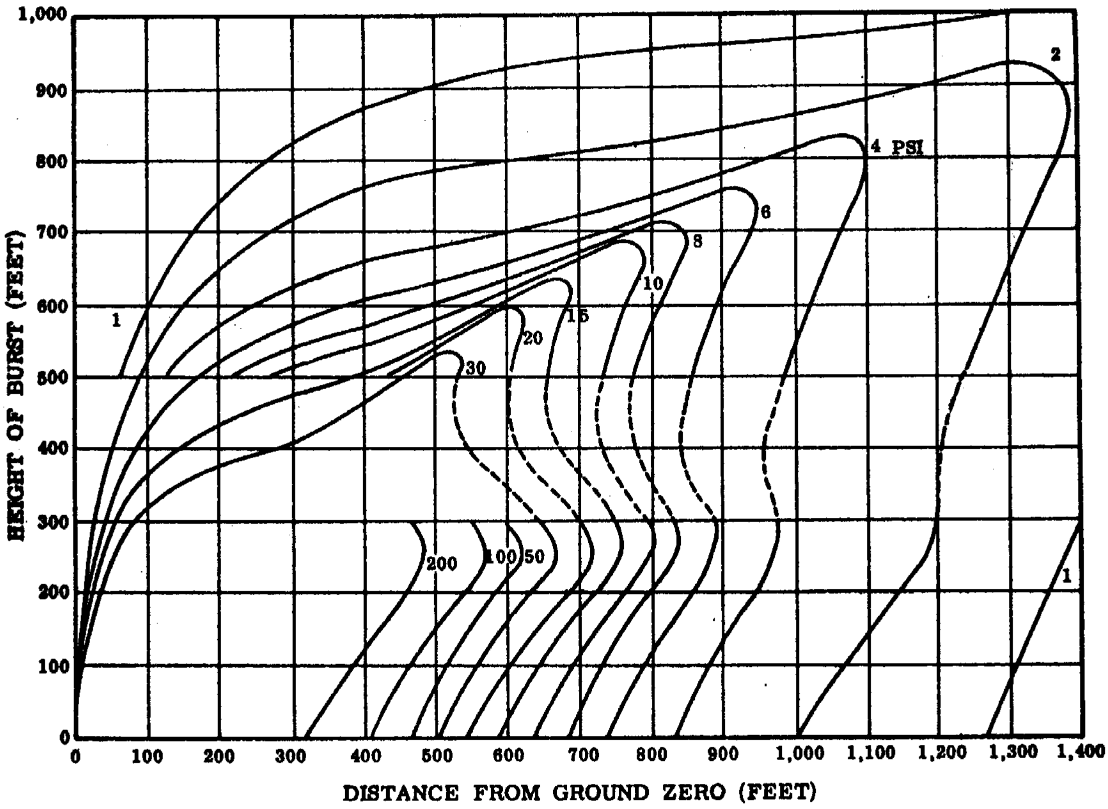

Figure 3.68. Horizontal component of peak dynamic pressure for 1-kiloton burst.

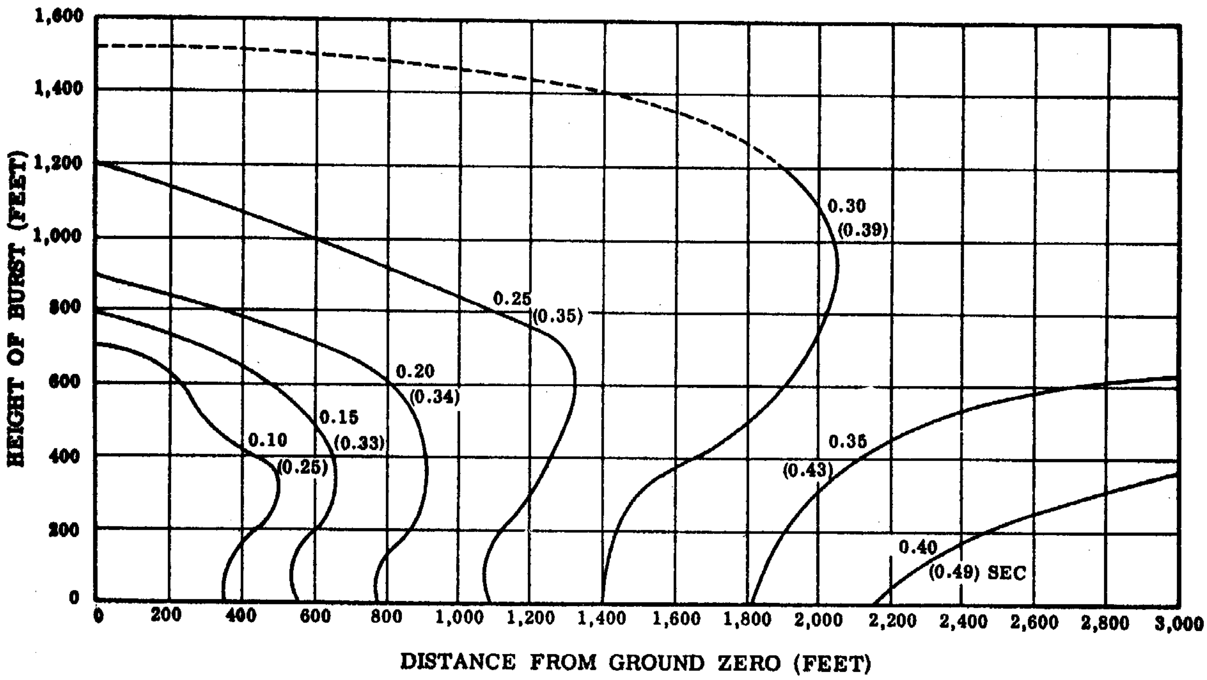

Figure 3.69. Positive phase duration on the ground of overpressure and dynamic pressure (in parentheses) for 1-kiloton burst.

(from Effects of Nuclear Weapons, 1964, pp 141, 143)

Figures 3.70a and b. Arrival times on the ground of blast wave for a 1-kiloton burst.

The curves in Figs. 3.70a & b give the time of arrival of the blast wave on the ground as a function of distance from ground zero and height of burst for a 1 KT burst in a standard sea-level atmosphere. The curves are considered appropriate for nearly-ideal surface conditions.

SCALING:

The required relationships are

$$\frac{d}{d_1} = \frac{h}{h_1} = \frac{t}{t_1} = W^{1/3}$$

where d_1, h_1, and t_1 are the distance from ground zero, height of burst, and time of arrival, respectively, for 1 KT; and d, h, and t are the corresponding distance height of burst, and time for W KT.

EXAMPLE:

GIVEN: A 1 MT explosion at a height of 5,000 feet.

FIND: The time of arrival of the blast wave at a distance of 10 miles from ground zero.

SOLUTION: The corresponding burst height for 1 KT is

$$h_1 = \frac{h}{W^{1/3}} = \frac{5,000}{(1,000)^{1/3}} = 500 \text{ feet}$$

The corresponding distance from ground zero for 1 KT is

$$d_1 = \frac{d}{W^{1/3}} = \frac{5,280 \times 10}{(1,000)^{1/3}} = 5,280 \text{ feet}$$

From Fig. 3.70b, at a height of burst of 500 feet and a distance of 5,280 feet from ground zero, the arrival time is 4.0 seconds for 1 KT.

The corresponding arrival time for 1 MT is

$$t = t_1 W^{1/3} = 4.0 \times (1,000)^{1/3} = 40 \text{ seconds ANSWER}$$

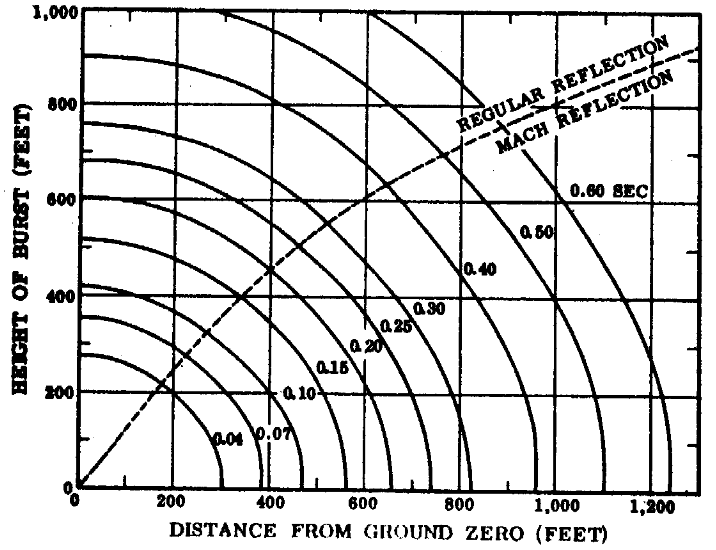

Figure 3.70a. Arrival times on the ground of blast wave for 1-kiloton burst (early times).

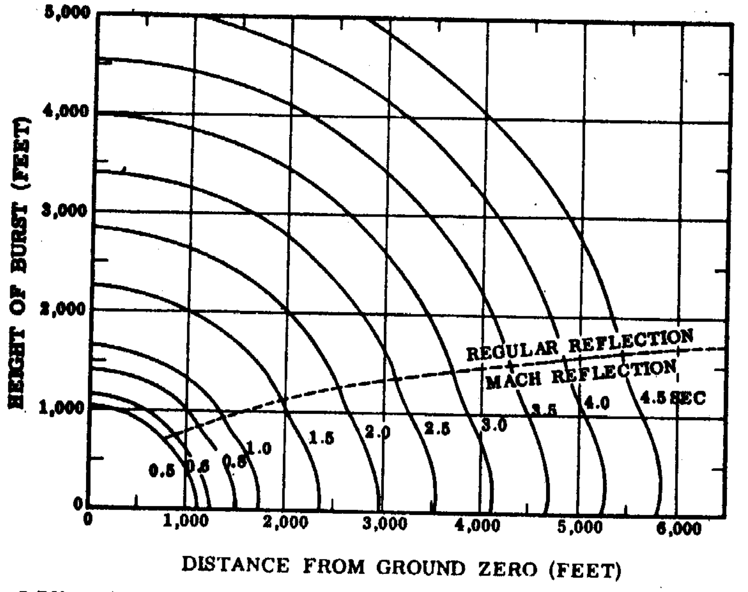

Figure 3.70b. Arrival times on the ground of blast wave for 1-kiloton burst (late times).

(from Effects of Nuclear Weapons, 1964, p 145)

SECTION A - BLAST & SHOCK

A-2 SURFACE & SUB-SURFACE BURSTS

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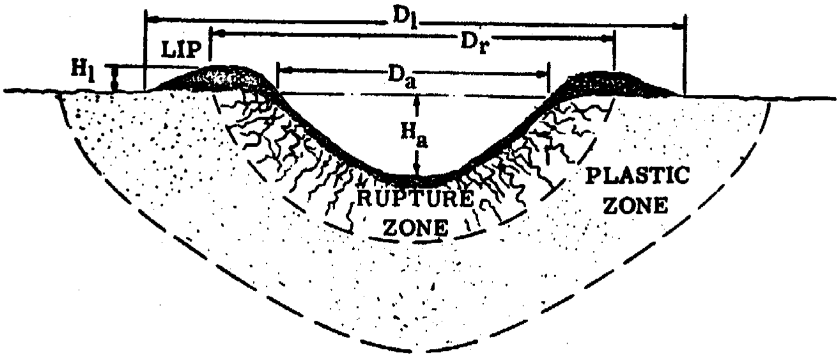

Figure 6.46. Characteristic dimensions of the crater in a surface burst.

The apparent crater, which has a diameter D_a and a depth H_a, as shown in Fig. 6.46, is the surface of the depression or hole left in the ground after the explosion. The true crater, diameter D_t, on the other hand, is the surface extending beyond the apparent crater where a definite shear has occurred.

The volume of the apparent crater, assumed to be roughly paraboloid, is given approximately by

$$\text{Volume of crater} = \frac{\pi D_a^2 H_a}{8}.$$

The diameter of the rupture zone, indicated by D_r in Fig. 6.46, is roughly one and one-half times the apparent crater diameter, i.e.,

$$D_r \approx 1.5\, D_a.$$

The overall diameter, including the lip, i.e., D_l, is twice the apparent crater diameter, so that

$$D_l \approx 2D_a,$$

The height of the lip, H_l, is approximately one-fourth of the depth of the apparent crater, i.e.,

$$H_l \approx 0.25 H_a.$$

(from Effects of Nuclear Weapons, 1964, pp 289, 290)

Figure 6.48. Apparent crater dimensions for bursts at the surface and at a depth of 150 $W^{0.3}$ feet in dry soil.

The curves in Fig. 6.48 give the values of apparent crater diameter and depth in dry soil as a function of explosion yield for (a) a surface burst, i.e., actual depth 5 $W^{1/3}$ feet above or below the ground, and (b) a burst at an actual depth of 150 $W^{0.3}$ feet. These curves represent the range in crater dimensions from a surface burst to the (approximate) maximum value for an underground burst.

A factor of 0.8 is used as a multiplier for estimating crater dimensions in rock, e.g., granite or sandstone.

EXAMPLE:

GIVEN: A 20 KT surface burst over sandstone.
FIND: The crater diameter and depth.
SOLUTION: From Fig. 6.48, the crater radius and depth for a 20 KT surface burst in dry soil are 170 feet and 80 feet, respectively. By applying the factor for sandstone (0.8), the estimated (approximate) crater dimensions are:

Crater Diameter (D_a) = 340 x 0.8 = 270 feet
Crater Depth (H_a) = 80 x 0.8 = 64 feet ANSWER

Figure 6.49. Apparent crater radius and depth as function of depth of burst for a 1-kiloton underground explosion in dry soil

The solid curves in Fig. 6.49 give the estimated apparent crater radius and depth as a function of depth of burst for 1 KT explosions in dry soil. The dashed curves indicate the reasonable range of variations to be expected under apparently similar conditions. For rock the multiplication factor of 0.8 should be used. The curves are uncertain at depths of burst greater than 150 $W^{0.3}$ feet.

SCALING:

To determine the crater radius and depth for a W KT yield, the actual burst depth is divided by $W^{0.3}$ to obtain the scaled depth. The radius and depth of crater for 1 KT at this depth of burst are obtained from Fig. 6.49. The dimensions are then multiplied by $W^{0.3}$. (Values of $W^{0.3}$ can be obtained from Figure 3.65, which is reproduced in Section E-1 of this handbook.

EXAMPLE:

GIVEN: A 20 KT burst at a depth of 50 feet in granite.
FIND: Crater radius and depth.
SOLUTION: The scaled burst depth is

$$\frac{d}{W^{0.3}} = \frac{50}{20^{0.3}} = \frac{50}{2.46} = 20 \text{ feet.}$$

From Fig. 6.49 the crater radius for a 1 KT explosion at this depth is 117 feet. The corresponding depth of the crater is 55 feet. Hence, the crater radius and depth for a 20 KT burst at a depth of 50 feet in granite are:

Crater Radius (R_a) = 117 x $20^{0.3}$ x 0.8 = 230 feet
Crater Depth (H_a) = 55 x 2.46 x 0.8 = 108 feet ANSWER

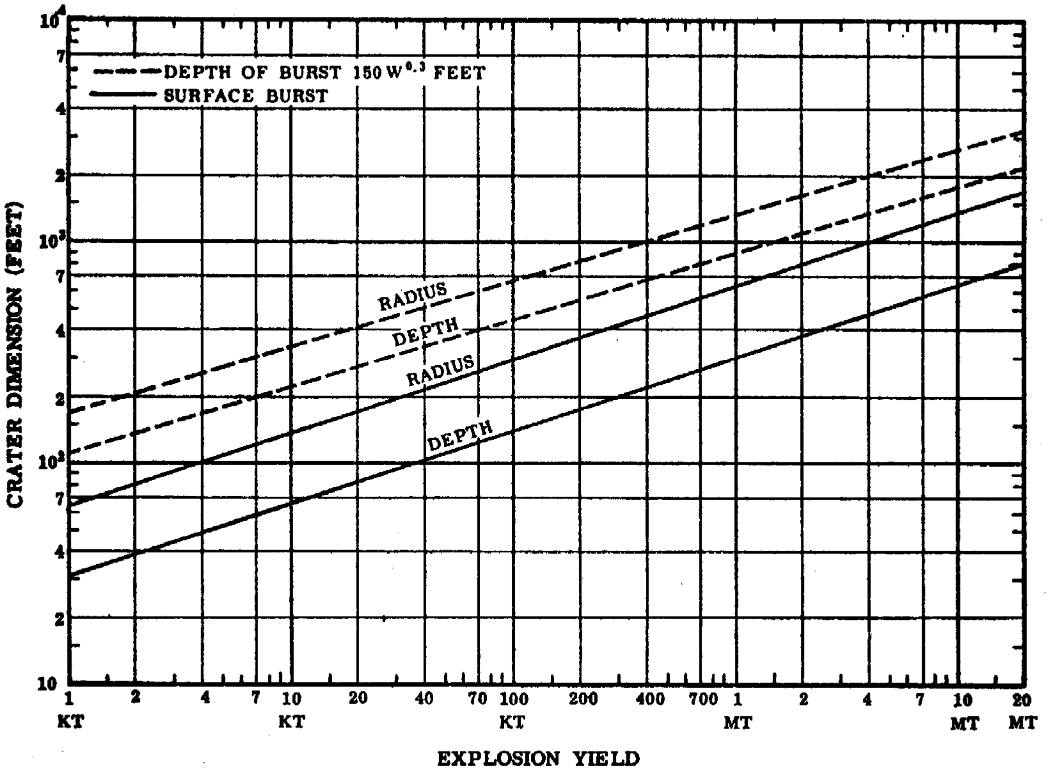

Figure 6.48. Apparent crater dimensions for bursts at the surface and at a depth of 150 $W^{0.3}$ feet in dry soil.

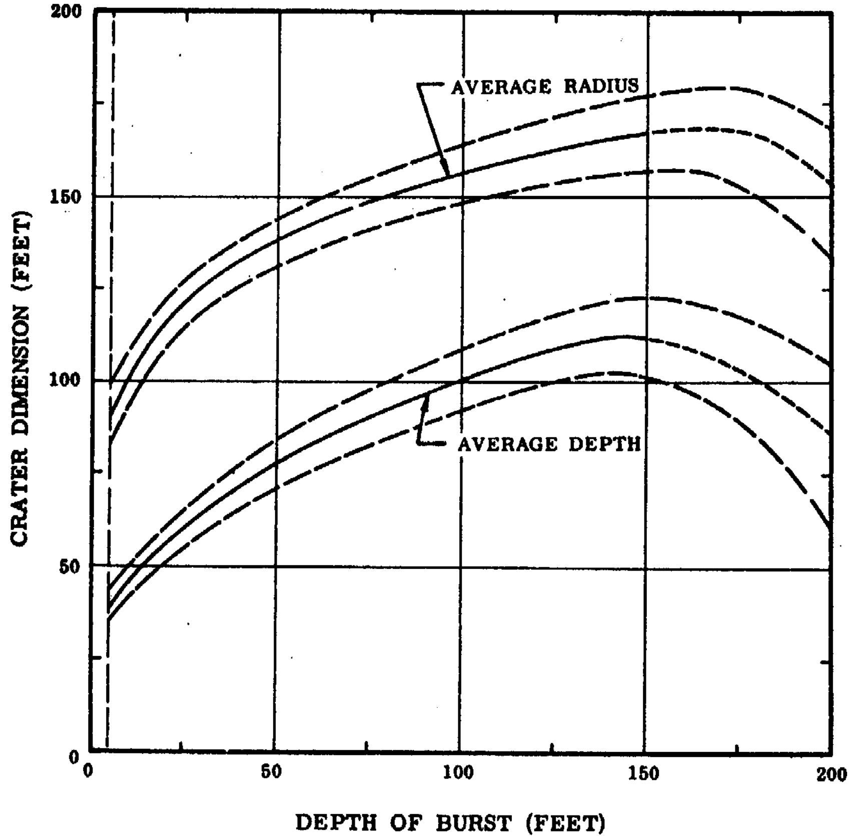

Figure 6.49. Apparent crater radius and depth as function of depth of burst for a 1-kiloton underground explosion in dry soil. (The data are uncertain for scaled depths of burst greater than 150 feet.)

(from Effects of Nuclear Weapons, 1964, pp 293, 295)

Figure 6.81. Dimensions of crater in underwater bursts as function of explosion yield.

The curves in Fig. 6.81 give the depth, diameter, and lip height of the underwater crater as functions of yield. The results are for a burst less than 15 feet deep and for one on the bottom in 50 feet of water for sand, sand and gravel, or soft rock bottom.

For other bottom materials the crater dimensions can be estimated by multiplying the values from Fig. 6.81 by the following factors:

Material	Diameter	Depth	Lip Height
Loess	1.0	1.7	0.7
Clay	1.0	2.3	2.3
Hard Rock	0.7	0.5	0.4
Mud or Muck	0.7	0.4	0.2

EXAMPLE:

GIVEN: A 200 KT weapon detonated in 50 feet of water; the bottom is predominately clay.

FIND: (a) The crater dimensions when the detonation is near the surface of the water.
(b) The crater dimensions when the detonation occurs on the bottom.

