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U.S. ATOMIC ENERGY COMMISSION

REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.91

EVALUATION OF EXPLOSIONS POSTULATED TO OCCUR ON TRANSPORTATION ROUTES NEAR NUCLEAR POWER PLANT SITES

A. INTRODUCTION

General Design Criterion 4, "Environmental and Missile Design Basis" of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that nuclear power plant structures, systems, and components important to safety be appropriately protected against dynamic effects resulting from equipment failures which may occur within the nuclear power unit as well as events and conditions which may occur outside the nuclear power unit. These latter events include the effects of explosion of hazardous materials which may be carried on nearby transportation routes. This guide describes a method acceptable to the Regulatory staff for determining safe distances from a nuclear power plant to a transportation route over which explosive material (not including gases) may be carried.

B. DISCUSSION

In order to meet General Design Criterion 2, "Design Basis for Protection Against Natural Phenomena," of Appendix A to 10 CFR Part 50 with respect to tornadoes, the structures, systems, and components important to safety of a nuclear power plant must be designed to withstand the wind pressure and sudden internal pressure changes due to a design basis tornado without causing an accident, and without damage that would prevent a safe and orderly shutdown. Since the nuclear power plant is designed to safely withstand the design basis tornado described in Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plants," an explosion which produces a peak overpressure no greater than the wind pressure caused by the tornado should not cause an accident or prevent the safe shutdown of the plant. It should be noted that this applies only to the adequacy of the plant with respect to external dynamic overpressure. The potential effect of missiles from these explosions is still under study. This regulatory guide describes a method for determining distances from the power plant to a railway, highway, or navigable waterway beyond which any explosion that might occur on these transportation routes is not likely to have an adverse effect on plant operation or prevent a safe shutdown. Under these conditions, a detailed review of the transport of explosives on these transportation routes would not be required.

In establishing the distances referred to above, it is necessary to determine the dynamic wind pressure associated with the wind speed of the design basis tornado determined from Regulatory Guide 1.76 for each of the three regions of the contiguous United States. Table 1 presents the wind speeds for the three regions and the associated dynamic pressures calculated from $q = 0.002558V^2$ (this represents the kinetic energy per unit volume of moving air), where is the dynamic pressure in pounds per square foot and V is the maximum wind velocity in miles per hour (see Reference 1).

TABLE 1

DESIGN BASIS TORNADO WIND SPEED CHARACTERISTICS

Region	*Maximum[a] Wind Speed, mph*	*Dynamic Wind Pressure, psi*	*Dynamic Wind Pressure, psf*
I	360	2.3	331.2
II	300	1.6	230.4
III	240	1.0	144.0

[a]The maximum wind speed is the sum of the rotational speed component and the maximum translational speed component.

The calculational method used to analyze the relationships of explosive charge to distance is first to assume that the limiting peak overpressure due to an explosion is equal to the dynamic wind pressure resulting from a design basis tornado for a specific region and then to calculate the limiting distance beyond which the peak overpressure resulting from an explosion will not exceed the design dynamic wind pressure.

The conservative correlation for determining the peak explosion overpressure as a function of distance and weight of explosive (TNT) is the curve for peak reflected pressure, P_r, on Figure 1. As defined in Reference 2, the peak reflected pressure occurs when the shock wave impinges on a surface oriented so that a line which describes the path of travel of the wave is normal to the surface. This curve is taken from Figure 4.12 of Reference 2 with some of the symbols modified.

Table 1 gives 2.3 psi as the external dynamic wind pressure due to a design basis tornado in Region I. From Figure 1, the scaled distance, Z_G, corresponding to a peak reflected pressure of 2.3 psi is found to be 41. The following function of distance and explosive charge is then determined for Region I:

$$R_G = 41W^{1/3}$$

Similarly, the correlations for the remaining regions are:

Region II $R_G = 55W^{1/3}$

Region III $R_G = 80W^{1/3}$

where R_G is the distance in feet from an exploding charge of W pounds of TNT. Reference 3 provides the TNT equivalents of other types of explosives. For hazardous materials not listed in Reference 3, the applicant should substantiate the derivation of the TNT equivalent used.

