# A Review of Regulatory Status and Standards of Physical Barriers Against Explosives and Vehicle-ramming Attacks

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## 1. Introduction

Terrorism using explosives and vehicles continues to occur all over the world. In preparation for this, the importance of physical barriers for national important facilities has been emphasized. In particular, nuclear facilities are national infrastructure, and if damage occurs, not only physical damage, but also the nation and the people may face various threats, so barriers are great importance. However, the regulatory standards related to the physical barrier performance of domestic nuclear facilities are insufficient. Therefore, it is necessary to verify the physical barrier performance of nuclear power plants, and this study focused on explosives and vehicle-ramming attacks. The target of explosion-proof performance is the door and the structures around the door installed in the vital area, and the target for vehicle barriers are roadblock, barricades, and sliding doors, etc. In this paper, the need to establish regulatory standards for domestic nuclear facilities is suggested by examining the current state of domestic and international physical barrier regulation against explosives and vehicle-ramming attacks.

## 2. Analysis of regulatory trends and standards

Since domestic regulations on physical barriers are insufficient, foreign data were mainly investigated and organized so that they can be used as comparison and verification data for establishing domestic regulations.

### *2.1. Explosion-proof performance regulatory trends and standards*

In Korea, there are insufficient standards related to the design of explosion-proof structures and verification of protection performance other than for military purposes. The standards provided by the Ministry of National Defense were prepared by referring to the design standards of the U.S Department of Defense. In the United States, the unified design standard UFC (Unified Facilities Criteria) 3-340-02 is applied by integrating the guidelines for explosion-proof and protection standards possessed by the Army, Navy, and Air Forced based on technical document TM 5-1300 (US Army, 1990) [1]. The UFC 3-340-02 documents are used in explosion-proof design around the world and present an explosion-proof design charts developed based on experimental data. These charts provide values for the incident and reflected pressures, impulses, the arrival time of the blast wave, and the durations and other parameters according to the explosion. The United States developed the ConWep program by computerizing the data in this chart. Through this program, it is used to calculate the blast load for various conditions, and the scaled distance is used as a key variable.

The scaled distance is used to evaluate explosives on the same criteria as the maximum overpressure varies with the mass of the explosive and its distance from the detonation source. A commonly used scaled law is Hopkinson-Cranz law, which is suitable for comparing explosive phenomena of high-performance bombs [2,3]. The scaled law can be expressed as in Equation (1), and is calculated using the weight of a standard explosive, which is based on TNT, a standard explosive for military use.

$$\mathrm{Z} = \mathrm{R}/E^{1/3} \; or \; \mathrm{Z} = \mathrm{R}/W^{1/3} \tag{1}$$

For explosives other than TNT, the equivalent energy is calculated and used using the TNT equivalent method. The TNT equivalent method is the same as Equation (2), and the equivalent energy according to the type of explosive is presented in Table 1 [3,4].

$$W_E = \frac{H_{EXP}^d}{H_{TNT}^d} W_{EXP} \tag{2}$$

Table 1. Equivalent energy according to explosive type

| Explosive type | Specific Energy [kJ/kg] | TNT Equivalent |
|---|---|---|
| Compound B (60% RDX + 40% TNT) | 5,190 | 1.148 |
| RDX | 5,360 | 1.185 |
| HMX | 5,680 | 1.256 |
| NG | 6,700 | 1.481 |
| TNT | 4,520 | 1.0 |
| Explosive gelatin | 4,520 | 1.0 |
| 60% NG dynamite | 2,710 | 0.6 |
| Semtex | 5,660 | 1.250 |
| C4 | 6,057 | 1.340 |

To calculate the explosive load, it is necessary to consider not only the explosive type and energy, but also the location of the explosion, the form of explosion, and the shape and size of the blast target.

Depending on the location of the explosion, it can be classified into a free-air bursts, air bursts, and surface bursts [1].

Since the blast target was set as the doors of a nuclear facilities and its surrounding facilities in this study, it is necessary to consider the structure, operation, and opening/closing types of the doors.

### *2.2. Vehicle barrier regulatory trends and standards*

DoS (Department of State) SD-STD-02.01, ASTM (American Society and Materials international) F2656-07, BSI PAS (British Standards Institute Publicly Available Specification) 68, ISO IWA (International Workshop Agreement) 14-1, etc. are generally applied to verify vehicle barriers performance, and the characteristics according to standard test methods are presented in Table 2 [5].