SOLUTION: From Fig. 6.81, the crater dimensions for a 200 KT explosion are as follows:

	(a) feet	(b) feet
Diameter	1,000	1,900
Depth	44	120
Lip Height	2.4	14

For a clay bottom, the multiplication factors are 1.0 for the diameter, and 2.3 for both the depth and lip height; hence, the required values are:

	(a) feet	(b) feet	
Diameter (factor 1.0)	1,000	1,900	
Depth (factor 2.3)	100	276	
Lip Height (factor 2.3)	5.5	32	ANSWER

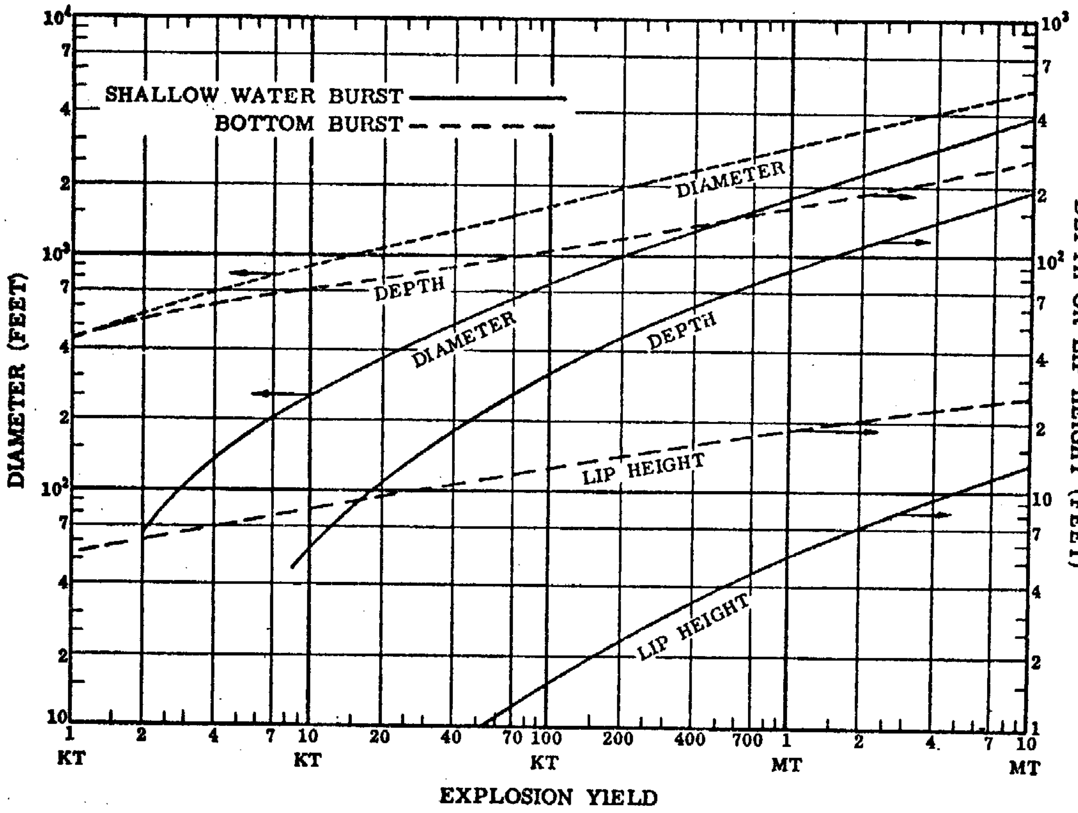

Figure 6.81. Dimensions of crater in underwater bursts as a function of explosion yield.

(from Effects of Nuclear Weapons, 1964, p 313)

Figure 6.79. Maximum wave height in different types of 1-kiloton underwater bursts.

The lower curve in Fig. 6.79 shows the approximate maximum crest-to-trough wave height versus horizontal surface distance for a 1 KT burst in water 85 feet deep. The upper curve is for a 1 KT burst in water more than 400 feet deep, so that the bottom does not affect the mechanism of wave formation.

SCALING:

At a given distance from surface zero, the wave height for an explosion of W kilotons is $W^{\frac{1}{2}}$ times the wave height at this distance from a 1 KT burst in water of the same scaled depth. The scaled depth is $d/W^{\frac{1}{4}}$, where d is the actual depth in feet. For the lower curve in the figure the scaled depth is 85 feet and for the upper curve it is more than 400 feet.

For scaled water depths less than 85 feet, i.e., actual depths less than 85 $W^{\frac{1}{4}}$ feet, the estimated maximum wave height is proportional to the depth of the water.

METHOD:

Wave height is, therefore, scaled as follows:

(1) Calculate scaled depth of water, using

$$d_1 = \frac{d}{W^{\frac{1}{4}}}$$

where, d_1 is scaled depth of water in feet,
d is actual depth of water in feet, and
W is yield in kilotons.

(2) Select appropriate curve in Fig. 6.79 and read off scaled wave height h_1 for actual distance R.

(3) Multiply scaled wave height h_1 by $W^{\frac{1}{2}}$

(a) For deep water (>85 scaled feet) this gives the estimated wave height h.

(b) In shallow water (<85 scaled feet) multiply h from step 3 by

$$\frac{d_1}{85}$$

to obtain the estimated wave height h.

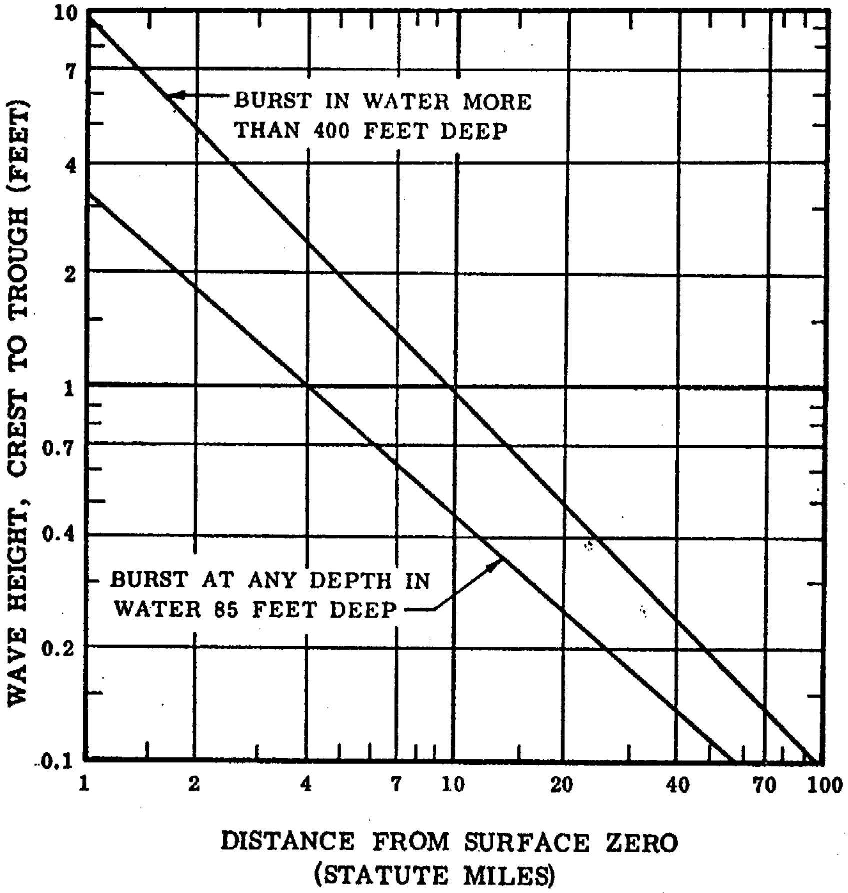

Figure 6.79. Maximum wave height in different types of 1-kiloton underwater bursts.

(from Effects of Nuclear Weapons, 1964, p 311)

SECTION A - BLAST & SHOCK

A-3 TARGET RESPONSE

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TABLE 4.38a

DAMAGE TO TYPES OF STRUCTURES PRIMARILY AFFECTED BY BLAST WAVE OVERPRESSURE DURING THE DIFFRACTION PHASE

Description of structure	Description of damage		
	Severe	Moderate	Light
Multistory reinforced concrete building with reinforced concrete walls, blast resistant design for 30 psi in Mach region from 1 MT; no windows.	Walls shattered, severe frame distortion, incipient collapse.	Walls breached or on the point of being so, frame distorted. Entranceways damaged, doors blown in or jammed, extensive spalling of concrete.	Some cracking of concrete walls and frame.
Multistory reinforced concrete building with concrete walls, small window area; 3 to 8 stories.	Walls shattered, severe frame distortion, incipient collapse.	Exterior walls badly cracked, interior partitions badly cracked or blown down. Structural frame permanently distorted, extensive spalling of concrete.	Windows and doors blown in, interior partitions cracked.
Multistory wall-bearing building, brick apartment house type; up to 3 stories.	Bearing walls collapse, resulting in total collapse of structure.	Exterior walls badly cracked, interior partitions badly cracked or blown down.	Windows and doors blown in, interior partitions cracked.
Multistory wall-bearing building, monumental type; up to 4 stories.	Bearing walls collapse, resulting in collapse of structure supported by these walls; some bearing walls may be shielded enough by intervening walls so that part of the structure may receive only moderate damage.	Exterior walls facing blast badly cracked, interior partitions badly cracked, although toward far end of building damage may be reduced.	Windows and doors blown in, interior partitions cracked.
Wood frame building, house type; 1 or 2 stories.	Frame shattered so that for the most part collapsed.	Wall framing cracked, roof badly damaged, interior partitions blown down.	Windows and doors blown in, interior partitions cracked.

(from Effects of Nuclear Weapons, 1964, p 161)

TABLE 4.38b

DAMAGE TO TYPES OF STRUCTURES PRIMARILY AFFECTED BY DYNAMIC PRESSURE DURING THE DRAG PHASE

Description of structure	Description of damage		
	Severe	Moderate	Light
Light steel frame industrial building, single story, with up to 5 ton crane capacity. Lightweight, low strength walls fail quickly.	Severe distortion or collapse of frame.	Some to major distortion of frame, cranes (if any) not operable until repairs made.	Windows and doors blown in, light siding ripped off.
Heavy steel frame industrial building, single story, with 25–50 ton crane capacity. Lightweight, low strength walls fail quickly.	Severe distortion or collapse of frame.	Some distortion to frame, cranes not operable until repairs made.	Windows and doors blown in, light siding ripped off.
Heavy steel frame industrial building, single story, with 60–100 ton crane capacity. Lightweight, low strength walls fail quickly.	Severe distortion or collapse of frame.	Some distortion to frame, cranes not operable until repairs made.	Windows and doors blown in, light siding ripped off.
Multistory steel frame office type building, 3–10 stories (earthquake resistant construction). Lightweight, low strength walls fail quickly.	Severe frame distortion, incipient collapse.	Frame distorted moderately, interior partitions blown down.	Windows and doors blown in, light siding ripped off, interior partitions cracked.
Multistory steel frame office type building, 3–10 stories (nonearthquake resistant construction) Lightweight, low strength walls fail quickly.	Severe frame distortion, incipient collapse.	Frame distorted moderately, interior partitions blown down.	Windows and doors blown in, light siding ripped off, interior partitions cracked.
Multistory reinforced concrete frame office type building, 3–10 stories (earthquake resistant construction). Lightweight, low strength walls fail quickly.	Severe frame distortion, incipient collapse.	Frame distorted moderately, interior partitions blown down. Some spalling of concrete.	Windows and doors blown in, light siding ripped off, interior partitions cracked.
Multistory reinforced concrete frame office type building, 3–10 stories (nonearthquake resistant construction). Lightweight, low strength walls fail quickly.	Severe frame distortion, incipient collapse.	Frame distorted moderately, interior partitions blown down. Some spalling of concrete.	Windows and doors blown in, light siding ripped off, interior partitions cracked.
Highway truss bridges, spans 150–250 ft.	Total failure of lateral bracing, collapse of bridge.	Some failure of lateral bracing such that bridge capacity is reduced about 50 percent.	Capacity of bridge unchanged, slight distortion of some bridge components.
Railroad truss bridges, spans 150–250 ft.	Total failure of lateral bracing, collapse of bridge.	Some failure of lateral bracing such that bridge capacity is reduced about 50 percent.	Capacity of bridge unchanged, slight distortion of some bridge components.
Highway and railroad truss bridges, spans 250–500 ft.	Total failure of lateral bracing, collapse of bridge.	Some failure of lateral bracing such that bridge capacity is reduced about 50 percent.	Capacity of bridge unchanged, slight distortion of some bridge components.

(from Effects of Nuclear Weapons, 1964, p 162)

TABLE 4.39

CONDITIONS OF FAILURE OF PEAK OVERPRESSURE-SENSITIVE ELEMENTS

Structural element	Failure	Approximate side-on blast overpressure
		psi
Glass windows, large and small	Shattering usually, occasional frame failure	0.5–1.0
Corrugated asbestos siding	Shattering	1.0–2.0
Corrugated steel or aluminum paneling	Connection failure followed by buckling	1.0–2.0
Brick wall panel, 8 in. or 12 in. thick (not reinforced).	Shearing and flexure failures	7.0–8.0
Wood siding panels, standard house constuction.	Usually failure occurs at the main connections allowing a whole panel to be blown in.	1.0–2.0
Concrete or cinder-block wall panels, 8 in. or 12 in. thick (not reinforced).	Shattering of the wall	2.0–3.0

TABLE 4.45

DAMAGE CRITERIA FOR SHALLOW BURIED STRUCTURES

Type of structure	Damage type	Peak over-pressure	Nature of damage
		psi	
Light, corrugated steel arch, surface structure (10-gage corrugated steel with a span of 20–25 ft), central angle of 180° with 5 ft of earth cover at the crown.*	Severe	45–60	Collapse.
	Moderate	40–50	Large deformations of end walls and arch, also major entrance door damage.
	Light	30–40	Damage to ventilation and entrance door.
Buried concrete arch with a 16 ft span and central angle of 180°; 8 in. thick with 4 ft of earth cover at the crown.	Severe	220–280	Collapse.
	Moderate	160–220	Large deformations with considerable cracking and spalling.
	Light	120–160	Cracking of panels, possible entrance door damge.

*In the case of arched structures reinforced with ribs, the collapse pressure is higher depending on the number of ribs.

(from Effects of Nuclear Weapons, 1964, pp 163, 164)

TABLE 4.47

DAMAGE CRITERIA FOR LAND TRANSPORTATION EQUIPMENT

Description of equipment	Damage	Nature of damage
Motor equipment (cars and trucks).	Severe	Gross distortion of frame, large displacements, outside appurtenances (door and hoods) torn off, need rebuilding before use.
	Moderate	Turned over and displaced, badly dented, frames sprung, need major repairs.
	Light	Glass broken, dents in body, possibly turned over, immediately usable.
Railroad rolling stock (box, flat, tank, and gondola cars).	Severe	Car blown from tracks and badly smashed, extensive distortion, some parts usable.
	Moderate	Doors demolished, body damaged, frame distorted, could possibly roll to repair shop.
	Light	Some door and body damage, car can continue in use.
Railroad locomotives (Diesel or steam).	Severe	Overturned, parts blown off, sprung and twisted, major overhaul required.
	Moderate	Probably overturned, can be towed to repair shop after being righted, need major repairs.
	Light	Glass breakage and minor damage to parts, immediately usable.
Construction equipment (bulldozers and graders).	Severe	Extensive distortion of frame amd crushing of sheet metal, extensive damage to tracks and wheels.
	Moderate	Some frame distortion, overturning, track and wheel damage.
	Light	Slight damage to cabs and housing, glass breakage.

TABLE 4.50

DAMAGE CRITERIA FOR PARKED AIRCRAFT

Damage type	Nature of damage	Overpressure	
			psi
Severe	Major (or depot level) maintenance required to restore aircraft to operational status.	Transport airplanes	3
		Light liaison craft	2
		Helicopters	3
Moderate	Field maintenance required to restore aircraft to operational status.	Transport airplanes	2
		Light liaison craft	1
		Helicopters	1.5
Light	Flight of the aircraft not prevented, although performance may be restricted.	Transport airplanes	1
		Light liaison craft	0.5
		Helicopters	0.5

(from Effects of Nuclear Weapons, 1964, pp 166, 167)

TABLE 4.53

DAMAGE CRITERIA FOR SHIPPING FROM AIR BLAST

Damage type	Nature of damage
Severe	The ship is either sunk or is damaged to the extent of requiring rebuilding.
Moderate	The ship is immobilized and requires extensive repairs, especially to shock-sensitive components or their foundations, e.g., propulsive machinery, boilers, and interior equipment.
Light	The ship may still be able to operate, although there will be damage to electronic, electrical, and mechanical equipment.

TABLE 4.55

DAMAGE CRITERIA FOR FORESTS

Damage type	Nature of damage	Equivalent steady wind velocity (*miles per hour*)
Severe	Up to 90 percent of trees blown down; remainder denuded of branches and leaves. (Area impassable to vehicles and very difficult on foot.)	130–140
Moderate	About 30 percent of trees blown down; remainder have some branches and leaves blown off. (Area passable to vehicles only after extensive clearing.)	90–100
Light	Very few trees blown down; some leaves and branches blown off. (Area passable to vehicles.)	60–80

(from Effects of Nuclear Weapons, 1964, p 169)

TABLE 6.69

DAMAGE CRITERIA FOR MODERATELY DEEP UNDERGROUND STRUCTURES

Structural type	Damage type	Distance from surface zero	Nature of damage
Relatively small, heavy well-designed underground structures.	Severe	1¼ apparent crater radii	Collapse.
	Light	2½ apparent crater radii	Slight cracking, severance of brittle external connections.
Relatively long, flexible structures, e.g., buried pipelines, tanks, etc.	Severe	1½ apparent crater radii	Deformation and rupture.
	Moderate	2 apparent crater radii	Slight deformation and rupture.
	Light	2½ to 3 apparent crater radii	Failure of connections.

(from Effects of Nuclear Weapons, 1964, p 300)

Figure 4.58a. Damage-distance relationships for structure of various types.

EXAMPLE 1:

GIVEN: Wood-frame building (Type 1). A 1 MT weapon is burst
(a) at the optimum height,
(b) at the surface.

FIND: The ranges from ground zero for severe and moderate damage.

SOLUTION:

(a) From the point 1, at the right, draw a straight line to 1 MT on the severe damage scale and another to 1 MT on the moderate damage scale. The intersections of these lines with the range scale give the required solutions for the optimum burst height, thus,

Range for severe damage = 29,000 feet
Range for moderate damage = 34,000 feet ANSWER

(b) For a surface burst the respective ranges are three-quarters those obtained above; hence,

Range for severe damage = 29,000 x 3/4 = 22,000 feet
Range for moderate damage = 34,000 x 3/4 = 26,000 feet ANSWER

(The values have been rounded off to two significant figures, since greater precision is not warranted.)

EXAMPLE 2:

GIVEN: A light steel-frame industrial building (Item 8), 2,100 feet from a 10 KT surface burst.

FIND: The nature of the damage to this structure.

SOLUTION:

As this is a surface burst and the data in Fig. 4.58a are for air bursts, the range must be scaled to an air burst equivalent. If surface burst ranges are 3/4 of air burst ranges, it follows that air burst ranges are 4/3 of surface burst ranges; hence the scaled distance in this case would be

$$2{,}100 \times \frac{4}{3} = 2{,}800 \text{ feet}$$

From point 8, at the right, draw straight lines to 10 KT on the severe damage scale and to 10 KT on the moderate damage scale. Note that 2,800 feet on the range scale lies between these lines. The building is beyond the range of severe damage, but within the range of moderate damage, therefore

Moderate damage ANSWER

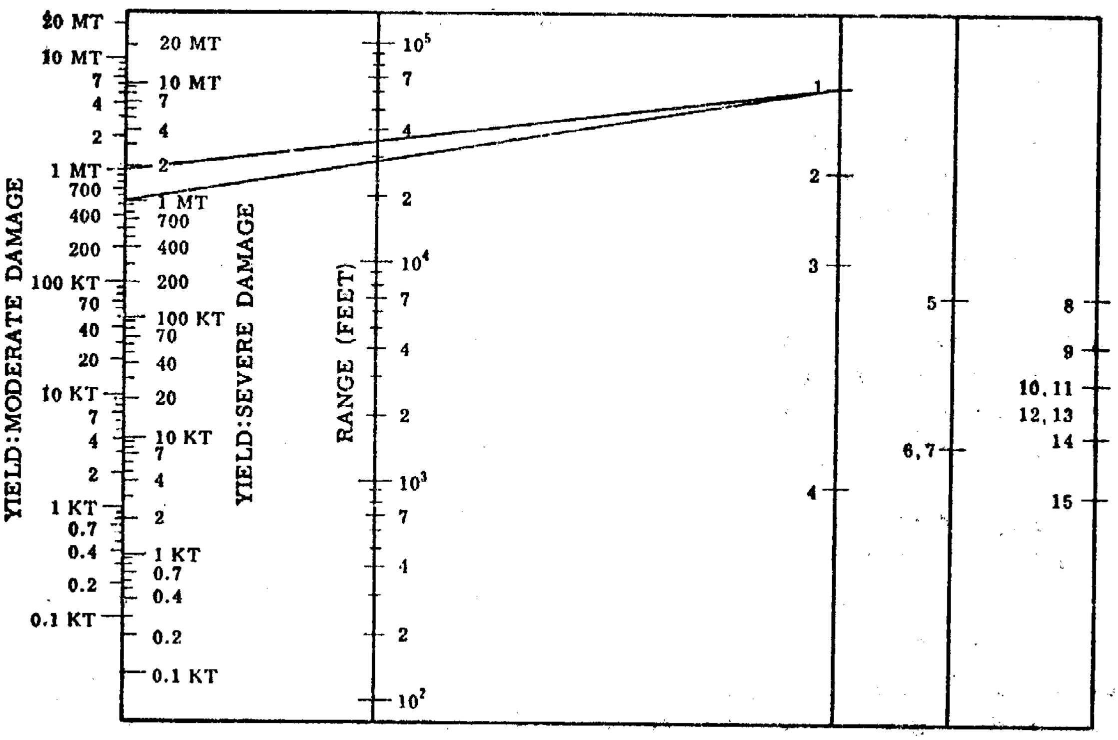

Figure 4.58a. Damage-distance relationships for structures of various types.

Types of Structures

1. Wood-frame building.
2. Multistory, wall-bearing buildings, brick apartment house type.
3. Multistory, wall-bearing buildings, monumental type.
4. Multistory, blast-resistant design, reinforced-concrete buildings.
5. Multistory, reinforced-concrete buildings, with concrete walls and small window area.
6. Highway truss bridges of 150 to 250 foot span (blast normal to longitudinal bridge axis).
7. Multistory, reinforced-concrete, frame office type buildings, earthquake resistant.
8. Light steel-frame industrial buildings.
9. Heavy steel-frame industrial buildings (25 to 50 ton crane).
10. Heavy steel-frame industrial buildings (60 to 100 ton crane).
11. Railroad truss bridges of 150 to 250 foot span (blast normal to longitudinal bridge axis).
12. Multistory, reinforced-concrete frame office type buildings.
13. Highway and railroad truss bridges of 250 to 400 foot spans (blast normal to longitudinal bridge axis).
14. Multistory, steel-frame office type buildings.
15. Multistory, steel-frame office type buildings, earthquake resistant.

