WASC 1910

Nat. Bomb
Data Center
Esta Blast Pressures

FEDERAL BUREAU
OF INVESTIGATION
UNITED STATES
DEPARTMENT OF JUSTICE

NATIONAL DATA BOMB CENTER

LAW ENFORCEMENT
ASSISTANCE ADMINISTRATION
UNITED STATES
DEPARTMENT OF JUSTICE

PICATINNY ARSENAL, DOVER, NEW JERSEY 07801

TEL: (201) 328-6781

GENERAL INFORMATION BULLETIN 74-9

1. **Classification:** **Unclassified.**

2. **Subject:** **Estimating Blast Pressures Resulting from the Detonation of Explosives Commonly Used in Improvised Explosive Devices (IED).**

3. **Source:** **National Bomb Data Center (NBDC), Picatinny Arsenal, Dover, New Jersey.**

4. **Background:** Technical Bulletin 41-72 provided NBDC participants with a general understanding of the blast pressure effects associated with the detonation of an explosive. It also provided information concerning distances at which personal injury and property damage could occur due to blast pressure.

General Information Bulletin 73-2 presented information concerning lung and ear injury which could result from exposure to blast pressure, and provided data about safety equipment which could be used to protect these organs from blast pressure.

The information in this bulletin is provided to enable the determination of peak blast pressure and its effects upon persons and structures. It includes graphs for use in determining incident pressure, reflected pressure, dynamic pressure, peak wind velocity and shock front velocity for a variety of explosives. Protection from fragmentation and other explosion related airborne missiles is not discussed.

GENERAL

An explosion releases energy which produces blast pressure. The blast pressure, in the form of a high pressure shock front, moves radially in all directions from the point of explosion and, like sound waves, will flow over and around a barrier. Also, as the blast wave collides with surfaces, these surfaces reflect and reinforce the initial pressure. The blast shock front travels as fast as 13,000 miles per hour initially, then slows down and stabilizes at approximately 750 miles per hour. As the blast shock wave travels out from the explosion, its pressures decrease until they finally degenerate into sound waves.

13 JUNE 1974

There are several types of blast pressure associated with an explosion. These pressures and the conditions under which they are encountered are listed below.

Incident pressure is the pressure level at right angles (90 degrees) to the direction of travel of the blast shock front. A person seeking shelter behind a barrier, wall, building, etc., which is in the line of travel of a blast shock front, would be exposed to incident pressure.

Dynamic pressure is the pressure resulting from the high wind velocity and increased density of the air behind a blast shock front. A person standing in the open, in the line of travel of a blast shock wave, would be exposed to dynamic pressure. Additionally, he would be exposed to incident pressure.

Reflected pressure is a rapid buildup of pressure that occurs when a shock front strikes a flat surface in its line of travel. A person standing near a barrier or wall facing an explosion would be exposed to reflected pressure.

Relatively low blast pressures are capable of inflicting injury to persons or damage to structures. Refer to table I for a listing of blast pressure effects upon unprotected persons, and to table II for the effects of blast pressure upon structures.

TABLE I

SHORT DURATION BLAST PRESSURE EFFECTS UPON UNPROTECTED PERSONS [1]

Pressure in Pounds Per Square Inch[2] (psi)	Effect
5	Slight chance of eardrum rupture
15	50 percent chance of eardrum rupture
30-40	Slight chance of lung damage
80	Severe lung damage
100-120	Slight chance of death
130-180	50 percent chance of death
200-250	Nearly 100 percent chance of death

[1] Source of information: DASA Report 1860 (See references at end of this bulletin).

[2] Pressure as listed in this table is the highest of incident pressure, the incident plus the dynamic pressures, or the reflected pressure, as applicable.

TABLE II

BLAST PRESSURE EFFECTS UPON STRUCTURES EXPOSED TO AN UNCONFINED EXPLOSION ON OPEN GROUND[1]

Pressure in Pounds Per Square Inch (psi)	Structure or Material
1/2 to 1	Shatter single strength glass
1 to 2	Crack plaster walls Shatter asbestos siding Buckle steel sheeting Failure of wooden wall
2 to 3	Crack nonreinforced cinder block wall Crack nonreinforced concrete block wall
2 to 8	Crack nonreinforced brick wall
5 to 10	Shatter safety glass in automobile

[1] Source of information: DA Pamphlet 39-3 (See references at end of this bulletin).

