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The relationship between false discharge of gaseous fire suppression systems and airborne dust

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ABSTRACT

Fire suppression system using gases is one of the most advanced fixed automatic fire suppression systems. The most common of fire suppression system using gases are clean agent systems which have clean extinguishing gases that are ineffective on environment, people and equipment. The famous types of clean extinguishing gases are FM 200 or called heptafluoropropane, Other type is NOVEC 1230, It belongs to a family of chemicals called halocarbons, a group which includes fluoroketones. There is another type of gaseous fire suppression system using Carbon dioxide as an extinguishing gas, but it's not classified as a clean agent. Gaseous fire suppression systems protect vital locations and critical assets. Clean agent systems and carbon dioxide systems are the most common types of gaseous fire suppression systems installed in the Company facilities. In fire case, smoke begins raised up, at least two detectors must sense the smoke to activate the system for extinguishing. In reality, not only smoke of fire can activate the system. In the last four years, only 12% of total times that the gaseous fire suppression systems activated for fire reasons. According to historical investigation reports, false discharges may occur due to many causes, most important of which are environment, human error and system trouble. This research studies these factors and focused on environmental factor that is responsible of around 68% of total activated times of gaseous fire suppression systems and it found associated correlation as well as proposes physical solutions to reduce the probability of false discharges. Linear regression analysis and ANOVA analysis will be applied.

Keywords— *Suppression system, Fire safety, Clean agent, Carbon dioxide, False alarm, Releasing factors*

1. INTRODUCTION

In many countries, fire outbreaks are widespread. When these fires occur, they can drastically cause billions of dollars' worth of damage to one's property and even life safety. It is for these reasons that regulations have been put in place to mitigate the safety of property and people alike. Fire alarm and detection systems are used for making it known when a fire has occurred. The primary purpose of using fire alarms is to detect a fire early on in its development even when no one is around. Once the fire alarm has detected a fire, it will emit a warning and, in some cases, activate the automatic fire suppression system. When detecting fires, there are many different options, two of which are temperature and smoke detectors. [1]

There are various types of detection systems. There are systems that detect smoke in numerous ways, and some systems that detect even flames in buildings. Smoke and fire detection equipment is an integral part of any building's safety. If properly working, they alert occupants in a building of a fire before it spreads, giving them enough time to evacuate. Some examples include, heat detectors, smoke detectors, flame detectors, and CO gas detectors. [2]

Fire alarms main components consist of signal initiating devices, control panels, backup power supplies, display panels. The alarm systems have two input devices, heat and smoke detectors that will detect any significant increase in temperature and smoke. If and when changes are detected, then the control panel will send signals to notify it of the changes. When this happens, the output devices will then be initiated by the use of lights, announcements, and horn to indicate the danger.
When it comes to components, these systems constantly change and improve when there are advances in technology. Any components of a system should be tested by A nationally reputable laboratory such as Underwriters Laboratories, FM Global and Intertek. These laboratories check the systems to help ensure their operability. [3]

Fire Detection and suppression systems are used to detect the presence of fire or products of combustion, to alert occupants and the fire department personnel of the condition, and to suppress and or extinguish the fire. [3]

The main function of fire suppression systems using suppression gases (GFSS) is extinguishing fires without any human's assistances. Extinguishing or suppression gases have special specifications and extinguishing characteristic to control and extinguish a fire once it occurs and in its incipient stage – before it has a chance to spread. However, there are 3 ways to extinguish any fire:

- Reduction of heat.
- Reduction or isolation of oxygen.
- Inhibiting the chain reaction of the above components.

