Preserving room integrity during clean agent discharges

Abstract

The discharge of most halocarbon clean extinguishing agent systems is characterized by a rapid drop in room pressure followed by a positive pressure spike. It is important that these peak pressures do not damage the protected enclosure. This paper reviews the existing data on clean agent system discharge pressures and the factors influencing the magnitude of peak positive and negative pressures, as well as the pressure load limits for enclosures of typical construction.

Introduction

When designing a clean agent fire protection system, it is important to consider the potential for any discharge to reduce the structural integrity of a protected space. The peak positive and negative enclosure pressures that characterize the discharge of halocarbon fire suppression systems could damage the structural members – the walling, studs and windows – of the protected space, if installed improperly.[1] If these structural members are damaged during the system discharge, there is no longer a guarantee that the protected enclosure will retain the desired concentration of agent long enough for sufficient suppression of the fire. It is therefore necessary to understand existing system discharge peak pressure data and the factors influencing the magnitude of both positive and negative peak pressures and how they compare to internal pressure load limits for typical construction types.

Clean Agent System Discharge Pressures

The distinctive transient pressure dynamics of a clean agent fire suppression system discharge differ depending on agent type. Inert gas clean agents and one halocarbon clean agent, HFC-23, have high vapor pressures and are characterized by positive enclosure pressures generated upon system discharge. Low pressure halocarbons, however, are characterized by an initial drop in enclosure pressure followed by an eventual transition to positive enclosure pressures. The initial negative pressure spike is the result of the cooling due to the agent's high heat capacity where sensible heat is absorbed during rapid vaporization during discharge.

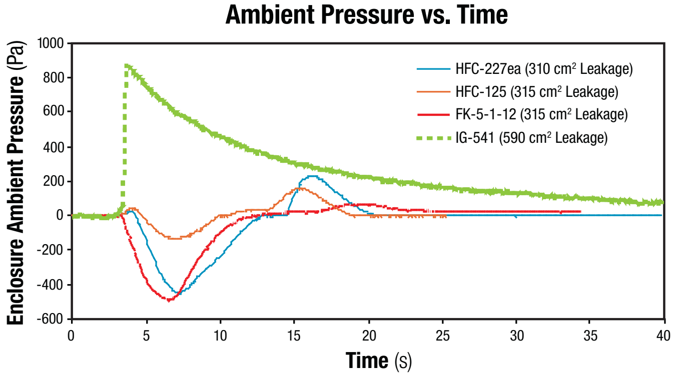

Figure 1 – Ambient Enclosure Pressures for Various Clean Agent System Discharges[2]

Agent	Max Negative PSF/Pa	Max Positive PSF/Pa
FK-5-1-12	22.0/1053	3.0/144
HFC-125	6.6/316	8.4/402
HFC-227ea	18.6/891	7.5/359

Table 1 – Representative Peak Pressure Values

The positive pressure spike that follows is the result of the relatively rapid introduction of the gaseous agent and propellant mass into the fixed enclosure volume. The magnitude of the positive and negative pressure spikes varies from agent to agent. Samples of enclosure pressures during system discharges are illustrated in Figure 1, which displays the enclosure pressures during discharges of three prominent halocarbon clean agents and one inert gas clean agent. Figure 1 shows the contrast between the negative to positive pressure swing for halocarbon system discharges and the single large positive pressure spike typical for inert gases.

The results reported in Figure 1 were determined during testing conducted by the room integrity technical subcommittee to the NFPA 2001 Committee in a single enclosure and generated under comparable conditions. Maximum negative and positive pressure values from this testing are given in Table 1. At each agent's minimum design concentration, with similar leakage areas, HFC-227ea tended to yield the greatest positive pressures. FK-5-1-12 produced the greatest negative pressures and the smallest positive pressures. HFC-125 tended to have the smallest negative pressures and the smallest magnitude transition from negative to positive pressure.

Agent choice, however, is only one of many factors that can impact the magnitude of the negative and positive pressure peaks within the protected space. Agent concentration, wall construction, enclosure leakage area and location, fire size, humidity and retention time are other important determinants of the overall pressure dynamics.

