

Changes shown by ↗

SCOPE

- I 1.1 This practice covers the design of blast resistant buildings.
- I 1.2 **An asterisk (*)** indicates that additional information from the Owner, or approval by the Owner is required.

SUMMARY OF ADDITIONAL REQUIREMENTS

- I ↗ 2.1 **Table 1** lists the practice, standard and specification which shall be used as specified in this practice.
- I ↗ * 2.2 **Table 2** lists the practice, specification and standards which shall be used with this practice **as applicable**.

TABLE 1

PRACTICE	
IP 4-3-1	Plant Buildings for Operation and Storage
STANDARD, PUBLICATION AND SPECIFICATION	
ACI Standard 318 Building Code Requirements for Reinforced Concrete ASCE Publication Design of Blast Resistant Buildings in Petrochemical Facilities	AISC Specification Structural Steel Buildings - Allowable Stress Design and Plastic Design Load & Resistance Factor Design

TABLE 2

PRACTICE	
IP 4-3-2	Blast Resistant Buildings
STANDARDS AND SPECIFICATION	
ACI Standard 531 Building Code Requirements for Concrete Masonry Structures AISI Specification Design of Cold-Formed Steel Structural Members ASTM Standards A 36 Structural Steel A 82 Steel Wire, Plain, for Concrete Reinforcement A 446 Steel Sheet, Zinc-Coated (Galvanized) by the Hot Dip Process, Structural (Physical Quality)	ASTM Standards (Cont) A 525 / A 525M General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process A 572 High-Strength Low Alloy Columbium-Vanadium Steel of Structural Quality A 615 Deformed and Plain Billet Steel Bars for Concrete Requirement A 792 Steel Sheet Aluminum-Zinc Alloy-Coated by Hot-Dip Process C 90 Hollow Load-Bearing Concrete Masonry Units C 1048 Standard Specification for Heat-Treated Flat Glass

- I ↗ * 2.3 Local codes and standards may be substituted for the ones referenced herein provided the following provisions are met:
 - a. The resultant design meets the safety and serviceability criteria attained through this practice.
 - b. Substitution is accepted by the authorities where the facility is to be located and by the Owner's Engineer.

DEFINITIONS

- I ↗ 3.1 **Vapor Cloud Explosion (VCE):** An incident producing a blast wave having a specified overpressure and duration. Three incidents are specified for the design of blast resistant buildings:
 - a. **VCE #1:** Characterized by high overpressure of relatively short duration, as specified in [Table 3](#). The blast resistant building must withstand this VCE with a low response, as defined in [Par. 3.5](#).
 - b. **VCE #2:** Characterized by low overpressure of relatively long duration, as specified in [Table 3](#). The blast resistant building must withstand this VCE with a low response, as defined in [Par. 3.5](#).
 - c. **VCE #3:** An extreme incident with high overpressure and relatively long duration. The blast resistant building must withstand this VCE with a high response, as defined in [Par. 3.5](#).
- I * 3.2 **Building categories** - buildings are categorized for the purpose of blast resistant design based on spacing from a credible VCE hazard. Spacing category for blast resistant building will be specified.

- I ♦ 3.3 **Blast-resistant buildings** shall be capable of resisting, in any direction, the applicable design vapor cloud explosions as follows:
- a. **Critical operations buildings** shall be designed to withstand VCE #1 and VCE #2. In addition, if normally occupied, they shall be designed to withstand VCE #3.
 - b. **Other normally occupied buildings** shall be designed to withstand VCE #3.
- * The building classification of critical and/or occupied will be specified by the Owner.
- I 3.4 **Dynamic resistance** or **equivalent static load** is the structural strength required or the capacity provided to permit a structural component to resist the effects of the blast loadings within the specified deformation limits.
- I ♦ 3.5 **Building response** - The following descriptions apply to the response of buildings from a VCE event:
- a. Low Response: Localized building/component damage. Building can be used; however, repairs are required to restore integrity of structural envelope.
 - b. High Response: Building/component damage is at the limit of structural integrity. Additional loading, subsequent to blast pressure, due to environmental conditions (i.e., wind, snow, rain) may lead to collapse.

LOADS

BLAST PRESSURES AND DURATIONS

- S 4.1 **Overpressures and durations** for the blast loads shall be as listed in **Table 3**.
- I ♦ 4.2 **Each blast load** shall be assumed to have a shock front and to decrease linearly from the specified peak pressure (P_o or P_r) to zero for the duration (t_o or t_e).
- S ♦ 4.3 **Structural components** of a blast resistant building shall be designed for the blast loads in **Table 3** based on the specified building category and applicable VCE.
- a. **Each Wall** shall be designed for the peak reflected pressure, P_r , with effective duration, t_e .
 - b. **Slab, cladding or beams** of a flat roof (sloped less than 20°) shall be designed for the peak incident overpressure, P_o and duration, t_o .
 - c. **Main structural framing** shall be designed for the blast load or its effects on any wall **per Par. 4.3a** and roof load **per Par. 4.3b**. The effect of an average roof load and rear wall loading may be included using procedures in the ASCE document.