A fire needs oxygen, fuel, and heat (fire triangle) to continue to burn. By eliminating one of these three elements, a fire can be suppressed or extinguished. While GFSS by clean agent works by removing the free radicals or heat elements from the fire triangle, a CO2 fire suppression system eliminates the oxygen to suppress the fire. The CO2 level in the space quickly increases as the oxygen level quickly drops causing the fire to be suppressed or extinguished. [4]

These types of extinguishing systems are exemplary for areas containing assets that could be damaged by water such as DATA Centers, Comms Rooms, telecommunication facilities, UPS rooms and control rooms or any area containing high value electrical equipment. GFSS are very expensive to maintaining and the gases which is used for fire suppression is costly when refilling, especially clean agent type. [4]

According to historical investigation reports and data records of gases discharge accidents (DACC) in an electricity transmission company in Saudi Arabia during the last four years of 2016, 2917, 2018 and 2019, it was found that the total cost of gases refilling due to DACC is approximately 34,868,088 SR. According to the reports, gas discharge accidents of gaseous suppression system may occur due to many causes, most important of which are environment, human error, system trouble and fire factors. Any of discharge accident occurred by any of causing discharge factor (CDF) except fire, we called it false discharge accidents (FDACC) of GFSS. The refilling costs (RC) associated with these causing factors represent 74%, 15%, 6% and 6% of the total refilling costs respectively.

2. METHODOLOGY

The study was conducted for study period of four years from 2016 – 2019. Figure (1) bellow shows the total number of discharge accidents in the company by each CDF and it clarify that most of them were occurred by environmental factor. In this paper, environmental factor defined as airborne dust which is responsible to effect on smoke detectors. ANOVA analysis and linear regression analysis were applied to find the correlation between these false discharge events and the airborne dust.

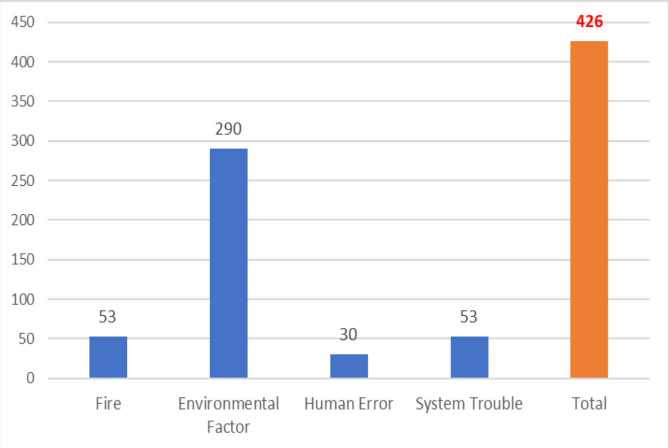

Fig. 1: Total discharges accidents by each CDF

In the following figure (2), it represents the total number of discharge accidents in each Saudi region.

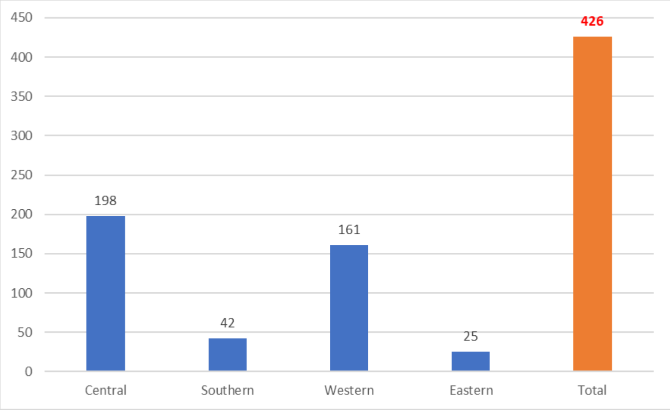

Fig. 2: Total discharges accidents in each region

Two sets of correlations between false discharge occurrence and airborne dust were performed. In the first set, false discharge was correlated to the daily particulate matter (PM10) concentration in the cities that have ambient air quality monitoring stations using ANOVA. In the second set, the correlation was analyzed between false discharge and the annual number of dust storms in selected cities.

Considering the first set of analysis, Table (1) shows the statistics of ANOVA analysis, which reveals that the correlation between false discharge occurrence and PM10.