For a surface burst multiply the range by three-quarters.

(from Effects of Nuclear Weapons, 1964, pp 172, 173)

Figure 4.58b. Damage-distance relationships for various targets.

EXAMPLE 1:

GIVEN: A transportation type vehicle (Item 3). A 10 KT weapon is burst at
(a) the optimum height,
(b) the surface.

FIND: The ranges from ground zero for severe and moderate damage.

SOLUTION:

(a) Draw straight lines from the points 3_s and 3_m, at the right, to 10 KT on the yield scale at the left. The intersections of these lines with the range scale give the solutions for severe and moderate damage, respectively, for the optimum burst height; thus,

Range for severe damage = 1,900 feet
Range for moderate damage = 2,900 feet ANSWER

(b) For a surface burst the ranges in this case are three-quarters of those obtained above, thus,

Range for severe damage = 1,900 x 3/4 = 1,400 feet
Range for moderate damage = 2,900 x 3/4 = 2,200 feet ANSWER

EXAMPLE 2:

GIVEN: A motorized scrapter (Item 2) located 7,000 feet from a 1 MT surface burst.

FIND: The nature of the damage suffered by this piece of equipment.

SOLUTION:

As this is a surface burst and the data in Fig. 4.58b are for air bursts, the range must be scaled to an air burst equivalent. If surface burst ranges are 3/4 of air burst ranges, it follows that air burst ranges are 4/3 of surface burst ranges, hence the scaled distance in this case will be

$$7,000 \times \frac{4}{3} = 9,300 \text{ feet} \quad (2 \text{ figs.})$$

Draw a straight line from 1 MT on the yield scale, on the left, through 9,300 feet (9.3×10^3) on the range scale to the extreme right hand scale. Note that it intersects the right hand scale between 2_m and 2_s.

The scraper is beyond the range of severe damage (2_s), but within the range of moderate damage, therefore

Moderate damage ANSWER

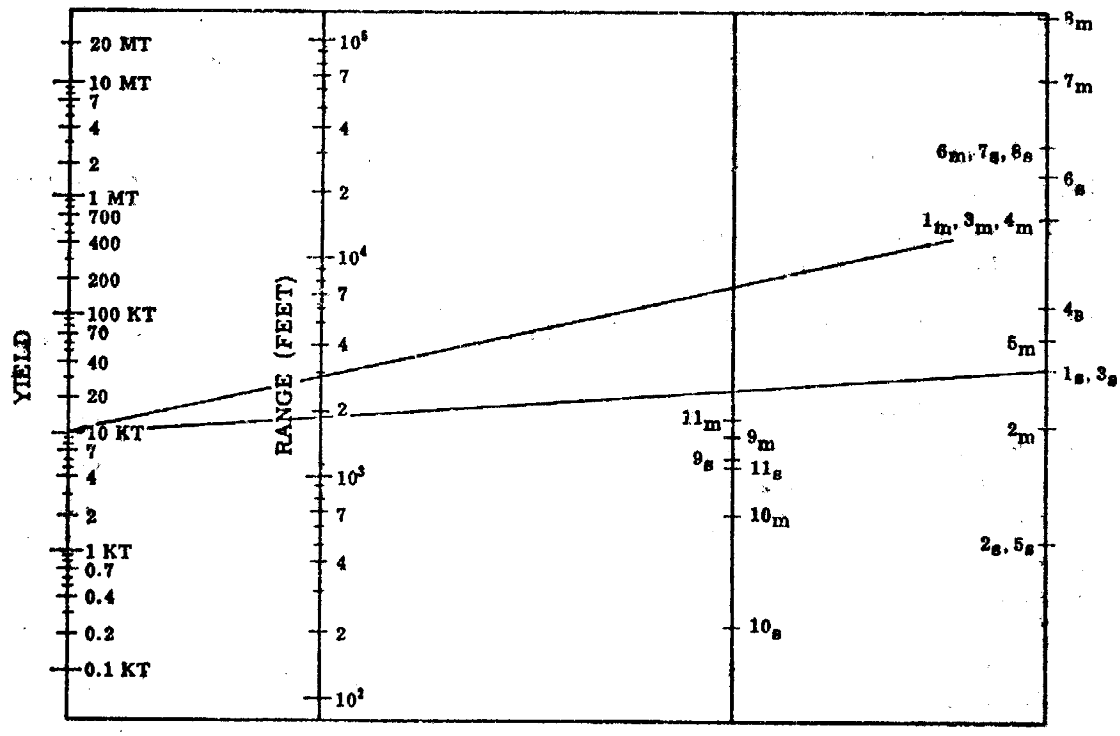

Figure 4.58b. Damage-distance relationships for various targets.

TARGETS

1. Truck mounted engineering equipment (unprotected).
2. Earth moving engineering equipment (unprotected).
3. Transportation vehicles.
4. Boxcars, flatcars, full tank cars, and gondola cars (side-on orientation).
5. Locomotives (side-on orientation).
6. Telephone lines (radial).
7. Telephone lines (transverse).
8. Average forest stand.
9. Boxcars, flatcars, full tank cars, and gondola cars (end-on orientation).
10. Locomotives (end-on orientation).
11. Merchant shipping.

Subscript "m" refers to moderate damage and subscript "s" refers to severe damage.

For a surface burst multiply the range by three-quarters for Items 1 through 8. For Items 9, 10, and 11, the ranges are the same for a surface burst as for the optimum burst height.

(from Effects of Nuclear Weapons, 1964, pp 174, 175)

TABLE 12.22a

DAMAGE RANGES FOR 20-KT TYPICAL AIR BURST

Peak Wind Velocity (mph)	Positive Phase Duration (sec)	Peak Dynamic Pressure (psi)	Peak Over-Pressure (psi)	Range from Ground Zero (MILES)	Range from Ground Zero (1000 FT)	Damage
				2		Light damage to window frames and doors, moderate plaster damage out to about 4 miles; glass breakage possible out to 8 miles.
70	0.95	0.09	2.0		10	
				1.8		Fine kindling fuels: ignited.
79	0.94	0.12	2.3		9	Wood-frame buildings: moderate damage. Smoke stacks: slight damage.
				1.6		
93	0.92	0.17	2.7		8	
				1.4		
112	0.90	0.27	3.2		7	Wood-frame buildings: severe damage. Radio and TV transmitting towers: moderate damage. Wall-bearing, brick building (apartment house type): moderate damage.
				1.2		
139	0.86	0.42	4.2		6	
						Wall-bearing, brick buildings (apartment house type): severe damage.
				1.0		Telephone & power lines: limit of significant damage.
190	0.80	0.80	6.0		5	Multistory, wall-bearing buildings (monumental type): moderate damage. Light steel-frame, industrial buildings: moderate damage.
				0.8		
291	0.72	1.50	10.0		4	
						Multistory, wall-bearing buildings (monumental type): severe damage. Light steel-frame industrial buildings: severe damage. Highway and RR truss bridges: moderate damage.
				0.6		
431	0.63	3.90	16.3		3	
						Multistory, steel-frame building (office type): severe damage. Transportation vehicles: moderate damage. Multistory, blast-resistant designed, reinforced-concrete building: moderate damage.
				0.4		
459	0.54	7.50	22.5		2	Multistory, reinforced-concrete, frame building (office type): severe damage. Multistory, blast-resistant designed, reinforced-concrete buildings: severe damage. All other (above ground) structures: severely damaged or destroyed.
				0.2		
260	0.44	2.70	30.0		1	
				0	0	Ground zero for 20 KT air burst.

(from Effects of Nuclear Weapons, 1964, p 639)

TABLE 12.22b

DAMAGE RANGES FOR 1-MT TYPICAL AIR BURST

Peak Wind Velocity (mph)	Positive Phase Duration (sec)	Peak Dynamic Pressure (psi)	Peak Over-Pressure (psi)	Range from Ground Zero (miles)	Range from Ground Zero (1000 ft)	Damage
				10		Light damage to window frames and doors, moderate plaster damage out to about 15 miles; glass breakage possible out to 30 miles.
44	3.45	0.036	1.2		50	
				9		
51	3.45	0.049	1.4		45	Fine kindling fuels: ignited.
				8		
60	3.44	0.072	1.7		40	
				7		
72	3.43	0.11	2.1		35	Smokestacks: slight damage.
				6		Wood-frame buildings: moderate damage.
89	3.40	0.16	2.6		30	Radio and TV transmitting towers: moderate damage.
				5		Wood-frame buildings: severe damage. Telephone & power lines: limit of significant damage.
117	3.24	0.28	3.5		25	Wall-bearing, brick buildings (apartment house type): moderate damage. Wall-bearing, brick buildings (apartment house type): severe damage.
				4		
177	3.02	0.60	5.5		20	Light steel-frame, industrial buildings: moderate damage. Light steel-frame, industrial buildings: severe damage. Multistory, wall-bearing buildings (monumental type): moderate damage.
				3		
278	2.69	1.40	9.4		15	Multistory, wall-bearing buildings (monumental type): severe damage. Highway and RR truss bridges: moderate damage. Multistory, steel-frame building (office type): severe damage. Transportation vehicles: moderate damage.
				2		
464	2.25	5.22	18.0		10	Multistory, reinforced-concrete frame buildings (office type): severe damage.
				1		Multistory, blast-resistant designed, reinforced-concrete buildings: moderate.
307	1.75	3.60	27.0		5	Multistory, blast-resistant designed, reinforced-concrete buildings: severe. All other (above ground) structures: severely damaged or destroyed.
				0	0	Ground zero for 1 MT air burst.

(from Effects of Nuclear Weapons, 1964, p 640)

SECTION B - THERMAL RADIATION & EFFECTS

B-1 EMISSION, TRANSMISSION & DELIVERY

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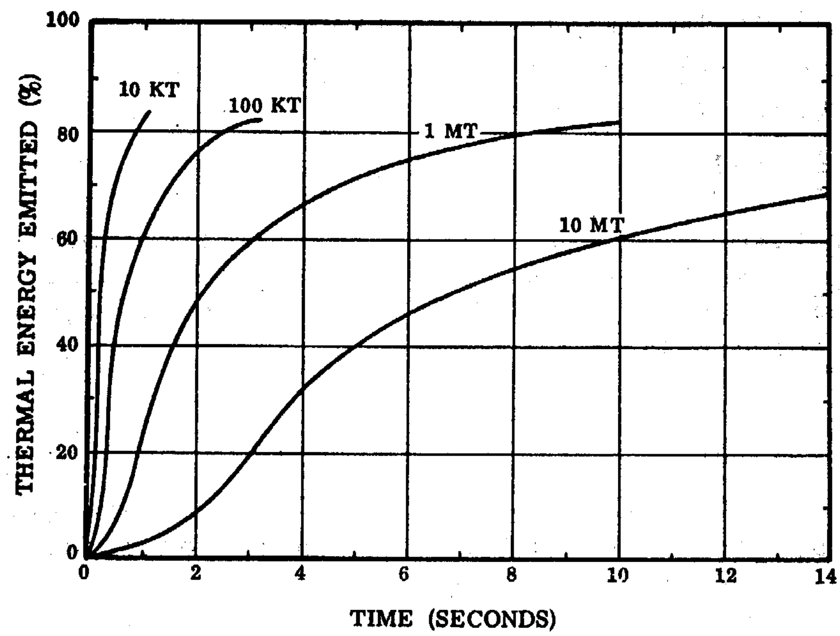

Figure 7.95. Percentage of thermal energy emitted as a function of time for air bursts of various yields.

(from Effects of Nuclear Weapons, 1964, p 360)

Figure 7.91. Scaled fireball power and fraction of thermal energy versus scaled time in second thermal pulse of an air burst.

The curves in Fig. 7.91 show the variation with the scaled time, t/t_{max}, of the scaled fireball power, P/P_{max} (left ordinate) and of the percent of the total thermal energy emitted, E/E_{tot} (right ordinate), in the second thermal pulse of an air burst.

SCALING:

In order to apply the data in Fig. 7.91 to an explosion of any energy, W kilotons, the following expressions are used:

P_{max} $4W^{\frac{1}{2}}$ kilotons per second

t_{max} $0.032\ W^{\frac{1}{2}}$ seconds

E_{tot} $\frac{1}{3}W$ kilotons,

Where t_{max} is the time after explosion for temperature maximum in second thermal pulse, P_{max} is the maximum rate (at t_{max}) of emission of thermal energy from fireball, and E_{tot} is the total thermal energy emitted by fireball in the second pulse.

EXAMPLE:

GIVEN: A 500 KT burst

FIND: (a) The rate of emission of thermal energy,
(b) The amount of thermal energy emitted, at 2 seconds after the explosion.

SOLUTION:

Since W is 500 KT, the value of $W^{\frac{1}{2}}$ is 22.4, so that t_{max} = 0.032 x 22.4 = 0.72 second, and the scaled time at 2 seconds after the explosion is

$$t/t_{max} = \frac{2.0}{0.72} = 2.8$$

(a) From Fig. 7.91, the value of P/P_{max} at this scaled time is 0.26, and since P_{max} = 4 x 22.4 = 90 kilotons per second, it follows that,

$$P = 0.26 \times 90 = 23 \text{ kilotons per second}$$
$$= 23 \times 10^{12} \text{ calories per second} \quad \text{ANSWER}$$

(b) At the scaled time of 2.8, the value of E/E_{tot} from Fig. 7.91 is 58 percent, i.e., 0.58, and

$$E_{tot} = 1/3 \times 500 = 167 \text{ kilotons}$$

Hence,

$$E = 0.58 \times 167 = 97 \text{ kilotons}$$

$$= 97 \times 10^{12} \text{ calories} \quad \text{ANSWER}$$

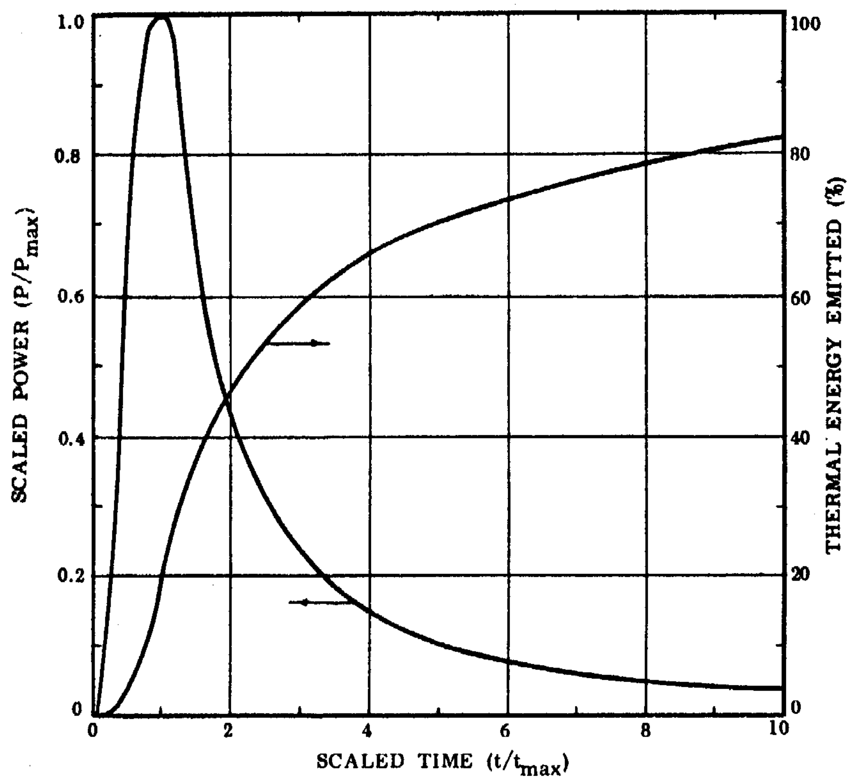

Figure 7.91. Scaled fireball power and fraction of thermal energy versus scaled time in second thermal pulse of an air burst.

(from Effects of Nuclear Weapons, 1964, p 359)

LAND SURFACE	HEIGHT OF BURST in FEET	VISIBILITY in MILES	TRANSMISSION COEFFICIENTS τ_A — HORIZONTAL RANGE IN FEET: 0	10,000	20,000	30,000	40,000	50,000	60,000	70,000	80,000
Bare of snow	5,000	2	0.53	0.20	0.05	0.01					
Bare of snow	30,000	2	0.19	0.16	0.13	0.10	0.07	0.05	0.04	0.02	
Bare of snow	5,000	10	0.90	0.75	0.50	0.32	0.23	0.16	0.10	0.08	0.06
Bare of snow	30,000	10	0.64	0.58	0.54	0.48	0.44	0.38	0.34	0.29	
Snow covered	5,000	10	1.05	1.12	0.80	0.50	0.30	0.20	0.15	0.10	0.06
Snow covered	30,000	10	0.58	0.56	0.51	0.47	0.43	0.37	0.33	0.30	
Snow covered	5,000	50	1.05	1.40	1.40	1.25	1.06	0.92	0.78	0.68	0.63
Snow covered	30,000	50	0.78	0.73	0.68	0.63	0.60	0.57	0.54	0.52	0.49
Bare of snow	0	2	0.58	0.13	0.02	0.01					
Bare of snow	0	10	0.90	0.64	0.35	0.19	0.11	0.07	0.04		
Snow Covered	0	50	1.0	0.90	0.75	0.63	0.54	0.47	0.42	0.38	

Table 4.10.1 TRANSMISSION COEFFICIENTS, τ_A, FOR VARIOUS ATMOSPHERIC AND GROUND COVER CONDITIONS

(from Incendiary Effects of Nuclear Weapons, Canada EMO, 1964, p 16)

GLAZING AND WINDOW SCREEN COMBINATIONS	TRANSMISSION COEFFICIENT τ_w
None	1.00
Single Window Screen	0.67
Single Pane Glazing	0.56
Single Pane Glazing, Single Screen	0.37
Double Pane Glazing	0.31
Double Pane Glazing, Single Screen	0.21

Table 5.11.1 TRANSMISSION COEFFICIENT, τ_w, FOR RADIANT HEAT THROUGH WINDOW GLASS AND MESH SCREEN[2]

(from Incendiary Effects of Nuclear Weapons, Canada EMO, 1964, p 32)

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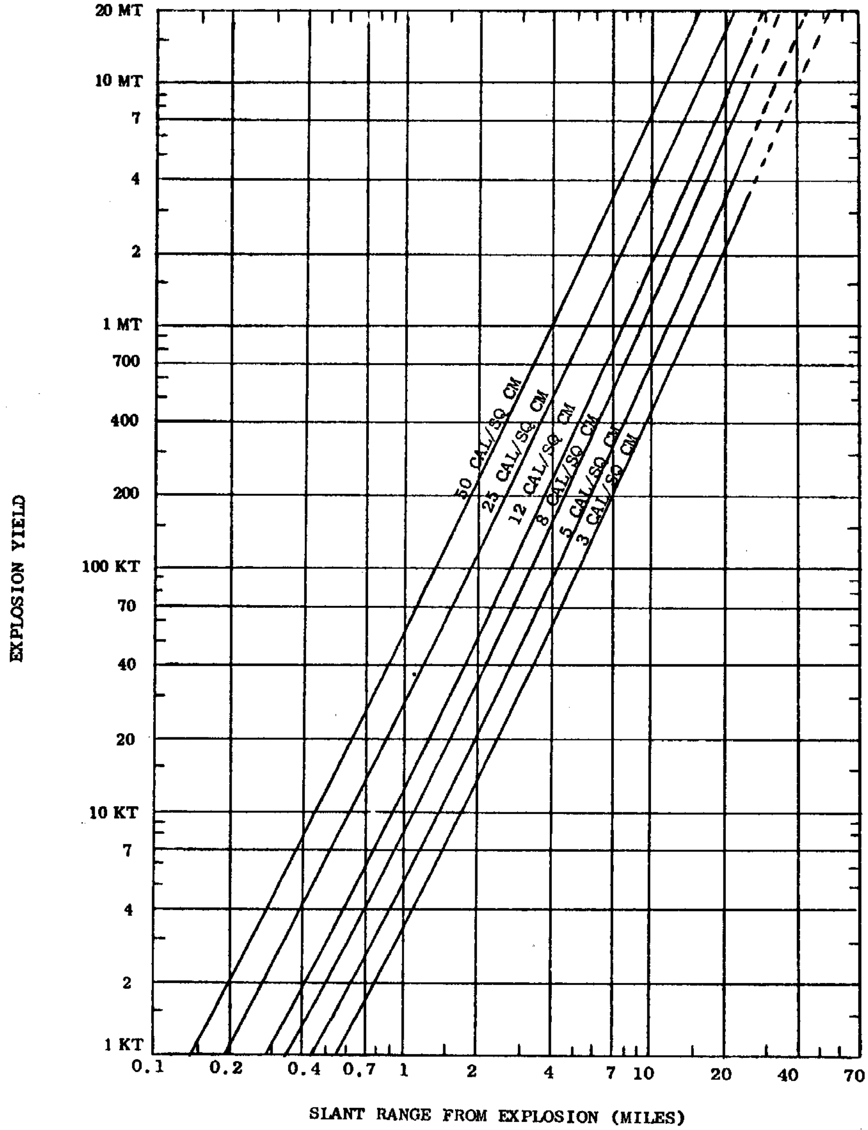

Figure 7.47. Slant ranges for specified radiant exposures as a function of energy yield of an explosion at moderate altitude (less than 20 miles) for 50-mile visibility.

(From Effects of Nuclear Weapons, 1964, p 333)

Figure 7.105. Radiant exposure as a function of slant range from a 1-kiloton air burst for visibilities of 10 miles and 50 miles.

The plot in Fig. 7.105, which is in two parts for convenience of representation, shows the amount of thermal energy (or radiant exposure) in calories per square centimeter received at various distances from a 1 KT air burst for atmospheric visibility between 10 and 50 miles.

SCALING:

The radiant exposure at any specified distance from a *W* KT explosion is *W* times the value for the same distance from a 1 KT burst.

EXAMPLE:

GIVEN: A 100 KT air burst and a visibility of between 10 and 50 miles.

FIND: The radiant exposure received at a distance of 3 miles from the explosion.

