White Paper: Blast Resistant Electrical Equipment Centers (Part 1)

Cost-effective, optimal protection of electrical controls in the event of overpressure incidents is now within reach of every petroleum refinery.

It is no secret that many of the process technologies within our industry carry their own set of challenges and risks. Inherent in hydrocarbon processing is the continual concern for worker and operations protection in the event of explosion and fire. The ongoing history of refining is replete with accounts of disasters arising from simple and complex causes. Pipe corrosion was determined to be the prime cause of a May 2009 explosion and fire at the ethylene unit of Sunoco's Marcus Hook refinery, located in Delaware. Superheated feed stock leaked out of a rusty pipe and ignited, causing a vapor cloud explosion (VCE). Even though the refining industry has experienced advances in process and safety technologies, risk of a blast event still comes with the territory, underscoring the need for greater emphasis on worker and equipment safety.

The design, development and deployment of blast resistant structures to protect workers, power and process controls has been ongoing within hydrocarbon processing (HP) and chemical manufacturing. In more recent years the demand for these types of buildings has resulted in the creation of a relatively new industry that can provide benefits physically and financially to petrochemical companies and other chemical processing plants.

Background

Although blast resistant shelters are being used at land-based chemical processing plants, their origins can be traced to the use of externally reinforced, steel intermodal shipping containers in offshore safety applications. Freight containers have been in plentiful supply since their inception, and their structural strength makes them natural candidates for personnel protection from low-level blasts. Converted containers are resistant to blast loads in the 1.0 to 2.0-psi range. However, much higher loads are experienced at refinery blast events, given distance and other variables affecting the force of a VCE, necessitating the use of stronger structures. This need led to the fabrication of the first, custom-designed blast resistant modules and the industry has been evolving ever since. The response of industry to the need for ensuring personnel and plant safety reached a high degree of intensity after March 23, 2005. On that day a series of explosions ripped through BP's Texas City, TX refinery during the restarting of process equipment at the refinery's isomerization unit, killing fifteen workers and injuring 180 others. A tremendous loss of manpower and equipment was suffered and as a result, the unit did not come back online for another two years.

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Since this incident, demand has increased significantly for blast resistant, steel-fabricated buildings providing protection at HP facilities. Industry guidelines have been established to facilitate the design, construction and optimal location of blast resistant modules for personnel protection, as well as blast resistant electrical equipment centers (BRECs) for protection of the critical electrical process functions of the facilities they serve.

The addressing of safety concerns at petrochemical and other hazardous manufacturing facilities began largely in the 1990s, resulting in publication of the Occupational Safety & Health Administration's (OSHA) Process Safety Management (PSM) standards. In response to the OSHA publication, a joint effort was initiated by the American Petroleum Institute (API) and the Chemical Manufacturers Association (CMA) to establish a set of guidelines directly addressing OSHA's concerns in the published PSM standards. This response is contained in API Recommended Practice 752, *Management of Hazards Associated with Location of Process Plant Buildings*.

Government, Industry and Market Response

Following the conclusions reached in the wake of events at Texas City, OSHA initiated a series of National Emphasis Program (NEP) Audits at U.S. refineries, during which OSHA inspectors began issuing citations to companies for failure to adequately protect essential or critical equipment at their facilities. This has added momentum to an already growing movement on the part of petrochemical firms to provide strong, ductile, affordable protective shelters. Advances in the design, testing and manufacture of such structures have served to further ensure market viability for them.

Protecting Personnel vs. Equipment

The primary function of blast resistant shelters has been to protect personnel at facilities at risk for accidental explosions. On the other hand, risk managers, engineers and owners of companies also realize that the risk of exposure to overpressure or blast wave extends to the critical and essential power and control systems of their facilities as well. Outside of protecting personnel during a blast event at a refinery, nothing is more critical than sustaining the proper function of process-related automatic shutoff valves and other critical power equipment, as well as water pumps for fire protection.

Personnel Protection

The manufacturing industry for blast resistant modules (BRMs) offers a wide range of sizes and blast ratings, conforming to IBC design and construction practices. BRMs are most often used as a substitute for unrated construction trailers but may be configured into multiple sections. Multi-sectional systems may be large single story buildings or stacked to create a multi-story configuration. Examples include offices, cafeterias, and even sleeping quarters.

Protecting Equipment

As mentioned earlier, The International Building Code (IBC) defines essential facilities as those whose processes must remain in operation or return to operation with minimal interruption during or after a catastrophic event. Essential equipment is defined as equipment used in the power and control systems which must remain online during an event to maintain the minimum necessary process functionality at the site. Critical equipment is that which is used in those systems that must be returned to functional status in minimal time, with minimal cost and effort.

While massive attention and effort have been given to provide blast resistant shelters for the protection of personnel in the area of potential for overpressure at hydrocarbon processing facilities, a commensurate effort is being directed at protecting critical and essential power and control systems. Concerning such processes and the associated critical equipment, OSHA's PSM standard specifically lists equipment which the employer deems critical to process safety, "…because of its potential for significant impact on the safety of a process involving highly hazardous chemicals if it did not maintain its mechanical integrity." The standard goes on to name types of equipment including, but not limited to:

- Relief and vent systems and devices
- Pumps
- Emergency shutdown systems
- Controls (including monitoring devices and sensors, alarms, and interlocks).

The logical and most effective solution for the protection for critical processes and their associated equipment is a blast resistant electrical equipment center (BREC) rated to handle pressures of the caliber and type experienced at Texas City in 2005.