♦ **TABLE 3 - BLAST LOAD OVERPRESSURES AND DURATIONS**

VCE LOAD CATEGORY AND CASE	PEAK INCIDENT OVERPRESSURE, P_o , psig (kPa)	OVERPRESSURE DURATION, t_o msec	PEAK REFLECTED PRESSURE, P_r psi (kPa)	EFFECTIVE DURATION, $t_e^{(1)}$ msec	
				One-Story	Two-Story
Category 0					
VCE #1	10.0 (70)	40	15.1 (104)	40	40
VCE #2	3.0 (21)	230	6.5 (44)	135	155
Category 1					
VCE #1	6.5 (45)	50	15.1 (104)	45	50
VCE #2	3.0 (21)	200	6.5 (44)	120	140
VCE #3	7.0 (48)	130	16.5 (113)	80	100
Category 2					
VCE #1	3.0 (21)	55	6.5 (44)	50	55
VCE #2	1.9 (13)	200	4.0 (27)	120	140
VCE #3	3.5 (24)	155	7.6 (52)	95	115
Category 3					
VCE #1	1.5 (10)	65	3.1 (21)	55	65
VCE #2	1.1 (7.5)	200	2.3 (16)	120	140
VCE #3	1.5 (10)	200	3.1 (21)	120	140

Notes:

- (1) "One-story" values are for buildings having height or half-width not more than 16 ft (4.9 m). "Two-story" values are for buildings having height or half-width not more than 32 ft (9.8 m). Linear interpolations may be used for values between these limits.

- I ♦ 4.4 Building shall be rectangular in shape without re-entrant corners. Blast loads on buildings with irregular shapes shall be subject to the approval of the Owner's Engineer.

- S 4.5 **Reduction of blast loading** due to shielding by obstacles or structural barriers shall not be applied unless approved by the Owner's Engineer.

RESISTANCE - STATIC LOAD EQUIVALENT OF BLAST LOADING

- I 4.6 **Static equivalent loads** may be used to represent the dynamic effects of the blast loading (pressure, duration, rebound) on each structural component provided that:
- Static equivalent load** shall be the resistance (R) or rebound, (R_r) required for the component to resist the specified blast loading without exceeding deformation limits specified in **Par. 4.10**.
 - Governing static equivalent load** for each structural component shall be for the VCE scenario that requires the greatest structural resistance according to **Par. 4.7**, taking into account the specified deformation limits for each VCE scenario.
- I 4.7 **Required dynamic resistance (R)** in the direction of blast loads shall be calculated in accordance with the procedure outlined in the ASCE publication, or an equivalent acceptable method which takes into account dynamic response. Required dynamic resistance may be calculated in accordance with the following general formula:

$$R = \frac{P}{\frac{\sqrt{\alpha}}{\pi\tau} + \frac{\alpha\tau}{2\mu_d(\tau+0.7)}}$$

- where:** R = Required dynamic resistance of structural element, expressed as static load equivalent of blast pressure and duration, psi (kPa)
 P = Peak blast load = P_r or P_o as appropriate for the element under consideration, psi (kPa)
 α = Energy absorption factor = $2\mu_d - 1$
 μ_d = Maximum ductility demand = X_m / X_y
 τ = Duration factor = t / T
 X_m = Maximum dynamic displacement, inches (mm)
 X_y = Effective displacement at yield of the equivalent bilinear load-displacement function, inches (mm)
 t = Duration of blast load, milliseconds
 T = Fundamental period of vibration of individual element under consideration, milliseconds

- I 4.8 **Required rebound resistance R_r** , opposite in direction to the blast loading, shall be determined in accordance with the ASCE publication, or an equivalent acceptable method, but shall not be less than 25 percent of the required dynamic resistance.

- S 4.9 **Minimum static equivalent loads** (resistance and rebound) for all structural components, except for lateral frames, in blast resistant buildings shall be as follows:

CATEGORY	RESISTANCE R psi (kPa)	REBOUND, R_r psi (kPa)
Category 0 and Category 1	2.0 (14)	1.0 (7.0)
Category 2	1.0 (7.0)	0.5 (3.5)
Category 3	0.5 (3.5)	0.25 (1.7)

DEFORMATION LIMITS

- S 4.10 Maximum deformation (μ_d , θ) of any structural element shall not exceed the limits of Low Response for VCE #1 & VCE #2 or High Response for VCE #3, as specified in [Tables 4, 5 and 6](#).
- I,O 4.11 **Deformation limits** specified for High Response may be used for all blast load cases for a protective structure around an existing building, provided that there is enough clearance to accommodate the deformation of the surrounding structure without damage to the protected building.
- S 4.12 Deformation limits for other structural materials or systems shall be approved by the Owner's Engineer.