Canadian Sheet Steel Building Institute

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Explosion Venting for Steel Framed Buildings

Executive Summary

The aim of this fact sheet is to advocate an alternative solution for the Steel Industry in regards to restrictive code provisions for explosion venting that are now mandated by the Ontario Fire Code (OFC). Due to a September 2000 amendment of code provisions dealing with explosion venting in the OFC, explosion vent designs were required to be in conformance with NFPA 68, the National Fire Protection Association's (NFPA) Guide for Venting of Deflagrations. NFPA 68 gives a prescriptive solution that has upper bound limits on size and mass of an explosion vent panel, which the Steel Industry finds are too small to be practical. The Canadian Steel Construction Council (CSCC) investigated this problem and identified an alternate design guideline from the Factory Mutual Insurance Company's (FM) Property Loss Prevention Data Sheets, numbered 1-44 and entitled "Damage Limiting Construction". FM's 1-44 Data Sheets can be used to develop an alternate solution for explosion venting that exceed the size and mass limits of the NFPA 68 prescriptive solution, and can be submitted for approval under the Compliance Equivalency provisions in the OFC. With the introduction of an objective-based National Building Code Canada (NBCC) in 2005 followed by Provincial code adoptions in 2006 it would be worthwhile to establish a precedent through the Compliance Equivalency provision in the OFC. Once a precedent setting case occurs, the "acceptable solution" or "compliance alternative" would go on record and aid in resolving subsequent proposals for Compliance Equivalency, and also support a future technical change in the OFC. The CSCC by way of this fact sheet would advocate this alternative solution for the Steel Industry when designing explosion vent panels in steel framed buildings.

Introduction

Buildings housing chemical or other manufacturing operations where storage spaces contain hazardous gases, dusts or liquids are mandated by building codes and fire codes to be designed to prevent critical structural and mechanical damage from an internal explosion. These buildings often require a design where explosion venting is necessary to relieve pressure waves emanating from an internal building explosion. When a flammable mixture of air and vapour/gas/dust is ignited an exothermic reaction follows where there is a rapid expansion of heated gases with a local pressure rise that is transmitted within the building's interior confines by sound waves. Experts in the field of explosions refer to these types of explosions as "deflagrations" to emphasize that the combustion zone propagates at a speed below the unburnt mixture's sound-wave speed (in contrast the term "detonation" refers to a combustion zone moving faster than the sound-wave speed). Explosion venting consists of devices designed to open at a predetermined pressure to relieve internal pressure build up within the building's interior confines, thereby mitigating structural and mechanical damage. An explosion inside a building should not cause progressive collapse of the building by displacement of load bearing walls and not create a risk for persons outside the building. To meet these building design objectives and relieve the building of high internal pressures there is a strong preference for steel framed buildings with lightweight panel walls or vent panels, rather than masonry construction.

Existing Code Provisions

Both the National Building Code of Canada (NBCC, 1995) and the Ontario Building Code (OBC, 1997) have similar articles, numbered identically as 6.2.2.5., on "Hazardous Gases, Dusts or Liquids". NBCC 1995 Article 6.2.2.5. refers to "systems" serving spaces that contain hazardous gases, dusts or liquids be designed, constructed and installed to conform with provisions within provincial (or territorial) legislation. OBC (1997) is more specific and states conformance with the provisions of the Ontario Fire Code (OFC, 1997) made under the Fire Marshals Act. Both articles continue on and say, "in the absence provincial/territorial legislation or OFC, to good engineering practice such as described in the publications of the National Fire Protection Association (NFPA) and in the National Fire Code of Canada (NFCC, 1995)".

Fire Codes, namely OFC (1997) and the NFCC (1995) have similar articles, numbered identically as 4.2.9.6., on "Explosion Venting". These articles refer directly to NFPA 68, "Guide for Venting of Deflagrations" with wording as follows:

> *Where Class 1A or 1B liquids are dispensed within a storage room, the room shall be designed to prevent critical structural and mechanical damage from an internal explosion in conformance with good engineering practice such as described in NFPA 68, "Venting of Deflagrations."*

In September 2000 Ontario Regulation 475/00 amended OFC (1997) with significant changes, one of which included a revision to Article 4.2.9.6. Article 4.2.9.6.

was changed to specify the minimum standard to which explosion venting must be provided when required by the Fire Code. Wording in the above-mentioned Article was changed to read as follows:

Where Class 1A or 1B liquids are dispensed within a storage room, the room shall be designed to prevent critical structural and mechanical damage from an internal explosion in conformance with NFPA 68, "Venting of Deflagrations."

