Literature Survey and Feasibility Analysis Related to Revising Vehicle Barrier System Regulations for LP-gas Cylinder Exchange Cabinets

Phase I Study

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EXECUTIVE SUMMARY

This report is the deliverable for Phase I of a research project sponsored by the National Propane Gas Association (NPGA) to investigate the history and technical validity of vehicle impact protection regulations in the International Fire Code (IFC)\(^1\) and assess the feasibility of successfully modifying the IFC requirements for protection of cylinder exchange cabinets from vehicular impact. The primary tasks associated with this project were surveying model codes, standards and other selected references and interviewing individuals who are considered to be influential in the IFC code development process.

The need for protection of equipment against vehicle impact is a well-recognized concept in the IFC, the International Building Code (IBC)\(^2\), National Fire Protection Association (NFPA) codes and standards, and other safety-related documents. In model codes and standards, impact protection is commonly required for fire-safety equipment (e.g., fire hydrants, free-standing fire department connections and emergency generators), fuel-gas supply equipment (e.g., natural gas meters), and hazardous material storage and processing equipment (e.g., tanks, fuel dispensers, loading/unloading racks).

Approaches used to protect equipment from vehicular impact are typically specified based on:

1. Achieving identifiable performance goals, such as survival of hypothetical impact scenarios, or
2. Satisfying prescriptive design and installation requirements that may or may not have identifiable performance goals.

Overview of Technical Approaches to Barrier Design and Performance

The science behind vehicle threat assessment and barrier design has become highly evolved, allowing for unique solutions to be crafted for specific risk scenarios. Where a specific level of performance is desired, barriers are engineered and sometimes tested to withstand prescribed impact scenarios. These scenarios may be based either on site-specific data identifying vehicle sizes, speeds and traffic patterns, or on a broader approach of probabilistic bracketing of worst-case impact conditions.

Guidance on vehicle barrier design and testing is available in documents published by the U.S. Department of State (DOS)\(^3\), the U.S. Department of Defense (DOD)\(^4\) and ASTM International\(^5\) (formerly the American Society for Testing and Materials). However, the testing and classification methods specified in documents published by these organizations are geared towards high-speed, intentional collisions. Testing performed to validate these barriers sometimes involves crashing one or more test vehicles at prescribed speeds to derive a kinetic energy resistance rating (K-Rating) and evaluate barrier performance with respect to energy absorption, deformation and vehicle penetration (i.e., distance past the barrier that a vehicle goes if the vehicle is not completely stopped at the barrier).

The level of performance sought for barrier systems specified by model codes and standards for protection of equipment is much less stringent, contemplating protection of equipment from accidental, as opposed to intentional, collisions. Accordingly, laboratory-scale analysis, such as testing using loads induced by a weighted pendulum, is considered acceptable in this realm.

A commonly referenced laboratory test uses a 12,000-lb pendulum, swung from varying heights, to impart a prescribed level of kinetic energy on a target. The energy and the location of the impact in this test method are carefully controlled. This pendulum test has two significant benefits, repeatability and low cost relative to full-scale vehicular impact testing. However, pendulum testing is limited with respect to the level of kinetic energy that can be imparted, so such tests are typically constrained to evaluating impacts that are representative of slow-moving vehicles (10 mph or less).

In lieu of barriers based on specific performance or testing, as described above, model codes and standards widely permit the use of prescriptive design methods for impact protection, e.g. a 4-inch diameter bollard made with concrete-filled steel pipes extending 3 feet or more above grade and set not less than 3-feet deep in a concrete base having a diameter of at least 15 inches.
There are three notable deficiencies in this prescriptive approach to providing barrier protection.

1. This prescriptive bollard design does not consider soil compressive strength or surrounding surface conditions (concrete or asphalt paving), which will affect performance.

2. Codes and standards specify, in some cases, a minimum 3-foot distance that must be provided between barrier posts and the equipment to be protected. However, without knowing soil and surface conditions or anticipated impact criteria, this distance may or may not be adequate to prevent damage to the protected equipment.

3. Codes and standards don’t generally specify whether it is permissible for some level of impact to be transmitted to the protected equipment if a barrier doesn’t adequately prevent vehicle penetration, so long as the equipment contact doesn’t yield an unacceptable outcome.

**Prospects for Code Advocacy**

It is the overall conclusion of this report that model codes and standards are substantially lacking with respect to having defensible requirements for vehicle impact protection. The inadequacies range from being too prescriptive (e.g., the IFC’s prescriptive bollard criteria, which can be used anytime the code calls for vehicular impact protection regardless of soil conditions or impact scenarios) to too vague (e.g., model codes and standards that simply require barriers to be approved by a local code official without specifying any particular performance or design objectives).

From NPGA’s perspective of possibly seeking changes to the IFC with respect to barrier requirements for LP-gas cylinder exchange cabinets appear good. The failure of current model codes and standards to provide a sound basis for vehicle barriers bolsters NPGA’s prospects for success because defending the status quo is difficult when the status quo can be shown to be technically deficient. Furthermore, discussions with influential individuals in the IFC code development arena revealed a recognition that current requirements could stand to be improved, and some individuals who were interviewed expressed a willingness to assist in developing, and even sponsoring or co-sponsoring, proposed changes. Nevertheless, there are many complex issues to be considered by NPGA in determining whether and how to proceed with resolving the Cylinder Exchange Council’s concerns related to current requirements for protecting cylinder exchange cabinets from vehicular impact.

This report provides technical and historic perspectives that will be of use to NPGA in choosing a path forward, and it offers guidance for testing and code advocacy if a decision is ultimately made to proceed with a code change proposal.
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1.0 OVERVIEW

Vehicle impact protection is often required for equipment located in or near traffic routes. Requirements for protection against accidental impact commonly come from public safety standards, such as those published by the National Fire Protection Association (NFPA) and the International Code Council (ICC), or from roadway construction standards. Vehicle impact protection may also be provided to resist deliberate attacks, and in such cases, guidelines published by the U.S. Department of State (DoS), the U.S. Department of Defense (DoD) or ASTM are likely to be considered.

There are many design parameters and prescriptive methods for vehicle barriers outlined in these and other documents. The derivation of the design parameters ranges from anecdotal evidence of past performance to full-scale vehicle testing and computer modeling, with the complexity of the design often proportional to the complexity or severity of the hypothetical incident. Accordingly, barriers intended to protect pedestrians and equipment against low-speed vehicle collisions may well be designed using anecdotal data and engineering judgment; whereas, critical barriers used to protect secure areas and installations from high-speed collisions tend to be designed, tested, and certified to comprehensive standards.

Model codes and standards lack specific performance goals for vehicle impact protection, but it is reasonable to assume that the impact scenario contemplated is an accidental collision from a standard passenger vehicle or light truck, traveling at low-to-moderate speed (typical of a parking lot setting). Such an assumption is supported in part by the fact that the International Fire Code permits the use bollards that are designed to a prescriptive standard that ignores performance-related variables. Furthermore, testimony and membership votes at past ICC code hearings support have made it clear that protection of buildings, and presumably equipment, from deliberate attacks is beyond the basic scope of building and fire-safety regulations.

LP-gas cylinders in exchange cabinets are included among installations that may be required by model codes and standards to be protected against vehicle impact. These installations are often found outside of retail stores, supermarkets and gas stations. When vehicle impact protection is required for cylinder exchange cabinets, bollard systems meeting the prescriptive design requirements in the IFC are commonly used. However, such bollards do not provide a consistent or known level of performance from one site to the next because of variations in soil types, compaction and surface materials (concrete versus asphalt).

In lieu of prescriptively designed bollard systems, model codes and standards also permit performance-based designs for impact resistance, but again, the criteria are vague with respect to defining desired objectives. This lack of well-defined objectives makes it difficult to assess the permissible use of alternative protection methods such as curbs, visual barriers or parking blocks.

Furthermore, with the exception of “protected” tanks for flammable and combustible liquid storage, which are allowed to consider a tank enclosure as a means of impact protection, model codes and standards don’t clarify whether protection may be regarded as adequate if a vehicle impacts equipment but does not cause equipment failure.

With the foregoing background in mind, this report accomplishes the following tasks to assist NPGA in understanding and evaluating options for modifying vehicle impact protection for LP-gas cylinder exchange cabinets:

1. Identification of model codes and standards and other regulations that require and/or specify design criteria for vehicle barrier protection,
2. Identification and summary of prescriptive and performance approaches to providing protective barrier systems based on a literature survey,
3. Identification of issues for consideration in designing and testing alternate vehicle impact resistance designs for protection of cylinder exchange cabinets, and
4. Assessment of the feasibility of changing model codes to avoid the need for bollards to protect cylinder exchange cabinets, based on a survey of individuals who are influential in the IFC code development process.
2.0 PRINCIPAL INVESTIGATORS

André Garabedian, P.E: The analysis was prepared in part by Mr. André Garabedian, P.E. Mr. Garabedian holds a Bachelor’s Degree in Structural Engineering and a Master’s Degree in Fire Protection Engineering from Worcester Polytechnic Institute. He has over 16 years of fire protection and life safety experience, including more than 10 years of full-scale testing experience, with specializations in the fire and blast resistance of structural systems.

Mr. Garabedian has spent the last 7 years serving as a Fire Protection and Code Consultant, and is currently a contract plans examiner for the U.S. Army Corps of Engineers at the San Antonio Joint Program Management Office, Fort Sam Houston. He is a licensed Fire Protection Engineer in the State of Texas, which he acquired through formal examination by The National Council of Examiners for Engineering and Surveying (NCEES). Mr. Garabedian is a member of the National Fire Protection Association (NFPA) and the International Code Council (ICC), and is a past-President of the Austin-San Antonio Chapter of the Society of Fire Protection Engineers (SFPE).

