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PROTECTION AGAINST MALEVOLENT USE OF VEHICLES AT NUCLEAR POWER PLANTS: VEHICLE BARRIER SYSTEM SITING GUIDANCE FOR BLAST PROTECTION

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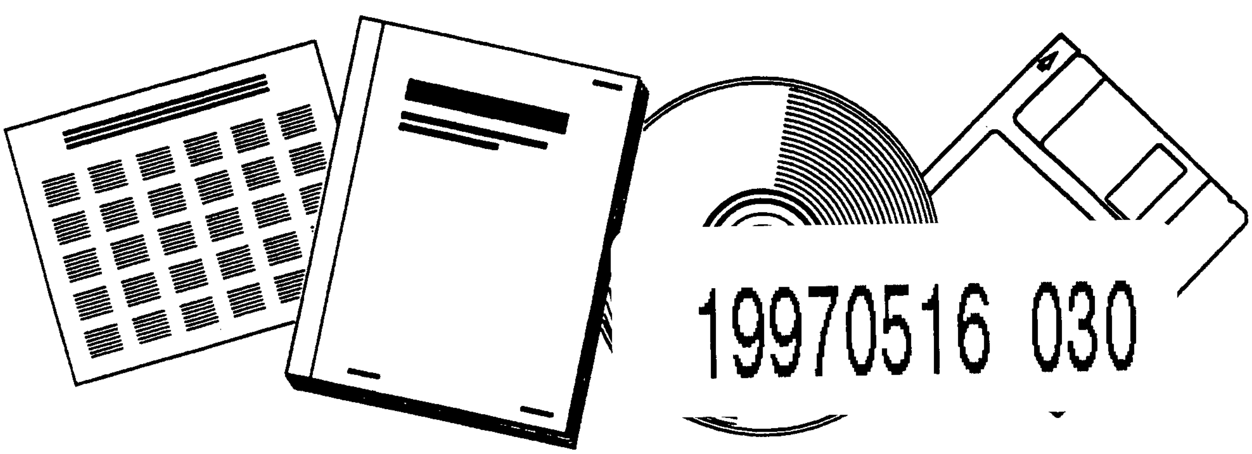

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Protection Against Malevolent Use of Vehicles at Nuclear Power Plants

Vehicle Barrier System Siting Guidance for Blast Protection

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U.S. Army Corps of Engineers

**Prepared for
U.S. Nuclear Regulatory Commission**

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This manual provides guidance for determining the minimum safe standoff distance between vital safety related equipment and the design basis vehicle bomb threat adopted by the U.S. Nuclear Regulatory Commission. Vital safety related equipment should survive the design basis vehicle bomb attack when the minimum safe standoff distance is provided. Guidance is provided for exposed vital safety related equipment and for equipment housed within vital area barriers.

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SECTION 1 - INTRODUCTION

1.1 Purpose

This manual provides guidance for determining the minimum safe standoff distance between common vital safety related equipment (hereafter referred to as equipment) and the design basis vehicle bomb threat adopted by the U.S. Nuclear Regulatory Commission. The guidance presented can be used to determine the adequacy of standoff distance from an existing vehicle barrier system (VBS) or it can be used for the siting of a new VBS. The user of this manual should either have a background in civil engineering or should consult a civil engineer when using the manual.

1.2 Protection Strategy

Protection from blast effects is primarily accomplished by keeping the explosive source at a distance from the target. This distance is referred to as standoff distance. The amount of standoff distance required to provide an acceptable level of protection to a vital area is a function of the quantity of explosives considered and the type of vital area barrier, if any, used. For bombs transported by vehicles, providing standoff distance is accomplished by installing a VBS. For further information on VBS refer to Volume 2 of this NUREG.