The words "good engineering practice such as described" were struck out from the above article. The article now makes it compulsory that a designer use NFPA 68 when sizing an explosion vent.

Although NFPA 68 provides the basis for an engineered solution, the methodology is incomplete and extremely complex, so code officials have seized upon the articles in NFPA 68 that describe several prescriptive solutions and now have a tendency to enforce these limits. The limits are restrictive, and NFPA 68 states that for "successful functioning, the panel area is limited to 3.1 m^2 (33 ft^2), and its mass is limited to12.2 kg/m^2 (2.5 lb/ft^2)". The NFPA 68 limits on vent panel size and mass are significantly lower than typical vent panels used by industry where panels are fitted economically along building walls yielding vent panels that are in the range of 11.6 m^2 to 13.9 m^2 (125 ft^2 to 150 ft^2) and, if insulated, are approximately 22 kg/m^2 (4.5 lb/ft^2).

Background Information on NFPA 68 (2002 Edition)

Section 9 of NFPA 68 (2002 edition) provides information on vents used to vent explosions or deflagrations that would occur for example in process buildings. Section 9.5, entitled Restraints for Large-Area Panels contains clause 9.5.3 with prescriptive type wording that limits the size and weight of the panel, as follows:

9.5.3 *The restraint system shown in Figure 9.5.3 is recommended for double-wall panels. For successful functioning, the panel area is limited to 3.1 m^2 (33 ft^2), and its mass is limited to12.2 kg/m^2 (2.5 lb/ft^2).*

Regarding the afore-mentioned Figure 9.5.3 in NFPA 68, it shows a restraint system for a double-wall insulated metal vent panel. This figure is identical to a Figure 11 used in a Plant/Operations Progress journal paper, entitled Tests of Explosion Venting of Buildings, by Howard and Karabinis (1982). NFPA 68 cites this article as item 30 in its Annex I Bibliography, under clause 9.4.5 entitled Large-Area Panels, as follows:

9.4.5 Large –Area Panels*. Large-area panels can be in a single layer or in multiple layers (insulated sandwich panel). The text and figures in Section 9.5 refer to tests carried out on metal-faced panels [30]. Alternate methods for other types of panels necessitate careful engineering design, and testing of a complete assembly is recommended.*

The experimental work of Howard and Karabinis (1982) is summarized in a 15-page paper that presents test results from four types of panels that used FRP (1.83 kg/m^2 or 0.375 lb/ft^2), aluminium (2.69 kg/m^2 or 0.55 lb/ft^2), galvanized steel (6.15 kg/m^2 or 1.26 lb/ft^2) and insulated metal (12.7 kg/m^2 or 2.6 lb/ft^2) and were tested under propane explosions within a test structure building having a 4.88 m by 3.66 m (16 ft by 12 ft) base plan and a height of 3.05 m (10 ft). The vent panel was 1.02 m (40 in or 3.33 ft) wide and covered the test structure from the uppermost girt to the top of a reinforced concrete slab on which the structure sat, thereby making the vent panel area equal to 3.05 m x 1.02 m (10 ft x 3.33 ft), or approximately 3.1 m^2 (33 ft^2). This value appears to correspond directly to the value given in NFPA 68 clause 9.5.3.

Also noteworthy on this matter is clause 9.5.1.1 that states the following:

9.5.1.1 *The restraining techniques shown are very specific to their application. They are intended only as examples. Each situation necessitates an individual design. Any vent restraint design should be documented by the designer.*

In Chapter 5, Fundamentals of Venting of Deflagrations, there are provisions for vent panels that exceed a mass of 12.2 kg/m^2 (2.5 lb/ft^2) in clause 5.6.14.3, as follows:

5.6.14.3 *A vent closure should have low mass to minimize inertia, thereby reducing opening time. If the total mass of a closure divided by the area of the vent opening does not exceed 12.2 kg/m^2 (2.5 lb/ft^2), all vent area correlations presented in this guide can be used without correction. For vent devices with greater mass per unit area, test data (see Lunn reference) show that corrections to vent area could be required. To determine this correction, full scale deflagration testing can be performed at the appropriate service conditions. For dusts, Annex F provides an analytical method to evaluate the effect on vent performance [112].*

Note, Annex F is entitled: Calculation Method for Correction Factor Due to Increased Vent Panel Mass. Also noteworthy is that NFPA 68 offers explanatory material for informational purposes in Annex A for various parts of the code, however no explanatory notes exist for Chapter 9.