Jeffrey M. Shapiro, P.E., FSFPE: The analysis was also prepared by Mr. Jeffrey M. Shapiro, P.E., FSFPE, President of International Code Consultants. Mr. Shapiro holds a Bachelor’s Degree in Fire Protection Engineering from the University of Maryland, and he is a licensed professional engineer in California and Texas. Mr. Shapiro previously served as Chief Executive of the International Fire Code Institute, publisher of the Uniform Fire Code (UFC), and prior to managing the UFC, he managed the Fire and Life Safety Program for a $2.9-billion international construction project for the U.S. Department of State. In that role, he was responsible for integrating fire safety with security in 22 embassy construction projects.

Mr. Shapiro is a nationally-recognized expert and lecturer in fire and building safety, and his areas of specialization include advocacy in model fire, building, mechanical and electrical code development, with particular expertise in hazardous materials; development of alternative strategies for code compliance; product design and approval guidance; forensic analysis; expert testimony; and development and delivery of professional development seminars. He is a member of the National Fire Protection Association (NFPA) and the International Code Council (ICC), and was the founding President of the Austin-San Antonio Chapter of the Society of Fire Protection Engineers (SFPE).
3.0 TECHNICAL DISCUSSION ON BARRIER SYSTEMS

Vehicle barriers range from simple visual deterrents to complex engineered systems designed to resist intentional collisions. A particular barrier design may conservatively assume that all impact energy will be transferred to the barrier, or it may take into account loss of energy associated with vehicle deformation resulting from a collision.

Systems that are intended to resist collisions may be fixed (rigid) or movable. Fixed systems, which will be quite substantial, must immediately transfer impact forces to a large mass, such as a foundation or the ground, with little or no movement.

Movable systems, which might involve posts and cables, “Jersey barriers,” and some types of planters, are designed to more gradually transfer impact forces through friction or other means. Depending on the design, such systems may require significant distances (sometimes exceeding 20 feet) between the barrier and the protected building or equipment so allow for stopping a vehicle.

Conceptually, the development of an effective barrier system is fairly straightforward. The barrier system must be able to absorb the kinetic energy associated with a predicted vehicular collision while preventing or limiting damage to the protected building or equipment. The difficulty in executing a design is primarily associated with predicting a reasonable accident scenario or threat that must be resisted, which defines the kinetic energy load. Once the load, or force, has been defined, barrier elements can be engineered to resist these forces in a manner that meets security and aesthetic objectives.
3.1. Defining Functional Objectives

Barriers for protection of cylinder exchange cabinets may have one of several functional objectives, depending on the intended application.

1. Act as a visual deterrent for vehicles.
2. Act as a visual deterrent and resist vehicular impact without deflection (might be specified for either low-speed or high-speed, depending on the application).
3. Act as a visual deterrent, resist vehicular impact with deflection, and prevent a vehicle from contacting the cabinet (might be specified for either low-speed or high-speed, depending on the application).
4. Act as a visual deterrent, resist vehicular impact with deflection, and allow a vehicle to contact the cabinet while limiting the impact force to prevent a release of LP-gas (might be specified for either low-speed or high-speed, depending on the application). In this case, contact with the cabinet does not constitute a failure. Instead, deformation of the cabinet and movement of cylinders would be considered acceptable if cylinders do not leak after impact, recognizing that DOT cylinders have measurable performance with respect to impact/drop testing associated with transportation.

Model codes and standards do not typically define specific functional objectives for vehicle impact protection, either in general or with respect to protection of cylinder exchange cabinets. Nevertheless, a review of these documents tends to indicate that the desired performance level is controlling a low-speed impact in accordance with either Option 2 or Option 3 above, without a defined impact scenario.

3.2. Impact Scenario Considerations

Hypothetical impact scenarios should identify the range of potential exposures (e.g., vehicle weights and speeds) that a barrier would be expected to encounter. It is important to note that the analysis must be based on credible scenarios, since extreme impact scenarios may not be cost-effective to resist.

In lieu of assigning an impact probability to any particular vehicle, it is customary to bracket the vehicle weights among automobiles or commercial vehicles, depending on the application, and choose a conservative vehicle weight for evaluation. Hypothetical impact scenarios that consider vehicle maneuverability in turns and straight acceleration can be combined with estimated vehicle weights to determine site-specific design parameters for barriers.

3.2.1. Vehicle Speeds

Most performance-based designs assign a velocity based on probabilistic analysis of the event (e.g., parking lot accidents typically occur at less than 20 mph, while vehicle vs. bridge support accidents on highways will occur in the vicinity of 70 mph). The expected impact speeds within a parking lot arrangement are greatly influenced by parking lot geometry and location of the target.

Consider the following parking lot arrangement. The two impact scenarios shown each depict a possible approach pattern at a large retail store. The straight paths, after negotiating a final 90° turn, can be 350 feet or 600 feet to assumed targets.
Alternately, a comparable approach pattern for a small gas station with a limited parking area might be on the order of 75-100 feet between the last negotiated turn and a target, providing a shorter distance for linear acceleration.

The computation of possible vehicle speeds on impact is as follows:

$$v_f = \sqrt{v_i^2 + 2as}$$

Where:

- $v_f$ = Velocity at impact (ft/s, m/s)
- $v_i$ = Initial velocity (ft/s, m/s)
- $a$ = Acceleration (ft/s², m/s²)
- $s$ = Travel distance (ft, m)

In any analysis, the designer must assume a reasonable acceleration rate. A car capable of going from 0 to 60 mph in 10 seconds produces an acceleration of 8.8 ft/s², the ability to go from 0 to 60 mph in 8 seconds produces an acceleration of 11 ft/s², and from 0 to 60 mph in 12 seconds produces an acceleration of 7.3 ft/s².

The vehicle speed prior to acceleration in a straight line is further affected by any turns the vehicle has made on approach. Depending on the turning radius, vehicles can only reach certain speeds before skidding. A typical 50-ft radius would support initial turn speeds of 10-30 mph. Since most retail facilities are on relatively level ground, the impact of hills and slope in a retail environment can often be neglected.

Consider a straight run approach of 350 feet with an acceleration from a stop of 8.8 ft/s². A vehicle following these criteria will achieve a speed of nearly 53.5 mph on impact. The relationship is shown in Figure 2. The same vehicle with an initial velocity of 20 mph (assumed to have negotiated a final turn), accelerating in the same 350 feet, would achieve a speed of roughly 57 mph.
3.2.2. Impact Energy and Absorbed Force

The primary factors in determining the impact energy expected at a barrier are vehicle weight and speed. The two parameters are combined to produce the following relationship:

\[ KE = C \cdot \frac{1}{2} m v^2 \]

Where:
- \( C \) = Conversion Constant (0.0668 for ft-lbf, 0.0077 for N-m)
- \( KE \) = Kinetic Energy (ft-lbf or N-m)
- \( m \) = Mass (lbm or kg)
- \( v \) = Velocity (mph or kph)

An average 4,000-lb vehicle traveling 10 mph creates roughly 13,350 ft-lbf (1,812 N-m) of energy. The kinetic energy for various classes of vehicles at various speeds is as follows:

<table>
<thead>
<tr>
<th>Vehicle Weight (lb)</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact</td>
<td>2,500</td>
<td>0.3</td>
<td>2.1</td>
<td>8.4</td>
<td>18.8</td>
<td>33.4</td>
<td>75.2</td>
<td>133.6</td>
</tr>
<tr>
<td>Sedan/Light Truck</td>
<td>4,000</td>
<td>0.5</td>
<td>3.3</td>
<td>13.4</td>
<td>30.1</td>
<td>53.4</td>
<td>120.2</td>
<td>213.8</td>
</tr>
<tr>
<td>Mid-SUV</td>
<td>5,000</td>
<td>0.7</td>
<td>4.2</td>
<td>16.7</td>
<td>37.6</td>
<td>66.8</td>
<td>150.3</td>
<td>267.2</td>
</tr>
<tr>
<td>Large-SUV</td>
<td>7,000</td>
<td>0.9</td>
<td>5.8</td>
<td>23.4</td>
<td>52.6</td>
<td>93.5</td>
<td>210.4</td>
<td>374.1</td>
</tr>
<tr>
<td>Truck</td>
<td>15,000</td>
<td>2.0</td>
<td>12.5</td>
<td>50.1</td>
<td>112.7</td>
<td>200.4</td>
<td>450.9</td>
<td>801.6</td>
</tr>
</tbody>
</table>

This kinetic energy calculation is used in performance-based barrier designs as a basis of assigning a \( K \)-rating to the barrier. A barrier capable of resisting a 15,000-lb truck traveling at 40 mph is identified in design standards as a K8 barrier, signifying the successful absorption of 800 ft-kips (800,000 ft-lbf) of energy.
The impact force is a function of the object’s velocity and the time in which the barrier takes to decelerate the object. The relationship is:

\[ F = C \cdot m \left( \frac{\Delta v}{t} \right) \]

Where:
- \( C \) = Conversion Constant (1.47 for lbf, 0.28 for N)
- \( F \) = Reaction Force (lbf or N)
- \( m \) = Mass (lbm or kg)
- \( v \) = Object initial velocity (mph or kph)
- Final velocity is assumed to be \( 0 \)
- \( t \) = Time to reach zero velocity

### 3.2.3. Penetration Rating

A “perfect” barrier decelerates a vehicle with no deflection, in minimal time. The reaction force needs to be very high to accomplish this.

Barriers that bend, crush, or otherwise “give,” extend the time to reach zero velocity and therefore provide less reactionary force. They may allow significant “penetration” of the vehicle beyond the barrier as a result.

