PROPERTY

COMMENTARY PAPER

The effects of fire extinguisher effluent on equipment

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In the event of a fire, utilizing a handheld extinguisher can be a quick and effective way to suppress a fire and prevent additional damage, or to aid in escape. There are different types of fire extinguishers available, each with specific intended uses in order to be the most effective.

Fire extinguisher history

Interestingly, there is conflicting information about when fire extinguishers were first invented, likely because they have evolved so much. In fact, one of the earliest fire extinguishers wasn't handheld. Instead, it involved an automatic system with gun powder igniting when fire attacked it, which caused an explosion that dispersed fire retardant chemical in the area. This suppression method introduced hazards of its own, but over time, evolved a similar chemical dispersant device that utilized a spring-loaded mechanism with a fusible link rather than an explosive charge.

One of the earliest handheld fire extinguishers was invented in 1818 in Britain, which sprayed potassium carbonate via pressurized air. This design of the fire extinguisher has been modified many times since then, resulting in extinguishers of different sizes, for different hazards, and that use different chemicals and technologies. However, the primary design goal has remained the same: to spray a chemical from a (typically) handheld container into a fire to extinguish it.

Picture credit: Fireranger – The Evolution of the Fire Extinguisher

Classes of fire extinguishers

Fires are currently classified in several different ways, each with specific types of fire extinguishers that are appropriate for that classification. These classifications can become confusing if people are not familiar with an extinguisher's purpose or if they do not take the time to familiarize themselves with the labels or instructions.

The most common fire classifications are as follows:

- **Class A:** Solid combustibles (wood, paper, textiles).
- **Class B:** Flammable liquids and gases (gasoline, diesel, alcohol, paraffin as well as methane, propane and hydrogen).
- **Class C:** Energized electrical equipment (computers and electric heaters).
- **Class D:** Flammable metals (magnesium, lithium, and aluminum).
- **Class K:** Cooking oils/fats (fryer oil, commercial cooking operations, grease).

An "ABC" extinguisher is commonly found in homes or businesses, since it's appropriate for Classes A, B, and C and therefore suitable for most hazards that would be identified in these environments (other than cooking fires). Most cooking/grease fires in a home can be addressed by simply covering the pot/pan while in a commercial kitchen, a Class K extinguisher is appropriate and required.

Fire extinguishing agents

The agents in handheld fire extinguishers — both chemical and gas — are somewhat varied, which is why the materials the extinguishers are effective for are also varied. After the fire is extinguished, there is typically fire damage to contend with in addition to potential contamination.

The following are agents utilized as extinguishing effluents (suppressants), although the list is not exhaustive:

Halon/Freon

Bromochlorodifluoromethane (CBrClF2), also known as Halon 1211 or Freon 12B1, is a suppressing agent that is utilized on fires involving solid materials, liquids and electronics. While production of Halon ceased in 1994 as part of the Montreal protocol — an agreement that was passed to protect the ozone by phasing out the production of ozone-depleting substances — recycling of Halon allows it to remain in use. Halon gas does not leave a residue behind and is non-corrosive and non-conductive.

Wet chemical

Wet chemical filled extinguishers contain water in addition to wetting agents, such as potassium acetate (CH3CO2K), potassium carbonate (K2CO3), potassium citrate (C6H5K3O7), or a combination of these chemicals or others, which do conduct electricity.

Carbon dioxide

Carbon dioxide (CO2) filled fire extinguishers are one of the safest solutions when considering a Classification B or C fire, including electronic equipment. The reason is that the extinguishing gas does not leave a residue once discharged, is non-corrosive and electrically non-conductive. The CO2 displaces oxygen around the fire, effectively eliminating one of the three elements that is needed to sustain a fire (oxygen, heat, and fuel, frequently referred to as the fire triangle).