1.3 Scope

This manual presents procedures for determining the minimum safe standoff distance for equipment that is either exposed or housed within vital area barriers. The procedure for exposed equipment is based on Department of Defense explosive safety criteria and analytical modeling. The procedure for equipment housed within vital area barriers is based on dynamic nonlinear blast analysis for several different vital area barriers. Vital area barriers considered are planar one- and two-way acting reinforced concrete slabs. These slabs may be either wall or roof slabs. The minimum safe standoff distance applies only to walls and roofs and not to doors, windows, and louvers. Vital area barriers and exposed equipment not addressed will require analysis beyond the scope of this manual. The procedures described in the manual are accepted ways of determining the minimum safe standoff distance; however, they are not exclusive. Other procedures based on sound scientific and engineering principles are also acceptable. More rigorous analysis may result in lesser standoff distances than are given in this manual.

1.4 Organization

Guidance for determining minimum safe standoff distance is organized into the sections indicated below.

Section	Topic
2	Design Basis
3	Determining Standoff Distance
4	Determining Minimum Safe Standoff Distance for Equipment Within Vital Area Barriers
5	Determining Minimum Safe Standoff Distance for Exposed Equipment
6	Documentation
7	Conclusions

SECTION 2 - DESIGN BASIS

The design basis vehicle bomb threat that equipment must resist is an explosive weight in terms of its equivalency to TNT. The design basis vehicle bomb threat and protection criteria have been provided to affected Nuclear Regulatory Commission (NRC) licensees in a separate document. The threat information, and any information derived from it, has been determined by the NRC to be Safeguards Information, and it should be handled accordingly.

SECTION 3 - DETERMINING STANDOFF DISTANCE

3.1 Purpose

This section defines the standoff distance that a vehicle barrier system (VBS) provides equipment.

3.2 Definition

For the purposes of this NUREG, the standoff distance for exposed equipment is defined as the shortest distance from the equipment to the closest exterior point of the VBS and the standoff distance for equipment housed within vital area barriers is defined as the shortest distance from the center of the face of the barrier to the closest exterior point of the VBS. Certain types of vehicle barriers, due to performance characteristics, require additional distance from the vital barriers or vital equipment to provide adequate protection. Refer to Volume 2 of this NUREG for information on the additional distance that needs to be provided beyond the minimum safe standoff distances cited in this volume.

3.3 Obstructed Facilities

In situations where an obstruction exists between the exposed equipment or vital area barrier and the VBS, in the absence of rigorous analysis, the obstruction should be disregarded and the standoff distance determined as defined in paragraph 3.2.

3.4 Maximum Considered Standoff Distance

If a standoff distance of 360 feet or greater is provided, no further analysis is required. It can be assumed that the equipment will be provided adequate protection.

SECTION 4 - DETERMINING MINIMUM SAFE STANDOFF DISTANCE FOR EQUIPMENT WITHIN VITAL AREA BARRIERS

4.1 Purpose

This section provides tables, with instructions, that can be used to determine minimum safe standoff distances for select one- and two-way reinforced concrete vital area barriers.

4.2 Basis of Tables

The tables presented in this section are based on the U.S. Army Corps of Engineers Protective Design - Mandatory Center of Expertise Technical Report PDC-TR 91-6, *Blast Analysis Manual, Part 1 - Level of Protection Assessment Guide*. Simplifying assumptions have been applied to the procedures contained in this document for both one- and two-way reinforced flat concrete slabs subject to airblast loads. These simplifying assumptions allow for expedient, conservative determination of the minimum safe standoff distance. The minimum applicable standoff associated with the design threat and the response mode valid for this procedure is 36 feet. The assumptions made on input parameters for the PDC-TR 91-6 chart for one-way slabs are as follows:

Compressive strength of concrete - 4,000 psi
Yield strength of reinforcing - 60,000 psi
Acceleration due to gravity - 386.4 in/sec^2
Weight density of section - 0.0868 lb/in^3
Simple supports
Average depth of tensile reinforcing - (thickness - 3 in)
Span length - less than or equal to 30 ft

The assumptions made on input parameters for the PDC-TR 91-6 chart for two-way slabs are as follows:

Compressive strength of concrete - 4,000 psi
Yield strength of reinforcing - 60,000 psi
Acceleration due to gravity - 386.4 in/sec^2
Weight density of section - 0.0868 lb/in^3
Simple supports
Boundary coefficient - 0.55 (ordinate term)
- 0.35 (abscissa term)
Average depth of tensile reinforcing -
(thickness - 3 in) for 12- & 18-in slabs
(thickness - 6 in) for 24- & 30-in slabs
Short span - greater than or equal to 8 ft
Aspect ratio - greater than or equal to 0.5