The degree of penetration is classified based on the distance a vehicle penetrates past the barrier. ASTM F2656-07 classifies penetration levels as follows:

<table>
<thead>
<tr>
<th>DESIGNATION</th>
<th>DEPTH OF PENETRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>3.3 ft</td>
</tr>
<tr>
<td>P2</td>
<td>3.31 to 23.0 ft</td>
</tr>
<tr>
<td>P3</td>
<td>23.1 to 98.4 ft</td>
</tr>
<tr>
<td>P4</td>
<td>98 ft</td>
</tr>
</tbody>
</table>

The penetration performance is an important criterion when establishing the final position of barriers with respect to protected sites or equipment. For example, barriers that are placed only 5 feet in front of protected equipment must be capable of generating the required barrier resistance and must have a P-Rating of “P1” to accomplish the objective of completely preventing impact with the equipment.

In the context of observed crashes into store fronts, most exterior walls using steel stud framing and brick veneer are capable of providing P1 or P2 protection during unintentional (driver assisted braking) collisions. This is evidenced by the observation that vehicle collisions into stores from the adjacent parking lot rarely produce more than 23 feet of penetration before the vehicle comes to a stop.

### 3.3. Barrier Validation - Tests and Models

Barrier testing for intentional collisions has gravitated to a limited number of recognized large-scale tests and empirical modeling. Although large scale tests are typically associated with high-speed/intentional collisions, the parameters of such tests can be adapted to evaluate the performance of barriers against vehicles of varying size and speed.
3.3.1. ASTM F2656-07 and DoS SD-STD-02.01

ASTM F2656-07 and its predecessor, Department of State SD-STD-02-01³ outline full-scale vehicle impact test methods. The standards outline subject vehicle weights and speeds for barrier certification, similar to those presented in Table 1 of this report, and employ the principles discussed in Sections 3.2.1, 3.2.2, and 3.2.3 of this report to calculate impact energy and measure barrier resistance.

Full scale tests are expensive, in part because test vehicles may be completely destroyed, but they have the advantage of providing a realistic evaluation of barrier performance. As alternatives, computer modeling has also evolved to become an accepted basis of barrier design, and for less severe impact scenarios, laboratory-scale tests can be used.

3.3.2. Pendulum Impact Model

A well-recognized laboratory test method involves striking a barrier with a known weight swung as a pendulum from a prescribed height. This standardized test method is found in Underwriter’s Laboratories (UL) Standard 2085⁶, which prescribes the test procedures for evaluating impact resistance of above-ground fuel storage tanks. The test procedure has been adopted by other certifying agencies, including Southwest Research Institute (SwRI)⁷, and is referenced in model codes and standards.

The UL2085 test procedure uses a 12,000-lb load, delivered to an impact area of one square foot (12 inches x 12 inches) from a prescribed height to produce a known level of impact energy.

\[ v = \sqrt{2gh} \]

Where:
- \( v \) = Pendulum impact velocity (ft/s, m/s)
- \( g \) = Gravitational constant (32.2 ft/s, 9.8 m/s)
- \( h \) = Height of drop (ft or m)

Using a swing height of 12 inches, the impact velocity of the pendulum is 8 ft/s (5.5 mph). With the 12,000-lb pendulum weight, the kinetic collision energy will be 12.1 ft-kips, which corresponds to a 4,000-lb vehicle traveling roughly 9.5 mph. This is consistent with one possible accident scenario involving a passenger vehicle in a parking lot.
3.4. Common Barrier Systems

3.4.1. Traditional Bollards

Concrete-filled steel bollards absorb energy by inelastic deformation of resistive soils and cracking along the surrounding concrete or asphalt. With a concrete-filled bollard, deformation of the cylinder itself is not typical; however, with a hollow steel pipe bollard some deformation may occur (see discussion on Penetration Rating in Section 3.2.3).

A filled bollard’s resistance is mostly based on embedment (depth into the soil), the size of the embedded footing and soil/paving conditions. When barriers are tested, the soil is typically low cohesive, well-graded crushed stone or broken gravel of a particular size distribution (DoS SD-STD-02.01 Table 2). Soil depth is typically specified to be at least 1.5 times embedment depth behind the installation or 2 feet, whichever is greater, up to a maximum of 6 feet. For good performance, soil should be compacted to a density of not less than 90 percent maximum dry density.

Bollards tend to be selected as the preferred method of vehicular impact protection in conditions where the barrier must be small and located very close to the protected item. In contrast, larger barrier systems that rely upon their weight and friction coefficient (e.g., jersey barriers) or on their own destruction (e.g., sand-filled or water-filled plastic drums) require more space and may be avoided where physical appearance is important.

According to one cited source, the cost to install a typical concrete-filled 8-inch bollard is $515, and this cost is often multiplied because bollards are typically installed in groups with no more than 4 feet between them.

3.4.2. Shallow-Foundation Bollards

Shallow-foundation bollards include a traditional steel pipe bollard, cast with a reinforced concrete base. The shallow-foundation bollards rely on the connectivity of the vertical bollard to a concrete slab or fitting. The slab footing can be as shallow as 9 inches. This design relies less upon the bearing strength of surrounding soils and more on resistance provided by paving.

These barriers are proprietary and can vary in cost and installation requirements.

3.4.3. Surface-Mounted Barriers

Where adequate space is available between parking lots and buildings, surface-mounted barriers can be used to provide protection from vehicular impact, even in a retail setting. Common surface-mounted barriers include concrete troughs fashioned as decorative planters, round concrete “pots” filled with soil and mid-sized trees and large concrete objects, such as spherical shapes. Large planter designs can be so effective that they can achieve K12 (very high) collision ratings.

Surface mounted barriers may simply use mass and friction to resist an impact, or they may be anchored to a foundation, pavement or soil below to provide adequate strength.

One source prices a concrete pot planter that is 48-inches diameter and 3-ft high at $1,000, and trough planters are estimated at $340 per cubic yard. Lower K-rated barriers, such as those that might be used to protect a cylinder exchange cabinet, would likely have lesser costs.
4.0 REQUIREMENTS FOR VEHICLE BARRIER SYSTEMS IN MODEL CODES AND STANDARDS

4.1. Code Background

The International codes (I-Codes) and NFPA codes and standards, collectively referenced herein as “model codes and standards,” contain a variety of requirements for vehicle barriers to protect equipment from accidental vehicle collisions. Impact protection is required for fire-safety equipment (e.g., fire hydrants, free-standing fire department connections and emergency generators), fuel-supply equipment (e.g., natural gas meters), and hazardous material storage and processing equipment (e.g., tanks, fuel dispensers, loading/unloading racks, etc.).

As stated above, there are a number of government standards geared towards resisting deliberate attacks (e.g., DoS, DoD criteria). However, neither the I-Codes nor NFPA codes and standards mandate compliance with Federal barrier regulations for equipment protection. Furthermore, when the subject of modifying the I-Codes to require protection of buildings to resist deliberate attacks has come up during past code hearings, the International Code Council membership has not embraced such an approach.

Accordingly, it is reasonable to conclude that the hypothetical accident scenario for vehicle impact protection in the IFC is an accidental collision from a standard passenger vehicle or light truck, traveling at low-to-moderate speed, which would be typical in a parking lot or access road setting. This conclusion is consistent with allowances in the International codes to use prescriptive bollards, as opposed to requiring engineered designs that are scenario driven, as a basis of achieving code compliance.

4.2. International Codes (I-Codes)

Prescriptive and performance guidelines for vehicle impact protection are included in many of the I-Codes. Noteworthy requirements in the International fire, building, mechanical and fuel gas codes are summarized below in Sections 4.2.1 through 4.2.4.

4.2.1. International Fire Code

When the IFC was initially drafted, beginning in 1997, the intent was to consolidate several regional codes that had been in use throughout the United States up to that point into a single document. These regional codes, collectively referred to as “legacy codes,” included the Uniform Fire Code (UFC), the Building Officials and Code Administrators National Fire Prevention Code (BNFPC) and the Standard Fire Prevention Code (SFPC).

IFC Section 312, which sets forth the IFC’s general requirements for vehicle impact protection, is commonly referenced by other code sections when impact protection is required. Section 312 contains two simple design options for barrier construction that are considered adequate whenever the code requires such protection. It is noted that Section 312 does not define functional objectives for vehicle impact barriers, as described in in Section 3.1 of this report, and it does not define the collision scenario that the code seeks to control with barrier construction.

The provisions in Section 312 were derived primarily from the UFC and the BNFPC. The two permissible design methods for providing vehicle impact protection are, 1) A prescriptive design using posts/bollards (IFC Section 312.2), and 2) A performance-design capable of resisting a prescribed load (IFC Section 312.3).

The basis of allowing both prescriptive and performance designs in Section 312 is not what it appears to be. On the surface, one might think that the criteria in Section 312.3 were intended to provide a performance-based equivalent to prescriptive bollard design requirements in Section 312.2. However, the true intent of including both of these sections was to continue allowing bollard design criteria that had previously been permitted by either the UFC or BNFPC so that jurisdictions using either code
would not be faced with having to switch design criteria for bollards when they switched to the IFC. This is further discussed later in this section.

**Summary of IFC Sections With Relevant Requirements:** Selected sections that include vehicular impact protection requirements in the IFC are listed in the table below. Most of these sections reference Section 312 for design and installation of barriers, and some include additional requirements. Where a code section has unique requirements, these have been included in the table.

