International Journal of Engineering Research and General Science Volume 8, Issue 3, May-June, 2020
ISSN 2091-2730

An Innovative Fireball Fire Extinguishing System to Enhance Industrial Safety

M. Rahman, A. Elahi, and A. Rashid

Department of Mechanical and Production Engineering (MPE)

Islamic University of Technology (IUT), Board Bazar, Gazipur 1704,

Dhaka, Bangladesh.

Email: rashidarmh@gmail.com

Abstract— Many fire-based accidents are occurring in Industries now. Consequently, massive losses of lives, as well as money, are suffered by the owners. The conventional fire extinguishing systems are found to be not enough to reduce losses, including eliminating them. Most are conversant in the fact that the large fires originate from very small sparks or pretty little fires which are very easy to manage. So, in this research, the main objective was to easily control these small fires at the initial phase. By using the traditional fire extinguisher, it's not always possible to extinguish a small fire. One of the main reasons for this inability is that the manual handling nature. So, the authors worked with the automated extinguishing equipment and tried to enhance them to extinguish the small fire at a very initial stage and prevent huge fire which will cause massive losses. In this research, a sustainable fireball was designed and manufactured using locally available raw materials. In the ball, dry powder is used as an extinguisher referred to as ABC dry chemical powder. A stands for ash, B stands for barrel while C stands for current. The powder is typically a mixture of mono ammonium phosphate and ammonium sulfate, the previous being the active one. The combination between the two agents is typically 40–60%, 60-40%, or 90-10% counting on local standards worldwide. An innovative fireball extinguisher system has been developed using this powder to extinguish the fire quickly and conveniently. In this paper, the design and fabrication procedures of an innovative fireball extinguisher system are described along with the test result

Keywords— Fire extinguishers, Dry powder, Mono ammonium phosphate, Sodium bicarbonate, ABC dry chemical powder, Fire extinguishing ball, Fire safety

INTRODUCTION

Fire is a common hazard for all industries. There are different methods and equipments have been developed to deal with fire hazard [1]. This research study aims to develop an innovative method to enhance industrial safety. Therefore an elaborate exploratory literature review has been done. After that it becomes evident that for small and medium type of industries or in general industries would benefit from a fire extinguishing systems like fire ball. So in this paper, fire extinguishing methods and different fire extinguishing equipments are described first. Afterwards, research gap, objectives of this study, design and fabrication of the fireball with actual experimental result of its effectiveness are briefly described.

FIRE EXTINGUISHERS

A fire extinguisher may be defined as an active fire protection device used to extinguish or control small fires. Frequently it is used in emergency situations. Out-of-control fire is not the target of such extinguisher. Examples of out of control fire are as one which has reached the ceiling, endangers the user (i.e., no escape route, smoke, explosion hazard, etc.). In such cases fire brigade is to be called in. A fire extinguisher normally consists of a hand-held cylindrical pressure vessel containing an agent. This extinguishing agent can be discharged to extinguish a fire. Fire extinguishers manufactured with non-cylindrical pressure vessels are rarely found [1, 2]

Two main types of fire extinguishers are: stored-pressure and cartridge-operated. Ambrose Godfrey, a renowned chemist, was known

to be the first person who patented a fire extinguisher in England in 1723 [3].

In stored pressure fire extinguisher units, the firefighting agent is located at the same chamber where the expellant is stored. Conditional to the agent used, different propellants are used. Nitrogen is typically used in the dry chemical extinguishers. Water and foam extinguishers usually use air. The most common type and mostly available fire extinguishers are stored pressure fire extinguishers [4].

Francois Carlier of France first patented the soda-acid extinguisher in 1866. It mixes a solution of water and sodium bicarbonate with tartaric acid, creating the propellant CO2 gas. One type of soda-acid extinguisher was patented in the U.S. in 1881 by Almon M. Granger. To expel pressurized water onto a fire, his extinguisher used the reaction between sodium bicarbonate solution and sulfuric acid [5].