The only input parameters are thickness and reinforcing ratio. The tables are conservative for members with greater material strengths and/or support conditions and lesser spans. For the purposes of this manual, the minimum safe standoff distance is that associated with the medium level of protection defined in PDC-TR 91-6. If a slab has a total area of openings greater than 2 percent of the total slab area being analyzed, a more rigorous structural analysis of the slab beyond the scope of this manual is required. If the equipment is not protected from components such as doors, windows, hatches, and louvers, a more rigorous analysis will be needed to show that it will not be damaged should these components be disengaged by the blast. Section 4.5 provides guidance for determining the safe standoff distance from openings to prevent airblast damage to equipment contained within the facility.

4.3 Types of Blast Loads

For the purposes of this manual, blast loads are separated into the two categories of reflected and side-on. A reflected load occurs when the vital area barrier faces, or nearly faces, the explosive source and is at approximately the same

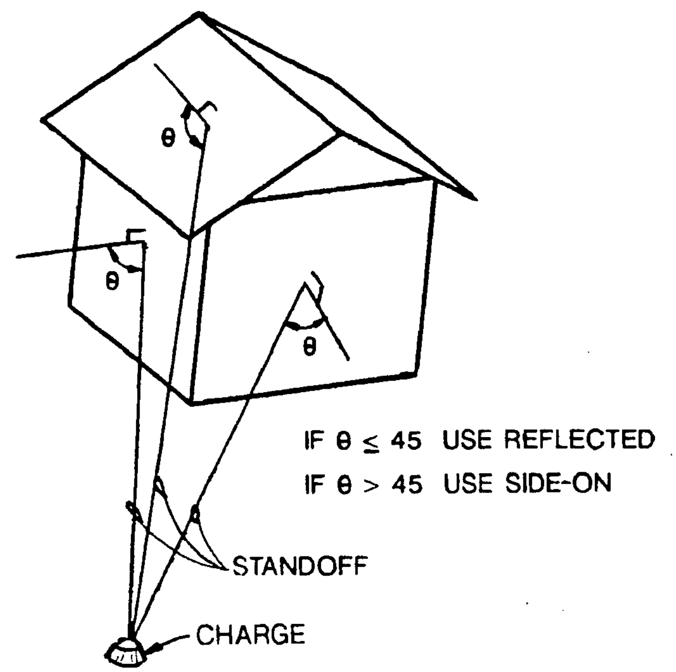

Figure 4.1 Criteria for using reflected or side-on blast loads

elevation. Side-on loading is applied to vital area barriers which do not face the explosive source or where the difference in elevation is large. Examples of vital area barriers which experience side-on loading are roofs, side walls, rear walls, and upper panels of the front wall of a tall building. When performing an assessment, loads can be defined using the following criteria in terms of the angle of the path of the blast wave with respect to a line perpendicular to the structural component from the center of the face:

- Angles less than or equal to 45 degrees, use reflected criteria

- Angles greater than 45 degrees, use side-on criteria

An illustration of this criteria is provided in figure 4.1.

4.4 Assessment Tables

Tables 4.1 and 4.2 represent two slab thicknesses and list five reinforcing ratios for one-way reinforced slabs. Tables 4.3 through 4.6 represent four slab thicknesses and list five reinforcing ratios for two-way reinforced slabs. Use the following steps with these tables.

4.4.1 Step 1

Determine if the tables apply to the vital area barrier to be considered; i.e., if the vital area barrier is a flat concrete slab with either one- or two-way reinforcing. If these tables do not apply, use an alternate analysis technique such as that contained in PDC-TR 91-6.

4.4.2 Step 2

Use as-built construction drawings to determine the slab thickness and reinforcing ratio. For two-way members use the average of the long and short span tensile reinforcing ratios.

4.4.3 Step 3

Determine if the vital area barrier will be subject to reflected or side-on blast loading in accordance with the information presented in paragraph 4.3.