**Table 3  IFC 2009 Edition - Selected References to Vehicle Impact Protection.**

<table>
<thead>
<tr>
<th>Code Section</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>312</td>
<td>Primary requirement for vehicle impact protection.</td>
</tr>
<tr>
<td></td>
<td>“312.1 <strong>General.</strong> Vehicle impact protection required by this code shall be provided by posts that comply with Section 312.2 or by other approved physical barriers that comply with Section 312.3.”</td>
</tr>
<tr>
<td></td>
<td><strong>312.2 Posts.</strong> Guard posts shall comply with all of the following requirements:</td>
</tr>
<tr>
<td></td>
<td>1. Constructed of steel not less than 4 inches (102 mm) in diameter and concrete filled.</td>
</tr>
<tr>
<td></td>
<td>2. Spaced not more than 4 feet (1219 mm) between posts on center.</td>
</tr>
<tr>
<td></td>
<td>3. Set not less than 3 feet (914 mm) deep in a concrete footing of not less than a 15-inch (381 mm) diameter.</td>
</tr>
<tr>
<td></td>
<td>4. Set with the top of the posts not less than 3 feet (914 mm) above ground.</td>
</tr>
<tr>
<td></td>
<td>5. Located not less than 3 feet (914 mm) from the protected object.</td>
</tr>
<tr>
<td></td>
<td><strong>312.3 Other barriers.</strong> Physical barriers shall be a minimum of 36 inches (914 mm) in height and shall resist a force of 12,000 pounds (53,375 N) applied 36 inches (914 mm) above the adjacent ground surface.”</td>
</tr>
<tr>
<td>507.5.6</td>
<td>Protection of fire hydrants (references Section 312).</td>
</tr>
<tr>
<td>912.3.3</td>
<td>Protection of fire department connections (references Section 312).</td>
</tr>
<tr>
<td>2206.4</td>
<td>Protection of above-ground tanks for motor vehicle fueling:</td>
</tr>
<tr>
<td></td>
<td>“Guard posts complying with Section 312 or other approved means shall be provided to protect above-ground tanks against impact by a motor vehicle unless the tank is listed as a protected above-ground tank with vehicle impact protection.”</td>
</tr>
<tr>
<td></td>
<td>This section references “other approved means” as being permissible, meaning that compliance with the technical requirements in Section 312 is not mandatory if other protection methods are approved by the local code official.</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
</tbody>
</table>
| 2206.7.3 | Protection of motor-fuel dispensing devices:  
“Dispensing devices, except those installed on top of a protected above-ground tank that qualifies as vehicle-impact resistant, shall be protected against physical damage by mounting on a concrete island 6 inches (152 mm) or more in height, or shall be protected in accordance with Section 312. Dispensing devices shall be installed and securely fastened to their mounting surface in accordance with the dispenser manufacturer’s instructions. Dispensing devices installed indoors shall be located in an approved position where they cannot be struck by an out-of-control vehicle descending a ramp or other slope.” |
| 2207.5.3 | Protection of LP-gas storage containers, pumps and dispensers (references Section 2206.4). |
| 2209.5.1 | Protection of hydrogen fuel dispensers (references Section 312). |
| 2703.9.3 | Protection of hazardous materials storage and handling equipment (references Section 312). |
| 3003.5.2 | Protection of compressed gas containers, cylinders, tanks and systems (references Section 312). |
| 3003.16.6 | Protection of above-ground compressed gas storage vaults (references Section 312). |
| 3403.6.4 | Protection of piping, valves and fittings handling flammable or combustible liquids (references Section 312). |
| 3404.2.8.6 | Protection of above-ground flammable and combustible liquid storage vaults (references Section 312). |
| 3404.2.9.7.5 | Protection of protected above-ground flammable and combustible liquid tanks:  
“Where protected above-ground tanks, piping, electrical conduit or dispensers are subject to vehicular impact, they shall be protected therefrom, either by having the impact protection incorporated into the system design in compliance with the impact test protocol of UL 2085, or by meeting the provisions of Section 312, or where necessary, a combination of both. Where guard posts or other approved barriers are provided, they shall be independent of each above-ground tank.”  
UL 2085 specifies a weighted pendulum test. The test specifies a 12,000 pound force applied at 10 miles-per-hour, in a 1-foot square area centered 18 inches above grade. The impact surface is a minimum 1/2-inch thick steel plate. |
<p>| 3404.4.5 | Protection of exterior containers and portable storage tanks for flammable or combustible liquids (references Section 312). |</p>
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3807.4</td>
<td>Protection of LP-gas containers, regulators and piping (references Section 312).</td>
</tr>
</tbody>
</table>
| 3809.13 | Protection of LP-gas containers awaiting use, resale or part of a cylinder exchange program:  
“LP-gas containers shall be stored within a suitable enclosure or otherwise protected against tampering. Vehicular protection shall be provided as required by the fire code official.”  
See “IFC Section 3809.13 – Requirements Specific to LP-gas Cylinder Exchange Cabinets” below for further discussion regarding the background of this section. |

**History and Analysis of Selected Sections of the IFC**

**IFC Section 312.2 – Prescriptive Requirements:** The IFC prescriptive design provisions in Section 312.2 were sourced from Section 8001.11.3 of the 1997 edition of the UFC, and they date back to the 1988 edition of the UFC, when a comprehensive re-write of the hazardous materials regulations in Article 80 was introduced. Although there is no documentation in the official code change records providing a basis for the vehicle barrier provisions that were included in Article 80, we were able to contact a member of the committee that drafted the revised article and learned that the provisions probably came from a California jurisdiction’s local code, perhaps the City of Sunnyvale. Nevertheless, we were not able to uncover a definitive technical basis for the IFC’s prescriptive bollard provisions.

The provisions specify 4-inch diameter concrete-filled steel pipes (bollards), set not less than 3 feet deep, in concrete bases having a diameter of at least 15 inches. The bollard height above surrounding grade must be at least 3 feet, and bollards must be placed at least 3 feet from a protected object (this was adjusted down from the UFC source provisions, which specified a separation distance of 5 feet).

The IFC Commentary on Section 312.2 states that the prescriptive design is intended to resist impacts from vehicles “…moving at low speeds, as they would be when pulling up to a pump at a motor fuel-dispensing facility.” Accordingly, the IFC Commentary implies that a 10-mph impact modeled by the pendulum collision discussed in Section 3.3.2 of this report would be in the “reasonable” range of the intended level of protection to be provided by bollard systems meeting the prescriptive design criteria in IFC Section 312.2.

**IFC Section 312.3 – Performance Requirements:** The IFC performance-based design provisions in Section 312.3 were sourced from Section F3205.4 of the 1996 edition of the BNFPC. The provisions are barrier oriented and are thereby not easily translated for use in evaluating curbs, ditches or other non-barrier approaches.

Section 312.3 requires that barriers must be able to “resist” a 12,000-pound force imposed 36 inches above the surrounding grade surface. The source provision in the BNFPC had specified an impact height of 30 inches, but the dimension was changed to 36 inches at some point in the IFC’s initial drafting process.

Although the requirements in Section 312.3 appear straightforward, there are two aspects of the code text that warrant further scrutiny. First, the 12,000-pound force is presented as a static load, i.e. a load with no associated velocity. Without knowing an intended impact velocity or vehicle weight, a kinetic energy rating (K-Rating) for a barrier cannot be accurately calculated.

Second, the term “resist” in the code text is undefined, which makes Section 312.3 unclear with respect to whether barrier deflection is permitted when an impact is absorbed. Unlike IFC Section
312.2, which requires a 3-foot space between a barrier and protected equipment, Section 312.3 requires no such “penetration zone” to accommodate barrier deflection. This could be interpreted as Section 312.3 not allowing deflection. Given these two deficiencies in the code text, one would have to make assumptions about vehicle size and speed and barrier deflection to estimate the level of protection that Section 312.3 seeks to achieve.

The IFC Commentary on Section 312.3 states that the intent of this section is to require protection that will resist an impact from moving vehicles traveling at relatively slow approach speeds. The Commentary goes on to state that the basis of the 12,000-pound figure is an impact by a 6,000 pound vehicle multiplied by a safety factor of 2. It suggests, based on unidentified Department of Transportation design criteria, that a 6-inch diameter concrete-filled bollard with a 42-inch embedment depth is a compliant solution.

Further research revealed the original change to the BNFPC that was the source of the current IFC provisions. The 12,000-pound criterion, which first appeared in the 1990 edition of the BNFPC, came from Code Change F38-88, and it only applied to protection of fuel dispensers at service stations. This proponent of this change was a BOCA ad hoc committee on storage tanks. The committee’s justification statement for Code Change F38-88 reveals the true intent of the current IFC Section 312.3 provisions:

“The dispenser protection was revised to require protection at the ends of each island. The protection is based on resisting an impact load from an average motor vehicle (3,000 lbs) and a standard factor of safety of 2. A typical assembly that would meet this criteria is a 6-inch concrete-filled steel pipe buried 42 inches in concrete. The point of impact could possibly be lowered to 18 inches, however, the committee maintained the 30-inch height based on U.S. DOT design guidelines. If the point of determining the force is lowered, the height of protection should be 30 inches. If the factor of safety of 2 is considered inappropriate, the resistance force could be lowered to 6,000 pounds. This is the maximum anticipated impact load from a passenger vehicle.”

In reading this statement, one notes that there is a problem with the mathematics that yielded the 12,000 pound load. The second sentence indicates that the anticipated impact load for a vehicle is 3,000 pounds, and with a safety factor of two, the total load would have been 6,000 pounds. At the end of the paragraph, the authors suggested that removing the safety factor would reduce the load from 12,000 pounds to 6,000 pounds. Presumably, because the code ended up with a 12,000 pound requirement, the authors may have incorrectly indicated 3,000 pounds, instead of 6,000 pounds, in the second sentence of the reason statement (this conclusion is supported by the 6,000-pound load factor specified by the IBC for parking barriers as described in Section 4.2.2 below).

