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Explosion and Fire Caused Due to Storage of Maleic Anhydride and Potassium Hydroxide Together

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Abstract

An incident of explosion followed by fire was reported in a warehouse in Bhiwandi (Maharashtra), which leases storage space to the stockists for keeping miscellaneous chemicals. Forensic investigation was carried out to find the cause of fire by examining the scene of fire, thoroughly. It was found that 800 bags of maleic anhydride and 200 bags potassium hydroxide, which are incompatible, were stored side by side along with other chemicals in the warehouse. After thorough Investigation, it was concluded that violent explosive exothermic reaction could have taken place between maleic anhydride and potassium hydroxide, causing an explosion and fire.

Keywords: Maleic Anhydride; Potassium Hydroxide; Sodium Sulphate; Potassium Carbonate; Incompatible Chemicals; Exothermic Reaction

Introduction

An incident of explosion followed by fire was reported on 10th May 2020 in a warehouse at Bhiwandi (Maharashtra), India, which leases storage space to stockists for keeping miscellaneous chemicals. The watchman of the warehouse who was residing in a small room nearby went to his room as usual, after the closure of the warehouse around 07:00 PM. On that fateful day at about 10:30 PM, he heard an explosion and also noticed unusual peculiar chemical smell. He rushed to the warehouse and found smoke emanating from the warehouse. Immediately he informed the warehouse keeper who also resided nearby. The warehouse keeper rushed to the warehouse after informing the fire brigade, opened warehouse and noticed white smoke and flames coming from the burning chemicals stored in the middle of the warehouse. He immediately tried to extinguish the fire using fire extinguisher, available in the warehouse. However, his attempts were futile as the fire spread rapidly to all the chemicals stored. In another 15 minutes i.e., about 10:45 PM the fire brigade arrived and extinguished the fire in half an hour.

Methodology

A thorough and in-depth forensic investigation of the affected premises was carried out by recording the condition of the site, searching and identifying relevant physical evidence. The employees and workers were interviewed and their statements recorded. The ware house keeper was interviewed and the records with him were thoroughly examined.

According to the warehouse keeper, the chemicals in the form of gunny bags, drums, and plastic cans etc., were stored in the warehouse, in two rows separated by about three feet distance for the free movement of workers, for loading and unloading operations. The warehouse was rectangular in shape with dimensions 90’ X 25’, with height varying from 13’ to 18’. For convenience’s sake, the warehouse was divided into 17 zones (Figure 1). The number of bags stored, the sequence of the bags before the incident of fire according to the warehouse keeper are detailed in Table 1.

Results

The fire affected warehouse was facing north (Figure 2). Extensive burning was observed on north western side of the warehouse i.e., zone 8 and 9. The asbestos roof above the chemical bags stored there, was found to be blown off (Figure 3) and the bags

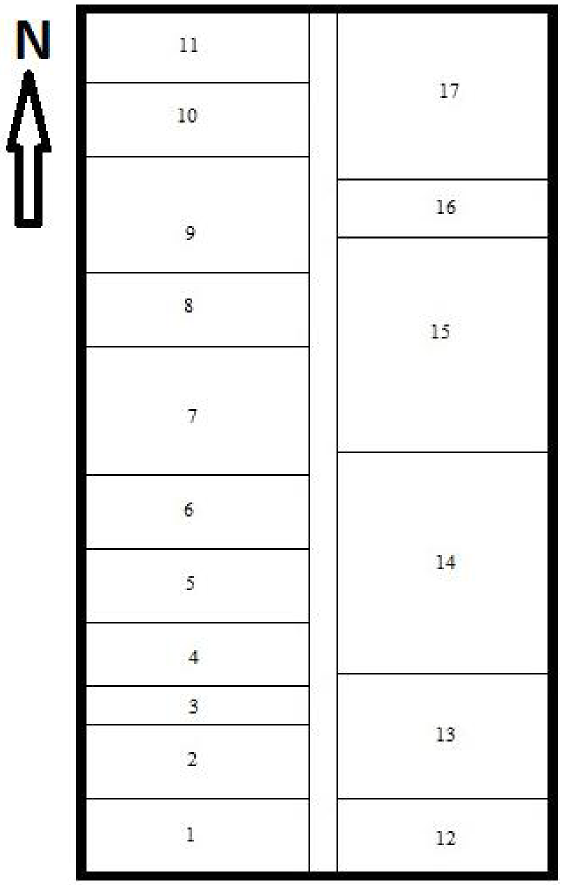


Figure 1: Sketch of the godown

Zone	Chemical Stored	No. of Bags	Bag Size
1,4,5,6,12	Sodium Sulphate	200 bags each	50 kg
2 & 13	Hydrogen peroxide	672 cans	30 L
3	Tri sodium polyphosphate	112 bags	50 kg
7	Sodium sulphate	480 bags	50 kg
8	Potassium Hydroxide/ Caustic Potash	200 bags	50 kg
9	Maleic Anhydride	800 bags	25kg
10	Sodium Carbonate (Soda Ash)	240 bags	50 kg
11	Potassium Carbonate	240 bags	50 kg
14, 17	Borax	798 bags	50 kg
15	Sodium Sulphate	480 bags	50 kg
16	Bleaching powder	80-90 bags	50 kg

Table 1: Details of Chemicals Stored before the fire

were burnt/ fused to various degrees. Further, the effect of fire was found to be maximum in zone 8 and 9 (Figures 3 and 4). From the examination of the records and interaction with warehouse keeper, it was found that 200 bags of potassium hydroxide (Caustic potash) and 800 bags of maleic anhydride were stored side by side in these zones 8 and 9 respectively.