DETERMINING PEAK INCIDENT PRESSURE

In order to determine the peak incident pressure likely to be encountered with a particular IED, it is necessary to first know the amount and kind of explosive involved. Once these are known, if the explosive is TNT, the pressure can be determined directly from graph I. If the explosive is not TNT, its equivalent weight in TNT must first be determined. This may be accomplished either by the use of table III which lists a relative effectiveness factor from which the equivalent weight of TNT can be computed; or by the use of table IV which directly relates the weight of various explosives to an equivalent weight of TNT. (When using table IV if the weight of explosive is not given, use the next higher weight.) See the following examples.

Problem (using table III)

What is the equivalent weight in TNT of 10 pounds of Composition C?

Solution

Referring to table III, the relative effectiveness factor for Composition C is 1.34. Therefore, the equivalent weight of TNT = 1.34 x 10 or 13.4 pounds.

TABLE III

RELATIVE EFFECTIVENESS OF EXPLOSIVES COMPARED TO TNT [1]

Type of Explosive	Relative Effectiveness Factor
TNT	1.00
Black powder	0.55
Nitroglycerin	1.50
Composition C-3/Composition C-4	1.34
40 percent straight dynamite	0.65
60 percent straight dynamite	0.83
40 percent ammonia dynamite	0.41
60 percent ammonia dynamite	0.53
40 percent gelatin dynamite	0.42
60 percent gelatin dynamite	0.76

[1] Source of information: Army Field Manuals 5-25 and 5-34 (See references at end of this bulletin).

Problem (using table IV)

What is the equivalent weight in TNT of 5 pounds of 40 percent straight dynamite?

Solution

Referring to table IV for 40 percent straight dynamite, the 5 pound weight is not given; therefore, use the next higher weight which is 7 1/2 pounds. This is equivalent to 5 pounds of TNT.

Upon establishing the weight of the TNT, or the equivalent weight in TNT of any other explosive encountered, determine the peak incident pressure from graph I as follows:

- Locate the line in the lower half of the graph corresponding to the weight of the TNT.
- Find the distance in feet from the point of detonation at which you wish to know the pressure.

- Proceed along a vertical line toward the top of the graph until the curved line is reached. (The point of intersection of the vertical and curved lines will also be intersected by a horizontal line.)
- Follow the horizontal line to the left side of the graph to find the peak incident pressure.

TABLE IV

WEIGHTS OF UNCONFINED EXPLOSIVES PRODUCING THE SAME PEAK INCIDENT PRESSURE

Type of Explosive	Weight of Explosive						
TNT	1	2	5	10	20	25	50
Black powder	1½	3½	9	18	36	45	90
Nitroglycerin	½	1	3	6	13	16	33
Composition C-3/Composition C-4	½	1½	3½	7	15	18	37
40 percent straight dynamite	1½	3	7½	15	30	38	76
60 percent straight dynamite	1	2	6	12	24	30	60
40 percent ammonia dynamite	2	4½	12	24	48	61	122
60 percent ammonia dynamite	1½	3½	9	18	37	47	94
40 percent gelatin dynamite	2	4½	11	23	47	59	119
60 percent gelatin dynamite	1	2½	6½	13	26	32	65

Following are examples of the use of graph I.