With this fairly comprehensive understanding of how Section 312 originated, we are able to draw several significant conclusions:

1. Section 312.3 is not truly a performance-based alternative design basis for the prescriptive provisions in Section 312.2. Instead, the two sections allow redundant and unrelated approaches to providing impact barriers, and there is no known technical relationship between the two design approaches. Section 312.2 was included in the IFC so that jurisdictions transitioning from the UFC to the IFC would not be forced into having to follow new barrier design criteria. Likewise, Section 312.3 was included in the IFC so that jurisdictions transitioning from the BNFPC to the IFC would not be forced into having to follow new barrier design criteria.

2. Contrary to what is indicated in the IFC Commentary, neither the 12,000-pound load factor nor the 30-inch height for load application specified in Section 312.3 is based on U.S. Department of Transportation (DOT) design criteria. Instead, only the 30-inch barrier height above finished grade was reportedly sourced from DOT requirements.
3. Given the original justification statement for the BNFPC provision that sourced IFC Section 312.3, it is clear that the science behind the IFC’s 12,000-pound requirement is weak. The 12,000-pound load factor represents twice the anticipated design load of 6,000 pounds (static), and the 2x factor of safety was established arbitrarily.

**IFC Section 2206.7.3 – IFC Requirements for Protection of Motor-Fuel Dispensers Provide a Relevant Historic Perspective:** Our research identified prior changes to vehicle impact barrier requirements for motor-fuel dispensers that are of interest to the current consideration of changing requirements for protecting LP-gas cylinder exchange cabinets. In the IFC 2000 edition, Section 2206.7.3 required fuel dispensers to be placed on a 6-inch high concrete island or protected with vehicle barriers meeting the requirements Section 313 (now 312). The North Carolina Fire Service Code Revision Committee submitted a proposal to change this requirement (Code Change F110-00) by eliminating the reference to Section 313 (now 312) and substituting “mounting on a concrete island six inches or more in height, or shall otherwise be suitably protected.” The change, which was accepted, was justified by the following statement:

“Section 313 (now 312) is more applicable to the protection of aboveground tanks and if taken literally for the protection of dispensers will require guard posts to be placed on 4 foot centers all the way around the dispensers. This type of installation will create a nuisance to people attempting to fuel vehicles and may create violations of ADA regulations. This change as submitted will allow the dispensers to be protected as needed, such as from the vehicular approach directions.”

The following year, Glendale, Arizona Fire Department submitted a proposal (Code Change F14-01) to change the newly-revised Section 2206.7.3 by reinstating the reference to Section 312. The justification statement for that proposal, which was approved, included the following:

“Last year Item F-110 removed the reference to Section 312 from Section 2206.7.3 which details the requirements for mounting of dispensers for flammable and combustible liquids. Removing this reference did not change the fact that the vehicle protection still needs to be in accordance with Section 312, it only made it more difficult for the reader to find out what standard must be followed to meet the criteria of “suitably protected” ... Hopefully, this solution (which reinstated the reference to Section 312) will meet the needs of the supporters of F-110 while providing a much-needed cross reference.”

In reviewing the balance of the substantiation statement and the subsequent changes made by the code development committee, it became evident that there was an understanding among those involved in that discussion that engineered solutions under Section 312.3 are not bound by any predetermined bollard spacing considerations, such as those specified in Section 312.2(2), which calls for bollards to be spaced at not more than 4 feet on center. Otherwise, the objective of Code Change F110-00 to allow avoidance of 4-foot on-center bollard spacing all the way around dispensers would not have been maintained when the reference to Section 312 was reinstated in Section 2206.7.3.

This is of interest with respect to LP-gas cylinder exchange cabinet protection because the same logic should apply, i.e., a protection scheme based on Section 312.3 should be permitted to consider providing protection only from directions that vehicle impact would be expected based on analysis of traffic patterns.

Accordingly, Section 312.3 should not be taken as automatically requiring bollards at 4-foot on-center spacing across the entire face of the cabinet. This level of flexibility, in itself, might be adequate to satisfy some of NPGA’s concerns with current IFC requirements for vehicle impact protection.

**IFC Section 3809.13 – Requirements Specific to LP-gas Cylinder Exchange Cabinets:** Section 3809.13 is the specific section in the IFC that includes a requirement for LP-gas cylinder exchange cabinets to be provided with vehicle impact protection. The code text of the section is as follows:
“LP-gas containers shall be stored within a suitable enclosure or otherwise protected against tampering. Vehicular protection shall be provided as required by the fire code official.”

The IFC Commentary provides some insight into the application of this section with respect to the requirement for protecting cylinder exchange cabinets from impact, as follows:

“At public facilities, tampering with LP-gas containers may be a problem. For that reason, locked metal cabinets are used to provide not only tamper protection, but also substantial protection from vehicular impact. At locations where the cabinet is installed close to the direct path of motor vehicles, the code official can require additional protection.”

Although not an official interpretation of the code, the Commentary text provides an interesting perspective that was not seen elsewhere in our research. The mention of a cylinder exchange cabinet providing “substantial protection from vehicular impact” and the mention of only requiring additional impact protection “where the cabinet is installed close to the direct path of motor vehicles” seemingly opens the door for two approaches to code advocacy that are further discussed in Sections 6.0 through 6.2 of this report: 1) Recognizing protection provided by an exchange cabinet, and 2) Varying protection based on impact risk factors.

It is also noteworthy that Section 3809.13 is unique among all IFC sections that discuss vehicle impact protection (outlined in Table 3 above), in that it does not directly reference Section 312 for design criteria. The basis of this omission is revealed by the source of the code text. Code Change 873-99 was submitted by the Washington State Chapter of the International Fire Code Institute during the IFC drafting process. The change, which was approved as submitted, contained two parts. Part one introduced the current text for vehicular impact protection, and part two introduced minimum requirements for separation distances between cylinder exchange cabinets and means of egress. The only justification offered with respect to impact protection was the statement, “Adding this section to the body of the code will be of benefit to the fire inspector in regulating the locations and barriers for these sites.”

The failure to reference Section 312 may have resulted from the fact that the foregoing proposal was introduced in the first round of changes to the first public draft of the IFC, and participants in the process were not entirely familiar with the code at that point. Simply put, the proponents may not have been aware of the prior effort to coordinate most other code provisions dealing with vehicle impact protection with a single set of technical requirements in Section 312, and the oversight could have been missed when as the change was processed at ICC’s Costa Mesa, CA hearing (which was two-weeks in length and processed thousands of code change proposals to the International Code drafts in preparation for publication of the initial codes in 2000).

As mentioned in the discussion of Section 2206.7.3 above, even if a code official were to take the position that compliance with Section 3809.13 requires compliance with barrier design provisions in Section 312, code history tells us that Section 312.3 should not be interpreted as mandating bollards all the way across or around cylinder exchange cabinets at 4-foot intervals. Instead, barrier posts should only be required as needed to provide protection from anticipated paths of approaching vehicles.

In researching this code section, we also noted that one of the legacy fire codes, the BNFPC, contained a similar provision, which was added to BNFPC Section 3605.4.1 of the 1996 edition of that code as follows:

“3605.4.1. Protection against vehicle impact shall be provided where vehicle traffic normally is expected at the container site.”

This provision came from BOCA Code Change Proposal F77-94, which was submitted by the Ohio Fire Chiefs Association. The originally proposed text was “Protection against vehicle impact shall be provided in accordance with good engineering practice where vehicle traffic normally is expected at the container site,” and this text was based on the following substantiation statement:
“The existing code text does not provide the code official with adequate requirements for dealing with LPG exchange and refilling operations of Use Group M Occupancies. In recent years there have been a significant increase in the number of LPG cylinder exchange and refill sites. Many large service stations’ dealers (BP) have taken on the operation of LPG cylinder exchange, also the hardware and building supply facilities have installed and operate LPG container exchange refilling operations. In past practice, the exchanges and refilling operations were conducted at facilities designed specifically for LPG operations by LPG dealers. All employees handling, servicing, and filling LPG cylinders at LPG designated dealer sites were trained employees. Observation of LPG operations at service stations, hardware and building supply operations by members of the Ohio Fire Chiefs Code Committee indicates that many of the employees have little or no training for handling or refilling of LPG containers. Similar language exists in NFPA 58 and to insure uniformity in enforcement in the field the proposed language is being submitted for placement into the body of the BOCA National Fire Prevention Code. Even though similar language exists in NFPA it is important that the material be readily available to the field inspector (in-service inspections by engine companies). It is impractical and cost prohibited for the field inspector to carry the reference standards.” (Note that NFPA refers to the National Fire Protection Association, otherwise known by NFPA)

The BNFPC staff provided a comment on the proposal as follows:

“The proposal lacks the necessary approval criteria for container protection in order to consider the requirements enforceable. Reliance on text which requires “approval” or “good engineering practice” raises questions as to enforceability...”

When this proposal was considered at a public hearing, the text was modified to delete the phrase “in accordance with good engineering practice,” which had been quoted from NFPA 58, because the text was considered by BOCA members and staff to be too subjective and not appropriate for inclusion in the BNFPC.

Ultimately, this BNFPC requirement was not included in the first draft of the IFC, perhaps because the BNFPC was the only legacy code to specifically address the issue (many issues were dropped during the IFC drafting process when only one of the three legacy codes addressed a topic) or perhaps because it was felt that the issue was adequately covered by NFPA 58 without needing a specific IFC requirement.

Note that IFC Section 3801.1 requires all storage, transportation and handling of LP-gas and the installation of LP-gas equipment to comply with both IFC Chapter 38 and NFPA 58, so theoretically, anything in NFPA 58 is technically unneeded in the IFC unless the IFC is amending the requirement or the IFC is duplicating the requirement for the convenience of inspectors who may not have NFPA 58 available in the field. Nevertheless, as discussed above, a requirement for vehicle impact protection for cylinder exchange cabinets was later added to the IFC based on Code Change Proposal Number 873-99.