Water spray or mist

Air pressurized water (APW) extinguishers are filled with tap water and pressurized with normal air. Water mist extinguishers contain deionized water, which is non-conductive. Water-type extinguishers are appropriate for Classification A fires. Depending on the ambient conditions that these extinguishers are supposed to be stored in, antifreeze may be introduced to maintain effectiveness during freezing conditions. Water filled extinguishers may also contain wetting agents that are designed to reduce the water's surface tension and increase its penetration and spreadability. This, in turn, helps increase the extinguishers effectiveness when suppressing a fire.

Standard and multipurpose dry chemical

The effluent discharged from standard dry chemical fire extinguisher is a fine powder. The powder is comprised of sodium bicarbonate (NaHCO3) or potassium bicarbonate (KHCO3). Multipurpose dry chemical extinguishers — known as ABC fire extinguishers — contain monoammonium phosphate (NH4H2PO4). Both standard and multipurpose dry chemical extinguishers blanket the fire fuel with an inert chemical similar to smothering a fire with sand or dirt.

Older extinguishers can have other chemicals in them, some of which are now known to be health hazards, such as carbon tetrachloride (CCl4), which were for a long time used in 'fire grenades' to be thrown into fires.

Equipment hazards from fire extinguisher chemicals

The University of Michigan (U-M) Environmental, Health & Safety Department published a paper titled "Special hazards fire extinguishing systems agents." The paper advises that while a large number of halogenated extinguishing agents exist, only the Halon 1211 can be found around campus in portable extinguishers. The paper states that "Halon is a colorless, odorless gas with a density approximately five times that of air. It is noncorrosive, non-reactive with water, and stable up to 900°F (482°C). Halon is typically employed in areas such as computer rooms, data storage areas, libraries and museums, where the use of water or solid extinguishing agents could cause secondary damage exceeding that caused by the fire itself. The non-conductive nature of Halon enables it to be used for the protection of electrical and electronic equipment, and its low toxicity allows its use in areas where the egress of personnel may be undesirable or impossible."

Based on these details, it would appear that Halon is an ideal type of extinguishing agent as it relates to electrical and electronic equipment. This would be true if a fire was not part of the equation. It may sound odd to consider deployment of a manual extinguisher without a fire, although plenty of losses occur because extinguishers are intentionally discharged without cause. Let's consider a situation where a fire is involved; it occurs and a halon filled extinguisher is discharged. The U-M paper describes the decomposition of Halon as follows, "The decomposition products have a sharp, acrid odor, even at very low concentrations of only a few parts per million. The amount of decomposition products will depend on the size of the fire, the concentration (quantity) of halon released, the length of time the agent is in contact with the flame or heated surface, and the volume of the room."

Halon decomposition byproducts:

- Halogen acids: Hydrofluoric Acid (HF), Hydrobromic Acid (HBr), Hydrochloric Acid (HCl)
- Free halogens: Bromine (Br_2), Fluorine (F_2), Chlorine (Cl_2)
- Possibly small amounts of Phosgene ($COCl_2$) or other Carbonyl Halides (COF_2, $COBr_2$)

The positive features of Halon gas (does not leave a residue behind, is non-corrosive and non-conductive) are overshadowed by the catastrophic effect an aqueous solution such as hydrochloric acid has on equipment. Hydrochloric acid is aggressive and corrodes ferrous metals (i.e. metals that contain iron), as well as copper, brass, aluminum, zinc and even gold.

Mosaic, a company that mines phosphate, published a safety data sheet (SDS) for monoammonium phosphate. As noted above, multipurpose ABC type powder extinguishers are filled with monoammonium phosphate. These extinguishers are the most common type sold for residential and office settings.

As with Halon, Monoammonium phosphate produces hazardous thermal decomposition products if heated to the point of decomposition. The SDS shows that these products include nitrogen oxides, sulfur oxides, phosphorous oxides and ammonia. According to Jackson Fire, "The powder particles are very fine which makes it easy for them to spread across a large area. They can affect a vast array of materials, corroding metal and damaging electrical equipment and machinery."