4.4.4 Step 4

Using the table for the thickness involved, move to the line for the appropriate reinforcing ratio. For thicknesses and reinforcing ratios greater than or between those provided in the tables, use the next lesser thickness or reinforcing ratio provided. Move across the row to the applicable blast loading criteria and read the minimum safe standoff distance.

4.4.5 Step 5

If the minimum safe standoff distance determined from the table is less than or equal to the existing or proposed standoff distance as defined by Section 3.2 of this manual, document the analysis and move on to the next vital area barrier to be considered. If the minimum safe standoff distance is greater than the standoff distance provided or proposed as defined by Section 3.2 of this manual, perform a more rigorous analysis or adjust the siting of the vehicle barrier system (VBS) to provide a standoff distance equal to or greater than the minimum safe standoff distance.

4.5 Pressure Leakage

The following formula can be used to determine the minimum safe standoff distance, R, from penetrations in vital area barriers.

$R = ((A/V)+0.7007)/0.001776$
A = Area of penetration, ft^2
V = Volume of room behind penetration, ft^3

If this standoff distance cannot be achieved, a more rigorous analysis must be performed. Use the greater of the minimum safe standoff distances determined for vital area barriers or pressure leakage.

Table 4.1 Minimum safe standoff distances for 12-inch-thick one-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	86	36
0.8	98	36
0.6	120	48
0.4	158	70
0.2	282	138

Table 4.2 Minimum safe standoff distances for 18-inch-thick one-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	58	36
0.8	68	36
0.6	80	36
0.4	108	40
0.2	186	82

Table 4.3 Minimum safe standoff distances for 12-inch-thick two-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	48	36
0.8	50	36
0.6	56	36
0.4	70	36
0.2	108	44

Table 4.4 Minimum safe standoff distances for 18-inch-thick two-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	38	36
0.8	40	36
0.6	46	36
0.4	56	36
0.2	84	36

Table 4.5 Minimum safe standoff distances for 24-inch-thick two-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	36	36
0.8	36	36
0.6	36	36
0.4	40	36
0.2	62	36

Table 4.6 Minimum safe standoff distances for 30-inch-thick two-way slabs

Reinforcing ratio (percent)	Reflected standoff (feet)	Side-on standoff (feet)
1.0	36	36
0.8	36	36
0.6	36	36
0.4	36	36
0.2	54	36

SECTION 5 - DETERMINING MINIMUM SAFE STANDOFF DISTANCE FOR EXPOSED EQUIPMENT

5.1 Purpose

This section provides the minimum safe standoff distances for aboveground equipment not housed within vital area barriers. Three categories of exposed equipment are addressed in this manual --heavy equipment, light equipment, and water tanks.

5.2 Basis of Minimum Safe Standoff Distances

The minimum safe standoff distances for heavy and light equipment are based on Department of Defense explosive safety criteria. The minimum safe standoff distance for water tanks is based on dynamic nonlinear finite element blast analysis.

5.3 Heavy Equipment

Heavy equipment, for the purposes of this manual, means equipment such as pumps, piping, valves, compressors, and motors. The minimum safe standoff distance for equipment of this type is 180 feet.

5.4 Light Equipment

Light equipment, for the purposes of this manual, means equipment such as ventilation equipment, electrical control panels, and switchgear. The minimum safe standoff distance for equipment of this type is 360 feet.

5.5 Water Tanks

The minimum safe standoff distance for water tanks that are maintained in a full or nearly full condition is 100 feet. This safe standoff distance includes considerations for airblast and fragmentation effects caused by the explosion.

SECTION 6 - DOCUMENTATION

Documentation guidelines are contained in Regulatory Guide 5.68.

SECTION 7 - CONCLUSIONS

This manual provides guidance for determining the minimum safe standoff distance between common vital safety related equipment and the design basis vehicle bomb threat adopted by the U.S. Nuclear Regulatory Commission. The guidance presented can be used to determine the adequacy of standoff distance from an existing vehicle barrier system (VBS) or it can be used for the siting of a new VBS.