Code Interpretation Problems in the Field

The problem for the Steel Industry has stemmed from the revised wording in the OFC (1997) brought on by Ontario Regulation 475/00 that amended OFC in September 2000. One case example of Fire Code officials enforcing vent panels to 3.1 m^2 (33 ft^2, as prescribed by NFPA 68 Article 9.5.3) occurred during November 2001. The designs of a Professional Engineer for a large size explosion vent panel (i.e., greater than 3.1 m^2 or 33 ft^2) were reviewed and only received acceptance by Fire Code officials if there was one restraint for every 3.1 m^2 (33 ft^2). Initially the Fire Code official was asking the vent panel size to be reduced to a maximum size of 3.1 m^2 (33 ft^2), the value provided in NFPA 68. A practical vent size was allowed however additional costs and delays were incurred due to a redesign of the restraint system.

In the above example, had vent panel areas been limited to 3.1 m^2 (33 ft^2), then approximately five small vent panels would be necessary for one 13.9 m^2 (150 ft^2) vent panel that is more normal in practice. For industry there are higher costs associated to make additional vent panels that require over two times more running trim members if one is required to provide five 3.1 m^2 (33 ft^2) vent panels instead of simply one 13.9 m^2 (150 ft^2) vent panel. Consequently, additional running trim members contribute significantly to an increase in the mass of the vent panel. Small vent panels will also require more sealing materials for panel perimeters, more complexity in the layout of structural steel in the wall to accommodate each panel, and more fit-up effort during erection. This has been validated by contact with a firm involved in the installation of vent panels and that an increased cost would result for the building owner.

An Alternative Solution

Over the course of two years relevant organizations were contacted by CSCC to resolve code interpretation problems as described above. The alternate solution identified for this problem is to use an alternate design guide for sizing explosion vents and to follow an OFC code provision on "Compliance Equivalency". The alternate design guideline is from the Factory Mutual Insurance Company (FM), Property Loss Prevention Data Sheets, numbered 1-44 and entitled "Damage-Limiting Construction". With the introduction of an objective-based NBCC in 2005 followed by Provincial code adoptions in 2006 it would be advisable to set a precedent in Ontario and follow through with the Compliance Equivalency provision in the OFC. Once a precedent setting case occurs the "acceptable solution" or "compliance alternative" will be logged into a database being set up by the National Research Council of Canada (NRCC). The objective-based code environment will produce a range of acceptable solutions for different prescriptive code provisions and as the alternate solutions tally up in the NRCC database they will instigate the future technical changes to the NBCC and NFCC.

In regards to OFC's code provision on Compliance Equivalency, Article 4.1.1.5. allows the Chief Fire Official to approve an alternative that provides a level of safety at least equivalent to that achieved by any provision in Part 4 of the OFC. This includes compliance with NFPA 68 where referenced in Part 4 of the OFC. An owner may pursue acceptance of FM Data Sheets 1-44 under this provision by making an application to the municipal fire department. Such an application will require the signature and seal of a professional architect or engineer. Article 4.1.1.5. appears as follows in the OFC:

> *Compliance equivalency*
> ***4.1.1.5.(1)*** *A requirement of this Part shall be deemed to be complied with if the composition, design, size and arrangement of any material, object, device or thing varies from the composition, design, size or arrangement prescribed in this Part where strength, health and safety are equal to or greater than the strength, health and safety in the composition, design, size or arrangement prescribed, and has been* ***approved*** *by the* ***Chief Fire Official****.*
>
> ***(2)*** *A proposal for compliance equivalency shall bear the signature and seal of a* ***Professional Engineer*** *or* ***Architect*** *or both.*

The FM Data Sheets 1-44 provides guidelines for the design and construction of building components for rooms or buildings where a combustion explosion (deflagration) hazard exists. The 27-page set of data sheets will allow a designer to select an appropriate explosion vent panel for industrial buildings in a stepwise manner using tables, illustrative figures, flowcharts and instructive text. The document was last revised in May 2002 and is used throughout North America and internationally by a large group of users who specify explosion vent panels.

