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PHYSICAL SECURITY OF CUT-AND-COVER UNDERGROUND FACILITIES

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Abstract

To aid designers, generic physical security objectives and design concepts for cut-and-cover underground facilities are presented. Specific aspects addressing overburdens, entryways, security doors, facility services, emergency egress, security response force, and human elements are discussed.

Introduction

The US Department of Energy (DOE) has both near and long term plans for the construction and use of Underground Facilities (UGF). For DOE operations involving nuclear materials and or weapons, underground facilities provide an excellent means of enhancing security system effectiveness against theft and sabotage (Matalucci 1989). The cut-and-cover construction method is commonly used for shallow buried facilities because of its simplicity and cost effectiveness (Kao 1985). As the name implies, a ground hole is cut, a building is constructed, and then covered. There are many design tradeoffs that occur in the development process of a cut-and-cover facility. One of these tradeoffs is the balance between a facility's daily operations and its physical security effectiveness. To aid designers in achieving this balance, generic design concepts and objectives have been developed from noteworthy designs of existing UGFs and Sandia's ongoing physical security efforts (Sandia 1997). The design aspects of overburdens, entryways, security doors, facility services, emergency egress, security response force, and human elements have been selected for discussion in this paper.

Overburden

"How deep is deep enough?" and "What materials should be used?" are commonly asked questions for shallow buried UGFs. When considering these questions, design objectives for the UGF overburden should include:

- Substantial delay times against forced entry attacks so that costly aboveground Perimeter Intrusion and Detection Systems (PIDAS) are not required.
- Maximum encapsulation of the facility is accomplished by the overburden.
- Adequate shock mitigation and separation is utilized to protect against sabotage by large surface explosives such as vehicle bombs.

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DISCLAIMER

For critical DoD national security facilities, the required overburden (both depth and type of material) is driven by requirements to survive nuclear attack (Patten JS, et al. 1983). For DOE facilities that store, process, and manufacture nuclear materials and weapons, the overburden is primarily driven, not by operational survivability, but by safety and security (adequate delay to protect against theft and sabotage). The most recent documented testing of shallow earth overburdens for protection against terrorist attack was conducted by the US Army in 1985 (Baylot JT 1985) where it was concluded that approximately 14 feet of overburden was capable of providing sufficient delay without the use of an aboveground PIDAS system. Use of this overburden depth and material as a possible standard is complicated by an ambiguous terrorist threat that is constantly changing. This ambiguity is illustrated by the assumptions in one study that equipped the threat with many M180 cratering weapons resulting in greater calculated penetration depths (Black and Veatch 1983).

A possible solution to the threat ambiguity may be to establish a conservative upper bound for shallow buried depths. This could be established by using the safety requirement to survive a 747 aircraft impact, used by NRC for nuclear reactor safety, in conjunction with the security requirement to survive a 500 lb. general purpose gravity bomb deployed from a small aircraft. It should be noted that these requirements were used in previous DoD studies for shallow buried high security UGFs. The requirement to protect against a standard 500 lb. gravity bomb necessitates a minimum depth of approximately 16 feet of soil and a 5000-psi concrete roof thickness of 30 inchs (Department of the Army 1965). The 16 feet of soil will in turn attenuate the peak vertical stress resulting from an aircraft crash to approximately half and yields a minimum 5000-psi two-way reinforced concrete roof thickness of 36 inches (Whitney MG, et al. 1983). A smaller overburden depth is possible by using 4 to 5 feet of 2 to 3 foot diameter rock rubble on the surface followed by sufficient soil fill to attenuate crash stresses for a given roof thickness. The rock rubble will appear to penetrating weapons with calibers equal to or less than the rock rubble diameter as semi-infinite in depth. The rubble will also aid defeat of bulk charges, cratering weapons, fuel-air explosives, and manual excavation efforts. Unfortunately, the answers to "How deep is deep enough?" and "What material should be used?" will remain qualitative and subjective until additional testing can be performed.