- Nitrogen dioxide (NO2) – NO2 affects metals by forming salts that increase corrosion.
- Sulfur oxides (SOx) – The European Environmental Agency reports that the most common sulfur oxide is sulfur dioxide (SO2). Sulfur dioxide is a colorless gas with a penetrating, choking odor. It dissolves readily in water to form an acidic solution, sulfurous acid (H2SO3).
- Phosphorous oxides (POx) are released during heating/burning, which creates a toxic and corrosive environment.

Determining the fate of contaminated equipment

When equipment is exposed to loss-related contamination, something will need to be done in an effort to restore it to a pre-loss condition. Depending on the condition of the equipment, cleaning followed by testing, repair and recalibration may be the solution. Replacement is another option if the equipment has deteriorated to the point whereby it cannot be economically restored.

If we consider a fire that was suppressed with a common ABC fire extinguisher, and the airborne powder made its way into the heating, ventilation and air conditioning (HVAC) system, loss-related contaminants could now be spread across areas that were not directly affected by the fire. To validate the presence of foreign contaminants versus their absence, testing should be performed so empirical data can drive the recovery process. This is true both to quantify the existence and quantity of contamination and for post cleaning quality assurance if restoration is a viable option. We need to remain cognizant that contamination exists just about everywhere — perhaps minimally in commercial cleanrooms — therefore differentiation between environmental debris, manufacturing by-product and loss-related particulate is important.

Wipe samples

According to the American Industrial Hygiene Association (AIHA), "It is essential to match the sampling method and media with the corresponding analysis to maintain the integrity of particles and residue of interest and support the scope of the investigation."

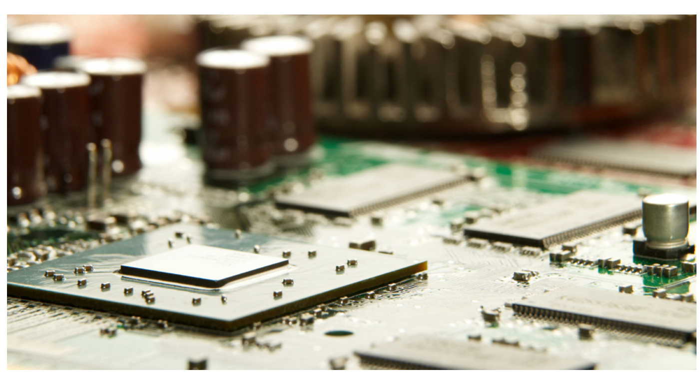
Wipe samples measure ionic contaminants such as bromides, chlorides, nitrates, phosphates, sulfates, ammonium and sodium, among others. The samples are analyzed with an ion chromatograph, an instrument that measures concentrations of ionic species by separating charged particles from a liquid, using SW9056A water extraction for anions and a modified ASTM D6919 water extraction method for cations. Wipe samples ascertain the levels of potentially corrosive particles that settled on a surface. Wipe samples should be used when the alteration of microscopic particle properties, depositional patterns or composition does not adversely impact the quality of the resultant data.

Equipment recovery

It's wishful thinking to assume that on every loss that requires quantitative sampling, it will take place before facility recovery activities begin. Experts that perform this testing are, at times, engaged several days or even weeks after the loss occurs, while facility recovery often starts the same day. As a result, it is important to understand what equipment remediation options could be employed, depending on the site conditions.

- **Power off equipment** — Equipment in commercial settings tend to be powered on continuously. Post loss, equipment should be powered off by qualified personnel. Doing so prevents contaminants from being drawn into control cabinets or computer equipment that utilize fans to introduce air into those assemblies for cooling purposes.
- **Poly sheeting** — Plastic tarps should be employed to cover equipment that was powered off.
- **Containment** — There are circumstances that prevent equipment from being powered off. In those cases, containment should be built to prevent contamination from further exposing the equipment. Equipment that is powered on should not be covered. Doing so may cause it to overheat.
- **Preservation** — Countless materials are used to build equipment. Some can withstand exposure to corrosive contaminants, while others quickly deteriorate. Equipment decontamination specialists utilize rust inhibiting lubricants to protect vulnerable metals. The most recognized rust inhibitor is WD-40, that can be found in large quantities at industrial supply and home improvement stores.