The maximum probable hazardous cargo for a single highway truck is approximately 43,000 pounds (equivalent TNT). The distance beyond which an exploding truck will not have an adverse effect on plant operations or will not prevent a safe shutdown is indicated in Figures 2, 3, and 4 for Regions I, II, and III, respectively.

Similarly, the maximum explosive cargo in a railroad box car is approximately 132,000 pounds (equivalent TNT). The distance beyond which an exploding railroad box car will not have an adverse effect on plant operations or will not prevent a safe shutdown is shown in Figures 2, 3, and 4. In this case, it is also necessary to consider the possible effects of a simultaneous explosion of connected box cars. For illustrative purposes an evaluation for three box cars is provided. The distance beyond which three box cars exploding simultaneously will not have an adverse effect on plant operations or will not prevent a safe shutdown is shown on Figures 2, 3, and 4. If there is a significant probability that more than three box cars of explosives will pass by the nuclear power plant in one shipment, further evaluation by the applicant will be necessary.

The largest probable quantity of explosive material transported by ship is approximately 10,000,000 pounds (equivalent TNT). The distance from the shipping channel beyond which such an explosive charge will have no adverse effect on plant operations or prevent a safe shutdown is shown on Figures 2, 3, and 4.

Table 2 summarizes the results of the minimum distances shown on Figures 2, 3, and 4 for the maximum postulated shipments by truck, railroad boxcar, multiple railroad boxcars, and ship.

TABLE 2

DISTANCES (IN FEET) TO EQUIVALENT TORNADO OVERPRESSURES

Tornado Region	*43,000-lb Truckload*	*132,000-lb 1-Boxcar Load*	*396,000-lb 3-Boxcar Load*	*10,000,000-lb Shipload*
I	1500	2100	3000	9000
II	1900	2800	4000	11500
III	2800	4000	5800	17000

C. REGULATORY POSITION

In the design of nuclear power plants, the ability to withstand the possible effects of explosions occurring on nearby transportation routes should be considered relative to the effects of the design basis tornado.

When carriers that transport explosives can approach vital structures of a nuclear facility no closer than the distances indicated in Figures 2, 3, and 4, no further consideration need be given to the effects of external dynamic overpressure in plant design. If transportation routes are closer to structures and systems important to safety than the distances indicated in Figures 2, 3, and 4, the applicant should show that the risk to the public is acceptably low on the basis of, for example, low probability of explosions or structural capability for safety-related structures to withstand explosions.

D. IMPLEMENTATION

The purpose of this section is to provide guidance to applicants and licensees regarding the Regulatory staff's plans for utilizing this regulatory guide.