Personnel and Vehicle Entryway Tunnel Ramps

A conceptual curvilinear entry tunnel ramp for both personnel and vehicle access is illustrated in Figure 1. The design objectives for the personnel and vehicle entryways include:

- Minimization of down-hole penetrations.
- Elimination of line-of-sight to down-hole operations using curvilinear, serpentine, or doglegged paths for defense against standoff weapons and concealment of operations.
- Vehicle bomb protection by using vehicle barriers and inspection portals at or before tunnel entrances.
- Early intruder warning by using intrusion detection and assessment equipment within the entry tunnel ramps.
- Aboveground surveillance of entry and exit areas by using day-night cameras.
- Limit of useable explosive weights by designing tunnel ceilings for overpressure collapse.

As shown conceptually, the personnel and vehicle sally port barriers are used with control and inspection portals located at the tunnel entrances. The layout facilitates easy transit by trucks and provides two separate exit paths to the surface. The tunnel ramp will also force adversaries to exit the tunnel to escape ear and lung damage during explosive attacks and thereby expose themselves to security force response fire.

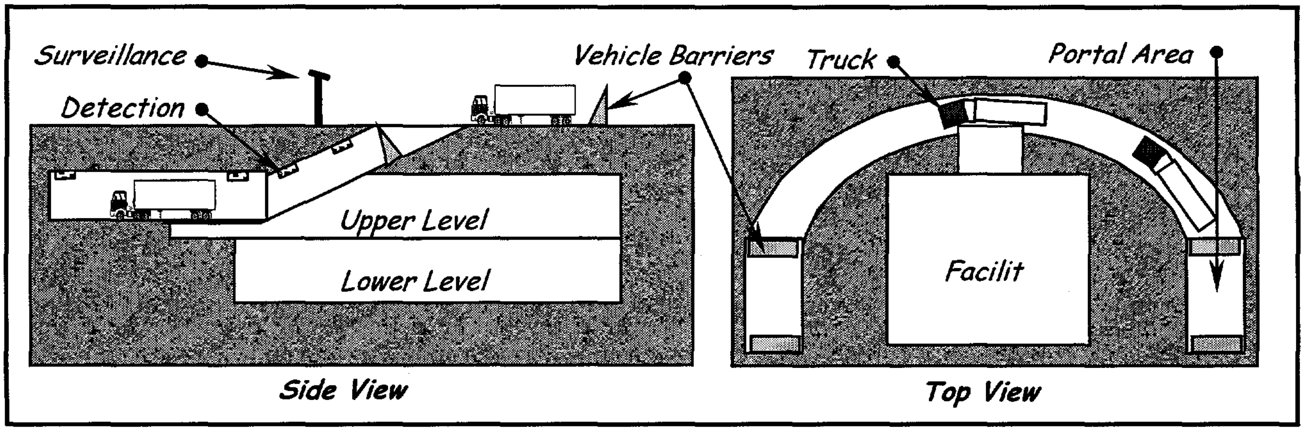

Figure 1. Shallow Buried Cut-and-Cover Facility with curvilinear access tunnel ramps shown from side and top views.

Facility Entry Security Doors

Since the facility entry security doors are typically the only means for accessing the UGF, a balance between functionality and security must be considered. A conceptual sally port security door layout capturing this balance is shown in Figure 2. Design objectives for the facility entry security doors include:

- Prevention of direct unimpeded access into the facility by using a sally port interlocked door configuration.
- Line-of-sight minimization into the facility by using serpentine paths in doorways and perpendicular positioning to the entry tunnel ramp area.
- Continuous operational status during preventive or corrective maintenance by use of door redundancy and designs that enable all maintenance to be conducted with the door in a fully shut and locked position.
- Elimination of operational override defeat mechanisms by placing all critical components on the interior door side.
- Protection against information and electronic warfare, and explosive electromagnetic weapon attacks by use of hardwire control interlocks.
- Effective access delay times against current and future threats using advance reconfigurable composite door designs.