Table 1: Results of ANOVA analysis of the correlation between false discharge occurrence and PM10

Analyses	Parameters				
ANOVA	F-value = 6.5, P-value = 0.011				
Regression	R^2 = 0.0017				
Means	Discharge	N	Mean	SD	95%CI
	0	3604	118.14	173.21	(112.40, 123.89)
	1	109	161.7	250.7	(128.7, 194.8)

In the second set of analysis, the number of false discharges was correlated to the number of dust storms that stroke the Saudi cities over the years 2016-2018. Two sets of linear correlations were conducted: (1) for all of the seven cities where false discharges were recorded and (2) for the top 4 cities where the highest numbers of discharges were recorded.

3. RESULTS

For the first set, the correlation between false discharge occurrence and PM10 is significant (P-value < 0.05) despite being very weak (r = 0.041). Figure (3) explains the reason of the significance of the relationship. The average PM10 concentration during the days where false discharge occurred was significantly higher than that where no discharge or where real discharge occurred. Figure (3) shows that there is no intersection between the 95% CI of both means.

For the second set, Figure (4) shows that there is a positive linear relationship between the number of dust storms and the number of false discharges. However, the relationship is weak and insignificant when monthly data are considered either for all cities (Fig.4 -a1; r = 0.061, P-value = 0.58) or the top cities (Fig.4 -a2; r = 0.142, P-value = 0.334). The relationship improves when considering the yearly occurrences of both dust storms and false discharges for all seven cities (Fig.4 -b1; r = 0.112, P-value = 0.629) and the top four cities (Fig.4 -b2; r = 0.275, P-value = 0.338). Further improvement is achieved considering the totals of the years for all cities (Fig.4 -c1; r =

0.262, *P*-value = 0.571) and for the top cities (Fig.4 -c2; *r* = 0.858, *P*-value = 0.142).