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Current Building Standards

Blast resistant buildings are not currently defined by a governing industry standard. Therefore, engineering analysis and testing are used to certify individual components and system designs. This responsibility falls primarily onto the shoulders of engineers, designers and manufacturing firms that produce blast resistant buildings.

Since the purpose of BRMs is to protect people, they must meet architectural and life safety codes. However, these requirements do not extend to equipment centers.

Typically the size of an office trailer, a BRM may be installed in a multitude of varying configurations (including multi-level) and floor plans. The buildings may be similar in design and construction to their first-generation cousins, steel shipping containers, but modern BRMs are larger, considerably stronger, and specially designed for placement in hazardous areas. Most of the standard features of shipping containers, i.e., all-welded steel construction, crimped plate walls, steel tube framing and reinforced plate roofs, also apply to blast resistant shelters. Modern BRMs are constructed with specially designed, heavy framed doors, windows, and HVAC; any external system or accessory must be designed and constructed to withstand the forces of the rated blast pressures. The majority of these construction features are also attributable to blast resistant electrical equipment centers (BRECs). The exterior of a blast resistant module will respond during an overpressure by deflecting, whereby some structural components may permanently deform. At the same time, the walls and roof are designed to remain intact, absorb the forces of the blast, and protect the occupants.

Functional Differences between BRMs and BRECs

Whereas blast resistant modules have the option of being installed as either permanent or temporary structures, blast resistant electrical equipment centers (BRECs) are sited within refineries as permanent structures.

The most desirable location for an electrical equipment center at a refinery is as close to the processing operation and maintenance personnel as possible. The owner has far more flexibility in siting BRECs than is available for siting BRMs. Siting decisions are based upon economics when the incident risk is immediate, and the costs of additional cabling and other delays from increased standoff distances are high.

Typical Construction of Type I, II and III Structures

Unlike commercial-grade, pre-engineered metal buildings, today's blast resistant equipment centers (BRECs) utilize heavy structural members and either crimped plate or interlocking heavy-gauge wall panels. Base members consist of C-channels, wide-flange structural beams, and wall panels are supported with tube steel. Up to 6 mm (1/4 inch) thick metal plate is continuously welded to the base to form the floor. Floor cutouts are made for all electrical equipment located within the shelter. Wall and roof construction details depend upon the maximum blast loadings.

Table 1 is a representative matrix of design configurations derived from the engineering analyses and experience of the authors. This table is intended to only show the variations in construction available, and should not be used as design guidance.

Table 1 - Design Features for Various Construction Types of BRECs

DESIGN CONSIDERATION	PERSONNEL	EQUIPMENT
Protection	People	Equipment
Allowable Response	Walls and roof may deform but must not generate heavy internal debris. Allowable deformations typically follow ASCE Guidance	Walls and roof may deform but must not impact equipment. Connections must have adequate protection to withstand relative movement. Some equipment may also be shock sensitive requiring flexible mountings.
Construction	Seam welded crimp plate, wood framing & sheetrock	All steel SWCP or interlocking panel Typically no interior "Finish out" is required
Access	IBC/ADA	OSHA
Foundation Type	Slab-on-grade	Elevated
Doors	Opened frequently	Open infrequently for equipment check

Functional differences between the standard practices employed in the construction of BRMs and BRECs are shown in Table 2.

Table 2 - Functional Differences between BRMs & BRECs

PRODUCT DESIGN FEATURE	CONSTRUCTION TYPE		
	TYPE I	TYPE II	TYPE III
Description	Medium Gage G90 Steel; Interlocking panels)	Heavy Gage G90 Steel; Interlocking panels)	Seal Welded Crimped Heavy Steel Plate
Panel Width	400 mm	300 mm	n/a
Panel Connection Type	Interlocking	Interlocking	Continuously welded
Exterior Wall/Roof Thickness	75 mm	100 mm	100 mm
Wall Deflection Space	0 - 140 mm	38 - 100 mm	64 - 178 mm
Total Wall Thickness	75 - 270 mm	100 - 280 mm	100 - 355 mm

It is also notable that the older, 14x40-foot size limitation for BRECs is no longer a factor, since any of the three types of unit can be constructed with custom dimensions and loadings in mind.

Conclusion:

In 1998, the American Society of Civil Engineers wrote, "*Blast-resistant control centers are essential to the safe operation of an industrial plant. More importantly, they are essential for the safe shutdown of a plant after an emergency. Structural design of these facilities can be rendered ineffective if the proper precautions are not taken to insure that such buildings operate as a blast-resistant system, rather than a blast-resistant structure. Architectural, mechanical, plumbing, and electrical details and systems need to be integrated into the design in order to ensure that a blast-resistant building behaves as a blast-resistant system.*"

Clearly the hydrocarbon processing industry and producers in other environments at risk for blast events can benefit physically, esthetically and fiscally with state-of-the-industry, safer equipment shelters as outlined in this article. An additional benefet is the fact that BRECs are typically designed and constructed within a controlled, offsite environment which allows for pre-testing and simulation of internal, custom-ordered electrical components. In turn, this limits on-site labor and safety considerations at the refinery. Finally, the degree of assurance that critical electrical plant operations will continue during and after a blast event need no longer be open to speculation.

In our next article, *Performance Limits of Blast Resistant Electrical Equipment Centers for Hydrocarbon Processing Facilities*, we will delve into the analyses, testing, test results and conclusions arrived at for construction types I, II and III.

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