Cartridge-operated extinguishers working principle is different. It contains the expellant gas in a separate cartridge which is punctured prior to discharge. Thus it exposes the propellant to the extinguishing agent. It was invented by Read & Campbell of England in 1881. It uses water or water-based solutions. They later invented a carbon tetrachloride model called the "Petrolex" which was mainly used in automotive sector [4].This type is not as common, used primarily in areas such as industrial facilities, where they receive higher-than-average use. Their main advantages are that they are simple and could be prompt recharged. So it permits an operator to discharge the extinguisher, recharge it, and return to the fire in a reasonable amount of time that may save many lives. Contrary to stored pressure types, these extinguishers use compressed carbon dioxide instead of nitrogen. Even though nitrogen cartridges are used on low temperature (-60 rated) models. In the U.S.A., Cartridge operated extinguishers are available in dry chemical and dry powder types and in water, wetting agent, foam, dry chemical (classes ABC and B.C.), and dry powder (class D) types in the rest of the world.

Fire extinguishers are further classified into handheld and cart-mounted (also called wheeled extinguishers). Handheld extinguishers weigh from 0.5 to 14 kilograms (1.1 to 30.9 lb). So they are easily portable by hand. Cart-mounted units typically weigh more than 23 kilograms (51 lb). These wheeled models are generally found at construction sites, airport runways, heliports, docks, and marinas.

The types of materials aka fire extinguishing agents used in the fire extinguishers include foams, water, wet chemicals, water additives, Halons, Carbon dioxide, etc [6, 7].

FIRE EXTINGUISHING BALLS

There are several types of modern "ball" or grenade-style extinguishers are available on the market. The modern form of the ball is a hard foam shell, wrapped in fuses that lead to a small black powder charge inside it. The ball bursts a few moment after contact with flame, thereby dispersing a cloud of ABC dry chemical powder which extinguishes the fire. The coverage area is about 5 m2 (54 sqft). The advantage of this type is that it may be used for passive suppression. The ball could be placed in a fire-prone area. As it is triggered by heart, it will be activated automatically if a fire develops. By rolling or tossing into a fire, they may also be manually activated. Most of them are designed to make a loud noise upon deployment [8].

This technology has been in place for some time. Glass fire grenades filled with suppressant liquids were widespread in the 1800s. These glass fire grenade bottles are sought by collectors [10]. Some later brands, for example Red Comet, were designed for passive operation. They included a special holder with a spring-loaded trigger that would break the glass ball when a fusible link melted. Typically some glass extinguishers contained the toxic carbon tetrachloride.

Fire Extinguisher Ball could be termed as a fully automatic type of fire extinguisher. When thrown or rolled into fire, it will burst and extinguish the fire instantly. It may be positioned where the hotspots are such as flammable objects, circuit breaker box, gas tank etc.
An activation or trigger strip is implanted into the ball's outer casing. It firmly holds the dry fire extinguishing agent inside. When the activator or trigger is exposed to flames for more than a few seconds, the casing will burst open and disperse a cloud of chemical powder in the surroundings.

RESEARCH REVIEW ON FIRE EXTINGUISHER BALLS

There are several variations in fire extinguisher balls as developed by the researchers and inventors in the last few decades. One of the prominent one was innovated by Woradech Kaimart. This fire extinguishing device of the explosive type is disclosed for use in interior or localized exterior conflagrations, wherein the force of detonation of the device is minimalized through the use of low density/low mass components; no part of the device having sufficient mass or density to typically constitute a safety hazard as flying debris, nor be dangerous in concussive shock due the explosive burst. The present invention is composed of a lightweight casing of rigid plastic foam or other suitably frangible material, with an abrasion-resistant, thin plastic, protective, exterior sheathing. Within the

internal cavity of the device, a low explosive yield detonator is located at or near the center of mass, and is actuated by fuse cord(s) extending from the detonator, the end(s) of which extend(s) from the interior detonator to a mounting at or near the exterior surface. The interior volume of the hollow casing is chargeable, through variations in internal configuration, with a variety of fire-retardant chemical agents, including dry powders, two-part reactants, liquid components or others, singly or in combination [10].