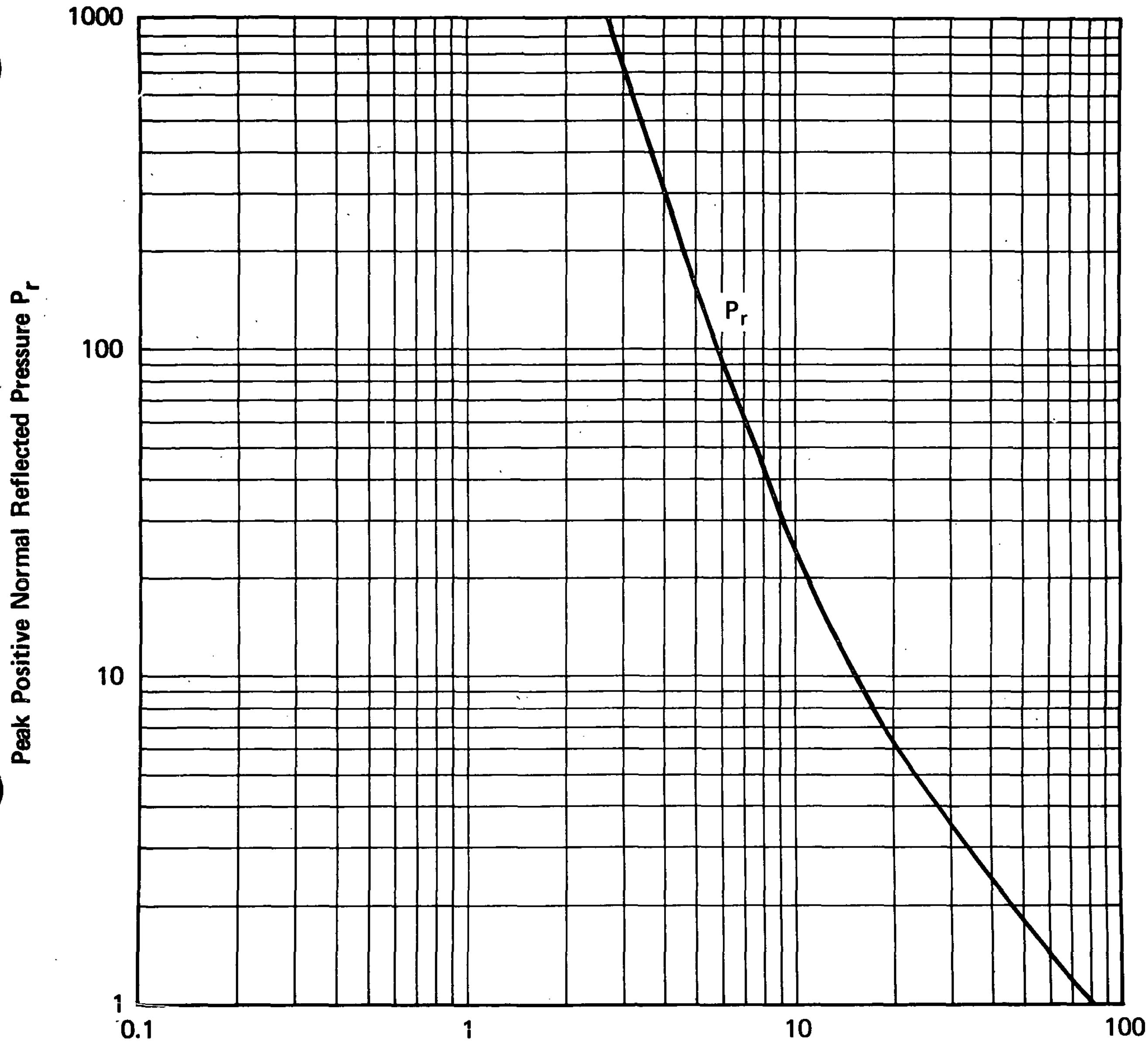
Except in those cases in which the applicant proposes an alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used in the evaluation of construction permit applications docketed on or after March 14, 1975.

REFERENCES

1. "Wind Forces on Structures" Paper No. 3269, ASCE Transactions, Vol. 126, Part II, 1961.

2. Department of the Army Technical Manual TM 5-1300, "Structures to Resist the Effects of Accidental Explosions." June 1969.

3. Annals of the New York Academy of Science, Volume 152, Article 1, "Prevention of and Protection Against Explosion of Munitions, Fuels and other Hazardous Mixtures." Part 4, October 28, 1968.



