ARIA News flash
December 2008

Accidents with CO_2 extinguishing systems

Gas-based extinguishing processes become attractive when water cannot be used (e.g. computer equipment, audio/video archives, ship engine rooms), yet the associated risks must not be underestimated, as witnessed by the example of CO_2 systems.
Two accidents that occurred during August 2008 in Germany (a country where extinguishing systems based on total CO_2 flooding are quite widespread), one of which (as detailed below) necessitated introducing extraordinary measures, recall the risks and the importance of both sufficient information and effective system maintenance. According to the FFMI (national fire prevention equipment federation), France contains some 2,000 CO_2 installations (all types combined), yet only few operate by means of total flooding, given that most of these have been replaced by other inert gases.

1st Case : August 16, 2008 : Mönchengladbach, Germany (ARIA 35063)

In a gloss plaint manufacturing plant, a carbon dioxide (CO_2) leak occurred around 6:00 am on an automatic fire extinguishing system triggered by the outbreak of a fire. The leak lasted beyond extinction of the flames due to a defect in the extinguishing device. Given the absence of wind, the CO_2 did not disperse into the atmosphere, allowing a cloud to form and spread into the surrounding neighbourhood: a total of 107 individuals were intoxicated, of whom 16 had to be hospitalised with 1 more seriously afflicted and requiring intensive care. The local authorities activated an emergency plan. The plant's CO_2 tank was practically emptied (40 m^3 of the 50-m^3 capacity, i.e. equivalent to 24 tonnes of liquefied CO_2).
During the emergency intervention that mobilised significant human and equipment resources (350 to 400 rescue vehicles: fire trucks, lorries, police, Red Cross response, etc.), a number of difficulties were encountered. The first vehicles arriving on the scene stalled due to the lack of oxygen. A 2-km safety perimeter was set up, and all rail and motorway traffic was halted. Some fifty residences located nearby (affecting 150 individuals) were evacuated until the cloud had sufficiently dissipated. During the afternoon, emergency personnel performed surveys and took CO_2 measurements in the cellars of dwelling units, deciding on a case-by-case basis whether to install fans to reduce excessive CO_2 concentrations.
Since the CO_2 cloud was not dissipating, two helicopters were eventually called in to fly over the area at low altitude stirring the air and enabling the CO_2 concentration to dilute several hours later. The evacuees were permitted to return to their homes by the end of the afternoon.
The operator provided details to the media during the crisis and apologised to all those who had been intoxicated and/or evacuated. An expert subsequently verified the defective CO_2 installation. According to the police, the fire would have been caused by the self-ignition of wood chips in contact with an oil-based coating (oils with a drying additive?).

CO_2 as an extinguishing agent...

Carbon dioxide (CO_2) is an inert, odourless and colourless gas at room temperature. It acts by means of blowing, cooling and smothering by reducing oxygen concentration in the premises being protected. Carbon dioxide was used as one of the very first extinguishing agents within fixed installations. It offers the advantage of being an effective extinguisher for electrical fires, inflammable liquids and greasy substances (i.e. Class B and C fires) as well as on Class A surface fires (i.e. involving solids like wood, paper, cardboard and fabric). Furthermore, this agent is not dirty and leaves no residual trace. On the other hand, it proves ineffective on deep-seated Class A fires, does not allow for long-distance fire-fighting efforts and, most importantly, is dangerous to human health at high concentrations (see insert below).
The total CO_2 «flooding» type of extinguishing process makes it possible to smother a fire source by means of early and rapid intervention. It should also be pointed out that these devices must be adapted when personal protection is at stake.

... and the associated risks:

Extinguishing protocols using inert gases serve to lower the rate of oxygen in air, typically to around 12%. At such content levels, the effects on human health entail respiratory disorders (uneven breathing, abnormal fatigue, etc.) due to insufficient oxygenation of the body, with such effects capable of becoming dangerous in the event of prolonged exposure.
CO_2 itself actually constitutes a special kind of physiological risk: asphyxiating effect, respiratory disorders and an acid-basic reaction of the body. At high concentrations, it is capable of causing depression of the central nervous system, convulsive coma and death, with such effects arising even more quickly as the transition from a healthy to a «polluted» atmosphere is sudden.
Note: A joint memorandum by MEDAT/DPPR/SEI, dated November 16, 2007, established the concentration levels corresponding to regulatory CO_2 thresholds for safety reports.