Problem

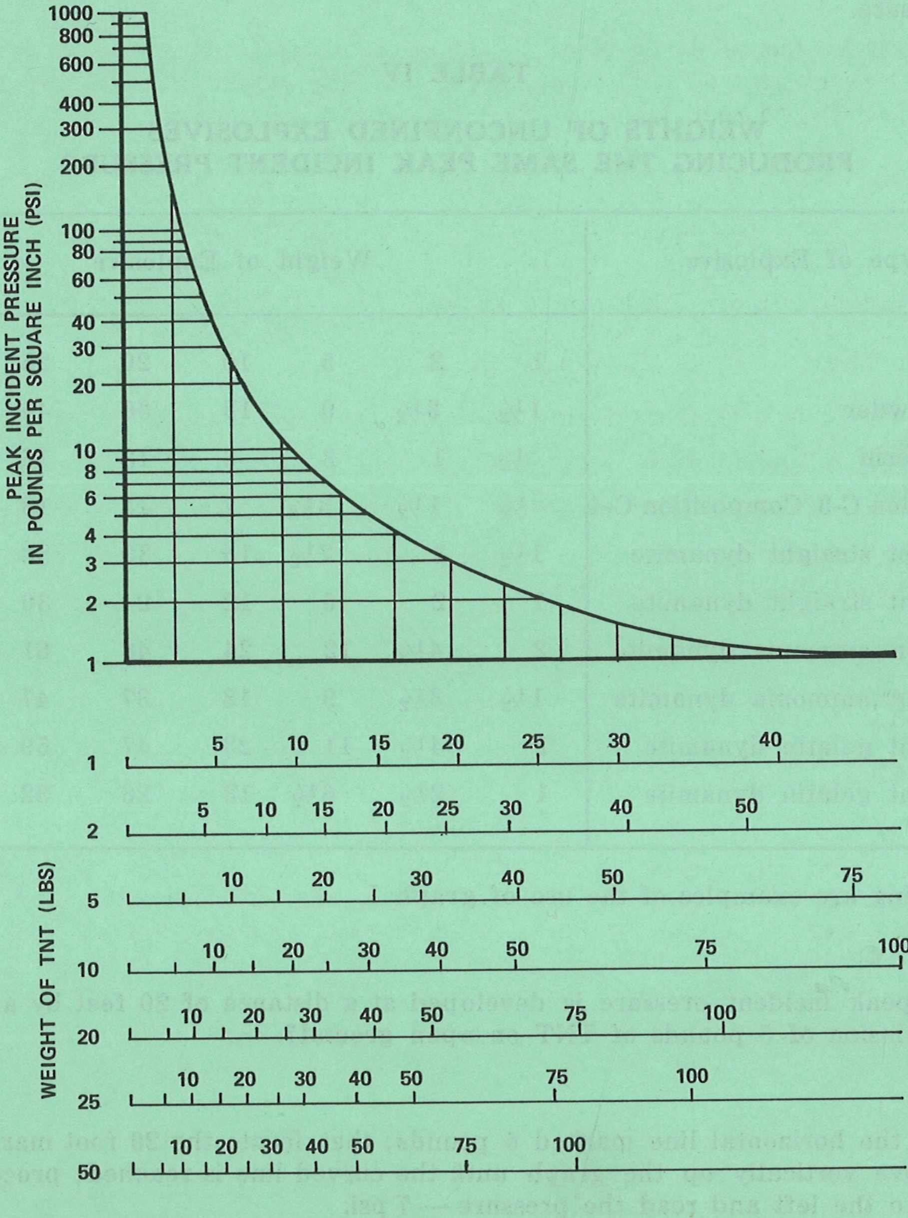
What peak incident pressure is developed at a distance of 20 feet by an unconfined explosion of 5 pounds of TNT on open ground?

Solution

Locate the horizontal line marked 5 pounds; then locate the 20 foot mark on this line. Move vertically up the graph until the curved line is reached; proceed horizontally to the left and read the pressure — 7 psi.

GRAPH I

PEAK INCIDENT PRESSURE VERSUS DISTANCE FROM DETONATION OF UNCONFINED TNT



Problem

An IED is known to contain 2 pounds of unconfined TNT. What peak incident pressure will be developed at 5 feet if the explosive detonates?

Solution

Locate the horizontal line marked 2 pounds; then locate the 5 foot mark on this line. Move vertically up the graph stopping at the curved line; proceed horizontally to the left and read the pressure — approximately 60 psi.

DETERMINING REFLECTED PRESSURE AND DYNAMIC PRESSURE

Use graph II to determine reflected pressure and/or dynamic pressure. The numbers on the left side of the graph relate to reflected pressure and are used with the reflected pressure line plotted on the graph. The numbers on the right side of the graph relate to dynamic pressure and are used with the dynamic pressure line plotted on the graph. Use this graph as follows:

- Find the known peak incident pressure (obtained from graph I) at the bottom of graph II.
- Proceed vertically up the graph to the slant line marked **reflected pressure.**
- Upon reaching this slant line, move horizontally to the left side of the graph to read the reflected pressure.

Following are examples of the use of graph II.

Problem

The peak incident pressure is 20 psi. What is the reflected pressure?