SCALED GROUND DISTANCE $Z_G = R_G / W^{1/3}$

P_r = Peak Positive Normal Reflected Pressure, psi
W = Charge Weight, lb
R_G = Radial Distance from Charge, ft
Z_G = Scaled Ground Distance, ft/lb$^{1/3}$

Figure 1

Peak Positive Normal Reflected Pressure for Hemispherical TNT Surface Explosion at Sea Level

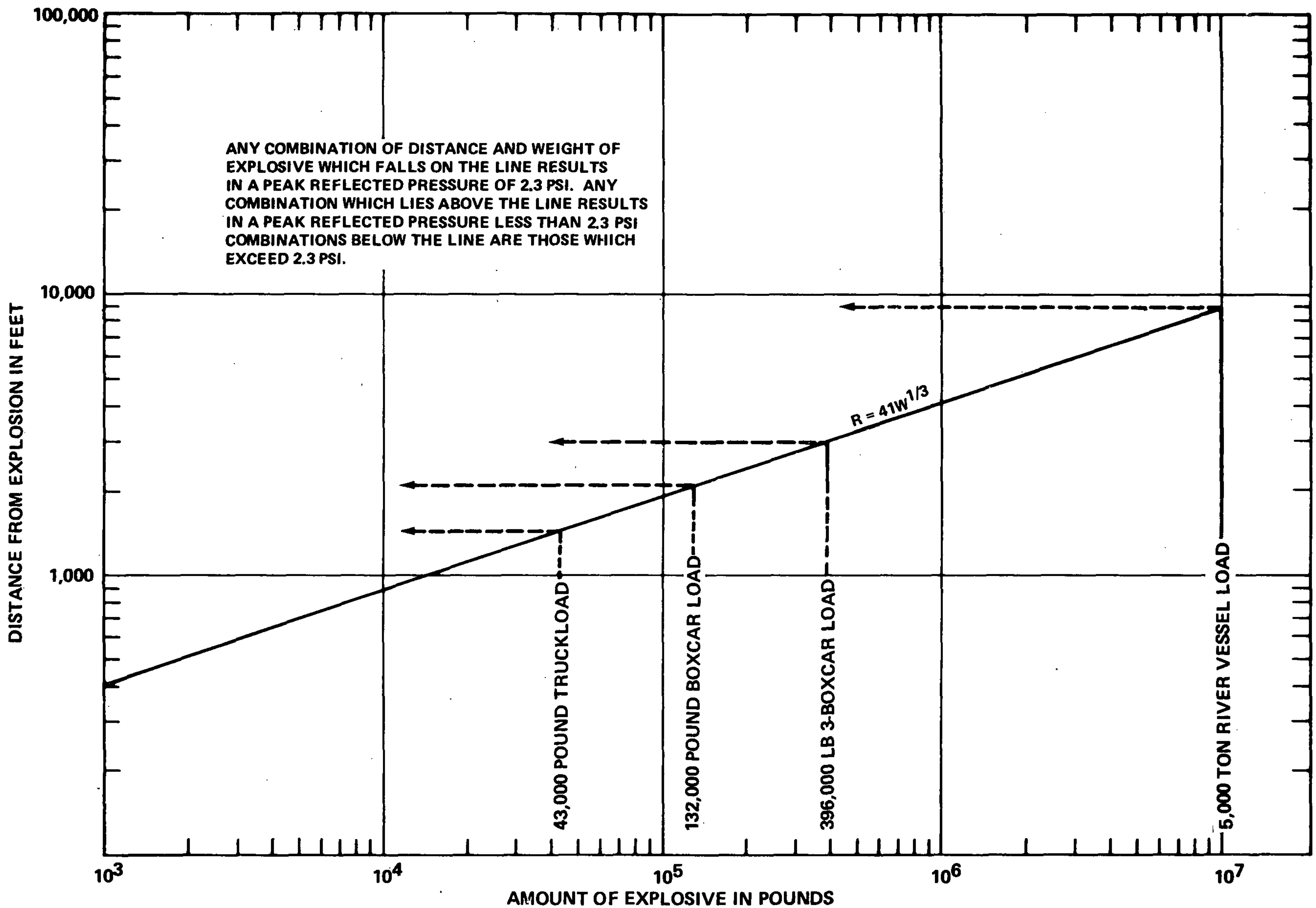


FIGURE 2 APPLICABLE TO TORNADO REGION I