Table 2. List and characteristics of standard test methods

| Standard | Region | Latest Version | Purpose and vehicle types used |
|---|---|---|---|
| ISO IWA 14-1:2013 | Global | 2013 | To provide a single international standard for impact testing and performance classification of VSBs*. Vehicle types: UK, European and North American vehicles. |
| ISO IWA 14-2:2013 | Global | 2013 | In support of IWA 14-1, designed to provide guidance on the selection, installation and use of VSBs. |
| BSI PAS 68:2013 | UK | 2013 | Defines a standard method for testing the impact performance and protection rating of a VSB when impacted by different categories of UK vehicles travelling at specified speeds. |
| BSI PAS 69:2013 | UK | 2013 | Guidance on the selection, installation and use of VSBs rated using PAS 68. |
| ASTM F2656/ F2656M -20 | USA | 2020 | Defines the method for impact testing and assigning performance ratings for a VSB when impacted by different categories of North American vehicles. Now includes a UK/European style vehicle type: C7 |
| CEN CWA 16221: 2010 | Europe | 2010 (Withdrawn 2018) | Derived from PAS 68 and PAS 69, this document covers both impact testing and guidance on selection, installation and use of VSBs. Vehicle types: European vehicles |
| DoS SD-STD-02.01 | USA | Rev. A, 2003 (Withdrawn) | Forerunner of ASTM F2656 Vehicle type: only USA vehicles and defines 'K' classifications. |

*VSB: Vehicle Security Barriers

The standard test methods proposed abroad determine barrier performance and protection class for European, American, and British vehicles. Therefore, there are limitations in applying it to the performance test according to the vehicle collision of the domestic physical barriers. It is necessary to establish a standard based on the type, weight, and speed of vehicles that can be used in Korea.

## 3. Status and limitations of domestic regulatory standards

In the 'Regulatory Standards and Guidelines for Light-Water Nuclear Power Plants' of the Korea Institute of Nuclear Safety, there are standards for evaluation of man-made accidents that may occur in the vicinity of nuclear facilities and regulations on flying debris. However, there are insufficient regulations on the protective performance of physical barriers against explosions and vehicle ramming attacks at nuclear facilities.

Besides nuclear facilities, there are no national standards for vehicle barrier performance, and no certificates are issued to prove the ability according to the class for defense strength or effectiveness. It has limitations in estimating the effectiveness of physical barriers because of the lack of specific regulations and verification through experiments.

In addition, there are limitations in applying foreign standards to Korea as they are due to differences in the domestic nuclear environment and possible threats. The UFC explosion-proof standards in the United States are widely used worldwide, and based on this, most of the domestic defense military facilities standards were prepared. However, this has a limitation in that it does not consider the effect on near-field explosion. Since nuclear facility sabotage is likely to use an attached explosive, it is necessary to establish regulatory standards in consideration of the impact of near-field explosions through additional calculations. Also, the performance evaluation of barriers for foreign vehicles was mainly performed based on the type and weight of vehicles used abroad, so if applied as it is in Korea, it may be regulated inappropriately for the domestic environment.

Therefore, it is necessary to prepare measures to apply its own regulatory standards suitable for the domestic environment by analyzing the foreign performance standard data.

## 4. Conclusions

As a result of analyzing domestic and foreign regulatory trends and standards, it was confirmed that it is necessary to supplement and establish physical barrier regulations for domestic nuclear facilities.

In the case of foreign countries, there are performance standards for the barriers in preparation for explosions and vehicle ramming attacks, and certificates are granted to products that have passed the standard to prove their effectiveness. However, there are limits to the application of foreign standards to Korea as it is, it is necessary to prepare its own performance verification standards. Therefore, we plan to study performance verification methods by referring to overseas regulatory data, and conduct data investigations on the status, manufactures, and certification bodies of physical barriers installed in domestic nuclear facilities. Based on this, threat scenarios according to protection area will be selected and standard M&S (Modeling & Simulation) models will be developed using a numerical analysis program to analyze the conditions of explosives and vehicles that can break the barriers of current nuclear facilities and enter them. After that, the necessary physical barrier performance conditions will be derived, and the development method, procedure, and results of these M&S models will be verified to establish the performance DB. It is expected that it will be able to prepare its own physical barrier regulation standards in consultation with the expert council.

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