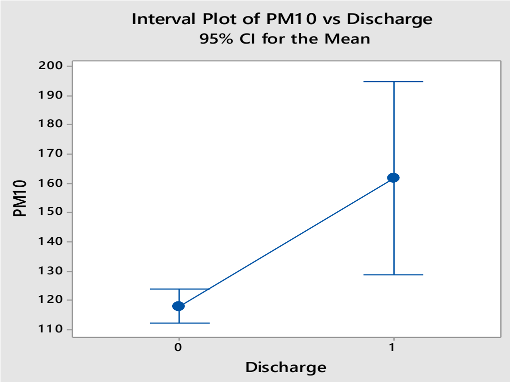

Fig. 3: Interval plot of PM10 versus false discharge occurrence results

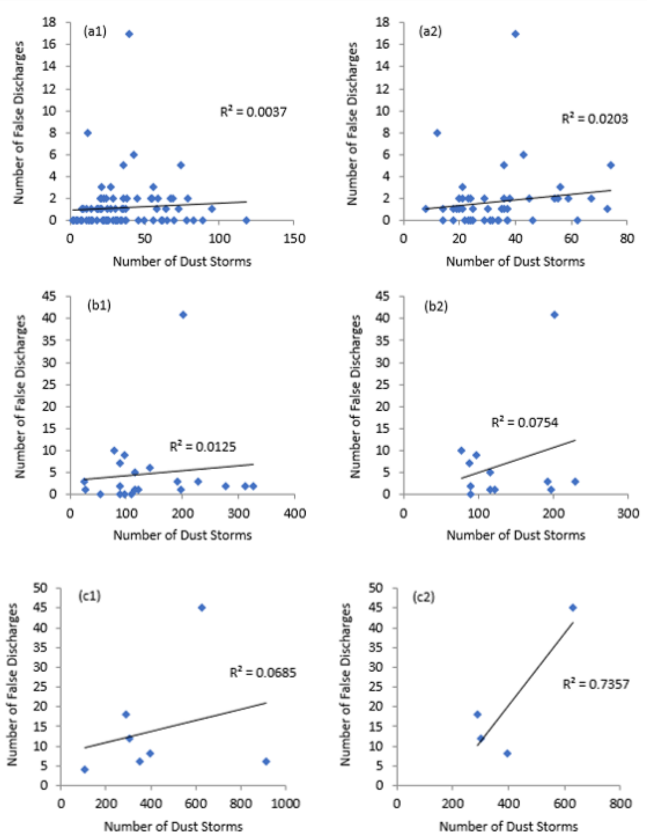

Fig. 4: Interval plot of PM10 versus false discharge occurrence results

Where:

(a1) Based on the monthly occurrences over 3 years for 7 cities

(a2) Based on the monthly occurrences over 3 years for top 4 cities

(b2) Based on the yearly occurrences (3 years) for 7 cities

(b2) Based on the yearly occurrences (3 years) for the top 4 cities

(c1) Based on the total occurrences of 3 years for 7 cities

(c2) Based on the total occurrences of 3 years for the top 4 cities

4. DISCUSSION

These results are in agreement with previous studies that found an impact of dust on false fire alarm or discharge [5] [6] [7]. In this case, there is no fire and the technical devices are functioning properly. However, the sensors react to parameters of fire-like phenomena (e.g. dust) in the absence of an actual fire [6].

The above statistical analysis shows that the effect of atmospheric conditions, especially airborne dust, on false discharge of firefighting systems should be given special consideration, even if the relationship is not significant or not strong for several reasons:

1. Atmospheric dust in Saudi Arabia is often high compared to other countries [8], that is to say, in most of the days, atmospheric dust concentration is high, especially the fine fraction (PM2.5). If atmospheric dust has impact on the occurrence of false discharge, it is likely that this impact is continuous in all days. During dust storm events, the concentration of dust is higher and, therefore, the likelihood of false discharge is slightly or moderately increased. This is evident in Table 1 and Fig. 3 where the average concentration of dust (PM10) in the days with no false discharge was 118.14±173.21 mg/m^3 which is higher than the averages in many countries. On the other hand, the average concentration of dust (PM10) in the days with false discharge was 161.7±250.7 mg/m^3. Considering the SD of both concentrations, it is obvious that there is overlap between them. Based on this, a wide range of dust concentration may affect false discharge.
2. There is a probability in some days with false discharge and low dust concentration or no dust storm that poor housekeeping condition resulted in increasing indoor dust concentration due to the presence of ground dust accumulated from previous dust storms.
3. The data of dust concentration in Saudi cities was limited and absent in some cities resulting in exclusion of the false discharge data of these cities from the statistical analysis. This situation might have resulted in the insignificant relationship between false discharge occurrence and airborne dust.

5. CONCLUSION

False discharge from gaseous fire suppression systems are a worldwide problem, but their underlying causes are not well understood. In addition, it is a critical issue that consume time and money. If funds and resources are inappropriately allocated to areas where they are not quite as needed, it will cost the organization more resource. This paper investigated the causes of false alarms with the aim of identifying measures to reduce the most significant that cause false discharge. It analyzed the four factors that cause it from different aspect. Linear regression analysis and ANOVA analysis were applied to find the correlation and the relationship between false discharge by environmental factor and dust storms. Regarding to the correlation analysis which applied, the research proved the probability of false discharge as well as low dust or no dust storm can be resulted in raise the indoor dust concentration level. This happened because of presence of ground dust accumulated from previous dust storms. The limitation of dust concentration data for some cities which is resulting in excluding these cities from the statistical analysis of this study. This situation might have resulted in the insignificant relationship between false discharge occurrence and airborne dust.

Finally, any organization should continuously evaluate its fire suppression systems and find solution of any issues that consume money, time and effort even if replacing by new one is the solution to save people and assets. This is important to do, otherwise several risks will increase when it is installed without gained no benefits.

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