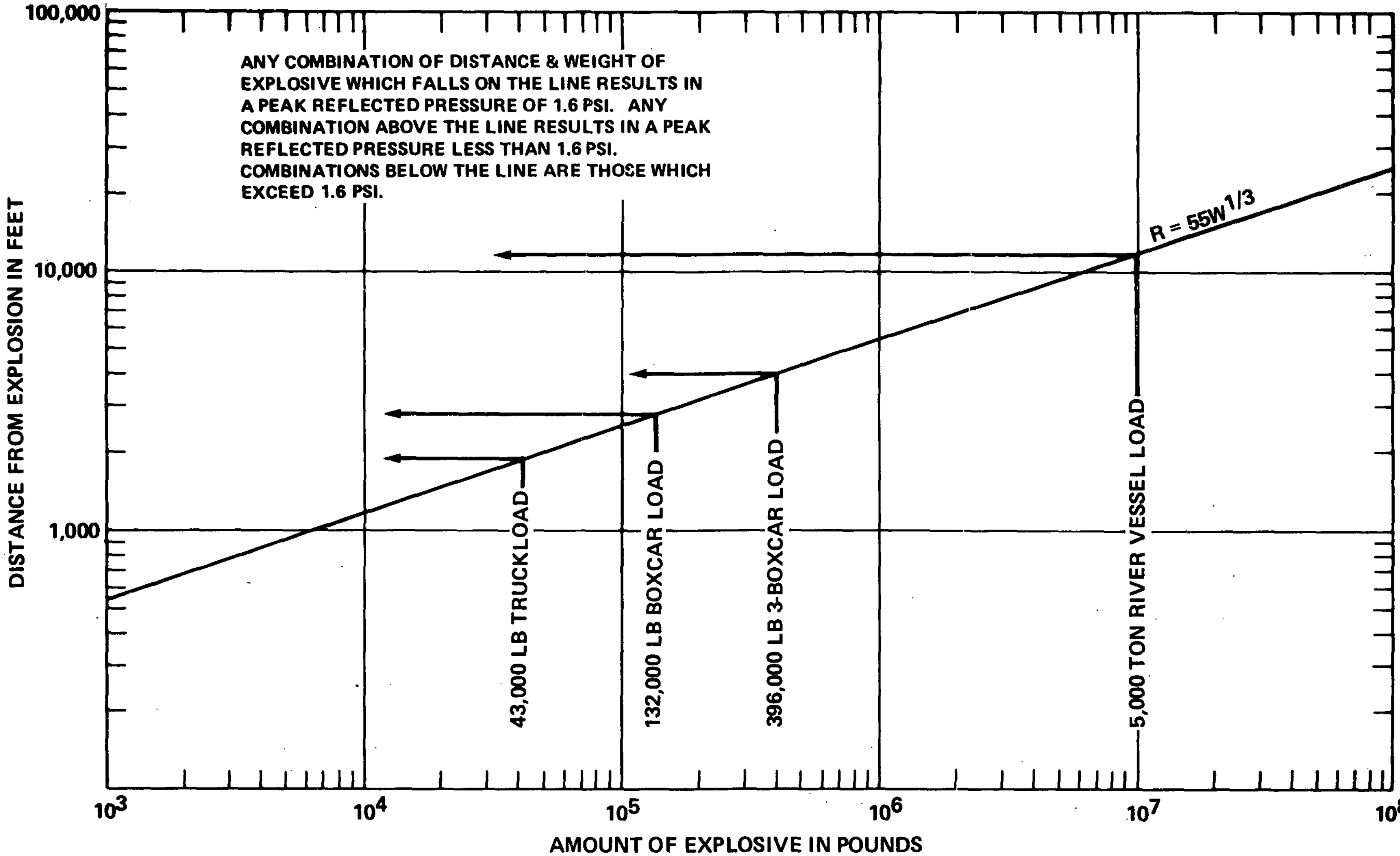


FIGURE 3 APPLICABLE TO TORNADO REGION II

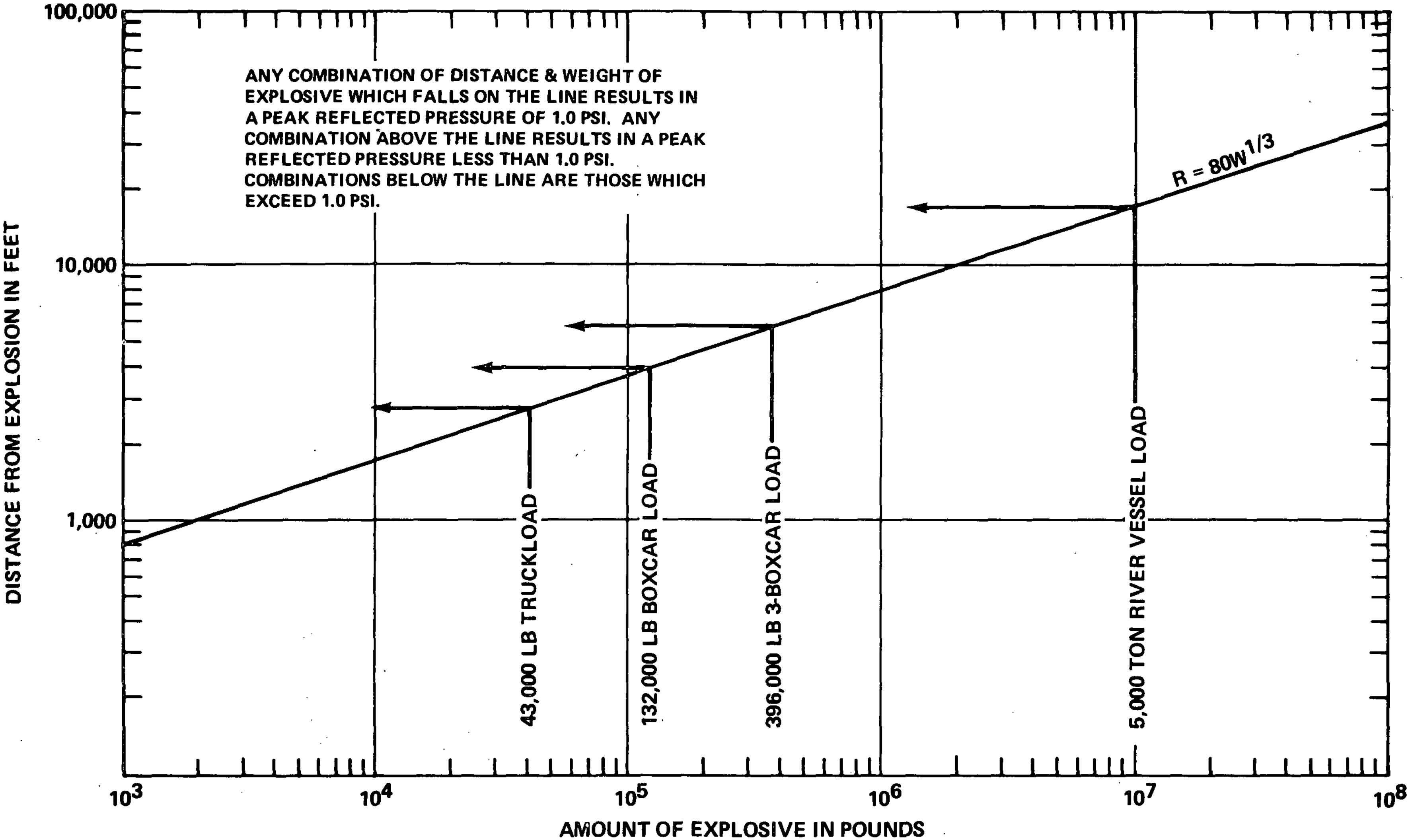


FIGURE 4 APPLICABLE TO TORNADO REGION III