Solution

Find 20 psi on the bottom of the graph and proceed vertically up the graph to the reflected pressure line; move horizontally to the left and read the reflected pressure — 60 psi.

Problem

The peak incident pressure is 80 psi. What is the dynamic pressure?

Solution

Find 80 psi at the bottom of the graph and proceed vertically up the graph to the dynamic pressure line; move horizontally to the right and read the dynamic pressure — approximately 85 psi.

DETERMINING PEAK WIND VELOCITY AND SHOCK FRONT VELOCITY

Use graph III to determine peak wind velocity and shock front velocity in feet per second (fps) or miles per hour (mph). Use this graph as follows:

- Find the known peak incident pressure (obtained from graph I) at the bottom of graph III.
- Proceed vertically up the graph to the peak wind velocity line or the shock front velocity line.
- Move horizontally to the right to read the velocity in fps; or to the left to read the velocity in mph.

Following are examples of the use of graph III.

Problem

The peak incident pressure is 4 psi. What is the peak wind velocity?

Solution

Locate the number 4 at the bottom of the graph, then move vertically up the graph to the line marked **peak wind velocity.** Proceed horizontally to the right to read the velocity in fps (approximately 190); or to the left to read the velocity in mph (approximately 140). In a similar manner, the shock front velocity of approximately 1,300 fps or 900 mph can be determined.

APPLICATION

The pressure or the combination of pressures and the velocities that an individual or structure is exposed to in the event of the explosion of an IED are dependent upon the circumstances which prevail at the time of the explosion. The solutions given to the following problem illustrate a variety of circumstances and how they relate to pressure and velocity.

Problem

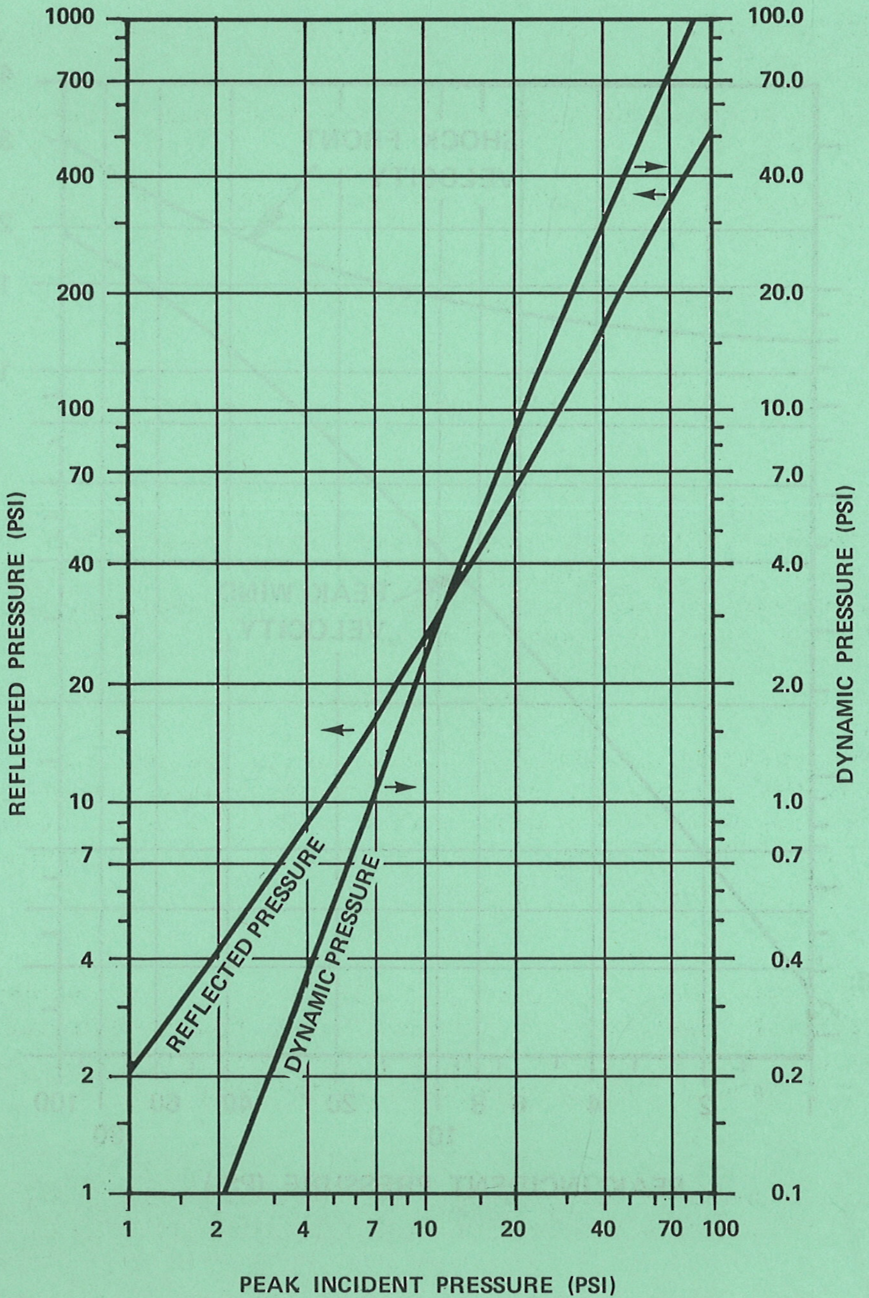
An IED is known to contain 2 pounds of unconfined TNT or another explosive whose weight is the equivalent of 2 pounds of TNT. What pressure would a person or structure be subjected to when located 15 feet away from the exploding IED? What injury or damage could be expected from the blast?