4.2.2. International Building Code

Vehicle impact requirements are found in a few sections of the International Building Code (IBC). These requirements are generally consistent with those specified for impact resistance in vehicle parking areas in ASCE-710, which is the nationally recognized standard that establishes design loads for buildings and other structures.
The IBC requirements resemble or are consistent with requirements in the IFC in several ways. First, a 6,000-pound static load is the specified basic design requirement. IFC Section 312.3 was based on this load with a 2x factor of safety. Second, the required barrier height of 2 feet, 9 inches in IBC Section 406.2.4 is close to the 3-foot requirement in IFC Sections 312.2 and 312.3; however, the load heights in IBC Section 1607.7.3 are set at 1 foot, 6 inches and 2 feet, 3 inches versus 3 feet load in IFC Section 312.3. One question that bears consideration is why the IFC requirements for impact protection are more restrictive than those in the IBC, which are intended to prevent vehicles from going over the edge of a parking garage.

4.2.3. International Mechanical Code

Impact protection is specified by the International Mechanical Code (IMC) for several conditions. These include installed appliances (e.g. heaters, blowers, etc.) that are considered at risk of mechanical damage. Where such equipment is at risk of vehicular impact, it must be positioned high enough above the finished floor to allow vehicles to pass under or motor vehicle impact protection must be provided. However, the IMC does not reference a particular design basis for such protection.
Table 5 IMC 2009 Edition - Selected References to Vehicle Impact Protection.

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>303.4</td>
<td>Protection of equipment and appliances: &lt;br&gt;“Appliances shall not be installed in a location where subject to mechanical damage unless protected by approved barriers.”</td>
</tr>
<tr>
<td>304.6</td>
<td>Protection of appliances in public garages, motor fuel-dispensing facilities, repair garages and other areas frequented by motor vehicles: &lt;br&gt;Appliances must be installed at 8 feet above the floor and not less than 1 foot above the height of the tallest garage door opening, unless appliances are protected from motor vehicle impact in accordance with IMC Section 303.4 and NFPA 30A (discussed in Section 4.3 of this report).</td>
</tr>
<tr>
<td>304.7</td>
<td>Protection of appliances in private garages and carports: &lt;br&gt;Appliances must be installed at 6 feet above the floor, unless appliances are protected from motor vehicle impact and installed in accordance with IMC Section 303.4.</td>
</tr>
<tr>
<td>603.15</td>
<td>Protection of exposed ductwork: &lt;br&gt;“Ducts installed in locations where they are exposed to mechanical damage by vehicles or from other causes shall be protected by approved barriers.”</td>
</tr>
<tr>
<td>1402.2</td>
<td>Protection of solar arrays from vehicle impact: &lt;br&gt;Solar equipment must be installed at 6 feet above the floor, unless motor vehicle impact protection is provided.</td>
</tr>
</tbody>
</table>

4.2.4. **International Fuel Gas Code (IFGC)**

The IFGC\textsuperscript{12} is primarily concerned with the protection of fuel gas supplies and distribution systems. When installed in areas subject to mechanical damage, these systems must be “protected by an approved means”; however, no specific requirements are provided.

Table 6 IFGC 2009 Edition – Selected References to Vehicle Impact Protection.

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>303.4</td>
<td>Protection of appliances: &lt;br&gt;“Appliances shall not be installed in a location subject to vehicle impact damage except where protected by an approved means.”</td>
</tr>
<tr>
<td>305.4</td>
<td>Essentially the same as IMC Section 304.6</td>
</tr>
<tr>
<td>305.5</td>
<td>Essentially the same as IMC Section 304.7</td>
</tr>
<tr>
<td>412.7.3</td>
<td>Protection of LP-gas storage containers, pumps and dispensers at LP-gas motor-fuel dispensing facilities: &lt;br&gt;“Vehicle impact protection for LP-gas storage containers, pumps and dispensers shall be provided in accordance with the International Fire Code.”</td>
</tr>
</tbody>
</table>
4.3. NFPA Codes and Standards

NFPA codes and standards include many requirements to protect critical equipment from vehicular impact. NFPA 1\textsuperscript{13} is NFPA’s consolidated fire prevention code, and it is largely a document that extracts duplicate requirements from other NFPA codes and standards. For this reason, NFPA 1 includes different requirements for different vehicle barrier applications. For example, barrier requirements for flammable and combustible liquids are different than those for LP-gas because NFPA has different technical committees developing regulations for these topics, and these committees produce two documents (NFPA 30 and NFPA 58), both of which contribute material to NFPA 1.

It should be noted that NFPA 1 is sometimes referred to as the Uniform Fire Code or the UFC because NFPA acquired the rights to the Uniform Fire Code title beginning with the 2003 edition. However, the NFPA 1 version of the UFC document bears little resemblance to the 2000 and prior editions of the Uniform Fire Code that were published by other organizations.

Selected vehicular impact protection requirements from NFPA codes and standards are listed in the table below.

<p>| NFPA 1-2009 Edition | | |
|---------------------|------------------|
| 42.3.3.7.2 A.42.3.3.7.2 | Prescriptive bollard design to protect aboveground fuel storage tanks in refueling facilities. Construction requirements are the same as IFC 312: Extracted from NFPA 30A Section 4.3.7.2 (see NFPA 30A below) |
| 42.5.3.4 | Dispensing devices protection requires mounting on a concrete island or otherwise protected against collision damage by means acceptable to the AHJ: Extracted from NFPA 30A Section 6.3.4 (see NFPA 30A below) |
| 42.10.4.3.2 | Protection of aircraft refueling pumps: “Pumps installed outside of buildings shall be located not less than 5 ft (1.5 m) from any building opening. They shall be substantially anchored and protected against physical damage from collision.” Extracted from NFPA407 Section 4.5.3.2 |
| 42.3.3.3.2.2 | Protection of aboveground vaults: Requires that vaults that are not resistant to damage from the impact of a motor vehicle be protected by collision barriers. Extracted from NFPA 30 Section 25.5.2.2 (see NFPA 30 below) |</p>
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
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| 60.1.15.1 & 2 | General requirements for protecting hazardous materials equipment from vehicular impact:  
  “Guard posts or other approved means shall be provided to protect the following areas where subject to vehicular damage:  
  (1) Storage tanks and connected piping, valves, and fittings  
  (2) Dispensing areas  
  (3) Use areas”  
  “Where guard posts are installed, the posts shall meet the following criteria:  
  (1) They shall be constructed of steel not less than 4 in. (102 mm) in diameter and concrete filled.  
  (2) They shall be spaced not more than 4 ft (1.2 m) between posts on center.  
  (3) They shall be set not less than 3 ft (0.9 m) deep in a concrete footing of not less than a 15 in. (380 mm) diameter.  
  (4) They shall be set with the top of the posts not less than 3 ft (0.9 m) above ground.  
  (5) They shall be located not less than 5 ft (1.5 m) from the tank.  
  These provisions mirror NFPA 30A, Section 4.3.7.2 and IFC 312. |
| 66.22.11.3.9 | Protection of aboveground storage tanks and vaults:  
  Requires that tanks and vaults that are not resistant to damage from the impact of a motor vehicle be protected by collision barriers.  
  Extracted from NFPA 30 Sections 22.11.3.9, 22.11.4.7, 22.15 and 25.5.2.2 (see NFPA 30 below) |
| 66.22.11.4.7 |  |
| 66.22.15 |  |
| 66.25.5.2.2 |  |
| 69.5.4.2.2 | Protection of LP-Gas cylinders:  
  Requires protection in accordance with good engineering practice where vehicle traffic is expected  
  Extracted from NFPA 58 Sections 8.4.2.2 and A.8.4.2.2 (see NFPA 58 below) |
| A.69.5.4.2.2 |  |
| **NFPA 30** |  |
| 22.11.3.9 | Protection of above-ground storage tanks:  
  “The tank shall be capable of resisting the damage from the impact of a motor vehicle, or collision barriers shall be provided.” |
| 22.11.4.7 |  |
| 22.15 | Protection of above-ground storage tanks:  
  “Where a tank is exposed to vehicular impact, protection shall be provided to prevent damage to the tank.” |
| 25.5.2.2 | Protection of storage tank vaults:  
  “Vaults that are not resistant to damage from the impact of a motor vehicle shall be protected by collision barriers.” |
| **NFPA 30A** |  |
| 4.3.3.2.2 | Protection of aboveground vaults: 
Requires that vaults that are not resistant to damage from the impact of a motor vehicle be protected by collision barriers. 

Extracted from NFPA 30 Section 25.5.2.2 (see NFPA 30 above) |
| --- | --- |
| 4.3.7.2 | Protection for aboveground fuel storage tanks: 
“Guard posts or other approved means shall be provided to protect tanks that are subject to vehicular damage. When guard posts are installed, the following design shall be acceptable: 

1. They shall be constructed of steel not less than 100 mm (4 inch) in diameter and shall be filled with concrete. 
2. They shall be spaced not more than 1.2 m (4 ft) on center. 
3. They shall be set not less than 0.9 m (3 ft) deep in a concrete footing of not less than 380 mm (15 inch) diameter.” 

[From NFPA 30A, Section A.4.3.7.2] 

“The top of the posts should be set not less than 0.9 m (3 ft) above ground and should be located not less than 1.5 m (5 ft) from the tank. Other approved means to protect tanks subject to vehicular damage include vehicle impact resistance testing such as that prescribed in UL 2085, Standard for Protected Aboveground Tanks for Flammable and Combustible Liquids, for protected aboveground tanks.” 