Figure 2: The front view of the fire effected warehouse

Figure 3: An overview of the fire effected warehouse showing the blown off roof over the area where maleic anhydride was stored indicating a low intensity explosion.

Some of the bags of sodium carbonate (Soda ash) stored (adjacent to zones 8 and 9, towards northern side) in zone 10 were also found fused. All the 480 bags of sodium sulphate stored in zone 15 (Figure 5), adjoining the completely affected zones 8 & 9, towards the eastern side were also found fused. The asbestos roof above this zone was also found to be blown off.

The sodium sulphate stored in zone 1 & 12 was marginally affected by fire. The hydrogen peroxide cans stored in zones 2 & 13 were partially damaged due to fire (Figure 6). The bags of trisodium polyphosphate, in zone 3, sodium sulphate stored in zones 4, 5 & 6 were partially affected. Sodium sulphate stored in zone 7 was also partially fused. Potassium carbonate in zone 11 and some bags of sodium carbonate (Soda ash) stored in zone 10 were marginally affected by fire (Figure 7). Borax stored in zone 17 & 14, bleaching powder in zone 16 were marginally affected by fire.

The sketch showing the consolidated damage is detailed in Figure 8, in which maximum damage is shown in red color.

A careful study of the electrical connections in warehouse indicated that there was no other connection except for lighting. The electric wires inside warehouse were found to be burnt due to external fire. The electric meter of the warehouse kept outside was intact and did not show any symptoms of short circuit such as beading, blackening etc., and hence, fire due to electrical related causes was ruled out.

Discussion

Flammability and Other Properties of the Chemicals Stored

1. Sodium Sulphate [1] (stored in zones 1,4,5,6,7,12&15): Non-flammable
2. Hydrogen Peroxide [2] (zones 2&13): Highly reactive Most cellulose (wood, cotton) materials contain enough catalyst to cause spontaneous ignition with 90% Hydrogen Peroxide. Hydrogen Peroxide is a strong oxide. It is not flammable itself, but it can cause spontaneous combustion of flammable materials and continued support of the combustion because it liberates oxygen as it decomposes. Hydrogen peroxide mixed with magnesium and a trace of magnesium dioxide will ignite immediately.
3. Tri Sodium Polyphosphate [3] (zone 3): Non-flammable

Figure 4: A view of the area after the incident of fire where the 200 bags of potassium hydroxide stored was completely burnt

Figure 5: A view of fused Sodium Sulphate bags. The blown off roof due to low intensity explosion can also be seen in the figure

Figure 6: A view of the partially effected Hydrogen Peroxide cans stored away from the origin of fire

Figure 7: A view of the marginally fire effected potassium carbonate and sodium carbonate bags stored far away from the origin of fire

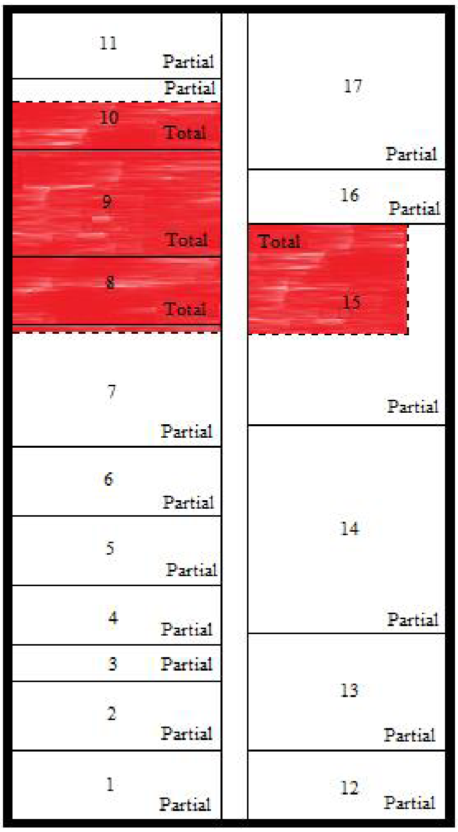
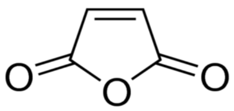