The explosion venting criteria in 1-44 Data Sheets are based on FM's own test work as well as other research into the phenomena of deflagrations. FM data show that the limits on panel mass per unit area in NFPA 68 are generally too low and that there is no need to limit individual panel size. Extensive test work and theoretical modelling, especially with respect to dust deflagration venting, allows FM to permit broad design flexibility with respect to vent panel mass and area. It follows, that the slower response of heavier panels in a venting situation may result in an increase in the total area of venting required compared with lighter panels. Design specifications for features such as tethering cables would have to be modified for the increased mass of the panel compared to the illustration in NFPA 68. FM leaves the details of this design to the installing contractor, subject to FM's review and acceptance.

FM 1-44 Data Sheets appear to offer a good alternative to NFPA 68 that has very conservative prescriptive limits for vent panel area and mass (3.1 m^2 or 33 ft^2 and 12.2 kg/ m^2 or 2.5 lb/ft^2, respectively) and also complicated formulae in their new Annex F (most recent 2002 edition) if one is trying to specify heavier panels than the prescriptive limit.

References

Factory Mutual Assurance Company (2002), *Property Loss Prevention Data Sheets, 1-44, Damage Limiting Construction*, Norwood, MA, USA.

Howard, W.B. and Karabinis, A.H. (1982), *Tests of Explosion Venting of Buildings, Plant/Operations Progress*, Vol. 1, No. 1, pp 51-65.

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National Research Council of Canada (1995), *National Fire Code of Canada 1995*, Ottawa, ON, Canada.

Ural, E.A. (2003), *NFPA 68: How the revised explosion guidelines affect your plant, Powder and Bulk Engineering*, Vol. 17, No. 6, 7 pages.

Addendum to CSSBI Sheet Steel Facts No. 19
Explosion Venting for Steel Framed Buildings
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CSSBI Sheet Steel Facts No. 19 was printed May 2005 and at the time referred to relevant editions of building/fire codes, NFPA 68 and FM 1-44 Data Sheets. Since that time all references in Sheet Steel Facts No. 19 have been reissued with more recent publication dates. Noteworthy, are the revisions to NFPA 68 that relate to subject matter in Sheet Steel Facts No. 19, hence the reason for this Addendum. NFPA regularly revises their documents and in the case of the NFPA 68 the 2002 edition that was referenced in Sheet Steel Facts No. 19 has now been published as a 2007 edition. In revising the document NFPA accepts proposals for recommendations on content during each document's revision cycle. A Report on Proposals and a Report on Comments was issued during 2005 and 2006, respectively, for revising NFPA 68's 2002 edition. The Canadian Steel Construction Council that prepared Sheet Steel Facts No. 19 submitted proposals for revising NFPA 68's content in regards to the prescribed limits for vent panel size and mass. NFPA 68, 2007 edition, contains revisions made by Technical Committee on Explosion Protection Systems who themselves also proposed a complete revision to NFPA 68, one that changes the document title and its type - from guide to standard. The difference in titles between the two editions is as follows:

2002 Edition: NFPA 68, Guide for Venting of Deflagrations
2007 Edition: NFPA 68, Standard on Explosion Protection by Deflagration Venting

The NFPA 68 Technical Committee incorporated completely new material that enables users to apply a performance-based design option if they choose and if they can satisfy the criteria in the new performance-based chapter, namely Chapter 5, Performance-Based Design Option. The Technical Committee also updated the fundamental dust vent sizing equation by incorporating additional test data, and revised dust equations for vent panel inertia, partial volume, elevated pressure and duct effects.

The revised 2007 edition of NFPA 68 with the "Performance-Based Design Option" in Chapter 5 and noting a new clause, 1.4 on Equivalency, support the use of FM 1-44 Data Sheets (also revised to a September 2006 publication from a July 1991 publication) to develop an alternative design for vent panel area and mass. In regards to NFPA 68's clause 1.4 on Equivalency, it reads as follows:

1.4 Equivalency. *Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.*

Also noteworthy in NFPA 68 (2007 Edition) is that the vent panel area and mass limits, prescribed as 3.1 m^2 (33 ft^2) and 12.2 kg/ m^2 (2.5 lb/ft^2), respectively, in Clause 9.5.3 of NFPA 68 (2002 Edition), have been relocated to Annex A, Explanatory Material, clause A.10.4, that is not a part of the requirements of the NFPA 68 document but is included for informational purposes only.

References

National Fire Protection Association (2006), *Report on Proposals F2006, NFPA 68*, Report of the Committee on Explosion Protection Systems, Quincy, MA, USA.

National Fire Protection Association (2007), *NFPA 68, Standard on Explosion Protection by Deflagration Venting*, Quincy, MA, USA.