Another latest innovation on fire extinguishing balls was developed by Mary M. Dwyer and Anushree Sridhar. It includes a housing comprising at least one escape hole, a first compartment within the housing containing a first extinguishing agent, and a second compartment within the housing containing a second extinguishing agent. The first compartment may be rotatable relative to the second compartment. The apparatus may further include a barrier disposed between the first compartment and the second compartment configured to separate the first extinguishing agent from the second extinguishing agent, and a barrier rupture mechanism. The barrier rupture mechanism may be configured to rupture the barrier in response to rotation of the first compartment relative to the second compartment to permit the first extinguishing agent to mix with the second extinguishing agent and cause a pressure generating reaction that forms an extinguishing mixture and forces the extinguishing mixture through the at least one escape hole of the housing [11].

RESEARCH GAP

From the literature review, it was found that different types of fire extinguisher balls were constructed by several researchers and commercial entities. However, situations in Bangladesh and some other developing countries are significantly different from most of the locations for which those variations of fireballs were designed. Therefore it was justified to design and fabricate an innovative fireball considering local circumstances

OBJECTIVES

We have five main objectives which are stated below-

- To prevent big fires by putting out small fires at the very initial stage
- To reduce damage originated from fire accidents
- To extinguish fire efficiently from a safe distance
- To extinguish fire without causing any harm to the environment
- To make the fire extinguishing device more user friendly

METHODOLOGY

The methodology followed in the research is as follows:

Prototype designing

The prototype was designed in order to develop the prevalent design. The shape was changed from circle to rectangular in order to increase efficiency of the device. The change in design also made this device user friendly.

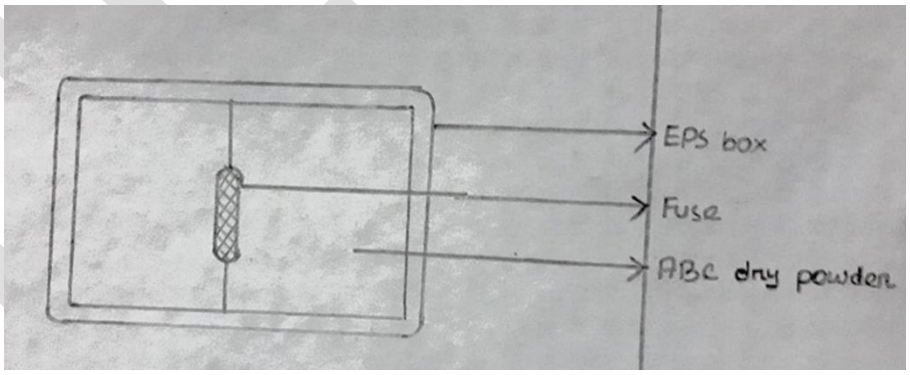

Figure 1: Final Design

The fuse was placed in the middle of the device. So when the explosion happens, the powder can cover the maximum amount of area. Surely it makes the device a more effective one.

Raw materials collection

Five raw materials were used to produce the fire extinguishing device. They were:

1. EPS Box: Expanded Polystyrene (EPS) is a lightweight cellular plastic material consisting of small hollow spherical balls. This closed cellular construction that provides EPS its remarkable characteristics. EPS is produced during a wide selection of densities providing a varying range of physical properties. These are matched to the varied applications where the material is employed to optimize its performance and strength.

2. ABC dry powder: ABC Dry Chemical, ABE Powder, tri-class, or multi-purpose dry chemical is a dry chemical extinguishing agent used on class A, class B, and class C fires. It uses a specially fluidized and siliconized mono ammonium phosphate powder. ABC dry chemical is typically a mixture of mono ammonium phosphate and ammonium sulfate, the previous being the active one. The combination between the two agents is typically 40–60%, 60-40%, or 90-10% counting on local standards worldwide. The USGS uses an identical mixture, called PhosChek G75F.

3. Ammo: Ammunition (informally ammo) is the material fired, scattered, dropped, or detonated from any weapon. Ammunition is both expendable weapons (e.g., bombs, missiles, grenades, land mines) and therefore the component parts of other weapons that make the effect on a target (e.g., bullets and warheads).Nearly all mechanical weapons require some sort of ammunition to work.

4. Fuse: In an explosive, pyrotechnic device, or military munitions, a fuse (or fuse) is the part of the device that initiates function. In common usage, the word fuse is employed indiscriminately. However, when being specific (and especially during a military context), the term fuse describes an easy pyrotechnic initiating device, just like the cord on a firecracker whereas the term fuse is occasionally used when pertaining to a more sophisticated ignition device incorporating mechanical and/or electronic components.