  Oil based rust inhibitors are not applied on printed circuit boards. Vapor phase corrosion inhibiting technologies are designed to safeguard electronics. These technologies form a protective molecular barrier on the surfaces with which they come in contact.
- **Decontamination** — For over forty years, professional equipment decontamination has been successfully employed on sensitive electronic assemblies — ranging from manufacturing controllers to data center computer servers and medical equipment. The cleaning techniques mirror those utilized in the printed circuit board industry.



Summary

Extinguishing agent effects on electrical and electronic assemblies

When electronic circuitry, such as printed circuit boards, are contaminated with an ABC powder extinguishing agent, the circuitry will initially experience a cooling effect. Thereafter, the powder that encapsulated the electronics will alter the heat dissipation characteristics of individual components causing heat retention. Circuitry that cannot dissipate heat as designed will experience failures, often in an exponential manner.

Extinguishing agent effects on mechanical assemblies

Introduction of extinguishing agents on mechanical components can cause wear on moving parts due to the abrasive nature of the ABC powder effluent. Unprotected metal surfaces — metal surfaces that are not painted or have self-passivating characteristics — may corrode due to the composition of the powder and presence of ambient moisture.

Retaining the right experts to sample the affected areas and develop a recovery scope based on empirical data will immediately help establish more accurate reserves. Experts who work with original equipment manufacturers (OEMs) and oversee the recovery can help minimize down time. This, in turn, translates to claim settlements whereby the equipment owners appreciate the proposed indemnity, and the adjuster can move on to helping another business recover.

About EFI Global

EFI Global, part of Sedgwick, is a well-established brand with an excellent reputation in the Americas, Africa, Asia-Pacific and Europe as a market leader in environmental consulting, engineering failure analysis and origin-and-cause investigations. Each year, EFI Global completes more than 45,000 projects worldwide for a wide range of clients, such as commercial, industrial, institutional, insurance, government, risk managers, public and private entities. EFI Global is one of the world's most respected emergency response firms, capable of providing practical solutions to the most complex problems. Our multidisciplinary team of first responders, project managers, engineers, geologists and scientists are selected for their technical proficiency and in-depth industry knowledge to aid clients in resolving technical problems. For more, see **efiglobal.com**.

Get in touch with an expert

Bryan Day – senior environmental advisor
Bryan Day has extensive experience in the assessment of indoor and outdoor air quality, fire damage, water and mold damage, asbestos, industrial hygiene, and safety. Mr. Day's involvement in these projects includes project management, performing initial damage assessments and post-remediation inspections, collecting samples, contractor oversight, project monitoring and documentation, development of remediation protocols, and report preparation. For more information, contact **bryan.day@efiglobal.com**.

Jay Kramarczyk, MS, PE, CFI – vice president & senior principal engineer
EFI Global's forensic fire protection and mechanical engineering teams are led by Jay Kramarczyk who also oversees the operation of EFI's northeast district. Jay is a licensed engineer in several states and is a practicing expert witness in fire protection, mechanical failures, and fire and explosion investigations. For more information, contact **jay.kramarczyk@efiglobal.com**.

James Woolf, IAAI-CFI(V), NAFI-CFEI – fire investigator/team lead
James Woolf has more than three decades of combined experience in the fire service and law enforcement — conducting over 1,100 origin and cause investigations. In his career, Mr. Woolf has served as a line firefighter and fire officer, fire investigator/inspector, fire service instructor, patrol officer, detective and chief of police. Mr. Woolf is also a U.S. Army veteran where he served as a legal specialist/sergeant and infantry paratrooper in the 82nd Airborne Division. For more information, contact **james.woolf@efiglobal.com**.

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