Figure 8: Sketch showing the effects of fire

4. Potassium Hydroxide [4] (zone 8): It is an inorganic compound with the formula KOH and is commonly called Caustic potash. It is colorless solid and is a strong base. It has many industrial applications based on its corrosive nature and its reactivity toward acids. Violent reaction or ignition under appropriate conditions with acids, alcohols, p- p-bis (1,3-dibromoethyl) benzene, cyclopentadiene, germanium, hyponitrous acid, maleic anhydride, nitroalkanes, 2-nitrophenol, potassium peroxydisulfate, sugars, 2,2,3,3-tetrafluoropropanol, thorium dicarbide. When wet, it attacks metals such as aluminum, tin, lead, and zinc, producing flammable hydrogen gas. Potassium hydroxide will cause violent explosive decomposition of maleic anhydride**.** Heat is generated if KOH comes in contact with water and carbon dioxide from the air.
5. Maleic Anhydride [5,6] (zone 9):



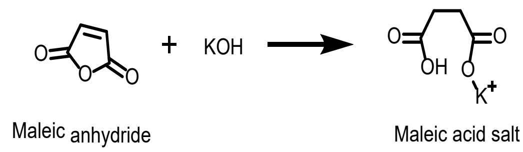
Maleic anhydride

Maleic anhydride, chemically 2-5- furandione, is an organic compound with the formula $C_2H_2(CO)_2O$. It is the acid anhydride of maleic acid. Maleic anhydride appears as colorless crystalline needles, flakes, pellets, rods, briquettes, lumps or a fused mass with an acrid odor. It is produced industrially on a large scale for applications in coatings and polymers. The melting point/freezing point of maleic anhydride is 53°C, lower explosion limit (LEL) 57 g/m^3, 1.4% and its upper explosion limit (UEL) 290g/m^3, 7.1%. It explodes if confined [7]. It has the Heat of Combustion -1389.5kJ/mol [8]. When heated to decomposition above 150°C maleic anhydride emits acrid smoke and irritating fumes [9]. Alkaline earth hydroxides, amines, pyridine, quinoline, sodium or potassium carbonates, aqueous ammonia, ammonium hydroxide or ammonium salts-at temperatures over 150°C, when mixed with maleic anhydride can react to produce carbon dioxide, heat and pressure. Under these conditions, a mixture can be explosive. Small amounts as low as 200 ppm of the above chemicals are sufficient to begin the decomposition [10]. The storage container must be dry and must be kept in a cool place. All equipment containing the chemical must be grounded. Corrosive materials should be stored in a separate safety storage cabinet or room.

6. Soda Ash/ Sodium Carbonate [11] (zone 10): Non-flammable
7. Potassium Carbonate [12] (zone 11): Non-flammable
8. Borax/ Sodium Borate [13] (zones 14&17): Non-flammable
9. Bleaching Powder/ Calcium hypochlorite (zone 16): Highly reactive but non-flammable

As the maximum damage occurred in zones 8 & 9 which extended to the adjoining zones 10 & 15 and the fact that the roof made up of asbestos sheets above zone 9 and zone 15 were blown off, indicates a low intensity explosion. As per ware house keeper, in zones 8 & 9, 200 bags (of 50 kg) of potassium hydroxide (Caustic potash) and 800 bags (of 25 kg) maleic anhydride were stored. All the bags were totally fused or burnt. Hence it is inferred that the fire originated from this area i.e., zone 8 & 9.

Maleic Anhydride undergoes violent explosive exothermic decomposition reaction producing carbon dioxide in the presence of strong base such as Potassium Hydroxide [14]. As potassium hydroxide and maleic anhydride were stored adjacent to each other in zones 8 & 9, they must have come into contact with each other. Being incompatible, potassium hydroxide and maleic anhydride must have undergone violent explosive exothermic reaction generating fire. Hydrolysis of maleic anhydride followed by neutralization with an alkali metal hydroxide results in maleate salt formation [15].



Due to the explosive force, the roof of the ceiling was blown off over zones 9 and 15 (Figures 3 and 5). The fire generated in the explosion burnt/fused all the 800 bags of maleic anhydride, 200 bags of potassium hydroxide and 480 bags of sodium sulphate stored in zones 8, 9 and 15. The fire so generated spread to the neighboring zone 10 where sodium carbonate (Soda ash) stored was also found fused.

Among the remaining chemicals stored in the warehouse, bleaching powder [16] and hydrogen peroxide [17] are known to be reactive and cause explosions and fire under certain conditions. However, as these were stored in zone 16 and zone 2 & 13 respectively far away from the origin of fire and were partially affected by fire, their role in causing the fire accident is ruled out. The remaining chemicals are stable and non-flammable; they were partially affected due to external fire.

The storage conditions of both potassium hydroxide and maleic anhydride stipulate that they have to be stored in cool, dry, well-ventilated area away from each other. However, in the instant case, potassium hydroxide and maleic anhydride were stored side-by-side in relatively hot environment without any proper ventilation, violating the basic storage criteria.

The open flame ignition sources such as cigarette butts etc. were also ruled out by careful inspection and interviews.

Conclusion

Based on a thorough and in-depth examination, inspection of site of fire, oral evidence, scientific and technical evaluation of the evidence, it is concluded that violent exothermic chemical reaction could have occurred between incompatible potassium hydroxide and maleic anhydride stored side by side resulting in possible explosion and fire. Thus, the root cause of the fire incident was ignoring the basic storage safety precaution in storing incompatible chemicals together, side by side.

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