Solution

1. Assuming a person is lying in the open with his head or feet extending toward the explosion, or is positioned a short distance behind a barrier or wall, he

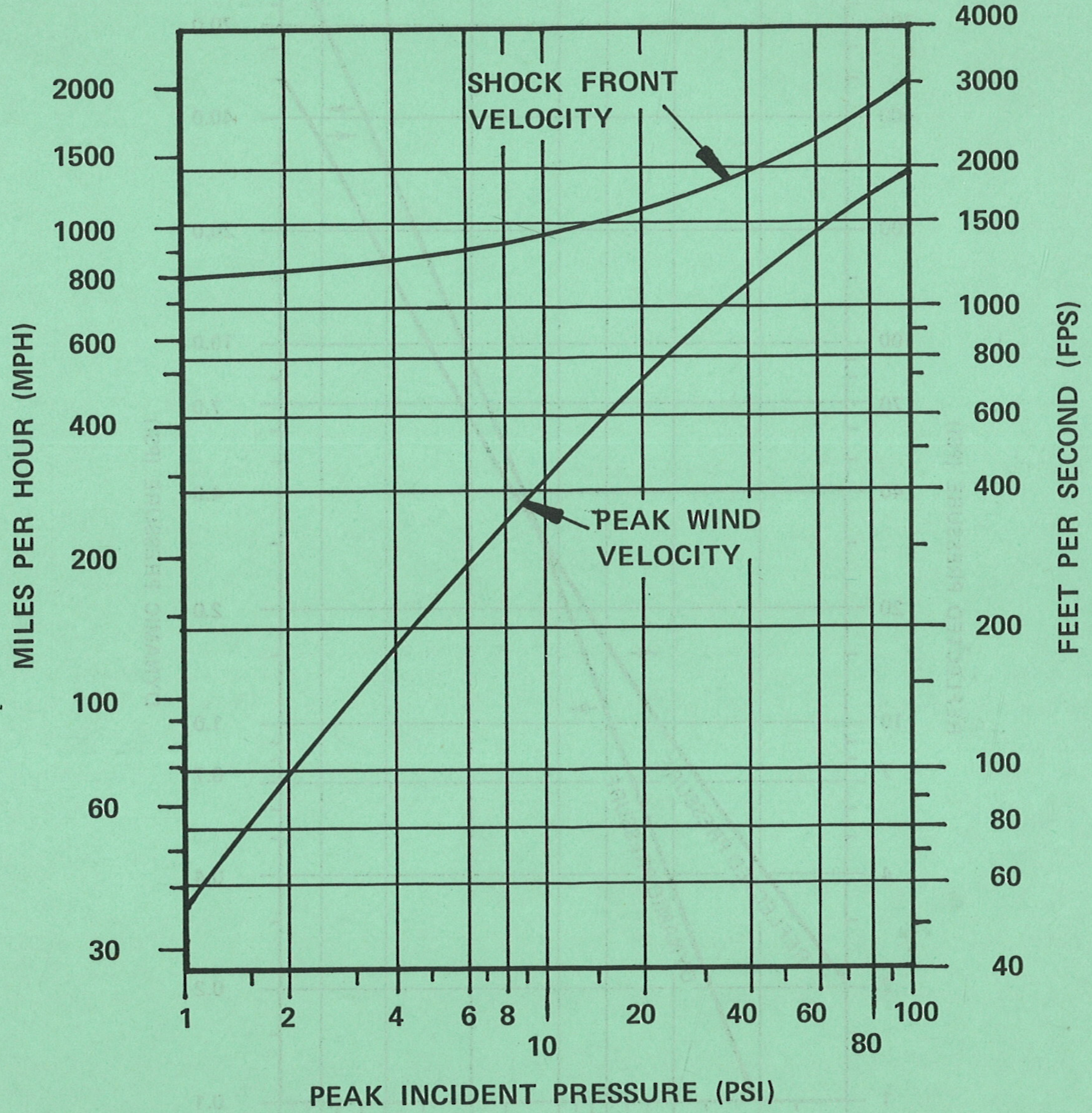
GRAPH II

REFLECTED PRESSURE AND DYNAMIC PRESSURE



GRAPH III

PEAK WIND VELOCITY AND SHOCK FRONT VELOCITY



would be subjected to peak incident pressure only. Referring to graph I, the peak incident pressure 15 feet from the explosion of 2 pounds of TNT is 7 psi. Referring to table I, exposure to 7 psi pressure would result in a slight chance of eardrum rupture assuming no ear protection is provided.

2. Assuming a person is immediately behind a suitable protective shield, he would be subjected to approximately half the peak incident pressure noted in solution 1. This would be approximately 3 1/2 psi and, in accordance with table I, should not cause eardrum rupture.

3. Assuming a person is standing in the open, he would be subjected to the incident pressure plus the dynamic pressure. Referring to graph II, and using the peak incident pressure of 7 psi obtained from graph I, the dynamic pressure is 1.0 psi. The total blast pressure in this instance is 8 psi. Referring to table I, this could cause eardrum rupture, assuming no ear protection is provided. As is evident from graph II, the dynamic pressure is not significant at peak incident pressures below approximately 10 psi but becomes significant at higher incident pressures.

4. Assuming a person is standing against a wall or reflecting surface which is facing the explosion, he and the wall would be subjected to the reflected pressure. Referring to graph II, and again using a peak incident pressure of 7 psi, the reflected pressure would be approximately 15 psi. Referring to table I, this pressure would result in a 50 percent chance of eardrum rupture assuming no ear protection is provided. Referring to table II, structures would be affected as indicated.