SOLUTION:

From Fig. 7.105 the amount of thermal energy received at 3 miles from a 1 KT air burst is between 0.07 and 0.10 calorie per square centimeter. Consequently, the radiant exposure received at 3 miles from a 100 KT air burst is between

$$100 \times 0.07 = 7 \text{ calories per square centimeter}$$

and

$$100 \times 0.10 = 10 \text{ calories per square centimeter}$$ ANSWER

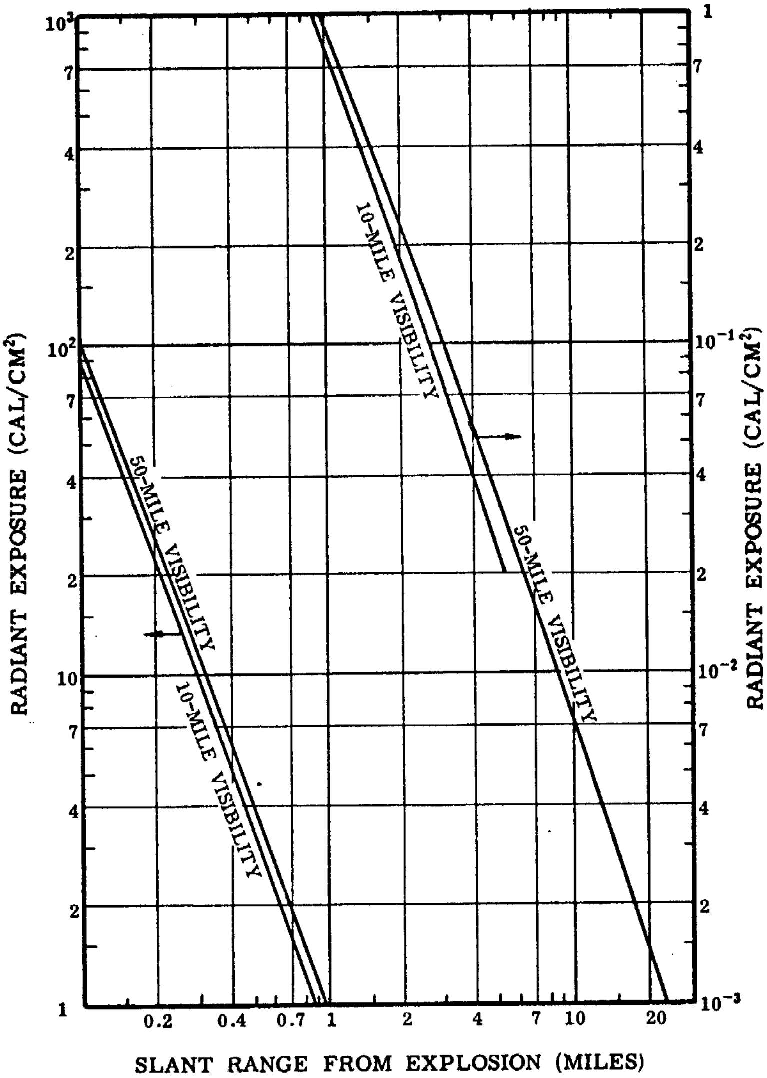

Figure 7.105. Radiant exposure as a function of slant range from a 1-kiloton air burst for visibilities of 10 miles and 50 miles.

(from Effects of Nuclear Weapons, 1964, p 365)

SECTION B - THERMAL RADIATION & EFFECTS

B-2 IGNITION & SPREAD OF FIRES

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TABLE 7.40

APPROXIMATE RADIANT EXPOSURES FOR IGNITION OF FABRICS*

Material	Weight	Ignition exposure** (cal/sq cm)		
	oz/sq yd	40 kilotons	1 megaton	10 megatons
Rayon gabardine (black)	6	9	20	26
Rayon-acetate drapery (wine)	5	9	22	28
Rayon gabardine (gold)#	7	(***)	24	28
Rayon twill lining (black)	3	7	17	25
Rayon twill lining (beige)	3	13	20	28
Acetate-shantung (black)#	3	10	22	35
Cotton chenille bedspread (light blue)#		(***)	11	15
Cotton venetian blind tape, dirty (white)		10	18	22
Cotton muslin oiled window shade (green)	8	7	13	19
Cotton corduroy (brown)	8	11	16	22
Cotton canvas (O.D.)	12	12	18	28
Cotton denim, new (blue)	10	12	27	44
Cotton venetian blind strap (white)#		13	27	31
Cotton shirting (khaki)	3	14	21	28
Cotton heavy draperies (dark colors)	13	15	18	34

*Certain materials listed in previous editions and printings have been deleted.

**The values given are for near sea level detonations of weapons of the yields indicated. Ignition levels (except where marked #) are estimated to be valid within ± 25% under standard laboratory conditions. Under typical field conditions the values listed are estimated to be valid within ± 50% with a greater likelihood of higher rather than lower values. For materials marked #, ignition levels are estimated to be valid within ± 50% under laboratory conditions and within ± 100% under field conditions.

***Data not available or appropriate scaling not known.

TABLE 7.44

APPROXIMATE RADIANT EXPOSURE FOR IGNITION OF HOUSEHOLD MATERIALS AND DRY FOREST FUELS*

Material	Weight	Ignition exposure** (cal/sq cm)		
	oz/sq yd	40 kilotons	1 megaton	10 megatons
Newspaper, shredded	2	4	6	11
Newspaper, dark picture area	2	5	7	12
Newspaper, printed text area	2	6	8	15
Paper, crepe (green)	1	6	9	16
Cotton string scrubbing mop, used (gray)#		10	15	21
Cotton string mop, weathered (cream)#		10	19	26
Matches, paper book, blue head exposed#		11	14	20
Excelsior, ponderosa pine (light yellow)#	2 lb/cu ft	(***)	23	23
Paper, Kraft, single sheet (tan)	3	10	13	20
Paper, bristol board, 3 ply (dark)	10	16	20	40
Paper, Kraft, carton, flat side, used (brown)	16	16	20	40
Paper, bond, typing, new (white)#	2	24	30	50
Dry rotted wood punk (fir)#		4	6	8
Deciduous leaves (beech)		4	6	8
Fine grass (cheat)		5	8	10
Coarse grass (sedge)		6	9	11
Pine needles, brown (ponderosa)		10	16	21

*Certain materials listed in previous editions and printings have been deleted.

**The values given are for near sea level detonations of weapons of the yields indicated. Ignition levels (except where marked #) are estimated to be valid within ±25% under standard laboratory conditions. Under typical field conditions the values listed are estimated to be valid within ±50% with a greater likelihood of higher rather than lower values. For materials marked #, ignition levels are estimated to be valid within ±50% under laboratory conditions and within ±100% under field conditions.

***Data not available or appropriate scaling not known.

(from Effects of Nuclear Weapons, 1964, pp 330, 332)

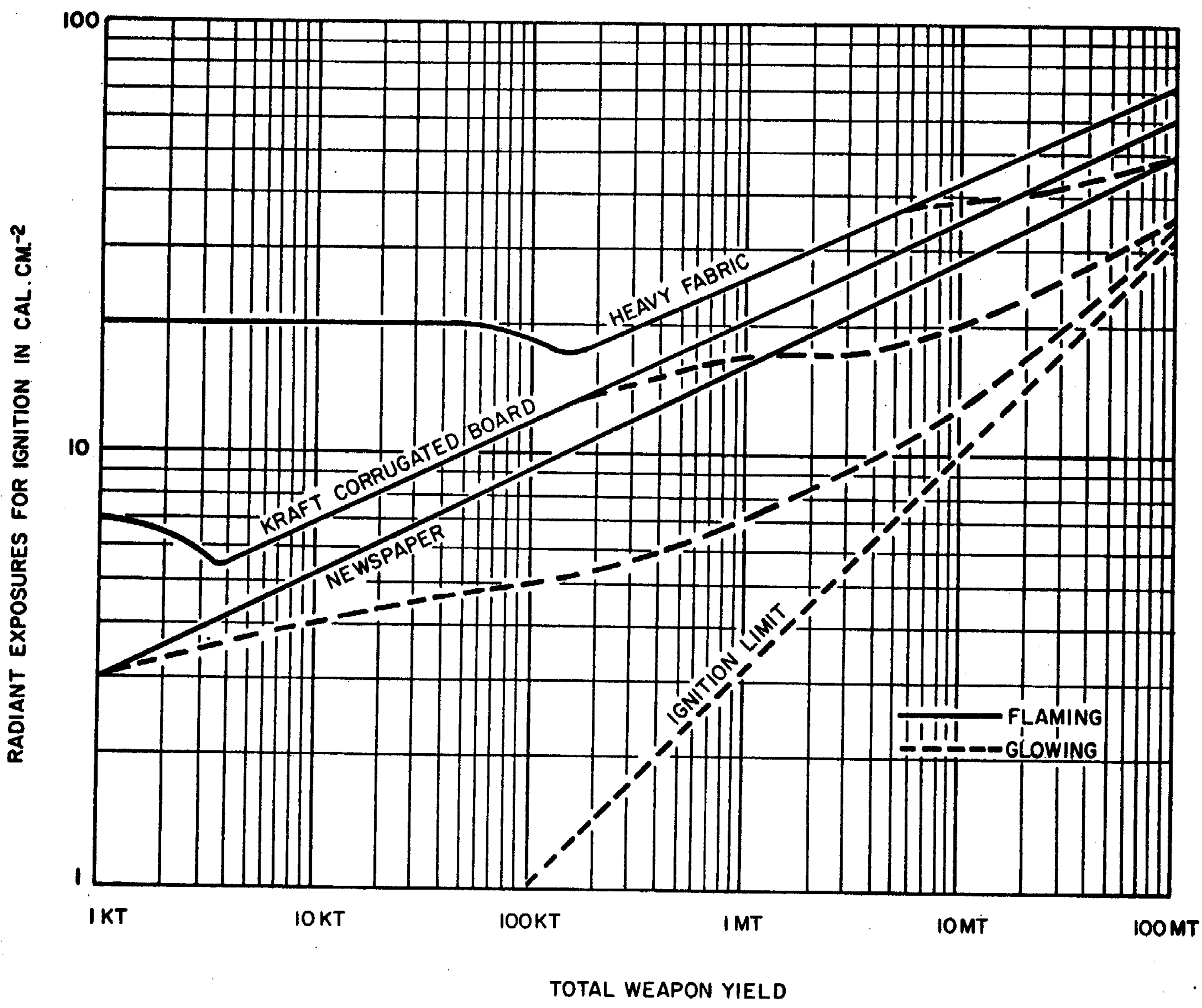

FIG. 7.16.1 RADIANT EXPOSURES TO IGNITE MATERIALS (40 TO 50% RELATIVE HUMIDITY) AS A FUNCTION OF TOTAL WEAPON YIELD, TAKEN FROM "THERMAL RADIATION AND FIRE EFFECTS OF NUCLEAR DETONATIONS" BY S. MARTIN AND A. BROIDO[9]

(from Incendiary Effects of Nuclear Weapons, Canada EMO, 1964, p 45)

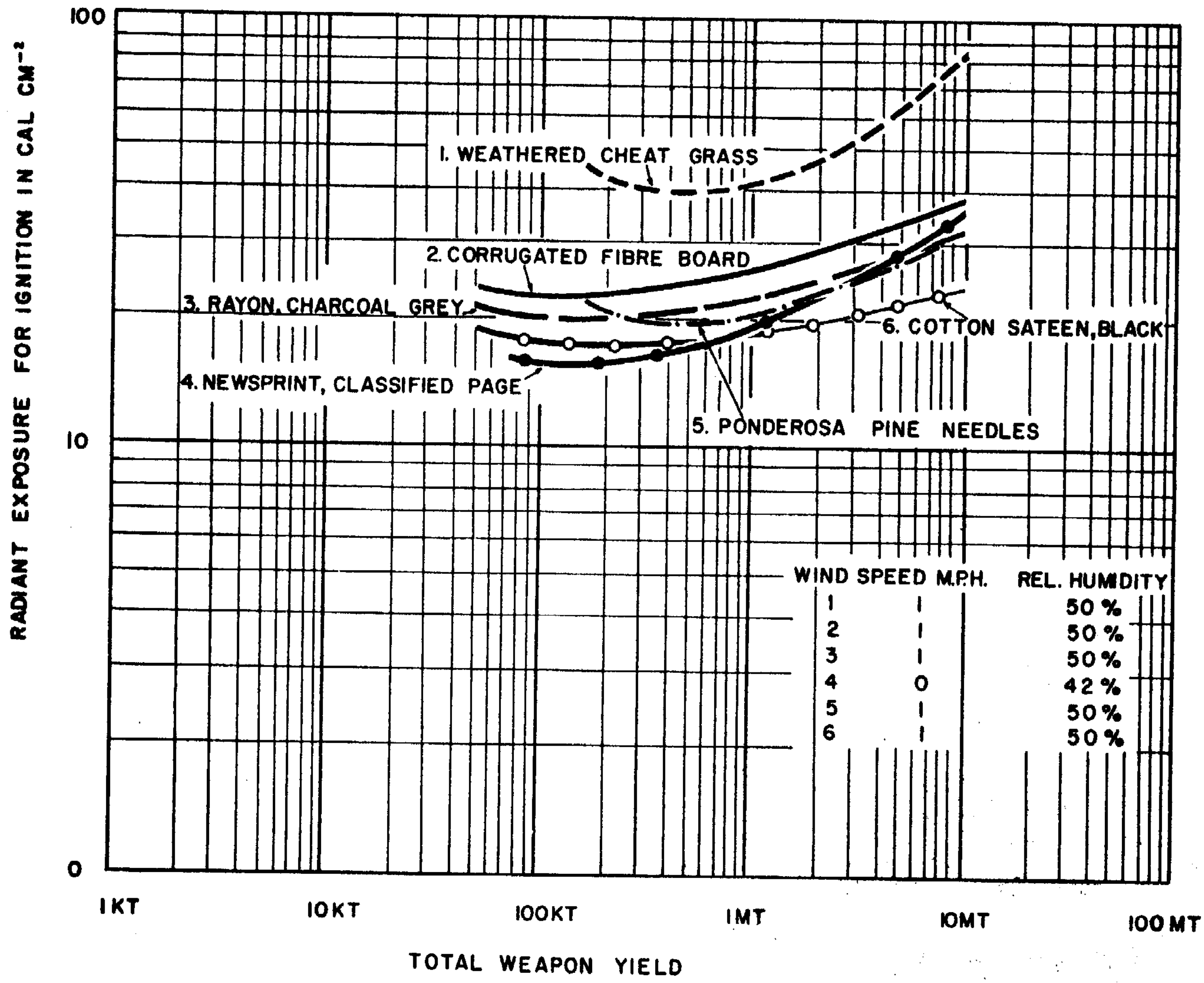

FIG. 7.16.2 RADIANT EXPOSURES TO IGNITE VARIOUS MATERIALS AS A FUNCTION OF TOTAL WEAPON YIELD, TAKEN FROM "TECHNICAL OBJECTIVE AW-7" by J. BRACCIAVENTI & F. DEBOLD, JULY 1960.

(from Incendiary Effects of Nuclear Weapons, Canada EMO, 1964, p 46)

			MAXIMUM DISTANCE FROM GROUND ZERO AT WHICH NEWSPAPER MAY SUSTAIN SPONTANEOUS FLAMING IGNITION. (FEET). TOTAL ENERGY YIELD OF WEAPON = 5 MEGATONS						
			GLAZING AND WINDOW SCREEN COMBINATIONS						
LAND SURFACE	HEIGHT OF BURST in Feet	VISIBILITY in Miles	NONE	SINGLE WINDOW SCREEN	SINGLE PANE GLAZING	SINGLE PANE GLAZING SINGLE SCREEN	DOUBLE PANE GLAZING	DOUBLE PANE GLAZING SINGLE SCREEN	PRIMARY IGNITION
Bare of Snow	5,000	2	21,000	17,000	16,500	14,500	14,000	12,000	Probable
			23,500	21,000	20,000	19,500	19,000	17,000	Possible
Bare of Snow	30,000	2	0	0	0	0	0	0	Probable
			28,000	21.000	18,000	8,000	2,000	0	Possible
Bare of Snow	5,000	10	36,000	31,000	30,000	25,500	24,500	21,500	Probable
			50,000	45,000	43,000	38,000	36,000	31.500	Possible
Bare of Snow	30,000	10	36,000	26,500	23,000	11.000	4,500	0	Probable
			64,000	53,000	50,000	40,000	36,500	27,000	Possible
Snow Covered	5,000	10	39,000	35.000	33,500	30,000	28,000	25,000	Probable
			54,000	48,000	46,000	41,000	39,000	35,500	Possible
Snow Covered	30,000	10	35,000	26,000	21,500	10,000	0	0	Probable
			64,000	53,500	49,000	40,000	36.000	26,500	Possible
Snow Covered	5,000	50	61,000	53,000	50,000	42,000	40,000	34,000	Probable
			90,000±	80,000	76,000	65,000	61,000	54,000	Possible
Snow Covered	30,000	50	44,000	33,000	28,500	18,000	13,000	0	Probable
			82,000	68,000	62,000	49,000	45,000	34,000	Possible
Bare of Snow	0	2	16,500	15,000	14,500	13,000	12.500	11,000	Probable
			19,500	19,000	18,000	17,500	17,000	15,500	Possible
Bare of Snow	0	10	30,000	27,000	26,000	23,000	22,000	19,500	Probable
			41,000	37,500	36,000	32,000	30,000	27,500	Possible
Snow Covered	0	50	48,000	41,000	39,000	33,000	30,000	26,000	Probable
			75,000±	65,000	61,000	52,000	48,500	42,000	Possible

Figure 7.22.1 DISTANCE FROM GROUND ZERO OF A 5 MEGATON TOTAL ENERGY YIELD NUCLEAR WEAPON AT WHICH SPONTANEOUS SUSTAINED FLAMING IGNITION OF NEWSPAPER MAY RESULT UNDER VARYING CONDITIONS OF ALTITUDE OF DETONATION, LAND SURFACE COVER, VISIBILITY AND WINDOW GLAZING AND SCREENING.

(from Incendiary Effects of Nuclear Weapons, Canada EMO, 1964, p 52)

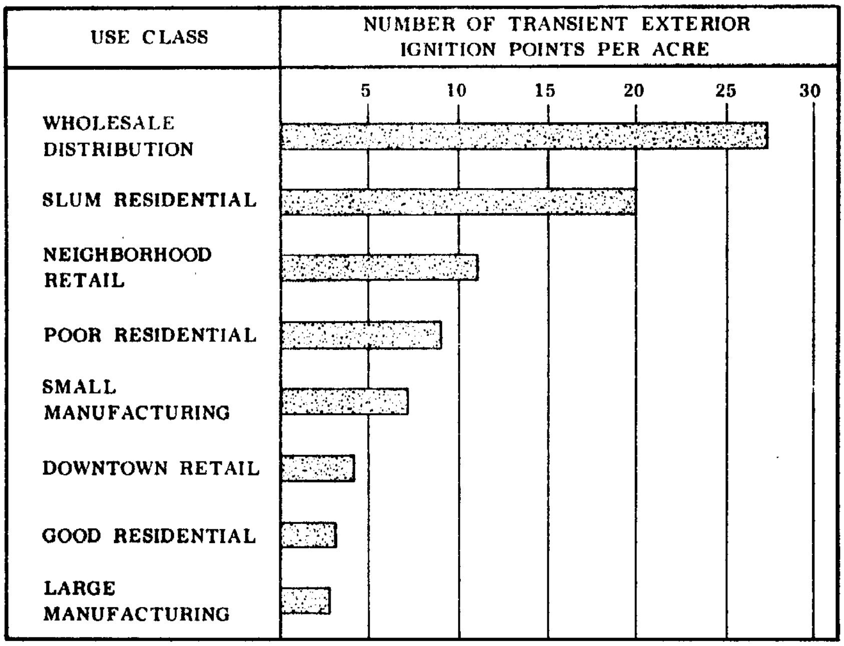

Figure 7.55. Frequency of exterior ignition points for various areas in a city

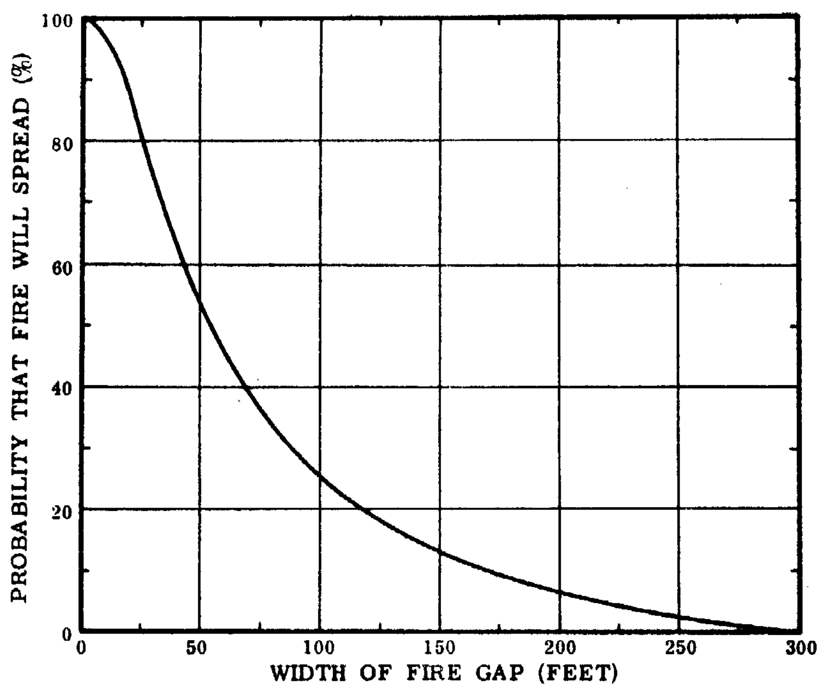

Figure 7.62. Width of gap and probability of fire spread.