5. Adhesive: Adhesive, also called glue, cement, mucilage, or paste, is any non-metallic substance applied to at least one or both surfaces of two separate items that binds them together and resists their separation. The utilization of adhesives offers many advantages over binding techniques like sewing, mechanical fastening, thermal bonding, etc. These include the power to bind different materials together, to distribute stress more efficiently across the joint, the value effectiveness of an easily mechanized process, an improvement in aesthetic design, and increased design flexibility. Disadvantages of adhesive use include decreased stability at high temperatures, relative weakness in bonding large objects with a little bonding area, and greater difficulty in separating objects during testing. Adhesives are typically organized by the method of adhesion. These are then organized into reactive and non-reactive adhesives, which ask whether the adhesive chemically reacts so as to harden. Alternatively, they will be organized by whether the raw stock is of natural or synthetic origin, or by their starting physical phase.

Producing fire extinguisher device

The device was handmade. It was produced inside a dormitory room, which proves the easiness of producing this device. Any factory can produce the amount of fire extinguishing device they need. The dry powder was placed inside the EPS box. The fuse was placed in the middle of the box. This would help to extinguish the maximum amount of fire.

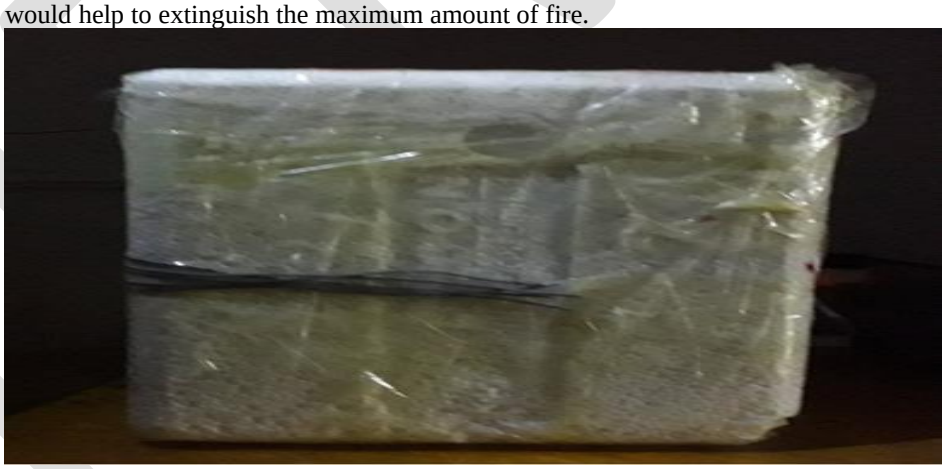

Figure 2: Fire extinguishing device

At the end, adhesive was used to make the EPS box come together. The production process was ended by wrapping up the box with tape. It will make the box resistant, so that the powders don't come out.

Testing the device in real situation

The device was tested in real situation. A fire of middle size was lit. After some time, the device was thrown into it. It exploded, the powder inside it spread into the area. And the fire was extinguished successfully. The whole area covered with powder. The picture

taken during the testing is shown in Fig 3.

Before **After**

Figure 3: Pictorial presentation about the test of the experimental fireball

The same area which was covered with fire later became covered with smoke as soon as the device was used. The whole area became free of fire. And a successful experiment of the newly produced device ended.

RESULT

We tried to develop the existing fire extinguishing ball and ended up making a device with more efficiency and more potential. The device certainly covers more area than the existing ball because of its shape.

We also found out the possibility of creating the device with a very low cost. So every factory can meet their own demand themselves. They don't need to buy it from outside. The apparatus may further include a barrier disposed between the first compartment and the second compartment configured to separate the first extinguishing agent from the second extinguishing agent, and a barrier rupture mechanism. That will surely save some cost for them. So that's how we managed to develop the existing fire extinguishing ball. They don't need to buy it from outside.

The apparatus may further include a barrier disposed between the first compartment and the second compartment configured to separate the first extinguishing agent from the second extinguishing agent, and a barrier rupture mechanism. That will surely save some cost for them. So that's how we managed to develop the existing fire extinguishing ball.