Notice the doors are interlocked in such a manner that the exterior doors must be fully closed before the interior doors can be opened and vise versa. A disadvantage with serpentine paths is the associated large footprint necessary for material and material handling equipment to maneuver through the doors.

The door construction must provide adequate delay times against current and future threats. Composite door designs employ multiple materials that are randomized within the door to defeat a wide spectrum of attack tools and weapons. Shown in Figure 3 is an I-Beam composite door concept, which is a variation of an earlier Sandia concept (Bauder 1976) and standard military suppressive shield cross-section designs. Modular material inserts can be placed in the channels created by the I-Beam matrix. This design allows the barrier to be rapidly reconfigured to address new threats by the insertion of additional and or different materials. The cross-sectional lengths of steel webbing within the door also provide a very effective mechanism for the breakup of munitions used in explosive attacks. The basic design concept can be scaled and adapted to various sizes, delay times, threats, and weight considerations.

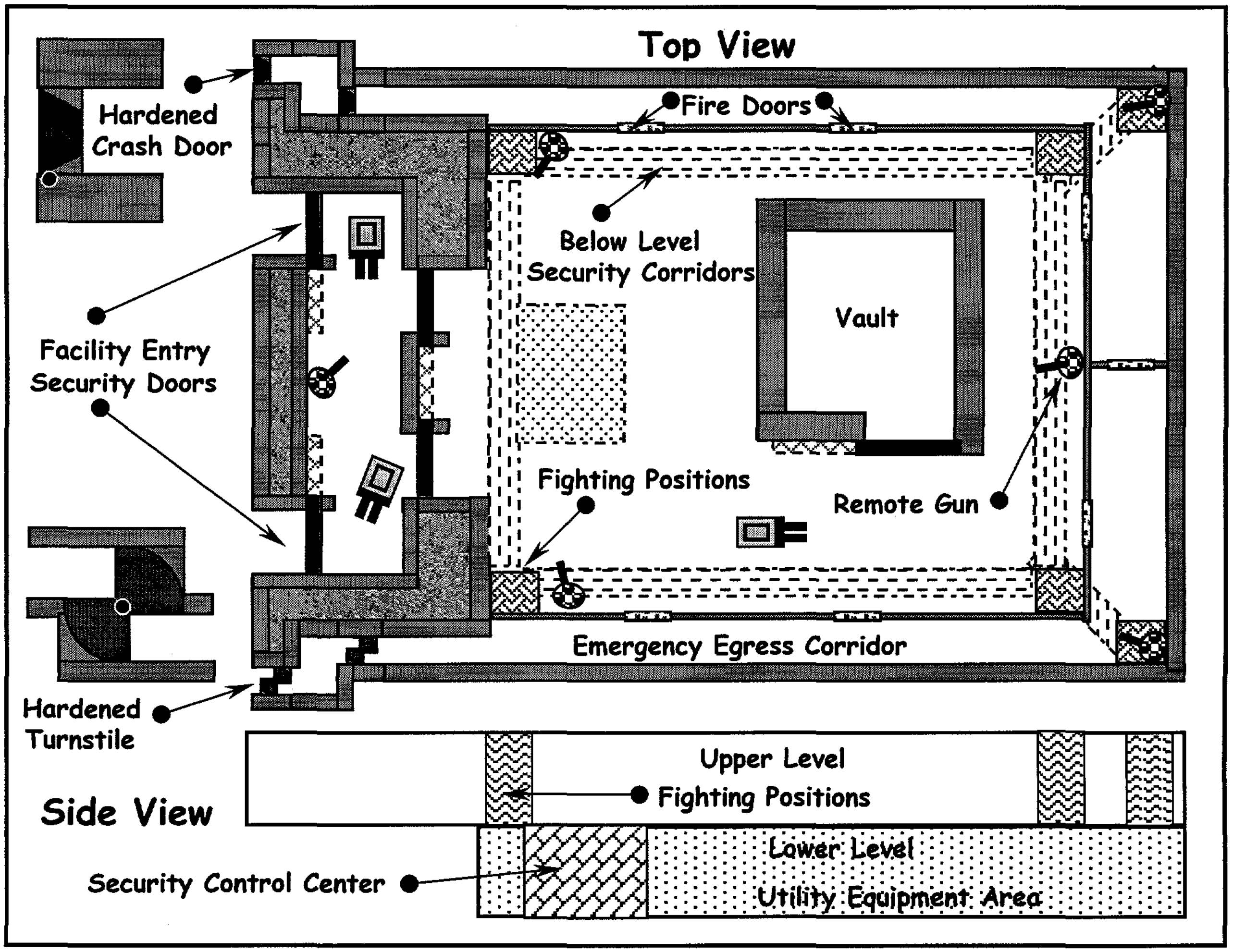

Figure 2. UGF emergency egress corridors shown with hardened turnstiles and crash doors. Security force separated in lower level with corridors to fighting positions.

Facility Air, Power, and Other Services

Protection of facility services can be elegantly accomplished by containing these systems totally within the UGF itself as conceptually shown in the UGF lower level in Figure 2. Design objectives for facility air, power, and other services include:

- Protection of facility services that impact the safety and security of personnel and material within the facility at equivalently hardened levels as the facility itself.
- Line-of-sight elimination into the facility by penetrations such as air ducts, conduits, and utility systems.
- Localization of all facility penetrations within the entry tunnel ramps.

- Elimination of entry paths that human adversaries or miniature remote devices could exploit for entry into the facility by use of chevron grating, razor tape, small diameter parallel ducts versus a single large duct, and so on.
- Protection against the injection of fuel-air explosives by using spark arrestor devices.
- Chemical attack protection by using CBR air filtration systems.
- Internal emergency backup power to support critical facility operations by uninterruptible power supplies (UPS) and emergency generators.

It is recommended that protection against chemical agents be provided to aid the security force response during a chemical attack as well as preclude the difficult task of facility and material chemical decontamination. Most of the costs to protect against CBR are associated with the periodic replacement of expensive gas filters (activated charcoal impregnated with cooper, silver, and chromium). It is recommended that even if CBR is not a functional requirement at the time of design and construction, it is a prudent cost-effective measure to incorporate a CBR filtration system (relatively inexpensive sheet metal enclosures) but without the filters installed. This way the CBR system can be easily brought online should the threat evolve to include CBR attacks.