(from Effects of Nuclear Weapons, 1964, pp 341, 344)

SECTION B - THERMAL RADIATION & EFFECTS

B-3 SKIN BURNS

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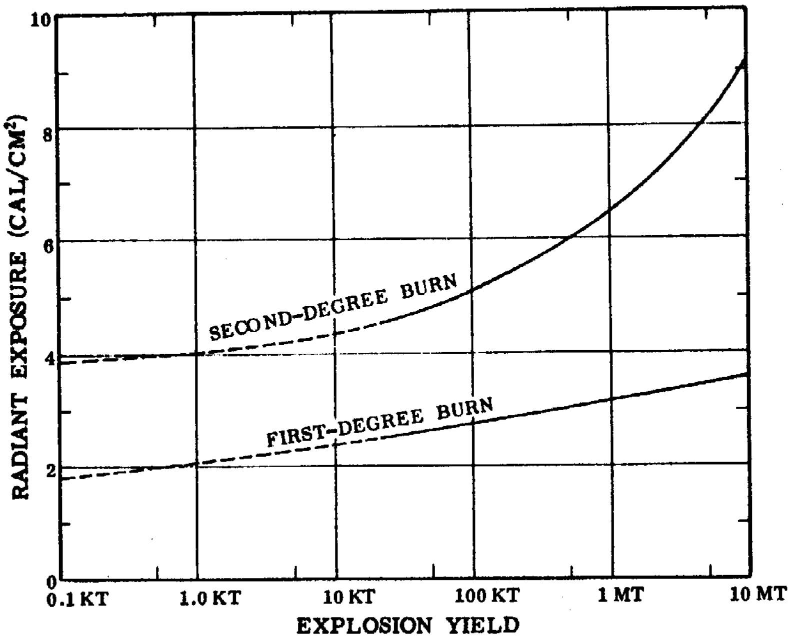

Figure 11.61. Radiant exposures required to produce first- and second-degree burns as a function of total energy yield.

(from Effects of Nuclear Weapons, 1964, p 571)

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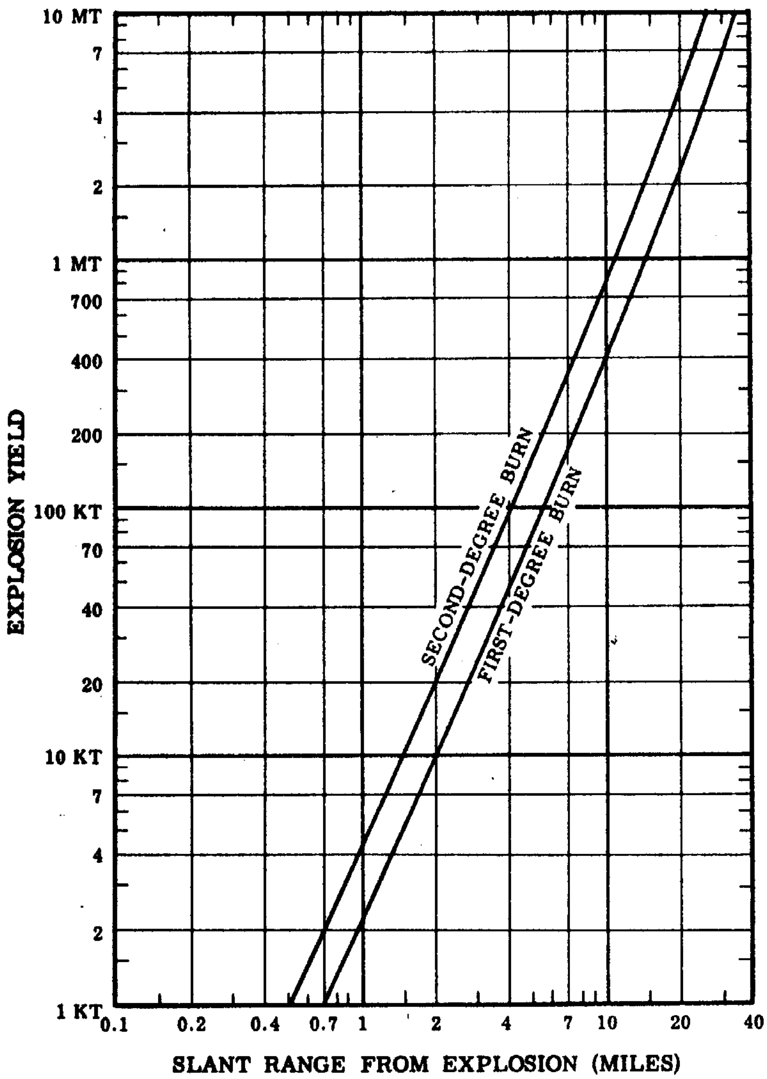

Figure 11.63. Ranges for first- and second-degree burns as a function of the total energy yield.

(from Effects of Nuclear Weapons, 1964, p 573)

SECTION C - INITIAL NUCLEAR RADIATION

C-1 GAMMA

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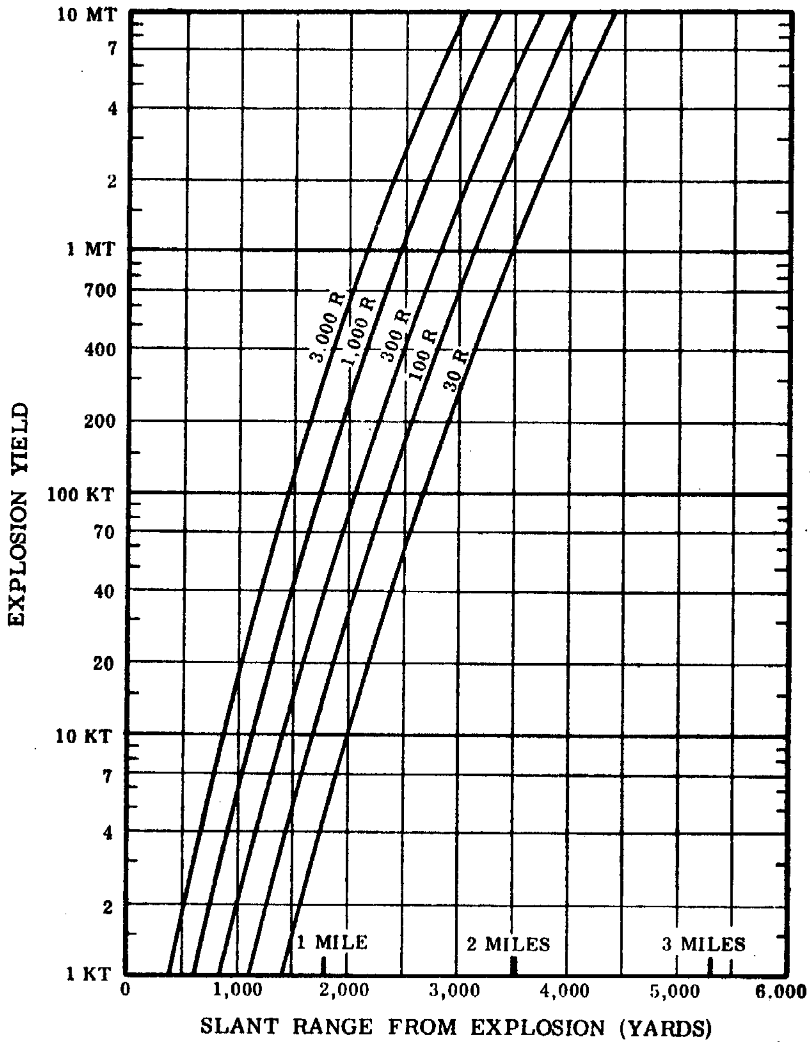

Figure 8.31. Slant ranges for specified initial gamma-ray doses as function of energy yield of the explosion.

(from Effects of Nuclear Weapons, 1964, p 380)

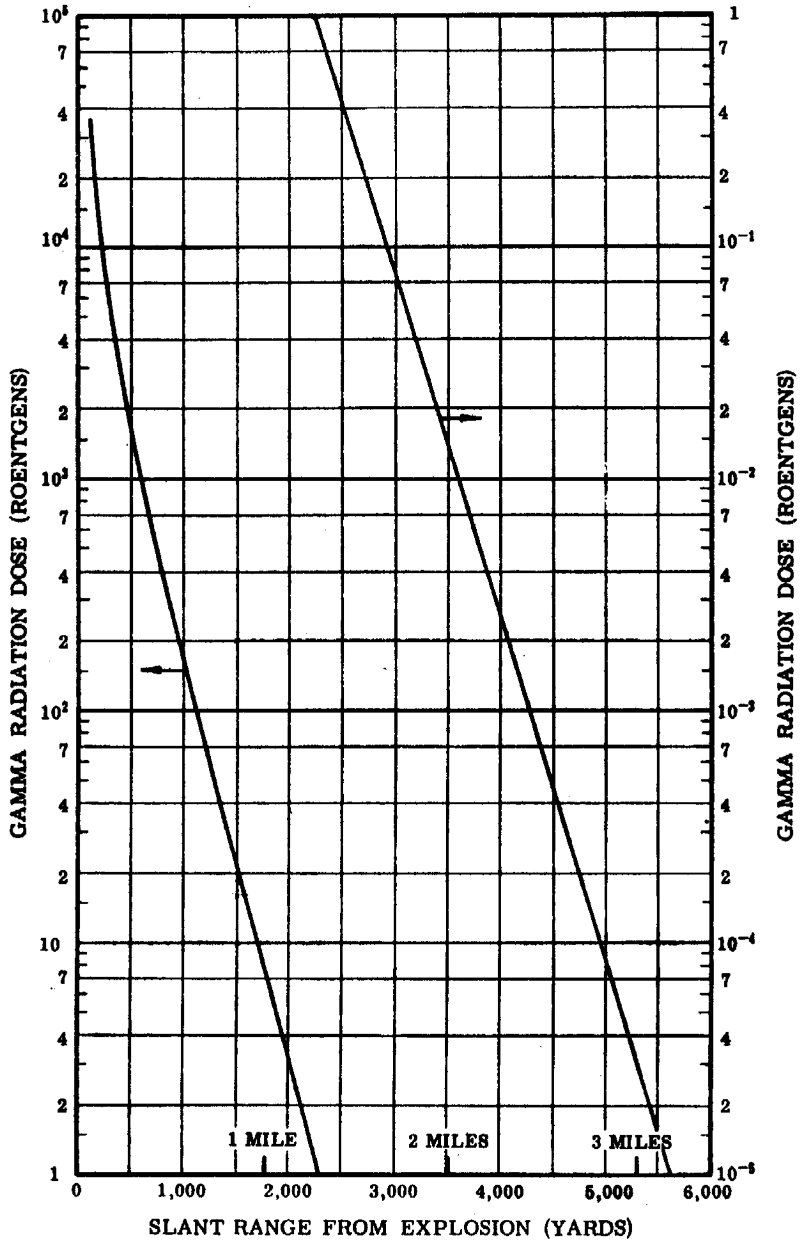

Figure 8.27a. Initial gamma-radiation dose as function of slant range from explosion for 1-kiloton air burst, based on 0.9 sea-level air density.

(from Effects of Nuclear Weapons, 1964, p 377)

The gamma-radiation exposure doses at known distances from explosions of different energy yields have been measured at a number of nuclear test explosions. The results obtained from air bursts are summarized in the form of two graphs: the first (Fig. 8.27a) shows the dependance of the initial gamma-ray dose on the actual distance (slant range) from a 1-kiloton explosion; the second (Fig. 8.27b) gives the

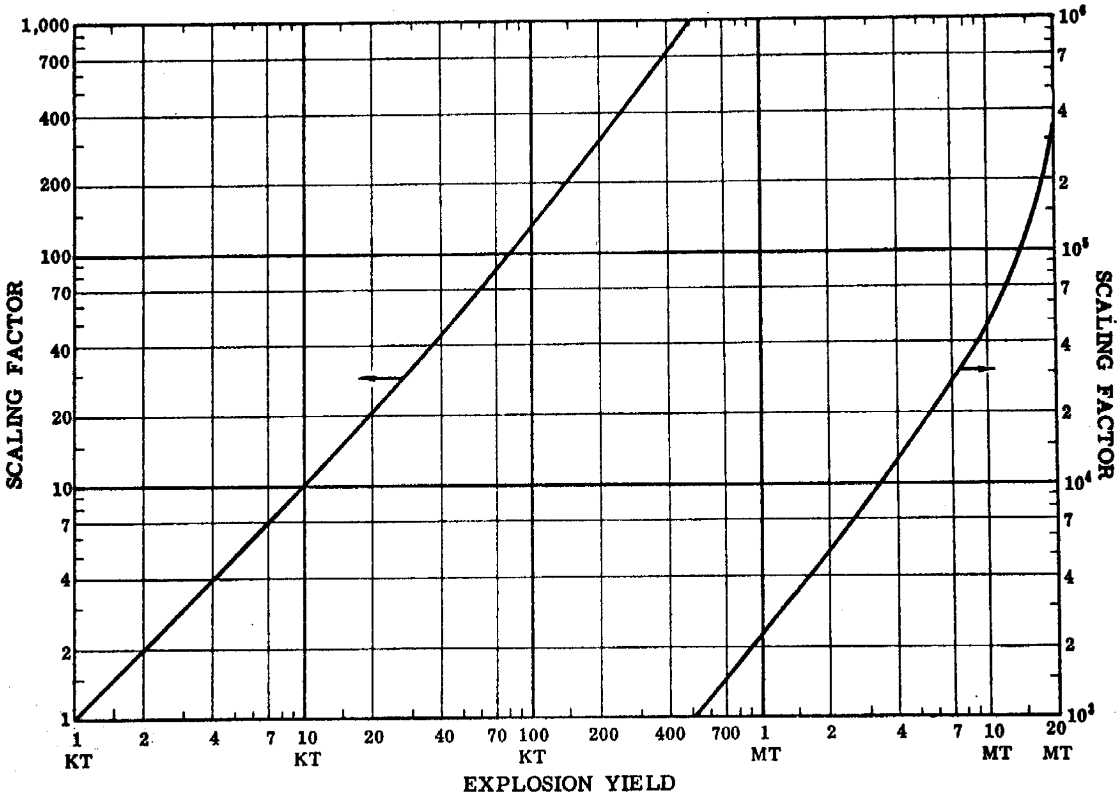

Figure 8.27b. Scaling factor for initial gamma-radiation dose.

(from Effects of Nuclear Weapons, 1964, p 378)

scaling factor to be used to determine the dose at the same slant range from an explosion of any specific energy yield up to 20 megatons*.

EXAMPLE:

GIVEN: 100-kiloton air burst.

FIND: Initial gamma-radiation dose at a distance of 1,700 yards.

SOLUTION:

From Fig. 8.27a, the exposure dose at this distance from a 1 KT air burst is 10 roentgens.

From Fig. 8.27b, the scaling factor for 100 KT is 120.

Hence, the gamma dose in this case is

10 x 120 = 1,200 roentgens ANSWER

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* See ENW, para. 8.27 and footnote.

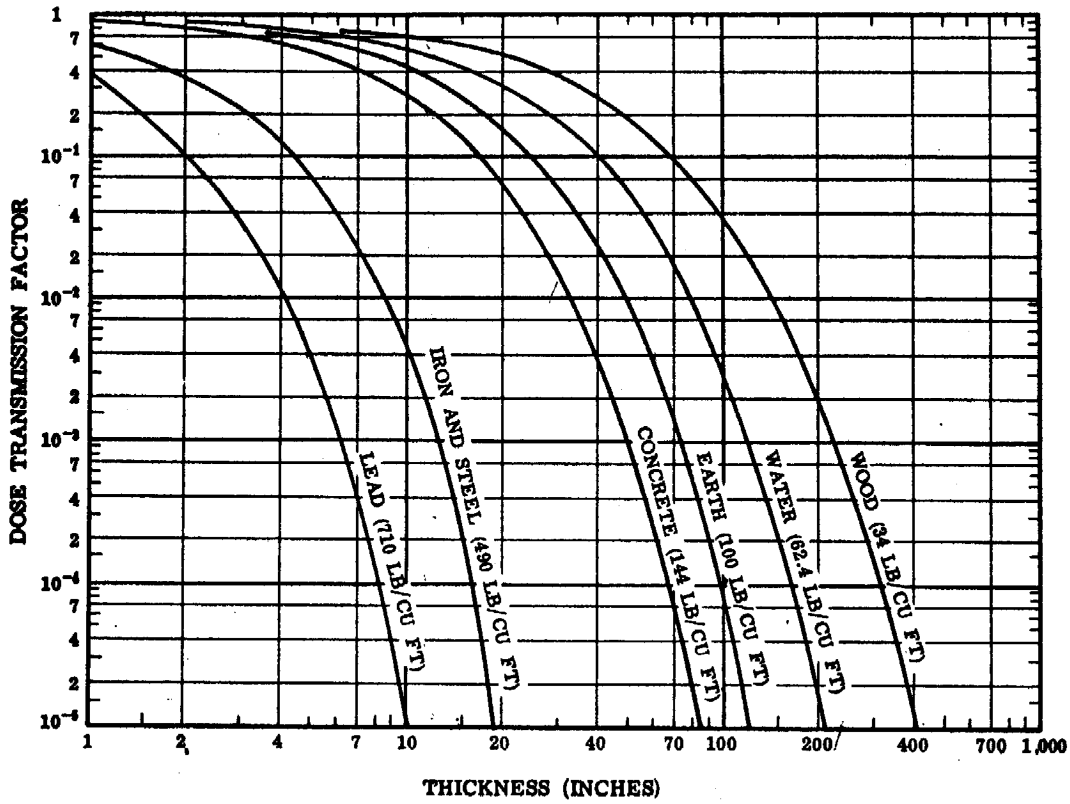

Figure 8.38. Dose transmission factors for initial gamma radiations of various materials as function of thickness.

(from Effects of Nuclear Weapons, 1964, p 384)

SECTION C - INITIAL NUCLEAR RADIATION

C-2 COMBINED NEUTRON & GAMMA

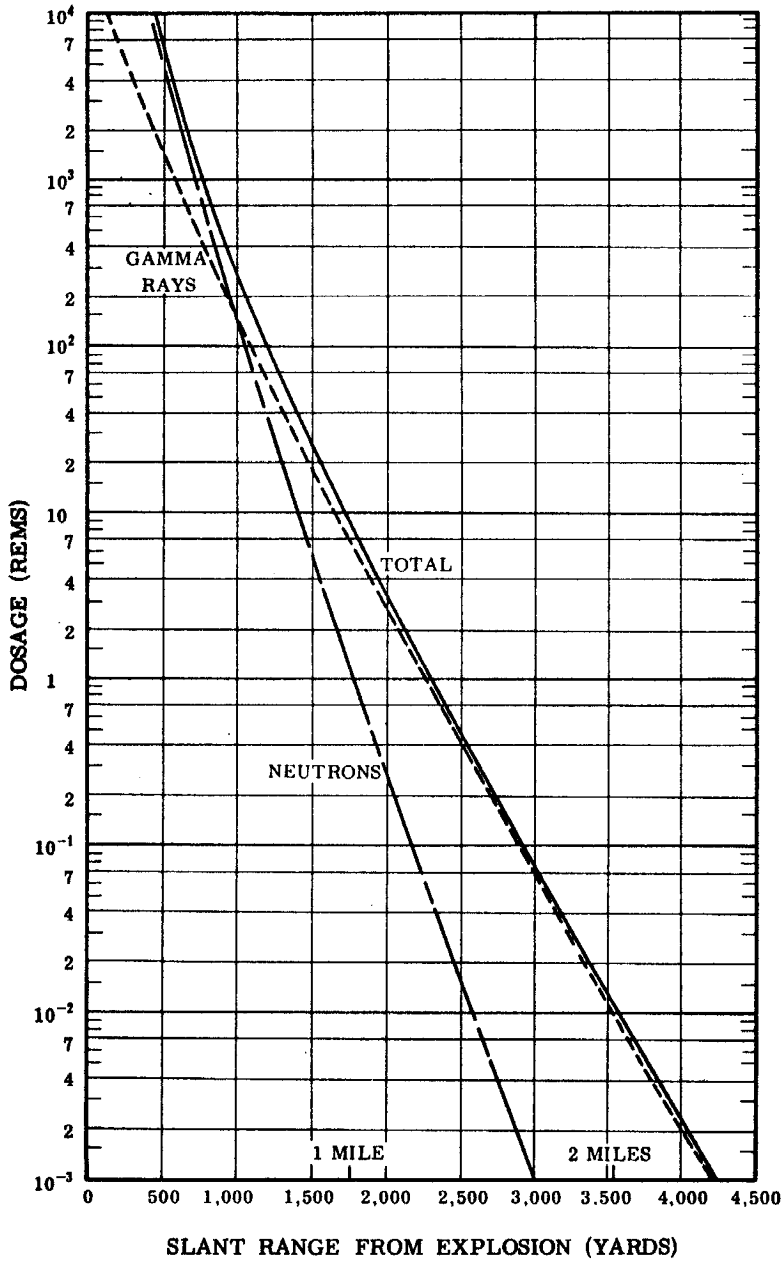

Figure 11.91. Initial gamma-ray and neutron doses as a function of range for a 1-kiloton air burst.

(from Effects of Nuclear Weapons, 1964, p 583)

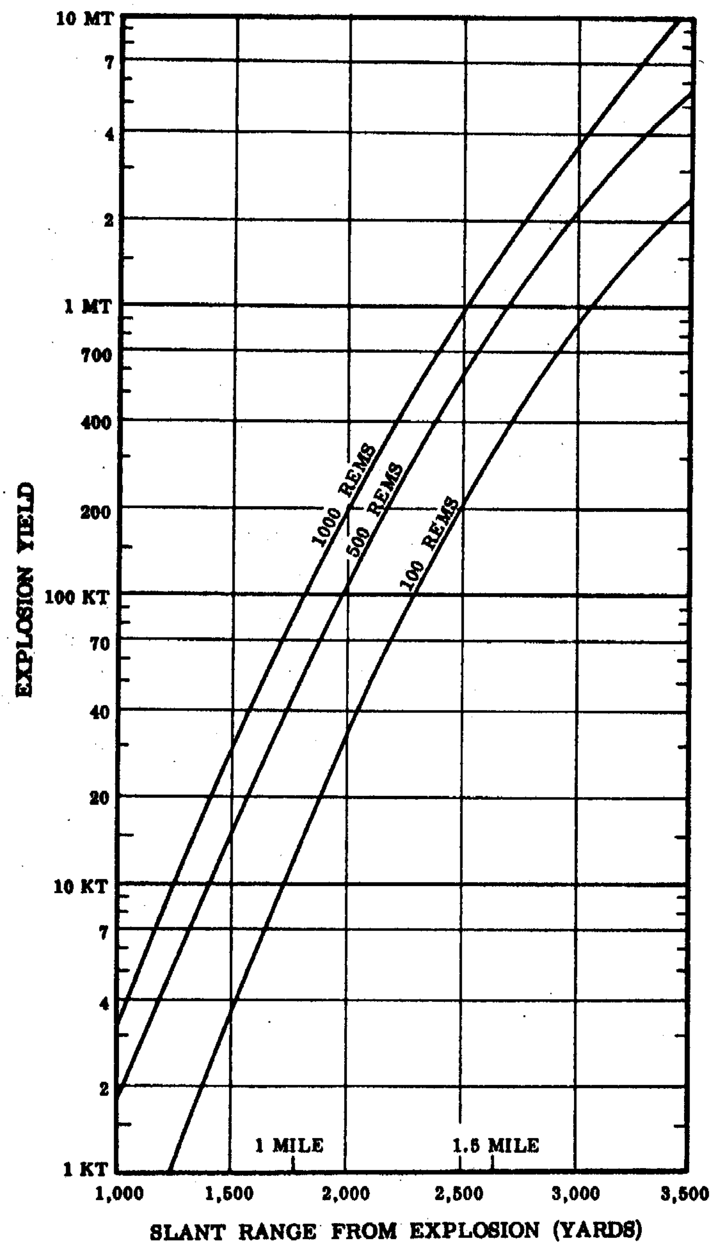

Figure 11.93. Ranges for total doses of 100, 500, and 1,000 rems of initial nuclear radiation as a function of the energy yield.