Mirrors provisions in IFC Section 312 of this report). |
| 6.3.4 | Protection of motor-fuel dispensing devices: 
“Dispensing devices shall be mounted on a concrete island or shall otherwise be protected against collision damage by means acceptable to the authority having jurisdiction. Dispensing devices shall be securely bolted in place. If located indoors, dispensing devices shall also be located in a position where they cannot be struck by a vehicle that is out of control descending a ramp or other slope.” |
| NFPA 52 | Protection of LNG containers on motor vehicles. This applies to cases where a vehicle-mounted tank may collide with a stationary object (such as a roof mounted tank on a bus). **The relevance of this section is the introduction of a stated impact velocity of 5 mph for designing a barrier:** 

“Where a container is installed above the operator or passenger compartment of a vehicle, the following requirements shall apply: 

1. The container and its piping, fittings, and valves shall be protected from damage by the following: 

   a. A guard rail or similar device that is designed to absorb the impact of a collision with a stationary object when the vehicle is moving either forward or backward at 5 mph (8 km/hr) 
   b. A shield designed to absorb impacts that can occur during loading, unloading, or use of the vehicle” |
| 12.4.1 | LNG vehicle fuel-dispensing devices:  
|        | “The dispensing device shall be protected from vehicle collision damage.” |

**NFPA 58**

| 8.4.2.2  | Protection of LP-gas cylinders  
| A.8.4.2.2 | “Protection against vehicle impact shall be provided in accordance with good engineering practice where vehicular traffic is expected at the location.”  
[From NFPA 58, Section A.8.4.2.2]  
“There are numerous effective means to provide protection against accidental vehicle impact or damage. The method selected depends upon local conditions with regard to the kinds of traffic that can be reasonably expected and the environment surrounding the location. While additional protection over and above that used to protect the building might not be needed at some locations, others might need additional protection. Examples of such additional protection could be the following:  
(1) Guard rails  
(2) Steel bollards  
(3) Raised sidewalks” |

**NFPA 385**

| 5.3.8.6.2 & 3 | Provides design criteria for pumper and bumper impact for tank vehicles for flammable liquid transport.  
|                | “Dimensionally, the bumper shall conform to U.S. Department of Transportation regulations in 49 CFR Part 393.86, “Rear Impact Guards and Rear End Protection.” Structurally, the bumper shall be designed to successfully absorb the impact of the vehicle with rated payload (i.e., prevent damage that will cause leakage of product), with a deceleration of 2g, using a factor of safety of 2 based on the ultimate strength of the bumper material.”  
|                | “For purposes of these regulations, such impact shall be considered uniformly distributed and applied horizontally (parallel to the ground) from any direction at an angle not exceeding 30 degrees to the longitudinal axis of the vehicle.”  
|                | This provision provides some guidance with respect to designing bumpers for impact. Specifically, the deceleration rate of 2g, the 2x factor of safety and the maximum design angle of impact may be of interest when considering modifications to performance design criteria for bollards. |

**NFPA 730**
E.2.1 This section contains a broad discussion of passive barriers for exterior protection. Included in the discussion are descriptions of three barrier types: concrete planters, bollards and Jersey barriers.

Section E.2.1.2.1 includes the following statement regarding performance testing of a bollard design scheme that provides some insight into the relative performance of the prescriptive bollard provisions in the IFC and various NFPA documents.

“In testing performed by the U.S. Army Corps of Engineers, concrete-filled steel bollards spaced 4 ft apart, at a height of 3 ft above grade, and buried in concrete to a depth of 4 ft stopped a 4,500 lb. vehicle traveling at 30 mph. The concrete portion of the bollard had a diameter of 8 inches, and the steel pipe was 1/2 inch thick.”

This impact rating would be equivalent to 135 ft-kips.

5.0 RECOMMENDATIONS FOR LABORATORY TESTING

The NPGA project includes an optional Phase II, which would encompass any testing deemed necessary for supporting a code change proposal. This report identifies several areas where testing may be beneficial in providing technical justification for changing code requirements, which are discussed in this section.

If testing is to be conducted, it is highly recommended that the input of influential code officials be sought in designing and reviewing test protocols. In addition, any test contract should include production of video documentation that would be suitable for presentation to code officials.

5.1. Testing to Quantify Performance of Currently Required Bollards

Determining the true performance (K-Rating) of barrier design criteria in IFC Sections 312.2 and 312.3 would allow NPGA to quantify current code requirements. Given that we have identified that the IFC appears to require two different levels of performance in these two sections, it would be beneficial to know which requirement reflects the minimum level of protection so that any alternative proposed by NPGA in a code change submittal could be quantitatively equated against that level.

It is envisioned that this testing would be conducted using individual bollards placed in various pavements and soils and impacted using a pendulum with varied force levels. Testing the traditional bollards with alternative burial depths and foundations may also be instructive in determining whether bollard designs that are lesser than those currently allowed by code might be adequate to meet the objective of resisting low-speed impacts.

Alternately, it is possible that this type of analysis could be performed using mathematical modeling software that was referenced in some of the literature reviewed for preparation of this report. At this point, we have not researched the capabilities of such software, so further work would be needed to identify whether this is a legitimate option.

5.2. Testing to Determine Performance of Alternative Barrier Methods

The code currently focuses on bollards and similar barriers. For low-speed impacts, parking blocks or curbs of varied height and design may provide adequate resistance to prevent an accidental impact. This analysis would have to consider various tire heights and vehicle weights, but it may be worth exploring. In addition, bollards that are bolted to and/or sunk into pavement versus requiring embedment in concrete foundations could be investigated for suitability in some applications.
One identified resource for information on curb installation is “Recommended Guidelines for Curb and Curb-Barrier Installations” NCHRP Report 537, published by the Transportation Research Board of the National Academies.

5.3. Testing to Determine Performance of Cylinder Exchange Cabinets

Because codes and standards currently permit “protected” aboveground tanks to use the outer casing of a tank assembly to protect the enclosed tank and because the IFC Commentary discusses this concept, it seems reasonable for exchange cabinets to be recognized as providing some degree of impact resistance to protect cylinders therein. Theoretically, a cylinder exchange cabinet should receive credit for providing impact protection to a level that prevents enclosed cylinders from leaking after a prescribed impact. Such an approach would provide credit for cylinder robustness, recognizing that cylinders are designed to resist impacts associated with transportation accidents.

Impact resistance provided by exchange cabinets, perhaps in combination with parking blocks, curbs or lightweight bollards, might constitute a “package” of protection that could be recognized in lieu of bollards.

Considerations for testing of cylinder exchange cabinets with respect to impact resistance should include:

1. **Cylinder tests** - Quantify the lateral impact energy that an upright cylinder alone can withstand. This test might initially be conducted with the cylinder in close contact with a resilient backstop, simulating the exterior of the building. Subsequent tests could be conducted with a simulated cabinet back and clear space beyond the cabinet. The pendulum height could be varied to impose different impact energies. Consideration would have to be given to cylinder pressure and whether the cylinders are pressurized pneumatically or hydrostatically to simulate LP-gas charged cylinders in tests.

2. **Cabinet design** – There may need to be a need to provide some internal space for cylinder movement in the event of an impact, perhaps with the specific intent of preventing cylinders from being pinned and compressed. This might involve using a weak back connection on cabinets that would allow cylinders to be released in avoidance of pinning and/or interior baffles to direct cylinder displacement.

3. **Bolt strength** – Cabinet anchoring will affect the process of energy absorption. A well anchored cabinet will absorb more energy in the cabinet body. A cabinet with breakaway bolts and a clear space on the non-traffic side to allow penetration will allow energy absorption through cabinet displacement.

4. **Penetration zone** – There may be a need to provide space between cabinets and backstops (exterior walls of buildings adjacent to cabinets) when cabinets are installed to accommodate movement and provide space for vehicle deceleration before pinning cylinders against an exterior wall.

5. **Standardizing a test method** – Because there are many different cabinet designs, a standardized test method, most likely using a pendulum, might be needed to qualify cabinet designs as impact resistant. The currently-adopted test parameter of a 12,000-lb pendulum swung from a height of 1 foot would likely be defendable as a testing basis. As identified in #1 above, consideration would have to be given to cylinder pressure and whether the cylinders are pressurized pneumatically or hydrostatically to simulate LP-gas charged cylinders in tests.

6. **Third-party listing** – Using cabinets as a component of an impact protection scheme might require some type of third party listing service to certify cabinets in a way that code officials would approve.
6.0 CONCLUSION AND CODE ADVOCACY

It is the overall conclusion of this literature survey that model codes and standards are substantially lacking with respect to providing suitable or defensible requirements for vehicle impact protection. The inadequacies range from being too prescriptive to too vague. For example, the IFC provides a single prescriptive design solution using bollards that is always permissible (i.e. without regard for impact scenarios or soil or pavement conditions) even though the level of impact resistance provided by this design solution is unknown. Clearly, the probability of vehicle impact and associated vehicle sizes and speeds are not constant in all locations where equipment must be protected, and the IFC’s current approach is therefore difficult to justify.

On the other end of the spectrum, some sections in model codes and standards provide nothing more than a general statement requiring that impact protection must be provided, must be “approved” (by a local code official) without specifying any particular performance or design objective, or must comply with “good engineering practice.”

From NPGA’s perspective of seeking changes with respect to barrier requirements for LP-gas cylinder exchange cabinets, the failure of current model codes and standards to provide a sound basis for vehicle barriers bolsters NPGA’s prospects for success because defending the status quo is difficult when the status quo can be shown to be technically deficient.


