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Topic

Carbon Dioxide Hazard and Safety Requirement Assessment

Author

Dermot Cotter, MD - Star Technical Solutions

Carbon Dioxide Hazard and Safety Requirement Assessment – a systematic approach to risk assessment and emergency planning.

Carbon Dioxide (R744) is an odourless gas and can cause harm when incidents occur resulting in its release. For owners and operators of carbon dioxide refrigerated systems it is essential to understand best practice, in order to minimise these risks.

In the UK, owners of carbon dioxide refrigeration systems should follow legally binding Statutory Instruments (SI) which require equipment to be risk assessed by competent persons during its lifetime to ensure it is safe to operate. These regulations are enforceable by the Health and Safety Executive (SHE) and published across the following three documents:

The Management of Health and Safety at Work Regulations, 1999 (MHSWR)

The Pressure System Safety Regulations, 2000 (PSSR)

The Dangerous Substance and Explosive Atmosphere Regulations, 2002 (DSEAR)

The British Standards Institution (BSI), the organisation appointed by the UK Government as the national standards body, has established that European Directives for carbon dioxide refrigeration systems must be given the status of national standards. Whilst European standards are not legally binding, the safety requirements detailed inside them are viewed by industry as "reasonably practicable" and therefore must be implemented to comply with regulations. These are:

EN378: Refrigerating Systems and Heat Pumps – Safety and Environment Requirements (Parts 1-4)

EN12693: Refrigeration Systems and Heat Pumps – Safety and Environmental Requirements – Positive Displacement Refrigerant Compressors

The legislation gives owners and users of carbon dioxide equipment legally binding responsibilities but there is little direct guidance in the regulations as to the exact requirements. The duty of ensuring that work equipment complies with regulations falls first and foremost to the employer, who must provide a safe working environment to everyone on their site as underlined in DSEAR : "Every employer shall ensure that risk is either eliminated or reduced so far as is reasonably practicable".

The HSE publishes approved codes of practice for the regulations but this still leaves an element of expert interpretation on how the requirements of legislation can be implemented.

To cover this gap, the European standard EN378, which lists safety requirements, outlines the specifications cooling and heating systems are required to meet. While EN378 is comprehensive, including provision for gas detection, ventilation and automatic shut off valves, the guidance it contains is not always clear to many working with refrigeration systems due to the omission of a specific systematic approach to assessing of risk, emergency planning and facility awareness based on industry good practice.

When carrying out a carbon dioxide hazard assessment, the outcome of the assessment is only as good as the knowledge of the assessor and their ability to identify the risks. A standard hazard assessment approach has been developed by Star Technical Solutions for assessing carbon dioxide refrigeration systems to ensure that all aspects of legislation and good practice are reviewed and recorded.

What are the risks?

Carbon dioxide is a colourless, odourless gas, denser than the air that occurs naturally in the earth's atmosphere. A person typically inhales and exhales air with carbon dioxide concertation of <0.05% and 4%. Whilst carbon dioxide toxicity is caused by displacing oxygen, lending to asphyxiation, the immediate danger to life would need to be in the order of 50% v/v. However carbon dioxide can cause an immediate threat to life at only 15% in air due to the toxicological impact it has on the body. The inhalation of Carbon dioxide increases the acidity in the blood and thus triggers adverse effects on the respiratory, cardiovascular and central nervous systems. The reported immediate effect of carbon dioxide exposure by inhalation:

2 to 5%	Headache, dizziness, sweating, shortness of breath
6 to 10%	Hyperventilation, tachycardia, worsening dizziness
11 to 17%	Drowsiness, muscle twitching, loss of consciousness
>17%	Convulsions, coma and death

However the likelihood of death due to exposure of carbon dioxide concentration is time dependent:

Inhalation Exposure Time	1-5% Fatalities Concentration in air v/v	50% Fatalities Concentration in air v/v
60 min	6.3%	8.4%
30 min	6.9%	9.2%
20 min	7.2%	9.6%
10 min	7.9%	10.5%
5 min	8.6%	11.5%
1 min	10.5%	14%

Inhalation Exposure Time versus Carbon dioxide Concentration

The UK HSE (EH40/2005) workplace exposure limit threshold limit value for an 8-hour period is 5000ppm, and for a 15-minute period, 15,000ppm.