(from Effects of Nuclear Weapons, 1964, p 584)

SECTION D - RESIDUAL NUCLEAR RADIATION & FALLOUT

D-1 HEIGHT OF BURST FOR EARLY FALLOUT

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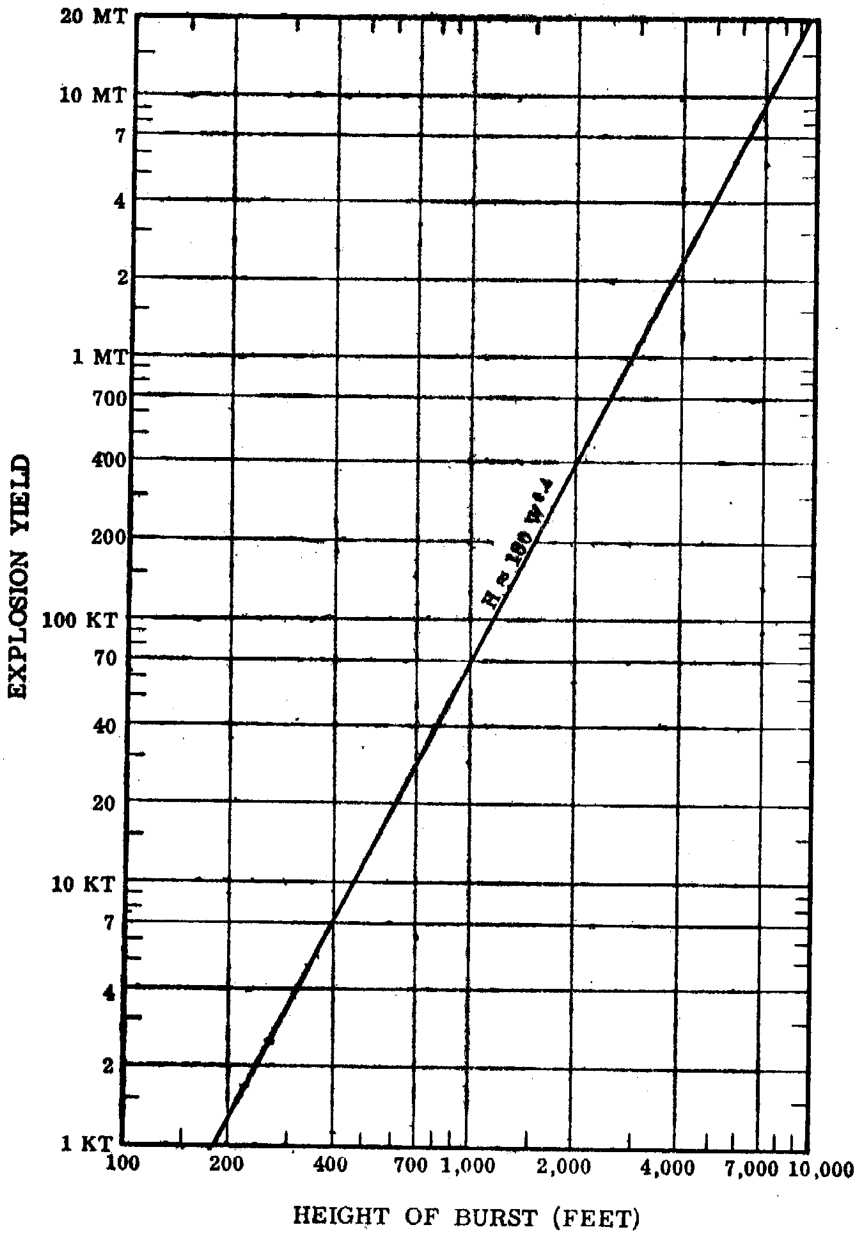

Figure 2.118. Approximate maximum height of burst for appreciable local fallout.

(from Effects of Nuclear Weapons, 1964, p 79)

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SECTION D - RESIDUAL NUCLEAR RADIATION & FALLOUT

D-2 DOSE RATE

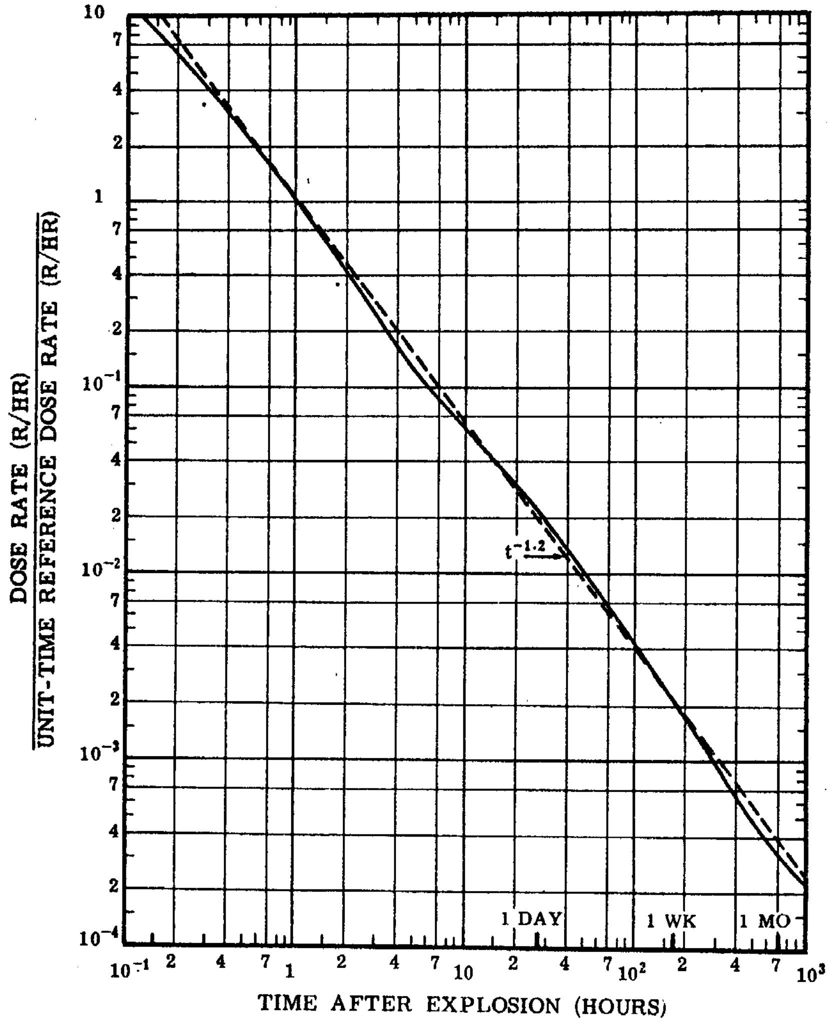


Figure 9.16a. Dependence of dose rate from early fallout upon time after explosion.

(from Effects of Nuclear Weapons, 1964, p 419)

Information concerning the decrease of dose rate in the early fallout can be obtained from the continuous curve in Figs. 9.16a and b, in which the ration of the approximate exposure dose rate (in R/hr) at any time after burst to a convenient reference value, called the "unit-time reference dose rate", is plotted against time in hours.

EXAMPLE: Suppose that at a given location, the fallout commences at 5 hours after the explosion, and that at 15 hours, when the fallout has ceased to descend, the observed dose rate is 4 R/hr. From the curve in Fig. 9.16a, it is seen that at 15 hours after the explosion the ration of the actual dose rate to the reference value is 0.04; hence, the reference dose rate must be 4.0/0.04 = 100 R/hr. By means of this reference value and the decay curves in Figs. 9.16a and b, it is possible to estimate the actual dose rate at the place under consideration at any time after fallout is complete. Thus, if the value is required at 24 hours after the explosion, Fig. 9.16a is entered at

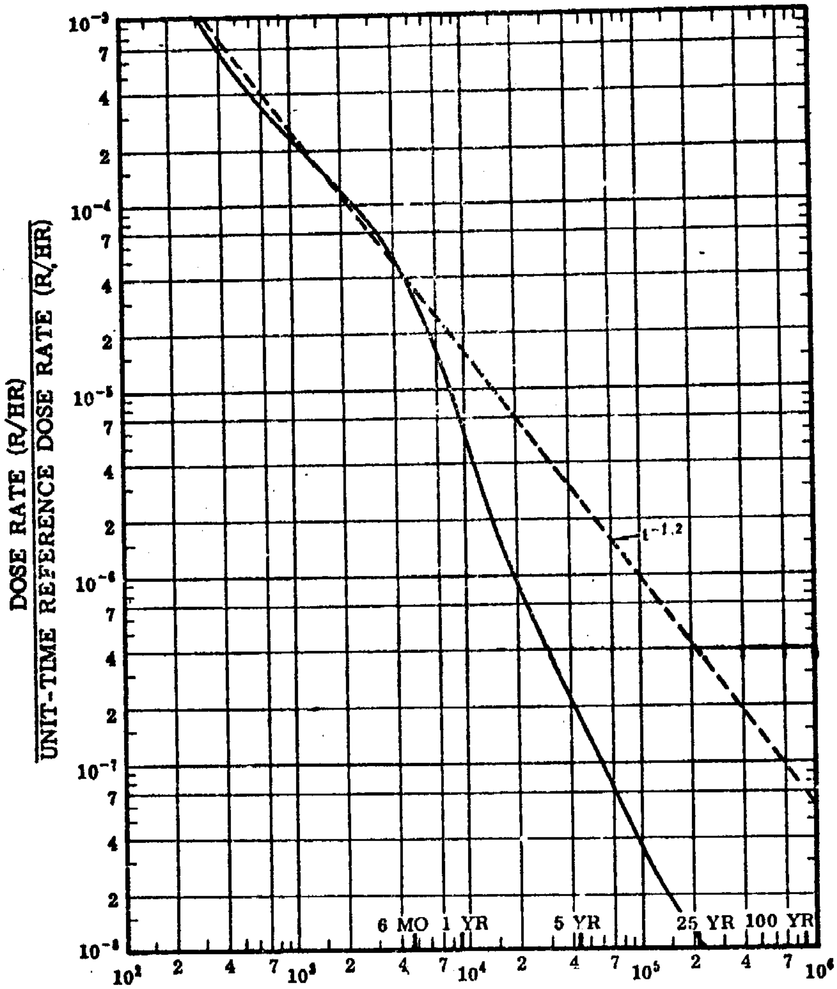


Figure 9.16b. Dependence of dose rate from early fallout upon time after explosion.

(from Effects of Nuclear Weapons, 1964, p 420)

the point representing 24 hours on the horizontal scale. Moving upward until the plotted (continuous) line is reached, it is seen that the required dose rate is 0.023 multiplied by the unit-time reference dose rate, i.e., 0.023 x 100 = 2.3 R/hr.

If the dose rate at any time is known, the value at any other time can be estimated.

EXAMPLE: Suppose the dose rate at 3 hours is 50 R/hr; what would be the value at 18 hours? The respective ratios, as given in Fig. 9.16a, are 0.23 and 0.33, with respect to the unit-time reference dose rate. Hence, the dose rate at 18 hours after the explosion is

$$50 \times \frac{0.033}{0.23} = 7.2 \text{ roentgens per hour.}$$

Figure 9.25. Nomograph for calculation of approximate dose rates from early fallout.

The nomograph in Fig. 9.25 gives an approximate relationship between the dose rate at any time after the explosion and the unit-time reference value. If the dose rate at any time is known, that at any other time can be derived from the figure. Alternately, the time after the explosion at which a specific dose rate is attained can be determined approximately.

EXAMPLE:

GIVEN: *THE RADIATION* dose rate due to fallout at a certain location is 8 roentgens per hour at 6 hours after a nuclear explosion.

FIND:

a. The dose rate at 24 hours after the burst.
b. The time after the explosion at which the dose rate is 1 roentgen per hour.

SOLUTION:

Using a straight edge, join the point representing 8 roentgens per hour on the left scale to the time 6 hours on the right scale. The straight line intersects the middle scale at 70 roentgens per hour; this is the unit-time reference value of the dose rate.

a. Using the straight edge, connect this reference point (70 R/hr) with that representing 24 hours after the explosion on the right scale, and extend the line to read the corresponding dose rate on the left scale, i.e.,

1.5 roentgens per hour. ANSWER

b. Extend the straight line joining the dose rate of 1 R/hr on the left scale to the reference value of 70 R/hr on the middle scale out to the right scale.

This is intersected at 34 hours. ANSWER

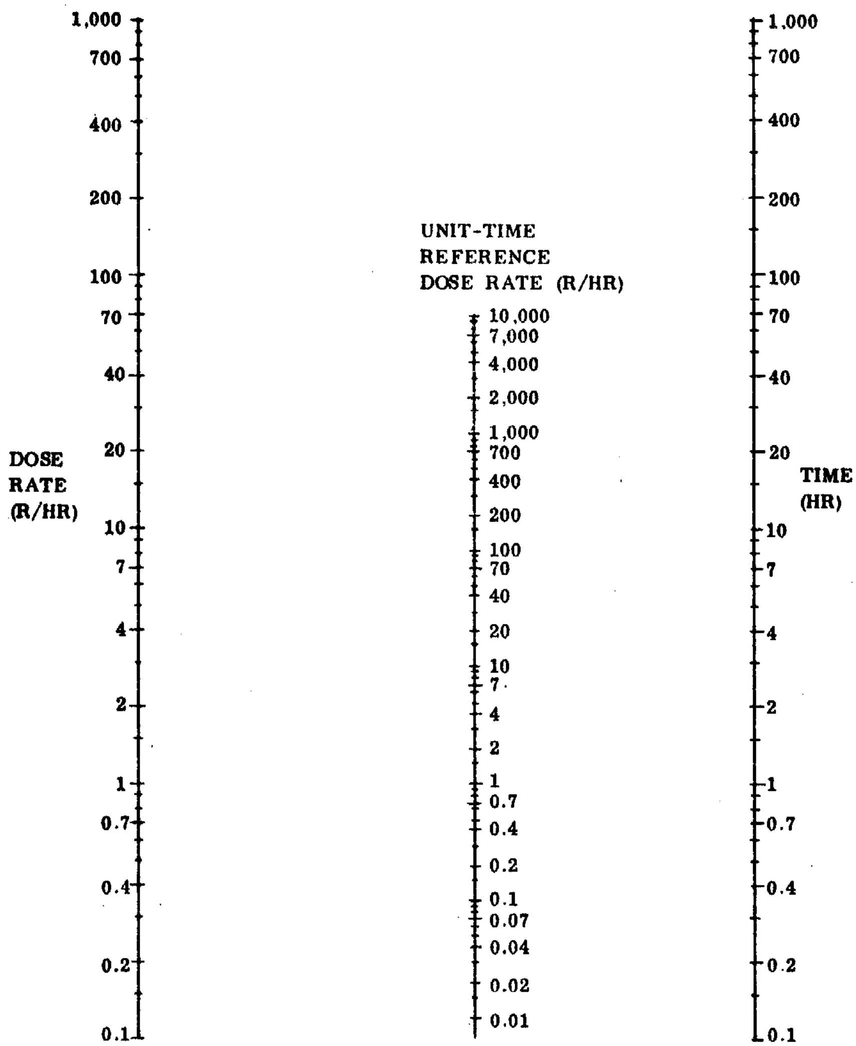


Figure 9.25. Nomograph for calculation of approximate dose rates from early fallout.

(from Effects of Nuclear Weapons, 1964, p 427)

SECTION D - RESIDUAL NUCLEAR RADIATION & FALLOUT

D-3 TOTAL DOSE

Entry Time - Stay Time - Total Dose Nomogram

EXAMPLE 1: (total dose)

GIVEN: The dose rate in an area at H + 8 is 10 R/hr.

FIND: The total dose received if a person enters this area at H + 10 and remains for four hours.

SOLUTION:

Find the dose rate at H + 1 (120 R/hr) as described in Section D-2. Using a straight edge, connect four hours on the "Stay Time" scale with 10 hours on the "Entry Time" scale. Find .21 on the "D/R_1" scale. Connect .21 on this scale with 120 R/hr on the "Dose Rate at H + 1" scale. Read the answer from the "Total Dose" scale:

25 R ANSWER

EXAMPLE 2: (entry time)

GIVEN: Dose rate in an area at H + 10 is 12 R/hr. Stay time is 8 hours and the mission dose is established at 50 R.

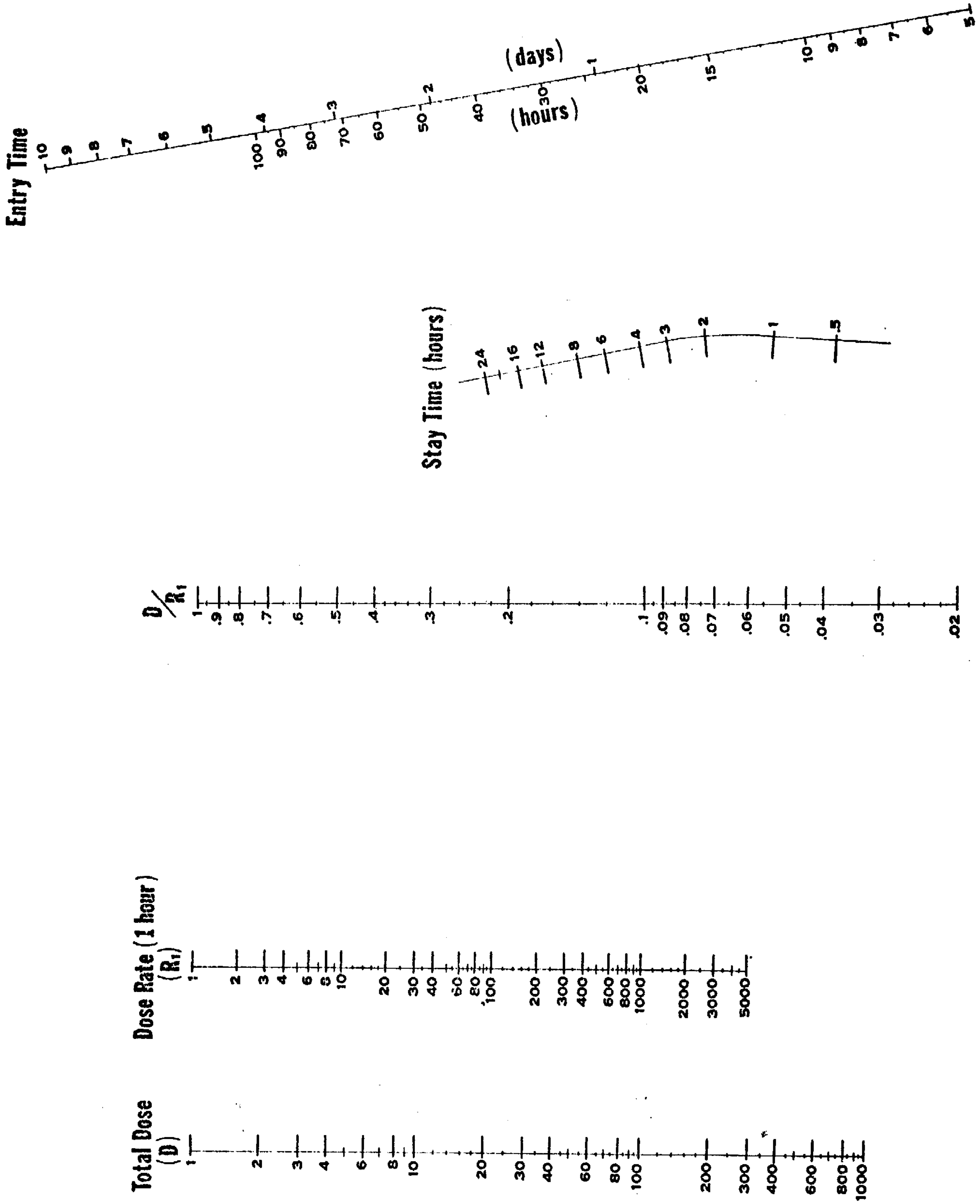
FIND: The earliest entry time into the area.

SOLUTION:

Find the dose rate at H + 1 (190 R/hr). Using a straight edge, connect 50 R on the "Total Dose" scale with 190 R/hr on the "Dose Rate at H + 1" scale. Find .26 on the "D/R_1" scale. Connect this point (.26) with 3 hours on the "Stay Time" scale. Read the answer from the "Entry Time" scale:

14 hours ANSWER

ENTRY TIME - STAY TIME - TOTAL DOSE NOMOGRAM



(from Handbook for Radiological Monitors, 1963, DOD, OCD)

Figure 9.26. Total radiation dose from early fallout based on unit-time reference dose rate.

From Fig. 9.26 the total radiation dose received from early fallout during any specified stay in a contaminated area can be estimated if the dose rate at some definite time after the explosion is known. Alternatively, the time can be calculated for commencing an operation requiring a specified stay and a prescribed total radiation dose.

EXAMPLE:

GIVEN: The dose rate at 4 hours after a nuclear explosion is 6 roentgens per hour.