The roots of Section 3909.13 suggest that opposition to changing/reducing vehicle impact protection for cylinder exchange cabinets could come from fire officials in Northeastern and Western states, where the UFC and BNFPC were previously used. This expectation is based upon the facts that, 1) The BNFPC was specifically modified to require impact protection for LP-gas cylinder exchange cabinets in the 1996 edition (see Section 4.2.1 of this report), and 2) The IFC change that led to the current requirement to protect cylinder exchange cabinets from vehicular impact was advocated in 1999 by the Washington State Chapter of the International Fire Code Institute (also known as the Washington State Association of Fire Marshals). It is also possible that opposition might come from one or more fire official groups in the Southeast because fire prevention officials from that area backed prior changes to NFPA 58 dealing with placement of cylinder exchange cabinets (See NFPA Standards Council Decision D98-7).

Support may come from fire officials in North Carolina and Arizona, who previously supported changes to the IFC that relaxed the requirements for bollards protecting motor-fuel dispensers on the basis of eliminating consumer accessibility obstacles.

With the foregoing in mind, we surveyed several fire officials and others who have been influential at past code development activities to get a sense of how supportive they are of current impact protection provisions and a sense of their flexibility with respect to possibly modifying the IFC requirements for protecting cylinder exchange cabinets and perhaps other equipment. Individuals who were surveyed represented a cross-section of geographic areas and both large (statewide) and small (fire districts) jurisdictions.

The following is a summary of the feedback that we received:

- Without exception, individuals who were interviewed agreed that the current “one size fits all” approach used by the IFC could be improved and that IFC Section 312 should be rewritten to address the topic of impact protection in a more scientific manner
- Without exception, individuals who were interviewed agreed that the vehicle impact provisions of the code should be varied based on the anticipated impact scenario, considering:
  - Vehicle speed
  - Traffic patterns
Literature Survey and Feasibility Analysis Related to Revising Vehicle Barrier System Regulations for LP-gas Cylinder Exchange Cabinets

- Vehicle size (from trucks/buses down to forklifts, and the weight of the anticipated load that a forklift might be carrying)
- Indoor vs. outdoor locations
- Setback distance of the equipment to be protected from the traffic lanes
- Proximity of equipment with respect to building walls (some commented that being next to a wall is beneficial as a visual deterrent to striking a cylinder exchange cabinet located along the wall, particularly if the wall is concrete or masonry)

- Most individuals who were interviewed agreed that some credit should be given to the protection provided by parking blocks and curbs
- Most individuals who were interviewed were not opposed to giving some credit for impact protection provided by a cylinder exchange cabinet if there were testing to quantify the degree of protection provided and demonstrate that cylinders won’t fail as a result of the prescribed impact condition.
- Results were mixed among jurisdictions as to whether they currently pay attention to the issue of vehicle impact protection for cylinder exchange cabinets. Some individuals who were interviewed admitted that they had no way of tracking installations and that exchange cabinets just seem to “pop up” without permits. One individual commented that they look for the lack of bollards as a method of identifying cabinets that were installed without approval.
- Several individuals who were interviewed commented that they either never require impact protection for cylinder exchange cabinets or only require protection when there is a clear risk. These individuals also tended to believe that placing a cabinet on an elevated walkway beyond a curb, beyond a parking block or against a building constituted adequate protection.
- A few individuals who were interviewed require all cylinder exchange cabinets to be provided with bollards or equivalent protection in accordance with IFC Section 312. This included the entire state of New York and much of Florida.

6.2. Considerations for Code Change Proposals

There are three clear options for NPGA to consider for dealing with concerns about vehicle impact protection requirements in the IFC for cylinder exchange cabinets.

1. **Do Nothing:** The current requirements of IFC Section 3809.13 do not specifically reference the vehicle barrier provisions in Section 312. Instead, the section only requires impact protection when deemed necessary by a local code official. Even then, no specific design requirements are mandated by the code, and Section 312 compliant bollards may or may not be required, as opposed to curbs, parking blocks or other means of inhibiting vehicular impact, depending on the opinion of the local code official. Our survey of code officials indicated that enforcement of barrier protection provisions varies significantly among jurisdictions.

   Given that the current lack of a reference to Section 312 for LP-gas cylinder exchange cabinets was seemingly the result of an oversight when the original code change proposal that added impact protection to Section 3809.13 was processed, NPGA should think carefully about whether or not to draw attention to the section. Doing so does introduce a risk of someone proposing to add the reference while making no other changes to the section.

2. **Propose a Targeted Fix:** A targeted “fix” to Section 3809.13 could be proposed to provide detailed instructions for permissible methods of vehicle impact protection that are considered by NPGA to be suitable for exchange cabinets. By including such provisions in IFC Chapter 38, the requirements would only apply to LP-gas, and they would “trump” the general
provisions of Section 312 because IFC Section 102.10 states that, where a conflict occurs in the code between a specific provision and a general provision, the specific provision prevails.

The technical content of a proposal to modify Chapter 38 could be based on one or more of the following:

   a. Changing the impact protection text in Chapter 38 to duplicate the requirements of NFPA 58 or mirror some other basis in existing codes or standards (such as protection requirements for motor vehicle fuel dispensers or protected above-ground tanks),

   b. Introducing provisions that have technical merit founded in research and testing under Phase II of this project, which could include:

      i. Alternative barrier design methods for protecting cylinder exchange cabinets,

      ii. Developing a tiered protection scheme that varies mitigation measures based on risk factors associated with individual installations. Such mitigation measures might include minimum separation distances from active traffic areas based on traffic patterns; curbs, parking blocks or ditches of various heights; low-resistance obstructions such as break-away posts or surface mounted posts that are bolted to pavement; or visual obstructions such as flexible plastic bollards,

      iii. Recognizing the direct response of various cylinder exchange cabinets to simulated vehicle impact scenarios. If cylinders are impacted using a suitable test method and don’t leak as a result, this could be considered a successful outcome even if a cabinet sustains damage and cylinders are dislodged.

3. **Propose a Broad Fix:** In lieu of submitting a code change proposal that only addresses NPGA’s concerns with respect to protecting cylinder exchange cabinets, there is also an option to use the findings of this report and any subsequent research in Phase II to make a broad “fix” to IFC Section 312, and then reference these provisions in Section 3809.13. For example:

   a. The tiered protection scheme proposed in Option #2b(i) above seems generally appropriate for all cases where impact protection is needed.

   b. Define the impact scenario(s) that Section 312 intends to address. Based on our research, it appears that model codes and standards generally contemplate an impact velocity in the 5-10 mph range. If this were agreed upon as a reasonable design basis, IFC Section 312.3 could be rewritten to provide a true performance-based design method for barriers based on kinetic energy associated with various impacts (as described in Table 1 of this report). It is noted that code users would likely choose to maintain an option to use the current prescriptive bollard design criteria in Section 312.2 to accommodate those who are not interested in a calculated solution.

By proposing a broad fix that is not LP-gas specific, NPGA might attract support from other interest groups if the proposal is properly crafted, enhancing prospects for success. Although the broad fix approach is often more complex to execute than a targeted fix, it is sometimes the most effective way to accomplish a code change, particularly when a code official group is willing to sponsor the proposal, as opposed to having an industry group as the proponent.

Should NPGA proceed with advocating a proposal to modify the IFC impact protection requirements for cylinder exchange cabinets, per Phase III of this project, the following deficiencies in the current code provisions should be considered in substantiating the proposal:
a. Actual performance of the barrier systems described in Section 312.3 is unknown because the provisions specify static loading, which is not directly representative of a collision.

b. The prescriptive bollard design provisions in the current code do not provide a consistent level of protection because the provisions do not consider soil compressive strength, foundations or surrounding surface conditions (concrete hard-deck or asphalt paving), which will affect bollard performance.

c. Codes and standards specify, in some cases, a minimum 3-foot distance that must be provided between barrier posts and the equipment to be protected, but without knowing soil conditions or anticipated impact criteria, this distance may or may not be adequate to prevent damage to protected equipment.

d. Codes and standards don’t generally specify whether it might be permissible for some level of impact to be transmitted to protected equipment if the equipment remains serviceable after the incident (the exception being protected above-ground tanks.

e. The current provisions in Section 312, which create a “one size fits all” approach to vehicle barriers with respect to prescriptive bollard designs or impact loads, is ill-conceived in that the level of protection required by the IFC should allow for variations based on reasonable impact scenarios for different applications (indoor vs. outdoor, distance to active traffic areas, etc.). Common sense tells us that the current approach in Section 312 is excessive for some cases and inadequate for others.

In summary, our research indicates that NPGA would likely succeed in modifying the current IFC requirements for vehicle impact protection if a proposed change were based on engineering principles, laboratory tests and/or other scientifically-based methods.

Nevertheless, NPGA must consider that any effort to change Section 3809.13 will open the door for further scrutiny of the requirements in this section by the fire service. Thereby, it is possible that the result of an effort to make things better could be making things worse (such as ending up with a direct reference from Section 3809.13 to Section 312 for all cylinder exchange cabinets). While we consider such an outcome highly unlikely if NPGA’s proposal were well crafted, the potential for a negative outcome vs. simply living with the status quo should not be ignored.

In lieu of proposing a change to the IFC, NPGA also has the opportunity to utilize research and testing results from Phase II of this project, if conducted, to support case-by-case solutions without exposing the current code text to further scrutiny by code developers. The general provision in the IFC that provides this flexibility is Section 104.9:

“The provisions of this code are not intended to prevent the installation of any material or to prohibit any method of construction not specifically prescribed by this code, provided that any such alternative has been approved. The fire code official is authorized to approve an alternative material or method of construction where the fire code official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.”

There is also an option to pursue an ICC Evaluation Service (ICCES) report as a basis of independently validating an alternative method proposal. ICCES reports are commonly accepted by code officials as a basis for approving alternative method proposal without additional scrutiny.
REFERENCES

7. Southwest Research Institute, SwRI 93-01: Testing Requirements for Protected Aboveground Flammable Liquid/Fuel Storage Tanks, 1993.