The priority of any risk-based analysis would identify that keeping carbon dioxide releases to a minimum reduced risk. A refrigeration system that does not release carbon dioxide will not result in areas containing toxic gas atmospheres and therefore can be considered safe. Stopping all potential carbon dioxide releases is not possible and safety systems are still required, however the goal must be to keep potential carbon dioxide releases to a minimum. In the event of a carbon dioxide release the safety system must be adequate to keep this risk to a minimum.

What are the safety requirements?

There are different requirements for safety systems for occupied spaces, machinery rooms and unoccupied spaces locations detailed in EN378.

Occupied locations and machinery rooms

For occupied locations with general public access, such as supermarkets, the refrigerant charge limit is calculated using by multiplying the toxicity limit by the room volume. Adding safety measures, such as ventilation, shut off or gas detection valves, increases the permitted charge.

For all other access and locations areas, there is no charge restriction for the use of carbon dioxide in occupied areas. The carbon dioxide quantity could be 50kg or 1 million tons. It is only logical that special provision (added safety measures) must be included for occupied spaces.

Current guidelines list machinery rooms as being unoccupied spaces without general access. Best practice here is to ensure the areas are airtight from other spaces. These types of locations should only be accessed by trained employees and must have gas detection and ventilation systems with extractor fans that increase emergency air flow if the carbon dioxide concentration exceeds safe limits.

Open air and unoccupied spaces

According to EN378, open air locations are "rooms where at least one of the longer walls is open to the outside air by means of louvres with 75% free area and covering at least 80% of the wall area". Even though these areas are open to outside air, they may still require gas detection and ventilation systems – and it's crucial to check to ensure carbon dioxide isn't stagnating.

EN378 requires unoccupied spaces to meet the same requirements as machinery rooms with 4 air charges per hour for occupancy ventilation and also the calculated emergency ventilation requirement. However where extract hood are installed above non permanent joints the ventilation can be greatly reduced. Extract hoods must be designed to account for the possible of a carbon dioxide releases when a technician is working on equipment inside the hood.

Relief valves

Wherever carbon dioxide relief valves are present, there's a risk solid material can block valve vent lines. To overcome this, the valve outlet pipework arrangement should be kept simple with no branches, tees, or other areas where this material could deposit following a discharge. I

t's vital to assess this hazard, as a release of solid carbon dioxide horizontally can act like a lethal bullet, exiting at high velocities of >200m/s. Assessors should also make sure that any discharged carbon dioxide is not sucked back into buildings through ventilation systems, as this can result in dangerously high atmospheric amounts.

Adequate response planning

As carbon dioxide falls under the DSEAR regulations, management must take steps to ensure an effective emergency response plan is in place to deal with related accidents and leaks. The plan should be tested to assess its workability and efficiency, preferably when all personnel are on site.

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Whilst the owner/user is responsible for compliance to DSEAR, EN378-2 requires the installer to provide information for safe operation of the refrigeration system and outline the emergency procedures for the site to use in the event of a carbon dioxide release. The regulation also requires arrangements to deal with accidents, incidents and emergencies.

Although the facility's management are ultimately responsible for any failures, they are also required to manage their contractors

Star Refrigeration

Thornliebank Industrial Estate, Nitshill Rd, Thornliebank, Glasgow G46 8JW

Tel: 0141 638 7916 star@star-ref.co.uk

@StarRefrig

www.star-ref.co.uk

working on site to HSE guidance HGS 159. When using a Permit To Work (PTW) system, those managing contractors must be competent to work to the HSE guidance HGS 250. There is a further requirement to provide employees with information, instruction and training.