2nd Case : July 28, 1998 : Idaho falls, USA (ARIA 35316)

Within a large nuclear research laboratory, the automatic fire extinguishing system based on total CO_2 flooding activated uncontrollably around 6:00 pm inside the electrical equipment building where preventive maintenance functions were being prepared for the electrical systems.
This unresponsive activation of the system's electrical control heads was caused by a current induced during opening of the cut-out on the last 4,160-volt circuit. The preliminary CO_2 discharge alarm, which gives a 30-second warning for onsite personnel to escape, was not triggered. The building where the 13 maintenance technicians were working abruptly filled with CO_2 (25 t), reducing visibility to zero.
The employees were not able to escape in an orderly or safe manner; they had not been trained, the emergency exits were not clearly marked or even lit, and no self-breathing apparatuses or backup fans were available. The accident resulted in 1 fatality and several serious injuries; in all, 15 individuals had to undergo medical treatment.
The investigation report noted that the risk management effort devoted to the CO_2 extinguishing system was subpar: absence of information and safety measures relative to CO_2 in the company's safety manuals, in the design of process controls, in company procedures, and lastly in staff training programmes.
Remedial actions were undertaken in all of these areas. Moreover, the system, installed in 1971 and then modified in 1997, had not been correctly designed as regards the American set of requirements for such systems; a second pre-discharge signal, operating independently of the system activation mode (i.e. automatic vs. manual), was missing.
Several accidents on the site dating back to 1996 had already demonstrated the need for risk analyses, along with a dramatic improvement in both organisational and work verification measurements.

Other accidents recorded in the ARIA base:

A total of 11 accidents related to CO_2 system deficiencies have been recorded into the ARIA database: 173, 21146, 35063, 35275, 35316, 35354, 35356, 35362, 35384, 35386 and 35387, of which 2 were located in France and 3 in Germany.
In addition, an American Environmental Protection Agency study inventoried 51 accidents involving CO_2 leaks on extinguishing systems between 1975 and 1999, with another dozen or so occurring since. The primary cause of death or injury in these accidents consists of accidental exposure to CO_2 during either maintenance or testing phases. The lack of information and inadequate personnel training on the CO_2 risk often lies at the origin of inappropriate behaviour.

A few questions that need to be asked

Design / Construction :

In France, the state-of-the-art in the construction of automatic CO_2-based extinguishing equipment has been described in the APSAD R13 rule (formerly known as R3 – Installation rules for automatic fixed extinguishing systems operated with CO_2 – use conditions and precautions, alarms, safe evacuation protocols, maintenance, etc.)).
These systems must be implemented by APSAD-certified installers.

- Has the extinguishing system been assembled according to APSAD R13 rules and by a certified organisation (design, suitability for the hazardous phenomena targeted by this control, etc.)?
- Are the premises verified to be airtight? If so, by what means (closure of all openings, turning off fans, etc.)?
- Has a sound and visual alarm, which is both distinct and recognisable, been installed in order to warn personnel to leave the site prior to a CO_2 release? Does this alarm remain activated as long as the oxygen concentration continues to be insufficient to return on the premises?

Operation / Information

- Have warning signs been posted at entrances and within zones protected by an automatic extinguishing system based on CO_2 flooding?
- Have all emergency exits and evacuation routes been addressed in a specific study? Are they well indicated and lit?
- What is the triggering mechanism mode (automatic, manual or both)? What is the response time? Does this value take into consideration, if applicable, the time required to evacuate individuals following the warning signal?
- Have staff been trained regarding this risk and in evacuation procedures? Are drills and exercises held on a regular basis?
- Are the systems inspected regularly and maintained under good operating conditions (semi-annual verifications by a certified installer)? Are verification and maintenance dates and results systematically logged on a register?
- Are personnel and emergency teams aware that access to the room, even when wearing protective gear, is forbidden immediately after gas emission so as to avoid rekindling the fire?

Verifications provided by the site operator (extract from the APSAD R13 rule)

Performed at least once a month (and more frequently in the event of major works) by specially-trained personnel knowledgeable of the installation.
« Visual control of: the condition of both electrical and non-electrical tripping devices; State of the DECT (electric control device); the presence of primary installation elements (DECT, extinguishing system components and controls, visible piping); the protected zone and the quality of its seal to ensure maintaining protection; the proper quantity of extinguishing agent (should a gas leak be discovered, the tank must be replaced or its contents refilled); the position of regulating valves and tank valves; and when applicable, an unencumbered and unrestricted access to the pressure surge limiter. »