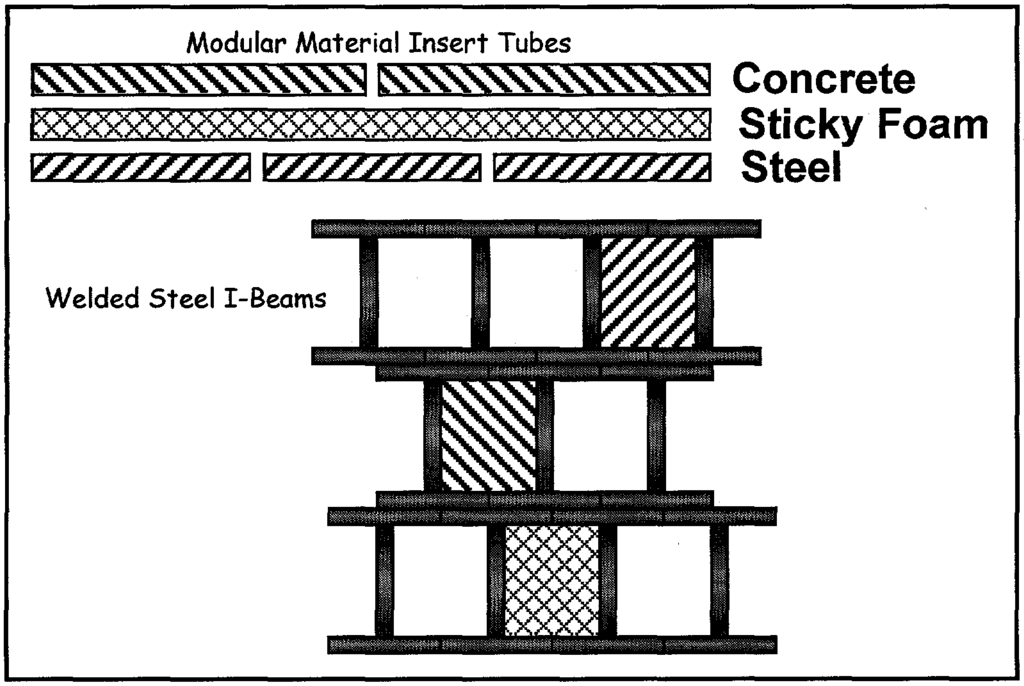

Figure 3. Composite Door Matrix

Emergency Egress

Life Safety Code requirements to provide unimpeded building emergency egress (NFPA 1997) are in some situations contrary to security goals, which strive to rigorously control and limit both ingress and egress. Shallow UGF emergency egress is typically accomplished by compartmentalized smoke-proof corridors that lead to an exit stairwell while deep UGFs provide smoke-proof safe refuges where personnel wait for rescue (Caromed and Sterling 1993). Figure 2 illustrates a conceptual smoke-proof two-exit egress corridor that surrounds the entire facility. Design objectives for emergency egress include:

- Emergency egress paths for fire and accidents without compromising security.

- Alternate emergency escape paths for exceptional events such as tunnel collapse.

The smoke-proof corridor is entered through interior fire doors. Personnel can then exit out of the facility on either side through hardened crash doors or turnstiles where the passage then parallels the access tunnel ramp to the surface exiting into a fenced collecting area. In addition to standard emergency egress routes an emergency escape path should be provided for exceptional events such as tunnel blockage resulting from an actual explosive attack. One possible approach already in use at one facility are secured pea gravel filled tubes leading to the surface that can be drained for personnel egress from the facility interior when activated.

Security Response Force

As shown conceptually in Figure 2, the security monitoring and response force is located in the lower level. Also in the lower level are dedicated passages that lead to protected fighting positions for enhanced capture recovery operations. Design objectives for the security force include:

- Protected fighting positions that provide cross-fields of fire and unobstructed views down main passageways.
- Dedicated response force passageways that provide multiple paths to fighting positions.
- Protection of the facility's security control center against electromagnetic energy weapons.

The potential integration of remotely operated weapons as part of an UGF design, in the possibly not too distant future, should be considered. Prepositioned remotely operated weapons will provide significant security force multiplication and enhancement by enabling near instantaneous response to attackers in many locations, increasing target accuracy, removal of personnel from direct weapon fire, immunity to suppressive fire, and reduction of the number of security officers needed to effectively respond. The technology has matured significantly in this area as demonstrated by the commercial availability of remote operated weapons (Precision Remotes, Inc. 1997).

Human Elements

Design objectives related to the human element include:

- Minimize the entry of nonroutine contract maintenance personnel by retaining a highly qualified mechanical and electrical maintenance team.
- Minimize the entry and exits of maintenance equipment by integrating a tool crib and shop area underground.
- Automate operations to fullest extent possible to reduce human access to materials, reduce human exposures, and simplify egress issues.
- Minimize entry and exit frequencies of personnel by providing accommodations underground such as lounge areas and exercise facilities.

Conclusions

Appropriate consideration of physical security objectives and design concepts play an important role in shallow buried UGFs. By selecting features from both existing and conceptual cut-and-cover UGF designs a balanced and optimal physical security system can be realized. The cost difference between an aboveground facility and an UGF can quickly be recovered. As an example, an existing operation was moved from an aboveground inset facility to an UGF and within five years the construction costs were totally recovered based primarily upon the reduced operational costs of the required security force.

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