An innovative fireball fire extinguisher system has been developed using this powder to extinguish fire quickly and conveniently. By using the conventional fire extinguisher, it is not always possible to extinguish small fire.

One of the major reasons of this inability is the manual handling nature. So, we worked with the automatic exciting equipment and tried to improve them in order to extinguish the small fire at a very initial stage. This is expected to lead us in a success in preventing huge fire that will cause massive losses. In our research project, dry powder is used as fire extinguisher known as ABC dry chemical powder. A stands for ash, B stands for barrel while C stands for current.

The powder is usually a mix of monoammonium phosphate and ammonium sulfate, the former being the active one. The mix between the two agents is usually 40–60%, 60-40%, or 90-10% depending on local standards worldwide. An innovative fireball fire extinguisher system has been developed using this powder to extinguish fire quickly and conveniently.

LIMITATIONS

Portable extinguishers are not designed to fight large or spreading fires. Even against small fires, they are useful only under certain conditions:

- The operator must know how to use the extinguisher.
- The extinguisher must be within easy reach, in working order, and fully charged.
- The operator must have a clear escape route that will not be blocked by fire.
- The extinguisher must match the type of fire being fought. (Extinguishers containing water are unsuitable for use on grease or electrical fires.)
- The extinguisher must be large enough to put out the fire. Many portable extinguishers discharge completely in as few as eight to ten seconds.
- A lot of collateral damage
- No/barely no cooling effect
- Damages electrical devices
- Increased risk of re-ignition
- Shorter extinguishing time
- Unsuitable for homes (training before use is recommended)
- Almost twice as heavy as the other extinguishers
- Suffocating for humans and animals

- May cause burn wounds

CONCLUSION

In this research, we tried to develop the existing fire extinguishing ball and ended up making a device with more efficiency and more potential. The device certainly covers more area than the existing ball because of its shape. We also fabricated it with a very low cost. So it is affordable for the factories in the developing countries to meet their own demand themselves. Therefore it is expected to play a role in the industrial development of these countries. Besides, researchers may continue to work on these fireballs specifically how the large fire could be addressed.

REFERENCES:

1. Della-Giustina DE. Fire safety management handbook. CRC Press; 2014 Feb 7.

2. International Association of Fire Chiefs. Fundamentals of fire fighter skills. Jones & Bartlett Learning; 2008.

3. Upadhyay R, Kumar. J. Facility Management Volume II. India: Notion Press; 2019.

4. Security Koorsen. Cartridge-Operated vs. Stored Pressure Fire Extinguishers [Internet]. Blog.koorsen.com. 2020 [cited 9 June 2020]. Available from: https://blog.koorsen.com/cartridge-operated-vs.-stored-pressure-fire-extinguishers

5.firefighter.com.my, HISTORY OF THE FIRE EXTINGUISHER:
FROM GUNPOWDER TO DRY POWDER, 2019.[Online]. Available: https://www.firefighter.com.my/blogs/news/history-of-the-fire-extinguisher. [Accessed: 23- Jun- 2019].

6. Conroy MT. NFPA Guide to Portable Fire Extinguishers. Jones & Bartlett Learning; 2003.

7. Liu Z, Kim AK, Carpenter D. A study of portable water mist fire extinguishers used for extinguishment of multiple fire types. Fire safety journal. 2007 Feb 1;42(1):25-42.

8. Aydin B, Selvi E, Tao J, Starek MJ. Use of Fire-Extinguishing Balls for a Conceptual System of Drone-Assisted Wildfire Fighting. Drones. 2019 Mar;3(1):17.

9.Fire Grenades: History and collectability [Internet]. Antique Trader. 2020 [cited 9 June 2019]. Available from: https://www.antiquetrader.com/glass/fire-grenades-history-and-collectability

10. Kaimart W, inventor; Siam Safety Empire Co Ltd, Siam Safety Premier Co Ltd, assignee. Fire extinguishing ball. United States patent US 6,796,382. 2004 Sep 28.

11. Dwyer MM, Sreedhar A, inventors. Fire extinguishing device. United States patent US 10,226,655. 2019 Mar 12.