5. The peak wind velocity and the shock front velocity figures given in graph III are used to determine the velocities present at the peak incident pressure obtained from graph I. These velocity figures can be used to assess injury or damage. For example, at 7 psi peak incident pressure the shock front would be traveling at approximately 1,400 fps or 900 mph. The peak wind velocity would be approximately 300 fps or 200 mph. While this wind velocity is relatively high, it would last for less than one second, assuming the detonation of less than 50 pounds of explosive. It could cause a standing person or a person not using a suitable protective shield to be blown down. It could also cause injury from debris, such as stones or wood, thrown from areas adjacent to the explosion.

The use of the tables and graphs contained in this bulletin will enable the determination of peak blast pressure and its effects upon persons and structures exposed to the explosion of an IED. It is emphasized that complete protection against fragmentation and other blast derived airborne missiles must be provided. Users of this bulletin are cautioned that the distance and velocity figures given are minimum figures for explosions occurring in an open area. The distance figures must be increased for explosions in a hilly area, in an area containing structures, or in a confined area such as a room or hallway.

REFERENCES

1. "THE RELATIONSHIP BETWEEN SELECTED BLAST-WAVE PARAMETERS AND THE RESPONSE OF MAMMALS EXPOSED TO AIR BLAST," Defense Atomic Support Agency Report 1860, November 1966.

2. "THE EFFECTS OF NUCLEAR WEAPONS," Department of the Army Pamphlet 39-3, April 1962.

3. "EXPLOSIVES AND DEMOLITIONS," Department of the Army Field Manual 5-25, February 1971.

4. "ENGINEER FIELD DATA," Department of the Army Field Manual 5-34, December 1969.