Failure Analysis of a Carbon Dioxide Fire Extinguisher

T. Dalton

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Fire extinguishers are a familiar sight on domestic and commercial premises, and although their presence usually goes unnoticed, they can literally be a lifesaver when the need arises. There are several different kinds of extinguisher, and in the case of the carbon dioxide type, they are charged to extremely high pressure and therefore contain a vast amount of stored energy. As such, the consequences of failure can be very serious. In this study, a situation is described where poor servicing practice meant that, rather than improving the safety of factory workers, the extinguishers themselves posed a serious threat to their well-being. The extinguishers were, in effect, time bombs in disguise. Following an explosion of one of the extinguishers, the owner took the responsible approach of commissioning a metallurgical investigation, which prevented further and potentially more serious incidents.

Keywords: ammonia, brass, stress-corrosion cracking (SCC)

Introduction

Fire extinguishers are a mandatory requirement for any commercial premises, and in the U.K., most aspects of nondomestic fire safety are controlled under the Fire Precautions (Workplace) Regulations of 1997 and its 1999 amendment.[1,2] In conjunction with these regulations, BS 5306 Part 3[3] provides information on the type, number, location, and servicing requirements for all fire extinguishers and thus provides a reassurance to the staff that the working environment is as safe as can be expected. In this study, however, a situation is described in which, rather than providing reassurance to the workers, the fire extinguishers themselves posed a serious threat to their safety.

Fire extinguishers fall into different categories that include water, foam, dry powder, and carbon dioxide types. Each type is suited to a particular application, and selection is based on a risk assessment of the type of fire that may be anticipated. One of the most popular extinguishers in the manufacturing industry is the carbon dioxide type, which can be used on electrical fires and is particularly suited to situations where there is a risk from flammable liquids. Use of this type of extinguisher also leaves no residue, meaning it does no harm to food, fabrics, machinery, or electrical equipment. However, in order to disperse the gas quickly and to ensure there is an acceptable period of operation, the carbon dioxide extinguisher needs to be charged to an extremely high pressure, typically approximately 150 bar (in excess of 2000 psi). Although incidents involving carbon dioxide fire extinguishers are extremely rare, it is clear that the consequences of a failure in such a high-pressure system are potentially very serious.

In order to maximize the safety and reliability of carbon dioxide fire extinguishers, BS 5306 Part 3 requires that they be subjected to a basic service every year and a more extensive overhaul every 10 years. While the basic service includes such actions as a general visual examination of all external components and a weight check to confirm that the contents are within 10% of the target value, the 10 year overhaul involves a complete strip-down and incorporates a hydraulic pressure test.

The Incident

The incident occurred at a U.K. biscuit manufacturing plant in November 2003. The fire extinguisher was reported to have been located on its bracket on the wall of the production office, close to the door that led to the main manufacturing area. On the day in question, just before lunchtime, a loud explosion was heard. The cylinder of the extinguisher was suddenly propelled across the office, deflecting off of two walls and destroying a computer before smashing through the office window and coming to rest in the parking lot. Although there were two people in the office at the time of the incident, neither sustained any physical injury.

T. Dalton, Royal and SunAlliance, 17 York Street, Manchester M2 3RS, U.K. Contact e-mail: tom.dalton@uk.royalsun.com.
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Subsequent examination of the fire extinguisher revealed that the sudden release of pressure had been caused by fracture of the brass valve where it entered the neck of the aluminum bottle. The biscuit manufacturer immediately began its own internal investigation into the incident, convinced that the extinguisher must have been subjected to some form of external impact. This, however, was refuted by both employees who were in the office at the time. Unable to establish the facts any further, and eager to restore confidence in the integrity of the remaining fire extinguishers, the biscuit manufacturer decided to commission a full metallurgical analysis.

The only information supplied with the extinguisher was that it had been purchased in 1993 and had been maintained and inspected in accordance with the requirements of BS 5306 Part 3. The most recent work had been carried out in August 2003 (approximately 3 months prior to the incident), and, because that was a 10 year inspection, it included a complete stripdown and hydraulic pressure test. Interestingly, it was reported that the service engineers who were commissioned to carry out this work were different from those previously used, with the

![Fig. 1 General view of failed fire extinguisher](image1)

![Fig. 2 General view of fracture face showing tooth-shaped profile and brown/black discoloration](image2)

![Fig. 3 Fracture face discoloration shown in greater detail](image3)

![Fig. 4 Secondary cracking in adjacent thread](image4)