FIND:

a. The total dose received during a period of 2 hours commencing at 6 hours after the explosion.

b. The time after the explosion when an operation requiring a stay of 5 hours can be started if the total dose is to be 4 roentgens.

SOLUTION:

The first step is to determine the unit-time reference dose rate (32 roentgens per hour).

a. Enter Fig. 9.26 at 6 hours after the explosion (horizontal scale) and move up to the curve representing a stay time of 2 hours. The corresponding reading on the vertical scale, which gives the multiplying factor to convert unit-time reference dose rate to the required total dose, is seen to be 0.19. Hence, the total dose received is

0.19 x 32 = 6.1 roentgens ANSWER

b. Since the total dose is given as 4 roentgens and the unit-time reference dose rate is 32 roentgens per hour, the multiplying factor is 4/32 = 0.125. Entering Fig. 9.26 at this point on the vertical scale and moving across until the (interpolated) curve for 5 hours stay is reached, the corresponding reading on the horizontal scale, giving the time after explosion, is seen to be

21 hours ANSWER

Figure 9.27. Total radiation dose from early fallout based on dose rate at time of entry.

From the chart in Fig. 9.27, the total radiation dose received from early fallout during any specified stay in a contaminated area can be estimated if the dose rate at the time of entry into the area is known. Alternatively, the time of stay may be evaluated if the total dose is prescribed.

EXAMPLE:

GIVEN: Upon entering a contaminated area at 12 hours after a nuclear explosion the dose rate is 5 roentgens per hour.

FIND:

a. The total radiation dose received for a stay of 2 hours.

b. The time of stay for a total dose of 20 roentgens.

SOLUTION:

a. Start at the point on Fig. 9.27 representing 12 hours after the explosion on the horizontal scale and move up to the curve representing a time of stay of 2 hours. The multiplying factor for the dose rate at the time of entry, as read from the vertical scale, is seen to be 1.9. Hence, the total dose received is

$1.9 \times 5 = 9.5$ roentgens ANSWER

b. The total dose is 20 roentgens and the dose rate at the time of entry is 5 roentgens per hour; hence, the multiplying factor is $20/5 = 4.0$. Enter Fig. 9.27 at the point corresponding to 4.0 on the vertical scale and move horizontally to meet a vertical line which starts from the point representing 12 hours after the explosion on the horizontal scale. The two lines are found to intersect at a point indicating a time of stay of about

$4\frac{1}{2}$ hours ANSWER

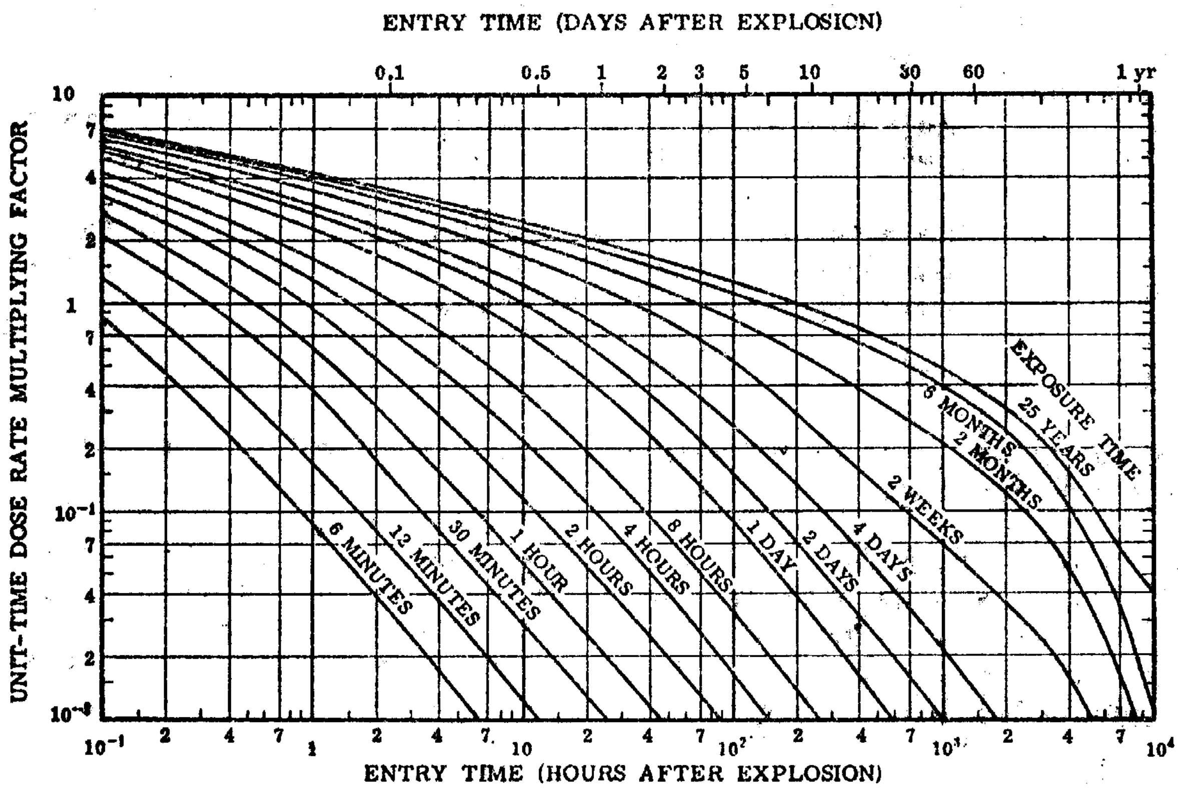


Figure 9.26. Total radiation dose from early fallout based on unit-time reference dose rate.

(from Effects of Nuclear Weapons, 1964, p 429)

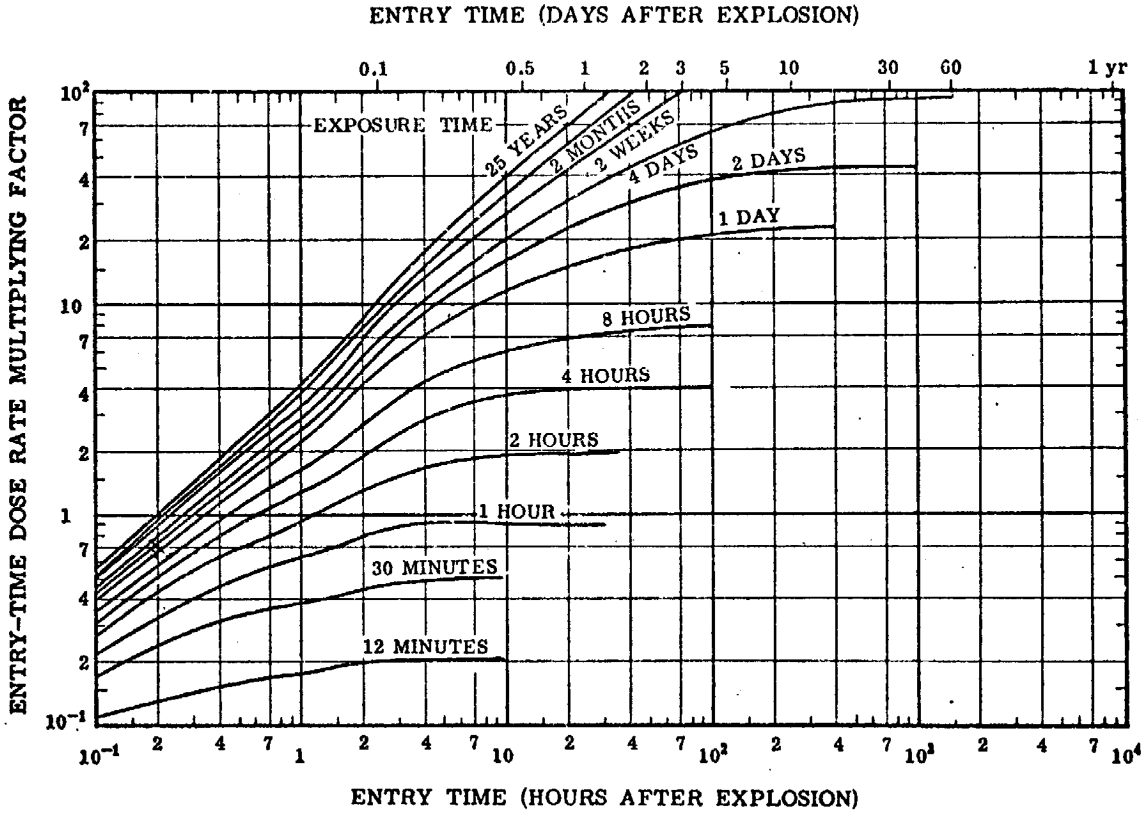


Figure 9.27. Total radiation dose from early fallout based on dose rate at time of entry.

(from Effects of Nuclear Weapons, 1964, p 431)

SECTION E - USEFUL RELATIONSHIPS

E-1 POWERS OF NUMBERS

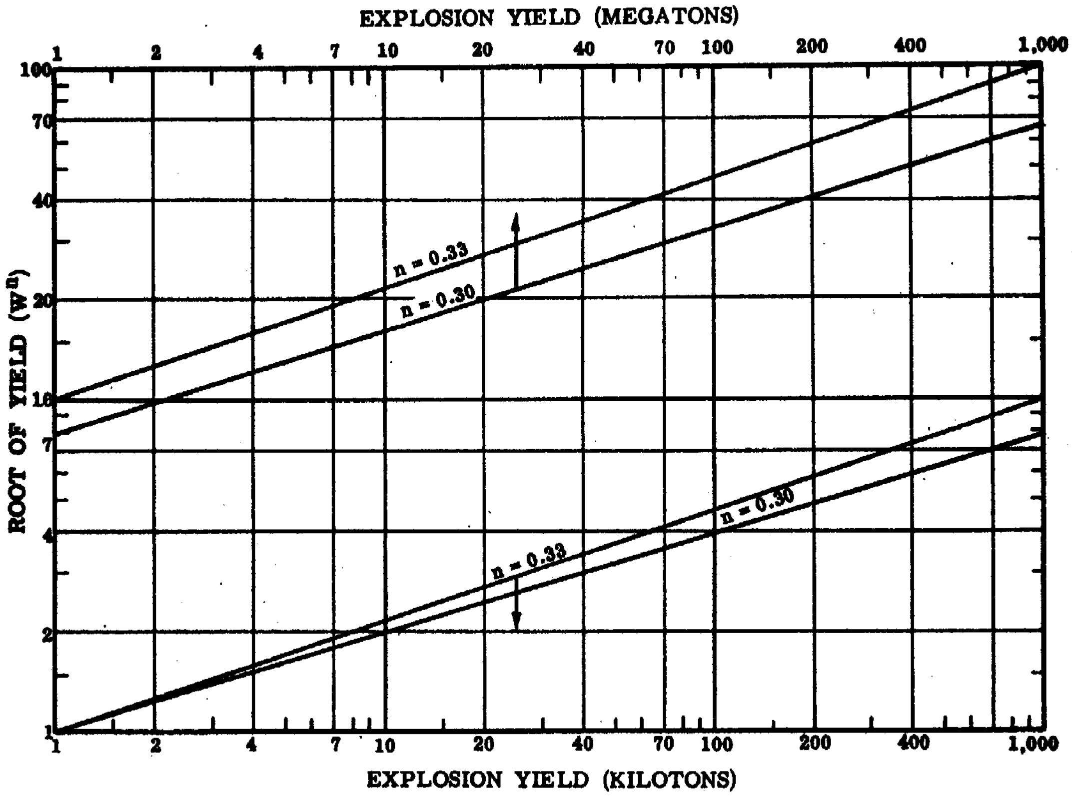


Figure 3.65. Values of $W^{0.33}$ ($W^{1/3}$) and $W^{0.3}$ for use in scaling calculations.

(from Effects of Nuclear Weapons, 1964, p 131)

NUMBER	0.25 POWER	CUBE ROOT	0.4 POWER	0.5 POWER OR SQUARE ROOT
0.5	0.84	0.794	0.758	0.707
1	1.00	1.00	1.00	1.00
2	1.19	1.26	1.32	1.41
4	1.41	1.59	1.74	2.00
6	1.56	1.82	2.05	2.45
8	1.68	2.00	2.30	2.83
10	1.78	2.15	2.51	3.16
12	1.86	2.29	2.70	3.46
14	1.93	2.41	2.88	3.74
15	1.97	2.47	2.96	3.87
16	2.00	2.52	3.03	4.00
17	2.03	2.57	3.11	4.12
18	2.06	2.62	3.18	4.24
20	2.12	2.71	3.32	4.47
25	2.24	2.92	3.62	5.00
30	2.34	3.11	3.90	5.48
35	2.43	3.27	4.15	5.92
40	2.52	3.42	4.38	6.32
45	2.59	3.56	4.58	6.71
50	2.66	3.68	4.78	7.07
55	2.72	3.80	4.96	7.42
60	2.78	3.91	5.15	7.75
65	2.84	4.02	5.31	8.06
70	2.90	4.12	5.47	8.37
75	2.94	4.22	5.63	8.66
80	2.99	4.31	5.77	8.94
85	3.04	4.40	5.91	9.22
90	3.08	4.48	6.05	9.49
95	3.12	4.56	6.18	9.75
100	3.17	4.64	6.30	10.0
110	3.24	4.79	6.56	10.5
120	3.31	4.93	6.80	11.0
130	3.38	5.07	7.00	11.4
140	3.44	5.19	7.22	11.8
150	3.50	5.31	7.42	12.3
155	3.53	5.37	7.50	12.5
160	3.56	5.42	7.62	12.7
165	3.58	5.48	7.70	12.9
170	3.61	5.54	7.80	13.0
175	3.64	5.59	7.90	13.2
200	3.76	5.85	8.33	14.1
250	3.98	6.30	9.10	15.8
300	4.16	6.69	9.80	17.3
350	4.33	7.05	10.4	18.7
400	4.46	7.37	11.0	20.0
450	4.60	7.66	11.5	21.2
500	4.73	7.94	12.0	22.4
550	4.85	8.19	12.5	23.5
600	4.95	8.43	12.9	24.5
650	5.05	8.66	13.4	25.5

NUMBER	0.25 POWER	CUBE ROOT	0.4 POWER	0.5 POWER OR SQUARE ROOT
700	5.14	8.88	13.8	26.5
750	5.25	9.09	14.2	27.4
800	5.31	9.28	14.5	28.3
850	5.40	9.47	14.9	29.2
900	5.47	9.65	15.3	30.0
950	5.55	9.83	15.5	30.8
1,000	5.61	10.0	15.9	31.6
1,200	5.90	10.6	17.1	34.6
1,400	6.10	11.2	18.1	37.4
1,600	6.30	11.7	19.2	40.0
1,800	6.50	12.2	20.0	42.4
2,000	6.69	12.6	20.9	44.7
2,200	6.85	13.0	21.8	46.9
2,400	7.00	13.4	22.5	49.0
2,600	7.10	13.8	23.3	51.0
2,800	7.30	14.1	23.9	52.9
3,000	7.40	14.4	24.6	54.8
3,200	7.50	14.7	25.3	56.6
3,400	7.60	15.1	25.8	58.3
3,600	7.75	15.3	26.4	60.0
3,800	7.90	15.6	27.0	61.6
4,000	7.94	15.9	27.6	63.3
4,200	8.05	16.1	28.2	64.8
4,400	8.10	16.4	28.6	66.3
4,600	8.20	16.6	29.2	67.8
4,800	8.30	16.9	29.6	69.3
5,000	8.40	17.1	30.2	70.7
5,200	8.50	17.3	30.7	72.1
5,400	8.55	17.6	31.0	73.5
5,600	8.65	17.8	31.5	74.8
5,800	8.75	18.0	32.0	76.2
6,000	8.80	18.2	32.5	77.5
6,500	9.00	18.7	33.5	80.6
7,000	9.15	19.1	34.5	83.7
7,500	9.30	19.6	35.5	86.6
8,000	9.40	20.0	36.5	89.4
8,500	9.60	20.4	37.3	92.2
9,000	9.70	20.8	38.2	94.9
9,500	9.90	21.2	39.0	97.5
10,000	10.00	21.5	39.9	100.
11,000	10.20	22.2	41.4	105.
12,000	10.50	22.9	43.0	110.
13,000	10.70	23.5	44.2	114.
14,000	10.90	24.1	45.6	118.
15,000	11.00	24.7	47.0	122.
16,000	11.20	25.2	48.0	126.
17,000	11.40	25.7	49.0	130.
18,000	11.60	26.2	50.4	134.
19,000	11.80	26.7	51.5	138.
20,000	11.90	27.1	52.5	141.

SECTION E - USEFUL RELATIONSHIPS

E-2 CONVERSION TABLES

Slant Range - Horizontal Distance Conversion Chart

NOTES:

1. As a general rule, conversion of Slant Range and Horizontal Distance is required when either of these distances is equal to or less than three times the Height of Burst.

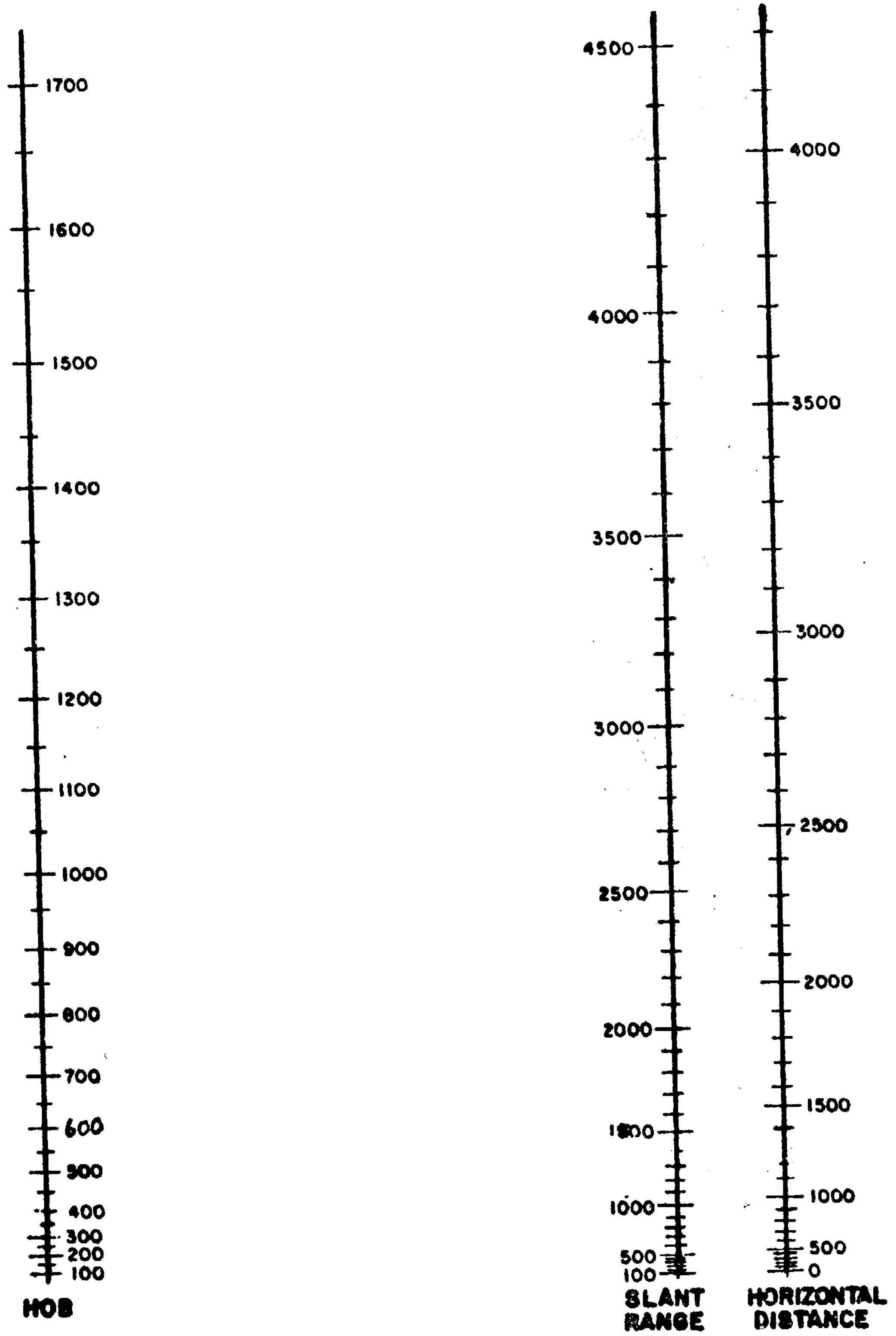
2. The same unit of measure must be used for all distances; e.g., if HOB and Slant Range are expressed in meters, the Horizontal Distance is also in meters.

3. Where distances are greater than those shown, divide all known values by 2, 3, or any other number and use nomogram in normal manner. Value read from nomogram must then be multiplied by the same number.