Room Overpressure Limits

Understanding the structural pressure load limits of the enclosure is important when designing clean agent fire suppression systems. These internal enclosure pressure load limits vary with the construction type and materials. A steel studded wall, for example, is sturdier than a wood studded wall, but not as strong as a brick wall. As a general rule, however, non-load bearing walls will be the weakest walls in any given structure. Therefore, non-load bearing wall strengths are considered the threshold for maximum discharge pressures in the design process of clean agent systems. One commonly quoted pressure limit for clean agent systems is a 5 psf (239pa) minimum load requirement for non-load bearing walls given in the International Building Code (IBC), established to address normal variation in continuous room conditions.[3] This value is often exceeded as evidenced in comparative testing and without apparent problems or damage reported in practice.

For example, in a typical hazard with a 10'-0"(3.05m) high ceiling, a hazard height 75% of the room height designed to a 10 minute hold time in accordance with NFPA 2001 and using design predictions determined from conventional room integrity modeling, peak room pressure predictions for both inert gas and halocarbon systems exceed that limit in most cases. This is assuming a worst case retention scenario where there is 50% of the leakage high and 50% of the leakage low in the room. In practice, there exists more leakage high than below, making it easier to achieve hold time, thus reducing resultant peak pressure.[4]

Dynamic pressure load limits for carbon dioxide suppression systems, whose pressure dynamics are similar to an inert gas, are given in the NFPA 12 Standard on Carbon Dioxide Extinguishing Systems for various construction types. NFPA 12 explains that relief venting, in the form of doors, windows and dampeners, exists in almost all enclosures, and although it cannot be easily quantified, presents sufficient venting for pressures up to 25 psf for 'light' construction and 50 psf for 'normal' construction.[5]

Attempts have also been made to model the ambient pressure load limits of studded walls based on the stud spacing and the yield or tensile strength of the stud material. This model predicts maximum pressure loads of 7 to 14 psf for 2 × 4 wood stud walls, depending on stud spacing and assumes that the entire pressure load will be carried by the studs, with no deformation or failure of the actual wallboard material.[6]

Existing testing has provided a range of peak pressures that can be expected during discharge of clean agent systems. Systems for every agent have demonstrated capability to generate peak pressures greater than the commonly accepted 5 psf value given in the IBC. The fact is, in acceptance testing, pressurization test equipment is often used to pressurize a protected space to 10 psf or more to demonstrate enclosure strength. Few room failures due to clean agent discharge pressures have been reported and only in extenuating circumstances.

Conclusions

Predicting exact peak pressure values of a given clean agent fire suppression system discharge is extremely difficult, with many factors influencing the enclosure pressure dynamics. Some factors, such as agent choice and concentration, wall construction, relative humidity, and enclosure leakage (to an extent), can be controlled. The uncontrollable factors of fire size and unforeseen leakages, however, have an effect, and the magnitude of the negative and positive pressure spikes cannot be predicted with confidence. Industry efforts continue to further define these and other parameters, endeavoring to achieve more accurate prediction of pressure and hold time.

The low five (5) psf IBC static pressure load limit is quite often exceeded in practice when installing clean agent systems. Such anecdotal expert experience in the field as well as reference of pressure limits given in gaseous standards such as NFPA 12 for carbon dioxide extinguishing systems may be reasonable pressure limits to apply to clean agent systems.

References

[1] 2008 Edition, NFPA 2001, Annex D, Standard on Clean Agent Fire Extinguishing Systems.

[2] Hetrick, TM, "Development and Validation of a Modified Clean Agent Draining Model for Total Flooding Fire Suppression Systems," M.S. thesis, Worcester Polytechnic Institute, Worcester, MA, 2009.

[3] IBC 1607.13, International Building Code, 2006.

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[6] Harry, LD, et. al. "Development of Room Pressure in the Discharge of FM-200, Compared to the Strength of Various Structural Components," Halon Options Technical Working Conference, 7th Proceedings, Albuquerque, NM, pp. 611-622, May 6-8, 1997.

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