A suitable and sufficient carbon dioxide release response plan should include emergency phone numbers, along with a location map detailing where carbon dioxide systems are present and where personnel should go in the case of a gas alarm or emergency if a leak or incident occurs, so that harms can be minimised quickly.

If personal detectors are issued to staff, they should be regularly checked as part of the testing process, while managers should know how to spot signs of carbon dioxide inhalation, as well as when to evacuate or contact emergency services.

Presenting response planning procedures in an easy-to-follow flow chart formula will allow staff to act swiftly in the case of an emergency –but any type of plan should cover all areas where carbon dioxide is present and could reach toxic levels.

Employee training

Employees, contractors and anyone working at locations with carbon dioxide systems must undergo an induction when they start at site. This should provide details of carbon dioxide refrigeration systems are located and how to spot signs of a release.

Staff should let management know in the event of an emergency before congregating at the assigned meeting point if they have concerns. They must be able to recognise the sound of installed alarms and know what to do when one is initiated. If a lot of carbon dioxide is stored onsite, managers and anyone who'll be entering high risk areas, such as machinery rooms, should complete a carbon dioxide safety course.

Approaching risk assessment of carbon dioxide refrigeration systems and emergency response planning systematically is the best way to ensure major risks are identified and minimised. Although current legislation doesn't go quite as far as to lay out full working practice, the European standards provide sufficient guidance for owners and operators to plan a measured response.

Carbon Dioxide Hazard Assessment Blueprint

A systemic approach for risk assessing carbon dioxide has been developed by Star Technical Solutions to assist in the assessment of risks, emergency planning and facility awareness based on industry good practice.

The goal of any carbon dioxide risk assessment is to establish the risk rating (frequency x severity). Where the risk rating is found to be too high, it should be reduced by appropriate actions.

A standard format for carbon dioxide hazard assessments is a combination of a hazard study and risk assessment. The document should be split into four sections:

1. Introduction, Actions and Compliance to Regulations
2. Carbon Dioxide Regulations, Standards and Good Practice
3. Compliance to Regulations and Good Practice
4. Risk Assessment

Section 1 should introduce the document and then detail the immediate actions required where the risk rating is considered too high under the headings: Pressure System Integrity Inspections, Site Management Systems, Safe Maintenance and Repair and Safety Hardware Compliance. There are further requirements related to the frequency of the actions that must be carried out to ensure the refrigeration systems remain safe.

Section 2 should identify the limitation of the risk assessment, characteristics of carbon dioxide with COSHH and toxic effects. The section should then go into further detail to scrutinise the requirement for: the avoidance of the release of hazardous substances, ventilation, gas detection system, the safe release of carbon dioxide, carbon dioxide release response plans and on-site personnel awareness.

Section 3 should detail the purpose and location of all carbon dioxide equipment, the gas detection system with auxiliaries, ventilation system safety systems, and state where carbon dioxide is vented directly or indirectly. There must be a list of compliance questions to assess system safety and compliance with the requirement set in section 2. If the requirement is not met, an action should be labelled and detailed in section 1.

Section 4 should include a carbon dioxide risk assessment and establish the risk rating for the present and future control measures.

Future proof cooling
Refrigeration systems charged with carbon dioxide offer a climate friendly, long term alternative to HFCs for numerous applications. Well designed, maintained and risk-assessed carbon dioxide systems are a safe, reliable and a highly efficient solution.

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While regulations do not detail safe work practices for refrigeration systems, European standards provide guidance on safety requirements for the design and operation of carbon dioxide refrigeration systems which must be followed to comply with UK legislation.

The systematic approach to assessing carbon dioxide refrigeration systems described in this article will ensure the safe operation of the equipment, minimise carbon dioxide leaks and institute a suitable plan to address any potential gas release.

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Thornliebank Industrial Estate, Nitshill Rd,
Thornliebank,
Glasgow G46 8JW

Tel: 0141 638 7916 star@star-ref.co.uk

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