CONVERSION TABLES

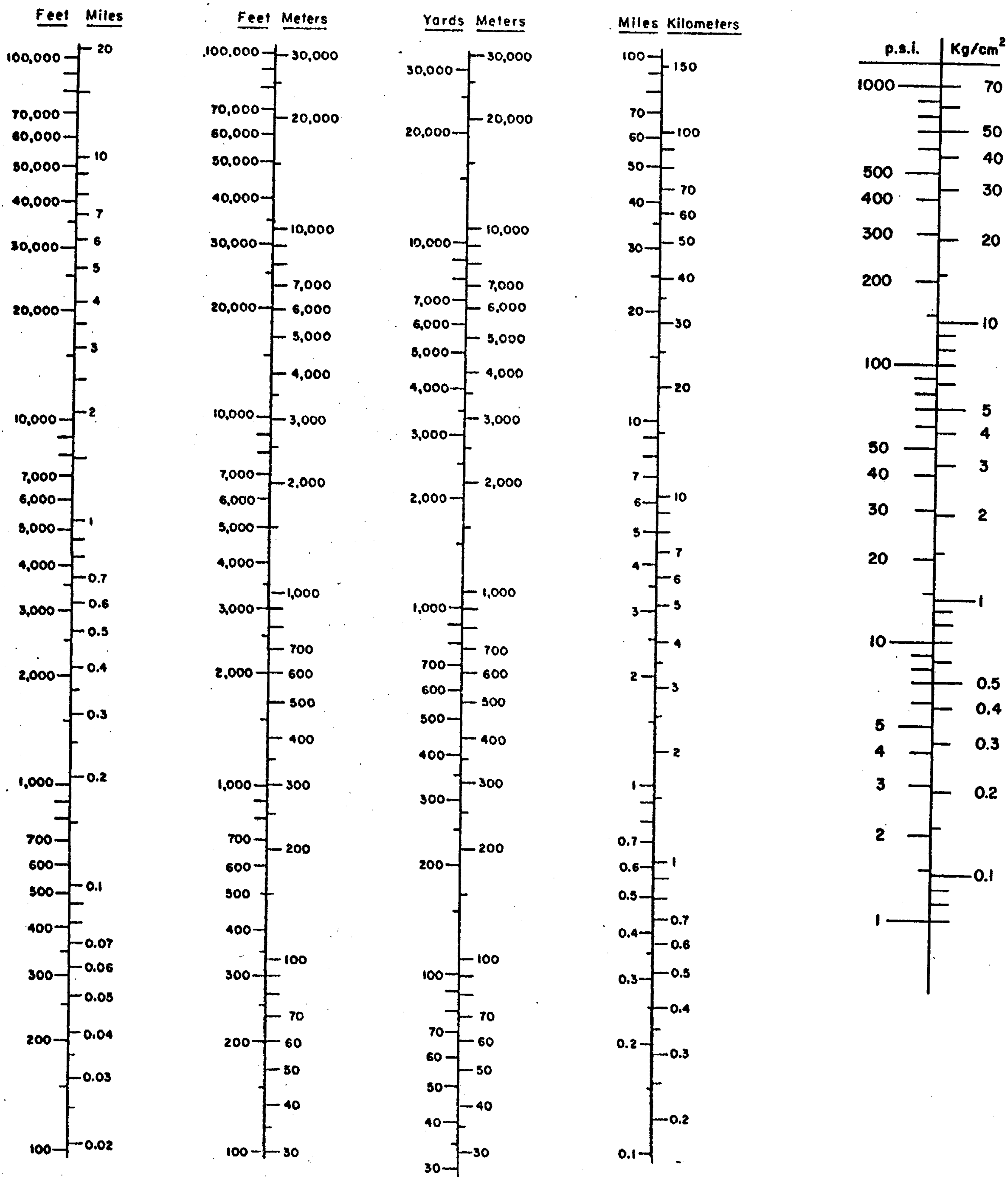
SLANT RANGE - HORIZONTAL DISTANCE

CONVERSION CHART



CONVERSION TABLES

USEFUL RELATIONSHIPS



CONVERSION FACTORS

To convert from	To	Multiply by
Acres	Square feet	43 560
	Square meters	4,047
	Square miles	0.001563
	Square yards	4 840
Atmospheres	Pounds per square foot	2,116.3
	Pounds per square inch	14.696
Btu	Calories	252
Btu/ft^2	Cal/cm^2	.271
Calories	Btu	3.968×10^{-3}
Cal/cm^2	Btu/ft^2	3.690
Centimeters	Inches	0.3937
Cubic feet	Cubic meters	0.028317
	Kilograms air	0.0347
Cubic meters	Kilograms air	1.226
	Cubic feet	35.335
Curies	Disintegrations per minute	2.2×10^{12}
	Disintegrations per second	3.7×10^{10}
Disintegrations per minute	Picrocuries	0.450
Disintegrations per minute per square foot	Millicuries per square mile	0.01256
Disintegrations per minute per liter	Microcuries per cubic centimeter	0.45×10^{-9}
Feet	Meters	0.3048
	Miles	0.000189
Feet per second	Miles per hour	0.68184
Grams	Pounds	0.0022046

CONVERSION FACTORS

To convert from	To	Multiply by
Grams per square centimeter	Pounds per square inch	0.014223
Inches	Centimeters	2.54
Kilograms	Pounds	2.2046
Kilograms air	Cubic feet	28.8
Kilograms air	Cubic meters	0.816
Kilograms per square centimeter	Pounds per square inch	14.223
Kilometers	Miles	0.621
Liquid quarts (US)	Liters	0.946
Liters	Liquid quarts (US)	1.057
Meters	Feet	3.28
Microcuries per cubic centimeter	Disintegrations per minute per liter	2.22×10^9
Microns	Centimeters	1×10^{-4}
Miles (nautical)	Miles (statute)	1.1516
Miles	Feet	5,280
	Kilometers	1.6093
Miles per hour	Feet per second	1.4667
Millicuries per square kilometer	Millicuries per square mile	2.59
Millicuries per square kilometer per centimeter	Picocuries per liter	100
Millicuries per square mile	Millicuries per square kilometer	0.386
	Disintegrations per minute per square foot	79.6

CONVERSION FACTORS

To convert from	To	Multiply by
Millicuries per square mile per inch	Picocuries per liter	15.2
Picocuries	Disintegrations per minute	2.22
Picocuries per liter	Millicuries per square kilometer per cm	0.01
	Millicuries per square mile per inch	0.0657
Pounds	Kilograms	0.45359
Pounds per square inch	Atmospheres	0.06805
	Kilograms per square centimeter	0.07031
Square centimeters	Square feet	0.0010764
Square feet	Square centimeters	929.0
Square inches	Square centimeters	6.452
Square kilometers	Square miles	0.386
Square miles	Acres	640.0
Square miles	Square kilometers	2.59

SECTION E - USEFUL RELATIONSHIPS

E-3 MISCELLANEOUS

(BLANK)

TABLE OF ELEMENTS

ELEMENT	SYM-BOL	AT. NO.	AT. WT.	ELEMENT	SYM-BOL	AT. NO.	AT. WT.
Actinium	Ac	89	(227)	Mercury	Hg	80	200.59
Aluminum	Al	13	26.9815	Molybdenum	Mo	42	95.94
Americium	Am	95	(243)	Neodymium	Nd	60	144.24
Antimony	Sb	51	121.75	Neon	Ne	10	20.183
Argon	Ar	18	39.948	Neptunium	Np	93	(237)
Arsenic	As	33	74.9216	Nickle	Ni	28	58.71
Astatine	At	85	(210)	Niobium (columbium)	Nb	41	92.906
Barium	Ba	56	137.34	Nitrogen	N	7	14.0067
Berkelium	Bk	97	(249)	Nobelium	No	102	(254)
Beryllium	Be	4	9.0122				
Bismuth	Bi	83	208.980	Osmium	Os	76	190.2
Boron	B	5	10.811	Oxygen	O	8	15.9994
Bromine	Br	35	79.909	Palladium	Pd	46	106.4
Cadmium	Cd	48	112.40	Phosphorus	P	15	30.9738
Calcium	Ca	20	40.08	Platinum	Pt	78	195.09
Californium	Cf	98	(251)	Plutonium	Pu	94	(242)
Carbon	C	6	12.01115	Polonium	Po	84	(210)
Cerium	Ce	58	140.12	Potassium	K	19	39.102
Cesium	Cs	55	132.905	Praseodymium	Pr	59	140.907
Chlorine	Cl	17	35.453	Promethium	Pm	61	(145)
Chromium	Cr	24	51.996	Protactinium	Pa	91	(231)
Cobalt	Co	27	58.9332	Radium	Ra	88	(226)
Copper	Cu	29	63.54	Radon	Rn	86	(222)
Curium	Cm	96	(247)	Rhenium	Re	75	186.2
Dysprosium	Dy	66	163.50	Rhodium	Rh	45	102.905
Einsteinium	Es	99	(254)	Rubidium	Rb	37	85.47
Erbium	Er	68	167.26	Ruthenium	Ru	44	101.07
Europium	Eu	63	151.96	Samarium	Sm	62	150.35
Fermium	Fm	100	(253)	Scandium	Sc	21	44.956
Fluorine	F	9	19.9984	Selenium	Se	34	78.96
Francium	Fr	87	(223)	Silicon	Si	14	28.086
Gadolinium	Gd	64	157.25	Silver	Ag	47	107.870
Gallium	Ga	31	69.72	Sodium	Na	11	22.9898
Germanium	Ge	32	72.59	Strontium	Sr	38	87.62
Gold	Au	79	196.967	Sulfur	S	16	32.064
Hafnium	Hf	72	178.49	Tantalum	Ta	73	180.948
Helium	He	2	4.0026	Technetium	Tc	43	(99)
Holmium	Ho	67	164.930	Tellurium	Te	52	127.60
Hydrogen	H	1	1.00797	Terbium	Tb	65	158.93
Indium	In	49	114.82	Thallium	Tl	81	204.37
Iodine	I	53	126.9044	Thorium	Th	90	232.038
Iridium	Ir	77	192.2	Thulium	Tm	69	168.934
Iron	Fe	26	55.847	Tin	Sn	50	118.69
Krypton	Kr	36	83.80	Titanium	Ti	22	47.90
Lanthanum	La	57	138.91	Tungsten	W	74	183.85
Lawrencium	Lw	103	(257)	Uranium	U	92	238.03
Lead	Pb	82	207.19	Vanadium	V	23	50.942
Lithium	Li	3	6.939	Xenon	Xe	54	131.30
Lutetium	Lu	71	174.97	Ytterbium	Yb	70	173.04
Magnesium	Mg	12	24.312	Yttrium	Y	39	88.905
Manganese	Mn	25	54.9380	Zinc	Zn	30	65.37
Mendelevium	Md	101	(256)	Zirconium	Zr	40	91.22

The value in parenthesis is the mass number of the most stable isotope.

GAMMA DOSE RATE AT 1 FOOT:

$$DR_{1ft} \approx 6\ C.E. \pm 20\%\ R/hr$$

where C is curies

E is Mev

BETA DOSE RATE AT 1 FOOT:

$$DR_{1ft} \approx 200\ C\ rads/hr$$

RANGE OF BETA IN AIR:

Energy (Mev)	Range (m)	Energy (Mev)	Range (m)
0.01	0.0022	0.2	0.36
0.02	0.0072	.3	0.65
0.03	0.015	.4	1.0
0.04	0.024	.6	1.8
0.05	0.037	.8	2.8
0.06	0.050	1.0	3.7
0.07	0.064	1.5	6.1
0.08	0.080	2.0	8.4
0.09	0.095	3.0	13.0
0.10	0.11	4.0	16.0
0.15	0.21	5.0	19.0

RANGE OF BETA IN WATER:

Energy (Mev)	R (inches)	Energy (Mev)	R (inches)
0.1	0.007	0.7	0.095
.2	.02	.8	.14
.3	.03	1.0	.15
.4	.045	2	.4
.5	.075	3	.65
.6	.08	4	.95

AREA OF THE EARTH:

	mi^2	km^2
land	57.467×10^6	148.892×10^6
oceans & seas	139.369 "	361.059 "
total	196.836 "	509.951 "

Latitude band

0-10	17.016×10^6	44.084×10^6
10-20	16.512 "	42.778 "
20-30	15.516 "	40.198 "
30-40	14.052 "	36.405 "
40-50	12.158 "	31.497 "
50-60	9.884 "	25.607 "
60-70	7.297 "	18.905 "
70-80	4.475 "	11.594 "
80-90	1.508 "	3.908 "

TEMPERATURE/ev:

The temperature associated with 1 ev is:

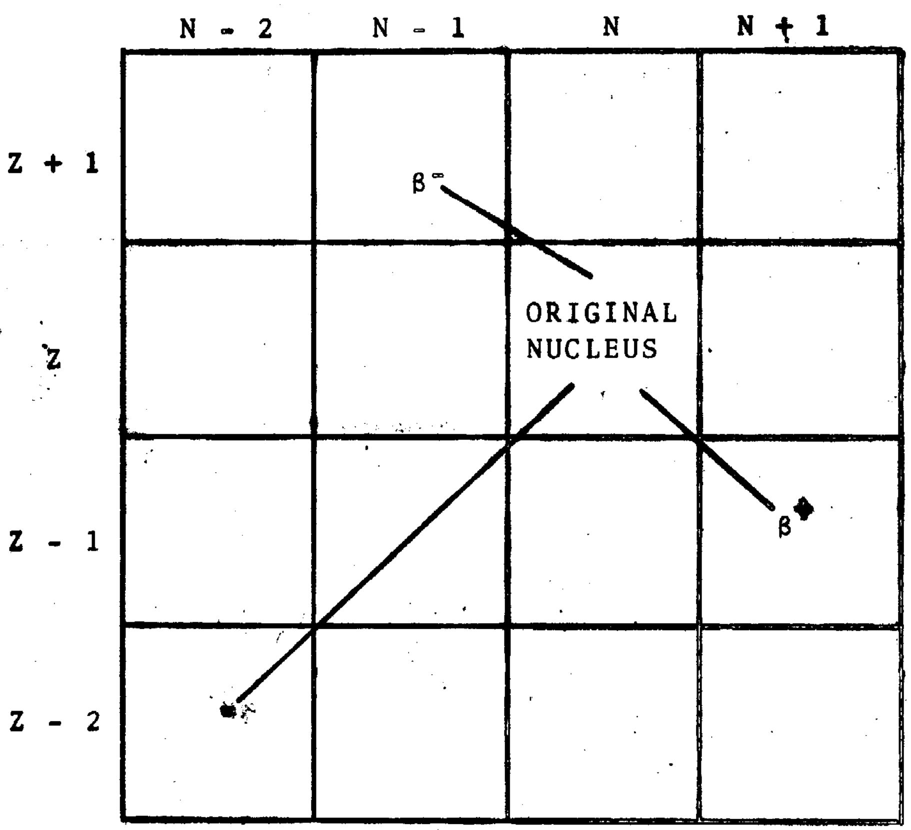
$$(1.16049 \pm .00005) \times 10^4 \text{ deg (ev)}^{-1}$$

DENSITIES OF COMMON MATERIALS:

	lbs/cu ft
Brick	120 - 140
Concrete	140 - 180
Reinforced Concrete	140 - 190
Aluminum	169
Wood: Hard	40 - 55
Soft	30 - 44
Earth	77 - 120
Clay:	145
Sand: Wet	115 - 130
Dry	90 - 110

	lbs/cu ft
Plaster	50 - 180
Steel	435 - 495
Iron	450 - 480
Lead	710
Copper	550
Rubber	58
Glass	160 - 170
Chalk	145
Sandstone	130 - 170
Limestone	130 - 140
Granite	165 - 175

DISPLACEMENT IN TABLE OF ELEMENTS CAUSED BY RADIOACTIVE DECAY



N = no. of neutrons

Z = no. of protons

Element is not shifted by emission of gamma radiation.

HALF-LIVES OF SOME RADIONUCLIDES OF INTEREST

	HALF-LIFE	EMITS	DECAYS TO
1. NEUTRON INDUCED ACTIVITIES			
a. In Air			
N^{16}	7 secs.	β γ	O^{16}
C^{14}	5,700 years	β	N^{14}
b. In Soil			
Na^{24}	15 hours	β γ	Mg^{24}
Mn^{56}	2.6 hours	β γ	Fe^{56}
Si^{31}	2.6 hours	β γ	P^{31}
Al^{28}	2.3 mins.	β γ	Si^{28}
Cl^{38}	37 mins.	β γ	A^{38}
c. Other			
Zn^{65}	245 days	β^+ γ	Cu^{65}
Cu^{64}	13 hours	β^+ or β^-, γ	Ni^{64} or Zn^{64}
2. SOME FISSION PRODUCTS			
Xe^{140}	16 secs.	β	Cs^{140}
Cs^{140}	66 secs.	β	Ba^{140}
Ba^{140}	13 days	β γ	La^{140}
La^{140}	40 hours	β γ	Ce^{140}
I^{137}	22 secs.	β	Xe^{137}
Xe^{137}	4 mins.	β	Cs^{137}

	HALF-LIFE	EMITS	DECAYS TO
Cs^{137}	30 years	β γ	Ba^{137}
Sn^{131}	3.4 mins.	β	Sb^{131}
Sb^{131}	22 mins.	β	Te^{131}
Te^{131}	30 hours	β γ	I^{131}
I^{131}	8 days	β γ	Xe^{131}
Kr^{90}	33 secs.	β	Rb^{90}
Rb^{90}	2.7 mins.	β γ	Sr^{90}
Sr^{90}	28 years	β	Y^{90}
Y^{90}	64 hours	β γ	Zr^{90}
Kr^{89}	3.2 mins.	β	Rb^{89}
Rb^{89}	15 mins.	β γ	Sr^{89}
Sr^{89}	54 days	β	Y^{89}
3. OTHERS			
H^3	12 years	β	He^3
Pu^{239}	24,300 years	α γ	U^{235}
U^{235}	7 x 10^8 years	α γ	Th^{231}
U^{238}	4.5 x 10^9 years	α γ	Th^{234}
Co^{60}	5.2 years	β γ	Ni^{60}

SECTION F - GLOSSARY OF TERMS

This glossary contains a limited selection of terms commonly used on the RSO course. A more comprehensive glossary of technical terms is contained in Effects of Nuclear Weapons, 1964. General terms used throughout the Emergency Measures Organizations in Canada are defined in A Guide to Civil Emergency Planning for Municipalities.

GLOSSARY OF TERMS

TERM	DEFINITION
ATOMIC NUMBER (Z)	The number of protons in the nucleus; the number of positive charges on the nucleus; the number of orbital electrons around the nucleus of a neutral atom.
ATOMIC WEIGHT (A)	The weighted mean of the masses of the neutral atoms of an element expressed in atomic weight units.
ATTO-	Prefix meaning 10^{-18}.
AVERAGE LIFE (mean life)	The average of the individual lives of all the atoms of a particular radioactive substance. It is 1.443 times the radioactive half life.
CURIE (Ci, also c)	The quantity of a radioactive nuclide in which the number of disintegrations is 3.700×10^{10} per second.
DOSE (DOSAGE)	The radiation delivered to a specified area or volume, or to the whole body. In recent years there has been an increasing tendency to regard a dose of radiation as the amount of energy absorbed by tissue at the site of interest per unit mass (see "rad") (see also "exposure").
ABSORBED DOSE	The quantity of energy imparted to a mass of material exposed to radiation.
ACCUMULATED DOSE	The total dose resulting from repeated exposures to radiation of the same region or of the whole body.
ACUTE DOSE	A dose of whole body irradiation received in a short time.
MAXIMUM PERMISSIBLE DOSE	The maximum dose of radiation which may be received by persons working with ionizing radiation.
MEDIAN LETHAL DOSE	See LD-50.

TERM	DEFINITION
DOSE RATE	Radiation dose delivered per unit time, e.g. roentgens per hour.
ELECTRON VOLT (ev)	A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of one volt. (Multiples are Kev, Mev, Bev)
EXPOSURE	The product of radiant flux density multiplied by exposure time.
ACUTE EXPOSURE	Radiation exposure of short duration (arbitrarily set, say at 24 hours or some other comparable interval).
CHRONIC EXPOSURE	Radiation exposure of long duration by fractionation or protraction.
FEMTO-	Prefix meaning 10^{-15}.
GIGA-	Prefix meaning one billion, 10^9.
GROUND ZERO (GZ)	The point on the surface of land, or water, vertically below or above, the centre of burst of a nuclear weapon.
HALF-LIFE, BIOLOGICAL	The time required for the body to eliminate one-half of an administered dose of any substance by regular processes of elimination.
HALF-LIFE, EFFECTIVE	The time required for a radioactive element fixed in the tissue of an animal body to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination. $Ehl = \frac{bhl \times rhl}{bhl + rhl}$
HALF-LIFE, RADIOACTIVE	The time required for a radioactive substance to lose 50 percent of its activity by decay.

GLOSSARY OF TERMS

TERM	DEFINITION
HALF THICKNESS (HALF VALUE LAYER)	The thickness of any particular material that will reduce the intensity of a beam of radiation to half its original value.
ISOTOPE	One of several nuclides having the same atomic number, but different mass numbers. Isotopes are either stable or radioactive.
Kev	Kiloelectron volts; thousand electron volts.
KILO-	Prefix meaning one thousand; 10^3.
KILOTON (KT)	One thousand tons.
LD-50 (LD_{50}; MLD, MEDIAN LETHAL DOSE)	That dose of a toxic agent which would be expected to kill 50% of a large group of individuals receiving it.
MASS NUMBER (A)	The number of nucleons (protons and neutrons) in the nucleus of an atom.
MEAN FREE PATH	The average distance that a particle travels between successive collisions with other particles.
MEAN LIFE	See "average life".
MEGA-	Prefix meaning one million; 10^6.
MEGATON (MT)	One million tons.
Mev	One million electron volts.
MICRO-	Prefix meaning one millionth; 10^{-6}.
MICRON	10^{-6} meters.
MILLI-	Prefix meaning one thousandth; 10^{-3}.
NANO-	Prefix meaning one billionth; 10^{-9}.
NOMINAL	Obsolescent designation of 20 KT nuclear weapons.

GLOSSARY OF TERMS

TERM	DEFINITION
NUCLEON	A constituent particle of the atomic nucleus.
NUCLIDE	A species of atom characterized by the constitution of its nucleus.
OPTIMUM HEIGHT	The height of burst at which some specified level of damage is at a maximum. (This term has fallen into disuse since the advent of high yield weapons)
PICO-	Prefix for 10^{-12}, e.g. one picocurie = $\frac{1}{1,000,000,000,000}$ curie.
PROTECTION FACTOR (PF)	The relative reduction in the amount of gamma radiation that would be received by an individual in a protected location, compared to the amount he would receive if unprotected.
RAD	Unit of absorbed dose of radiation; one hundred ergs of absorbed energy per gram of absorbing material.
RELATIVE BIOLOGICAL EFFECTIVENESS (RBE)	The ratio of gamma, or X-ray, dose to the dose that is required to produce the same biological effect by the radiation in question.
REM (ROENTGEN EQUIVALENT, MAN)	That quantity of any type of ionizing radiation which, when absorbed by man, produces an effect equivalent to the absorption by man of one roentgen of gamma or X-radiation.
ROENTGEN (R)	The quantity of gamma or X-radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of electricity of either sign.

GLOSSARY OF TERMS

TERM	DEFINITION
SCALING	Calculating the effects of a specified yield of weapon from the observed effects of a different yield of weapon.
SPECIFIC ACTIVITY	The activity per unit mass of material.
TERA-	Prefix for one million million; 10^{12}.
YIELD	The energy released in a nuclear explosion (usually expressed in tons, kilotons, or megatons, equivalent of TNT).
Z	See "Atomic Number".